FINAL REPORT

EVALUATING ENVIRONMENTAL AND ECONOMIC IMPACT FOR BEEF PRODUCTION IN ALBERTA USING LIFE CYCLE ANALYSIS - PHASE 2

Prepared For:
Alberta Agriculture and Rural Development

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EXECUTIVE SUMMARY

Conestoga-Rovers & Associates (CRA) was retained by Alberta Agriculture and Rural Development (ARD) to complete Phase 2 of Evaluating Environmental and Economic Impact for Beef Production in Alberta using Life Cycle Analysis (LCA). CRA teamed with JRG Consulting Group (JRG) to form a project team (Project Team) for this assignment.

The Phase 1 component of the overall project, as completed by CRA, yielded an estimate of the carbon footprint intensity and other environmental impacts such as eutrophication, acidification, and non-renewable energy consumption, of the beef sector on a per kilogram basis (live shrunken weight, up to the door of the slaughterhouse). Conclusions were made in the report regarding the various hotspots in the production cycle, and identified that enteric fermentation emissions were the most significant overall emission as it pertains to greenhouse gas emissions (GHGs) (accounting for more than half of the total), followed by on-farm energy consumption, nitrous oxide emission from soil and manure management, and total forage and cereal activities.

The aim of this Phase 2 study is to build on the results of Phase 1 in terms of quantifying the relative benefits of the selected beneficial management practices (BMPs) from an environmental footprint standpoint, but also to assess the relative cost/benefit of these practices such that the cost implications of implementation are understood.

The five BMPs, as selected by ARD, have been modeled using the LCA model completed during Phase 1:

1. Composting and other improved solid manure management practices
    - Windrow composting of manure to determine GHG emission changes, nutrient capture, and costs/benefits
2. Increased efficiency in cow/calf feeding and grazing
    - Use of swath grazing and stockpile grazing to determine effects of both grazing systems
3. Use of ionophores in roughage diets (cow/calf operation)
    - Effects of addition of ionophores to all cattle on pasture using the Phase 1 diet
4. Reducing age to slaughter
    - Reduction of age to slaughter through the use of a supplement to increase weight gain during the last days on the feedlot, and through the removal of the backgrounding stage and the modification of diets to introduce higher concentrate diets sooner

5. Superior residual feed intake (RFI) genetics in breeding animals
    - Testing potential breeding bulls for the RFI genes for the purpose of breeding and uptake of the gene

The Phase 1 model is based on a baseline year of 2001. As requested by ARD, the Phase 1 model was updated to reflect the implementation of the BMPs in 2010. The costs and benefits were then analyzed based on any additional implementation of the BMPs from 2010 conditions.

During the completion of Phase 2, some modifications were made to the Phase 1 2001 baseline model as a starting point for the Phase 2 work. Generally, these were undertaken for the sake of completeness. As a result of these modifications, the total GHG emissions of the Alberta beef production system are now 14.7 kg carbon dioxide equivalents (CO_2e)/kg shrunk live weight. In the original Phase 1 work, the total GHG emissions were calculated as 14.5 kg CO_2e/kg shrunk live weight.

The scenarios modeled and the environmental and economic impact results are summarized below. All results are based on one calf crop.

BMP 1 – Composting of feedlot manure

Four scenarios were created for BMP 1 to capture the most likely variables that would occur with the implementation of this BMP:

- BMP 1.1a – windrow turning machine and on-site source of clay for compost pad
- BMP 1.1b – windrow turning machine and off-site source of clay for compost pad
- BMP 1.2a – existing front-end loader and on-site source of clay for compost pad
- BMP 1.2a – existing front-end loader and off-site source of clay for compost pad

Composting of feedlot manure is currently being conducted by about 15 percent of feedlots in Alberta. The Phase 1 model was updated to reflect this participation in the practice. The 2010 baseline model assumes that only on-farm equipment is being used to turn the composting material and that clay was obtained from off-site sources (conservative assumption).

The changes in emissions for all environmental impact categories from 2010 to 100 percent adoption of BMP 1 are summarized below:

	Global warming potential	Acidification	Eutrophication	Non-renewable energy resources
BMP 1.1a	4.5% increase	9.6% increase	18.9% increase	3.1% increase
BMP 1.1b	4.6% increase	9.7% increase	18.9% increase	3.1% increase
BMP 1.2a	4.8% increase	8.6% increase	20.4% increase	12.0% increase
BMP 1.2b	4.9% increase	8.6% increase	20.4% increase	12.0% increase

BMP 2 – Extended grazing on winter pasture

The two most likely scenarios that would occur with the implementation of extended grazing on winter pasture were modeled for BMP 2:

- BMP 2.1 – swath grazing on annual crops
- BMP 2.2 – stockpile grazing on perennial crops

There was no data to indicate the current participation of either of these practices in Alberta, and therefore the 2001 baseline model was not updated to 2010 conditions.

The changes in emissions for all environmental impact categories from 2001/2010 to 100 percent adoption of BMP 2 are summarized below:

	Global warming potential	Acidification	Eutrophication	Non-renewable energy resources
BMP 2.1	1.0% reduction	2.4% reduction	1.8% increase	7.6% reduction
BMP 2.2	4.2% increase	7.6% increase	9.2% increase	0.3% reduction

BMP 3 – Ionophores in roughage diets

The use of ionophores in roughage diets on cow/calf operations results in improved feed efficiency in cows and replacement heifers.

There was no data to indicate the current participation of this practice in Alberta, and therefore the 2001 baseline model was not updated to 2010 conditions.

The changes in emissions for all environmental impact categories from 2001/2010 to 100 percent adoption of BMP 3 are summarized below:

	Global warming potential	Acidification	Eutrophication	Non-renewable energy resources
BMP 3	1.4% reduction	0.7% reduction	1.1% reduction	0.3% reduction

BMP 4 – Reduced age to slaughter

Based on the draft quantification protocol guidance documents in Alberta, the two scenarios modeled for reducing the age to slaughter are as follows:

- BMP 4.1 – reduction in the number of days on feed in feedlot during the final stages of growth (introduction of Ractopamine Hydrochloride [RAC] during the last 28 days on feed to allow cattle to gain more weight during the last stage of feeding)
- BMP 4.2 – reduction in the age at harvest by adjusting the diet to introduce feeder and finishing diets sooner (removal of the backgrounding stages of feeding regimes for calf-fed cattle)

Based on discussions with slaughterhouse personnel, BMP 4.1 is currently in use by about 40 to 50 percent of operations in Alberta. Forty five percent implementation of BMP 4.1 was assumed for the 2010 baseline. There was no data to indicate the current participation of BMP 4.2 in Alberta, and therefore the 2001 baseline model was updated to 2010 conditions.

The changes in emissions for all environmental impact categories from 2010 (BMP 4.1) and from 2001 (BMP 4.2) to 100 percent adoption of BMP 4 are summarized below:

	Global warming potential	Acidification	Eutrophication	Non-renewable energy resources
BMP 4.1	0.3% reduction	0.5% reduction	0.8% reduction	0.5% reduction
BMP 4.2	2.8% reduction	1.7% reduction	5.6% reduction	7.7% reduction

BMP 5 – Superior residual feed intake (RFI) genetics for breeding animals

The intent of this BMP is to select beef breeding bulls through RFI testing and placing this genetic potential into the cow/calf sector such that feed consumption and feed requirements will be reduced in both the cow/calf and feedlot sectors.

Data was obtained for the total number of potential breeding bulls tested in Alberta from 2001 to 2008 and the capacity of commercial testing facilities in Alberta. The maximum testing capacity in Alberta was the limitation placed on the BMP 5 model, and this capacity was assumed to be reached by 2010. The 2001 baseline was updated with available data for maximum testing capacity for 2010, based on the guidance available in the draft Alberta quantification protocol for this practice.

The changes in emissions for all environmental impact categories from 2010 to 2029 (linear results after maximum testing capacity used for 5 years straight) for BMP 5 are summarized below:

	Global warming potential	**Acidification**	**Eutrophication**	**Non-renewable energy resources**
BMP 5	0.02% reduction	0.03% reduction	0.006% reduction	0.006% reduction

Cost Benefit Analysis Results

A ranking of each BMP by their contribution to reducing emissions as measured by the total change in GHG emissions (ΔCO_2e) is provided in the table below.

BMP	**Description**	**ΔCO_2e**	**ΔCO_2e per kg all beef**	**ΔCO_2e per kg affected beef**	**Net Annual Benefits**	**Market NPV BCR[1]**
		tonnes	**kg**	**kg**	**$ million**	**ratio**
BMP 4.2	Fewer days on feed	**-853,667**	**-0.406**	**-1.513**	**$56.12**	2.24
BMP 3	Ionophores in roughage diets	**-292,611**	**-0.205**	**-2.244**	**$101.53**	2.85
BMP 2.1	Swath grazing	**-218,177**	**-0.153**	**-1.673**	**$243.31**	1.94
BMP 4.1	Growth promotant - last 28 days	**-59,659**	**-0.042**	**-0.046**	**$12.41**	12.48
BMP 5	Selection for superior RFI	**-3,839**	**-0.003**	**-1.285**	**$0.23**	2.91
BMP 2.2	Stockpile grazing	882,725	0.619	0.007	**$2.79**	0.96
BMP 1.1a	Composting - Windrow on-site clay	962,702	0.675	0.743	**($322.35)**	0.18
BMP 1.1b	Composting – Windrow off-site clay	974,634	0.683	0.752	**($322.35)**	0.17
BMP 1.2a	Composting – Loader on-site clay	1,022,630	0.717	0.789	**($413.76)**	0.16
BMP 1.2b	Composting – Loader off-site clay	1,042,414	0.731	0.804	**($413.76)**	0.14

Note:

[1] BCR (benefit-cost ratio): ratio of NPV of benefits to NPV of costs

Results are presented in this table in terms of impact on GHG emissions across all produced beef, and also on the basis of the beef affected by implementation of the BMP to provide additional context for the results. As the data indicates, the relative environmental benefits or costs of the BMPs show different rankings when considering only the affected beef, indicating that some BMPs have proportionally greater impact on the relevant subset of beef production than they do on the entire beef production cycle.

A ranking of each BMP based on the economics of the practice is provided in the table below.

BMP	Description	ΔCO_2e	ΔCO_2e per kg all beef	ΔCO_2e per kg affected beef	Net Annual Benefits	Market NPV BCR
		tonnes	kg	kg	$ million	ratio
BMP 4.1	Growth promotant - last 28 days	**-59,659**	**-0.042**	**-0.046**	**$12.41**	12.48
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BMP 1.2b	Composting – Loader off-site clay	1,042,414	0.731	0.804	**($413.76)**	0.14

The above suggests that the following BMPs be further considered for implementation in the Alberta beef sector (based on [1] reducing CO_2e emissions, and [2] an attractive BCR in the sector):

- **BMP 4.1 Growth promotant (RAC) - last 28 days**
- **BMP 5 Selection for superior RFI**
- **BMP 3 Ionophores in roughage diets**
- **BMP 4.2 Fewer days on feed**
- **BMP 2.1 Swath grazing**

Although the results of the models for BMP 4.1 and 4.2 indicate reductions in GHG emissions and a positive cost benefit analysis, it is advised that further research be completed on this BMP to ensure that positive results for beef quality are achievable.

ACKNOWLEDGMENT

Alberta Agriculture and Rural Development (ARD) would like to thank the Project Steering and Technical Committees which comprise members from ARD, Alberta Livestock and Meat Agency Ltd., Alberta Cattle Feeders' Association and Alberta Beef Producers. The Steering and Technical Committee members provided valuable contributions of their time, expertise and industry contacts in developing the project Terms of Reference, data, information and advice in the implementation of the project.

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Clinton Dobson– Alberta Livestock and Meat Agency Ltd.
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1.0 INTRODUCTION

Conestoga-Rovers & Associates (CRA) was retained by Alberta Agriculture and Rural Development (ARD) to complete Phase 2 of Evaluating Environmental and Economic Impact for Beef Production in Alberta using Life Cycle Analysis (LCA). CRA teamed with JRG Consulting Group (JRG) to form a project team (Project Team) for this assignment.

ARD has initiated this project to assess the environmental and economic impacts of beef production in order to create the opportunity for Alberta to offer products that will provide the desired environmental benefits. This type of initiative is especially important given the current and future expected changes in regulations that have, at their core, an emphasis on greenhouse gas (GHG) reporting and mitigation.

The Phase 1 component of the overall project, as completed by CRA, yielded an estimate of the carbon footprint intensity and other environmental impacts such as eutrophication, acidification, and non-renewable energy consumption, of the beef sector on a per kilogram basis (live shrunken weight, up to the door of the slaughterhouse). Conclusions were made in the report regarding the various hotspots in the production cycle, and identified that enteric fermentation emissions were the most significant overall emission as it pertains to GHGs (accounting for more than half of the total), followed by on-farm energy consumption, nitrous oxide emission from soil and manure management, and total forage and cereal activities.

The completion of Phase 1 offers opportunities for mitigation projects that can reduce the overall environmental impact of the beef production sector in Alberta. Of note, as the baseline year for the Phase 1 study was 2001, various modifications to the beef production sector have already been initiated in the interim. Further modifications, or implementation of select beneficial management practices (BMPs), offer opportunity for additional reductions in environmental footprint. The aim of this Phase 2 study is to build on the results of Phase 1 in terms of quantifying the relative benefits of the selected BMPs from an environmental footprint standpoint, but also to assess the relative cost/benefit of these practices such that the cost implications of implementation are understood.

The boundary placement for the Phase 2 study is identical to the boundaries placed for Phase 1.

The five BMPs, as selected by ARD, have been modeled using the LCA model completed during Phase 1:

1. Composting and other improved solid manure management practices
    - Windrow composting of manure to determine GHG emission changes, nutrient capture, and costs/benefits
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    - Use of swath grazing and stockpile grazing to determine effects of both grazing systems
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    - Effects of addition of ionophores to all cattle on pasture using the Phase 1 diet
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    - Reduction of age to slaughter through the use of a supplement to increase weight gain during the last days on the feedlot, and through the removal of the backgrounding stage and the modification of diets to introduce higher concentrate diets sooner
5. Superior residual feed intake (RFI) genetics in breeding animals
    - Testing potential breeding bulls for the RFI genes for the purpose of breeding and uptake of the gene

A cost/benefit analysis (CBA) has been conducted for each BMP to provide ARD with an understanding of the effects of the implementation of each BMP. CRA is the lead on this project, and is responsible for the majority of the data collection and modelling; JRG is involved to complete the CBA.

The Phase 1 model is based on a baseline year of 2001. As requested by ARD, the Phase 1 model was updated to reflect the implementation of any of the BMPs in 2010. The costs and benefits were then analyzed based on any additional implementation of the BMPs from 2010 conditions. It is important to note that many of the assumptions inherent to the modeling provide a linear cause-effect relationship, and thus the relative cost/benefit aspect is generally independent of assumptions related to the percent adoption (or uptake) of the BMPs.

This Final Report provides the results of Phase 1 (Literature Review), Phase 2 (Data Collection), and Phase 3 (Quantification of Environmental Footprint and Estimation of Costs/Benefits of Selected BMPS) of the project, and follows the Draft Report and Final Draft Report. This report has been organized into the following sections:

- Section 1.0: Introduction to report and CBA, and outline of edits to Phase 1 2001 baseline
- Section 2.0: CBA of BMP 1 – composting of feedlot manure
- Section 3.0: CBA of BMP 2 – increased efficiency in cow/calf feeding
- Section 4.0: CBA of BMP 3 – use of ionophores in roughage diets
- Section 5.0: CBA of BMP 4 – reduced age to slaughter
- Section 6.0: CBA of BMP 5 – use of animals possessing superior residual feed intake genetics
- Section 7.0: BMP ranking
- Section 8.0: Limitations of the study
- Section 9.0: References
- Section 10.0: Disclaimer

The technical analysis, modeling assumptions, modeling outputs, and CBA are presented for each BMP in Sections 2 through 6.

1.1 COST BENEFIT ANALYSIS OF BMPS IN THE BEEF SECTOR

Cost benefit analysis (CBA) is an analytical approach where the benefits of a certain initiative, or change, are compared to the costs associated with that initiative or change. CBA is often used by government to evaluate the feasibility of a regulatory intervention, a policy change, or infrastructure project. CBA is sometimes refereed to as benefit cost analysis (BCA), where the term places the initial emphasis on benefits of a change. CBA weighs the expected costs of a new project, or initiative, in relation to the benefits where benefits are costs that are measured using the same unit of measurement – usually in dollar terms. The results of the analysis can be expressed as net benefits, which are the measured benefit minus measured cost (B – C). Another measure is the benefit to cost ratio; a B/C ratio >1 indicates that measured benefits exceed measured costs.

There is no standard approach for each cost-benefit analysis; however, **industry insight and input is required** for a meaningful analysis. As noted in a Treasury Board (1998) guide on cost benefit analysis,

> "*There is no 'cookbook' for benefit-cost analysis. Each analysis is different and demands careful and innovative thought. It is helpful, however, to have a standard sequence of steps to follow. This provides consistency from one analysis to another, which is useful to both the analysts doing the study and the managers reading the report.*

> *Obviously, the ... "steps cannot be performed by the analyst in isolation and will require consultations with the decision-maker and others, the gathering of a wide variety of information, and the use of a number of analytical techniques. It is important that, as the analyst proceeds, the decision-maker is kept in touch with the form of the analysis and the assumptions being made".*
>
> *- Treasury Board, Benefit-Cost Analysis Guide, 1976"*

There is no standard approach to CBA; however, there are a few **principles** that should be used to guide the analysis[1]. These principles that have guided prior CBA analyses conducted by JRG are provided in Appendix A.

1.1.1 ACTIVITIES REQUIRED FOR COST BENEFIT ANALYSIS

The CBA principles listed in Appendix A suggest that the following activities are embedded in our CBA of BMPs:

1. The **objectives** for the major stakeholders are documented for each proposed BMP.
2. **Stakeholders** are identified along with **system boundaries** and identification of the stakeholder groups that have **standing.**
3. A solid **description and documentation is provided for each proposed BMP**. The **BMP is contrasted to the current situation** (or status quo). This description includes the operating environment and any changes in the operating environment.
4. The **changes** that occur with moving from the current situation to the BMP are well described.
5. **Data** is gathered that allows for **measurement of costs and benefits** associated with the current situation, the BMP, and the associated change – this includes physical data such as input-output relationships, as well as price data to measure costs and returns.
6. **Benefits and costs** are computed for **each affected stakeholder group** to show the net benefit or cost on this group – the costs and benefits that are internal to a stakeholder group are first considered to indicate the net marketplace benefit. Time horizon considerations are included in the analysis as required. A

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[1] For interested readers, a classic in the areas of cost benefit analysis is Gittinger, J. Price, "Economic Analysis of Agricultural Projects", Economic Development Institute, The World Bank, 1984. The book is written for analysis of development projects; however, a number of the concepts and illustrations apply to most analyses.

secondary computation can include the non-market benefits and associated externalities, such as the reduction in GHGs.

7. **Calculations of benefit** are provided, which can include the benefit-cost ratio (BCR), absolute net benefits, internal rate of return, and cost effectiveness ($ of cost/unit of GHG reduction). If the costs and/or benefits vary over time, a net present value analysis should be conducted. A net present value example is provided in Appendix B.
8. **Sensitivity analyses** of the results are provided based on changes in key operating parameters, or assumptions.
9. **Suggestions for change** are provided based on the analysis and a reasoned consideration of the quantifiable and non-quantifiable costs and benefits throughout the beef supply chain.
10. **Presentation of findings** for potential decision making.

1.2 THE LINKAGE BETWEEN LCA AND CBA

LCA and CBA are not two alternative approaches to help make decisions on BMPs. A LCA highlights all of the "cradle-to-grave" (or other ending point) impacts of a technology, practice, or sector. A LCA is only concerned with physical units and physical impacts, such as feed required and equivalent carbon dioxide emissions (CO_2e) emitted, and changes therein with adoption of a BMP. A LCA usually does not consider non-environmental costs and benefits. From a policy perspective, a LCA does not offer any obvious decision rules for investing in a BMP.

A LCA is required to conduct a CBA on a BMP. The strength of a LCA is the identification of the physical units required for a BMP and outputs resulting from a BMP. A CBA starts with the output of a LCA (or more precisely the LCA associated with a base case and with alternatives [options]) and the CBA begins with placing values in a common unit of measurement on these inputs and outputs. Such valuation would be on inputs and outputs with a market price (e.g., finished beef cattle going to slaughter, feed purchased and/or produced to finish an animal), and those outputs (and inputs) that do not have a market value such as the emitted GHG in each stage of the beef supply chain (the externalities).

CBA is a second but important step after completing a LCA. Moreover the requirements of a CBA must be considered within a LCA, such as the ability to compare alternatives (e.g., two BMPs, or a BMP relative to the current situation).

There are other economic measures that have been used along side a LCA. These include cost–effectiveness analysis (CEA), the cost effectiveness ratio (CER) and life cycle costing (LCC). These are not as robust a measure as a CBA for helping in the decision making process. These other measures are briefly overviewed in Appendix C.

A CBA that involves environmental issues will invariably have to deal with **externalities** or spillovers. An externality is when an action by one party has an impact on others – whether a benefit or a cost. Within the beef sector, methane emissions can be considered an externality – a cost imposed on other by the action of the beef cow/calf operation. Placing a value on an externality is a requirement in conducting a full CBA, and when attempting to have decision makers internalize the cost of an externality. Without valuing externalities such as emissions into the environment, there is little information available to illustrate whether a BMP has benefits that exceed costs, whether viewed by a decision maker such as feedlot operator, or viewed from a societal perspective. Thus a value is required for emissions affect by the implementation of a BMP, such as methane (CH_4), CO_2, etc. Various approaches have been used to place monetary values on flows that do not have a market-determined price (e.g., hedonic prices, travel cost, willingness to pay studies, revealed preferences, stated preferences, etc). Without such valuations "*recommendations based on LCA fail to address possible trade-offs between environmental protection and both social and economic concerns in the product life cycle*" (Dreyer et al., 2006).

A literature search indicated that very few CBA have been applied to LCA, and those that have been conducted were not in the agri-food sector. A literature review is provided in Appendix D of some cost benefit analysis and other economic approaches that were used as part of an LCA. This literature review highlighted a few key points. These include:

- A comprehensive (environmental) CBA must be integrated with a LCA, or have access to a LCA findings for the base case as well as to considered alternatives
- Many of the comments in the literature revolve around issues of not having a full CBA linked to a LCA
- The literature is long on suggestions on how to improve LCA, but short on applications using CBA linked to a LCA

1.3 MODIFICATION TO PHASE 1 2001 BASELINE

During the completion of Phase 2, some modifications were made to the Phase 1 2001 baseline model as a starting point for the Phase 2 work. Generally these were undertaken for the sake of completeness; otherwise, the intent was to maintain the model formulation and boundaries established during Phase 1. These modifications are outlined below:

- Diet Supplements tab, Cell B12: Number of days the cows/bulls are included in the model for each calf crop. This value was 182.5 days, and has been modified to 365 days to represent 1 full year.
- Cattle N excretion tab: The ADG values were inserted in lbs, not kg, as the stated units in the table. The values have been converted from lbs to kg.
- The Phase 1 model assumed that both the cow/calf and the feedlot operations both managed manure by allowing a fraction of the manure to be left on pasture and for the remaining to be collected and stockpiled as solid storage prior to pick-up. This baseline model was updated to apply the manure left on pasture to only the cow/calf operations and the manure solid storage to only the feedlot. This had an effect on the Cattle CH_4 Manure Emission tab, the N_2O Dir Manure emission HOLOS tab, and the N_2O Indir Manure emiss Holos tab.

As a result of these modifications, the total GHG emissions of the Alberta beef production system have increased slightly from 14.5 to 14.7 kg carbon dioxide equivalents (CO_2e)/kg shrunk live weight. This forms the basis of the models modified to reflect the BMPs.

2.0 CBA OF BMP 1 – COMPOSTING OF FEEDLOT MANURE

BMP 1 considers the composting of managed beef manure in Alberta. As it is understood that the majority of managed manure is on the feedlot, only manure generated on the feedlot has been included in this analysis.

2.1 DESCRIPTION OF BMP 1 – COMPOSTING OF FEEDLOT MANURE

The intent of this BMP is to generate fewer GHG emissions through composting instead of the current practice of storing manure in a pile prior to transportation off site.

The operating assumptions include:

- A percentage of feedlot manure will be composted. For the 2010 baseline, ARD advised that about 15 percent of the current beef feedlots in Alberta are composting manure.
- Two separate technologies will be used to turn the compost material:
  1. Using a windrow turning machine (BMP 1.1)
  2. Using existing farm equipment (front-end loader) (BMP 1.2)
- It was assumed that compacted clay will be used as the compost pad. Two separate scenarios have been assumed for the construction of the clay composting pad:
  1. Clay is available on site (scenario "a")
  2. Clay must be purchased from off-site sources and shipped to the site (scenario "b")
- Assumptions made for the 2010 baseline were that 15 percent of feedlots currently compost manure, existing on-farm equipment is used to turn the material, and clay was acquired from off-site sources to build the compost pad (a conservative assumption).
- Four scenarios in addition to the 2010 baseline (BMP 1) will be run to assess the impact of existing machinery to turn compost and the source of clay for the composting pad. These are BMP 1.1a, BMP 1.1b, BMP 1.2a, and BMP 1.2b.
- Labour requirements will increase with the BMP involving a front-end loader, as compared to a windrow turner.
- There are capital expenditures associated with this BMP, with a life expectancy of 20 years for a windrow machine and for a front-end loader.

- The clay used for the composite pad has a 20-year useful life, with a new compost pad with equipment developed every 20 years.
- Transportation of compost off of the feedlot is assumed to be arranged by the buyer/user of the material.
- Transportation of manure off of the feedlot is assumed to be arranged by the feedlot owner using on-farm trucks and equipment. The cost of fuel used to transport the manure off of the feedlot is saved by the feedlot owner if composting is conducted as a function of the volume/mass reduction involved in composting.
- There will be no impact on the volume or quality of beef supplied to the slaughter plant.
- Available amendment material for the composting process was divided into northern and central/southern Alberta regions, where wood waste/wood chips were assumed to be the available amendment material in northern Alberta and straw was assumed to be the available amendment material in central/southern Alberta.

The direct impacts in the feedlot sector include:

- Outputs:
  - No change in the annual volume of finished beef supplied to slaughter plants.
  - Fewer emissions from the stored manure that is subject to composting (at least the methane emissions from manure storage). It is noted here that the HOLOS model used to calculate the emissions from manure during storage and composting assumes that the direct nitrous oxide emissions increase with the passive windrow composting process; however, in reality, if composting was conducted properly, this may not be the case. Emissions of nitrous oxide and methane from the composting process tend to be a function of the success of the composting operation to provide adequate control over the windrows and appropriate aeration of the material. The current model formulation and constraints are a key element of the final results in terms of emissions from composting and the consequences on the cost-benefit analysis. Please refer to Section 2.2 for further information.
  - Change in the volume of manure/compost shipped off of the feedlot operation due to composting. Note that the price of compost is for compost picked up from the composting location, and therefore, the transportation of compost off site has not been included in the analysis (emissions or costs).
  - Change in the value of the manure/compost shipped off site. The compost is valued at $6/tonne for use in cropping activities. A higher value, such as bagged for retail (residential) use, is not used to value the output. The bagged residential

market is a local market, with a limited market requirement. This market is assumed to be well served, and expansion of this volume can significantly lower prices due to over-supply. As well, compost cannot be shipped long distances, such as to other major cities (e.g., Vancouver) as the trucking costs can soon outweigh the value of the compost. For this reason, a cropping value is used.

- Inputs:
  - No change in the inputs purchased to produce beef (e.g., feed, supplements, etc.).
  - Purchase of equipment (windrow turner).
  - Higher usage of existing front-end loader. Assume replacement not required for 20-year analysis, as this equipment typically has a lifespan in this range.
  - Higher labour requirements for use of front-end loader for turning compost.
  - Higher energy consumption for composting; higher energy consumption for the front-end loader compared to the windrow turner.
  - Lower energy consumption for disposing of manure.
  - Purchase and transportation of amendment materials for the composting process.
  - Construction of the clay composting pad required for the composting process (may include the purchase, transportation, and compaction of the clay).

In addition to these direct impacts, there are potential indirect impacts based on linkages. These include:

- Reduction in emissions from trucking manure off site
- Increase in emissions due to the excavation, transportation, and compaction of clay for construction of the composting pads
- Emissions from transportation of wood waste for the composting process
- Emissions from production and transportation of straw for the composting process
- Emissions from manufacturing and transportation of windrow turners
- Emissions from production and combustion of diesel required for composting process

It should be noted here that the LCA model is linear throughout adoption rate, and does not capture curvilinear tendencies, which may be realized through actual implementation. These may include increased efficiencies in labour, decreases in capital costs as the practice becomes widespread and investment costs reduce.

2.2 BMP 1 – MODELLING LCA AND IMPACT

This BMP consists of utilizing feedlot beef manure for compost as an alternative to chemical fertilizers and current disposal methods.

Based on assumptions applied to the current LCA model, manure deposited in feedlots is collected using a removal vehicle. The manure is then transferred and stockpiled in a specific area of each feedlot where it is temporarily stored.

After the manure has been stockpiled, it may be managed using any of the following options:

- Dispose of Manure (baseline): The manure is transported off site for land application or left unmanaged on site. In the baseline, 48 percent of Alberta's beef manure was collected for further use (47 percent solid manure, 1 percent liquid slurry) (assumed feedlot). The currently "managed" portion of the manure may be treated to improve manure management practices (i.e., composting) or may continue to be transported off site for direct land application. Only the managed fraction as generated in the feedlots has been considered for this BMP.
- Compost Manure On Site: The manure will be composted on feedlots and transported off site for land application; this option was not included in the baseline scenario and comprises the major element of this BMP.
- Compost Manure Off Site: The manure will be transported from the feedlots to a composting facility and then transported for land application (bulk sale or commercial sale). It is expected that consolidated composting operations in a central location will be quite rare, given the negative economics of transporting materials. The actual emission profile from this activity is identical to the baseline scenario, in that the manure undergoes emissions during storage prior to trucking off site. Emissions due to trucking of the material off site are considered; however, emissions produced or mitigated once off site are beyond the boundaries of the project and have not been considered. This is consistent with the boundaries drawn for the baseline.

2.2.1 CHANGES TO THE PHASE 1 BASELINE LCA MODEL

CBA compares the costs of a change (i.e., the BMP) to the benefits associated with the change for the relevant decision makers. Accordingly, the change in outputs and inputs used by the feedlot sector are of major concern, along with the values of these inputs and outputs.

2010 Baseline Model

The Phase 1 LCA model was updated to 2010 conditions to include the percentage of beef manure composting that is currently occurring on farms in Alberta (15 percent, as provided by ARD) (scenario BMP 1). The Phase 1 LCA model assumed that no manure composting was being conducted in 2001. ARD noted that windrow composting would be the most prominent and likely type of composting to be used on beef farms. The remaining 85 percent was assumed to be transported off site for land application, as in the 2001 baseline.

As there are currently no specific regulations for the operation of a windrow composting facility in Alberta, ARD's Facilities and Environment: Composting Animal Manures document (ARD, October 2009) was used for guidance. The main part of a windrow composting facility is the 0.5 m compacted pad. Clay-type soil was assumed to be the material as very low permeability rates of the pad must be obtained (5×10^{-8} metres per second [m/sec]). The clay pad was the only construction activity assumed in the LCA model as the other controls for the compost pad will vary depending on site (i.e., run-on and run-off control systems). A suitable source of clay may not be available at the composting site, and thus may need to be purchased and transported to the site.

In order to turn the composting material, either a front-end loader or a windrow turning machine can be used. The front-end loader has been assumed to already be available at the site, while a windrow turner must be purchased. The windrow turner requires a smaller composting pad, and uses less time and fuel to turn the material, but is generally more suitable for larger operations.

The 2010 baseline model assumes that only on-farm equipment is being used to turn the composting material and that clay was obtained from off-site sources (conservative assumption).

Additional Model Scenarios

Based on the variables outlined above (source of clay and turning equipment), the updated 2010 model was then revised to create four additional scenarios:

- BMP 1.1a – windrow turning machine and on-site source of clay for compost pad
- BMP 1.1b – windrow turning machine and off-site source of clay for compost pad
- BMP 1.2a – existing front-end loader and on-site source of clay for compost pad
- BMP 1.2a – existing front-end loader and off-site source of clay for compost pad

For each scenario, there is an option to revise the following:

- Percent of feedlot beef manure composted on site in Alberta
- Percent of farms using existing equipment to turn compost
- Percent of farms using windrow turners to turn compost
- Percent of farms using an on-site source of clay for compost pad
- Percent of farms using an off-site source of clay for compost pad

As the model is linear in nature, the four scenarios above were run assuming 100 percent of feedlot beef manure is composted on site, with 100 percent of each of the two variables, in order to formulate the CBA. This allows the impact of each variable to be separated, to realize the impacts of the costs/benefits of each option. The percent of feedlot manure that is transported off site for either composting or land application is also automatically adjusted based on the inputs.

Overview of Additional Changes to the LCA Model for On-Site Composting

Construction activities included excavating clay, transporting clay (if from off-site source), compacting clay, manufacturing windrow turners, and transporting windrow turners to the site. It was assumed that clearing of land or any additional construction activity would not be required and would be too variable to be included in this study. No maintenance was assumed for the clay pad, as it should have at least a 20-year life span.

The total amount of manure generated on Alberta beef feedlots for one calf crop, as indicated in the model, was divided into the northern and central/southern Alberta regions, based on Statistics Canada feedlot information, in order to identify the type of amendment and to calculate the amount required for the composting process. It was assumed that wood waste/wood chips would be the source of amendment material in northern Alberta, while straw was assumed for central/southern Alberta. ARD's Manure Composting Manual was used to calculate the total amount of amendment required to compost the beef manure (ARD, 2005).

The space for a composting area compared to an area for storage of manure varies as composting requires a windrow configuration of piles that are of manageable height and that must be turned. The overall assumption is that appropriate, controlled composting using consistent turning and application of amendment will be used.

The size of the composting pad, total labour time required to turn the material, total amount of diesel consumed during the process, and the total number of units was calculated assuming typical farm front-end loader information and a windrow turner model that maximizes composting space and turning time (Vermeer, 2010). All of these inputs have been adjusted in the model calculations.

The existing manure storage area was assumed to be part of the total size of the composting pad requirements. According to the Province of Alberta, Agricultural Operation Practices Act, Standards and Administration Regulation (Alberta Regulation 267/2001), there must be adequate manure storage on feedlots to contain nine consecutive months of manure generation. Therefore, assuming a maximum height of 2.5 m for manure (Guidelines to Beneficial Management Practices: Environmental Manual for Poultry Producers in Alberta. November 2003. Section 7), an existing manure storage area was calculated and the total amount of clay was offset by this existing area.

Windrow composting time periods include an active composting period where the composting material is turned 15 times in the first 6 weeks (5.5 turns per week for first 2 weeks, and 1 turn per week for next 4 weeks), and the curing period where the material is turned every 4 weeks for 13 weeks (0.25 turns per week). The total composting time is 19 weeks. This is based on CRA's experience with composting, the Ontario Regulation 101/94, "*Recycling and Composting of Municipal Waste*" where pathogen reduction is acquired by achieving 55 degrees C for a minimum of 15 days, and from ARD's and Saskatchewan Ministry of Agriculture's composting manure guidelines for composting times (ARD, 2005) (Saskatchewan Ministry of Agriculture, 2008).

Pathogen reduction is achieved by maintaining a temperature of 55 degrees C within a composting pile for a minimum of 15 days. This pathogen reduction phase is then followed by a curing period of at least 6 months, during which the compost is turned at least once per month.

Transportation emissions and costs for trucking manure off site have been adjusted for the amount of feedlot manure composted on site. Transportation emissions for trucking compost off site have been assumed to be outside the boundaries of the current study as the cost for composted manure is based on bulk weight picked up from the composting site; construction and operations activities for off-site composting are also excluded, being outside of the project boundaries.

Typically, the biggest market for manure compost is supplying it to farms for spreading on agricultural land as a replacement for chemical fertilizers. The displacement of chemical fertilizer will reduce the emissions associated with the production of those chemicals; the amount of fertilizer displaced depends on the nutrient content supplied by the finished compost as compared to fertilizer and in incremental benefit compared to unprocessed manure, as in the baseline situation. The finished compost may be used for: soil amendment, fertilizer supplement, top dressing for pastures and hay crops, mulch for homes and gardens, or a potting mix component. In the baseline scenario, the usage of the final manure in terms of emissions ended at the door of the receiving entity, although transportation of the material off site was included (average distance of 7 km). For this BMP, the displacement of fertilizer resulting from application of manure off site will not be included in order to maintain consistency with the baseline; the primary effect of composting on site should thus relate to the mitigation of methane and nitrous oxide during the storage/composting phase and the reduced off-site trucking requirements. Although the final emissions created or mitigated off site attributed to raw or composted manure are outside of the boundaries of this analysis, the economic value differential between the two products has been considered in the CBA for the feedlot.

The total nutrient content of the compost as compared to the manure is outlined below:

- Feedlot manure
  - Nitrogen content - 1.30 kg/kg dry wt
  - Phosphorus content - 0.37 kg/kg dry wt
  - Water content - 68%
- Amendment material (wood waste)
  - Nitrogen content - 0.14 kg/kg dry wt
  - Phosphorus content - 0 kg/kg dry wt
  - Water content - 15%
- Compost from manure and wood waste
  - Nitrogen content - 0.85 kg/kg dry wt
  - Phosphorus content - 0.30 kg/kg dry wt
  - Water content - 27%

- Amendment material (straw)
  - Nitrogen content - 1.10 kg/kg dry wt
  - Phosphorus content - 0 kg/kg dry wt
  - Water content - 16%
- Compost from manure and straw
  - Nitrogen content - 1.21 kg/kg dry wt
  - Phosphorus content - 0.28 kg/kg dry wt
  - Water content - 25%

Methane and nitrous oxide emissions associated with the baseline were assumed to have been reduced as composting practices increase based on CRA's composting knowledge, but are additionally dependent on the efficacy of the composting practiced. The HOLOS model was used to calculate the methane and nitrous oxide emissions from manure in the baseline. This model is based on IPCC methodology updated with Canadian-specific information; however, the calculations for emissions from manure hold many limitations. Manure emissions due to composting affect backgrounding cattle, and calf-fed and yearling-fed steers and heifers on feedlots. Emissions are calculated for each animal within a certain period, such as a feeding period. Once they leave that feeding period (i.e., backgrounding) the emissions from the manure generated during that period cease emitting. HOLOS is not able to capture those emissions over a longer period of time, which means that it is assumed that the manure is collected after each feeding period and no additional emissions are emitted. It is noted that additional functionality on this subject is being considered as an area of interest for future versions of the HOLOS model.

In order to update the manure emissions in the model, it was assumed that feedlot manure is collected at least on a monthly basis to allow for the materials composted to be adequate for proper composting. For any period of feeding in the model that was longer than 1 month, the emissions were divided between 1 month and the remaining time to assume that the manure only sat on the feedlot for a maximum time of 1 month, and that emissions were only emitted from that entire amount of manure generated during that time period for a total of 1 month. For any feeding period less than 1 month, it was assumed that the manure was collected and composted immediately. There is no methodology to accurately divide emissions generated between different manure management systems, such as solid storage (baseline) and passive windrow composting (BMP). HOLOS provides different methane conversion factors for solid storage of manure and passive windrow composting which decreases the methane emissions from manure by approximately 75 percent. Based on HOLOS, the indirect nitrous oxide emissions do not change from solid storage to passive windrow composting, but the direct nitrous oxide emissions increase; the nitrous oxide emission factor for passive windrow composting is two times higher than the emission factor for solid storage. This methodology may prove to be an oversimplification of the manure emissions profile; however, there are no other means to quantify changes in emissions.

After further review, CRA was unable to find any other emission factors for manure composting to be used for comparison with the results obtained using the HOLOS model. This data gap is a significant issue as it relates to establishing the actual benefits of composting as it relates to reducing GHG emissions.

In reality, a properly configured and operated composting operation with appropriate amendment should mitigate nitrous oxide and methane emissions. The HOLOS formulation currently prevents this characterization of the composting operation such that nitrous oxide emissions increase during composting; this is likely an overestimation of actual likely conditions. The modeling approach for composting has been one of assuming best management composting practice, which should prevent these emissions.

Refer to Appendix E for the activity maps and data collected to model this BMP.

2.3 BMP 1 – RESULTS OF GHG EMISSIONS AND OTHER IMPACTS

The impacts on the four environmental impact categories (GHG, acidification, eutrophication, and non-renewable resources) were modelled for the entire Alberta beef production system to reflect the changes to the model with the implementation of the BMP. The graphs in this section show the total impact of each category from the entire system for the baseline years, and also show the difference in these impacts from the baselines to the implementation of the BMP based on percent adoption of the BMP.

The following graph shows the total GHG emissions versus the percent adoption for all four scenarios.

Figure 2.1: BMP 1 – GHG Emissions and Percent Adoption

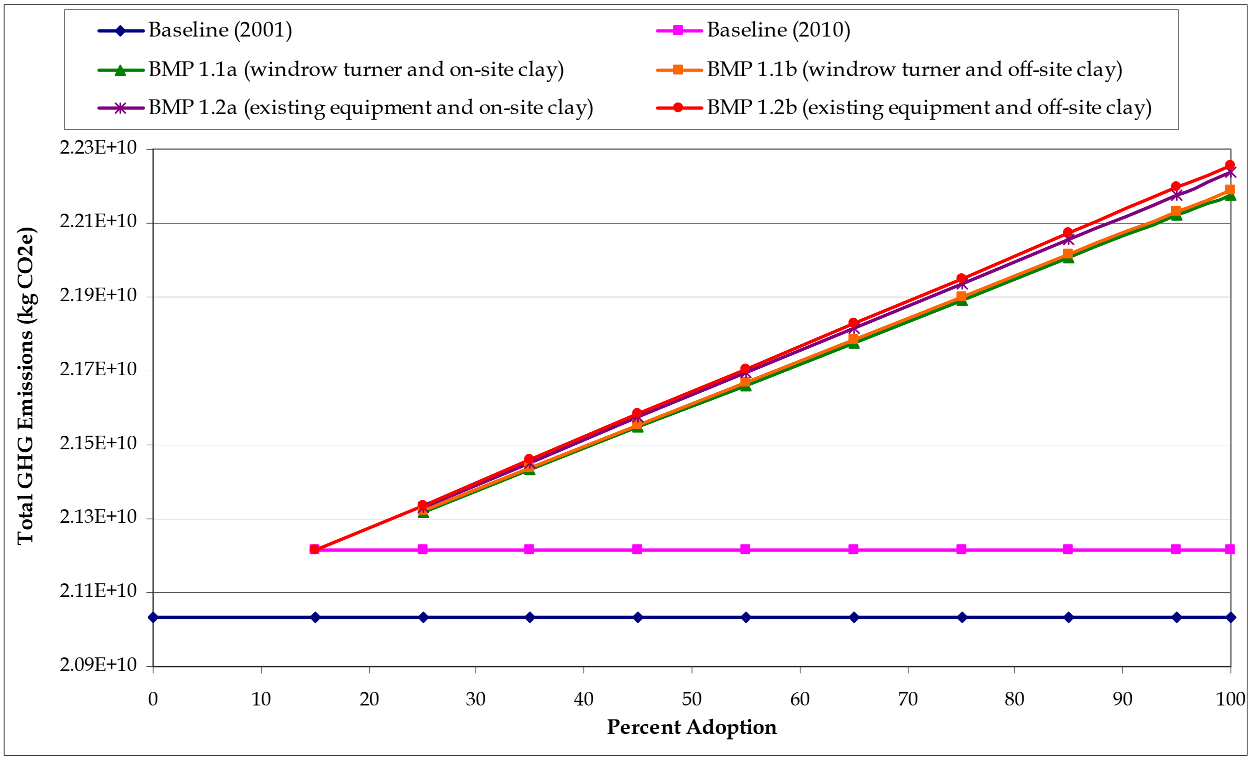


Table 2.1 illustrates the major components of the model where the changes in GHG emissions are occurring from the 2001 baseline, to the 2010 baseline, to the other four scenarios.

The change in GHG emissions from 2010 to 100 percent adoption (in kg CO_2e/kg shrunk live weight) are shown in Table 2.1 and below:

BMP 1.1a (windrow turner/on-site clay)	4.5% increase
BMP 1.1b (windrow turner/off-site clay)	4.6% increase
BMP 1.2a (existing loader/on-site clay)	4.8% increase
BMP 1.2b (existing loader/off-site clay)	4.9% increase

Note that construction-related activities are a one-time event, and therefore, these impacts would only be applied to the year of construction and not on an annual basis. All LCA results presented in this report include the impacts of construction activities. Table 2.1 provides the change in overall GHG impact both with and without the effect of the construction activities, for comparison purposes. The construction activities do increase the GHG emissions and the impacts for the other three environmental impact categories; however, the impacts of the construction activities do not affect the overall conclusions of this report and cannot be excluded.

The main sources of GHG emissions changes occur from the following components:

- Construction activities (excavate clay, transport clay, construct compost pad, manufacture windrow turners, transport windrow turners)
- Energy generation and usage activities (produce crude, transport crude, refine crude into diesel, transport diesel, combust diesel – all for equipment used to turn composting material)
- Feedlot activities (dispose of manure off site, transport wood waste to site for amendment material, produce straw for amendment material, transport straw for amendment material)
- Methane emissions from manure
- Nitrous oxide emissions from manure

All sources of GHG emissions changes are increases in emissions, except for the transportation of manure off site and methane emissions from manure.

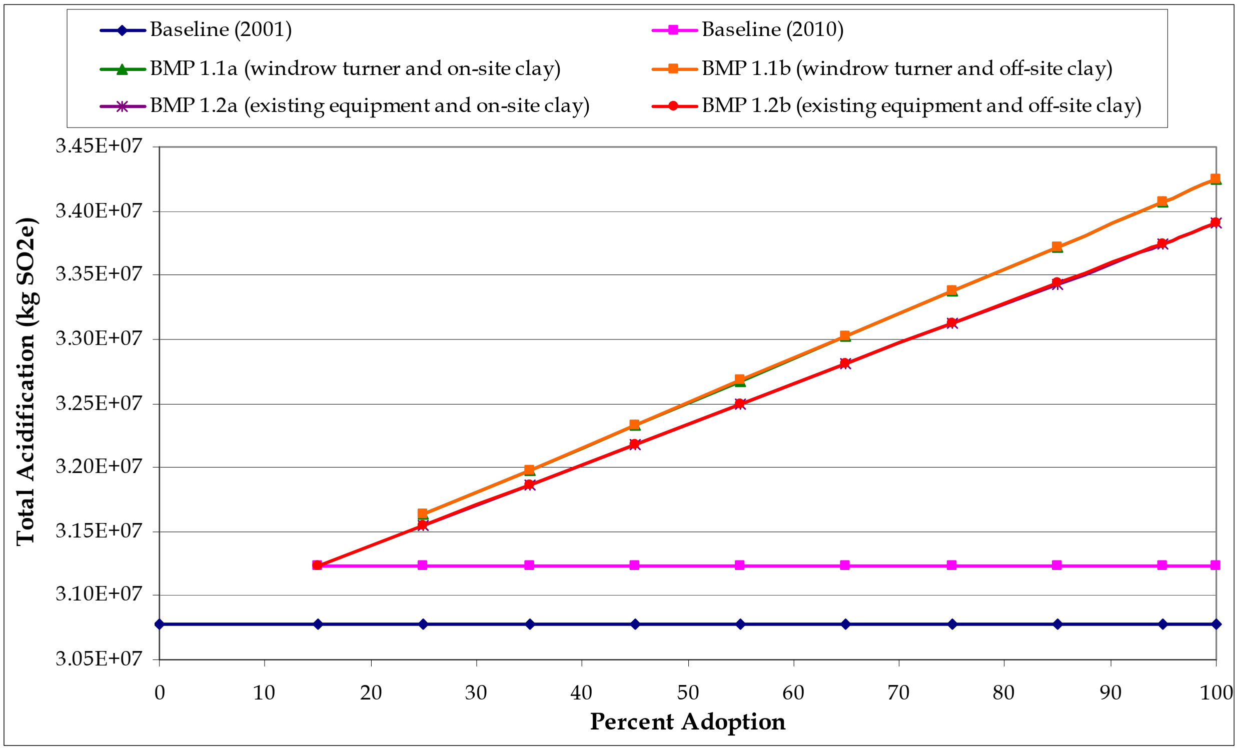
For the windrow turner scenarios, the components that contributed to over 95 percent of the changes in GHG emissions were the manufacturing of the windrow turners, the production of straw for amendment material, methane emissions reductions from manure, and the nitrous oxide emission increases from manure.

For the existing equipment scenarios, the components that contributed to over 98 percent of the changes in GHG emissions were all emissions associated with the production and combustion of diesel, the production of straw for amendment material, methane emissions reductions from manure, and the nitrous oxide emission increases from manure.

Although the modeling indicates, based on the methods used in the baseline, that there will be an increase in GHG emissions from the implementation of this BMP, CRA does not believe that this would actually be the case if the composting process was conducted in a reasonable manner. The model formulation and the data sources (IPCC) have forced the results into an increase in GHG emissions. Approximately 20 percent of the total GHG emissions for all four scenarios are contributed by methane and nitrous oxide emissions from manure. With proper composting techniques, it is expected that these emissions would be essentially negligible. However, as stated above in Section 2.2.1, there are currently no other methodologies to estimate the reduction in these emissions.

The following graph shows the total acidification impact versus the percent adoption for all four scenarios. The main elements that resulted in changes to the acidification impact were the construction activities for the windrow turner and clay pad, diesel generation and combustion for turning, and the production and transport of straw for composting amendment material. There is minimal difference between using off-site or on-site clay.

Figure 2.2: BMP 1 – Acidification and Percent Adoption

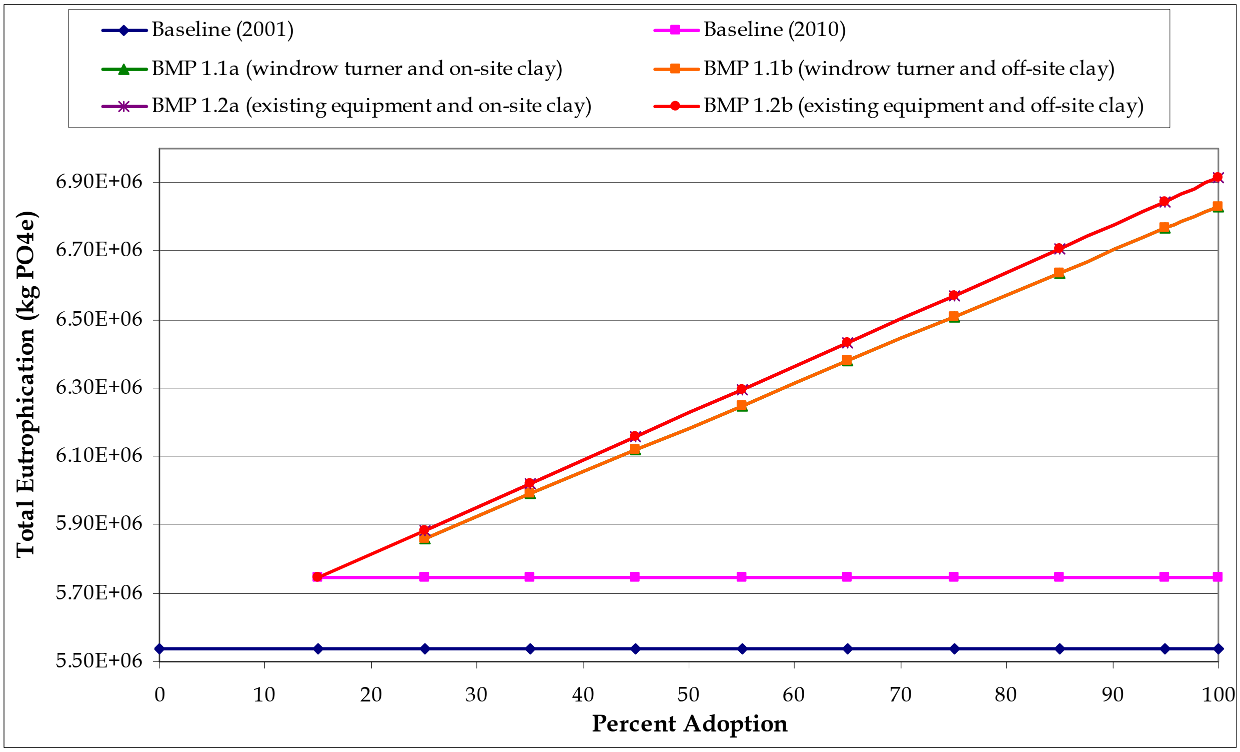


The change in acidification impacts from 2010 to 100 percent adoption (in kg SO_2e/kg shrunk live weight) are shown below:

- BMP 1.1a (windrow turner/on-site clay) 9.6% increase
- BMP 1.1b (windrow turner/off-site clay) 9.7% increase
- BMP 1.2a (existing loader/on-site clay) 8.6% increase
- BMP 1.2b (existing loader/off-site clay) 8.6% increase

The following graph shows the total eutrophication impact versus the percent adoption for all four scenarios. The main elements that resulted in changes to the eutrophication impact were the same as for acidification: construction activities for the windrow turner and clay pad, diesel generation and combustion for turning, and the production and transport of straw for composting amendment material. There is minimal difference between using off-site or on-site clay.

Figure 2.3: Eutrophication and Percent Adoption

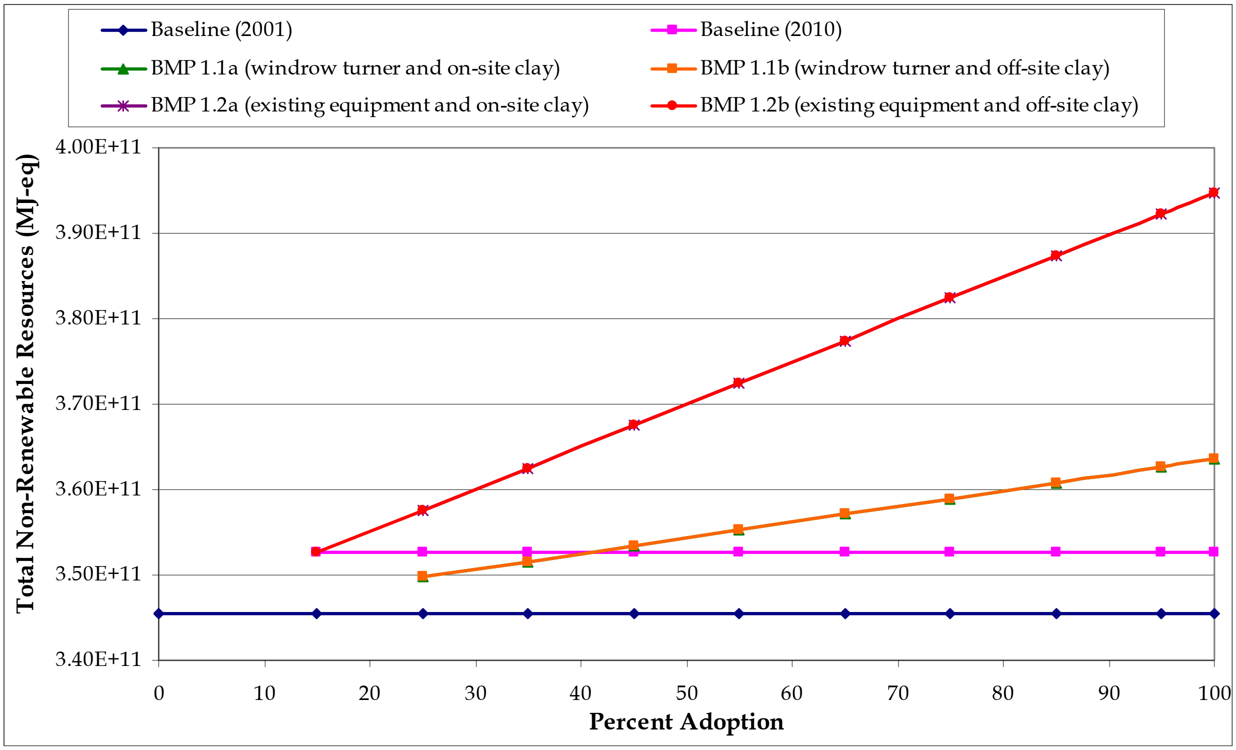


The change in eutrophication impacts from 2010 to 100 percent adoption (in kg PO_4e/kg shrunk live weight) are shown below:

BMP 1.1a (windrow turner/on-site clay)	18.9% increase
BMP 1.1b (windrow turner/off-site clay)	18.9% increase
BMP 1.2a (existing loader/on-site clay)	20.4% increase
BMP 1.2b (existing loader/off-site clay)	20.4% increase

The following graph shows the total non-renewable resources impact versus the percent adoption for all four scenarios. The main elements that resulted in changes to the non-renewable resources impact were the same as for acidification and eutrophication: construction activities for the windrow turner and clay pad, diesel generation and combustion for turning, and the production and transport of straw for composting amendment material. Windrow turners utilize much less diesel than front-end loaders, causing a significant difference in the impact on non-renewable resources. There is minimal difference between using off-site or on-site clay.

Figure 2.4: Non-Renewable Resources and Percent Adoption



The change in total non-renewable resources impacts from 2010 to 100 percent adoption (in MJ-eq/kg shrunk live weight) are shown below:

• BMP 1.1a (windrow turner/on-site clay)	3.1% increase
• BMP 1.1b (windrow turner/off-site clay)	3.1% increase
• BMP 1.2a (existing loader/on-site clay)	12.0% increase
• BMP 1.2b (existing loader/off-site clay)	12.0% increase

2.4 CBA AND BMP 1 – COMPOSTING OF FEEDLOT MANURE (2010 BASELINE)

BMP 1 (2010 baseline) is based on the assumption that 15 percent of feedlots are composting using on-farm supplied front-end loaders to turn composting material. The first CBA **(CBA 1)** for this BMP is for the feedlot operation based on changes in market value inputs and outputs. The value of any changes in GHG emissions is not accounted for. The benefits to the feedlot operator are less fuel to haul manure off site and a higher value of the manure output when sold as compost at $6/tonne, or $40/head of finished beef. As noted above in Section 2.1, the value of compost at $6/tonne reflects the value as bulk fertilizer for field application. The total benefits are $12.9 million, as shown in the upper portion of Table 2.2 below.

Table 2.2: Benefits and Costs of BMP 1 at the Feedlot in 2010 – Market Values

Items	**Units**	**Volume Change**	**Unit Price ($/unit)**	**Total Impact ($ million)**
Benefits - Input Cost Savings				
Fuel consumed to transport manure off-site for disposal	L	-1,045,037	$0.75	-$0.78
Total - Input Cost Savings				**-$0.78**
Benefits - Higher Value of Outputs				
Manure sold for land application	kg	-3,762,900,274	$0.00	$0.00
Compost sold for land application	tonne	2,148,560	$6.00	$12.89
Total - Higher Value of Outputs				**$12.89**
Costs - Higher Input Usage				
Fuel/energy required to operate composting equipment	L	11,880,334	$0.75	$8.89
Labour to operate equipment	hrs	474,445	$16.22	$7.70
Purchased amendment materials (wood waste/wood chips)	kg	77,800,839	$0.13	$10.29
Purchased amendment materials (straw)	kg	1,025,615,118	$0.06	$59.81
Total - Higher Annual Input Operating Costs				**$86.69**
Purchase of composting equipment (Windrow turner)	turners	0	$175,000	$0.00
Purchase of clay for composting pad and compaction	m^3	3,374,460	$28.00	$94.48
Compaction of clay (source on site)	m^3	0	$15.00	$0.00
Transportation costs for clay to site (250 km assumed)	tonne	4,386,798	$25.00	$109.67
Total - Higher Capital Input Costs				**$204.15**

The costs of composting using a front-end loader include higher labour hour requirements (to operate the equipment), fuel usage for the front-end loader, and purchases of amendments (wood waste or chips and straw) to assist in the compost manufacturing process. These incremental costs of composting are $86.7 million, or $271/head shipped to the slaughter plant in a year.

There are also capital costs that need to be considered, such as purchase of clay which is required as an impermeable liner for the compost piles. The one-time cost for the 2010 baseline is $204 million, or $10 million per year with straight line amortization over the 20 years of useful life.

Before considering associated capital costs, the annual costs of this BMP in 2010 exceed the annual benefits by $73 million, as shown in Table 2.3. The BCR (benefit cost ratio) is 0.16 reinforcing the view that this BMP is not a financially sound investment when considering only market values.

The NPV (net present value) of annual benefits over 20 years is also shown in Table 2.3 and is calculated to be $211 million[2]. The NPV of costs is $1.54 billion, and includes the upfront capital costs. The BCR is 0.14:1 signifying the general conclusion that composting is not a paying proposition for a feedlot operator.

Table 2.3: Benefit Cost Ratio at the Feedlot for BMP 1 in 2010 – Market Values

Total Annual Benefits ($ million)	**$13.67**
Total Annual Costs ($ million)	**$86.69**
Net Annual Benefits [Benefits - Costs] ($ million)	**-$73.02**
Ratio of Annual Benefits to Annual Costs	**0.16**
NPV of benefits ($ million)	**$210.55**
NPV of costs ($ million)	**$1,539.05**
Ratio of NPV of Benefits to NPV of Costs	**0.14**

The second CBA (CBA 2) retains the feedlot operation focus and considers the impact on emissions. This BMP increases GHG emissions as illustrated in Table 2.4. While the BMP reduces methane from the stored manure, the use of equipment and required energy consumption increases, with a net increase in emissions of CO_2e of 79,170 tonnes. The value of this increase is estimated to be $1.6 million, based on carbon equivalents trading at $20/tonne.

The emissions associated with construction of the facility are 5,900 tonnes CO_2e as indicated in the lower portion of Table 2.4.

Table 2.4: Benefit of Emission Reduction at the Feedlot in 2010 - BMP 1

Reduction in Feedlot Emissions	**Units**	**Volume Change**	**Unit Price ($/unit)**	**Total Impact ($ million)**
Methane emissions from stored manure	kg CO_2e	-9,973,412	$0.02	-$0.20
N_2O emissions from stored manure (direct)	kg CO_2e	33,522,710	$0.02	$0.67
Energy generation and consumption activities	kg CO_2e	57,361,116	$0.02	$1.15
Feedlot activities	kg CO_2e	-1,740,899	$0.02	-$0.03
Totals - On-going		**79,169,515**		**$1.58**
Construction activities	kg CO_2e	5,894,107	$0.02	$0.12
Total - One-time	kg CO_2e	**5,894,107**	**$0.02**	**$0.12**

When valuing the higher emissions, the BCR for annual benefits in relation to annual costs falls to 0.15 as shown in Table 2.5.

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[2] Based on a 2 percent inflation rate and a 5 percent discount rate.

Table 2.5: Benefit Cost Ratio at the Feedlot for BMP 1 in 2010

Total Annual Benefits ($ million)	**$13.67**
Total Annual Costs ($ million)	**$88.27**
Net Annual Benefits [Benefits - Costs] ($ million)	**-$74.60**
Ratio of Annual Benefits to Annual Costs	**0.15**
NPV of benefits ($ million)	**$211**
NPV of costs ($ million)	**$1,564**
Ratio of NPV of Benefits to NPV of Costs	**0.13**

2.5 CBA AND BMP 1.1A – COMPOSTING OF FEEDLOT MANURE WITH WINDROW TURNING AND USING EXISTING ON-SITE CLAY

BMP 1.1a captures change from the 2010 baseline with all feedlots composting manure using windrow turners and having clay on site that can be used as a compost pad. The industry wide benefits include the 12.2 million tonnes of compost sold for an annual value of $73 million (as shown in Table 2.6), with another $4.4 million in reduced fuel costs to haul less -manure from the feedlot.

Table 2.6: Benefits and Costs of BMP 1.1a at the Feedlot – Market Values

Items	**Units**	**Volume Change**	**Unit Price ($/unit)**	**Total Impact ($ million)**
Benefits - Input Cost Savings				
Fuel consumed to transport manure off site for disposal	L	-5,921,879	$0.75	-$4.43
Total - Input Cost Savings				**-$4.43**
Benefits - Higher Value of Outputs				
Manure sold for land application	kg	-21,323,101,554	$0.00	$0.00
Compost sold for land application	tonne	12,175,175	$6.00	$73.05
Total - Higher Value of Outputs				**$73.05**
Costs - Higher Input Usage				
Fuel/energy required to operate composting equipment	L	5,468,530	$0.75	$4.09
Labour to operate equipment	hrs	-92,521	$16.22	-$1.50
Purchased amendment materials (wood waste/wood chips)	kg	440,871,424	$0.13	$58.32
Purchased amendment materials (straw)	kg	5,811,819,001	$0.06	$338.92
Total - Higher Annual Input Operating Costs				**$399.83**
Purchase of composting equipment (Windrow turner)	turners	2,055	$175,000	$359.69
Purchase of clay for composting pad and compaction	m^3	-3,374,460	$28.00	-$94.48
Compaction of clay (source on site)	m^3	13,609,353	$15.00	$204.14
Transportation costs for clay to site (250 km assumed)	tonne	-4,386,798	$25.00	-$109.67
Total - Higher Capital Input Costs				**$359.67**

The annual costs are predominately the costs associated with amendments (wood waste and straw) to develop the compost material. These costs are $400 million and as noted in Table 2.7, the annual costs exceed the annual benefits to the feedlot operation by $322 million, or by $150/head of finished beef cattle. The main reason for the poor economics is that the cost of the amendments exceeds the value of the compost. The BCR of these annual benefits and costs is well below 1:1, at 0.19:1.

Table 2.7: Benefit Cost Ratio at the Feedlot for BMP 1.1a in 2010 – Market Values

Total Annual Benefits ($ million)	**$77.48**
Total Annual Costs ($ million)	**$399.83**
Net Annual Benefits [Benefits - Costs] ($ million)	**-$322.35**
Ratio of Annual Benefits to Annual Costs	**0.19**
NPV of benefits ($ million)	**$1,193.14**
NPV of costs ($ million)	**$6,516.57**
Ratio of NPV of Benefits to NPV of Costs	**0.18**

Once the capital costs are considered and the annual benefits and costs are considered over the 20-year life of the turning equipment, which is valued at $175,000 per windrow turner, the NPV of the benefits are only 18 percent of the NPV of the costs. Without any other benefit stream, or a lower cost profile, feedlot operators have no financial incentive to compost manure.

Composting is not shown to reduce GHG emissions with annual volumes of CO_2e increasing by 151,680 tonnes, as shown below in Table 2.8. Valued at $20/tonne, the annual negative net benefits (net costs) of this BMP increases to -$325 million (refer to Table 2.9). This BMP has a cost of $153/head of beef cattle shipped to slaughter plants.

Table 2.8: Benefit of Emission Reduction at the Feedlot - BMP 1.1a

Reduction in Feedlot Emissions	**Units**	**Volume Change**	**Unit Price ($/unit)**	**Total Impact ($ million)**
Methane emissions from stored manure	kg CO_2e	-56,516,000	$0.02	-$1.13
N_2O emissions from stored manure (direct)	kg CO_2e	189,962,026	$0.02	$3.80
Energy generation and consumption activities	kg CO_2e	26,403,381	$0.02	$0.53
Feedlot activities	kg CO_2e	-8,172,135	$0.02	-$0.16
Totals - On-going		**151,677,271**		**$3.03**
Construction activities	kg CO_2e	252,390,645	$0.02	$5.05
Total - One-time	kg CO_2e	**252,390,645**	**$0.02**	**$5.05**

Factoring in the costs associated, the BCR based on the NPV of costs and benefits remains at 0.18:1.

Table 2.9: Benefit Cost Ratio at the Feedlot for BMP 1.1a – Valuing Emissions

Total Annual Benefits ($ million)	**$77.48**
Total Annual Costs ($ million)	**$402.87**
Net Annual Benefits [Benefits - Costs] ($ million)	**-$325.38**
Ratio of Annual Benefits to Annual Costs	**0.19**
NPV of benefits ($ million)	**$1,193**
NPV of costs ($ million)	**$6,568**
Ratio of NPV of Benefits to NPV of Costs	**0.18**

2.6 CBA AND BMP 1.1B – COMPOSTING OF FEEDLOT MANURE WITH WINDROW TURNING AND USING OFF-SITE CLAY

Table 2.10 shows the operating costs and benefits associated with BMP 1.1b, where off-site clay needs to be transported to the feedlot. This substantially increases the one-time costs to $979 million.

Table 2.10: Benefits and Costs of BMP 1.1b at the Feedlot – Market Values

Items	Units	Volume Change	Unit Price ($/unit)	Total Impact ($ million)
Benefits - Input Cost Savings				
Fuel consumed to transport manure off-site for disposal	L	-5,921,879	$0.75	-$4.43
Total - Input Cost Savings				**-$4.43**
Benefits - Higher Value of Outputs				
Manure sold for land application	kg	-21,323,101,554	$0.00	$0.00
Compost sold for land application	tonne	12,175,175	$6.00	$73.05
Total - Higher Value of Outputs				**$73.05**
Costs - Higher Input Usage				
Fuel/energy required to operate composting equipment	L	5,468,530	$0.75	$4.09
Labour to operate equipment	hrs	-92,521	$16.22	-$1.50
Purchase of amendment materials (wood waste/wood chips)	kg	440,871,424	$0.13	$58.32
Purchase of amendment materials (straw)	kg	5,811,819,001	$0.06	$338.92
Total - Higher Annual Input Operating Costs				**$399.83**
Purchase of composting equipment (Windrow turner)	turners	2,055	$175,000	$359.69
Purchase of clay for composting pad and compaction	m^3	10,234,893	$28.00	$286.58
Compaction of clay (source on-site)	m^3	0	$15.00	$0.00
Transportation costs for clay to site (250 km assumed)	tonne	13,305,360	$25.00	$332.63
Total - Higher Capital Input Costs				**$978.90**

The associated BCR is shown in Table 2.11. Using NPV computations, the BCR is 0.17 based on costs well exceeding modeled benefits.

Table 2.11: Benefit Cost Ratio at the Feedlot for BMP 1.1b in 2010 – Market Values

Total Annual Benefits ($ million)	**$77.48**
Total Annual Costs ($ million)	**$399.83**
Net Annual Benefits [Benefits - Costs] ($ million)	**-$322.35**
Ratio of Annual Benefits to Annual Costs	**0.19**
NPV of benefits ($ million)	**$1,193.14**
NPV of costs ($ million)	**$7,135.80**
Ratio of NPV of Benefits to NPV of Costs	**0.17**

2.7 CBA AND BMP 1.2A – COMPOSTING OF FEEDLOT MANURE WITH EXISTING EQUIPMENT AND USING EXISTING ON-SITE CLAY

BMP 1.2a is based on the assumption that existing front-end loaders on the farm can be used to turn the windrows and there is sufficient clay on site to create the necessary base for the compost area. This results in lower capital costs ($133 million in Table 2.12 compared to the capital costs with BMP 1.1 a of $360 million – in Table 2.6).

Table 2.12: Benefits and Costs of BMP 1.2a at the Feedlot – Market Values

Items	Units	Volume Change	Unit Price ($/unit)	Total Impact ($ million)
Benefits - Input Cost Savings				
Fuel consumed to transport manure off-site for disposal	L	-5,921,879	$0.75	-$4.43
Total - Input Cost Savings				**-$4.43**
Benefits - Higher Value of Outputs				
Manure sold for land application	kg	-21,323,101,554	$0.00	$0.00
Compost sold for land application	tonne	12,175,175	$6.00	$73.05
Total - Higher Value of Outputs				**$73.05**
Costs - Higher Input Usage				
Fuel/energy required to operate composting equipment	L	67,321,893	$0.75	$50.39
Labour to operate equipment	hrs	2,688,520	$16.22	$43.61
Purchase of amendment materials (wood waste/wood chips)	kg	440,871,424	$0.13	$58.32
Purchase of amendment materials (straw)	kg	5,811,819,001	$0.06	$338.92
Total - Higher Annual Input Operating Costs				**$491.24**
Purchase of composting equipment (Windrow turner)	turners	0	$175,000	$0.00
Purchase of clay for composting pad and compaction	m³	-3,374,460	$28.00	-$94.48
Compaction of clay (source on-site)	m³	22,495,500	$15.00	$337.43
Transportation costs for clay to site (250 km assumed)	tonne	-4,386,798	$25.00	-$109.67
Total - Higher Capital Input Costs				**$133.28**

With 100 percent adoption, the annual operating costs exceed annual benefits by $413 million, or by a factor of at least 6. As reported in Table 2.13, the BCR is 0.16 when considering only annual costs and benefits, or comparing the NPV of benefits and costs.

Table 2.13: Benefit Cost Ratio at the Feedlot for BMP 1.2a in 2010 – Market Values

Total Annual Benefits ($ million)	**$77.48**
Total Annual Costs ($ million)	**$491.24**
Net Annual Benefits [Benefits - Costs] ($ million)	**-$413.76**
Ratio of Annual Benefits to Annual Costs	**0.16**
NPV of benefits ($ million)	**$1,193.14**
NPV of costs ($ million)	**$7,697.70**
Ratio of NPV of Benefits to NPV of Costs	**0.16**

2.8 CBA AND BMP 1.2B – COMPOSTING OF FEEDLOT MANURE WITH EXISTING EQUIPMENT AND USING OFF-SITE CLAY

In BMP 1.2b, when off-site clay is used, with existing equipment, the one-time costs increase to over $1.1 billion for all feedlots. This is shown in Table 2.14. Annual operating costs are comparable to BMP 1.2a.

Table 2.14: Benefits and Costs of BMP 1.2b at the Feedlot – Market Values

Items	**Units**	**Volume Change**	**Unit Price ($/unit)**	**Total Impact ($ million)**
Benefits - Input Cost Savings				
Fuel consumed to transport manure off-site for disposal	L	-5,921,879	$0.75	-$4.43
Total - Input Cost Savings				**-$4.43**
Benefits - Higher Value of Outputs				
Manure sold for land application	kg	-21,323,101,554	$0.00	$0.00
Compost sold for land application	tonne	12,175,175	$6.00	$73.05
Total - Higher Value of Outputs				**$73.05**
Costs - Higher Input Usage				
Fuel/energy required to operate composting equipment	L	67,321,893	$0.75	$50.39
Labour to operate equipment	hrs	2,688,520	$16.22	$43.61
Purchase of amendment materials (wood waste/wood chips)	kg	440,871,424	$0.13	$58.32
Purchase of amendment materials (straw)	kg	5,811,819,001	$0.06	$338.92
Total - Higher Annual Input Operating Costs				**$491.24**
Purchase of composting equipment (Windrow turner)	turners	0	$175,000	$0.00
Purchase of clay for composting pad and compaction	m^3	19,121,040	$28.00	$535.39
Compaction of clay (source on-site)	m^3	0	$15.00	$0.00
Transportation costs for clay to site (250 km assumed)	tonne	24,857,352	$25.00	$621.43
Total - Higher Capital Input Costs				**$1,156.82**

The amount of clay used in BMP 1.2b is much greater than the amount used in BMP 1.1b due to the larger composting area required to turn the compost material with a front-end loader compared to a windrow turner, which is more efficient at turning the material in a smaller area.

The net result is that compared to BMP 1.2a, the BCR based on NPV computation is even lower at 0.14:1 (Table 2.15).

Table 2.15: Benefit Cost Ratio at the Feedlot for BMP 1.2b in 2010 – Market Values

Total Annual Benefits ($ million)	**$77.48**
Total Annual Costs ($ million)	**$491.24**
Net Annual Benefits [Benefits - Costs] ($ million)	**-$413.76**
Ratio of Annual Benefits to Annual Costs	**0.16**
NPV of benefits ($ million)	**$1,193.14**
NPV of costs ($ million)	**$8,721.25**
Ratio of NPV of Benefits to NPV of Costs	**0.14**

The costs associated with these BMP variations have comparable results, with the associated BMP costs well exceeding the benefits by a factor of at least six. This BMP, as modeled should not be pursued for two reasons: (1) the annual operating costs exceed annual benefits, and (2) the BMP works against the objective of reducing GHG emissions into the environment. Please refer to Section 2.3 for the overall change in GHG emissions and the impact on total CO_2e emissions per kg of beef for the other three scenarios.

3.0 CBA OF BMP 2 – INCREASED EFFICIENCY IN COW/CALF FEEDING AND GRAZING

The intent of the BMP related to increasing efficiency in cow/calf feeding within the beef production system in Alberta to improve the cow/calf economics based on lower feed expenses while preventing over-grazing and associated pasture degradation and protection of riparian areas and surface water bodies.

With respect to the reduction of the GHG emissions related to the cow/calf feeding practices, the key agricultural management practices included in this BMP are:

- Conversion of cropland to pasture for additional grazing
- Winter grazing management

Conversion of Cropland to Pasture

Converting annual cropland to pasture decreases net GHG emissions by sequestering more carbon. Perennial grasses sequester more carbon than annual crops because of their fibrous root system. Perennial grasses also store more soil carbon than perennial legumes (Tyrchniewicz Consulting, 2006).

Winter Grazing Management

The management of winter grazing on Canadian farms involves the management of pasture land along with the control of livestock access to the pasture land. Beneficial management practices allow for a sustainable increase in pasture forage production, higher stocking rates per unit of pasture land, improved livestock weight gain, controlled access of livestock to riparian areas and, eventually, greater financial returns to the farmer (Statistics Canada, 2005). While providing cattle with quality forage, grazing management also offers a significant potential to reduce GHG emissions by the sequestration of carbon from the atmosphere.

The main strategies of winter grazing management are presented below. These practices are currently applied to various extents by different producers in Alberta, while the research stage for the most beneficial management practices are still being developed (Tyrchniewicz Consulting, 2006):

- Forage mix for improved pasture: a diversity of native plant species, especially deep-rooted and productive forms, vigorous healthy plants with well-developed root systems, adequate vegetative cover to protect soils from erosion and to conserve scarce moisture (Alberta Government, 2005)

- Fertilization of pasture
- Stocking rates
- Balancing livestock demands with the available forage supply; the rancher leaves adequate ungrazed residue to protect plants and soil
- Promoting even livestock distribution by using tools like fencing, salt placement and water development to spread the grazing "load" over the landscape

3.1 DESCRIPTION OF BMP 2 – INCREASED EFFICIENCY IN COW/CALF FEEDING AND GRAZING

The operating assumptions for BMP 2, increased efficiency in cow/calf feeding and grazing, include:

- Fewer kilograms of alfalfa/grass hay are required, resulting from total or partial replacement of the baseline winter diet for a period of either 30 or 90 days with stockpile and swath grazing, respectively
- All feed consumed by the cow/calf operation for winter feeding is purchased versus being -produced on the cow/calf operation
- The amount of labour required for winter feeding decreases due to the changes in management practices
- The number of cattle produced for slaughter does not change, despite animals being on modified feeding patterns, with the winter alfalfa/grass hay diet being replaced totally (swath grazing) or partially (stockpile grazing) by extended grazing on pasture
- Capital expenditures associated with this BMP are related to the grazing management strategies and consist of fencing for directional grazing and windbreakers for sheltering

In Phase 1 of the Beef LCA project, alfalfa/grass hay was the only feed produced for winter feed in the cow/calf sector. This crop, as defined in the baseline, had specific nutrient requirements and received a proportion of the manure from feedlot operations as soil amendment, and therefore had a certain fertilizer requirement based upon the nutritional needs of the crop and the nutrients available from the applied manure. Under BMP 2, both the crops produced for winter feed as well as the proportion of manure used as soil amendment have changed, altering the balance of crop nutrient requirements and nutrients available from manure identified in the baseline.

In BMP 2, alfalfa is no longer included in winter feed production for the cow/calf sector, a change by itself that alters the amount of fertilizer which must be applied and therefore produced. Additionally, it is assumed that no manure from feedlots is applied to crops grown for swath or stockpile grazing. Instead it is assumed that the only manure applied to those crops is directly deposited by cattle while grazing, changing the characteristics of the manure through differing diets as well as the manner of application and incorporation.

Consequently, implementation of BMP 2 changes the fertilizer requirements of crops throughout the entire beef industry in that a larger proportion of feedlot manure is available for use on the remaining alfalfa/grass hay as well as feed crops produced for the feedlot sector, thereby reducing the amount of fertilizers that must be consumed for the production of those crops, while a completely different balance of nutrient requirement vs. manure/fertilizer application occurs in the cow/calf sector.

The two options considered in the implementation of BMP 2 are:

- BMP 2.1: Extended Grazing on Winter Pasture -Swath Grazing
- BMP 2.2: Extended Grazing on Winter Pasture - Stockpile Grazing

BMP 2.1: Swath Grazing

Swath grazing is a management practice used to extend the grazing season through winter, while reducing feed and labour costs for cattle producers. Annual cereals are seeded in mid-May to early June and swathed from late August to mid-September when the crop reaches the soft to late dough stage and before killing frosts. The swaths are left in the field for the cattle to graze during the winter (Agri-Facts, October 2004).

The rations presented in the first phase of the modeling exercise (CRA, 2010) - were adjusted based on replacement of winter feed with extended grazing.

The structure of the swath grazing model is based on:

- Selection of crops (Agri-Facts, September 2008):
  - Cereal/Annual crops: breakdown of crops by region, respectively: Dry Prairie (DP), Parkland (P) and Northern Region (NR)
- Swath grazing management (Agri-Facts, October 2004; Agri-Facts, September 2008).

Selected crops:

- Cereal (annual)
  - Dry Prairie: oats and triticale
  - Parkland: oats and triticale
  - Northern Region: oats and triticale

BMP 2.2: Stockpile Grazing

Stockpiling pasture is a form of deferred grazing. The forage grown during the spring and summer is used when other pasture is in short supply or when cattle need fall or winter feed. By stockpiling pasture, harvesting, hauling and feeding costs associated with alfalfa/grass hay are eliminated.

The structure of the stockpile grazing model is based on:

- Selection of crops (Agri-Facts, October 2008):
  - Perennial: Dry Prairie, Parkland, Northern Regions
- Stockpile grazing management (Agri-Facts, October 2008)

Selected crops:

- Dry Prairie: grass, mixture of meadow brome, Russian wild rye and pubescent wheatgrass
- Parkland: grass, meadow brome
- Northern Region: grass, meadow brome

The direct impacts of BMP 2 implementation in the cow/calf sector include:

Outputs (same for both BMP 2.1 – Swath grazing and BMP 2.2 – Stockpile grazing):

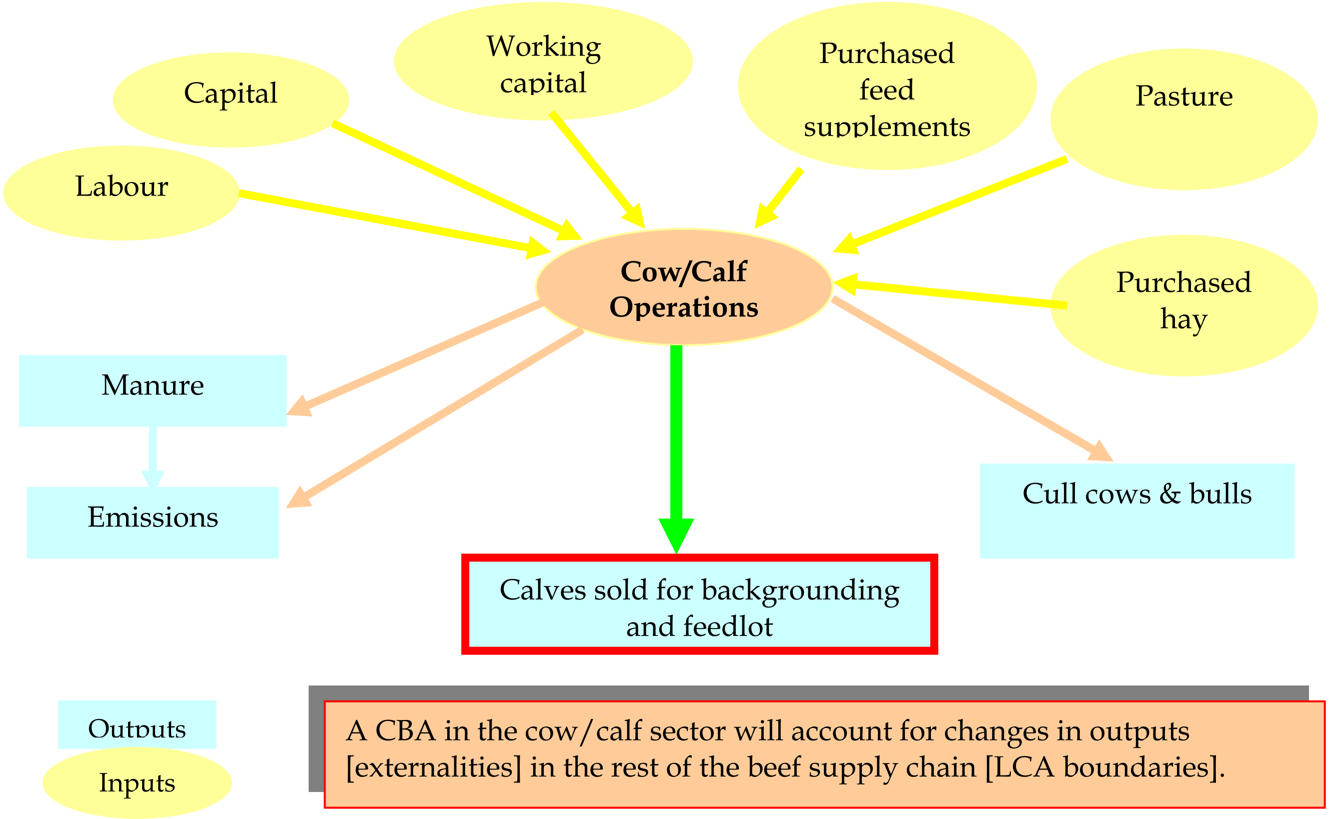
- No change in annual volume of finished cattle supplied to slaughter plants
- Modified emissions from manure
- Modified soil N_2O emissions from cropping and land use
- Modified P_2O_5 runoff from cultivation activities
- Modified soil carbon change

Inputs (same for both BMP 2.1 – Swath grazing and BMP 2.2 – Stockpile grazing):

- Less alfalfa/grass hay for winter feed (removing days of baseline winter diet, replaced by the swath grazing and stockpile grazing periods)
- New grass and cereal crops for extended grazing through winter
- Modified amount of cereal/grass seed
- Modified amount of fertilizer needed (chemical and soil amendment)
- Modified amount of pesticide needed
- Energy Generation Activities
  - Change in gasoline, diesel, and electricity used based on extended grazing
- Forage Activities (new crops)
  - Modified fuel consumption for cultivating soil, applying fertilizer, planting crop, irrigating crop, applying chemical treatment
  - No transportation of harvested crop
  - Modified soil N_2O emissions from cropping and land use
  - Modified P_2O_5 runoff from cultivating
  - Modified soil carbon change
- Pasture Activities
  - No garbage to dispose of on site
  - Decrease of fuel consumption to produce bedding, transport bedding and bedding livestock
  - Less plastics to be produced (if additional feed is required to the winter grazing – bales of hay)

Figure 3.1 is provided to show the boundary associated with the cow/calf sector. It indicates that all pasture is provided by the operation, with hay purchased from other sources. The assumptions made were that existing pasture land will be managed more intensely to generate the necessary feed to have an extended grazing season, before outside hay is purchased for feeding through the remainder of the winter period.

Figure 3.1: Boundary and Potential Resource Impacts in the Cow/Calf Sector



A CBA in the cow/calf sector will account for changes in outputs [externalities] in the rest of the beef supply chain [LCA boundaries].

In addition to the above direct impacts, there are indirect impacts based on linkages. This would include the lower emissions associated with less hay production purchased from third parties, as well as (possibly) higher emissions based on larger deliveries to the cow/calf operation (i.e., fertilizer, seeds, etc.).

3.2 BMP 2 – MODELLING LCA AND IMPACT

The LCA of BMP 2 follows the structure of the model used during the first phase of the project (CRA, 2010). Additional information is represented by:

- Data collection:
  - Type of crops (species) selected
  - Yield for each of the selected crops
  - Number of cattle allocated to each region (Dry Prairie, Parkland and Northern Region) and type of crops (annual, perennial)
  - Number of days on swath/stockpile grazing
  - Necessary logistics for the grazing management (fencing, windbreakers)
- Calculations:
  - the area cultivated to meet the needs of the swath/stockpile grazing
  - the logistics used for the management of extended grazing during the winter (fencing, sheltering etc).

Based on the implementation of BMP 2, new crops are added to the initial model, while the alfalfa-grass hay needs are adjusted. Calculations of changes in feed, cropping needs, cropping practices, and biological activity of the cattle followed by calculations of overall emissions are carried through by the basic structure of the initial model.

A crucial step in the current modeling exercise is to determine the area allocated to each of the selected crops for extended grazing. Currently, the extended grazing practice in Alberta is encompassed within a significant range of flexible 300+ day grazing systems on cow/calf operations. Winter grazing as practiced by different cow/calf operators is optimized, with a high degree of flexible management, to accommodate their personal beef business (ARECA, 2006). Data collection efforts did not reveal referenced sources indicating the area of land currently involved in swath/stockpile grazing in Alberta.

This significant data gap was addressed by the most conservative and basic assumption, 100 percent implementation of BMP 2, as described below:

- Swath grazing: 90 days of winter diet from the baseline model, from beginning of December to the end of February, and based entirely on alfalfa-grass hay, are replaced by swath grazing for all cattle in the model.
- Stockpile grazing: 90 days of winter diet from the baseline model, from beginning of December to the end of February, based entirely on alfalfa-grass hay, are reduced by stockpile grazing for all cattle for 30 days during the month of December.

Several observations presented below highlight the versatility of the model to accommodate further changes of the extended grazing practices and/or availability of new data:

- The 100 percent implementation of the BMP can be revised by adjusting the number of cattle on extended grazing.
- Periods on extended grazing can be revised. The current selection of the swath/stockpile grazing periods is based on review of available sources (ARECA, 2006) and a certain degree of generalization.
- Selection of the crops can be revised, in order to accommodate new data sources or revised extended grazing practices.
- Calculation strategy:
  - Summarize the crops for swath/stockpile grazing according to the current practice in Alberta, as described by ARD documents (Agri-Facts, October 2004; Agri-Facts, September 2008, ARECA, 2006). In order to support the functionality of the model, a certain degree of generalization in crop selection was assumed.
  - Estimate the yield for each selected crop. The yield of a crop is regarded as a function of:
    - Regional area: Dry Prairie, Parkland, Northern Regions
    - Crop characteristics
  - Determine the number of cattle on each crop. A first breakdown of cattle numbers by regions, respectively Dry Prairie, Parkland and Northern Region, was performed based on the information available from Statistics Canada (2001 census data). A further breakdown of cattle numbers in each geographic area by crop, was structured to allow customized inputs, based on availability of appropriate data.
  - Allocate the number of days on pasture (ARECA, 2006).
  - Based on the stocking rate of a grazing system (Pratt and Rasmussen, 2001), calculate the swath/stockpile grazing allocated areas. Calculation of the swath/stockpile grazing area takes into account the following factors: crop characteristics (including yield as dry matter), number of cows/bulls on the pasture, available forage coefficient, weight of cows/bulls, food coefficient intake, animal unit (AU) equivalents and days on pasture. Since the baseline winter diet is replaced by extended grazing for all the cattle on cow/calf operations in the baseline model, the total area allocated for swath/stockpile grazing represents the most conservative assumption.

Several more assumptions were made at this stage:

  - Available forage coefficient: assigned as 80 percent. This coefficient was treated as a wastage coefficient with a 20 percent loss of available feed (due to use as bedding, wind losses, wildlife consumption, excessive snow cover, etc.) on a dry matter basis (ARECA, 2006).
  - The body weight of the cattle was assigned to be consistent with the ration formulations used during the Phase 1. The rations were calculated based on a one animal unit (AU) animal, which converts to a body weight of 1,000 lbs (454 kg) which was assumed to be typical for cows. Bulls were assumed to be 1.2 AU or 1,200 lbs (544 kg).
  - The food intake coefficient was assigned as 0.75.
- Compare the calculated number of swath/stockpile grazing areas to the available pasture land statistics (Statistics Canada, 2001) and adjust the model to implement the best swath/stockpile grazing strategy
- Allocate the cereal/grass crop activities (current LCA model) to the calculated crop areas
- Allocate the cow/calf operations (current LCA model) to the corresponding number of cattle
- Calculate emissions related to the implementation of the BMP

ARD was very helpful in providing data to model this BMP. All data collected for this BMP was compiled and evaluated to ensure that the most appropriate data was utilized to obtain the most accurate results for conditions in Alberta.

3.3 BMP 2 – RESULTS OF GHG EMISSIONS AND OTHER IMPACTS

The impacts on the four environmental impact categories (GHG, acidification, eutrophication, and non-renewable resources) were modelled for the entire Alberta beef production system to reflect the changes to the model with the implementation of BMP 2, extended grazing, respectively BMP 2.1 Swath grazing and BMP 2.2 Stockpile grazing. The graphs in this section show the total environmental impact by category for the entire production system in the baseline year (2001), and also show the change from the baseline based on 100 percent adoption of the BMP.

GHG Emissions

The sources of GHG emissions changes are generated by the replacement of cattle days on alfalfa/grass hay - with cattle days on swath/stockpile grazing. The following emission components for BMP 2.1 and BMP 2.2 are modified:

- Forage and cereal sub-activities, forage activities and pasture activities. The activities related to the alfalfa/grass hay from the baseline are replaced by activities related to the new crops for swath/stockpile grazing.
- Energy generation and usage activities (reduction in GHG emissions from producing crude, transporting crude, refining crude into diesel, transporting diesel, combusting diesel - reduction in diesel to feed cattle).
- Soil carbon change from changes in land use.
- Carbon dioxide from managed soils.
- N_2O emissions from soil and cropping.

The change in GHG emissions from 2010 to 100 percent adoption (in kg CO_2e/kg shrunk live weight) are as follows:

BMP 2.1 – swath grazing	1.0% reduction
BMP 2.2 – stockpile grazing	4.2% increase

Swath grazing

All the graphs pertaining to BMP 2.1 Swath grazing are based on cattle being allocated to swath grazing.

Figure 3.2a: BMP 2.1 Swath grazing – GHG Emissions and Percent Adoption

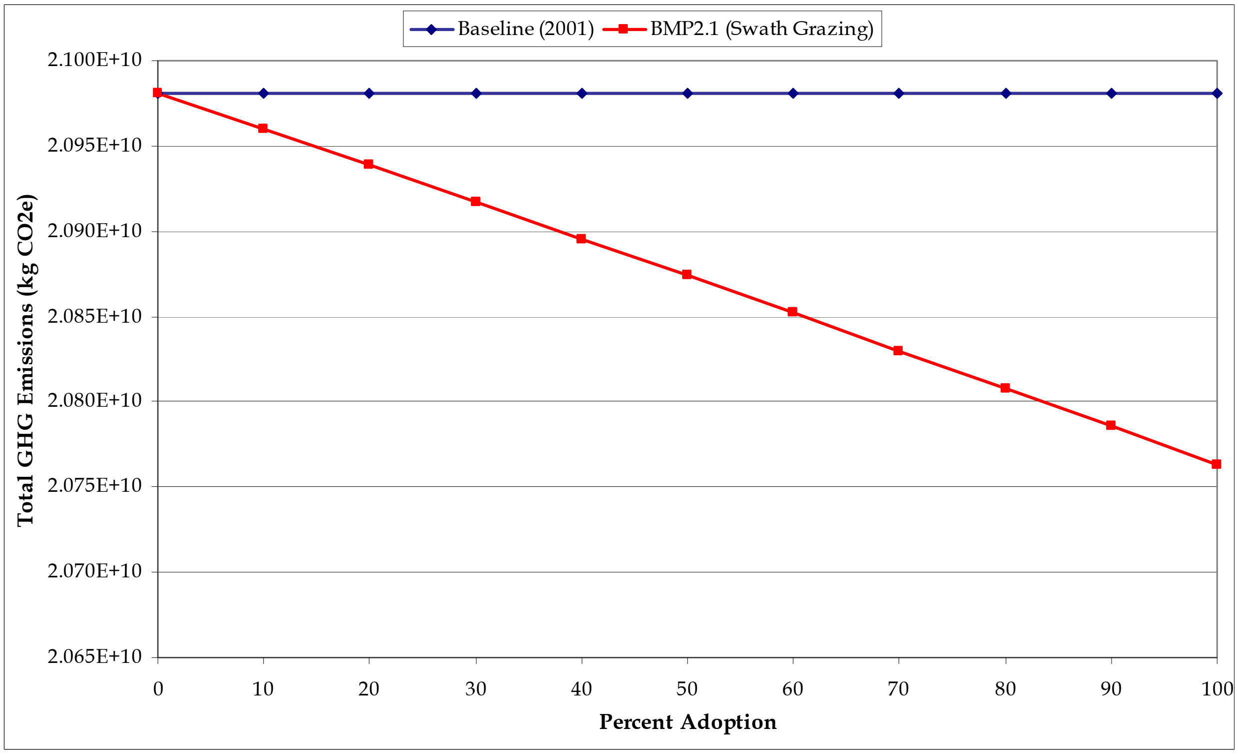


Figure 3.2a shows the total GHG emissions versus the percent adoption of BMP 2.1 for swath grazing. Examination of Figure 3.2a shows a net environmental benefit in terms of the GHG emissions with the implementation of BMP 2.1.

The change in GHG emissions from the 100 percent adoption (in kg CO_{2e}/kg shrunk live weight) are shown in Table 3.1.1 and below.

Note that swath grazing construction-related activities are a one-time event, and therefore, these impacts would only been applied to the year of construction and not on an annual basis.

The main sources of GHG emissions changes occur from the following components:

- Forage and cereal sub-activities (produce seed, process seed, produce and transport fertilizer, produce and transport pesticide/herbicide)
- Energy generation and usage activities (produce crude, transport crude, refine crude into diesel, transport diesel, combust diesel)
- Forage activities (cultivate soil, apply fertilizer, plant crop, irrigate crop, apply chemical and mechanical treatment, harvest crop and transport harvested crop)

- Feedlot and Pasture activities (producing bedding material, feed livestock, production of plastic)
- Soil carbon change from land use
- Direct CO_2 emissions from managed soils
- N_2O emissions from soil and cropping

The sources of GHG emissions changes are as follows:

- Increases: Forage and cereal sub-activities, Soil carbon change from land use, N_2O emissions from soil and cropping
- Decreases: Energy generation activities, Forage activities, Feedlot and pasture activities, Direct CO_2 emissions from managed soils

Stockpile grazing

All the graphs pertaining to BMP 2.2 Stockpile Grazing are based on the cattle being allocated to extended grazing. In comparison to the swath grazing model, where the entire amount of alfalfa/grass hay used to feed the cattle during the baseline winter diet was replaced by extended grazing for 90 days, in the stockpile grazing model only the initial 30 days of the baseline winter diet are being replaced by extended grazing, while the remaining 60 days are the baseline winter diet.

Figure 3.2b: BMP 2.2 Stockpile Grazing – GHG Emissions and Percent Adoption

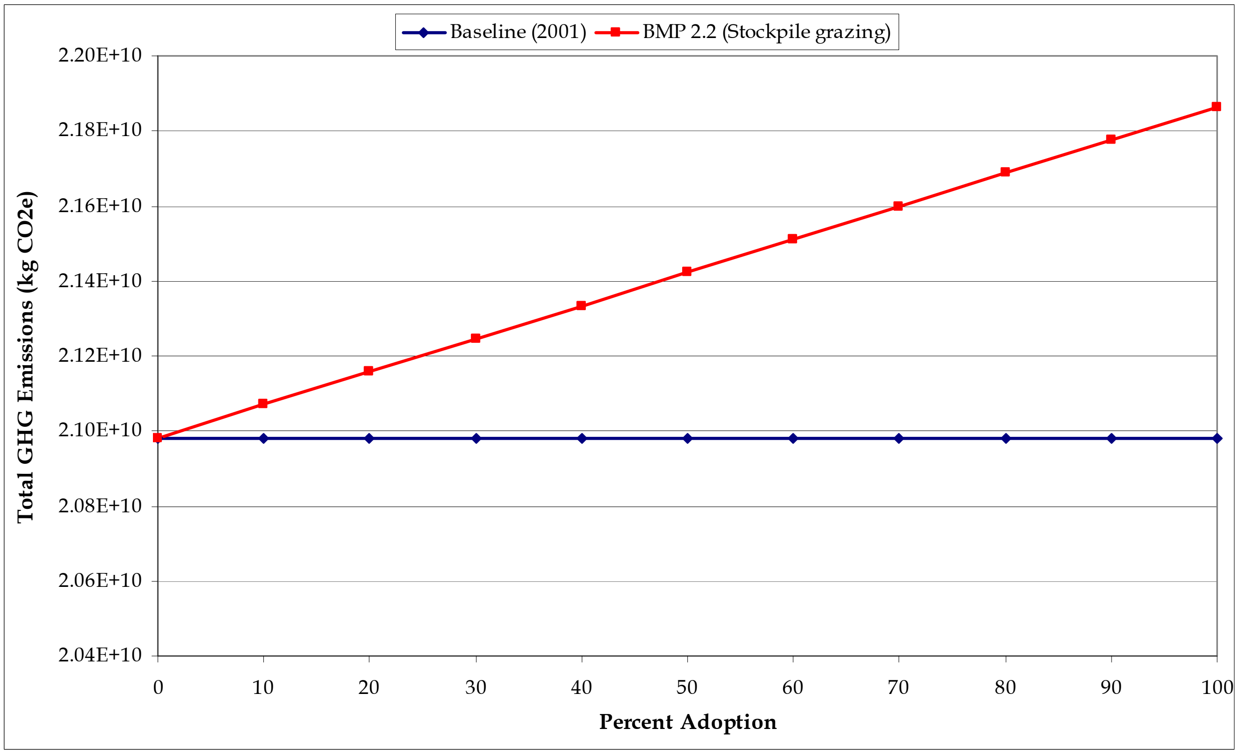


Figure 3.2b shows the total GHG emissions versus the percent adoption of BMP 2.2 for stockpile grazing. Examination of Figure 3.2b shows an increase in GHG emissions with the percent adoption of BMP 2.2.

Stockpile grazing construction-related activities are a one-time event, and therefore, these impacts would only been applied to the year of construction and not on an annual basis.

The change in GHG emissions from the 100 percent adoption (in kg CO_{2e}/kg shrunk live weight) are shown in Table 3.1.2 and discussed below.

The main sources of GHG emissions changes occur from the following components:

- Forage and cereal sub-activities (produce seed, process seed, produce and transport fertilizer, produce and transport pesticide/herbicide)
- Energy generation and usage activities (produce crude, transport crude, refine crude into diesel, transport diesel, combust diesel)
- Forage activities (cultivate soil, apply fertilizer, plant crop, irrigate crop, apply chemical and mechanical treatment, harvest crop and transport harvested crop)

- Feedlot and Pasture activities (producing bedding material, feed livestock, production of plastic)
- Soil carbon change from land use
- Direct CO_2 emissions from managed soils
- N_2O emissions from soil and cropping

The sources of GHG emissions changes are as follows:

- Increases: Forage and cereal sub-activities, Soil carbon change from land use, Direct CO_2 emissions from managed soils, N_2O emissions from soil and cropping
- Decreases: Energy generation activities, Forage activities, Feedlot and pasture activities

Acidification Emissions

The sources of acidification changes are generated by the replacement of cattle days on alfalfa/grass hay with cattle days on swath/stockpile grazing.

The change in acidification impacts from 2010 to 100 percent adoption (in kg SO_2e/kg shrunk live weight) are as follows:

• BMP 2.1 – swath grazing	2.4% reduction
• BMP 2.2 – stockpile grazing	7.6% increase

Swath grazing

Figure 3.3a: BMP 2.1 Swath Grazing – Acidification and Percent Adoption

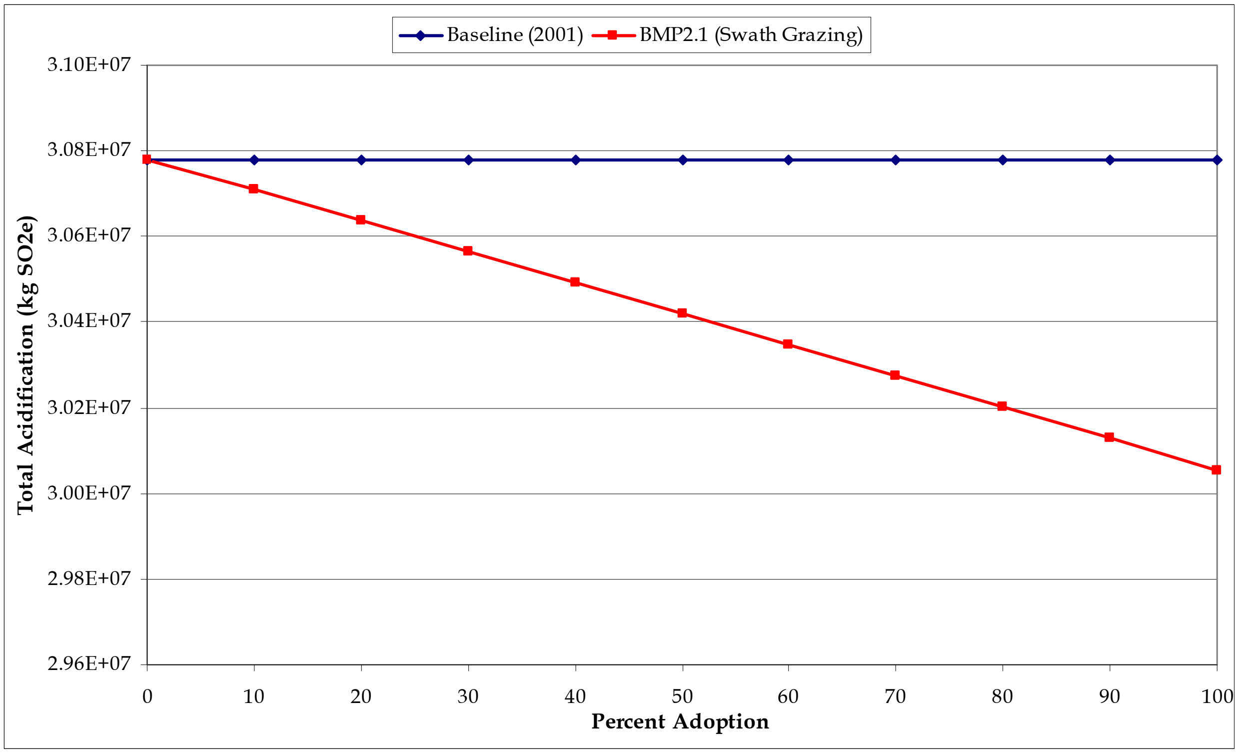


Figure 3.3a shows the acidification impact versus percent adoption of BMP 2.1, swath grazing. Examination of Figure 3.3a shows a net environmental benefit in terms of the acidification impact with the implementation of BMP 2.1.

The main sources of acidification emissions changes occur from the following components:

- Forage and cereal sub-activities (produce seed, process seed, produce and transport fertilizer, produce and transport pesticide/herbicide)
- Energy generation and usage activities (produce crude, transport crude, refine crude into diesel, transport diesel, combust diesel)
- Forage activities (cultivate soil, apply fertilizer, plant crop, irrigate crop, apply chemical and mechanical treatment, harvest crop and transport harvested crop)
- Feedlot and Pasture activities (producing bedding material, feed livestock, production of plastic)

All the sources of acidification emissions changes represent decreases compared to the 2001 baseline model.

Stockpile grazing

Figure 3.3b: BMP 2.2 Stockpile Grazing – Acidification and Percent Adoption

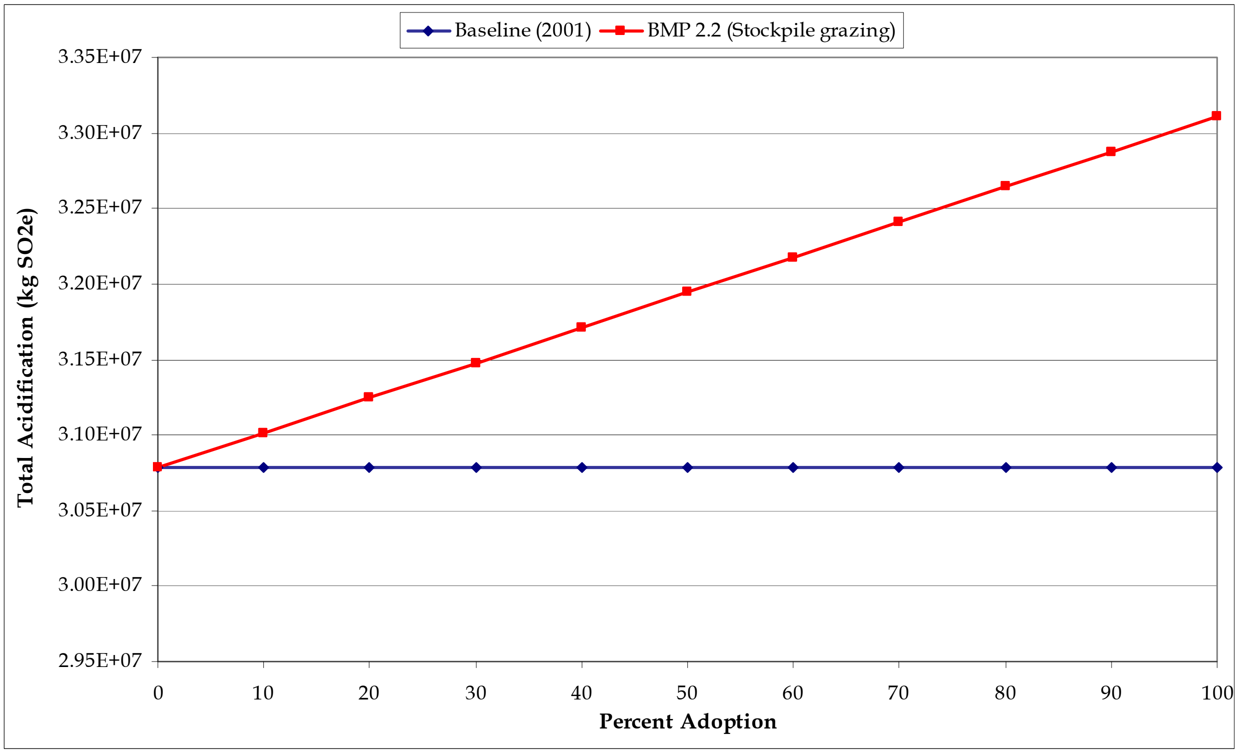


Figure 3.3b shows the acidification impact versus percent adoption of BMP 2.2, stockpile grazing. Examination of Figure 3.3b shows an increase in acidification emissions with the implementation of BMP 2.2.

The main sources of acidification emissions changes occur from the following components:

- Forage and cereal sub-activities (produce seed, process seed, produce and transport fertilizer, produce and transport pesticide/herbicide)
- Energy generation and usage activities (produce crude, transport crude, refine crude into diesel, transport diesel, combust diesel)
- Forage activities (cultivate soil, apply fertilizer, plant crop, irrigate crop, apply chemical and mechanical treatment, harvest crop and transport harvested crop)

- Feedlot and Pasture activities (producing bedding material, feed livestock, production of plastic

The sources of acidification emissions changes are as follows:

- Increases: Forage and cereal sub-activities
- Decreases: Energy generation activities, Forage activities, Feedlot and pasture activities

Eutrophication Emissions

The sources of eutrophication changes are generated by the replacement of cattle days on alfalfa/grass hay with cattle days on swath/stockpile grazing.

The change in eutrophication impacts from 2010 to 100 percent adoption (in kg PO_4e/kg shrunk live weight) are as follows:

BMP 2.1 – swath grazing	1.8% increase
BMP 2.2 – stockpile grazing	9.2% increase

Swath grazing

Figure 3.4a: BMP 2.1 Swath Grazing – Eutrophication and Percent Adoption

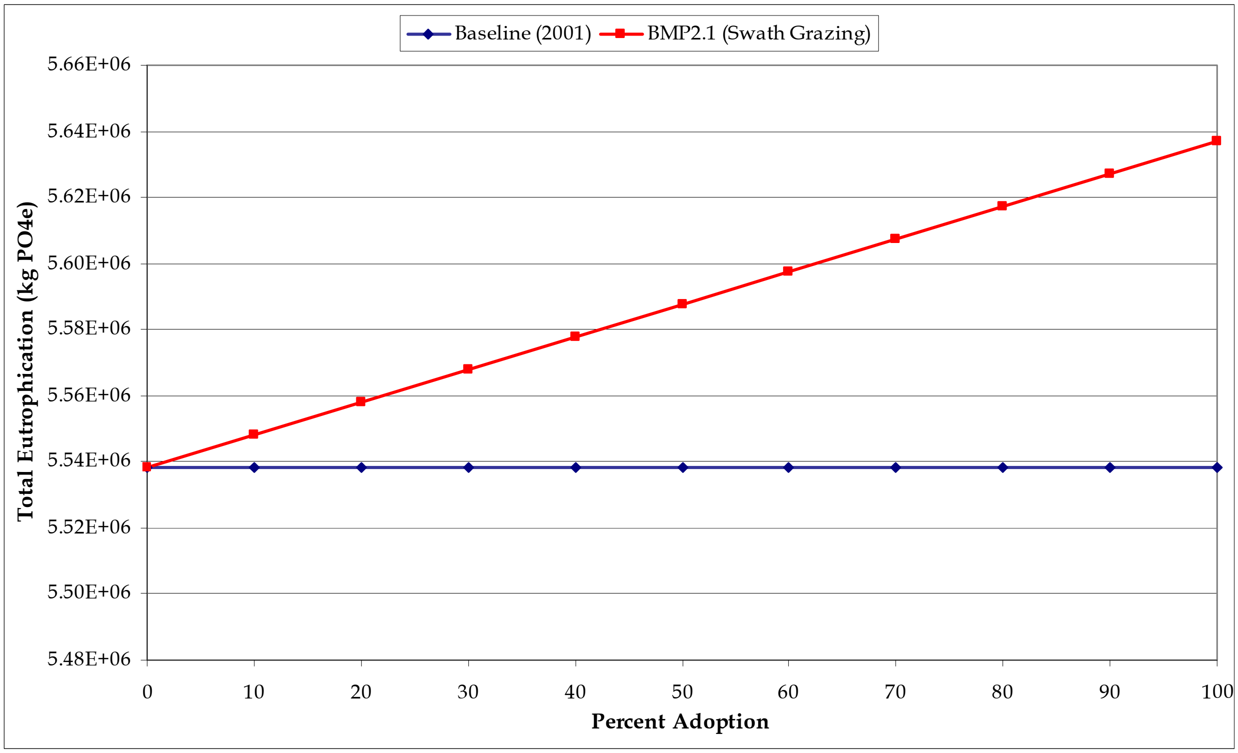


Figure 3.4a shows the eutrophication impact versus percent adoption of BMP 2.1, swath grazing. The higher emissions are due to the cattle grazing on cereal crops, which are intensive in fertilizer consumption and, consequently, generate a more significant eutrophication effect. However, as observed from the graph, the increase of the eutrophication emissions as described by a linear trend does not represent a significant increase of emissions from the baseline model.

The main sources of eutrophication emissions changes occur from the following components:

- Forage and cereal sub-activities (produce seed, process seed, produce and transport fertilizer, produce and transport pesticide/herbicide)
- Energy generation and usage activities (produce crude, transport crude, refine crude into diesel, transport diesel, combust diesel)
- Forage activities (cultivate soil, apply fertilizer, plant crop, irrigate crop, apply chemical and mechanical treatment, harvest crop and transport harvested crop)

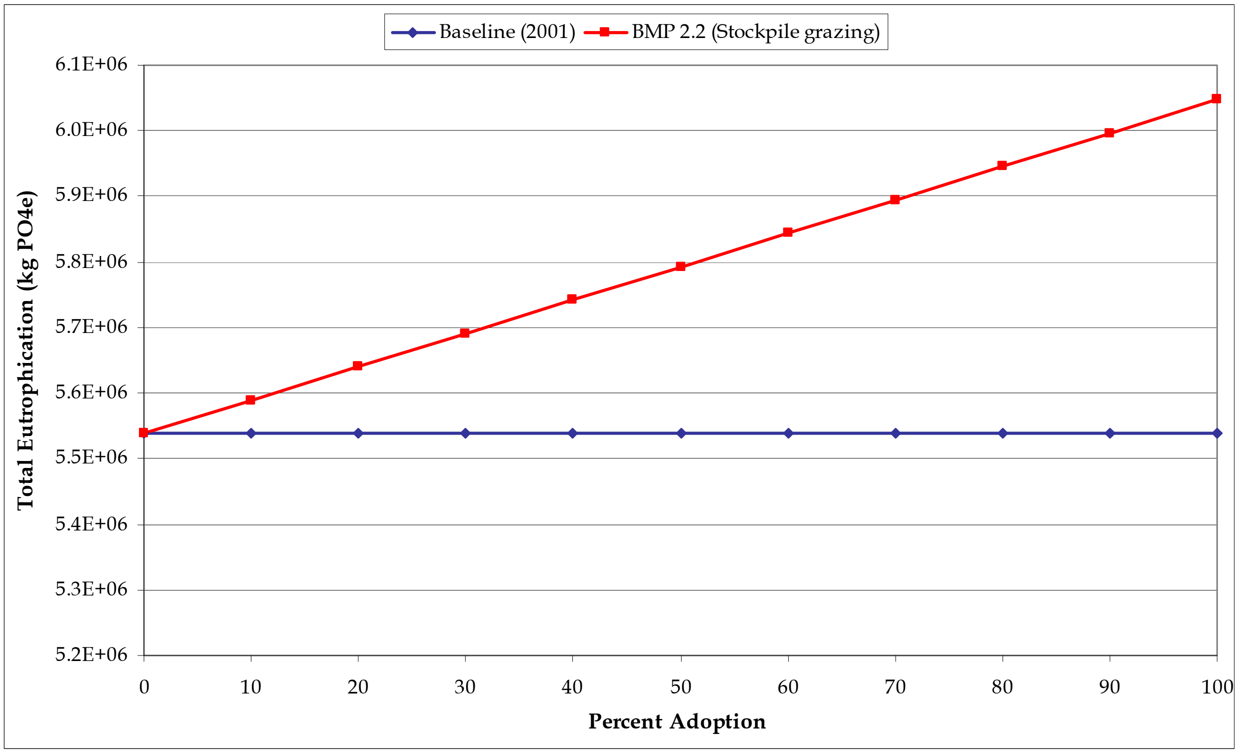
- Feedlot and Pasture activities (producing bedding material, feed livestock, production of plastic
- Total phosphorus (P) emissions from run-off

The sources of eutrophication emissions changes are as follows:

- Increases: Forage and cereal sub-activities, Total P emissions from run-off
- Decreases: Energy generation activities, Forage activities, Feedlot and pasture activities

Stockpile grazing

Figure 3.4b: BMP 2.2 Stockpile Grazing – Eutrophication and Percent Adoption



Examination of Figure 3.4b shows an increase in eutrophication impact with the implementation of BMP 2.2.

The main sources of eutrophication emissions changes occur from the following components:

- Forage and cereal sub-activities (produce seed, process seed, produce and transport fertilizer, produce and transport pesticide/herbicide)
- Energy generation and usage activities (produce crude, transport crude, refine crude into diesel, transport diesel, combust diesel)
- Forage activities (cultivate soil, apply fertilizer, plant crop, irrigate crop, apply chemical and mechanical treatment, harvest crop and transport harvested crop)
- Feedlot and Pasture activities (producing bedding material, feed livestock, production of plastic
- Total P emissions from run-off

The sources of eutrophication emissions changes are as follows:

- Increases: Forage and cereal sub-activities, Total P emissions from run-off
- Decreases: Energy generation activities, Forage activities, Feedlot and pasture activities

Non-Renewable Resources

The sources of non-renewable resources changes are generated by the replacement of cattle days on alfalfa/grass hay with cattle days on swath/stockpile grazing.

The change in total non-renewable resources impacts from 2010 to 100 percent adoption (in MJ-eq/kg shrunk live weight) are as follows:

BMP 2.1 – swath grazing	7.6% reduction
BMP 2.2 – stockpile grazing	0.3% reduction

Swath grazing

Figure 3.5a: BMP 2.1 Swath Grazing – Non-Renewable Resources and Percent Adoption

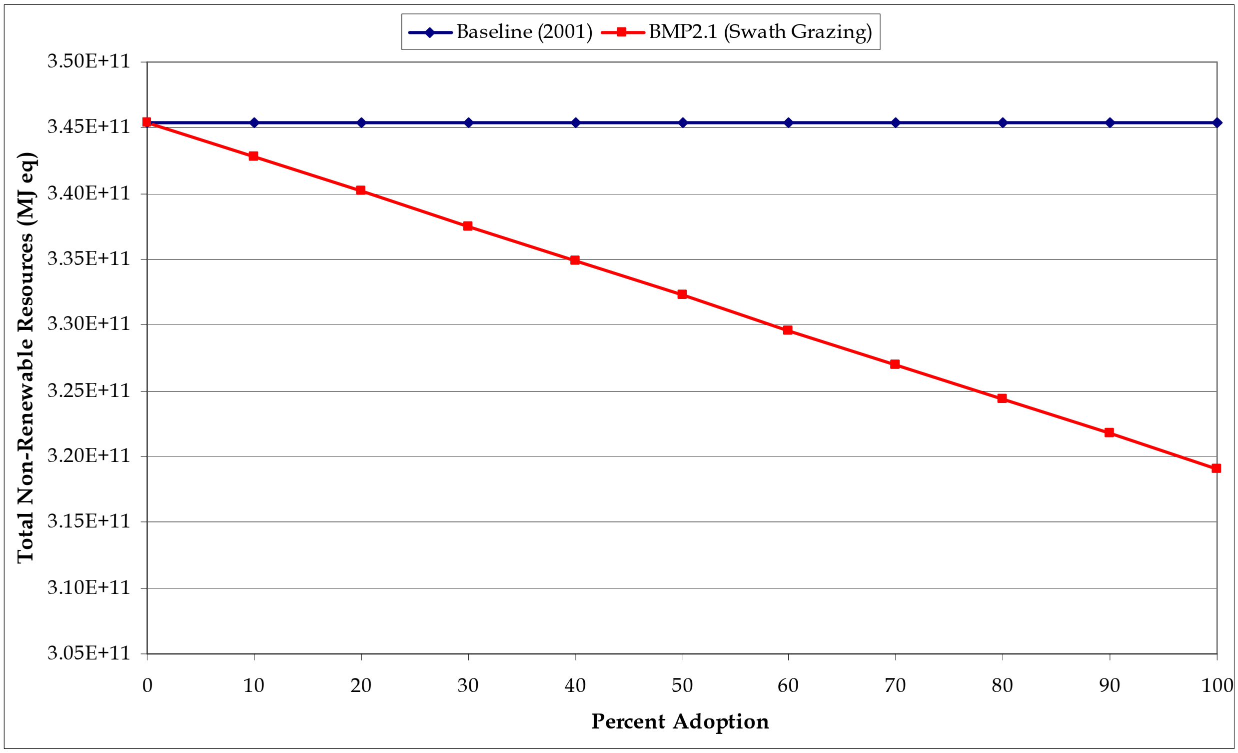


Figure 3.5a shows the non-renewable resources impact versus percent adoption of BMP 2.1, swath grazing. Examination of Figure 3.5a shows an environmental benefit in terms of the non-renewable resources impact. The changes to the energy generation activities are mainly related to the reduction in diesel used to feed cattle, due to the replacement of alfalfa/grass hay with extended grazing.

The main sources of non-renewable resources emissions changes occur from the following components:

- Forage and cereal sub-activities (produce seed, process seed, produce and transport fertilizer, produce and transport pesticide/herbicide)
- Energy generation and usage activities (produce crude, transport crude, refine crude into diesel, transport diesel, combust diesel)
- Forage activities (cultivate soil, apply fertilizer, plant crop, irrigate crop, apply chemical and mechanical treatment, harvest crop and transport harvested crop)
- Feedlot and Pasture activities (producing bedding material, feed livestock, production of plastic

All the non-renewable resources emissions changes represent decreases compared to the 2001 baseline.

Stockpile grazing

Figure 3.5b: BMP 2.2 Stockpile Grazing – Non-Renewable Resources and Percent Adoption

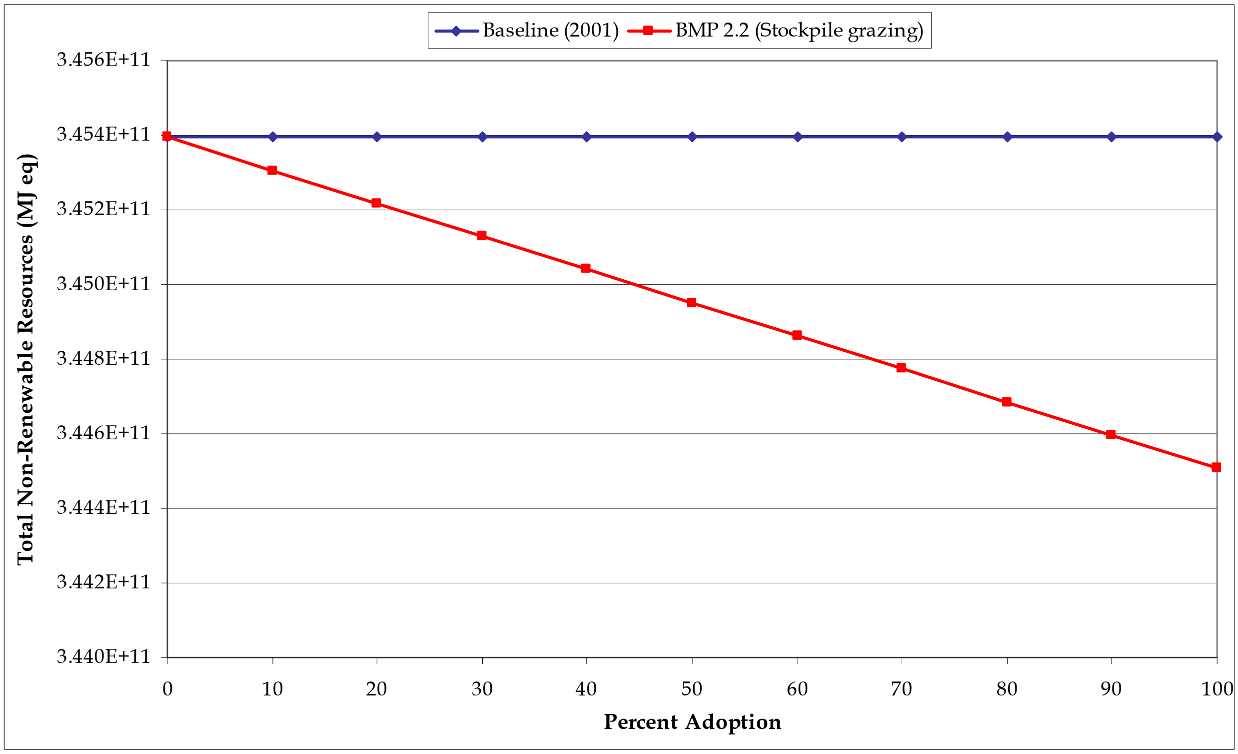


Figure 3.5b shows the non-renewable resources impact versus percent adoption of BMP 2.2, stockpile grazing. Examination of Figure 3.5b shows an environmental benefit in terms of the non-renewable resources impact. The changes to the energy generation activities are mainly related to the reduction in diesel used to feed cattle, due to the replacement of alfalfa/grass hay with extended grazing.

The main sources of non-renewable resources emissions changes occur from the following components:

- Forage and cereal sub-activities (produce seed, process seed, produce and transport fertilizer, produce and transport pesticide/herbicide)
- Energy generation and usage activities (produce crude, transport crude, refine crude into diesel, transport diesel, combust diesel)

- Forage activities (cultivate soil, apply fertilizer, plant crop, irrigate crop, apply chemical and mechanical treatment, harvest crop and transport harvested crop)
- Feedlot and Pasture activities (producing bedding material, feed livestock, production of plastic

The sources of non-renewable resources emissions changes are as follows:

- Increases: Forage and cereal sub-activities
- Decreases: Energy generation activities, Forage activities, Feedlot and pasture activities

3.4 CBA AND BMP 2.1 – SWATH GRAZING

BMP 2.1 extends the grazing season for the cattle on cow/calf operations through the use of swath grazing. The baseline has 2,568,007 cows and bulls. Swath grazing of cereal crops extends the grazing season by 3 months, which significantly reduces the volume of alfalfa/grass hay that needs to be purchased (by the cow/calf sector).

The first CBA **(CBA 1)** for this BMP is for cow/calf operations based on changes in the market value of inputs used. These benefits and costs are provided in Tables 3.2 and 3.4 (The value of any changes in GHG emissions is accounted for in a following section).
As shown in Table 3.2, the benefits through reduced input usage is $479 million, or approximately $187 per head. The major savings is reduced expenditures on alfalfa/grass hay, followed by lower fuel costs for feeding and transporting bedding.

Table 3.2: Benefits and Annual Costs of BMP 2.1 for Cow/Calf Operations – Market Value

Items	Units	Volume Change	Unit Price ($/unit)	Total Impact ($ million)
Benefits - Input Cost Savings				
Purchased alfalfa/grass hay	kg	-2,839,032,231	$0.14	-$389.43
Fuel consumed to collect manure - winter feeding	L	0	$0.75	$0.00
Production of bedding	kg	-100,131,666	$0.03	-$2.67
Fuel consumed to transport bedding	L	-71,053,883	$0.75	-$53.29
Fuel consumed to feed livestock	L	-44,640,145	$0.75	-$33.48
Labour (change)	hr	-12,840	$16.62	-$0.21
Total - Input Cost Savings				**-$479.09**
Costs - Higher Input Usage				
Purchase of seed for alfalfa/grass	kg	-882,113	$1.21	-$1.07
Purchase of seed for oats	kg	33,517,641	$0.26	$8.71
Purchase of seed for triticale	kg	25,088,879	$1.23	$30.97
Purchase of chemical fertilizer				
Urea, as N	kg	820,506	$0.45	$0.37
Ammonia, liquid	kg	642,847	$0.88	$0.57
Monoammonium phosphate, as P_2O_5	kg	0	$0.62	$0.00
Monoammonium phosphate, as N	kg	0	$0.62	$0.00
Ammonium sulphate, as N	kg	2,870,815	$0.44	$1.25
Fuel consumed to transport fertilizer	L	60,529	$0.75	$0.05
Fuel consumed to transport manure	L	2,000,740	$0.75	$1.50
Purchase of pesticide/herbicide	kg	382,775	$88.74	$33.97
Fuel consumed to transport pesticide	L	689	$0.75	$0.00
Fuel consumed for forage activities				
Fuel consumed to cultivate soil	L	3,690,386	$0.75	$2.77
Fuel consumed to apply fertilizer	L	1,269,703	$0.75	$0.95
Fuel consumed to plant crop	L	1,875,956	$0.75	$1.41
Fuel consumed to irrigate crop	L	98,780	$0.75	$0.07
Fuel consumed to apply chemicals to crop	L	415,724	$0.75	$0.31
Fuel consumed to harvest crop	L	2,611,269	$0.75	$1.96
Purchase of water to irrigate crop	m^3	13,876,276	$1.22	$16.88
Cropping costs (annual)	ha	459,895	$294	$135.12
Total - Annual Operating Costs				**$235.8**

The change in annual operating costs is $235.8 million, consisting of mostly cropping costs such as the annual machinery costs associated with various field operations (e.g., applying fertilizer, swathing) and other cropping inputs such as pesticides, seed fertilizer, and water (and some fuel).

Comparing these annual costs to annual benefits generates an annual net benefit of $243.3 million, and a benefit cost ratio associated with annual benefits and costs of 2.0:1, which indicates this (swath grazing) version of the extended grazing BMP is a paying proposition, as reported in Table 3.3.

Table 3.3: Benefit Cost Ratio for BMP 2.1 – Market Values

Total Annual Benefits ($ million)	**$479.09**
Total Annual Costs ($ million)	**$235.78**
Net Annual Benefits [Benefits - Costs] ($ million)	**$243.31**
Ratio of Annual Benefits to Annual Costs	**2.03**
NPV of benefits ($ million	**$7,377.34**
NPV of costs ($ million	**$3,801.81**
Ratio of NPV of Benefits to NPV of Costs	**1.94**

This BMP has associated capital costs, as provided in Table 3.4. Capital costs are incurred for fencing materials, which are $98 million for the sector, or $38 per head. The NPV3 of all costs are $3.8 billion over the 20-year period, with the assumption made that the fencing materials are replaced every 10 years. The NPV of the benefits to the cow/calf operations is $7.4 billion indicating a BCR (ratio of NPV of benefits to NPV of costs) of 1.9:1 (see Table 3.3 above). This suggests that there is a built-in financial incentive for the cow/calf operators to invest in this BMP.

Table 3.4: Capital Costs of BMP 2.1 for Cow/Calf Operations – Market Value

Items	**Units**	**Volume Change**	**Unit Price ($/unit)**	**Total Impact ($ million)**
Capital Costs - Fencing elements				
Charger (energizer)	unit	25,680	$799.00	$20.52
High tensile wire - 14 gauge	m	41,328,066	$0.06	$2.58
Connectors - wire tensioners	unit	77,040	$4.50	$0.35
Grounding rod	unit	128,400	$62.34	$8.00
Insulators	unit	128,400	$0.39	$0.05
Posts - wood	unit	6,545,647	$6.69	$43.79
Posts fibreglass	unit	1,377,602	$3.59	$4.95
Voltage meter	unit	12,840	$148.99	$1.91
Barbed wire	m	97,414,308	$0.16	$15.34
Windbreakers	feet	75,895	$5.00	$0.38
Total - Fencing costs				**$97.87**

The second CBA **(CBA 2)** retains the cow/calf operation focus and considers the impact on annual emissions that are directly associated with activities on cow/calf operation. Cropping activities on the cow/calf operations to create the swath grazing increases CO_2e emissions by 212,132 tonnes as shown in Table 3.5. In some activities there is a reduction in CO_2e emissions, such as energy generation and consumption and soil carbon. This increase in emissions is valued at $4.2 million per annum.

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[3] The per unit price associated with costs and benefits are assumed to increase by 2 percent per annum, and a discount rate of 5 percent is used for computing the NPVs.

Table 3.5: Change in Emissions at Cow/Calf Operations – BMP 2.1

Reduction in Cow/Calf Emissions	Units	Volume Change	Unit Price ($/unit)	Total Impact ($ million)
Methane emissions from stored manure	kg CO_2e	0	$0.02	$0.00
Enteric fermentation emissions	kg CO_2e	0	$0.02	$0.00
N_2O emissions from stored manure (direct)	kg CO_2e	0	$0.02	$0.00
N_2O emissions from stored manure (indirect)	kg CO_2e	0	$0.02	$0.00
N_2O emissions from cropping and land use	kg N_2O	147,534,866	$0.02	$2.95
Total P emissions from run-off	kg P	628,103	--	$0.00
Soil carbon change in soil from land use	kg CO_2e	-38,986,494-	$0.02	-$0.78
Direct CO_2 emissions from managed soils	kg CO_2e	1,289,067	$0.02	$0.03
Forage and cereal sub-activities	kg CO_2e	224,359,952	$0.02	$4.49
Energy generation and consumption activities	kg CO_2e	-215,533,375-	$0.02	-$4.31
Forage activities	kg CO_2e	54,784,881	$0.02	$1.10
Pasture activities	kg CO_2e	38,683,401-	$0.02	$0.77
Totals	**kg CO_2e**	**212,505,737**	**$0.02**	**$4.24**

If cow/calf operations had to pay for these emissions at $20/tonne of CO_2e, the annual cost increases to $240 million and the BCR decreases slightly to 2.0:1 as shown in the top portion of Table 3.6.

Similarly, the BCR based on the NPV computations decreases slightly to 1.9:1 as shown in Table 3.6 (in relation to not considering the cost of higher GHG emissions).

Table 3.6: Benefit Cost Ratio at Cow/Calf Operations for BMP 2.1

Total Annual Benefits ($ million)	**$479.09**
Total Annual Costs ($ million)	**$240.02**
Net Annual Benefits [Benefits - Costs] ($ million)	**$239.07**
Ratio of Annual Benefits to Annual Costs	**2.00**
NPV of benefits ($ million)	**$7,377.34**
NPV of costs ($ million)	**$3,867.14**
Ratio of NPV of Benefits to NPV of Costs	**1.91**

The modeled changes in emissions that occur elsewhere, such as those associated with changes in purchased hay requirements are illustrated in Table 3.7. The CO_2e emissions decrease by 444,683 tonnes per annum for an additional annual benefit of $8.9 million to society.

Table 3.7: Change in Emissions Beyond Cow/Calf Operations – BMP 2.1

Reduction in other Emissions	Units	Volume Change	Unit Price ($/unit)	Total Impact ($ million)
Forage and cereal sub-activities	kg CO_2e	-177,599,587	$0.02	-$3.55
Forage activities	kg CO_2e	-74,504,725	$0.02	-$1.49
N_2O emissions from cropping and land use	kg CO_2e	-141,064,378	$0.02	-$2.82
Total P emissions from run-off	kg PO_4-eq	-443,252	-	$0.00
Soil carbon change in soil from land use	kg CO_2e	7,840,721	$0.02	$0.16
Direct CO_2 emissions from managed soils	kg CO_2e	-9,713,047	$0.02	-$0.19
Transportation	kg CO_2e	-49,641,836	$0.02	-$0.99
Total	**kg CO_2e**	**-444,682,851**	**$0.02**	**-$8.89**

This BMP has significant system wide benefits with a BCR of 1.94:1 (see Table 3.8) based on NPV computations, which suggests and IRR of approximately 10 percent. While this BMP increases emissions on the cow/calf operations, it has an overall system wide reduction of 218,177 tonnes of CO_2e. This BMP reduces emissions by 0.153 kg CO_2e for each kg shrunk live weight shipped to the slaughter plant, and by 1.67 kg of CO_2e per kg of shrunk live weight for the annual volume of cows and bull shipped to slaughter plants.

Table 3.8: System Wide Benefit Cost Ratio for BMP 2.1

Total Annual Benefits ($ million)	**$487.98**
Total Annual Costs ($ million)	**$240.02**
Net Annual Benefits [Benefits - Costs] ($ million)	**$247.96**
Ratio of Annual Benefits to Annual Costs	**2.03**
NPV of benefits ($ million)	**$7,514.29**
NPV of costs ($ million)	**$3,867.14**
Ratio of NPV of Benefits to NPV of Costs	**1.94**

3.5 CBA AND BMP 2.2 – STOCKPILE GRAZING

BMP 2.2 for stockpile grazing is based on having extended grazing based on perennial forage crops. The first CBA **(CBA 1)** for this BMP is for cow/calf operations based on changes in the market value of inputs used. The annual benefits and costs are provided in Table 3.9.

The major benefit of stockpile grazing is the reduced alfalfa/grass hay purchases due to the extended 30-day grazing period with stockpile grazing. This benefit is $49 per head and is $125 million across all operations.

The annual operating costs associated with this BMP are estimated at $176.4 million. The major costs are cropping related expenses such as annualized machinery related costs, fertilizer, pesticides, and water costs.

Table 3.9: Benefits and Annual Costs of BMP 2.2 for Cow/Calf Operations – Market Value

Items	Units	Volume Change	Unit Price ($/unit)	Total Impact ($ million)
Benefits - Input Cost Savings				
Purchased alfalfa/grass hay	kg	-914,606,005	$0.14	-$125.46
Production of bedding	kg	-23,283,848	$0.03	-$0.70
Fuel consumed to transport bedding	L	-16,522,324	$0.75	-$12.37
Fuel consumed to feed livestock	L	-10,380,276	$0.75	-$7.77
Labour (change)	hr	-11,600	$16.62	-$0.19
Total - Input Cost Savings				**-$146.49**
Costs - Higher Input Usage				
Purchase of seed for alfalfa/grass	kg	-284,176	$1.21	-$0.34
Purchase of seed for Grass DP	kg	15,370	$8.64	$0.13
Purchase of seed for Grass P	kg	288,521	$5.97	$1.72
Purchase of seed for Grass NR	kg	174,235	$5.97	$1.04
Purchase of chemical fertilizer				
Urea, as N, at regional storehouse	kg	19,166,611	$0.45	$8.71
Ammonia, liquid, at regional storehouse	kg	55,950,352	$0.88	$49.24
Monoammonium phosphate, as P_2O_5	kg	48,482,123	$0.62	$30.06
Monoammonium phosphate, as N	kg	11,372,350	$0.62	$7.05
Fuel consumed to transport fertilizer	L	858,087	$0.75	$0.64
Fuel consumed to transport manure	L	1,686,961	$0.75	$1.26
Purchase of pesticide/herbicide	kg	322,744	$88.74	$28.64
Fuel consumed to transport pesticide	L	581	$0.75	$0.00
Fuel consumed for forage activities				
Fuel consumed to cultivate soil	L	528,033	$0.75	$0.40
Fuel consumed to apply fertilizer	L	1,090,040	$0.75	$0.82
Fuel consumed to plant crop	L	268,418	$0.75	$0.20
Fuel consumed to irrigate crop	L	84,803	$0.75	$0.06
Fuel consumed to apply chemicals to crop	L	356,899	$0.75	$0.27
Purchase of water to irrigate crop	m^3	11,912,784	$1.22-	$14.49
Cropping costs	ha	394,820	$81-	$32.01
Total - Annual Operating Costs				**$176.4**

These annual costs exceed the annual benefits, with a net benefit value of -$30 million, or $11.65/head. This generates a BCR of annual benefits and costs of 0.83:1, as illustrated in Table 3.10. This BCR of less than 1.0 underscores the point that associated incremental benefits of stockpile grazing are less than the incremental costs.

Table 3.10: Benefit Cost Ratio for BMP 2.2 – Market Values

Total Annual Benefits ($ million)	**$146.5**
Total Annual Costs ($ million)	**$176.4**
Net Annual Benefits [Benefits - Costs] ($ million)	**-$29.91**
Ratio of Annual Benefits to Annual Costs	**0.83**
NPV of benefits ($ million)	**$2,256**
NPV of costs ($ million)	**$2,860**
Ratio of NPV of Benefits to NPV of Costs	**0.79**

These annual benefits and costs are before considering the investments in the fencing required to benefit from stockpile grazing. These costs, which are incurred once every 10 years are shown in the lower portion of Table 3.11 and total to $82.1 million, or $32/head of mature cattle.

Table 3.11: Capital Costs of BMP 2.2 for Cow/Calf Operations – Market Value

Items	**Units**	**Volume Change**	**Unit Price ($/unit)**	**Total Impact ($ million)**
Capital Costs - Fencing elements				
Charger (energizer)	unit	23,201	$799.00	$18.54
High tensile wire - 14 gauge	m	37,338,284	$0.06	$2.33
Connectors - wire tensioners	unit	69,603	$4.50	$0.31
Grounding rod	unit	116,005	$62.34	$7.23
Insulators	unit	116,005	$0.39	$0.05
Posts - wood	unit	5,217,094	$6.69	$34.90
Posts fibreglass	unit	1,244,609	$3.59	$4.47
Posts metal	unit	0	-	$0.00
Voltage meter	unit	11,600	$148.99	$1.73
Barbed wire	m	77,560,378	$0.16	$12.21
Windbreakers	feet	68,557	$5.00	$0.34
Total - Fencing costs				**$82.12**

The net present value of the annual benefit stream is $2.3 billion, while the net present value of the annual costs and the capital costs (incurred in year 1 and year 11) are $2.9 billion (see Table 3.10 above). The ratio of these (NPV) benefits to costs is less than one (0.96:1) which indicates that without any incremental benefits, this BMP is not an economical proposition.

The second CBA **(CBA 2)** retains the cow/calf operation focus and considers the BMP's impact on changes in emissions at the cow/calf operation. The change in GHG emissions with this BMP that are directly associated with activities on the cow/calf operation are illustrated in Table 3.12, with GHG emissions increasing by 980,162 tonnes

CO_2e. This modelled BMP does not reduce GHG emissions and the annual cost to society is $19.8 million based on a CO_2e price of $20/tonne. The increase is due to the emission associated with cropping activities that support extended grazing.

Table 3.12: Change in Emissions at Cow/Calf Operations – BMP 2.2

Reduction in Cow/Calf Emissions	Units	Volume Change	Unit Price ($/unit)	Total Impact ($ million)
N_2O emissions from cropping and land use	kg CO_2e	659,720,196	$0.02	$13.19
Total P emissions from run-off	kg P	641,963	--	$0.00
Soil carbon change in soil from land use	kg CO_2e	-5,478,698	$0.02	-$0.11
Direct CO_2 emissions from managed soils	kg CO_2e	30,111,960	$0.02	$0.60
Forage and cereal sub-activities	kg CO_2e	328,876,142	$0.02	$6.58
Energy generation and consumption activities	kg CO_2e	-50,118,475	$0.02	-$1.00
Forage activities	kg CO_2e	17,197,876	$0.02	$0.34
Pasture activities	kg CO_2e	-146,574	$0.02	$0.00
Totals	**kg CO_2e**	**980,162,427**	**$0.02**	**$19.60**

Assuming that cow/calf operations had to pay for higher emissions, then the annual costs increase to $196 million, and the BCR decreases slightly to 0.75:1 (compare Table 3.13 to Table 3.10). The NPV of the emissions costs adds another $302 million to NPV of the costs, lowering the BCR of the NPV of benefits and costs to 0.7:1.

Table 3.13: Benefit Cost Ratio at Cow/Calf Operations for BMP 2.2

Total Annual Benefits ($ million)	**$146.5**
Total Annual Costs ($ million)	**$196.0**
Net Annual Benefits [Benefits - Costs] ($ million)	**-$49.5**
Ratio of Annual Benefits to Annual Costs	**0.75**
NPV of benefits ($ million)	**$2,256**
NPV of costs ($ million)	**$3,162**
Ratio of NPV of Benefits to NPV of Costs	**0.71**

The modeled changes in emissions that occur elsewhere, such as those associated with changes in purchased hay requirements are illustrated in Table 3.14. The CO_2e emissions decreased by 109,277 tonnes per annum. This provides a $2.2 million benefit to society each year, when CO_2e emissions are valued at $20/tonne.

Table 3.14: Change in Emissions Beyond Cow/Calf Operations – BMP 2.2

Reduction in Other Emissions	**Units**	**Volume Change**	**Unit Price ($/unit)**	**Total Impact ($ million)**
Forage and cereal sub-activities	kg CO_2e	-31,933,884	$0.02	-$0.64
Feedlot and pasture activities	kg CO_2e	-2,401,616	$0.02	-$0.05
Forage activities	kg CO_2e	-24,002,006	$0.02	-$0.48
N2O emissions from cropping and land use	kg CO_2e	-50,573,122	$0.02	-$1.01
Total P emissions from run-off	kg PO_4-eq	-142,787	-	$0.00
Soil Carbon Change in Soil From Land Use	kg CO_2e	2,525,921	$0.02	$0.05
Direct CO_2 emissions from managed soils	kg CO_2e	-2,891,967	$0.02	-$0.06
Total	**kg CO_2e**	**-109,276,674**	**$0.02**	**-$2.19**

From an overall systems perspective, the annual benefits associated with this BMP are less than the costs, with a BCR that is 0.86:1 when the NPV of costs and benefits are considered (see Table 3.15). As well, this BMP has the consequence of increased CO_2e emissions by 882,725 tonnes, and results in an increase in emissions of 0.619 kg CO_2e per kg live shrunk weight.

GHG emissions increase with stockpile grazing as a result of the extensive use of perennial forages with low yields, as mentioned in Section 3.3.

Table 3.15: System Wide Benefit Cost Ratio for BMP 2.2

Total Annual Benefits ($ million)	**$148.7**
Total Annual Costs ($ million)	**$196.0**
Net Annual Benefits [Benefits - Costs] ($ million)	**-$47.3**
Ratio of Annual Benefits to Annual Costs	**0.76**
NPV of benefits ($ million)	**$2,289**
NPV of costs ($ million)	**$3,162**
Ratio of NPV of Benefits to NPV of Costs	**0.72**

4.0 CBA OF BMP 3 – USE OF IONOPHORES IN ROUGHAGE DIETS

BMP 3 is the "use of ionophores in cow and replacement heifer diets to improve hay based feed efficiency."

4.1 DESCRIPTION OF BMP 3 – USE OF IONOPHORES IN ROUGHAGE DIETS

The intent of this BMP is to improve feed efficiency through use of ionophores in beef cows and replacement heifers, and generate fewer GHG emissions. This BMP should result in fewer upstream emissions based on fewer acres and resources devoted to hay (alfalfa/grass hay) production.

From an economic perspective of the cow/calf operation, this BMP involves higher input costs through the purchase of ionophores, and lower feed costs through lower dry matter intake (DMI). The LCA model assumes that the cow calf operation purchases all hay (alfalfa) and supplies its own pasture requirements.

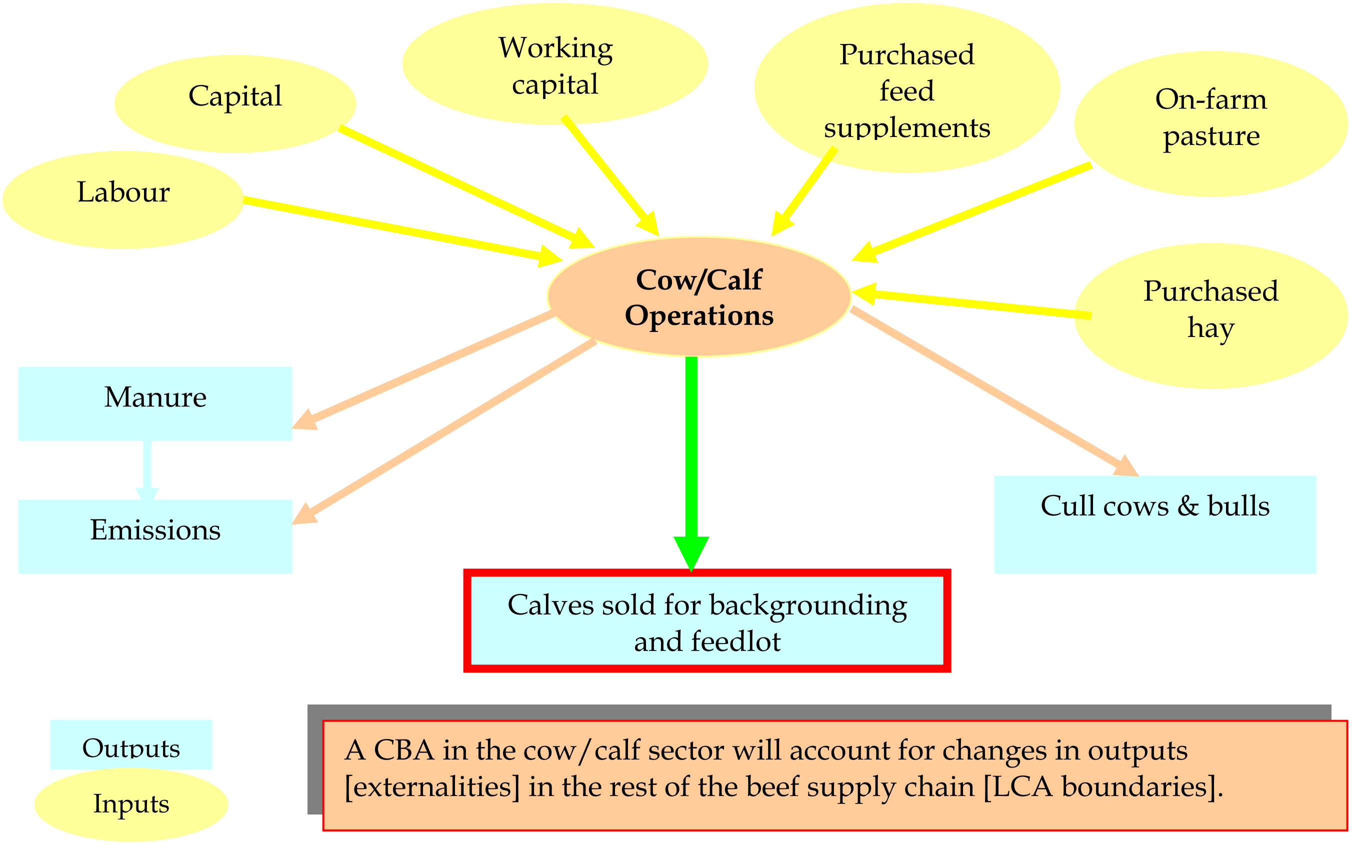
The operating assumptions include:

- Ionophores supplementation is based on Monensin sodium (Monensin) following CFIA Claim 4 – increased rate of weight gain in pasture cattle (stocker, feeder cattle, and beef and replacement heifers)
- Supplementation is via a mineral carrier provided to the herd
- Pregnant cows and heifers are fed ionophores as part of a supplement package in their diet (1) for 60 days prior to birth (i.e., the last 60 days of the winter diet, from January to February) and (2) for the first 60 days of the calving diet period (from March to April)
- All bred heifers and cows are fed ionophores, implying 100 percent adoption
- The use of ionophores results in less hay consumption
- All pasture is owned by the cow/calf operation
- All hay (alfalfa/grass hay) and feed supplements are purchased by the cow/calf operations
- Methane produced through enteric fermentation may decrease through lower feed intake
- The impacts of this BMP are time invariant, implying that the impact will be the same in year 1 as in year 5

- There are no significant changes in labour requirements
- There are no capital expenditures associated with this BMP

Figure 4.1 is provided to show the boundary associated with the cow/calf sector (it indicates that all pasture is owned by the cow/calf operation, and supplements and hay are purchased by the cow/calf operation).

Figure 4.1: Boundary and Potential Resource Impacts in the Cow/Calf Sector



A CBA in the cow/calf sector will account for changes in outputs [externalities] in the rest of the beef supply chain [LCA boundaries].

The direct impacts of BMP 3 in the cow/calf sector include:

- Outputs:
  - No change in the annual volume of feeder calves supplied by the cow/calf sector to the feedlot or backgrounding sector
  - No change in the annual volume of finished beef supplied to slaughter plants
  - Less methane produced by pregnant cows and heifers due to lower feed intake

- Inputs:
    - Purchase and use of ionophores
    - Less hay consumed by pregnant cows and heifers
    - Fewer hay producing acres required to support the cow/calf operation

In addition to these direct impacts, there are indirect impacts based on linkages. These can include lower GHG emissions associated with a lower land use requirement for hay production to support the cow and replacement heifer population.

4.2 BMP 3 – MODELLING LCA AND IMPACT

The LCA of BMP 3 follows the structure of the model from the first phase of the project (CRA, 2010). Additional information is represented by:

- Data collection:
    - Number of pregnant cows in the model
    - Reduction in DMI intake during late gestation and early lactation
    - Manure collection and handling
    - Dosage rates of ionophores
- Calculations:
    - Number of cattle days allocated to each stage of feed, as follows:
        - Cow days on normal winter diet, for all cows, for 30 days (December)
        - Cow days on normal winter diet, for open cows, for 60 days (January and February)
        - Cow days on reduced winter diet for pregnant cows, for 60 days (January and February)
        - Cow days on normal calving diet, for open cows, for 60 days (March and April)
        - Cow days on reduced calving diet, for pregnant cows, for 60 days (March and April)
        - Cow days on normal calving diet, for all cows, for 30 days (May)
    - Total supplement with and without ionophores being fed to the cows

Based on the implementation of BMP 3, the forage diet needs are adjusted. Calculations of changes in feed, cropping needs, cropping practices, and biological activity of the cattle followed by calculations of overall emissions are carried through the basic structure of the initial model.

4.3 BMP 3 – RESULTS OF GHG EMISSIONS AND OTHER IMPACTS

The impacts on the four environmental impact categories were modelled for the entire Alberta beef production system, and have been discussed below. The graphs show the total impact of each category from the entire system from the baseline years, and also show the difference in these impacts from the baselines to the implementation of the BMP.

The sources of GHG emissions changes are generated by the replacement of cattle days for pregnant cows on the baseline winter diet (alfalfa/grass hay) with cattle days of pregnant cows on a reduced winter diet, due to supplementation of diet with ionophores. The following items have been modified for BMP 3:

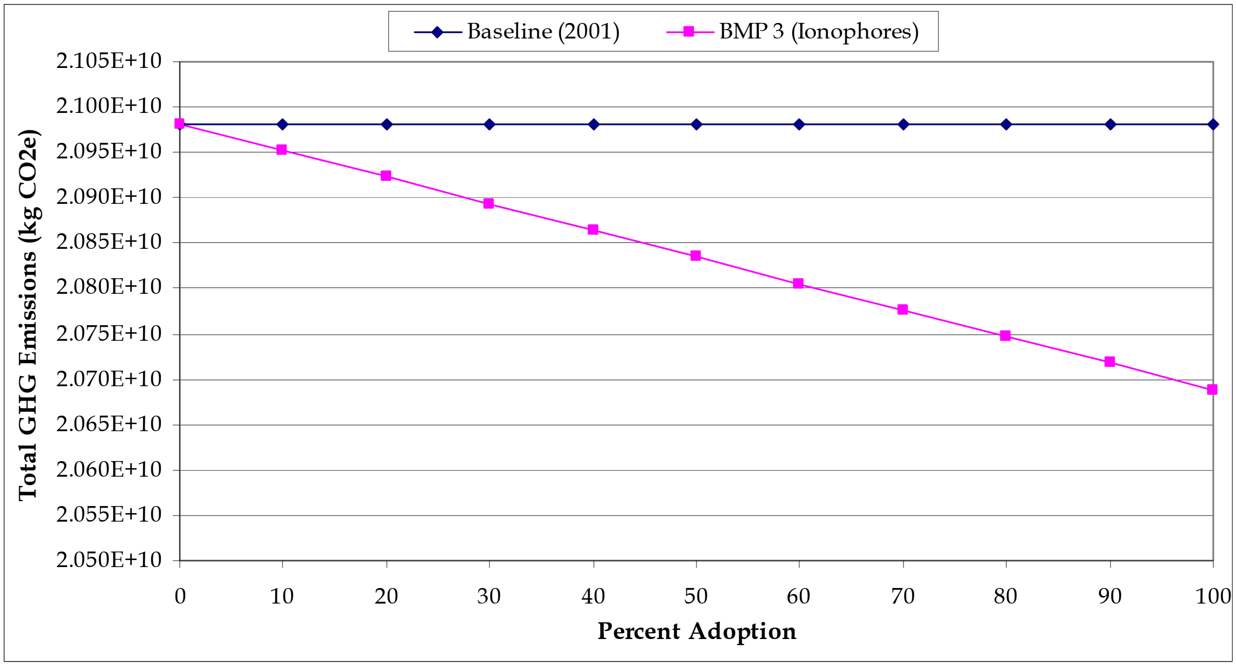
- Number of animals supplemented with ionophores
- Total alfalfa/grass hay for winter feed
- Amount of fertilizer needed (chemical and soil amendment)
- Amount of alfalfa/grass hay seed needed
- Amount of pesticide/herbicide needed
- Gasoline, diesel, electricity used based on increased ionophores production and transport
- Fuel consumption for cultivating soil, applying fertilizer, planting crop, irrigating crop, apply chemical treatment, harvesting crop, transporting crop
- Plastics to be produced
- Enteric fermentation emissions
- N_2O emissions from manure
- Soil N_2O emissions from cropping and land use
- Soil carbon change
- P_2O_5 runoff from cropping

Modifications of these items are addressed in the following sections of the LCA activity map:

- Forage and cereal sub-activities, forage activities, feedlot and pasture activities. The activities related to the alfalfa/grass hay from the winter diet are adjusted to allow for reduced feed requirements due to supplementation with ionophores.
- Energy generation and usage activities (reduction in GHG emissions from producing crude, transporting crude, refining crude into diesel, transporting diesel, combusting diesel – all for the reduction in diesel used to feed cattle and to collect manure).
- Enteric fermentation emissions.
- Methane emissions from manure.
- Soil carbon change from land use.
- Carbon dioxide from managed soils.
- N_2O emissions from manure, cropping and land use.
- P_2O_5 run-off.

The following graph shows the total GHG emissions versus the percent adoption for BMP 3.

Figure 4.2: BMP 3 - GHG Emissions and Percent Adoption



Examination of Figure 4.2 shows the net environmental benefits in terms of GHG emissions based on adoption of BMP 3 at different percentages. The percent adoption adjusts the actual number of cattle on the diet supplemented with ionophores.

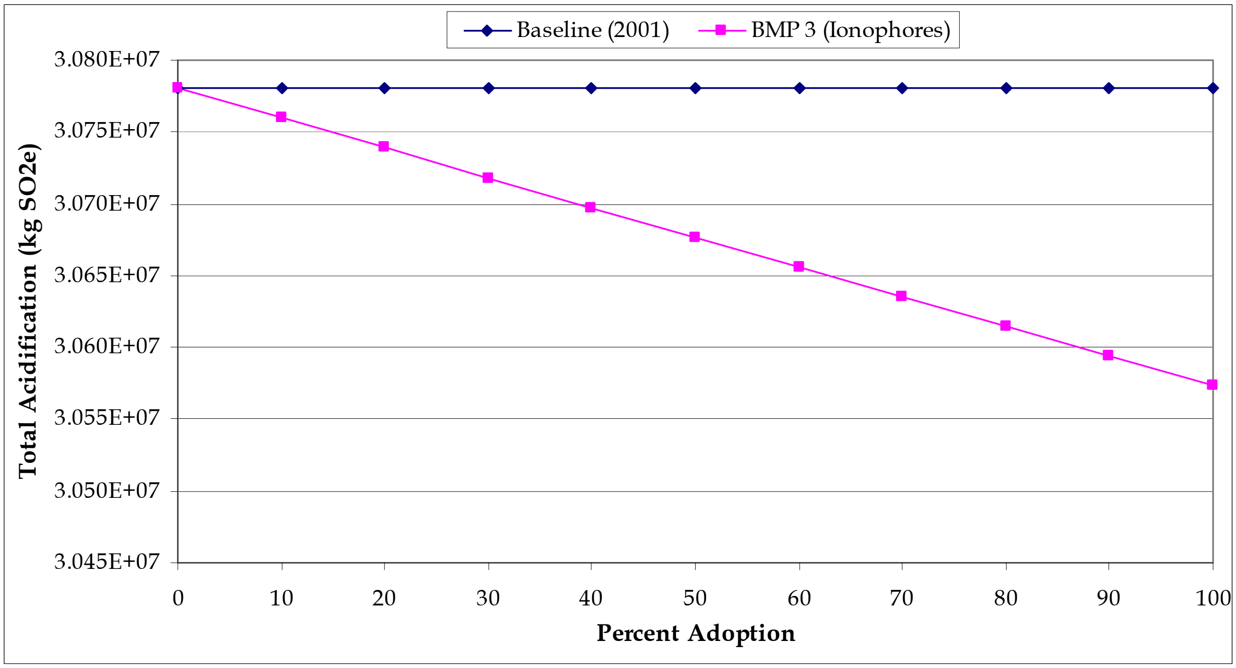
Table 4.1 illustrates the major components of the model where the changes in GHG emissions are occurring from the 2001 baseline to BMP 3.

The change in GHG emissions from 2010 to 100 percent adoption (in kg CO_2e/kg shrunk live weight) is a reduction of 1.4 percent.

The sources of GHG emissions changes occur from the following components for BMP 3:

- Forage and cereal sub-activities forage activities (reduction in GHG emissions from the production, transportation etc. of alfalfa/grass hay)
- Energy generation and usage activities (reduction in GHG emissions from reduction in diesel used to feed cattle and to collect manure)
- Enteric fermentation emissions (reductions in enteric fermentation emissions due to use of ionophores)
- Methane emissions from manure (reductions due to reduced amount of manure generated, based on food intake)
- Soil carbon change from land use (reductions in soil sequestration due to the reduced alfalfa/grass hay cropping)
- Carbon dioxide from managed soils (reductions in carbon dioxide emissions due to the reduction in alfalfa/grass hay cropping)
- N_2O emissions from manure (reduction due to less manure being generated by cows on a reduced diet)

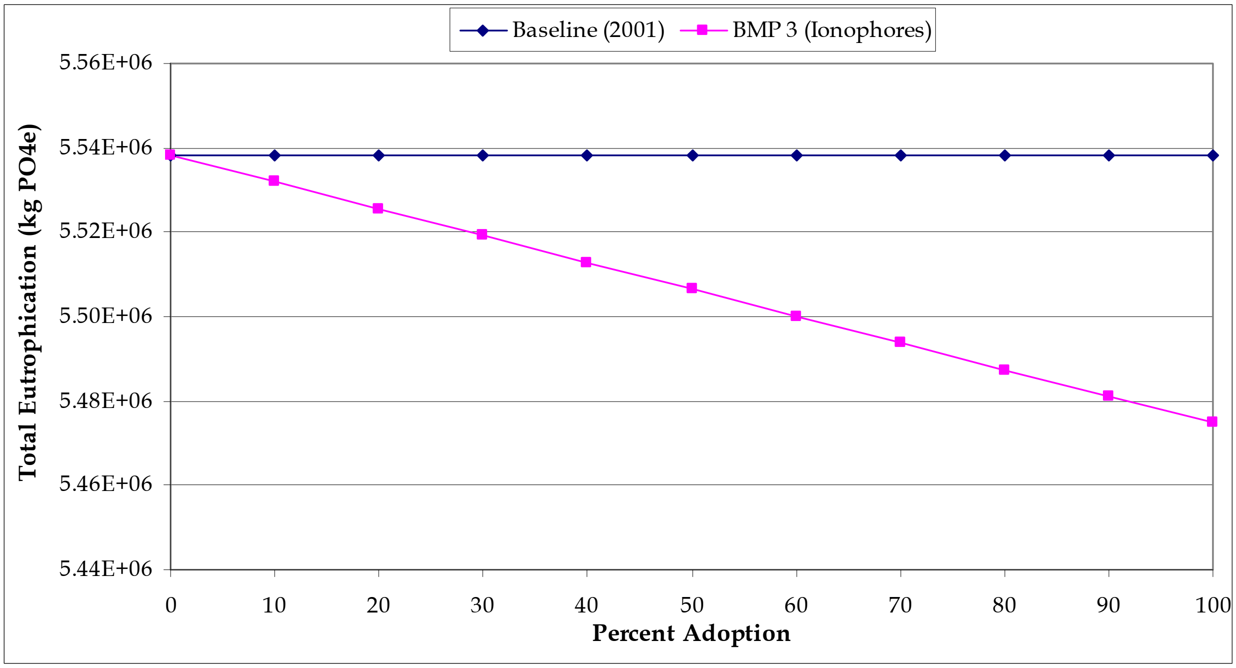
Figure 4.3: BMP 3 - Acidification and Percent Adoption



Examination of Figure 4.3 shows the net environmental benefits in terms of acidification impact based on adoption of BMP 3 at different percentages. The percent adoption adjusts the actual number of cattle on the diet supplemented with ionophores.

The change in acidification impacts from 2010 to 100 percent adoption (in kg SO_2e/kg shrunk live weight) is a reduction of 0.7 percent.

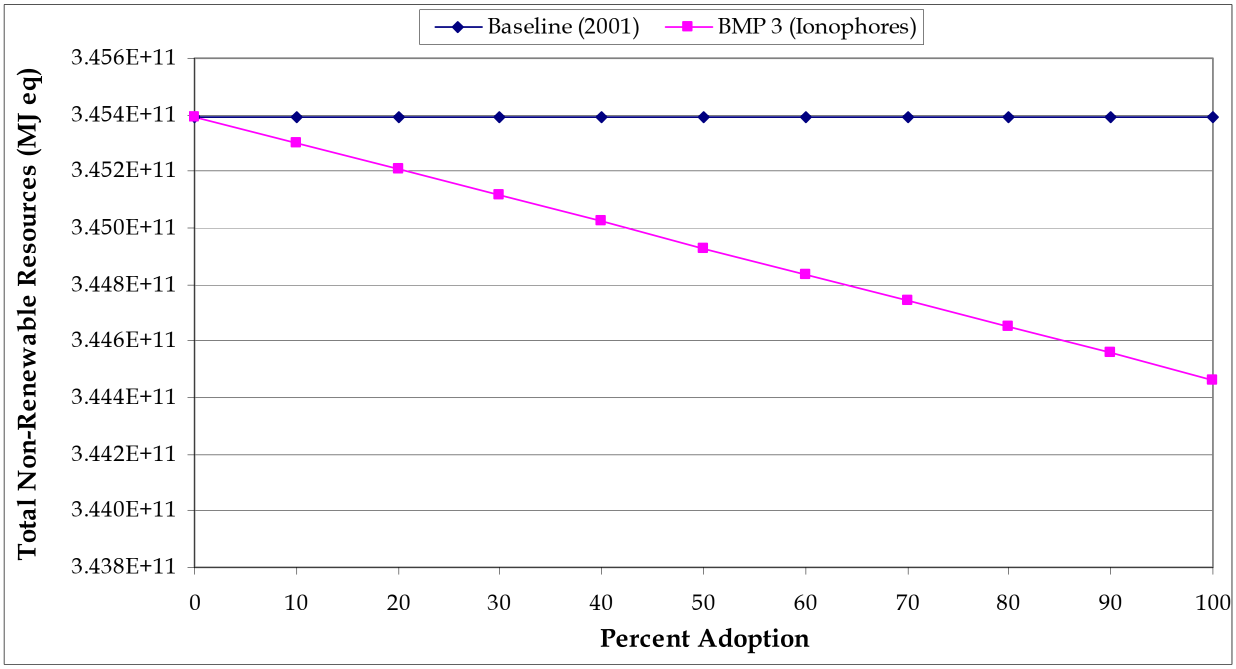
Figure 4.4: BMP 3 - Eutrophication and Percent Adoption



Examination of Figure 4.4 shows the net environmental benefits in terms of eutrophication impact based on adoption of BMP 3 at different percentages. The percent adoption adjusts the actual number of cattle on the diet supplemented with ionophores.

The change in eutrophication impacts from 2010 to 100 percent adoption (in kg PO_4e/kg shrunk live weight) is a reduction of 1.1 percent.

Figure 4.5: BMP 3 – Non-Renewable Resources and Percent Adoption



Examination of Figure 4.5 shows the net environmental benefits in terms of non-renewable resources impact based on adoption of BMP 3 at different percentages. The percent adoption adjusts the actual number of cattle on the diet supplemented with ionophores.

The change in total non-renewable resources impacts from 2010 to 100 percent adoption (in MJ-eq/kg shrunk live weight) is a reduction of 0.3 percent.

4.4 CBA AND BMP 3 – USE OF IONOPHORES IN ROUGHAGE DIETS

The first CBA **(CBA 1)** for BMP 3 is for the cow/calf operation based on changes in market value inputs and outputs and does not place any value on the reduction in emissions. The cost to the cow/calf operations is the higher supplement costs, which include the ionophores. The supplements with ionophores increase by 30,569 tonnes for a cost of $55 million, as noted in the lower half of Table 4.2.

Table 4.2: Benefits and Costs of BMP 3 at the Cow/Calf Operation – Market Values

Items	Units	Volume Change	Unit Price ($/unit)	Total Impact ($ million)
Benefits - Input Cost Savings				
Purchased alfalfa/grass hay	kg	-374,868,925	$0.14	-$51.36
Fuel consumed to feed livestock	L	-1,063,695	$0.75	-$0.80
Purchased supplements w/o ionophores	kg	83,196,320	$1.25	-$104.40
Total - Input Cost Savings				**-$156.56**
Costs - Higher Input Usage				
Purchased supplements with ionophores	kg	30,569,415	$1.80	$55.02
Total - Higher Input Costs				**-$55.02**

At the same time, the supplements (without ionophores in them) that are replaced by the supplements with ionophores decrease by 83,196 tonnes, which is a benefit to operators. The other economic benefits to cow/calf operators are lower usage and lower purchases of hay ($51.4 million), and reduced fuel requirements for feeding activities for a total of $156.6 million in cost savings. After comparing costs to benefits, this BMP has a net benefit of $101.5 million for cow/calf operators. As shown in Table 4.3, the resulting benefit cost ratio is 2.85:1. This result suggests that cow/calf operations should invest in this BMP.

Table 4.3: Benefit Cost Ratio at the Cow/Calf Operation for BMP 3 – Market Values

Total Benefits	**$156.56**
Total Costs	**$55.02**
Net Benefits [Benefits - Costs]	**$101.53**
Ratio of Benefits to Costs	**2.85**

The second CBA (**CBA 2**) retains the cow/calf operation focus and considers the benefits of reducing the externalities (emissions) by cow/calf operations. The lower volume of hay consumed by cows due to the use of ionophores reduces the emissions load of the cow/calf sector. The largest reduction is in enteric fermentation emissions, which has a value of $3.6 million per annum, based on pricing CO_2e at $20/tonne. Total emissions reduction at the cow/calf operations due to this BMP is 253,006 tonnes CO_2e, which has an attributed value of $5.1 million per annum, as noted in Table 4.4.

Table 4.4: Benefit of Emission Reduction at the Cow/Calf Operation - BMP 3

Reduction in Cow / Calf Emissions	Units	Volume Change	Unit Price ($/unit)	Total Impact ($ million)
Methane emissions from stored manure	kg CO_2e	-3,852,501	$0.02	-$0.08
Enteric fermentation emissions	kg CO_2e	-181,763,433	$0.02	-$3.64
N_2O emissions from stored manure (direct)	kg CO_2e	-50,961,637	$0.02	-$1.02
N_2O emissions from stored manure (indirect)	kg CO_2e	-11,280,571	$0.02	-$0.23
Energy generation and consumption activities	kg CO_2e	-5,135,,776	$0.02	-$0.10
Feedlot and pasture activities	kg CO_2e	-11,823	$0.02	-$0.0002
Totals	kg CO_2e	**-253,005,741**	**$0.02**	**-$5.06**

This $5 million benefit of reduced emissions, assuming it is captured by cow/calf operations, increases the total and net benefits for this BMP as shown in Table 4.5. The benefit cost ratio also increases to 2.9:1.

Table 4.5: Benefit Cost Ratio at the Cow/Calf Operation for BMP 3 – Market Values

Total Benefits	**$161.62**
Total Costs	**$55.02**
Net Benefits [Benefits - Costs]	**$106.59**
Ratio of Benefits to Costs	**2.94**

The third CBA for this BMP (**CBA 3**) considers any upstream or downstream changes in emissions, which are additional to those realized within the cow/calf sector. These are upstream benefits of less area required to produce the lower hay requirement. As shown in the first row of Table 4.6, the CO_2e reduction due to less N_2O was 16,616 tonnes, and all reduced emissions beyond the cow/calf sector was 39,605 tonnes, for an annual benefit of another $0.79 million per annum associated with this BMP.

Table 4.6: Additional Benefits of System Wide Emission Reduction - BMP 3

Reduction in Other Emissions	Units	Volume Change	Unit Price ($/unit)	Total Impact ($ million)
N_2O emissions from cropping and land use	kg CO_2e	-16,616,146	$0.02	-$0.33
Total P emissions from run-off	kg PO_4-eq	-58,523	-	$0.00
Soil carbon change in soil from land use	kg CO_2e	1,035,297	$0.02	$0.02
Direct CO_2 emissions from managed soils	kg CO_2e	-1,160,659	$0.02	-$0.02
Forage and cereal sub-activities	kg CO_2e	-13,009,461	$0.02	$0.26
Forage activities	kg CO_2e	-9,837,685	$0.02	-$0.20
Pasture activities	kg CO_2e	-16,766	$0.02	-$0.0003
Total	kg CO_2e	**-39,605,420**	**$0.02**	**-$0.79**

This BMP reduces GHG by 292,611 tonnes, or by 0.205 kg of CO_2e/kg of live shrunk weight for all beef cattle shipped to the slaughter plant. The cattle consuming these ionophores are cows and bulls, and the reduction in CO_2e/kg of live shrunk weight for these cows and bulls when they are shipped to the slaughter plant is 2.24 kg of CO_2e/kg of live shrunk weight (affected). From a systems perspective, this BMP has a positive net benefit of just over $100 million, and a BCR of 2.95:1 (see Table 4.7). These modeled results suggest that this BMP should have a rather high adoption rate in the Alberta cow/calf sector, with primary benefits being a reduction in feeding costs to cow/calf operators.

Table 4.7: System Wide Benefit Cost Ratio for BMP 3 – Full Adoption

Total Benefits	**$162.41**
Total Costs	**$55.02**
Net Benefits [Benefits - Costs]	**$107.39**
Ratio of Benefits to Costs	**2.95**

5.0 CBA OF BMP 4 – REDUCED AGE TO SLAUGHTER

BMP 4 is "introducing a feeding system that results in the finished beef animal reaching slaughter weight at a younger age with less feed intake".

5.1 DESCRIPTION OF BMP 4 – REDUCED AGE TO SLAUGHTER

Two approaches are used to model this BMP and its impact on GHG emissions. The first approach introduces Ractopamine Hydrochloride (RAC) into all of the feeders' diet for the last 28 days on feed to reach slaughter weight quicker. The second approach involves management practices to have beef cattle reach market weight (for slaughter) in fewer months, specifically 14 months versus 18 months.

Based on discussions with slaughterhouse personnel, Approach 1 (BMP 4.1) is currently implemented by 40 to 50 percent of the Albertan feedlots. Therefore, the beef system has been modelled for current conditions (assuming 45 percent usage of RAC to reduce days on feedlot), to create a 2010 baseline, compared to the 2001 baseline with no usage. The 2010 baseline for Approach 2 (BMP 4.2) is the same as 2001 as there is no evidence that the practice is currently implemented in Alberta.

BMP 4 generates costs and benefits for feedlot operators, as well as generating impacts through the beef supply chain. The boundaries of the feedlot operation and the purchase of most inputs for feeding beef cattle is illustrated in Figure 5.1, with feed requirements purchased from third parties, versus being home-grown.

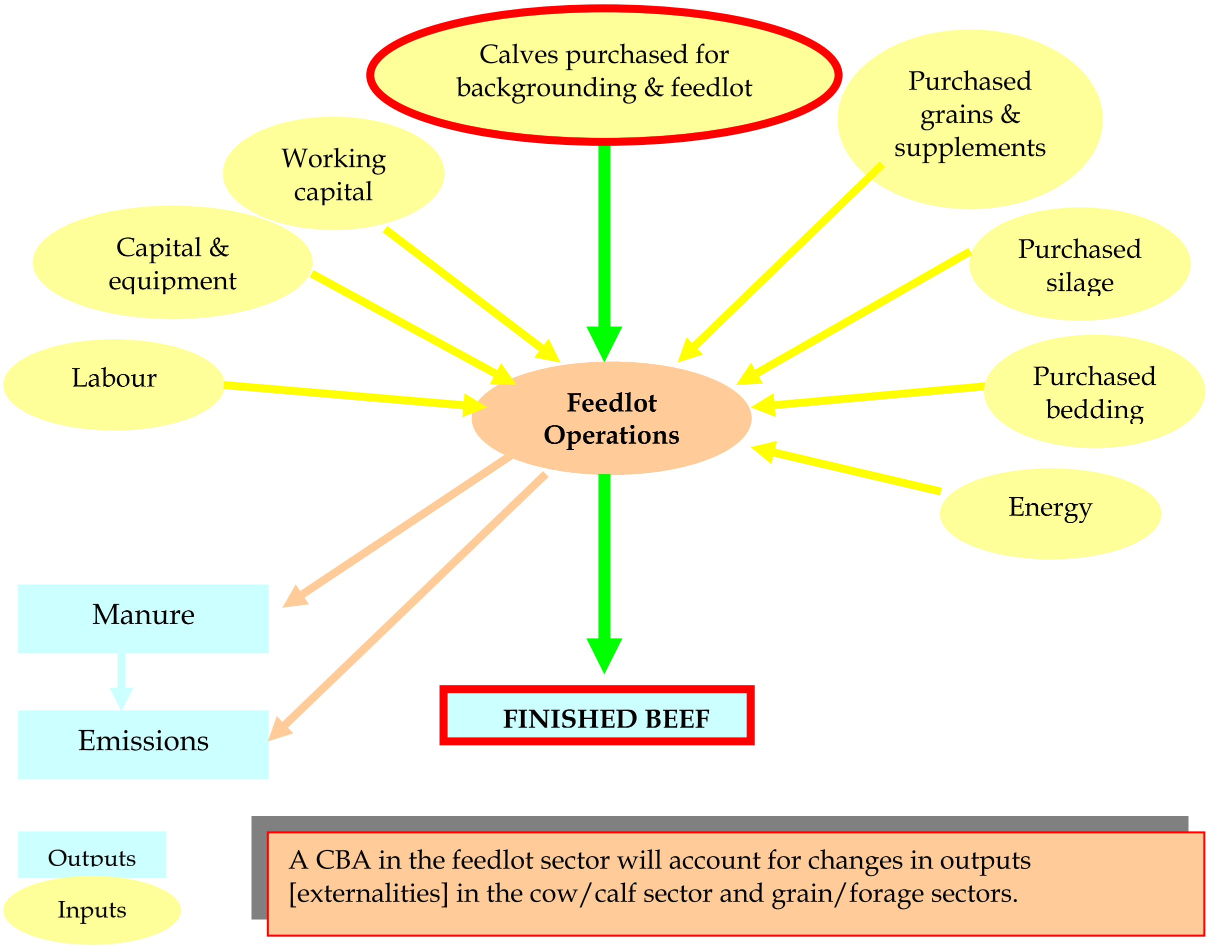
The operating assumptions include:

- Fewer kilograms of feed are required per finished animal resulting from (a) fewer days of maintenance diet due to the addition of a growth promotant during the last 28 days on feed to increase weight gain and reach final weight quicker, and (b) fewer days of maintenance diet due to the introduction of the finishing diet sooner.
- All feed used in the feedlot is purchased versus being home-grown on the feedlot farm.
- The amount of labour required to feed beef cattle decreases due to the fewer days the cattle are in the feedlot.
- The number of cattle produced for slaughter does not change, despite animals being fewer days on feed. Note that this economic benefit has not been included in the analysis because one of the most important assumptions for the LCA is that the total

amount of beef produced remains consistent such that any changes to the LCA can be compared to the baseline appropriately (i.e., functional unit).

- Depreciation (deterioration) of feedlot plant and equipment is not altered with this BMP with depreciation more dependent on the number of years in operation, and is minimally affected by fewer animal days in a feedlot.
- There are no capital expenditures associated with this BMP.

Figure 5.1: Boundary and Potential Resource Impacts in the Feedlot Sector



The direct impacts in the feedlot sector include:

- Outputs (same for both BMP 4.1 and 4.2):
  - No change in the annual number of finished beef supplied to slaughter plants (slight decrease in annual volume for BMP 4.2, as discussed later in this section)
  - With BMP 4.1, cattle are shipped to the slaughter plant a few days earlier (approximately 5 days earlier)
  - With BMP 4.2, cattle are shipped to feedlot 3.1 to 4 months earlier
  - Potential change in the quality of beef supplied to the market based on a younger beef animal
  - Potential change in distribution of when finished beef marketings occur over the year
  - Less methane produced by cattle while in the feedlot
  - Less manure produced and requiring disposal
  - Fewer emissions from the lower volume of stored manure
- Inputs:
  - BMP 4.1:
    - Less barley, barley silage, and supplements purchased
    - Purchase of growth promotants
    - Less energy used to feed livestock, provide livestock bedding and manure removal
    - Fewer days in feedlot
    - Lower labour requirements to feed beef cattle
    - Lower interest costs associated with working capital requirements
  - BMP 4.2:
    - Less barley silage purchased
    - More feed barley purchased
    - More feed supplements purchased
    - Less energy used to feed livestock, provide livestock bedding and manure removal
    - Fewer days in feedlot
    - Lower labour requirements to feed beef cattle
    - Lower interest costs associated with working capital requirements

There are also indirect impacts, such as those that occur with changes in cropping requirements to support the feedlot feeding practices (an upstream practice), and the possible impacts associated with manure disposal (a downstream impact).

5.2 BMP 4 – MODELLING LCA AND IMPACT

This BMP consists of reducing the feed consumption and time on feedlots to reduce the overall age of cattle at slaughter.

ARD provided CRA with draft guidance documents pertaining to the reduction in age of cattle for slaughter (Draft Guidance Document for Reducing the Number of Days on Feed of Beef Cattle, June 2010, Version 7; Draft Guidance Document for the Quantification Protocol for Reducing Age at Harvest, June 2010, Version 7). The actual methods to reduce the number of days on feed in beef cattle or to reduce the age at harvest are not outlined within these documents.

Based on these guidance documents, there are two methods to reducing the age to slaughter of Alberta beef cattle:

1. Reduce number of days on feed in feedlot during the final stages of growth (BMP 4.1)
2. Reduce age at harvest by adjusting the diet to introduce feeder and finishing diets sooner (BMP 4.2)

Both methods to reduce the age to slaughter were modelled to calculate the impacts and economics of each separately. These approaches are described in detail below.

Reducing the Number of Days on Feed of Beef Cattle (BMP 4.1)

Based on Alberta Environment's Specified Gas Emitters Regulation for the Quantification Protocol for Reducing Days on Feed of Cattle (August 2008, Version 1.1), direct and indirect reductions in GHG emissions from reducing days on feed for cattle being finished on feedlots is possible, in terms of enteric fermentation emissions from cattle and emissions from manure handling, storage and application during the time spent in feedlots.

A simplified case study was provided at the end of this guidance document where feed rations did not differ between the project and the baseline, with the exception of the addition of RAC during the final 28 days of feeding of the animals in the project condition. Typically RAC is added to the final 28 days of feed for feedlot cattle to increase the final weight, not to reduce actual time to slaughter. Based on the data collection, the average dosage of RAC during the final stages of feeding is 200 mg/head/day for 28 days. The Draft Guidance Document provided a range of additional gain in final weight and an increase in Average Daily Gain (ADG). These values were similar to what was found in other literature, and therefore they were used to calculate the reduction in days to reach the baseline final weight with the addition of RAC for 2 days. So, instead of increasing the final weight, the time to slaughter was reduced due to the increase in ADG with RAC usage.

Reducing Age at Harvest (BMP 4.2)

Based on the report from Basarab et al., 2008, GHG emissions and costs can be reduced by reducing the age to slaughter, which also reduces the feed requirements for each animal. Basarab et al., 2008 discussed the ability to reduce the age to slaughter from 18 months to 14 months, and that the age to slaughter can be reduced by 1 to 4 months within all of the Alberta operations for feeder cattle. This report has assumed that carcass weights and quality of meat with the reduction in the age to slaughter will be equivalent to current practices.

ADG is consistent throughout the 0 to 3 months, 3 to 6 months, and during the last stage in the feedlot. The project increases the ADG during the 6 to 7 months feedlot stage and starts the last stage in the feedlot diet much sooner than in the baseline. The overall differences in the diet include an increase in grain by 60 percent, a slight increase in silage by 5.5 percent, complete removal of hay from the diet, and a large reduction in pasture intake by 83 percent.

The Reducing Age at Harvest draft guidance document (provided to CRA by ARD) provides general diet classes and range of diets that are typical of diets fed to cattle in Alberta. These diet classes and timing on each diet class also provides diet classes and timing for ages at harvest of 12 and 21 months in addition to the 14 and 18 months. The guidance document mentions that 55 percent of all calves in Alberta are sent for backgrounding, and these are the types of calves that can provide benefits with regards to reducing emissions because the backgrounding stages of the diet are eliminated. Therefore, 55 percent of the beef production industry in Alberta will realistically benefit from implementing a reduction in the age to slaughter. The model is set up in such a way that all calves in Alberta undergo a backgrounding stage, based on the typical diets provided by a qualified ruminant nutritionist. This has only been applied to the calf-fed cattle which represent about 45 percent of the annual beef production in Alberta, and the age to slaughter will be reduced from 18 months to 14 months. This conservatively takes into account the effects of implementing this BMP on the 55 percent of calves in Alberta that are actually backgrounded.

5.2.1 CHANGES TO THE PHASE 1 BASELINE LCA MODEL

CBA compares the costs of a change (i.e., the BMP) to the benefits associated with the change for the relevant decision makers. Accordingly, the change in outputs and inputs used by the feedlot sector are of major concern, along with the values of these inputs and outputs.

As discussed above, these two methods of reducing the age to slaughter of feeder cattle have been implemented into the model separately to calculate the impacts and costs:

1. Provide RAC as a feed additive to allow the cattle to gain more weight during the last stage of feeding (BMP 4.1)
2. Remove backgrounding stages of feeding regimes for calf-fed cattle to introduce feeder diet at a younger age (BMP 4.2)

Reducing the Number of Days on Feed of Beef Cattle (BMP 4.1)

The Phase 1 LCA model was updated to 2010 conditions to include the percentage of feedlots supplying RAC to the feeder cattle prior to slaughter (45 percent as outlined above).

The Draft Guidance Document for Reducing the Number of Days on Feed of Beef Cattle outlines that feeding RAC during the last 28 to 42 days on feedlot will increase the final weight by 1.2 to 2.1 percent. Assuming a feeding dosage of 200 mg/head/day as general practice, an average of 1.65 percent greater weight was assumed, with an increase of 20 percent ADG.

Using the diets prepared by the ruminant nutritionist for Phase 1, and the increase of 20 percent ADG during the last 28 days in the feedlot, a reduction in days on feedlot was calculated assuming that the slaughter weight stays constant as the baseline and no increase in final weight is achieved. The following is a summary of the reduced days on feedlot for each cattle category:

• Yearling-fed steers:	4.9 days
• Yearling-fed heifers:	5.0 days

- Calf-fed steers: 5.4 days
- Calf-fed heifers: 5.1 days

The reduced days in feedlot also reduces the days on feed. The diets were reduced, which adjusts all linked activities in the model accordingly (cereal and forage activities, enteric fermentation emissions, methane emissions from manure, N_2O emissions from manure, etc.).

The reduction in the amount of feed also reduces the amount of garbage (plastics) used for the feed.

The amount of manure generated was reduced accordingly, as the manure production in the model is based on daily rates. Enteric fermentation emissions and bedding requirements (production and transportation) were adjusted in the same manner, as the diet remains the same during the last 4 or 5 days on the feedlot.

The diesel requirements to feed cattle and collect manure have been adjusted based on the reduction in feed and manure generated. Labour is also reduced due to less feed and manure handling. The weight of the bedding that was reduced was less than 4 percent of the feed reduced. Consequently, the fuel saved from supplying bedding to the cattle can be considered negligible and was not calculated.

The emissions from the production of RAC have not been included, as emission factors for this process are not available. This remains a data gap. The transportation of RAC has been included in the model.

There are varying references regarding the effect of RAC on beef quality and quantity. Vogel et al. (2009) studied the effects of steers on RAC for 28 to 38 days. A decrease in Canada Prime/AAA beef was realized, and an increase of AA/A quality beef was concluded. Quinn et al. (2008) studied the effects of heifers on RAC for 28 days and slight changes in quality grades were realized. These reductions were based on US quality grades, but were generically translated to Canadian quality grades so that these changes could be captured in the model. A slight increase in Canadian AAA and a slight decrease in Canadian AA/A was shown in this study.

A phone conversation with a professional in the slaughterhouse industry indicated that RAC is in use for approximately 40 to 50 percent of all beef in Canada. Forty five percent implementation has been assumed for 2010, and it was expressed by the slaughterhouse industry professional that an increase in RAC usage in Alberta will be detrimental to the beef production system in Alberta. A significant reduction in beef quality is anticipated if the usage increases. Therefore, if 50 percent or more of the Alberta beef production system is modelled as using RAC, a change in beef quality as outlined above may be realized.

The average price per weight of beef has been calculated for the years 2008 to 2010 for AAA quality beef and AA/A quality beef. The price change in the quality grades based on 50 percent of RAC usage or more have been captured in the model. This assumes that the decrease in revenue for the slaughterhouse is directly proportional to the decrease in the revenue for the feedlots.

Reducing Age at Harvest (BMP 4.2)

It is not known whether the reduction in the age at harvest by reducing time in backgrounding feedlot is actually being practiced in Alberta, and therefore, the 2010 baseline is exactly the same as the 2001 baseline (Phase 1).

To implement this practice into the model, many of the same changes have been made to this model as for BMP 4.1.

The Draft Guidance Document for Reducing Age at Harvest outlines the options for reducing time in the backgrounding feedlot and introducing a higher concentrates diet sooner. This was applied to the calf-fed cattle in the model only. A step-up diet was introduced into the model that used all the diets from the 2001 baseline but altered the amount on each diet to reflect the total time for the step up diet in the Guidance Document. The final diet from the 2001 baseline was introduced much sooner and was applied for a longer period of time with the implementation of this BMP. The same characteristics of the baseline diets were applied to this model. The age of calf-fed steers was reduced from 18 months to 14.9 months, and the age of calf-fed heifers was reduced from 18 months to 14.2 months.

Based on these diet changes, the amount of feed required, plastics for feed used, diesel used to collect manure and to feed cattle, manure generated, enteric fermentation emissions, methane and N_2O emissions from manure were all adjusted to reflect the changes in the diets.

There is very minimal literature available that discusses the effects of this type of diet change on the final quality of the beef. Based on a discussion with a slaughterhouse industry professional, complete adoption of this BMP in Alberta would be highly negative. The slaughterhouses would have to process all beef within a few months, and there is insignificant capacity and human-power available to do so. Access to beef year round is important to the clients of Alberta beef. The slaughterhouse industry professional also commented that there is a chance of reduced marbling but this may be offset by an increase in tenderness. However, a smaller finished animal is most likely in a feeding regime such as this. Consequently, it is also anticipated by industry professionals that there will be a reduction in both quality grade and yield grade of the beef, but there is no available peer-reviewed scientific literature at this time to confirm and quantify the changes.

A reduction in carcass weight of 20 kg was assumed with a slight decrease of AAA grade beef to AA/A grade of ±5 percent in the model to reflect impact on the beef market. The average price of AAA and AA/A beef over 2008 to 2010 using weekly price averages was used to calculate the reduction in revenue to the slaughterhouse, which was assumed to be directly proportional to the reduction in revenue for the feedlots (based on limited data availability). Also, a price difference for beef sold in September/November to May/July was included in the analysis based on the 2005 to 2010 steer and heifer prices on Canfax. There is a slight increase in the price of beef in May/July as compared to September/November.

5.3 BMP 4 – RESULTS OF GHG EMISSIONS AND OTHER IMPACTS

The impacts on the four environmental impact categories (GHG, acidification, eutrophication, and non-renewable resources) were modelled for the entire Alberta beef production system to reflect the changes to the model with the implementation of the BMP. The graphs in this section show the total impact of each category from the entire system for the baseline years, and also show the difference in these impacts from the baselines to the implementation of the BMP based on percent adoption of the BMP. The y-axis scales have been kept the same for both BMP 4.1 and 4.2, for comparison purposes.

The following graphs show the total GHG emissions versus the percent adoption for BMP 4.1 and BMP 4.2.

Figure 5.2a: BMP 4.1 - GHG Emissions and Percent Adoption

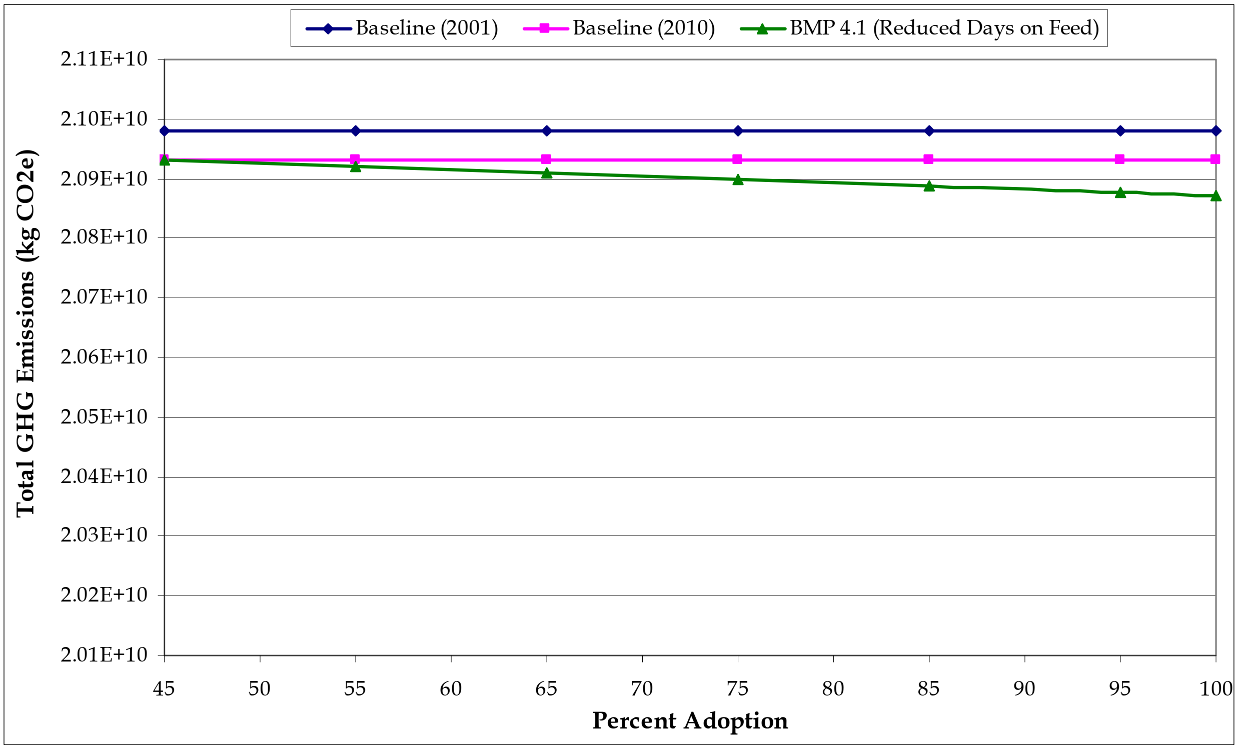


Figure 5.2b: BMP 4.2 - GHG Emissions and Percent Adoption

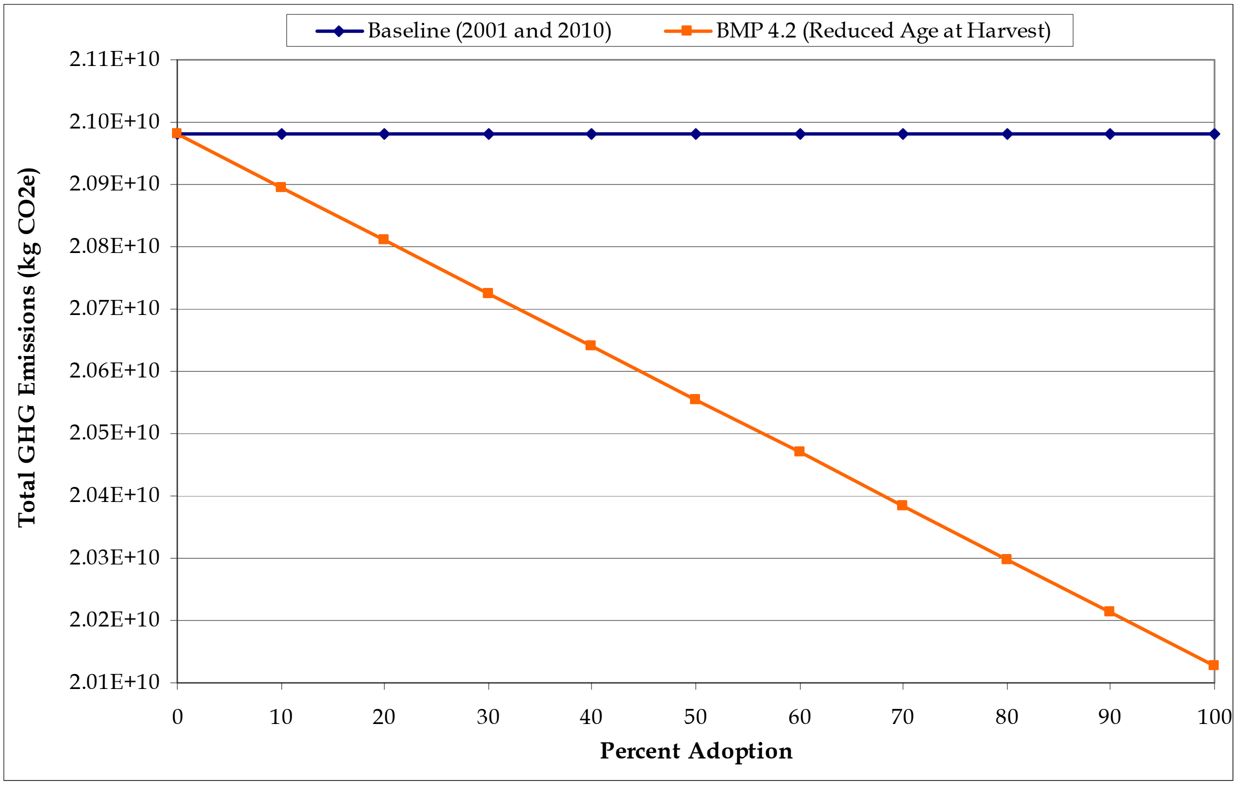


Table 5.1 illustrates the major components of the model where the changes in GHG emissions are occurring from the 2001 baseline, to the 2010 baseline (for BMP 4.1 only), to BMP 4.1 and 4.2.

The change in GHG emissions from 2010 to 100 percent adoption (in kg CO_2e/kg shrunk live weight) are shown in Table 5.1 and below:

- BMP 4.1 0.3% reduction
- BMP 4.2 2.8% reduction

The sources of GHG emissions changes occur from the following components for BMP 4.1:

- Forage and cereal sub-activities, cereal activities, forage activities (reduction in GHG emissions from the production, transportation, etc. of barley and barley silage)
- Energy generation and usage activities (reduction in GHG emissions from producing crude, transporting crude, refining crude into diesel, transporting diesel, combusting diesel – all for the reduction in diesel used to feed cattle and to collect manure)

- Enteric fermentation emissions (reduction in enteric fermentation emissions due to reduced days on the feedlot)
- Methane emissions from manure (reduction due to reduced days on the feedlot)
- Soil carbon change in soil from land use (reduction in soil sequestration due to the reduced barley and barley silage)
- Carbon dioxide from managed soils (reduction in carbon dioxide emissions due to the reduction in barley and barley silage)
- N_2O emissions from manure (reduction due to reduced days on the feedlot)

The components that contributed to more than 95 percent of the reductions in GHG emissions for BMP 4.1 were all emissions associated with the forage and cereal sub-activities and cereal activities (barley production), the production and combustion of diesel, and the reduction in enteric fermentation emissions and N_2O emissions from manure.

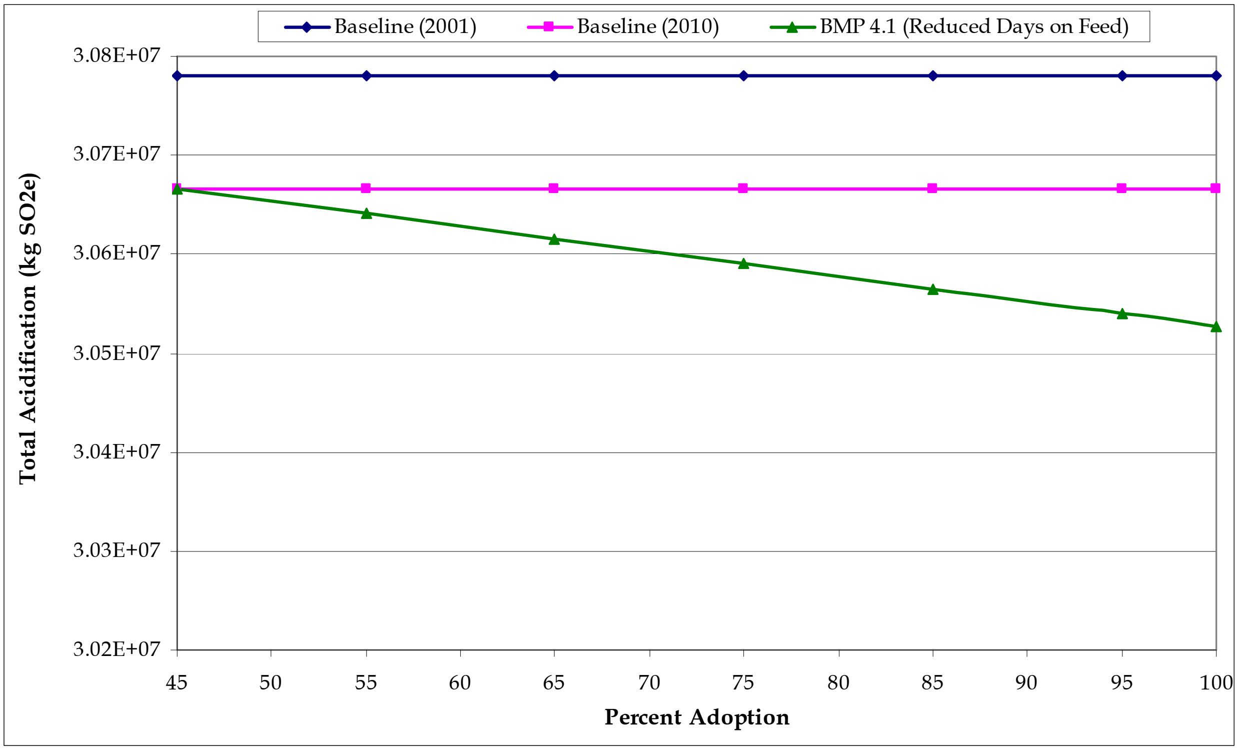
The sources of GHG emissions changes occur from the following components for BMP 4.2:

- Forage and cereal sub-activities and cereal activities (increase in emissions due to the production of more barley)
- Forage activities (reduction in GHG emissions from the reduction in barley silage)
- Energy generation and usage activities (same as for BMP 4.1)
- Feedlot and pasture activities (reduction in GHG emissions from the reduction in bedding production, mineral and vitamins, and plastic production and disposal)
- Transportation of all cattle (slight increase only due to the fact that the total weight of slaughtered cattle has been slightly reduced to account for the reduced age at slaughter)
- Enteric fermentation emissions (same as for BMP 4.1)
- Methane emissions from manure (same as for BMP 4.1)
- Soil carbon change in soil from land use (same as for BMP 4.1)
- Carbon dioxide from managed soils (increase in GHG emissions due to the increase in barley production)
- N_2O emissions from manure (reduction due to reduced days on the feedlot)

The components that contributed to more than 95 percent of the reductions in GHG emissions for BMP 4.2 were all emissions associated with the forage and cereal sub-activities and cereal activities (barley production), the production and combustion of diesel, and the reduction in enteric fermentation emissions and N_2O emissions from manure.

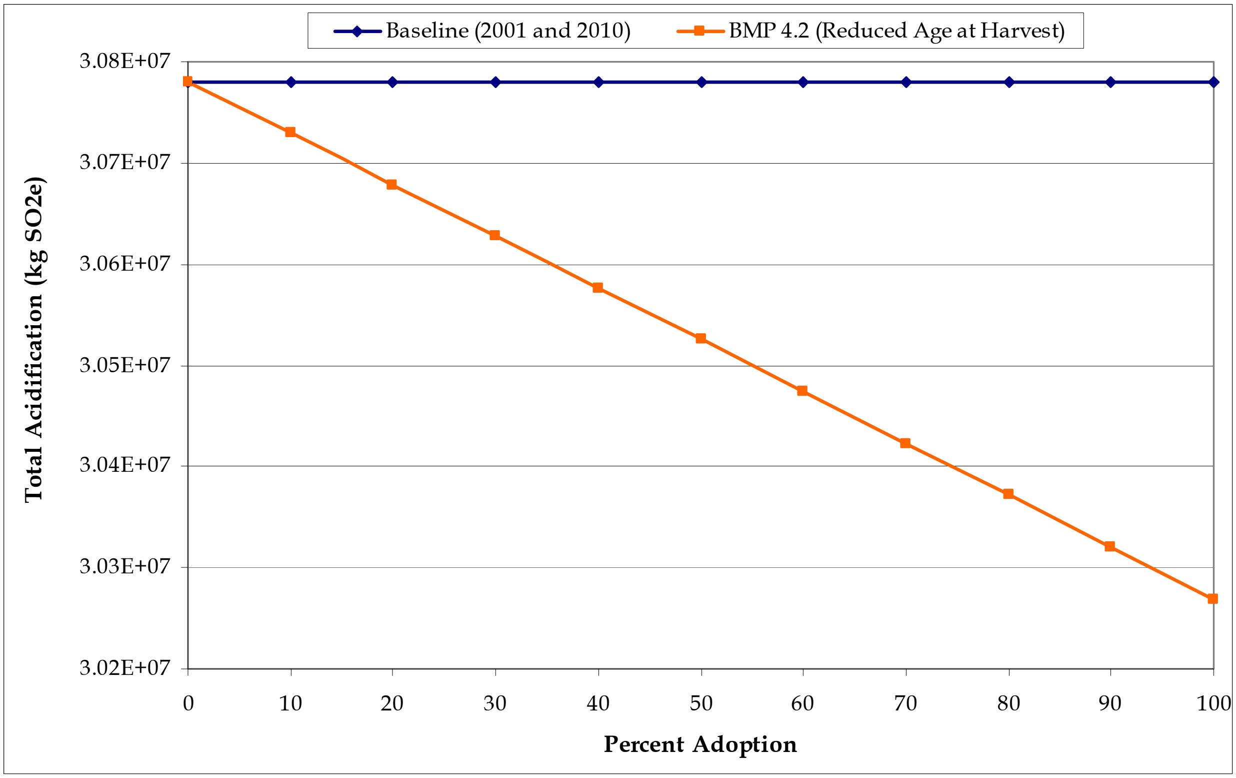
The following graphs (Figures 5.3a and 5.3b) show the total acidification impact versus the percent adoption for BMP 4.1 and 4.2.

Figure 5.3a: BMP 4.1 – Acidification and Percent Adoption



The main elements that resulted in changes to the acidification impact for BMP 4.1 were the reductions from production, transportation, etc. of barley and barley silage, and the reduction in production and combustion of diesel to feed cattle and to collect manure on the feedlot.

Figure 5.3b: BMP 4.2 – Acidification and Percent Adoption



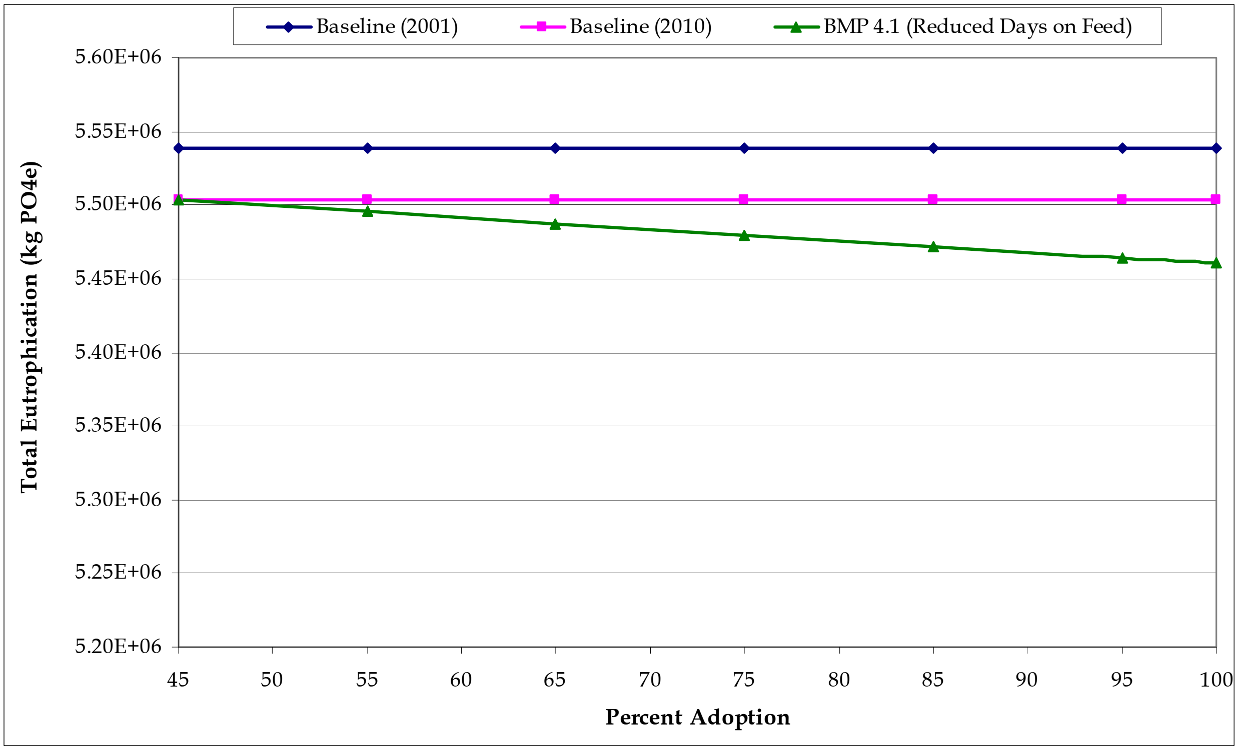
The main elements that resulted in changes to the acidification impact for BMP 4.2 were the reductions from the production and combustion of diesel to feed cattle and to collect manure on the feedlot and for the production and transportation of less barley silage, and the increases from the production and transportation of barley.

The change in acidification impacts from 2010 to 100 percent adoption (in kg SO_2e/kg shrunk live weight) are shown below:

BMP 4.1	0.5% reduction
BMP 4.2	1.7% reduction

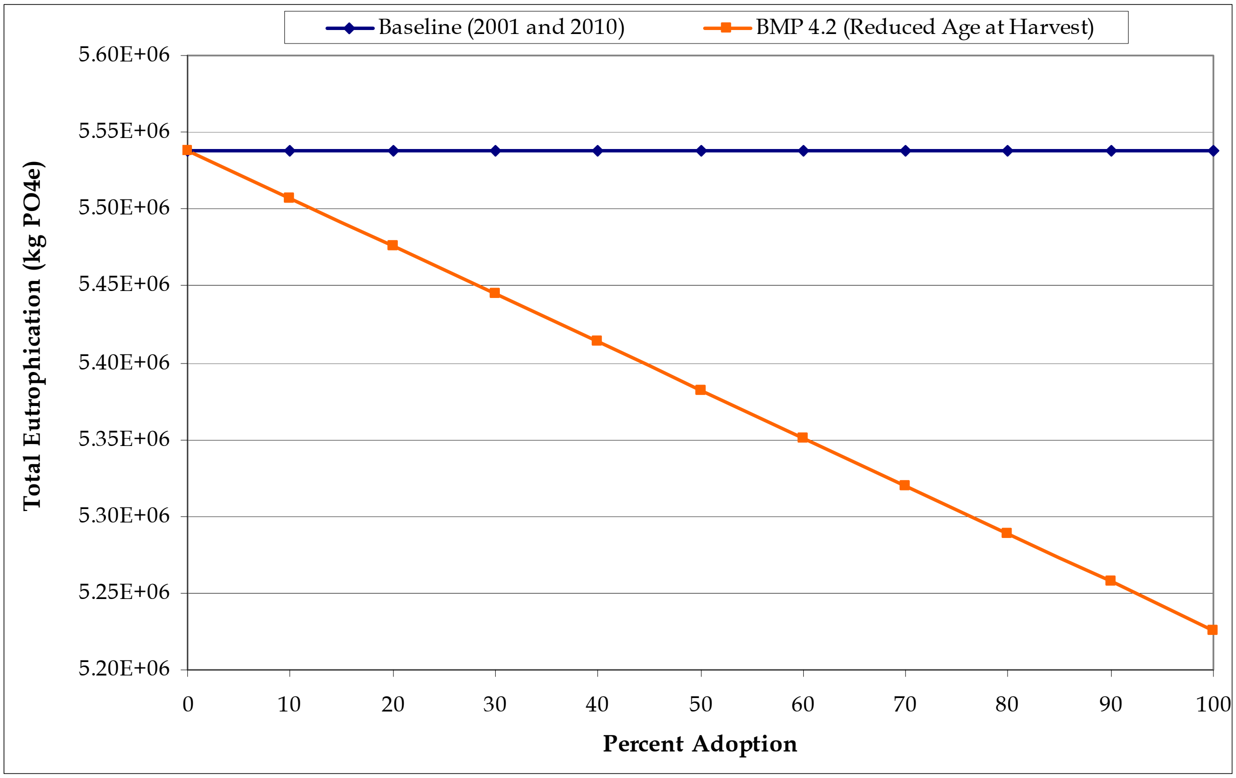
The following graphs (Figures 5.4a and 5.4b) show the total eutrophication impact versus the percent adoption for BMP 4.1 and 4.2.

Figure 5.4a: BMP 4.1 – Eutrophication and Percent Adoption



The main elements that resulted in changes to the eutrophication impact for BMP 4.1 were the reductions from production, transportation, etc. of barley and barley silage, the reduction in production and combustion of diesel to feed cattle and to collect manure on the feedlot, and the reduction in total phosphorous emissions from run-off.

Figure 5.4b: BMP 4.2 – Eutrophication and Percent Adoption



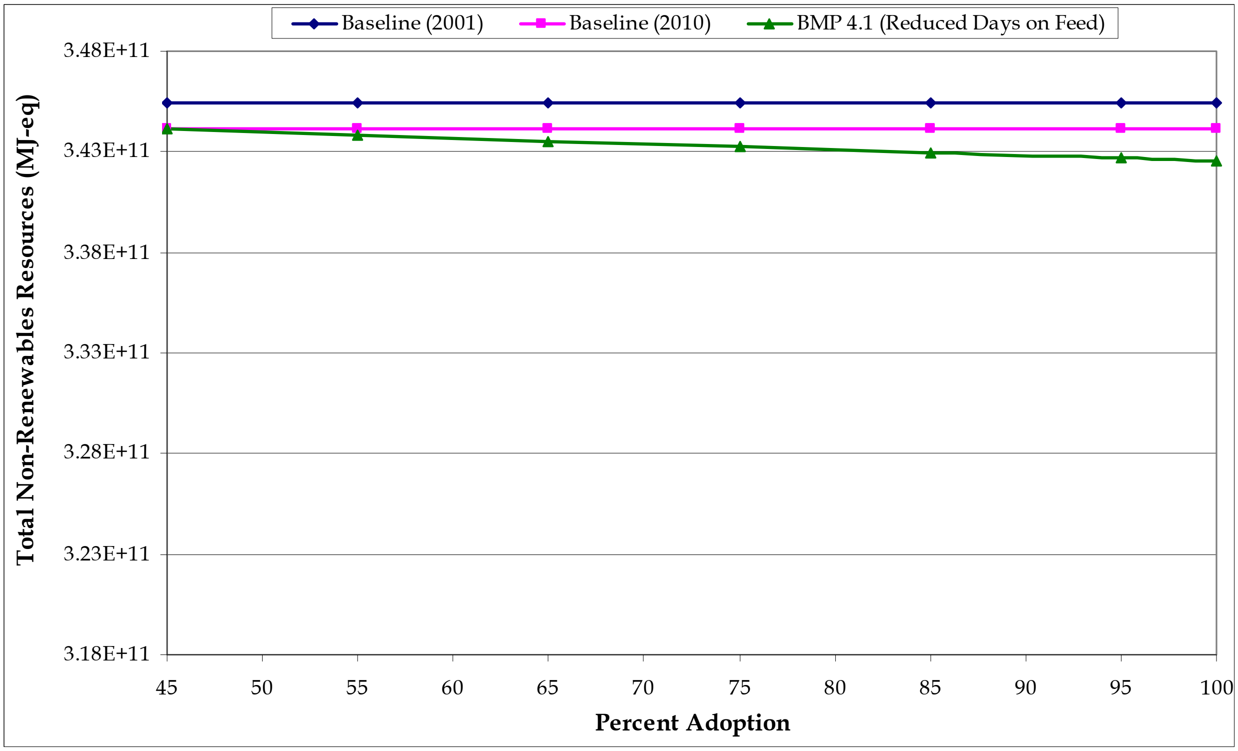
The main elements that resulted in changes to the eutrophication impact for BMP 4.2 were the reductions from production, transportation, etc. of barley silage, the reduction in production and combustion of diesel to feed cattle and to collect manure on the feedlot, and the reduction in total phosphorous emissions from run-off. There was a slight increase in eutrophication impacts due to the increased amount of barley required for BMP 4.2.

The change in eutrophication impacts from 2010 to 100 percent adoption (in kg PO_4e/kg shrunk live weight) are shown below:

- BMP 4.1 0.8% reduction
- BMP 4.2 5.6% reduction

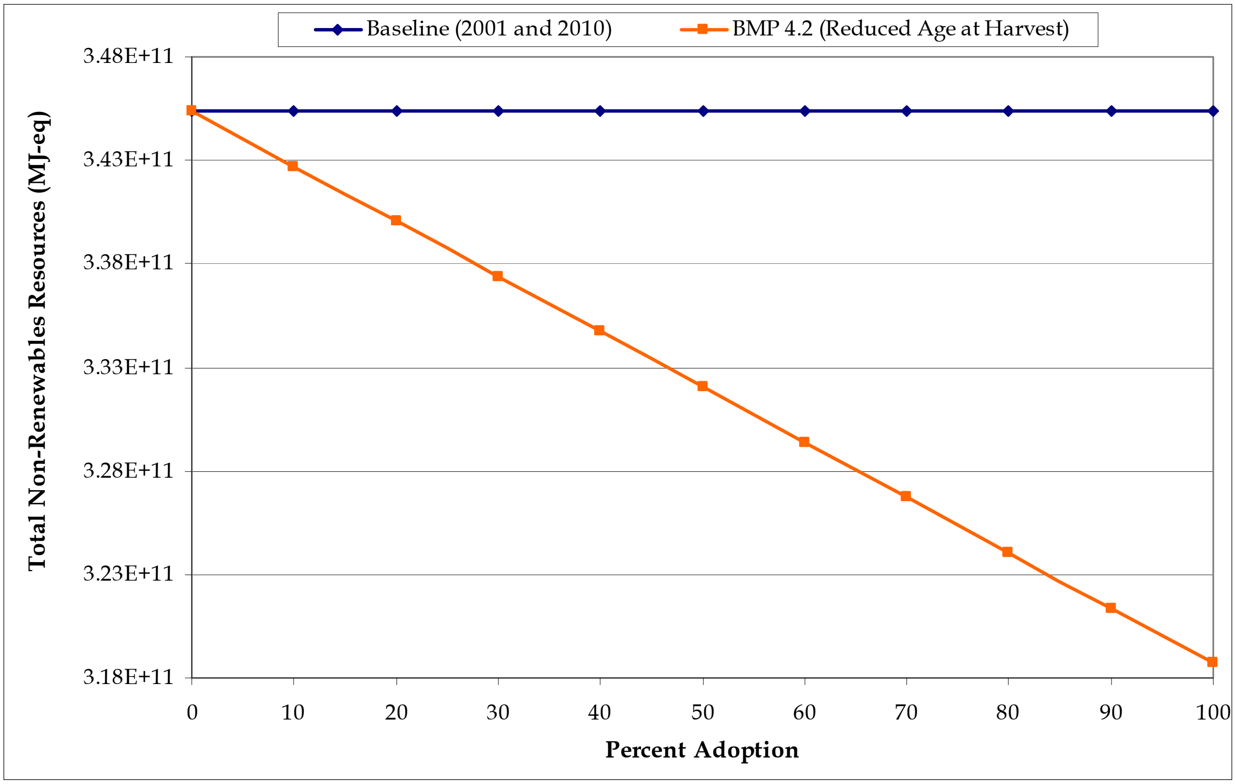
The following graphs (Figures 5.5a and 5.5b) show the total non-renewable resources impact versus the percent adoption for BMP 4.1 and 4.2.

Figure 5.5a: BMP 4.1 – Non-Renewable Resources and Percent Adoption



The main elements that resulted in changes to the non-renewable resources impact for BMP 4.1 were the reductions from production, transportation, etc. of barley and barley silage, and the reduction in production and combustion of diesel to feed cattle and to collect manure on the feedlot.

Figure 5.5b: BMP 4.2 – Non-Renewable Resources and Percent Adoption



The main elements that resulted in changes to the non-renewable resources impact for BMP 4.2 were the reductions from production, transportation, etc. of barley silage and the reduction in production and combustion of diesel to feed cattle and to collect manure on the feedlot. There was a slight increase in non-renewable resource impacts due to the increased amount of barley required for BMP 4.2, however, the energy generation activities were the primary component to this impact.

The change in total non-renewable resources impacts from 2010 to 100 percent adoption (in MJ-eq/kg shrunk live weight) are shown below:

- BMP 4.1 0.5% reduction
- BMP 4.2 7.7% reduction

5.4 CBA AND BMP 4.1 – USE OF GROWTH PROMOTANT FOR LAST 28 DAYS

With BMP 4.1 there were no animals on RAC in the 2001 baseline, with 45 percent of beef cattle assumed on the growth promotant program in 2010. This amounts to 959,612 cattle in 2010 and 583,376 tonnes of shrunk live weight affected by this BMP. For each beef animal using the RAC growth promotant over the last 28 days, the animal is on feed for approximately 5 fewer days. Full adoption of this BMP affects all 2,132,470 beef cattle and 1,296,392 tonnes of shrunk live weight (excluding cows and bull shipped to slaughter).

The first CBA **(CBA 1)** focuses on the feedlot operation and uses market values and does not place any value on the externalities (i.e., the reduction in emissions). Compared to 2001, the 45 percent adoption rate in 2010 generated the impacts summarized in Table 5.2.

BMP 4.1 reduces the costs of selected inputs by a total $11.0 million, as shown in the first section of Table 5.2. The cost savings are a reduction in overall feed and feed supplements consumed. For example, each finishing animal consumes about 58 fewer kilograms of barley. These are the benefits of using growth promotants for the last 28 days, which is $11.46/head of affected[4] beef cattle shipped to the slaughter plant.

The incremental costs of BMP 4.1 in 2010 are twofold. First, there are higher input costs associated with growth promotants of around $7,700, as shown in the middle portion of Table 5.2. The other cost area is the loss in meat value, with fewer kilograms being graded as AAA or better due to the usage of RAC. This loss is estimated to be $0.88 million. The lower value of the beef cattle shipped to the slaughter plant is based on the modelled reduction in the volume of meat that will be graded as AAA or better.

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[4] $11 million divided by 959,612 head of cattle.

Table 5.2: Benefits and Costs of BMP 4.1 at the Feedlot in 2010 – Market Values

Items	Units	Volume Change	Unit Price ($/unit)	Total Impact ($ million)
Benefits - Input Cost Savings				
Purchased barley	kg	-56,001,427	$0.16	-$9.04
Purchased barley silage	kg	-15,839,047	$0.04	-$0.63
Purchase of min., trc min., cobalt, protein suppl., antibiotic	kg	-944,052	$0.48	-$0.45
Purchase of vitamins	kg	-1,401	$1.37	$0.00
Purchased bedding	kg	-2,409,539	$0.06	-$0.14
Fuel consumed to feed livestock	L	-918,748	$0.75	-$0.69
Fuel consumed to collect manure	L	-9,059	$0.75	-$0.01
Labour (change)	hrs	-1,724	$16.22	-$0.03
Working capital interest	$	0	-	-
Total - Input Cost Savings				**-$10.98**
Costs - Higher Input Usage				
Purchase of RAC	kg	6,332	$1.22	$0.0077
Total - Higher Input Costs				**$0.0077**
Costs - Change in Value of Output				
Manure sold for land application	kg	-68,180,107	$0.00	$0.00
Meat downgraded from Canada AAA to AA/A	kg	-1,834,564	$0.48	-$0.88
Total - Loss in Meat Value				**-$0.88**

All incremental benefits of $11 million are compared to the incremental costs in Table 5.3, with the costs being the higher input costs combined with the reduction in meat value of $0.88 million. This indicates that the net benefits are $10.1 million and the benefit cost ratio is 12.4:1[5], which implies an IRR (internal rate of return) to the feedlot operator of about 60 percent[6].

Table 5.3: Benefit Cost Ratio at the Feedlot for BMP 4.1 in 2010 – Market Values

Total Benefits ($ million)	**$10.98**
Total Costs ($ million)	**$0.88**
Net Benefits [Benefits - Costs] ($ million)	**$10.10**
Ratio of Benefits to Costs	**12.43**

For modeling purposes, the operating assumption is made that with this BMP, the entire beef sector will migrate to 100 percent use of this practice (calf-fed and yearling-fed cattle). As stated in Section 5.2.1, it has been suggested to CRA that additional implementation of this BMP (let alone full implementation) can have significant effects on the beef market, such as on the distribution of quality and processor desire for certain beef characteristics. The associated modeled benefits and costs when all 2,132,470 cattle

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[5] 12.4:1 signifies a benefit to cost ratio of 12.4 to 1.0.

[6] Based on the formula BCR = IRR/cost of capital, with cost of capital assumed to be 5 percent.

are using RAC for 28 days prior to slaughter are illustrated in Table 5.4, which shows the changes in inputs and outputs from the 2010 values. The cost savings per head are $11.50/head[7] shipped to the slaughterhouse.

Table 5.4: Benefits and Costs of BMP 4.1 at the Feedlot with Full Adoption – Market Values

Items	Units	Volume Change	Unit Price ($/unit)	Total Impact ($ million)
Benefits - Input Cost Savings				
Purchased barley	kg	-68,446,188	$0.16	-$11.05
Purchased barley silage	kg	-19,358,835	$0.04	-$0.77
Purchase of min., trc min., cobalt, protein suppl., antibiotic	kg	-1,281,636	$0.48	-$0.61
Purchase of vitamins	kg	-1,713	$1.37	$0.00
Purchased bedding	kg	-2,944,992	$0.06	-$0.17
Fuel consumed to feed livestock	L	-1,122,915	$0.75	-$0.84
Fuel consumed to collect manure	L	-11,073	$0.75	-$0.01
Labour (change)	hrs	-2,107	$16.22	-$0.03
Working capital interest	$	0	-	$0.00
Total - Input Cost Savings				**-$13.49**
Costs - Higher Input Usage				
Purchase of RAC	kg	7,740	$1.22	$0.01
Total - Higher Input Costs				**$0.01**
Costs - Change in Value of Output				
Manure sold for land application	kg	-83,331,242	$0.00	$0.00
Meat downgraded from Canada AAA to AA/A	kg	-2,242,245	$0.48	-$1.07
Total - Loss in Meat Value				**-$1.07**

With full adoption of this BMP the benefit to cost ratio is 12.5:1 indicating a high rate of return to the feedlot operator for using this management practice. This suggests that there is sufficient incentive for the feedlot operator/owner to adopt this BMP on the cattle that are currently not on the growth promotant.

Table 5.5: Benefit Cost Ratio for BMP 4.1 at the Feedlot with Full Adoption – Market Values

Total Benefits ($ million)	**$13.49**
Total Costs ($ million)	**$1.08**
Net Benefits [Benefits – Costs] ($ million)	**$12.41**
Ratio of Benefits to Costs	**12.48**

The second CBA (**CBA 2**) retains the feedlot focus and considers the externalities (emissions) associated with feedlot operations. This includes a reduction in methane from less stored manure as well as from reductions in emissions from enteric fermentation (due to fewer days on feed and based on less barley and barley silage used

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[7] Based on dividing $13.49 million by (2,132,470 minus 959,612 head).

because of fewer days on feed). Expressed in CO_2e and valued at $0.02/kg (or $20/tonne), the total reduction is valued at $0.62 million, as shown in Table 5.6. The largest reduction is in the enteric fermentation category.

Table 5.6: Benefit of Emission Reduction at the Feedlot with BMP 4.1 - 2010

Reduction in Feedlot Emissions	Units	Volume Change	Unit Price ($/unit)	Total Impact ($ Million)
Methane emissions from stored manure	kg CO_2e	-789,333	$0.02	-$0.02
Enteric fermentation emissions	kg CO_2e	-14,572,647	$0.02	-$0.29
N_2O emissions from stored manure (direct)	kg CO_2e	-2,542,624	$0.02	-$0.05
N_2O emissions from stored manure (indirect)	kg CO_2e	-2,383,710	$0.02	-$0.05
Energy generation and consumption activities	kg CO_2e	-8,959,359	$0.02	-$0.18
O&M activities	kg CO_2e	0	$0.02	$0.00
Feedlot activities	kg CO_2e	-1,520,130	$0.02	-$0.03
Totals	kg CO_2e	**-30,767,803**	$0.02	**-$0.62**

Assuming that society paid the feedlot operator $20/tonne for a reduction in CO_2e emissions, the benefits realized by the feedlot sector in 2010 would have increased by $0.62 million to $11.60 million, with a resulting benefit to cost ratio increasing slightly to 13.1:1, from the value shown in Table 5.3.

Table 5.7 summarizes the benefits of the reduction in feedlot emissions from the 2010 baseline, based on full adoption of this BMP and retaining a $20/tonne valuation of a tonne of CO_2e. Net benefits increase by $0.75 million to $13.2 million and the benefit cost ratio becomes 13.2:1 (when moving from 2010 values to full adoption).

Table 5.7: Benefit of Emission Reduction at the Feedlot with BMP 4.1 –Full Adoption

Reduction in Feedlot Emissions	Units	Volume Change	Unit Price ($/unit)	Total Impact ($ Million)
Methane emissions from stored manure	kg CO_2e	-964,740	$0.02	-$0.02
Enteric fermentation emissions	kg CO_2e	-17,811,013	$0.02	-$0.36
N_2O emissions from stored manure (direct)	kg CO_2e	-3,107,652	$0.02	-$0.06
N_2O emissions from stored manure (indirect)	kg CO_2e	-2,913,424	$0.02	-$0.06
Energy generation and consumption activities	kg CO_2e	-10,950,327	$0.02	-$0.22
O&M activities	kg CO_2e	0	$0.02	$0.00
Feedlot activities	kg CO_2e	-1,857,936	$0.02	-$0.04
Totals	kg CO_2e	**-37,605,092**	$0.02	**-$0.75**

The third CBA **(CBA 3)** goes a step further than CBA 2 and considers any upstream changes in emissions. This include the lower emissions associated with less cropland needed to support the beef sector (based on fewer days on feed for maintenance requirements), such as the change in soil N_2O emissions from cropping and land use, the change in P_2O_5 runoff from cultivating; and soil carbon impacts. These are shown in

Table 5.8 for the 2010 baseline relative to 2001, with a total volume of CO_2e reduction at 18,035 tonnes[8], which has a total value of value of $0.36 million based on a $20/tonne valuation.

Table 5.8: Benefits of System Wide Emission Reduction with BMP 4.1 – 2010

Reduction in Other Emissions	Units	Volume Change	Unit Price ($/unit)	Total Impact ($ million)
N_2O emissions from cropping and land use	kg CO_2e	-4,866,012	$0.02	-$0.10
Total P emissions from run-off	kg PO_4-eq	-29,737	-	$0.00
Soil carbon change in soil from land use	kg CO_2e	2,066,704	$0.02	$0.04
Direct CO2 emissions from managed soils	kg CO_2e	-1,517,171	$0.02	-$0.03
Forage and cereal sub-activities	kg CO_2e	-8,887,880	$0.02	-$0.18
Cereal activities	kg CO_2e	-4,220,821	$0.02	-$0.08
Forage activities	kg CO_2e	-236,164	$0.02	$0.00
Feedlot activities	kg CO_2e	-373,863	$0.02	-$0.01
Total	kg CO_2e	**-18,035,207**	**$0.02**	**-$0.36**

These incremental GHG reduction benefits increase the overall system benefits to $12.0 million, when the CO_2e reduction is valued at $20/tonne. The results in a 13.5:1 benefit cost ratio for 2010 as reported in Table 5.9.

Table 5.9: System Wide Benefit Cost Ratio for BMP 4.1 in 2010

Total Benefits ($ million)	**$11.96**
Total Costs ($ million)	**$0.88**
Net Benefits [Benefits - Costs] ($ million)	**$11.08**
Ratio of Benefits to Costs	**13.53**

In 2010, the total reduction in GHG (expressed as CO_2e reduction) is the sum of the totals in Tables 5.6 and 5.8, for a 48,800 tonne reduction from 2001 baseline values, which can be valued at $0.98 million per annum.

With full adoption of BMP 4.1, the system wide reduction in GHG emissions from the 2010 baseline are reported in Table 5.10, at 22,054 tonnes. When valued at $20/tonne, the value of this reduction is $0.44 million per annum, which is just over $0.20 per head of affected beef cattle shipped to a slaughter plant.

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[8] Which excludes a valuation of less P run-off.

Table 5.10: Benefits of System Wide Emission Reduction with BMP 4.1 – Full Adoption

Reduction in Other Emissions	Units	Volume Change	Unit Price ($/unit)	Total Impact ($ Million)
N_2O emissions from cropping and land use	kg CO_2e	-5,950,849	$0.02	-$0.12
Total P emissions from run-off	kg PO_4-eq	-36,345	-	$0.00
Soil carbon change in soil from land use	kg CO_2e	2,525,971	$0.02	$0.05
Direct CO_2 emissions from managed soils	kg CO_2e	-1,856,147	$0.02	-$0.04
Forage and cereal sub-activities	kg CO_2e	-10,868,832	$0.02	-$0.22
Cereal activities	kg CO_2e	-5,158,781	$0.02	-$0.10
Forage activities	kg CO_2e	-288,645	$0.02	-$0.01
Feedlot activities	kg CO_2e	-456,943	$0.02	-$0.01
Total	kg CO_2e	**-22,054,226**	**$0.02**	**-$0.44**

The resulting system wide net benefit approaches $13.6 million, with a 13.6:1 benefit to cost ratio, as noted below in Table 5.11.

Table 5.11: System Wide Benefit Cost Ratio for BMP 4.1 – Full Adoption

Total Benefits ($ million)	**$14.68**
Total Costs ($ million)	**$1.08**
Net Benefits [Benefits - Costs] ($ million)	**$13.60**
Ratio of Benefits to Costs	**13.59**

With full adoption of BMP 4.1, the GHG reduction from 2010 values is the sum of the 22,054 tonnes of CO_2e in Table 5.10 and the 37,605 tonnes in Table 5.7. This annual volume CO_2e reduction of 59,659 tonnes has an attributed value of $1.2 million.

The impact of having this BMP in place, when viewed from a 2001 baseline is an annual 108,460 tonne CO_2e reduction. This is a 0.076 kg CO_2e reduction per kg of live shrunk weight, from 2001 to full implementation.

The effects on the beef market with the implementation of this BMP beyond the level at which it is currently in use is unknown, with some costs that may not be accounted for. Further research is recommended before the usage of RAC with Alberta beef is promoted beyond current levels.

5.5 CBA AND BMP 4.2 – FEWER DAYS ON FEED

The second approach (BMP 4.2) involves management practices to have cattle reach slaughter weight in fewer months, such as 14 months versus 18 months. The BMP involves shortening the backgrounding stage of calf-fed heifers and steers and introducing them to the feedlot growth diets sooner.

With BMP 4.2, there were no animals on this program in the 2001 baseline, and also with none on this program in 2010. As a result, the 2010 baseline for BMP 4.2 is the same as 2001. For modeling purposes, BMP 4.2 assumes that all calf-fed steers and heifers are on this diet, and involves 959,612 cattle in 2010 that are shipped to slaughterhouses accounting for 564,184 tonnes of live shrunk weight. The effect of this BMP is to have calf-fed steers on feed (shipped to market) 3.1 months (95 days) earlier and calf-fed heifers shipped to market 3.8 months (117 days) earlier compared to not introducing this BMP. As stated in Section 5.2.1, it has been suggested to CRA that implementation of this BMP (let alone full implementation) can have significant effects on the beef market.

The CBA **(CBA 1) for the feedlot operation using market values** shows that costs are reduced in the area of barley silage, feed supplements, bedding, fuel, and labour. The total cost savings is $101.4 million (or $47/head [calf-fed and yearling-fed] or $106/affected head [calf-fed only]). The largest cost saving is lower purchases of barley silage as shown in Table 5.12.

Table 5.12: Benefits and Costs of BMP 4.2 with Full Adoption – Market Values

Items	Units	Volume Change	Unit Price ($/unit)	Total Impact ($ million)
Benefits - Input Cost Savings				
Purchased barley silage	kg	-1,835,646,766	$0.04	-$73.43
Purchase of min., trc min., cobalt, protein suppl., antibiotic	kg	-13,398,398	$0.48	-$6.37
Purchase of vitamins	kg	-18,035	$1.37	-$0.02
Purchased bedding	kg	-50,701,602	$0.06	-$2.96
Fuel consumed to feed livestock	L	-22,944,030	$0.75	-$17.17
Fuel consumed to collect manure	L	-184,111	$0.75	-$0.14
Labour (change)	hrs	-80,357	$16.22	-$1.30
Working capital interest	$	0	-	-
Total - Input Cost Savings				**-101.39**
Costs - Higher Input Usage				
Purchased barley	kg	41,564,501	$0.16	$6.71
Total - Higher Input Costs				**$6.71**
Costs - Change in Value of Output				
Manure sold for land application	kg	-750,809,979	$0.00	$0.00
Value change all shipments in May/June	kg	564,184,229	$0.004	$2.31
Reduction in carcass weight in Sept/Nov	kg	19,192,230	$1.91	-$36.67
Meat downgraded from Canada AAA to AA/A	kg	**-8,801,274**	**$0.48**	-4.20
Total - Loss in Meat Value				**-$38.57**

Costs associated with BMP 4.2 include the higher volumes of barley consumed per animal, at approximately 43 kg higher, for a cost increase of $6.7 million. The other cost is the reduction in meat value shipped to the slaughterhouse. This includes the lower carcass weights (collective lower weight of 19.2 million kg)[9] and the lower quality of meat grade (assumed to be passed on back to the feedlot). These costs are somewhat offset by the larger volume of cattle shipped to slaughter in the May/July period, which commands a slight price premium over the fall (September/November) marketing period when these cattle would have been shipped, had it not been for the BMP. Overall the loss in meat value is $38.6 million to the feedlot, or $18/head (calf-fed and yearling-fed) or $40/affected head (calf-fed only).

The incremental costs of $45.3 million compared to the incremental benefits of $101.4 million, provide a net benefit stream of $56.12 million to the feedlot sector. This assumes no loss in revenues in manure sold from the feedlot operation – based on the user taking the manure away without any net debit or credit to the feedlot.

The resulting benefit cost ratio is 2.2:1, suggesting that feedlot operators are financially ahead by employing this BMP in their operations (see Table 5.13). The internal rate of return (IRR) can be imputed to be just over 11 percent. This benefit is based on the above accounting for all of the costs in the beef market associated with this BMP.

Table 5.13: Benefit Cost Ratio for BMP 4.2 at the Feedlot with Full Adoption – Market Values

Total Benefits ($ million)	**$101.39**
Total Costs ($ million)	**$45.28**
Net Benefits [Benefits - Costs] ($ million)	**$56.12**
Ratio of Benefits to Costs	**2.24**

The second CBA **(CBA 2)** retains the feedlot focus and considers the externalities [emissions] associated with feedlot operations. The amount of GHG emissions reductions and their valuation are shown in Table 5.14. GHG emissions are reduced by 795,933 tonnes CO_2e, with the largest reduction coming from fewer emissions due to enteric fermentation.

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[9] The slaughterhouse will incur some loss as well, which is the profit margin due to the lower volume of 19 million fewer kilograms of carcass weight not merchandized.

Table 5.14: Benefit of Emission Reduction at the Feedlot with BMP 4.2 –Full Adoption

Reduction in Feedlot Emissions	Units	Volume Change	Unit Price ($/unit)	Total Impact ($ Million)
Methane emissions from stored manure	kg CO_2e	-13,019,992	$0.02	-$0.26
Enteric fermentation emissions	kg CO_2e	-501,786,346	$0.02	-$10.04
N_2O emissions from stored manure (direct)	kg CO_2e	-25,614,357	$0.02	-$0.51
N_2O emissions from stored manure (indirect)	kg CO_2e	-24,013,460	$0.02	-$0.48
Energy generation and consumption activities	kg CO_2e	-223,336,472	$0.02	-$4.47
O&M activities	kg CO_2e	0	$0.02	$0.00
Feedlot activities	kg CO_2e	-465,645	$0.02	-$0.01
Totals	kg CO_2e	**-788,236,273**	**$0.02**	-$15.76

Assuming that society paid the feedlot operator $20/tonne for a reduction in CO_2e, the benefits realized by the feedlot sector would have increased by $15.8 million. This increases the total benefits to $117.2 million to the feedlot sector with this BMP, and the net benefits to $71.9 million. Table 5.15 indicates the attractive benefit cost ratio of 2.6:1 at the feedlot operator level.

Table 5.15: Benefit Cost Ratio for BMP 4.2 at the Feedlot with Full Adoption – Including Valuation of Reduced GHG at the Feedlot

Total Benefits ($ million)	**$117.16**
Total Costs ($ million)	**$45.28**
Net Benefits [Benefits - Costs] ($ million)	**$71.88**
Ratio of Benefits to Costs	**2.59**

The third CBA **(CBA 3)** goes a step further than CBA 2 and considers any upstream changes in emissions. This include the lower emissions associated with less cropland needed to support the beef sector (based on fewer days that cattle are on feed), such as the change in soil N_2O emissions from cropping and land use, the change in P_2O_5 runoff from cultivating; and soil carbon impacts. These are shown in Table 5.16, with a total volume of CO_2e reduction at 65,431 tonnes, which has a total value of value of $1.3 million based on a $20/tonne valuation.

Table 5.16: Benefits of System Wide Emission Reduction with BMP 4.2 – Full Adoption

Reduction in Other Emissions	Units	Volume Change	Unit Price ($/unit)	Total Impact ($ Million)
N_2O emissions from cropping and land use	kg CO_2e	-49,751,405	$0.02	-$1.00
Total P emissions from run-off	kg PO_4-eq	-220,677	-	$0.00
Soil carbon change in soil from land use	kg CO_2e	13,786,976	$0.02	$0.28
Direct CO_2 emissions from managed soils	kg CO_2e	1,712,760	$0.02	$0.03
Forage and cereal sub-activities	kg CO_2e	-239,447	$0.02	$0.00
Cereal activities	kg CO_2e	3,132,711	$0.02	$0.06
Forage activities	kg CO_2e	-27,369,931	$0.02	-$0.55
Feedlot activities	kg CO_2e	-6,702,746	$0.02	-$0.13
Total	kg CO_2e	**-65,431,081**	**$0.02**	**-$1.31**

These incremental GHG reduction benefits generated upstream from the feedlot and at the feedlots result in a total GHG reduction volume of 853,667 million tonnes CO_2e, which can have an annual value of $17.1 million to society. This is a GHG emissions reduction of 0.41 kg CO_2e /kg of live shrunk weight for the entire beef system, or 1.51 kg CO_2e /kg of live shrunk weight for the calf-fed animals assumed to be on this program.

Adding together the feedlot sector benefits, with those accruing to society, the net benefits are $73.2 million per annum as shown in Table 5.17, with $56.1 million accruing to feedlot operators through the marketplace (see also Table 5.13).

Table 5.17: System Wide Benefit Cost Ratio for BMP 4.2 – Full Adoption

Total Benefits ($ million)	**$118.47**
Total Costs ($ million)	**$45.28**
Net Benefits [Benefits - Costs] ($ million)	**$73.19**
Ratio of Benefits to Costs	**2.62**

The effects on the market with the implementation of this BMP, as suggested to CRA, may incur other costs that have not been considered. For example, issues such as sufficient chilling and storage capacity at the slaughterhouse may require additional capital costs for this BMP if there is a significant change in slaughter age and the associated distribution of when (the months) that fed cattle are shipped to the slaughterhouse. There may also be effects on marketing Alberta beef with the implementation of this BMP. Further research is recommended before the early introduction of high concentrates diet and reduction of age to slaughter with Alberta beef is promoted.

6.0 CBA OF BMP 5 – USE OF BEEF ANIMALS POSSESSING SUPERIOR RESIDUAL FEED INTAKE GENETICS

BMP 5 is the "use of breeding animals that possess superior residual feed intake (RFI) genetics".

6.1 DESCRIPTION OF BMP 5 – USE OF BEEF ANIMALS POSSESSING SUPERIOR RESIDUAL FEED INTAKE GENETICS

The intent of this BMP is to select beef breeding bulls through RFI testing and placing this genetic potential into the cow/calf sector such that feed consumption and feed requirements will be reduced in both the cow/calf and feedlot sectors. By extension, with lower feed intake, GHG emissions should be lower through enteric fermentation as well as through the cropping activities that support feed production.

The operating assumptions include:

- Superior genetics, once identified, are dispersed into the Alberta beef herd through individual bulls used on a cow/calf operation, in which all breeding bulls are assumed to be purchased from seedstock breeders. Using the 2001 Canadian census data, there were approximately 19 calves born per bull that year. This assumption will be used throughout this BMP.
- There is no use of artificial insemination (AI) to disperse the genetics more rapidly through the beef herd, as this is not the most prevalent breeding method used today in Alberta.
- A percentage of males and females born on the cow/calf operation, which are offspring of the low RFI sire, are retained as breeding bulls and replacement heifers for use in the herd and/or sale to other cow/calf operations.
- All pasture is part of the cow/calf operation, with hay purchased from third parties.
- All feed used on the feedlot is purchased by the feedlot.
- Traceability programs are in place allowing for easy identification of feeder calves with low RFI genetics.
- Feeder calves sold to feedlots, which possess the low RFI gene, may receive a price premium based on the proven superior feed conversion. This premium is assumed to be a function (e.g., 50 percent) of the saved feed costs (currently there is no premium in Alberta for low RFI calves)
- Days to market are not affected, with the major impact being reduced DMI.

- Feed (pasture, hay, supplements) consumption by the cow/calf sector decreases.
- Feed (barley, barley silage, supplements) consumption in the feedlot sector decreases.
- Methane produced from enteric fermentation and manure generation decreases, and nitrous oxide (both direct and indirect) emissions from manure decrease.
- The Alberta wide impacts of this BMP are time dependent, based on how quickly the superior RFI genetics are dispersed into the beef herd. As indicated in the Interim Report, current practices with regards to RFI testing in Alberta are understood to the extent that this BMP could be modelled for at least each individual calf crop. The actual gradual uptake in the RFI gene across Alberta would need to be modeled based on an advanced statistical analysis; such studies have been completed in the literature. This trait has been proven in the literature to be moderately heritable and is anticipated to have an exponential increase in RFI uptake for Alberta.
- Potential breeding bulls are tested post weaning around 8 months of age. It has been assumed that after testing (3 months in length), they will participate in the breeding period for that same year, producing progeny the following year. Impact is shown as soon as the bulls are tested as their DMI is lower than anticipated. The first realizable impact would occur in the following year when feeder calves with low RFI genetics are placed in feedlots or kept as replacement heifers or bulls. Testing has been conducted in Alberta since 2000. The starting year for the low RFI testing draft protocol in Alberta uses 2002 as the baseline year. Therefore, the model has included tested animals and offspring since 2002. The 2010 baseline year has been modelled to provide additional comparison with 2001 for future years.
- There are no significant changes in labour requirements (reduction in feed from 2002 to 2010 less than 1 percent).
- There are no capital expenditures associated with this BMP, besides the cost for RFI testing.

With this BMP there are direct impacts in both the cow/calf sector and in the feedlot sector. The direct impacts in the cow/calf sector include:

- Outputs:
  - No change in the annual volume of feeder calves supplied by the cow/calf sector to the feedlot or backgrounding sector
  - A change in the quality of feeder calves supplied to the feedlot or backgrounding sector (improved DMI with feeder calves having the low RFI genetics)
  - Higher prices received for feeder calves with low RFI genes

  - Lower DMI of affected feeder calves, cows and bulls with low RFI genes
  - Less methane produced by cows and bulls with low RFI genes through enteric fermentation and manure, and less nitrous oxide emissions from manure
- Inputs:
  - Lower alfalfa/grass hay purchased due to lower DMI requirements of animals with low RFI genes
  - Lower pasture requirements
  - Potentially higher prices paid by cow/calf operations for bulls with low RFI genes

The direct impacts in the feedlot sector include:

- Outputs:
  - No change in the annual volume of finished cattle supplied to slaughter plants
  - Less methane produced by feeder cattle possessing the superior RFI genes and emissions from manure generated
  - Less manure produced and nitrous oxide and methane emissions due to lower feed intake
- Inputs:
  - Potentially higher price paid for feeder cattle possessing the superior RFI genes
  - Less feed required by feeder cattle possessing the superior RFI genes

In addition to these direct impacts, there are indirect impacts based on linkages. These can include lower emissions associated with lower cropping and land use requirements for alfalfa/grass hay, barley and barley silage production.

Cost benefit analyses will be conducted with a primary focus on both the cow/calf and the feedlot sector.

Based on a discussion with an RFI testing professional in Alberta, it was noted that the amount of RFI testing conducted may be decreasing with time, rather than increasing as the economics have not been beneficial and interest has decreased. However, with financial incentives and with the approval of the draft Alberta protocol for this BMP, interest may begin to rise again and RFI testing may increase in the future.

6.2 BMP 5 – MODELLING LCA AND IMPACT

This BMP consists of testing potential breeding bulls for RFI with the intent to introduce bulls with low RFI into the breeding program to propagate these genes throughout the Alberta beef production system.

Australia is the most advanced country in the selection of breeding animals based on superior residual feed intake genetics and most of the available literature on this topic stems from work conducted in Australia. Research has also been conducted in Alberta over the last 10 years , but limited literature has been produced from this work.

The Technical Protocol Plan (TPP) for Selection for residual feed intake in beef cattle quantification protocol (proposed quantification protocol for the Alberta Offset System), as provided to CRA by ARD, acknowledges that there is a reduction in emissions from calves, cows and bulls with the selection of breeding animals based on low RFI. Carbon credits are available for animals with low RFI Estimated Breeding Values (EBVs), but only for their first generation progeny. Testing is currently being conducted at seven testing facilities in Alberta, mostly on post-weaning calves 8 to 13 months of age. According to the protocol, percent reduction in DMI is applied to cattle with low RFI values for cattle groupings of similar weight and ration for the year of interest.

The Draft Alberta Environment protocol entitled Selection for Residual Feed Intake in Beef Cattle Quantification Protocol (September 2009, draft Version 2.0) was also provided to CRA by ARD. According to this draft protocol, EBVs are to be set to zero for all animals born in the year of interest or earlier in order to track the EBVs over several years. Animals are tested at or after 240 days old. There is a 21-day pre-conditioning period where the animals are given time to adapt to the facility and the diet, followed by a 70 day test period. Using the range of 8 to 13 months of age for testing animals in Alberta, it has been assumed that the testing phase will be completed after the backgrounding stage for calf-fed cattle (7 to 10 months of age) and after the backgrounding feedlot stage for yearling-fed cattle (7 to 11 months of age).

6.2.1 CHANGES TO THE PHASE 1 BASELINE LCA MODEL

As directed by ARD, the seven existing genetics testing facilities in Alberta will be used for this BMP implementation. No new construction is anticipated to occur. The capacity of the commercial facilities (four commercial facilities in total; three facilities are research-based) has been used as the maximum capacity for commercial RFI testing in Alberta, as per the Science Discussion Paper by Paul Arthur (Arthur, N.D.). The number of cattle tested from 2000 to 2008 was also outlined in the Science Discussion Paper, so a yearly average with a slight increase in total cattle tested per year was assumed for these years. Estimates for the total number of cattle tested in 2009 and 2010 were calculated based on the 2000 to 2008 data. For 2011 and on, it was assumed that the maximum capacity of the commercial testing facilities is being utilized for RFI testing.

As approximately 80 to 90 percent of the genetic improvement in a herd comes through the sires, it is expected that only potential breeding bulls will be tested in Alberta to maximize the impact on the beef herd. The progeny of low RFI bulls may have superior genetics for feed efficiency based on heritability. This will result in a feed savings for calves in the feedlot and for replacement heifers and bulls (Agri-Facts, July 2006).

It is noted here that the benefit of this BMP is limited by the capacity of the testing facilities, and therefore, superior genetics uptake from breeding animals with low RFI could in fact have a larger impact in Alberta if somehow RFI testing is maximized to contribute the most impact to the beef breeding system.

As RFI testing has been conducted in Alberta since 2000, the LCA model has been configured in such a way that any year between 2000 and 2030 could be modelled to account for the life span of low RFI cattle.

The total number of bulls tested for each year has been inserted into the model. From there, the number of bulls tested with low RFI genes is calculated. The total number of bulls in the beef system with low RFI genes is the sum of the bulls tested with low RFI genes for the previous 4 years, assuming a bull culling rate of 4 years. This allows for a reduction in DMI for all bulls in the system for that year with low RFI genes to be accounted for. An RFI EBV is then assigned to the low RFI bulls, and a percent reduction in DMI is calculated. Reduction in DMI is assumed for all 4 years the bulls are in the beef system. The maximum RFI EBV has been used in the model to maximize the impact of this BMP on the beef system.

Calves born from these low RFI bulls for all 4 years are estimated based on the 19 calves per bull in the Phase 1 2001 baseline model. A heritability factor that has been assigned to the model is then used to calculate the number of these calves that are born with the low RFI genes. The heritability of the low RFI genetics ranges from 16 to 39 percent in the literature for the cattle breeds that have been tested to date (Notter, David R., ND; Arthur et al., 2008). The maximum heritability factor was assumed for the model as the impact of this BMP using a heritability factor of 39 percent is minimal. This is attributed to the confined testing capacity in Alberta. The calves deemed to carry the low RFI gene are then assigned an RFI value equal to the average or the mean of the parents. As the

RFI is not known for the dam, zero was assumed. Percent reduction in DMI is then calculated for these calves.

Using the replacement percentages from the 2001 baseline for heifers and bulls, a percentage of the calves with low RFI genes are assumed to be replacement heifers and bulls. These replacement cattle remain in the model for 4 breeding years; however, the progeny of these cattle are not assumed to carry the low RFI genes as they have not been tested and do not have a certified EBV, as per Alberta's draft protocol.

Cattle are then categorized as calf-fed steers or heifers, or yearling-fed steers or heifers based on 2001 ratios between these categories. The reduction in DMI is carried throughout the entire life of these calves to the end of the feedlot. Actual intake on pasture is difficult to quantify and therefore, any benefits associated with the reduction in pasture intake from low RFI cows and calves has not been captured in the model.

Due to the fact that the dams are never tested in the model and are not provided with certified EBVs, and the fact that the protocol states that only the first progeny of low RFI breeding bulls qualify for emissions reductions, the uptake of this gene is difficult to track over time. A genetics modelling software package may be able to provide information on the uptake of this gene.

Total feed requirements for the entire beef system were adjusted in the model to reflect the reduction in DMI for bulls, cows, backgrounders, and feeders. The feedlot diets were used for the testing period for both the calf-fed and yearling-fed calves, and the diets that will be offset from the time spent testing have been adjusted appropriately.

The reduced DMI for cattle in the cow/calf sector and the feedlot sector affects all cereal and forage activities, enteric fermentation emissions, methane emissions from manure, N_2O emissions from manure, etc. The reduction in the amount of feed also reduces the amount of garbage (plastics) used for the feed; however, as the amount of feed to be reduced is less than 1 percent of the total feed, a reduction in plastics was considered negligible and was not calculated.

The amount of manure generated was reduced according to the percent reduction in DMI for each category of cattle. Enteric fermentation emissions and methane and nitrous oxide emissions from manure were updated to reflect the change in DMI.

The diesel requirements to feed cattle and collect manure have been adjusted based on the reduction in feed required and manure generated. The change in labour was assumed to be negligible due to such a small reduction in DMI and was not included in the analysis.

Transportation was included for weaned steers from the calf-fed and yearling-fed systems to and from the RFI testing facilities, assuming 200 km one-way.

Review of literature shows that it is possible to select low RFI animals to be used for breeding animals with no effect on the final weight or quality of the meat at slaughter and this will be used as the assumption for modeling; however, future scientific research is required to validate this assumption.

The impacts of BMP 5 implementation have been analyzed for the 2010 baseline and for the 2029-2030 calf crop for comparison. Although testing was initiated in Alberta in 2000, any testing conducted before 2002 is not included in the protocol guidelines, and therefore, it was assumed that this BMP was not implemented in the 2001 baseline.

6.3 BMP 5 – RESULTS OF GHG EMISSIONS AND OTHER IMPACTS

The impacts on the four environmental impact categories (GHG, acidification, eutrophication, and non-renewable resources) were modelled for the entire Alberta beef production system to reflect the changes to the model with the implementation of the BMP. The graphs in this section show the total impact of each category from the entire system for each year from 2001 to 2029, and show the trending difference in these impacts over this time based on the assumptions outlined in Section 6.2.1 above. The year 2029 was assumed as the last analytical year so the results of this BMP can be compared to the results of the other four BMPs with a 20-year life.

The following graph shows the total GHG emissions per year.

Figure 6.1: BMP 5 - GHG Emissions from 2001 to 2029

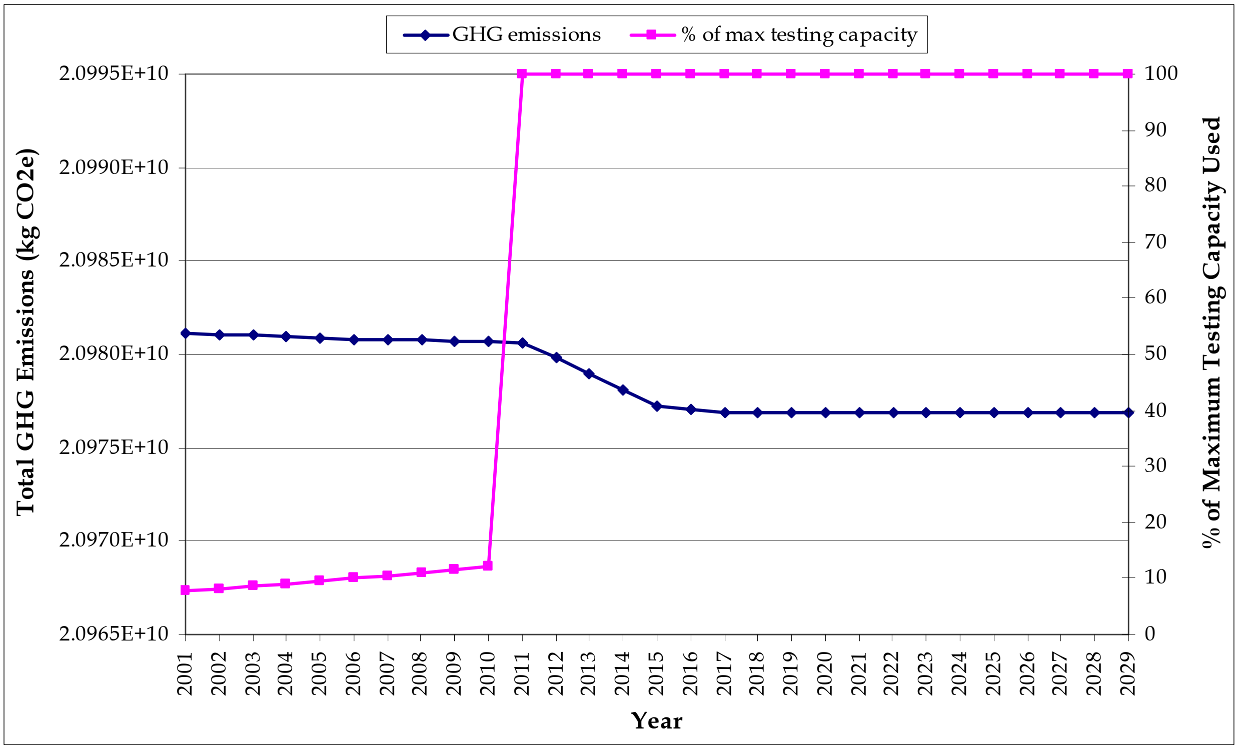


Table 6.1 illustrates the major components of the model where the changes in GHG emissions are occurring over time from 2001 to 2010 to 2029.

The change in GHG emissions from 2001 to 2010 to 2029 (in kg CO_2e/kg shrunk live weight) are shown in Table 6.1 and below:

- From 2001 to 2010 0.002% reduction
  - 8% (2001) to 12% (2010) of maximum testing facilities used
- From 2010 to 2029 0.02% reduction
  - 12% (2010) to 100% (2029) of maximum testing facilities used. 100% assumed to be used in 2011 and all years thereafter

The main sources that contributed approximately 98 percent of the GHG emissions reductions occur from the following components:

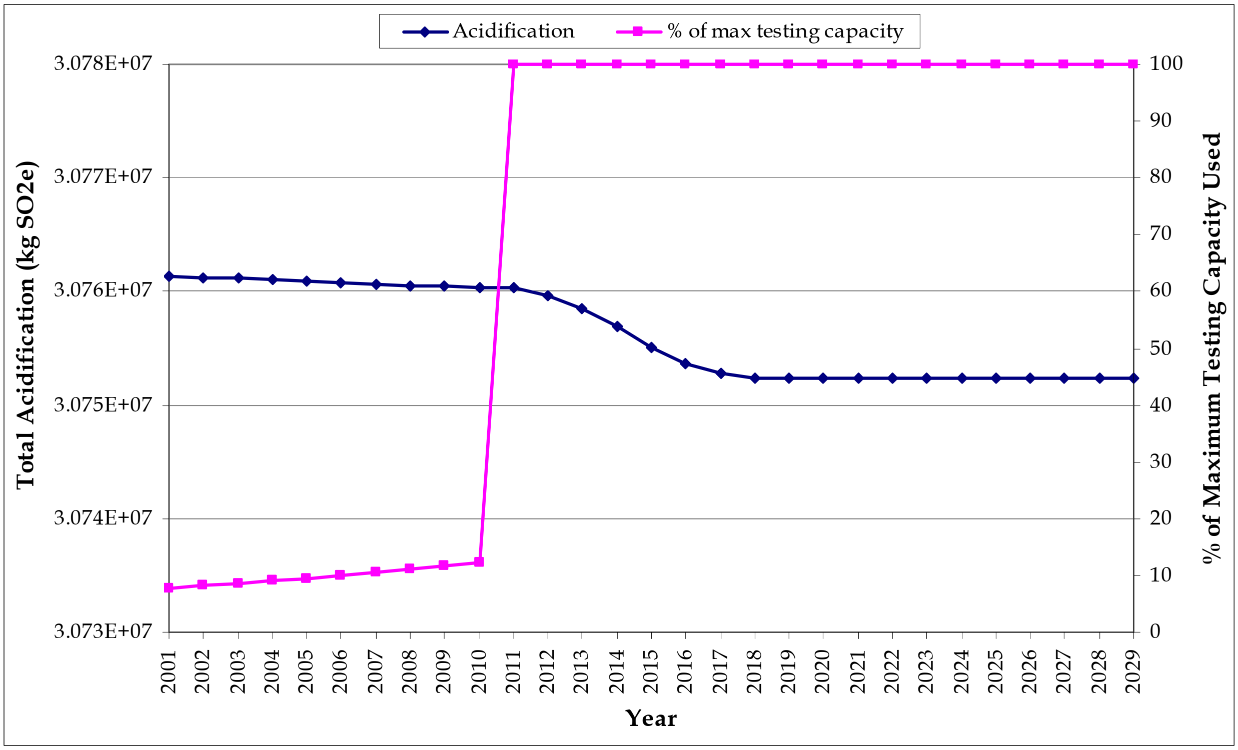
- Energy generation and usage activities (produce crude, transport crude, refine crude into diesel, transport diesel, combust diesel – all from the fuel savings of feeding cattle and collecting manure)

- Feedlot and pasture activities (reduction in emissions from disposal of manure off-site from feedlots due to the decrease in manure production, and the reduction in processing grains [mix feed], mineral production and transportation, transport millrun carrier, transport vitamin – all aspects of reducing DMI)
- Enteric fermentation emissions (more than 70 percent of the emissions reductions, due to reduced DMI)
- Methane emissions from manure (due to reduced manure production)
- Nitrous oxide emissions from manure and cropping activities (70 percent reduction in nitrous oxide emissions is from manure, and 30 percent from cropping activities)

There was a slight increase in emissions due to the additional transportation of the calf-fed and yearling-fed calves to the testing facilities, but these emissions were minor in comparison to the emissions reductions. There was also a slight decrease in soil sequestration due to the reduction of feed required.

The following graph shows the total acidification impact for each year. The main elements that resulted in reductions to the acidification impact were all the forage and cereal activities, diesel generation and combustion for reduced feeding and manure collection, disposal of manure off site from feedlots, and all activities associated with minerals, millrun carrier, and vitamins. There was a slight increase in acidification impact due to the additional transportation for testing; however, this is a very minor increase.

Figure 6.2: BMP 5 – Acidification from 2001 to 2029

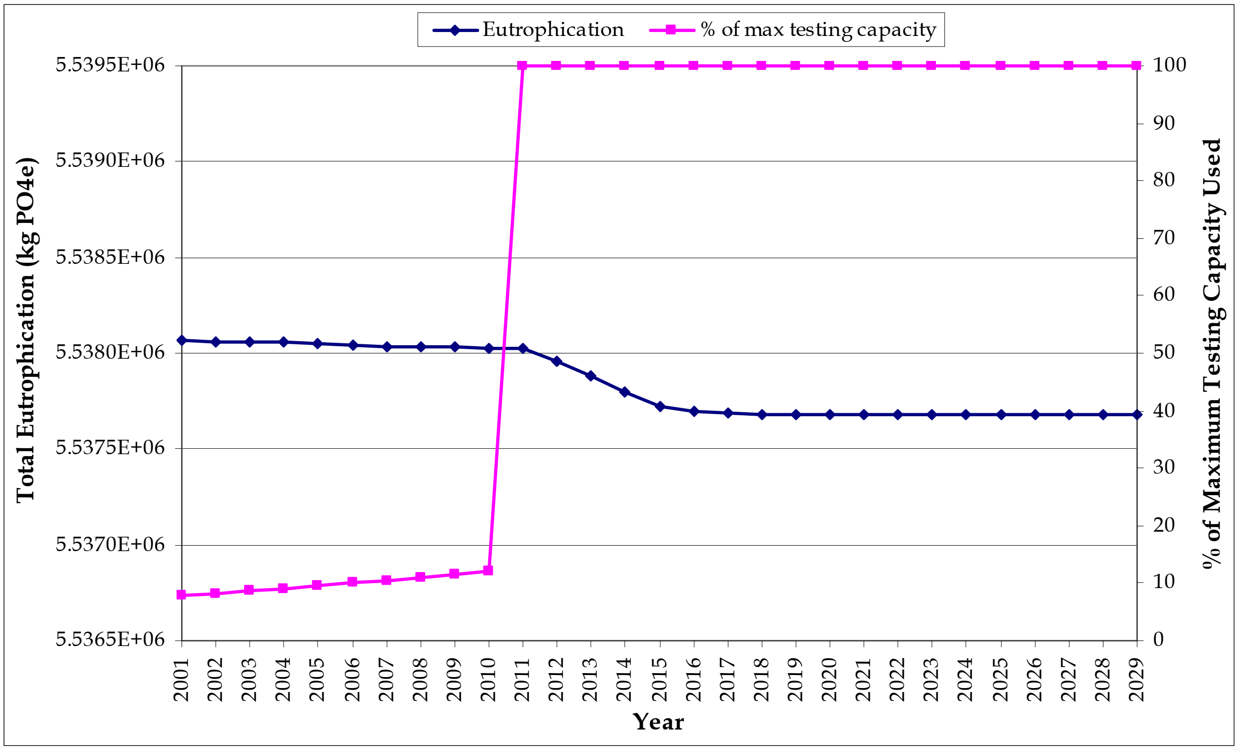


The change in acidification impacts from 2001 to 2010 to 2029 (in kg SO_2e/kg shrunk live weight) are shown below:

- From 2001 to 2010 0.003% reduction
- From 2010 to 2029 0.03% reduction

The following graph shows the total eutrophication impact for each year. The main elements that resulted in reductions to the eutrophication impact were diesel generation and combustion for reduced feeding and manure collection, disposal of manure off site from feedlots, all activities associated with minerals, millrun carrier, and vitamins, and the reduction in phosphorous emissions from run-off. There was a slight increase in eutrophication impact due to the additional transportation for testing; however this is a very minor increase.

Figure 6.3: BMP 5 – Eutrophication from 2001 to 2029

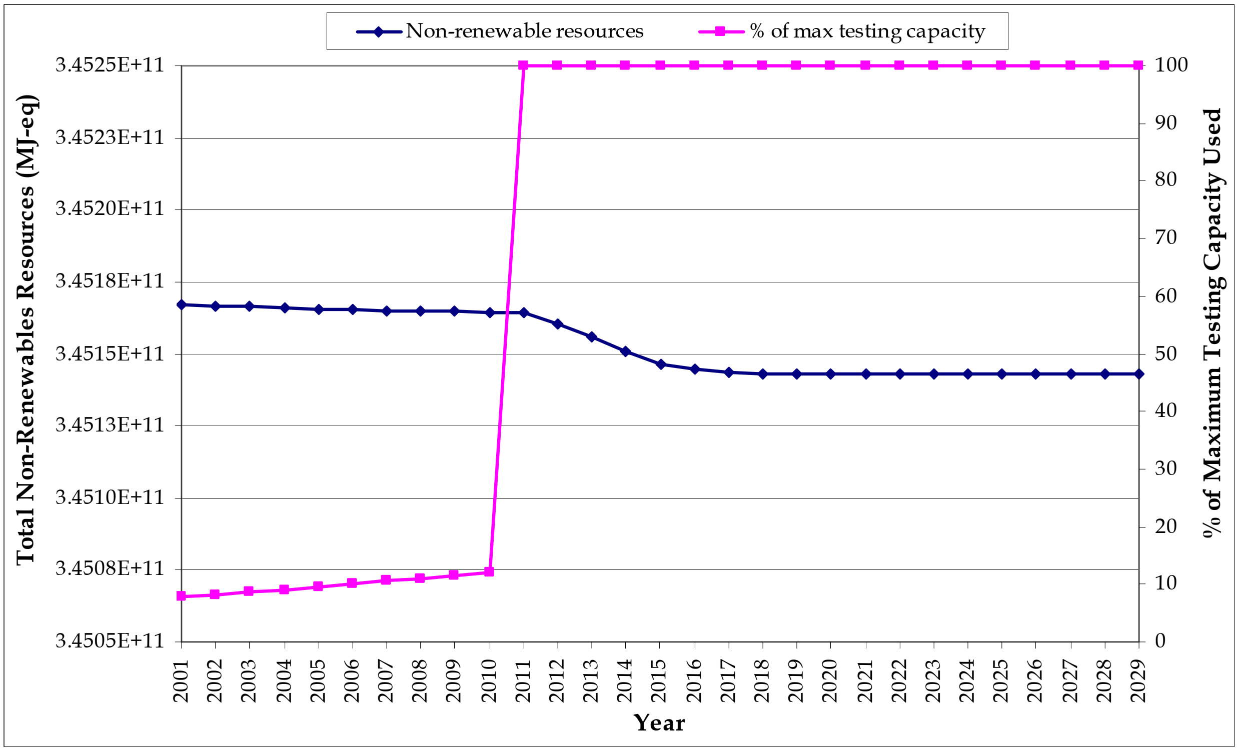


The change in eutrophication impacts from 2001 to 2010 to 2029 (in kg PO_4e/kg shrunk live weight) are shown below:

- From 2001 to 2010 0.001% reduction
- From 2010 to 2029 0.006% reduction

The following graph shows the total non-renewable resources impact for each year. The main elements that resulted in reductions to the non-renewable resources impact were diesel generation and combustion for reduced feeding and manure collection, disposal of manure off site from feedlots, all activities associated with minerals, millrun carrier, and vitamins. There was a slight increase in non-renewable resources impact due to the additional transportation for testing; however this is a very minor increase.

Figure 6.4: BMP 5 – Non-Renewable Resources from 2001 to 2029



The change in total non-renewable resources impacts from 2001 to 2010 to 2029 (in MJ-eq/kg shrunk live weight) are shown below:

- From 2001 to 2010 0.001% reduction
- From 2010 to 2029 0.006% reduction

6.4 CBA AND BMP 5 – USE OF BEEF ANIMALS POSSESSING SUPERIOR RESIDUAL FEED INTAKE GENETICS IN 2029 – 2030

With this BMP the number of calves exhibiting low FRI traits increases each year based on the increasing sire (bull) population that can pass on the low RFI trait. In year 2029, 1,498 bulls are assumed tested for the low RFI trait (maximum capacity of existing testing facilities), with 187 testing positively for the RFI trait. Based on the build-up of positively tested bulls from prior years (for 4 years total), there are a total of 749 bulls in the breeding population for the year 2029 with low RFI characteristics. This is estimated to generate a population of 5,550 calves exhibiting this trait, which is 39 percent of all calves born from the low RFI bulls, and 0.26 percent of all calves born that year.

The CBA analysis is conducted for year 2029 at the cow/calf sector and the impacts in the feedlot are captured based on a 2030 time frame. The overall benefits and costs increase each year by a scalar factor based on the number of bulls with the RFI trait in the breeding herd.

Benefits and Costs in the Cow Calf Sector

The benefits at the cow/calf operation of this BMP are the reduced costs of alfalfa/grass hay and feed supplements as shown in the top portion of Table 6.2, plus the lower amount of fuel needed to feed the cattle (**CBA 1**). These benefits add up to $207,000, and are just under $38/calf with the low RFI trait. These benefits are incremental to the number of bulls and associated offspring that exhibited the RFI trait in 2010.

An assumed secondary benefit is the marginally higher value of the low RFI calf sold to feedlot operations. Currently no premium is being paid for low RFI calves sold to the feedlot in Alberta. This value capture has been modeled based on the cow/calf operation obtaining almost 50 percent of the estimated savings in feed costs in the feedlot, which is rounded to $12/head low RFI calf sold. This assumption requires the cow/calf operator to have each low RFI calf readily identifiable.

Table 6.2: Benefits and Costs of BMP 5 at the Cow/Calf Operation in 2029 – Market Values

Items	**Units**	**Volume Change**	**Unit Price ($/unit)**	**Total Impact ($ million)**
Benefits - Input Cost Savings				
Purchased hay	kg	-529,808	$0.14	-$0.07
Purchase of min., trc min., cobalt, protein suppl., antibiotic	kg	-275,735	$0.48	-$0.13
Purchase of vitamins	kg	-8.2	$1.37	$0.00001
Fuel used to feed livestock	L	-4,685	$0.75	$0.004
Total - Input Cost Savings				**-$0.207**
Benefits - Higher Value of Outputs				
Higher value of low RFI calves sold	head	5,550	$12.00	$0.07
Total - Higher Value of Outputs				**$0.067**
Costs - Higher Input Usage and Prices				
Purchase of RFI testing	tests	1,316	$91.00	$0.12
Purchased bull premium	head	164	$0.00	$0.00
Fuel consumed to transport livestock for testing	L	2,103	$0.75	$0.00
Total - Higher Operating Costs				**$0.12**

The costs to the cow/calf operator include the RFI testing costs and the extra fuel required to transport bulls to testing stations for testing. Since there are no reported premiums being paid for low RFI bulls in Alberta at this time, and since it is assumed that the young potential breeding bulls sent for testing originate from within the owner's beef herd, no incremental cost has been used for purchasing potentially lower RFI bulls. Similarly no value is provided for potential sales of bulls testing with low RFI. The annual costs are $120,000 across the 187 bulls.

This BMP has a net annual benefit of $150,000 as indicated in Table 6.3, with the BCR of 2.3:1, indicating that annual benefits in 2029 are two times larger than the costs.

Table 6.3: Benefit Cost Ratio at the Cow/Calf Operation in 2029 – Market Values

Total Annual Benefits ($ million)	**$0.27**
Total Annual Costs ($ million)	**$0.12**
Net Annual Benefits [Benefits - Costs] ($ million)	**$0.15**
Ratio of Annual Benefits to Annual Costs	**2.26**

The second CBA **(CBA 2)** retains the cow/calf focus and considers the impact on emissions. The reduction in GHG emissions due to this BMP is illustrated in Table 6.4. This BMP reduces GHG emissions in the cow/calf sector by 627 tonnes CO_2e, which provides an annual benefit of $13,000, based on valuing the reduction at $20/tonne of CO_2e.

Table 6.4: Benefit of Emissions Reductions at the Cow/Calf Operation in 2029 - BMP 5

Reduction in Cow/Calf GHG Emissions	**Units**	**Volume Change**	**Unit Price ($/unit)**	**Total Impact ($ million)**
Methane emissions from stored manure	kg CO_2e	-8,249	$0.02	-$0.0002
Enteric fermentation emissions	kg CO_2e	-389,200	$0.02	-$0.008
N_2O emissions from stored manure (direct)	kg CO_2e	-108,316	$0.02	-$0.002
N_2O emissions from stored manure (indirect)	kg CO_2e	-23,976	$0.02	-$0.0005
Energy generation and consumption activities	kg CO_2e	-94,155	$0.02	-$0.002
Feedlot and pasture activities	kg CO_2e	-3,389	$0.02	-$0.0001
Total - On-going	kg CO_2e	**-627,285**	**$0.02**	**-$0.013**

Assuming that the cow/calf sector receives a $20/tonne value for this reduction, the annual benefits increase to $0.29 million, and the BCR increases to 2.4:1 (as shown in Table 6.5) compared to the value shown in Table 6.3.

Table 6.5: Benefit Cost Ratio at the Cow/Calf Operations for BMP 5 in 2029

Total Annual Benefits ($ million)	**$0.29**
Total Annual Costs ($ million)	**$0.12**
Net Annual Benefits [Benefits - Costs] ($ million)	**$0.17**
Ratio of Annual Benefits to Annual Costs	**2.36**

Benefits and Costs in the Feedlot Sector

This BMP also provides direct benefits to the feedlot through improved feed conversion efficiency. Table 6.6 summarizes the direct costs and benefits that accrue to feedlot operators that purchase these low RFI calves for feeding (an assumption has been made for a premium for these calves). The low RFI calves generate a $26/head costs savings, with the aggregate value of $150,000. The largest savings to the feedlot is the modeled savings in feed.

The cost to the feedlot is the estimated higher price paid for low RFI (identifiable) animals. At an extra $12/head, this is an extra $60,000 per annum.

Table 6.6: Benefits and Costs of BMP 5 at the Feedlot in 2029 – Market Values

Items	**Units**	**Volume Change**	**Unit Price ($/unit)**	**Total Impact ($ million)**
Benefits - Input Cost Savings				
Purchase of barley	kg	-283,991	$0.16	-$0.05
Purchase of barley silage	kg	-2,081,774	$0.04	-$0.08
Purchase of min., trc min., cobalt, protein suppl., antibiotic	kg	-21,311.4	$0.48	-$0.01
Purchase of vitamins	kg	-27.5	$1.37	$0.00004
Fuel consumed to feed livestock (change)	L	-8,575.2	$0.75	-$0.006
Fuel consumed to collect manure (change)	L	-96.8	$0.75	$0.0001
Total - Input Cost Savings				**-$0.15**
Costs - Higher Input Costs				
Purchase of low RFI calves premium	head	4,952	$12.00	$0.06
Total - Higher Operating Costs				**$0.06**

The net benefits are $90,000 as shown in Table 6.7, with a benefit cost ratio of 2.5:1, indicating that the feedlot is a beneficiary of low RFI calves.

Table 6.7: Benefit Cost Ratio at the Feedlot in 2030 – Market Values

Total Annual Benefits ($ million)	**$0.15**
Total Annual Costs ($ million)	**$0.06**
Net Annual Benefits [Benefits - Costs] ($ million)	**$0.09**
Ratio of Annual Benefits to Annual Costs	**2.45**

The impact of this BMP on emissions generated at the feedlot is highlighted in Table 6.8, with the reduced emissions related to lower feed intake by the low RFI animals. The amount of GHG emissions is reduced by 2,484 tonnes of CO_2e, which increases benefits by $100,000 per annum (when valued at $20/tonne) at the feedlot.

Table 6.8: Benefit of Emissions Reductions at the Feedlot in 2030 – Market Values

Reduction in Feedlot Emissions	Units	Volume Change	Unit Price ($/unit)	Total Impact ($ million)
Methane emissions from stored manure	kg CO_2e	-111,677	$0.02	$0.002
Enteric fermentation emissions	kg CO_2e	-2,297,311	$0.02	-$0.05
N_2O emissions from stored manure (direct)	kg CO_2e	-20,614	$0.02	$0.0004
N_2O emissions from stored manure (indirect)	kg CO_2e	-19,325	$0.02	$0.0004
Energy generation and consumption activities	kg CO_2e	-34,827	$0.02	$0.001
Feedlot activities	kg CO_2e	-11,731	$0.02	$0.0002
Yearling-fed system activities (transportation)	kg CO_2e	6,954	$0.02	-$0.05
Calf-fed system activities (transportation)	kg CO_2e	4,410	$0.02	$0.0001
Total - One-time	kg CO_2e	**-2,484,121**	**$0.02**	**-$0.10**

If feedlot operators were compensated for reduced GHG emissions as illustrated in Table 6.8, then the net benefits increase to $190,000 and the BCR increases to 4.13. This suggests that feedlot operators would have reasonable incentive to source low RFI calves.

Table 6.9: Benefit Cost Ratio at the Feedlot for BMP 5 in 2030

Total Annual Benefits ($ million)	**$0.25**
Total Annual Costs ($ million)	**$0.06**
Net Annual Benefits [Benefits - Costs] ($ million)	**$0.19**
Ratio of Annual Benefits to Annual Costs	**4.13**

Benefits and Costs in the Beef Supply Chain

With both cow/calf operations and the feedlot sector benefiting from low RFI animals, the benefits can be combined for the two sectors, when adjusting for a cow/calf sector benefit that is a feedlot cost (such as the higher price paid for low RFI calves). The supply chain marketplace benefits are valued at $0.35 million, while the costs are $0.12 million, resulting in a BCR of 2.9:1 (see Table 6.10). This BCR suggests that the marketplace incentives should be strong enough to support an increase in use of low RFI cattle. Some institutional design may be required, such as promoting the low RFI attributes and ensuring unique identification of low RFI calves throughout the animal's life.

Table 6.10: Benefit Cost Ratio for the Beef Supply Chain for BMP 5 in 2029-2030

Total Annual Benefits ($ million)	**$0.35**
Total Annual Costs ($ million)	**$0.12**
Net Annual Benefits [Benefits - Costs] ($ million)	**$0.23**
Ratio of Annual Benefits to Annual Costs	**2.91**

The reduction in emissions associated with this BMP that are in cropping activities that are not in the feedlot or cow/calf sector is shown in Table 6.11. These reductions are 728 tonnes CO_2e emissions.

Table 6.11: Other Emissions Reductions in 2029 with BMP 5

Reduction in Other Emissions	**Units**	**Volume Change**	**Unit Price ($/unit)**	**Total Impact ($ million)**
N_2O emissions from cropping and land use	kg CO_2e	-73,630	$0.02	$0.001
Total P emissions from run-off	kg PO_4e	-228	-	-
Soil carbon change in soil from land use	kg CO_2e	12,948	$0.02	$0.0003
Direct CO_2 emissions from managed soils	kg CO_2e	-9,634	$0.02	$0.0002
Forage and cereal sub-activities	kg CO_2e	-62,407	$0.02	$0.001
Cereal activities	kg CO_2e	-18,126	$0.02	$0.0004
Forage activities	kg CO_2e	-15,903	$0.02	$0.0003
Feedlot activities	kg CO_2e	-561,316	$0.02	-$0.01
Total	kg CO_2e	**-728,068**	**$0.02**	**$0.015**

System wide benefits in 2029-30 are $0.48 million, with net benefits being $0.36 million, and an attractive BCR of 3.96. These system wide benefits are the addition of the beef supply chain market place benefits along with the attributed value of reduced emissions (as noted in Table 6.4, Table 6.8, and Table 6.11).

Table 6.12: System Wide Benefits and Costs for BMP 5 in 2029-2030

Total Annual Benefits ($ million)	**$0.48**
Total Annual Costs ($ million)	**$0.12**
Net Annual Benefits [Benefits - Costs] ($ million)	**$0.36**
Ratio of Annual Benefits to Annual Costs	**3.96**

This suggests that this BMP provides a financial benefit to the beef supply chain, while reducing overall emissions by 3,839 tonnes of CO_2e, which is a 0.003 kg CO_2e reduction per kg of live shrunk weight in a year (across all cattle) and by 1.29 kg CO_2e per kg live shrunk weight for the low RFI animals shipped for slaughter in 2030.

6.5 CBA AND BMP 5 – USE OF BEEF ANIMALS POSSESSING SUPERIOR RESIDUAL FEED INTAKE GENETICS – INCREASES IN BENEFITS OVER TIME

The discussion in the prior section was based on having this BMP in effect for a number of years, resulting in a build-up of bulls with the trait and consequently the number of calves born with the low RFI trait. With testing for low RFI bulls each year, the total number of bulls with the low RFI genes increase, which allows for an increase in the number of low RFI calves born each year. The above analysis was based on 5,550 calves being born with this characteristic each year. This BMP was partially in place in 2010. The benefits are somewhat less in the first year, due to the smaller sire population dispersing the desired trait to a smaller number of calves.

The following is a comparison of the BCR in 2010 when bull population with demonstrated low RFI trait was 85 (compared to 749 in 2029) and consequently the number of low RFI calves is much smaller at 598 calves.

The BCR at the cow/calf operation is slightly lower at 1.86:1 in 2010, versus 2.26:1 in 2029. This is based on higher costs per low RFI calf cost attributable to RFI testing.

Table 6.13: Benefit Cost Ratio at the Cow/Calf Operation in 2010 and 2029 – Market Values

Item	2010-11	2029-30
Total Annual Benefits ($ million)	$0.03	$0.27
Total Annual Costs ($ million)	$0.02	$0.12
Net Annual Benefits [Benefits - Costs] ($ million)	$0.01	$0.15
Ratio of Annual Benefits to Annual Costs	1.86	2.26

After considering the reduction in GHG emissions at the cow/calf operation, the same relationship holds in Table 6.14 as in the above table, when only market values were considered.

Table 6.14: Benefit Cost Ratio at the Cow/Calf Operation for BMP 5 in 2010 and 2029

Item	2010-11	2029-30
Total Annual Benefits ($ million)	$0.03	$0.29
Total Annual Costs ($ million)	$0.02	$0.12
Net Annual Benefits [Benefits - Costs] ($ million)	$0.02	$0.17
Ratio of Annual Benefits to Annual Costs	1.95	2.36

At the feedlot, the BCR is somewhat higher in 2011 versus in 2030, however the per unit costs and benefits are rather comparable. When the reduced GHG emissions are valued, the BCR is somewhat higher in 2030 versus 2011 as shown in Table 6.16.

Table 6.15: Benefit Cost Ratio at the Feedlot in 2011 and 2030 – Market Values

Item	2010-11	2029-30
Total Annual Benefits ($ million)	$0.02	$0.15
Total Annual Costs ($ million)	$0.01	$0.06
Net Annual Benefits [Benefits - Costs] ($ million)	$0.01	$0.09
Ratio of Annual Benefits to Annual Costs	2.64	2.45

Table 6.16: Benefit Cost Ratio at the Feedlot for BMP 5 in 2011 and 2030

Item	2010-11	2029-30
Total Annual Benefits ($ million)	$0.02	$0.25
Total Annual Costs ($ million)	$0.01	$0.06
Net Annual Benefits [Benefits - Costs] ($ million)	$0.02	$0.19
Ratio of Annual Benefits to Annual Costs	3.48	4.13

When the marketplace benefits and costs are considered for the beef supply chain, the BCR is slightly larger in 2029-30 versus in the 2010-2011 period. The BCR of 2.57:1 in 2010 indicates that RFI testing should be implemented by the beef supply chain, notwithstanding the on-farm environmental benefits.

Table 6.17: Benefit Cost Ratio for the Beef Supply Chain (Cow/Calf and Feedlot) for BMP 5 in 2010-2011 and 2029-2030

Item	2010-11	2029-30
Total Annual Benefits ($ million)	$0.04	$0.35
Total Annual Costs ($ million)	$0.02	$0.12
Net Annual Benefits [Benefits - Costs] ($ million)	$0.03	$0.23
Ratio of Annual Benefits to Annual Costs	2.57	2.91

Overall, the system wide BCR is 3:1 in 2010 indicating a potential positive return to adopting this BMP; however, based on discussions with professionals in this field, this practice is currently not practiced due to economics. This could relate to the need for cow/calf operators to be able to identify all superior RFI calves to be able to capture some of the benefits. It can be noted that with a BCR of 3:1, the internal rate of return (IRR) with a 5 percent social discount rate is approximately 15 percent. At the same time, the GHG emissions reductions are 0.0003 kg CO_2e per kg live shrunk weight in a year (across all cattle) and 1.42 kg CO_2e per kg of live shrunk weight for the low RFI animals shipped for slaughter in 2011.

Table 6.18: System Wide Benefits and Costs for BMP 5 in 2010-2011 and 2029-2030

Item	2010-11	2029-30
Total Annual Benefits ($ million)	$0.05	$0.48
Total Annual Costs ($ million)	$0.02	$0.12
Net Annual Benefits [Benefits - Costs] ($ million)	$0.04	$0.36
Ratio of Annual Benefits to Annual Costs	3.11	3.96

As with most genetic improvements, the effect is expected to plateau over time, meaning that the gene uptake in the beef system will begin to remain constant once a certain amount of time is reached.

7.0 RANKING OF BMPs

The various BMPs modeled had differing economic consequences for operators in the beef supply chain, and they had differing modeled impacts on GHG reductions as summarized by the tonnes of CO_2e. Table 7.1 provides a summary of the impact of these modeled BMPs on the change in GHG emissions (shown as ΔCO_2e) and the corresponding change in kg CO_2e per kg live shrunk weight. The last two columns summarize the net annual market place benefits realized by operators in the beef supply chain, and the benefit cost ratio (BCR) based on using the NPV of incremental marketplace costs and benefits (without placing a value on the reduced GHG emissions).

Table 7.1: Summary of BMP Impact on GHG Emissions and Beef Supply Chain Operators

BMP	Description	ΔCO_2e	ΔCO_2e per kg all beef	ΔCO_2e per kg affected beef	Net Annual Benefits	Market NPV BCR
		tonnes	kg	kg	$ million	ratio
BMP 1.1a	Composting - Windrow on-site clay	962,702	0.675	0.743	($322.35)	0.18
BMP 1.1b	Composting – Windrow off-site clay	974,634	0.683	0.752	($322.35)	0.17
BMP 1.2a	Composting – Loader on-site clay	1,022,630	0.717	0.789	($413.76)	0.16
BMP 1.2b	Composting – Loader off-site clay	1,042,414	0.731	0.804	($413.76)	0.14
BMP 2.1	Swath grazing	**-218,177**	**-0.153**	**-1.673**	**$243.31**	1.94
BMP 2.2	Stockpile grazing	882,725	0.619	0.007	($29.91)	0.79
BMP 3	Ionophores in roughage diets	**-292,611**	**-0.205**	**-2.244**	**$101.53**	2.85
BMP 4.1	Growth promotant - last 28 days	**-59,659**	**-0.042**	**-0.046**	**$12.41**	12.48
BMP 4.2	Fewer days on feed	**-853,667**	**-0.406**	**-1.513**	**$56.12**	2.24
BMP 5	Selection for superior RFI	**-3,839**	**-0.003**	**-1.285**	**$0.23**	2.91

There are some BMPs that have a larger impact on the environment. A ranking of each BMP by their contribution to reducing emissions as measured[10] by the ΔCO_2e is provided in Table 7.2. The BMP with the largest ΔCO_2e impact is BMP 4.2 where cattle are shipped to the slaughter plant by up to 4 fewer months due to being placed on a finishing ration much earlier in their life cycle. The ΔCO_2e/kg live shrunk weight (all beef) is 0.406 kg CO_2e/kg live shrunk weight, which is a 3 percent reduction in GHG emissions. This BMP also has an attractive BCR for the feedlot operator at 2.24:1.

The next most attractive BMP for GHG reduction is ionophores in roughage diets (cattle on cow/calf operation), with a reduction in GHG emissions of 0.205 kg CO2e/kg live shrunk weight (all beef), which is a 1.4 percent reduction in GHG emissions.

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[10] The reduction is based on full adoption of the BMP and is relative to the 2010 baseline, where appropriate. It should be remembered that with some BMPs, such as BMP 5 (selecting for superior RFI), the entire beef herd is not affected by this BMP.

Table 7.2 provides the rankings of BMPs based on change in emissions for all shrunk live weight, as well as the effect of each BMP based on the change in emissions per kg affected live shrunk weight (third column in the table). This allows for a better understanding of the effect of each BMP as it relates to the affected beef in the BMP as some BMPs do not affect the entire beef herd. For example, while BMP 3 (ionophores for cattle on cow/calf operation) had the largest impact per kg of cattle directly related to slaughter (of cows and bulls), BMP 4.1 (fewer days on feed) has a larger impact across all beef slaughtered in the province.

The analysis indicates that the first five BMPs listed in Table 7.2 should be adopted if the industry wants to decrease GHG emissions.

Table 7.2: Ranking of BMPs Based on GHG Reduction

BMP	**Description**	**ΔCO_2e**	**ΔCO_2e per kg all beef**	**ΔCO_2e per kg affected beef**	**Net Annual Benefits**	**Market NPV BCR**
		tonnes	**kg**	**kg**	**$ million**	**ratio**
BMP 4.2	Fewer days on feed	**-853,667**	**-0.406**	**-1.513**	**$56.12**	2.24
BMP 3	Ionophores in roughage diets	**-292,611**	**-0.205**	**-2.244**	**$101.53**	2.85
BMP 2.1	Swath grazing	**-218,177**	**-0.153**	**-1.673**	**$243.31**	1.94
BMP 4.1	Growth promotant - last 28 days	**-59,659**	**-0.042**	**-0.046**	**$12.41**	12.48
BMP 5	Selection for superior RFI	**-3,839**	**-0.003**	**-1.285**	**$0.23**	2.91
BMP 2.2	Stockpile grazing	882,725	0.619	0.007	**($29.91)**	0.79
BMP 1.1a	Composting - Windrow on-site clay	962,702	0.675	0.743	**($322.35)**	0.18
BMP 1.1b	Composting – Windrow off-site clay	974,634	0.683	0.752	**($322.35)**	0.17
BMP 1.2a	Composting – Loader on-site clay	1,022,630	0.717	0.789	**($413.76)**	0.16
BMP 1.2b	Composting – Loader off-site clay	1,042,414	0.731	0.804	**($413.76)**	0.14

Table 7.2 indicates that stockpile grazing with perennial crops and composting should not be considered, as they do not reduce GHG emissions.

From an economic perspective, the BMP with the largest pay-off to the beef supply chain is using RAC for the last 28 days in the feedlot (see Table 7.3). The BCR is close to 12.5:1, suggesting that this BMP would be beneficial as an industry standard on all cattle, provided that further studies show positive results for beef quality (see Section 5.2.1).

Table 7.3: Ranking of BMPs Based on Economics

BMP	Description	ΔCO_2e	ΔCO_2e per kg all beef	ΔCO_2e per kg affected beef	Net Annual Benefits	Market NPV BCR
		tonnes	kg	kg	$ million	ratio
BMP 4.1	Growth promotant - last 28 days	**-59,659**	**-0.042**	**-0.046**	**$12.41**	12.48
BMP 5	Selection for superior RFI	**-3,839**	**-0.003**	**-1.285**	**$0.23**	2.91
BMP 3	Ionophores in roughage diets	**-292,611**	**-0.205**	**-2.244**	**$101.53**	2.85
BMP 4.2	Fewer days on feed	**-853,667**	**-0.406**	**-1.513**	**$56.12**	2.24
BMP 2.1	Swath grazing	**-218,177**	**-0.153**	**-1.673**	**$243.31**	1.94
BMP 2.2	Stockpile grazing	882,725	0.619	0.007	**($29.91)**	0.79
BMP 1.1a	Composting - Windrow on-site clay	962,702	0.675	0.743	**($322.35)**	0.18
BMP 1.1b	Composting – Windrow off-site clay	974,634	0.683	0.752	**($322.35)**	0.17
BMP 1.2a	Composting – Loader on-site clay	1,022,630	0.717	0.789	**($413.76)**	0.16
BMP 1.2b	Composting – Loader off-site clay	1,042,414	0.731	0.804	**($413.76)**	0.14

Genetic improvement also has an attractive BCR at 2.9:1, which implies an IRR of over 12 percent. The net benefits and ΔCO_2e are low in comparison to other BMPs – this is only due to the low assumed adoption rate based on the ability to test for and identify bulls with superior RFI genes. The change in emissions per kg affected live shrunk weight is the fourth highest of all BMPs, making this BMP very effective at reducing GHG emissions per beef affected. Use of artificial insemination, or bull sharing, will greatly increase the benefits to the sector and to the overall GHG emissions reduction.

The above suggests that the following BMPs be further considered for implementation in the Alberta beef sector (based on [1] reducing CO_2e emissions, and [2] an attractive BCR in the sector):

- **BMP 4.1 Growth promotant (RAC) - last 28 days**
- **BMP 5 Selection for superior RFI**
- **BMP 3 Ionophores in roughage diets**
- **BMP 4.2 Fewer days on feed**
- **BMP 2.1 Swath grazing**

8.0 LIMITATIONS OF THE STUDY

The objective of Phase 2 was to assess the environmental and economic impacts of beef production with the implementation of beneficial management practices. The LCA completed by CRA in Phase 1 was used and updated to model the effects of these BMPs.

Performing any LCA is an intensive process. The complexity of the beef system in Alberta and its interaction with adjacent livestock systems and practices made the task of performing the Phase 1 LCA bore with it many challenges.

It is acknowledged that availability of reliable data can greatly impact the accuracy of the final results. Therefore, emphasis was placed on gathering information from updated, reliable, and expert sources.

Some of the limitations of the Phase 1 LCA model which are either limitations for the Phase 2 project as well, or that can have an impact on the final results are:

- Delineation of the boundaries of the system is dependent on user definition. While efforts were made to include the entire life cycle of all the logistic and processes involved in the life cycle of beef cattle, some of the processes were omitted due to the lack of both primary and secondary data.
- Estimation of environmental emissions generated by the diverse and interlinked processes within the system is a key point of success for building a comprehensive inventory. However, the databases currently available do not reach a consensus in methodological terms and accuracy when reporting emissions. Every effort was made to use the most reliable environmental emissions for the processes involved in the analysis.
- Where primary and secondary data gaps were encountered, educated assumptions were made to capture relevant processes in the calculations.
- The complexity and diversity of different methods for modelling the transfer processes in the manure management and cropping practices can have an effect on the final outcomes. In addition to the recognized IPCC 2006 and Environment Canada 2008 Tier 2 standard methodologies, new methodologies developed specifically for conditions in Canada, and specifically Alberta, can lead to different results in emissions from manure management and cropping practices.
- While industrial processes are relatively well defined and characterized in terms of environmental emissions, agricultural practices tend to be more variable. The data used to quantify environmental emissions from agricultural practices in different geographic settings may introduce a source of uncertainty in the results. However,

every effort was made to adjust the agricultural practices and associated emissions to conditions specific for the area of the current study.

- The LCIA methodology and equivalence factors used to quantify some environmental impacts are generic. To date, representative factors for Alberta have not been developed.
- The LCIA results were based on the IPCC 2007 GWP (100 years) quantification methodology and IMPACT 2002+.

The results presented in this report are subject to these and other inherent limitations as they relate to data inputs and the ability of the various models and techniques utilized to accurately reflect actual conditions. It is also recognized that the Phase 1 LCA baseline model was a first approximation of the life cycle of the Alberta beef sector. For Phase 2, only activities associated with each of the BMPs have been revised from 2001 conditions to reflect current conditions (2010). Additional refinement and analysis of input parameters for the entire model will yield more robust results.

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10.0 DISCLAIMER

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All of which is respectfully submitted,

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TABLE 2.1

PERCENT CHANGE IN GHG EMISSIONS WITH BMP 1
ALBERTA BEEF LCA - PHASE 2
Alberta Agriculture and Rural Development

				BMP 1.1a		*BMP 1.1b*		*BMP 1.2a*		*BMP 1.2b*	
	Baseline (2001)	*Baseline (2010)*		*Windrow turner, on-site clay*		*Windrow turner, off-site clay*		*Existing equipment, on-site clay*		*Existing equipment, off-site clay*	
	(kg CO2e/ kg live weight)	*(kg CO2e/ kg live weight)*	*% change from 2001 baseline*	*(kg CO2e/ kg live weight)*	*% change from 2010 baseline*	*(kg CO2e/ kg live weight)*	*% change from 2010 baseline*	*(kg CO2e/ kg live weight)*	*% change from 2010 baseline*	*(kg CO2e/ kg live weight)*	*% change from 2010 baseline*
Construction Activities	0.000	0.004	**100%**	0.181	**4282%**	0.189	**4485%**	0.014	**232%**	0.028	**578%**
Increased emissions components											
Excavate clay (increase)	*0.000*	*0.002*		*-0.002*		*0.006*		*-0.002*		*0.012*	
Transport clay (increase)	*0.000*	*0.000*		*0.000*		*0.000*		*0.000*		*0.000*	
Construct composting pad (increase)	*0.000*	*0.002*		*0.006*		*0.006*		*0.012*		*0.012*	
Manufacture equipment (increase)	*0.000*	*0.000*		*0.171*		*0.171*		*0.000*		*0.000*	
Transport equipment (increase)	*0.000*	*0.000*		*0.001*		*0.001*		*0.000*		*0.000*	
		0.004		*0.177*		*0.184*		*0.010*		*0.024*	
Forage and Cereal Sub-activities	0.845	0.845	0%	0.845	0%	0.845	0%	0.845	0%	0.845	0%
Energy Generation Activities	2.695	2.735	**1.5%**	2.754	**0.7%**	2.754	**0.7%**	2.963	**8.3%**	2.963	**8.3%**
Increased emissions components											
Produce crude (increase)		*0.006*		*0.003*		*0.003*		*0.036*		*0.036*	
Transport crude (increase)		*0.002*		*0.001*		*0.001*		*0.012*		*0.012*	
Refine crude into diesel (increase)		*0.004*		*0.002*		*0.002*		*0.022*		*0.022*	
Transport diesel (increase)		*0.004*		*0.002*		*0.002*		*0.021*		*0.021*	
Combust diesel (increase)		*0.024*		*0.011*		*0.011*		*0.137*		*0.137*	
		0.040		*0.019*		*0.019*		*0.228*		*0.228*	
O&M Activities	0.000	0.000	0%	0.000	0%	0.000	0%	0.000	0%	0.000	0%
Cereal Activities	0.237	0.237	0%	0.237	0%	0.237	0%	0.237	0%	0.237	0%
Forage Activities	0.200	0.200	0%	0.200	0%	0.200	0%	0.200	0%	0.200	0%
Feedlot and Pasture Activities	0.314	0.381	**21.6%**	0.767	**101.2%**	0.767	**101.2%**	0.767	**101.2%**	0.767	**101.1%**
Increased emissions components											
Dispose of manure (transport off site)		*-0.002*		*-0.011*		*-0.011*		*-0.011*		*-0.011*	
Transport wood waste		*0.00004*		*0.0002*		*0.0002*		*0.0002*		*0.0002*	
Produce straw for amendment		*0.069*		*0.391*		*0.391*		*0.391*		*0.391*	
Transport straw		*0.001*		*0.005*		*0.005*		*0.005*		*0.005*	
		0.068		*0.386*		*0.386*		*0.386*		*0.386*	
Transport (Cow Activities)	0.017	0.017	0%	0.017	0%	0.017	0%	0.017	0%	0.017	0%
Transport (Bull Activities)	0.002	0.002	0%	0.002	0%	0.002	0%	0.002	0%	0.002	0%
Transport (Yearling-fed System Activities)	0.076	0.076	0%	0.076	0%	0.076	0%	0.076	0%	0.076	0%
Transport (Calf-Fed System Activities)	0.046	0.046	0%	0.046	0%	0.046	0%	0.046	0%	0.046	0%
Cattle Enteric Fermentation Emissions	7.423	7.423	0%	7.423	0%	7.423	0%	7.423	0%	7.423	0%
Cattle Methane Emissions from Manure	0.206	0.199	**-3.4%**	0.159	**-20.0%**	0.159	**-20.0%**	0.159	**-20.0%**	0.159	**-19.9%**
(decrease due to composting)		-0.007		-0.040		-0.040		-0.040		-0.040	
Soil Carbon Change in Soil From Land Use	-0.165	-0.165	0%	-0.165	0%	-0.165	0%	-0.165	0%	-0.165	0%
Direct CO2 Emissions From Managed Soils	0.132	0.132	0%	0.132	0%	0.132	0%	0.132	0%	0.132	0%
N2O from Beef Activity (manure), Soil, Crop	2.677	2.701	**0.9%**	2.834	**4.9%**	2.834	**4.9%**	2.834	**4.9%**	2.834	**4.9%**
(increase due to composting)		0.023		0.133		0.133		0.133		0.133	
Total	14.705	14.834	**0.9%**	15.509	**4.5%**	15.517	**4.6%**	15.551	**4.8%**	15.565	**4.9%**
Total (excluding construction activities)	14.705	14.830	**0.8%**	15.328	**3.4%**	15.328	**3.4%**	15.537	**4.8%**	15.537	**4.8%**

TABLE 3.1.1

PERCENT CHANGE IN GHG EMISSIONS WITH BMP2.1
SWATH GRAZING
ALBERTA BEEF LCA - PHASE 2
Alberta Agriculture and Rural Development

	Baseline (2001)	*100% Adoption*	
	(kg CO2e/ kg live weight)	*(kg CO2e/ kg live weight)*	*% change from 2001 baseline*
Construction	0.00	0.00	0%
Forage and Cereal Sub-activities	0.845	0.877	**3.88%**
Change in emissions		*0.033*	
Energy Generation Activities	2.695	2.544	**-5.60%**
Change in emissions		*-0.151*	
O&M Activities	0.00	0.00	0%
Cereal Activities	0.237	0.237	0%
Forage Activities	0.200	0.187	**-6.90%**
Change in emissions		*-0.014*	
Feedlot and Pasture Activities	0.314	0.306	**-2.45%**
Change in emissions		*-0.008*	
Transport (Cow Activities)	0.017	0.017	0%
Transport (Bull Activities)	0.002	0.002	0%
Transport (Yearling-Fed System Activities)	0.076	0.076	0%
Transport (Calf-Fed System Activities)	0.046	0.046	0%
Swath Grazing Management	0.000	0.010	0%
		0.010	
Cattle Enteric Fermentation Emissions	7.423	7.423	0%
Change in emissions			
Cattle Methane Emissions from Manure	0.206	0.206	0%
Change in emissions			
Soil Carbon Change in Soil From Land Use	-0.165	-0.187	**13.20%**
Change in emissions		*-0.022*	
Direct CO2 Emissions From Managed Soils	0.132	0.127	**-4.46%**
Change in emissions		*-0.006*	
N2O from Beef Activity (manure), Soil, Crop	2.677	2.682	**0.17%**
Change in emissions		*0.005*	
Total	**14.705**	**14.552**	**-1.04%**

TABLE 3.1.2

PERCENT CHANGE IN GHG EMISSIONS WITH BMP 2.2
STOCKPILE GRAZING
ALBERTA BEEF LCA - PHASE 2
Alberta Agriculture and Rural Development

	Baseline (2001)	*100% Adoption*	
	(kg CO2e/ kg live weight)	*(kg CO2e/ kg live weight)*	*% change from 2001 baseline*
Construction	0.00	0.00	0%
Forage and Cereal Sub-activities	0.845	1.053	**24.64%**
Change in emissions		*0.208*	
Energy Generation Activities	2.695	2.660	**-1.30%**
Change in emissions		*-0.035*	
O&M Activities	0.00	0.00	0%
Cereal Activities	0.237	0.237	0%
Forage Activities	0.200	0.196	**-2.38%**
Change in emissions		*-0.005*	
Feedlot and Pasture Activities	0.314	0.312	**-0.57%**
Change in emissions		*-0.002*	
Transport (Cow Activities)	0.017	0.017	0%
Transport (Bull Activities)	0.002	0.002	0%
Transport (Yearling-Fed System Activities)	0.076	0.076	0%
Transport (Calf-Fed System Activities)	0.046	0.046	0%
Stockpile grazing management	0.000	0.008	0%
		0.008	
Cattle Enteric Fermentation Emissions	7.423	7.423	0%
Change in emissions			
Cattle Methane Emissions from Manure	0.206	0.206	0%
Change in emissions			
Soil Carbon Change in Soil From Land Use	-0.165	-0.168	**1.25%**
Change in emissions		*-0.002*	
Direct CO2 Emissions From Managed Soils	0.132	0.152	**14.40%**
Change in emissions		*0.019*	
N2O from Beef Activity (manure), Soil, Crop	2.677	3.104	**15.95%**
Change in emissions		*0.427*	
Total	**14.705**	**15.324**	**4.21%**

TABLE 4.1

PERCENT CHANGE IN GHG EMISSIONS WITH BMP 3
ALBERTA BEEF LCA - PHASE 2
Alberta Agriculture and Rural Development

	Baseline (2001)	*BMP 3*	
	(kg CO2e/ kg live weight)	*(kg CO2e/ kg live weight)*	*% change from 2001 baseline*
Construction	0.00	0.000	0%
Forage and Cereal Sub-activities	0.845	0.835	**-1.08%**
Change in emissions		*-0.009*	
Energy Generation Activities	2.695	2.692	**-0.13%**
Change in emissions		*-0.004*	
O&M Activities	0.00	0.000	0%
Cereal Activities	0.237	0.237	0%
Forage Activities	0.200	0.193	**-3.44%**
Change in emissions		*-0.007*	
Feedlot and Pasture Activities	0.314	0.314	**-0.01%**
Change in emissions		*0.000*	
Transport (Cow Activities)	0.017	0.017	0%
Transport (Bull Activities)	0.002	0.002	0%
Transport (Yearling-Fed System Activities)	0.076	0.076	0%
Transport (Calf-Fed System Activities)	0.046	0.046	0%
Cattle Enteric Fermentation Emissions	7.423	7.296	**-1.72%**
Change in emissions		*-0.127*	
Cattle Methane Emissions from Manure	0.206	0.203	**-1.31%**
Change in emissions		*-0.003*	
Soil Carbon Change in Soil From Land Use	-0.165	-0.165	**-0.44%**
Change in emissions		*0.001*	
Direct CO2 Emissions From Managed Soils	0.132	0.132	**-0.61%**
Change in emissions		*-0.001*	
N2O from Beef Activity (manure), Soil, Crop	2.677	2.622	**-2.06%**
Change in emissions		*-0.055*	
Total	**14.705**	**14.500**	**-1.39%**

TABLE 5.1

PERCENT CHANGE IN GHG EMISSIONS WITH BMP 4
ALBERTA BEEF LCA - PHASE 2
Alberta Agriculture and Rural Development

				BMP 4.1			*BMP 4.2*	
	Baseline (2001)	*Baseline (2010)*		*Fewer Days in Feedlot*		*Baseline (2001/2010)*	*Reduced Age at Harvest*	
	(kg CO2e/ kg live weight)	*(kg CO2e/ kg live weight)*	*% change from 2001 baseline*	*(kg CO2e/ kg live weight)*	*% change from 2010 baseline*	*(kg CO2e/ kg live weight)*	*(kg CO2e/ kg live weight)*	*% change from 2001/2010 baseline*
Construction Activities	0.000	0.000	0%	0.000	0%	0.000	0.000	0%
Forage and Cereal Sub-activities	0.845	0.838	**-0.7%**	0.831	**-0.9%**	0.845	0.856	**1.3%**
Change in emissions		*-0.006*		*-0.008*			*0.011*	
Energy Generation Activities	2.695	2.689	**-0.2%**	2.681	**-0.3%**	2.695	2.573	**-4.5%**
Change in emissions		*-0.006*		*-0.008*			*-0.122*	
O&M Activities	0.000	0.000	0%	0.000	0%	0.000	0.000	0%
Cereal Activities	0.237	0.234	**-1.2%**	0.230	**-1.5%**	0.237	0.242	**2.3%**
Change in emissions		*-0.003*		*-0.004*			*0.005*	
Forage Activities	0.200	0.200	**-0.1%**	0.200	**-0.1%**	0.200	0.184	**-8.3%**
Change in emissions		*0.000*		*0.000*			*-0.017*	
Feedlot and Pasture Activities	0.314	0.312	**-0.4%**	0.311	**-0.5%**	0.314	0.313	**-0.3%**
Change in emissions		*-0.001*		*-0.002*			*-0.001*	
Transport (Cow Activities)	0.017	0.017	0%	0.017	0%	0.017	0.018	**1.4%**
Change in emissions							*0.0002*	
Transport (Bull Activities)	0.002	0.002	0%	0.002	0%	0.002	0.002	**1.4%**
Change in emissions							*0.00003*	
Transport (Yearling-Fed System Activities)	0.076	0.076	0%	0.076	0%	0.076	0.077	**1.4%**
Change in emissions							*0.001*	
Transport (Calf-Fed System Activities)	0.046	0.046	0%	0.046	0%	0.046	0.047	**1.4%**
Change in emissions							*0.001*	
Cattle Enteric Fermentation Emissions	7.423	7.413	**-0.1%**	7.401	**-0.2%**	7.423	7.168	**-3.4%**
Change in emissions		*-0.010*		*-0.012*			*-0.255*	
Cattle Methane Emissions from Manure	0.206	0.205	**-0.3%**	0.204	**-0.3%**	0.206	0.199	**-3.1%**
Change in emissions		*-0.001*		*-0.001*			*-0.006*	
Soil Carbon Change in Soil From Land Use	-0.165	-0.164	**-0.9%**	-0.162	**-1.1%**	-0.165	-0.158	**-4.6%**
Change in emissions		*0.001*		*0.002*			*0.008*	
Direct CO2 Emissions From Managed Soils	0.132	0.131	**-0.8%**	0.130	**-1.0%**	0.132	0.135	**2.3%**
Change in emissions		*-0.001*		*-0.001*			*0.003*	
N2O from Beef Activity (manure), Soil, Crop	2.677	2.671	**-0.3%**	2.662	**-0.3%**	2.677	2.643	**-1.3%**
Change in emissions		*-0.007*		*-0.008*			*-0.034*	
Total	**14.705**	**14.671**	**-0.2%**	**14.629**	**-0.3%**	**14.705**	**14.299**	**-2.8%**

TABLE 6.1

PERCENT CHANGE IN GHG EMISSIONS WITH BMP 5
ALBERTA BEEF LCA - PHASE 2
Alberta Agriculture and Rural Development

	Baseline (2001)	*Baseline (2010)*		*BMP 5 (2029)*	
	(kg CO2e/ kg live weight)	*(kg CO2e/ kg live weight)*	*% change from 2001 baseline*	*(kg CO2e/ kg live weight)*	*% change from 2010 baseline*
Construction Activities	0.0000	0.0000	0%	0.0000	0%
Forage and Cereal Sub-activities	0.8445	0.8445	**-0.0006%**	0.8445	**-0.005%**
Change in emissions		*-5.24E-06*		*-4.37E-05*	
Energy Generation Activities	2.6953	2.6952	**-0.0004%**	2.6951	**-0.003%**
Change in emissions		*-1.08E-05*		*-9.04E-05*	
O&M Activities	0.0000	0.0000	0%	0.0000	0%
Cereal Activities	0.2369	0.2369	**-0.0006%**	0.2369	**-0.005%**
Change in emissions		*-1.53E-06*		*-1.27E-05*	
Forage Activities	0.2004	0.2004	**-0.0007%**	0.2004	**-0.006%**
Change in emissions		*-1.32E-06*		*-1.11E-05*	
Feedlot and Pasture Activities	0.3136	0.3135	**-0.014%**	0.3131	**-0.129%**
Change in emissions		*-4.53E-05*		*-4.04E-04*	
Transport (Cow Activities)	0.0174	0.0174	0%	0.0174	0%
Transport (Bull Activities)	0.0022	0.0022	0%	0.0022	0%
Transport (Yearling-Fed System Activities)	0.0755	0.0755	**0.0009%**	0.0755	**0.006%**
Change in emissions		*6.75E-07*		*4.87E-06*	
Transport (Calf-Fed System Activities)	0.0462	0.0462	**0.0009%**	0.0462	**0.007%**
Change in emissions		*4.28E-07*		*3.09E-06*	
Cattle Enteric Fermentation Emissions	7.4234	7.4231	**-0.0030%**	7.4213	**-0.025%**
Change in emissions		*-2.26E-04*		*-1.88E-03*	
Cattle Methane Emissions from Manure	0.2055	0.2055	**-0.0049%**	0.2054	**-0.041%**
Change in emissions		*-1.01E-05*		*-8.41E-05*	
Soil Carbon Change in Soil From Land Use	-0.1654	-0.1654	**-0.0007%**	-0.1654	**-0.005%**
Change in emissions		*1.09E-06*		*9.07E-06*	
Direct CO2 Emissions From Managed Soils	0.1325	0.1325	**-0.0006%**	0.1324	**-0.005%**
Change in emissions		*-8.10E-07*		*-6.75E-06*	
N2O from Beef Activity (manure), Soil, Crop	2.6774	2.6774	**-0.0008%**	2.6772	**-0.006%**
Change in emissions		*-2.05E-05*		*-1.72E-04*	
Total	**14.7052**	**14.7049**	**-0.0022%**	**14.7022**	**-0.018%**

APPENDIX A

PRINCIPLES GUIDING CBA ANALYSIS

There is no standard approach to CBA, however there are a few **principles** that have guided prior CBA analyses by JRG and should be followed to the degree possible [1] [2] [3]:

1. The focus of CBA is on the ***impact of achieving an objective***, which requires that the ***objective needs to be clearly articulated***. In the case of any of the BMPs being considered the objectives of government and the objectives of industry need to be documented. An objective for government is a reduction in GHGs, while the objectives for industry are more likely focused on profitability and positioning of Alberta beef in a global marketplace.
2. CBA typically looks at ***comparing a few options (a BMP) that can be used to achieve the stated objectives***. With each BMP being considered, the assessment is relative to the current situation. For example, in the case of composting manure, achieving the target level of this BMP is evaluated in relation to the current volumes of composting and other existing solid manure handling practices.
3. A determination is required as to which ***stakeholders will be considered by the CBA***, also known as ***standing*** – referring to whose benefits and costs counts. In this case of BMP with the Alberta beef supply chain, the benefits and costs to each segment of the beef supply chain within Alberta will be considered, as well as the benefits and costs to al Albertans after considering the externalities of emissions. In some CBA, the benefits and costs to other jurisdictions can be considered.
4. An ***adequate description of the current situation and current operating environment*** is required. This includes an adequate description of the current situation, it strengths and weaknesses, and other aspects of the current operating environment.
5. The ***operating environment associated with each option*** (***BMP)*** needs to be clearly described. In particular, the operating environment may change to facilitate the requested regulatory change. This includes a description of all of the elements and operating environment associated with the change. For example, with the BMP of reduced age to slaughter, a description is required for how this reduced age is to be achieved in the cow/calf, backgrounding, and finishing segments of the beef supply chain.

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[1] For interested readers, a classic in the areas of cost benefit analysis is Gittinger, J. Price. Economic Analysis of Agricultural Projects. Economic Development Institute, The World Bank, 1984. The book is written for analysis of development projects; however, a number of the concepts and illustrations apply to most analyses.

[2] See also David Pearce, Giles Atkinson, and Susana Mourato. Cost-Benefit Analysis and the Environment, Recent Developments. OECD, 2006.

[3] There can be other principles that should be considered in large-scale investment projects, such as building a new highway or deciding to proceed with a nuclear energy program.

6. The analysis should be based on ***incremental change*** associated with the BMP from the existing situation, which becomes the baseline for analysis. This allows for the analysis to focus on the impact associated with the change created by the BMP target.

7. There is typically a ***range of costs and benefits that need to be considered*** which result from the changes (BMP). The dimensions of this range to consider can include all of the supply chain participants (e.g., grain production through to feedlots). In some cases such as with more efficient utilization of feed grains, while from a LCA point of view there is an impact on the feed grain production sector through a lower environment impact, the CBA does not consider the feed grain sector based on the assumption that a lower volume of feed grain requirements does not affect the market price of feed grains. Such feed grain pricing is influenced predominately by the global supply and demand balance for feed grains. As well, ***secondary benefits and costs may be important***. An example can be that the level of economic activity in a region may be higher or lower. As well, if upstream GHG are less due to a BMP, this benefit should be accounted for in the analysis.

8. The ***benefits associated with each option should be compared to the costs of each option*** to allow for an assessment of whether a BMP such as the use of ionophores in cow diets is preferred to the current situation. While the overall benefits, after accounting for externalities, may exceed costs from a cow/calf operator's perspective to adopt a BMP, the measured benefits must exceed the measured costs that are internal to their operation.

9. ***Costs and benefits to various stakeholder groups should remain identifiable*** to allow for an indication of advantages and disadvantages to various groups and stakeholders associated with a BMP, which ties into the issue of who has standing. For example, if a BMP is directed at the feedlot, the benefit cost ratio should be developed for this segment of the supply chain – this mimics the internalization of benefits and costs for a feedlot decision maker. The benefit cost relationship for society can change when the societal benefit of less GHG emission is part of the measurable benefit. However, if the BMP were described to have feedlots obtain credits for GHG reduction attributable to their own operations, these credits would be part of the benefit valuation. This pricing feature would be designed to have the costs and benefits of an operation be internalized within the operation.

   If a BMP involves more than one segment of the beef supply chain (e.g., cow/calf and feedlots) then a separate computation is made for the benefits and costs that are attributable to (incurred by) these distinct segments.

   As a result, while a BMP that improves feed utilization efficiency (and the LCA would indicate less GHG impact through feed grain production), a CBA would typically not apply to this part (feed grain production) of the supply chain. The exception being if there was a measurable impact of a BMP in the beef production segment that had a material impact on costs or returns in the feed grain production sector. However, the CBA in the beef sector should account for any reduction in GHG in feed grain production attributable to a BMP in the beef production sector as identified through LCA.

10. Benefits and costs should be measured in the ***same units of measurement***, typically using a monetary value. This allows for a direct comparison between all benefits with all associated costs. To the degree possible, a ***monetary value should be assigned to all non-monetary benefits and costs***. For example, with a BMP reducing GHG emissions, this reduction should be assigned a monetary value, where appropriate (such as when computing the overall or societal net benefit or B/C ratio).
11. Not all benefits and costs are tangible and measurable. There are some ***costs and benefits that are intangible and difficult, if not impossible to quantify***. For example, the reduction in nitrous oxide may not have a defensible monetary value. In cases where the cost or benefit cannot be quantified, the benefit or cost should be identified and described. Attempts should be made to quantify the intangible costs and benefits that are considered important due to the change.
12. The time value of money should be considered when benefits and costs occur in separate time periods. This implies that ***benefits and costs must be accounted for in each time period*** (typically a year), with appropriate discounting of future costs and benefits to assess the ***present value of costs and benefits***. This is referred to as the ***net present value (NPV)***[4]. This is particularly important in investment projects, where costs are typically incurred at the beginning with benefits accruing in the future. This may apply to a BMP such as composting with a large initial capital expenditure.
13. Future prices and costs are ***valued in current (real) dollars***, meaning that future benefits and costs expressed in nominal dollars are adjusted to current dollars for anticipated inflation. As well, if a change in relative prices is expected, these should be considered.
14. In situations when the incidence of costs and benefits is invariant with respect to time (benefits and costs are the same in each year before or after inflation adjustment), then the ***analysis can be collapsed into a single year analysis***. This is due to the fact that the NPV will be a scalar of the net benefits in any year. This may be the case for most of the BMPs being considered (if not all), where annual benefits and costs are the same in each time period. An exception could be when an upfront capital investment is made, that needs to be amortized over its useful life, such as an enclosed composting facility.

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[4] The NPV is the sum of annual values of present value of benefits and costs, or the sum of the discounted value of net benefit in each year. In any year the discounted value is the annual net benefit divided by the applicable discount factor (see Appendix B for an example).

15. In some cases, ***sensitivity analysis*** can be conducted to see how the outcome is affected by changes in assumptions on certain key parameters. Most importantly, these assumptions must be realistic and supported by industry. An example could be the value placed on reduced levels of GHG emissions.

16. ***Avoid double counting*** of benefits or costs. An example of double counting can be attributing benefits realized in the cow/calf sector to feedlot operations.

17. When ***uncertainty*** exists concerning an outcome, this can be accounted for by placing probabilities on potential outcomes and then computing the ***expected value*** of the associated costs and benefits[5] (i.e., ***the expected net present value [ENPV]***).

18. Provide the appropriate ***measurement of benefits and costs to assist decision-making***. These measures can include net benefits for a time invariant analysis, the NPV of benefits, a B/C ratio, or the internal rate of return (IRR), which shows the rate of return on the investment. Computation of costs and benefits should highlight distributional issues and indicate what stakeholder group wins and who loses, as well as indicate aggregate benefits and costs. Once the benefits and costs are measured based on considering the above principles, a decision can be made with respect to any of the BMPs. ***Decision making on a BMP*** can be based on the absolute size of the net benefits, or on the ratio of benefits to costs for any BMP.

19. A related issue for consideration is ***whether waiting provides better information on costs and benefits*** (to make a decision on supporting or investing in a BMP). If waiting does not provide additional information, then the decision should not be deferred. However, if a net benefit is close to zero, waiting may provide more insight on whether costs or benefits change with a proposed option[6]. This is related to the irreversibility of a decision, implying a policy or regulatory change is rather difficult to change. If a decision cannot be easily reversed, then it is advisable to ensure that the benefits exceed costs for a number of potential future operating environments.

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[5] This is computed by attaching probabilities to a range of plausible outcomes and then determining the expected value.

[6] This comment is an extension of "real options" analysis. More information can be found in Carter, C. D. Berwald & A. Loyns. The Economics of Genetically Modified Wheat. Canada Donner Foundation (2005) and Luehrman, Timothy. Strategy as a Portfolio of Real Options. Harvard Business Review Sept. - Oct. 1998 (Reprint 98506).

APPENDIX B

NET PRESENT VALUE

A dollar expended or received in the future does not have the same value as a dollar expended or received today. The difference is due to the time value of money which is represented by a discount rate ("d"), or an interest rate, which is typically equal to a return that could be earned in financial markets with comparable risk profiles, or can be equal to expected costs of borrowing funds or the weighted average cost of capital (opportunity cost of capital). The resulting present value (PV) of future cash inflows and outflows, or the net cash inflow ("Return") for any future time period ("t") can be represented by:

$$PV = \text{Return}_{t} / (1 + d)^{t}$$

The **net present value (NPV)** is the sum of these discounted returns over the life of a project of n+1 years, where year 0 is the year of the capital expenditure, and can be represented by:

$$NPV = \square^{n}_{t=0} \text{Return}_{t} / (1 + d)^{t}$$

The NPV compares the value of today's invested dollar with the future flow of funds resulting from that investment. The NPV is sensitive to the discount rate used, with higher discount rates lowering the NPV and the attractiveness of an investment.

The following table illustrates the PV and NPV through an investment of $3 million that returns $350,000 per annum to an operation before considering annual operating costs of $20,000. With a 10 year project life, the net benefit before considering the time value of money is $301,000 (see last row in column four. After applying the discount factor of $1/(1 + d)^{t}$ the PV of costs and benefits are provided in columns 6 and 7 to compute the PV of net benefits in each year. The sum of the annual PV of **net benefits** is the NPV, which in this example **is negative** (-$784,673). The ratio of benefits to costs (B/C) is 75% indicating that the NPV of benefits is only equal to 75% of the NPV of costs. On this basis, the project should not be initiated as costs are not covered[1].

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[1] With a discount rate of 1.75%, the NPV of net benefits is >0, and the B/C = 101%

Year	Costs	Benefits	Net Benefit	Discount Factor	PV of Costs	PV of Benefits	PV of Net Benefits
0	$3,000,000	$1,000	-$2,999,000	1.00	$3,000,000	$1,000	-$2,999,000
1	$20,000	$350,000	$330,000	1.08	$18,519	$324,074	$305,556
2	$20,000	$350,000	$330,000	1.17	$17,147	$300,069	$282,922
3	$20,000	$350,000	$330,000	1.26	$15,877	$277,841	$261,965
4	$20,000	$350,000	$330,000	1.36	$14,701	$257,260	$242,560
5	$20,000	$350,000	$330,000	1.47	$13,612	$238,204	$224,592
6	$20,000	$350,000	$330,000	1.59	$12,603	$220,559	$207,956
7	$20,000	$350,000	$330,000	1.71	$11,670	$204,222	$192,552
8	$20,000	$350,000	$330,000	1.85	$10,805	$189,094	$178,289
9	$20,000	$350,000	$330,000	2.00	$10,005	$175,087	$165,082
10	$20,000	$350,000	$330,000	2.16	$9,264	$162,118	$152,854
Totals	**$3,200,000**	**$3,501,000**	**$301,000**		**$3,134,202**	**$2,349,528**	**-$784,673**
NPV of Net Benefits							**-$784,673**
B/C ratio							**75%**

APPENDIX C

OTHER ECONOMIC MEASURES USED WITH A LCA

In some cases when it is difficult to assign a monetary value to some benefits, such as to a reduction in overall GHG emissions, decision making by government on projects can also be aided by computing the cost effectiveness of a BMP and comparing cost effectiveness to another BMP, or option. **Cost–effectiveness analysis (CEA)** measures the cost incurred to achieve a given reduction in a pre-defined single objective (such as a reduction in GHG emissions). Cost effectiveness is measured as the cost incurred to achieve a reduction in and indicator of effectiveness (E), such as a reduction in GHG emissions. As with a CBA, a CEA requires the input of LCA. The cost effectiveness ratio **(CER)** is simply effectiveness (E) divided by the costs incurred to achieve E. For example, a BMP could achieve a 20 kg reduction in CO_2e emissions at a cost of a dollar, while an alternative may only achieve a 15 kg reduction for the same expenditure. The more cost-effective (a higher CER) would be chosen – achieving a desired outcome at lowest cost[1].

BMPs can also be compared on this CER dimension; however it does not help make the decision as to whether a BMP is worth doing. This is because the numerator and denominator are in different units of measurement, and the CER does not provide any guidance as to whether it is worth doing (unless there was a mandate for reduction in which case the CER could indicate which BMP to pursue). Determining whether a BMP should be pursued requires a CBA as it compares the benefits of a BMP to the associated costs. Moving from a CEA, with costs captured, to a CBA requires a valuation of benefits incurred.

Life Cycle Costing (LCC) is an approach that calculates costs throughout the supply chain generated by the life cycle of a product. Life cycle costs refer to all costs associated with the system as applied to the defined life cycle. LCC is required to conduct a CEA or compute a CER, and requires the completion of a LCA. LCC computes system costs, but on its own does not help in decision-making.

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[1] The inverse of this ratio is $/unit of reduction.

APPENDIX D

ECONOMIC CONCEPTS AND CBA APPLIED TO LCA: A LITERATURE REVIEW

The Canadian Institute for Environmental Law and Policy in a brief indicate that a LCA should not be used as a decision making tool due to its weakness of not taking into account economic (or social) impacts. Rather a LCA should be used as a decision-supporting tool (CIELAP, 2009). This is a common view through the LCA and Life Cycle Management literature[1], and underscores the need to using methodologies that account for economic impacts associated with product life cycles and proposed BMPs. For example, Jeswani et al. (2010) argue that LCAs need to be deepening (more guidance on system boundaries) and broadening (integration of LCA with social and economic dimensions of sustainable development).

Norris (2001) in an article titled "Integrating Economic Analysis into LCA" compares LCA with LCC. Norris notes that a typical LCA methodology does not account for economic consequences, however he argues that LCA must take into account economic consequences of alternative products (or product designs) to support decision making. An LCC with its objective of looking at the cost effectiveness of alternative investments (business decisions) of an economic decision maker such as a manufacturing firm. Norris correctly notes that a LCC is only interested in the direct costs and benefits from a decision makers perspective, while a LCA takes a cradle to grave view of all material flows and can involve multiple decision makers. To fully integrate economics in a LCA requires more than just treating economic costs as another flow.

While LCC has weaknesses as noted above, Norris indicates that factors central to LCC, which are absent from an LCA, include:

- Cash flows related to investments in products/process changes
- Costs and revenue streams which are not proportional to, or even dependent at all upon, physical flows which are modeled in LCAs
- The timing of cash flows (costs and benefits) and the present value of these flows
- The risks of costs, and their alteration or avoidance as a function of the product/process design options

Hunkler and Rebitzer (2005) suggest that a LCC can be synergistic with a LCA when they utilize common data and models.

Given the private decision maker perspective of a LCC, it is an essential link for connecting environmental concerns with core business strategies. "*Synergies between the environment and economic considerations have to be utilized in order to move towards sustainable development*" (Hunkler

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[1] Sustainable development is typically viewed through three inter-related pillars of ecological, economic, and social. An important tissue is how much weight to place on each, and having a common unit of measurement (for addressing inter-relationships and trade-offs).

and Rebitzer, 2003). However, while LCC applies to all costs as defined by the life cycle, in many cases LCC suffers from a narrow system boundary. This is in evidence as Rebitzer and Hunkler (2003)discuss some of the limitations of LCC and how to deal with externalities. They discuss the issue of whether costs that are external to a firm (decision maker) as with externalities should be included in a LCC analysis (Rebitzer and Hunkler, 2003). Their discussion extends to suggest that a LCC should be defined broadly enough to include all relevant parties that are affected by the product life cycle. As noted previously, a comprehensive CBA addresses these boundary issues and conducts a CBA from each stakeholders perspective, as well as from an overall societal perspective where the value of externalities are considered, since they are internal to a broad life cycle system boundary.

At Carnegie Mellon the Green Design Initiative uses an Economic Input-Output-Based Life-Cycle Assessment (EIO-LCA) to address the economic and environmental impacts of sectors or products[2]. At Green Design it is argued that LCA while going from cradle–to-grave still has a boundary problem in that inputs used in the production process rely on other inputs (e.g., trucks to deliver grain are made of steel and other materials, which requires iron ore, energy, etc. to manufacture). As a result a LCA may not necessarily track all of the direct and indirect interactions in the economy depending on the data available and can thereby miss some environmental burdens. Green Design starts with a traditional input-output (I-O) model that has all of the linkages within the economy (via input-output tables supplied by the federal government) and augments these tables with appropriate sectoral environmental impact indices. As a consequence, the EIO-LCA approach can analyze the environmental impacts of changes in output in a sector of the economy. While this approach can apply to a sector, it is heavily dependent on linkages between inputs and outputs captured by census of manufacturing surveys and requires significant efforts to adopt to capture the impact of BMP in a sector such as beef.

In the EU a number of studies have been completed on waste management and recycling of paper and cardboard. LCA and CBA have been used in the EU to support decisions on approaches to waste management. The Danish Topic Centre on Waste and Resources prepared a booklet (Copenhagen Resource Institute, 2008) that highlighted the advantages and limitations of these two approaches. The report notes that LCA and CBA can give contradictory results on waste paper management (e.g., recycling may or may not be preferred to incineration with energy recovery). This reflects the strengths and weaknesses of each of approach, with the noted strength of CBA being its focus on monetizing impact areas. It noted that a LCA strongly supported one approach to recycling, while a CEA suggested another approach. The booklet indicates that both CBA and LCA are subject to misuse, which is one reason why the standardization process of the LCA occurred in the 1990s and resulted in the ISO 14040

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[2] See for example www.eiolca.net accessed October 12, 2010.

standard series – the report also suggests that CBA may benefit from a similar standardization process[3]. The Danish report also noted that both LCA and CBA should be transparent, as well as have a sensitivity analysis of key assumptions.

Application of CBA to environmental issues is just beginning as the weaknesses of an LCA are becoming apparent in making economic related policy decisions. Whether researchers conduct a complete CBA, or whether they are linked to (or consider all of the flows) of a LCA is an issue. The European Environment Agency recently completed a study that reviewed the use of LCA and CBA approaches in the recovery and disposal of paper and cardboard (Villanueva et al., 2006). The report did note that a CBA has a much broader scope than a LCA due to CBA quantifying more than just the environmental impact. As noted by others, the report states, "*an ideal CBA would include a full LCA up to the impact assessment stage, as just on element of the scope*" (page 10). This report provides some useful insight on how CBA have been used in the EU, which is more advanced in the use of CBA than in North America, and can provide some perspective for this project.

One interesting point is that none of the studies reviewed conducted a full CBA, which includes conducting all of the basic steps for conducting a CBA. The six steps considered in their review were: (1) problem definition, (2) scope definition, (3) monetary valuation, (4) use of discounting, (5) evaluation using NPV, and (6) evaluation of uncertainty. Of interest the criteria used to review the nine applicable studies included[4]:

- Objectives of the analysis, what scenarios are analyzed?
- Is system delimitation presented?
- Has the study gone through the six basic CBA steps[5]?
- What parts of the life cycle stages are accounted for in the study[6]?
- Which environmental and economic parameters are included in each stage of the life cycle?
- Have the assumptions for estimating the environmental emissions/impact and economic costs been presented in a transparent way?
- Are corrections in prices included (e.g., inflation, tax distortions and changes in relative prices)[7]?

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[3] It should be noted that the principles outline in a prior section for a CBA reflect the basic of a CBA and cover those suggested by Pearce et al in the cited OECD document.

[4] This list can be used to guide our methodology.

[5] It should be noted that the principles proposed above for this CBA are more comprehensive than the six basic steps proposed for their review.

[6] Some CBA did not account for all applicable life cycle stages.

[7] In terms of valuing the emissions per unit value of emissions had quite a range between studies. For example, CO_2 ranged from EUR 3 per tonne to EUR 109/tonne and CH_4 from around EUR 100/tonne to over EUR 18,000/tonne.

- What is the discount rate (level, fixed, or varying [declining])?
- Has a sensitivity analysis been conducted? On what parameters?
- Are distributive consequences presented?

Overall the report concludes that there is room for improvement on how CBA are conducted in the subject area, notably in the areas of (1) improved transparency, (2) improved economic methodology to derive prices, and (3) the use of more consistent system boundary.

Jeswani et al. (2010) indicate that in some CBAs the upstream and downstream impacts are evaluated based on the inventory phase of a LCA. This way a CBA can account for both the direct and indirect costs and benefits of an option (BMP) – with indirect costs and benefits including the externalities (e.g., emissions and other environmental impacts) that receive a monetary value.

The introduction of CBA into LCA has occurred in Europe, in areas such as waste management and landfills. As a consultant in Denmark, Bo Weidema has conducted some of these LCA that has incorporated economic considerations. He notes that the economic considerations in a CBA are the typical costs and benefits to the various economic agents, changes in capital stock (investments), and can sometimes include considerations such as time (e.g., for commuting or sorting waste), and distributional issues (e.g., resulting incomes between certain sectors) (Bo Weidema, 2006). In his analyses he has used social indicators such as Years of Well Being Loss, Years Lost to Disability, and Quality Adjusted Life Years in LCA. A remaining issue is to place a monetary value on these indicators to allow for a complete cost benefit analysis.

Hanley and Spash (1993) highlight five problem areas that may arise when applying CBA to environmental issues[8]:

- **Valuation of non-market goods**: What valuation methods have been chosen, and how reliable and correct are the monetary value estimates? The results of some studies are used in others due to the costs and difficulties inherent in valuing non-market goods (the externalities). There are also risks of using outdated values.
- **Ecosystem complexity**: How are the effects on the environment (and ecosystem) predicted? This issue can be resolved within the LCA.
- **Discounting and discount rate**: Should discounting be used, and what level of social discount rate should be used? Over a long period of time, any discount rate greater than zero will place minimal to zero value on an event in the distant future. As an example, a

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[8] A discussion of these issues can be found in Villanueva et al. Paper and Cardboard – Recovery or Disposal?. Technical report Nr. 5, European Environment Agency, Copenhagen, Denmark, 2006.

BMP taken today may not produce the environmental impact until 10 or 15 years, and a high discount rate will generate a small net present value of the benefit, (e.g., a 7 percent discount rate has a discount factor of 0.13 after 30 years.) Some guidelines suggest using a 3 to 4 percent discount rate.

- **Institutional capture**: Is the CBA a truly objective way of making decisions or can institutions capture their own ends? This suggests the need for transparency.
- **Uncertainty and irreversibility**: How are these aspects included in the CBA? Sensitivity and risk analysis can be used to address these important issues.

An interesting issue is whether sunk costs should be included, or excluded, from analysis. These sunk costs are for investments and costs already incurred with existing systems. Some argue for their inclusion to provide a full comparison, whereas others suggest that they be excluded due to the costs being sunk[9]. A possible solution lies in the length of run of the analysis and the objective of the CBA – is it to compare two systems or to assess the costs and benefits of adopting a BMP relative to the sunk costs of the status quo.

Books and reports that have been prepared to assist in applying CBA to environmental issues. A Nordic CBA guideline developed to assist in waste management (Nordic Council of Ministers, 2007) and the previously mentioned OECD guideline (Pearce et al., 2006), designed to assist in conducting environmental CBA, are rather comprehensive documents.

A literature search restricted to North America did not generate any examples of using an environmental CBA or a CBA integrated with a LCA. Also while there are a number of LCAs in the agriculture area, there were no examples found of a CBA linked to a LCA in the agricultural area.

This literature review highlights a few key points. These include:

- A comprehensive (environmental) CBA must be integrated with a LCA, or have access to LCA findings for the base case as well as to considered alternatives
- Many of the comments in the literature revolve around issues of not having a full CBA linked to a LCA
- The literature is long on suggestions on how to improve LCA, but short on applications using CBA linked to a LCA

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[9] See for example Villanueva et al. Paper and Cardboard – Recovery or Disposal?. Technical report Nr. 5, European Environment Agency, Copenhagen, Denmark, 2006.

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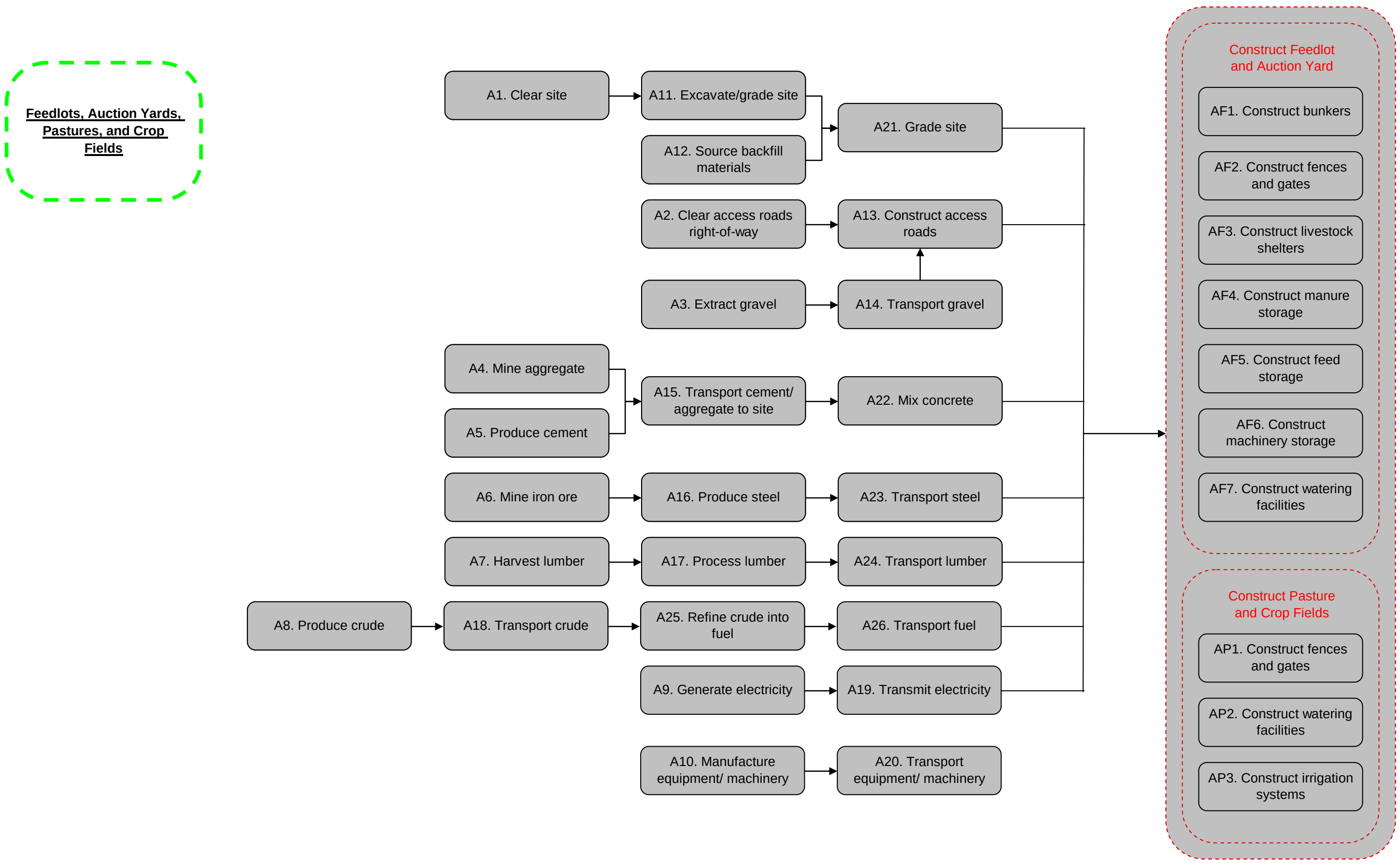
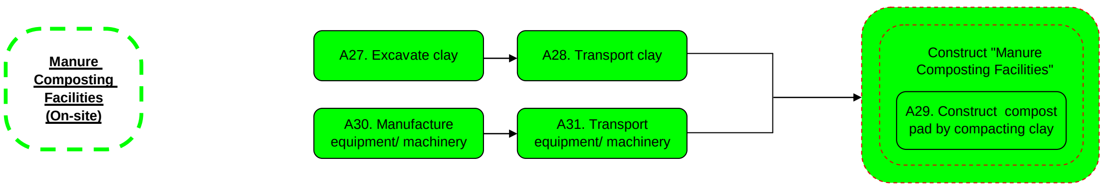
APPENDIX E

BMP 1 – COMPOSTING OF FEEDLOT MANURE

ACTIVITY MAPS AND DATA COLLECTION

A: Construction





Legend:

- Activity
- 🟩 New Activity for BMP Implementation
- 🟨 Activity - Affected by BMP Implementation
- ▨ Activity - Not Included
- Functional Unit

FIGURE BMP 1a

ACTIVITY MAP
BMP #1 - COMPOSTING AND OTHER SOLID MANURE MANAGEMENT PRACTICES
LIFE CYCLE ASSESSMENT - BEEF
ALBERTA AGRICULTURE AND RURAL DEVELOPMENT
Edmonton, Alberta

CRA

the PEMBINA institute
Sustainable Energy Solutions

B: Operation and Maintenance

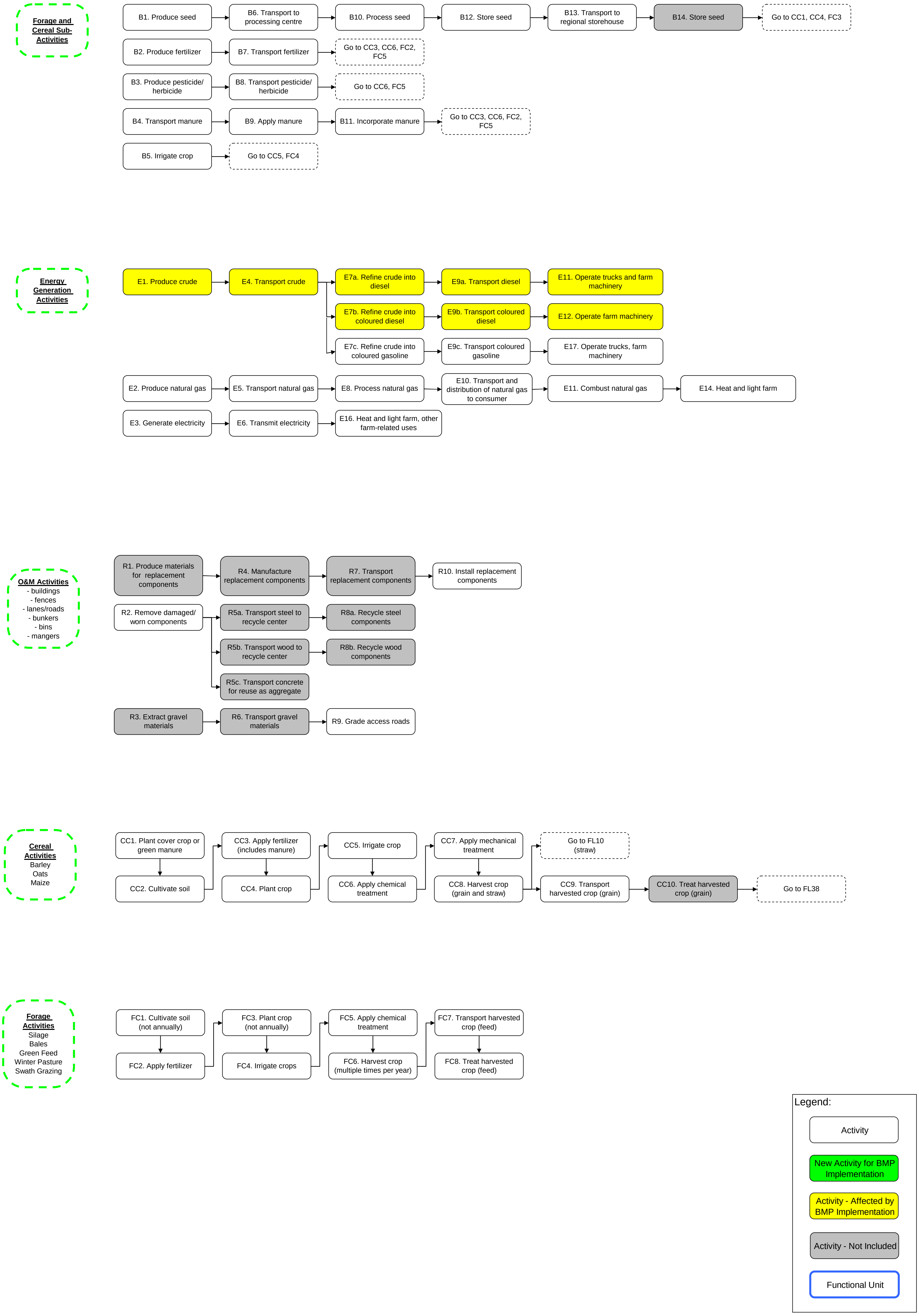


FIGURE BMP 1b

ACTIVITY MAP
BMP #1 - COMPOSTING AND OTHER SOLID MANURE MANAGEMENT PRACTICES
LIFE CYCLE ASSESSMENT - BEEF
ALBERTA AGRICULTURE AND RURAL DEVELOPMENT
Edmonton, Alberta

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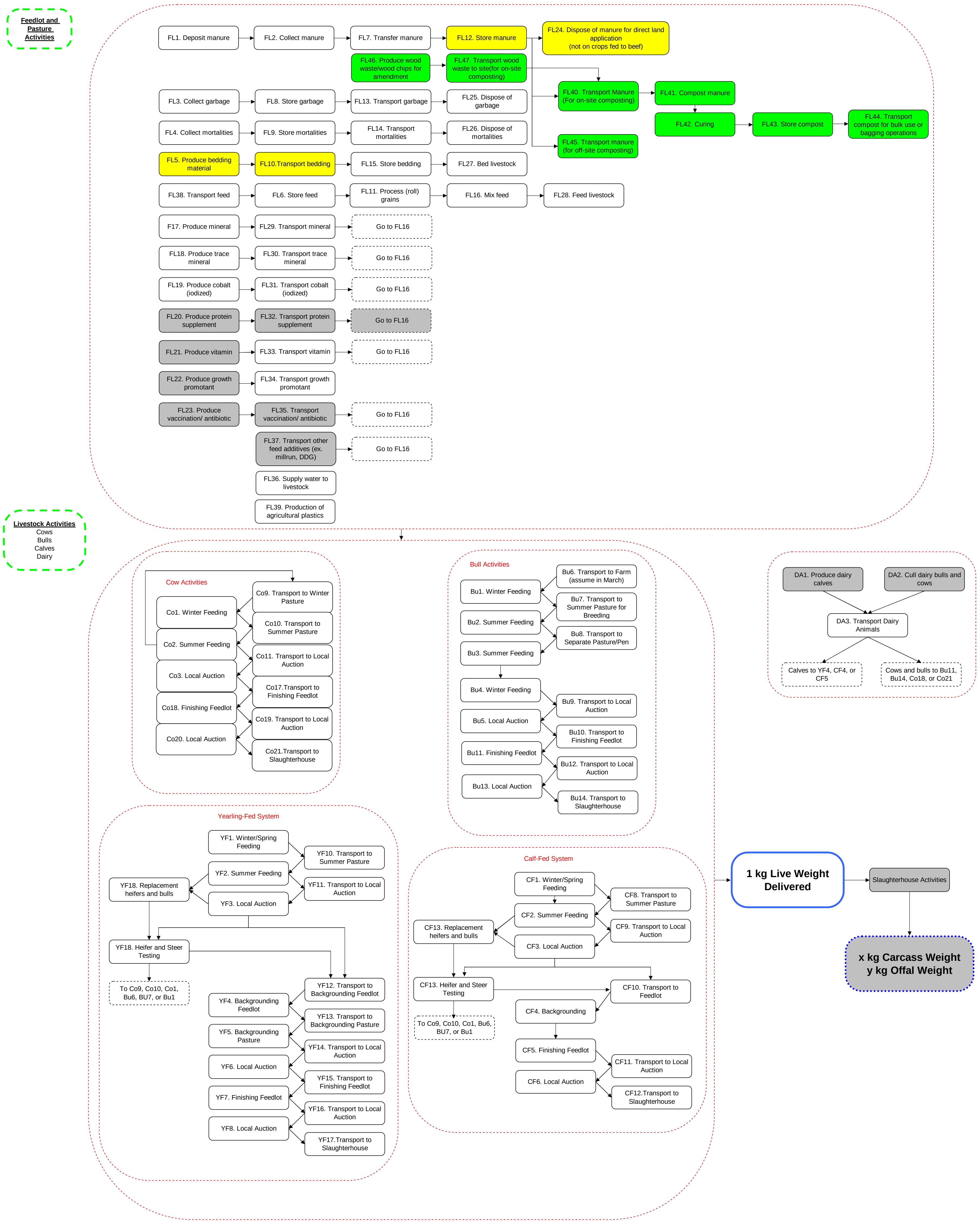
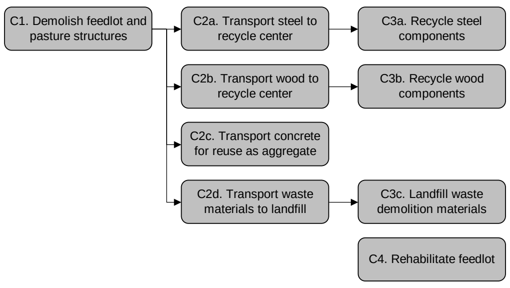
B: Operation and Maintenance



C: Decommissioning



Legend:

- Activity
- 🟩 New Activity for BMP Implementation
- 🟨 Activity - Affected by BMP Implementation
- ▨ Activity - Not Included
- Functional Unit

FIGURE BMP 1c

ACTIVITY MAP
BMP #1 - COMPOSTING AND OTHER SOLID MANURE MANAGEMENT PRACTICES
LIFE CYCLE ASSESSMENT - BEEF
ALBERTA AGRICULTURE AND RURAL DEVELOPMENT
Edmonton, Alberta

BMP 1 - DATA

References

Manure for composting

Total managed solid manure from feedlots	25,086,001,829	kg	From Feedlot & Pasture Act tab
Total managed solid manure for on-site composting	**3,762,900,274**	**kg**	From Feedlot & Pasture Act tab

Divide manure generation on feedlots (above) between northern and southern/central Alberta to account for the availability of amendment materials most realistic for composting (wood chips for northern and straw for southern/central)

Alberta 2001 Census Agricultural Regions and Census Divisions. Map 1. Statistics Canada. Assume Regions 6 and 7 are northern, and the rest southern/central.

Cattle in feedlots in northern regions of Alberta	151,642		Statistics Canada - Catalogue No. 95F0301XIE. Table 19.3 Cattle and calves, by province,
% of total	9%		Census Agricultural Region (CAR) and Census Division (CD), May 15, 2001
Cattle in feedlots in southern/central regions of Alberta	1,601,465		Statistics Canada - Catalogue No. 95F0301XIE. Table 19.3 Cattle and calves, by province,
% of total	91%		Census Agricultural Region (CAR) and Census Division (CD), May 15, 2001
Total managed solid manure for on-site composting (northern Alberta)	**325,487,106**	**kg**	Calculated from above
Total managed solid manure for on-site composting (southern/central Alberta)	**3,437,413,169**	**kg**	Calculated from above

Manure for composting - Northern Alberta (WOOD CHIPS for amendment material)

Composition of feedlot beef manure with bedding

Nitrogen (dry weight)	1.3%		Government of Alberta. Alberta Agriculture and Rural Development. Manure Composting
C:N ratio (dry weight)	18		Manual. Available at:
Moisture content	68%		http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex8875 (Note: C:N ratio
Bulk density (at that moisture content)	710	kg/m^3	stated at 1.8 but not realistic. Calculator on this website indicates 18 as the ratio; therefore

Composition of wood waste (chips) for composting amendment material

Nitrogen (dry weight)	0.14%		Government of Alberta. Alberta Agriculture and Rural Development. Manure Composting
C:N ratio (dry weight)	212		Manual. Available at:
Moisture content	15%		http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex8875
Bulk density (at that moisture content)	264	kg/m^3	

Amount of amendment material required (wood chips)

Definitions and values:

a		mass of amendment per kg manure	Factor to be calculated
b	1	kg manure	Assumed
M	50.0%	desired mix moisture content	Government of Alberta. Alberta Agriculture and Rural Development. Manure Composting Manual. Available at:
Ma	15%	moisture content of ingredient a	From above
Mb	68%	moisture content of ingredient b	From above
%Ca	not req'd	percent carbon of ingredient a (dry weight basis)	
%Cb	not req'd	percent carbon of ingredient b (dry weight basis)	
%Na	0.135%	percent nitrogen of ingredient a (dry weight basis)	From above
%Nb	1.3%	percent nitrogen of ingredient b (dry weight basis)	From above

BMP 1 - DATA

			References
R	30	desired C:N ratio of mix	Government of Alberta. Alberta Agriculture and Rural Development. Manure Composting Manual. Available at:
Ra	212.0	C:N ratio of ingredient a	From above
Rb	18	C:N ratio of ingredient b	From above

Ingredient a	wood chips
Ingredient b	beef feedlot manure

Mass of amendment per kg manure:

$$a = \frac{\%\ Nb}{\%\ Na} \times \frac{(R-Rb)}{(Ra-R)} \times \frac{(1-Mb)}{(1-Ma)}$$

$$= 0.24 \text{ kg}$$

Total mass of woodchips required **77,801 tonnes**

Moisture content of composting materials

Moisture content check of composting materials:

$$= \frac{\text{weight of water in ingredient a + weight of water in ingredient b}}{\text{total weight of all ingredients}}$$

$$= \frac{(a * Ma) + (b * Mb)}{a + b}$$

$$= 57.8\%$$

Nitrogen content in composting materials

Nitrogen content in composting materials: (for 1 kg manure and 0.24 kg wood chips)

Dry matter of manure	0.32	kg
Dry matter of wood chips	0.20	kg
Mass of nitrogen in manure	0.00416	kg
Mass of nitrogen in wood chips	0.000274	kg
Total nitrogen in composting materials	0.004434	kg
Dry matter of composting materials (check)	0.523	kg
% nitrogen content of composting materials	0.85%	

Phosphorus content in composting materials

Mass of phosphorus in manure (dry matter basis)	0.37%	Bremer,V.R. et al. Total and Water Soluble Phosphorus Content of Feedlot Cattle Feces and Manure. Animal Science Department. Nebraska Beef Cattle Reports. University of Nebraska.
No losses in phosphorus content after composting		Saskatchewan Agriculture, Composting Solid Manure, December 2008. Available at: http://www.agriculture.gov.sk.ca/Composting_Solid_Manure

Typical starting and ending mass quantities and other characteristics for composting

Water loss in composting materials from composting	80%	F.J. Larney, X. Hao. Composting as a management alternative for beef feedlot manure in southern Alberta, Canada. Nutrient and Carbon Cycling in Sustainable Plant-Soil Systems. Available at: http://www.ramiran.net/doc04/Proceedings%2004/Larney.pdf
Solids loss in composting materials from composting	25%	
Volume loss for composting materials due to composting	50%	Saskatchewan Agriculture, Composting Solid Manure, December 2008. Available at: http://www.agriculture.gov.sk.ca/Composting_Solid_Manure

Manure Start (kg)	Amendment Start (kg)	Mix Start (kg)	Compost End (kg)

BMP 1 - DATA

					References
Manure	1000	239	1239	536	Assumed
Water	680	36	716	143	Calculated based on information above
Solids	320	203	523	392	Calculated based on information above
Nitrogen	4.16	0.27	4.43	3.33	Calculated based on information above. Decrease in nitrogen due to reduced solids.
Phosphorus	1.184	0	1.184	1.184	Calculated based on information above
Volume (m^3)	1.408	0.905	2.314	1.157	Calculated based on information above
Bulk density (kg/m^3)	710	264	624	463	Calculated based on information above
Mass reduction (%)	-	-	-	46%	Calculated based on information above

Manure for composting - Southern / Central Alberta (STRAW for amendment material)

Composition of feedlot beef manure with bedding

Nitrogen (dry weight)	1.3%		Government of Alberta. Alberta Agriculture and Rural Development. Manure Composting
C:N ratio (dry weight)	18		Manual. Available at:
Moisture content	68%		http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex8875 (Note: C:N ratio
Bulk density (at that moisture content)	710	kg/m^3	stated at 1.8 but not realistic. Calculator on this website indicates 18 as the ratio; therefore

Composition of general straw for composting amendment material

Nitrogen (dry weight)	1.1%		Government of Alberta. Alberta Agriculture and Rural Development. Manure Composting
C:N ratio (dry weight)	48		Manual. Available at:
Moisture content	15.5%		http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex8875
Bulk density (at that moisture content)	207.5	kg/m^3	

Amount of amendment material required (general straw)

Definitions and values:

a		mass of amendment per kg manure	Factor to be calculated
b	1	kg manure	Assumed
M	50.0%	desired mix moisture content	Government of Alberta. Alberta Agriculture and Rural Development. Manure Composting Manual. Available at:
Ma	15.5%	moisture content of ingredient a	From above
Mb	68%	moisture content of ingredient b	From above
%Ca	not req'd	percent carbon of ingredient a (dry weight basis)	
%Cb	not req'd	percent carbon of ingredient b (dry weight basis)	
%Na	1.1%	percent nitrogen of ingredient a (dry weight basis)	From above
%Nb	1.3%	percent nitrogen of ingredient b (dry weight basis)	From above
R	30	desired C:N ratio of mix	Government of Alberta. Alberta Agriculture and Rural Development. Manure Composting Manual. Available at:
Ra	48.0	C:N ratio of ingredient a	From above
Rb	18	C:N ratio of ingredient b	From above

Ingredient a	straw - general
Ingredient b	beef feedlot manure

Mass of amendment per kg manure:

$$a = \frac{\%\ Nb}{\%\ Na} \times \frac{(R-Rb)}{(Ra-R)} \times \frac{(1-Mb)}{(1-Ma)}$$

$$= 0.30\ kg$$

BMP 1 - DATA

References

Total mass of general straw required **1,025,615 tonnes**

Moisture content of composting materials

Moisture content check of composting materials:

$$= \frac{\text{weight of water in ingredient a + weight of water in ingredient b}}{\text{total weight of all ingredients}}$$

$$= \frac{(a * Ma) + (b * Mb)}{a + b}$$

$$= 55.9\%$$

Nitrogen content in composting materials

Nitrogen content in composting materials: (for 1 kg manure and 0.24 kg wood chips)

Dry matter of manure	0.32 kg
Dry matter of straw	0.25 kg
Mass of nitrogen in manure	0.00416 kg
Mass of nitrogen in straw	0.002773 kg
Total nitrogen in composting materials	0.006933 kg
Dry matter of composting materials (check)	0.572 kg
% nitrogen content of composting materials	1.21%

Phosphorus content in composting materials

Mass of phosphorus in manure (dry matter basis)	0.37%	Bremer,V.R. et al. Total and Water Soluble Phosphorus Content of Feedlot Cattle Feces and Manure. Animal Science Department. Nebraska Beef Cattle Reports. University of Nebraska.
No losses in phosphorus content after composting		Saskatchewan Agriculture, Composting Solid Manure, December 2008. Available at: http://www.agriculture.gov.sk.ca/Composting_Solid_Manure

Typical starting and ending mass quantities and other characteristics for composting

Water loss in composting materials from composting	80%	F.J. Larney, X. Hao. Composting as a management alternative for beef feedlot manure in southern Alberta, Canada. Nutrient and Carbon Cycling in Sustainable Plant-Soil Systems. Available at: http://www.ramiran.net/doc04/Proceedings%2004/Larney.pdf
Solids loss in composting materials from composting	25%	
Volume loss for composting materials due to composting	50%	Saskatchewan Agriculture, Composting Solid Manure, December 2008. Available at: http://www.agriculture.gov.sk.ca/Composting_Solid_Manure

	Manure Start (kg)	Amendment Start (kg)	Mix Start (kg)	Compost End (kg)	
Manure	1000	298	1298	574	Assumed
Water	680	46	726	145	Calculated based on information above
Solids	320	252	572	429	Calculated based on information above
Nitrogen	4.16	2.77	6.93	5.20	Calculated based on information above. Decrease in nitrogen due to reduced solids.
Phosphorus	1.184	0	1.184	1.184	Calculated based on information above
Volume (m^3)	1.408	1.438	2.846	1.423	Calculated based on information above
Bulk density (kg/m^3)	710	208	595	404	Calculated based on information above
Mass reduction (%)	-	-	-	43%	Calculated based on information above

Total weight of manure **3,762,900 tonnes**

BMP 1 - DATA

References

Total weight of wood chips (amendment)	**77,801**	**tonnes**
Total weight of straw (amendment)	**1,025,615**	**tonnes**
Total weight of compost	**2,148,560**	**tonnes**
Total volume of manure	**5,299,860**	**m^3**
Total volume of wood chips (amendment)	**294,700**	**m^3**
Total volume of straw (amendment)	**4,942,723**	**m^3**
Total volume of compost	**5,268,642**	**m^3**

Typical windrow pile sizing information (for detailed info to be used in this model, please refer to BMP 1-Windrow Sizing tab)

	Min. (m)	Max. (m)	
Height	1	2.8	Government of Alberta. Alberta Agriculture and Rural Development. Manure Composting Manual. Available at:
Width	3	6	
Front End Loader	Min. (ft)	Max. (ft)	
Height	6	12	Alberta Environment. Leaf and Yard Waste Composting Manual. 1st Edition, 1st Printing. April 1998. Revised December 1999.
Width	10	20	
OMAFRA suggest windrows no higher than 8 ft and no wider than 12 ft			Ontario Ministry of Agriculture, Food & Rural Affairs. Agricultural Composting Basics. 2005. Available at: http://www.omafra.gov.on.ca/english/engineer/facts/05-023.htm
Values to use in model:	See BMP 1-Windrow Sizing tab		

Construction activities

Total area of clay composting pads			
Front end loader	6748920.327	m^2	From BMP 1-Windrow Sizing tab
CT 1010TX (windrow turner)	0	m^2	From BMP 1-Windrow Sizing tab
Area requirements for manure storage	9	months	Province of Alberta. Agricultural Operation Practices Act. Standards and Administration Regulation. Alberta Regulation 267/2001. Section 10.1.
(manure storage facilities must be large enough to store all manure produced by the operation for at least 9 consecutive months)			
Typical max height of manure piles	2.5	m	Guidelines to Beneficial Management Practices: environmental Manual for Poultry Producers in Alberta. November 2003. Section 7.
** Assume that the required area above is already available at the feedlots, and therefore, the existing pad will be extended to achieve the area required for composting			
Total manure required to be stored	9,132,508,124	kg	Using manure generated by heifers and steers, and including only 9 months of backgrounding and feedlot manure for storage.
Bulk density of feedlot manure	710	kg/m3	From above data
Total volume of this manure	12,862,687	m3	
Assume manure stockpiled in a manner to optimize area (no accounting for slopes, etc. to be conserv	**2,268**	**m^2**	
Adjusted composting area required (in addition to what is already available)			
Front end loader	**6,748,920**	**m^2**	From BMP 1-Windrow Sizing tab

BMP 1 - DATA

			References
CT 1010TX (windrow turner)	**0**	**m^2**	From BMP 1-Windrow Sizing tab
Thickness of clay pad	0.5	m	Government of Alberta. Alberta Agriculture and Rural Development. Facilities and Environment: Composting Animal Manures. Available at: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/beef11831
Permeability of clay pad	<5 x 10^{-8}	m/sec	Government of Alberta. Alberta Agriculture and Rural Development. Facilities and Environment: Composting Animal Manures. Available at: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/beef11831
2% slope also required for clay composting pad, with run-on control system to prevent surface water to flow onto pad, and run-off control system to protect surface water quality. **Assume no run-on or run-off in model.**			Government of Alberta. Alberta Agriculture and Rural Development. Facilities and Environment: Composting Animal Manures. Available at: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/beef11831
Volume of clay soil needed (at permeability above)	**3,374,460**	**m^3**	
Typical bulk density of clay soil	1.3	g/cm^3	Wikipedia. Porosity. Available at: http://en.wikipedia.org/wiki/Porosity
	1,300	kg/m^3	
Mass of clay needed	**4,386,798**	**tonnes**	
Mass of clay to be transported to the site	**4,386,798**	**tonnes**	From Summary Tab
Volume	**3,374,460**	**m^3**	
Mass of clay available at the site	**0**	**tonnes**	From Summary Tab
Volume	**0**	**m^3**	
Excavating clay			
(Assume 330D Cat - Large Hydraulic Excavator)			
(Fuel consumption and operating speed taken from similar model)			
Operating speed	160	m^3/hr	http://www.aefinley.com/uploads/products/pdfs/20081218121127592815.pdf
Fuel Consumption	48	L/hr	http://www.aefinley.com/uploads/products/pdfs/20081218121127592815.pdf
Time to excavate	21,090	hrs	
Fuel consumed	1,012,338	L diesel	
	895,919	**kg diesel**	
Transport clay - assumed long distance	**250**	**km**	Assumed distance for transporting clay to site (i.e. from Calgary to Lethbridge)
Compacting clay			
(Soil compactor SWR214)			
Rated power	85	kW	http://www.alibaba.com/product-gs/252377194/Soil_Compactor_SWR214.html
Rated fuel consumption	215	g/kW*h	
	21	L/hr	
Compaction requirements for clay pad	0.5	ha per day	Typical construction knowledge of compacting clay (10 hrs per day)
	5000	m2/day	
Time to compact (assuming 10 hr days)	13,498	hrs	
Fuel consumed	278,727	L diesel	
	246,673	**kg diesel**	
Vermeer CT1010TX Compost Turner			

BMP 1 - DATA

			References
# of units required	**0**	**units**	See BMP 1-Windrow Sizing tab
weight	43,000	lbs	Vermeer. CT1010TX Compost Turner. Available at: http://www2.vermeer.com/vermeer/AP/en/N/equipment/compost_turners/ct1010tx
Total weight of turners to transport	**0**	**lbs**	
	0	kg	
Closest Vermeer dealer located in Saskatchewan. Assumed transport distance	**500**	**km**	

Windrow composting time periods and turning requirements

	Min. (days)	Max. (days)	
Active Period	21	40	Government of Alberta. Alberta Agriculture and Rural Development. Manure Composting Manual. Available at:
		120	Saskatchewan Agriculture, Composting Solid Manure, December 2008. Available at: http://www.agriculture.gov.sk.ca/Composting_Solid_Manure
Curing	30		Government of Alberta. Alberta Agriculture and Rural Development. Manure Composting Manual. Available at:
	30	90	Saskatchewan Agriculture, Composting Solid Manure, December 2008. Available at: http://www.agriculture.gov.sk.ca/Composting_Solid_Manure
Total composting and curing time (using windrow turner)	60	120	Basic On-Farm Composting Manual. Final Report. Prepared for The Clean Washington Center. May 1997. Prepared by Peter Moon, Land Technologies.

Pathogen reduction by achieving 55 degrees C for a minimum of 15 days		Alberta Environment. Leaf and Yard Waste Composting Manual. 1st Edition, 1st Printing. April 1998. Revised December 1999.
Pathogen reduction by achieving 55 degrees C for a minimum of 15 days, and cure for 6 months turning at least one time per month		Ontario Regulation 101/94. Recycling and Compost of Municipal Waste.
Turning frequency		
Beginning of composting period	1 turn/day	Alberta Environment. Midscale Composting Manual. 1st Edition. First Printing. December
Closer to end of composting period	1 turn/week	Alberta Environment. Midscale Composting Manual. 1st Edition. First Printing. December
Initial 2-3 weeks	turn at regular intervals	

Turning schedule to be used in model	Days	Turning Rate	
Active composting	40	1 turn/day for first 2 weeks	Assumed based on information above
		1 turn/week after first 2 weeks	Assumed based on information above
Curing	90	1 turn/month	Assumed based on information above

Transportation costs of trucking manure

Total manure to be trucked off feedlots	21,323,101,554	kg	
Transportation distance	7	km	
Fuel consumption of transport truck	35.1	L/100 km	Canadian Vehicle Survey 2005, Summary Report. Available at: http://oee.nrcan.gc.ca/Publications/statistics/cvs05/chapter5.cfm?attr=0
Rated load weight for heavy duty truck	8,847	kg	Dieselnet. Canada: On-road vehicles. Available at: http://www.dieselnet.com/standards/ca/#hdv
Number of trucks required	2,410,207	trucks	
Diesel consumed	5,921,879	L	

BMP 1 - DATA

Additional Labour for Composting

	Min. (hrs)	Max. (hrs)	References
Man-hours per week (with windrow turner)	4	16	Basic On-Farm Composting Manual. Final Report. Prepared for The Clean Washington Center. May 1997. Prepared by Peter Moon, Land Technologies.

Front end loader	**474,445 hrs**	Calculated from BMP 1-Windrow Sizing tab
Vermeer CT1010TX Compost Turner	**0 hrs**	Calculated from BMP 1-Windrow Sizing tab

Compost Trucking Requirements

Typical truck volume for transporting manure or compost	12	m^3	Saskatchewan Agriculture, Composting Solid Manure, December 2008. Available at: http://www.agriculture.gov.sk.ca/Composting_Solid_Manure
Manure			
Total volume of manure	5,299,860	m^3	
Truck trips required	441,655	trips	
Mass of manure per truck	8,520	kg	
Mass of solids per truck	2,726	kg	
Mass of N per truck	35	kg	
Mass of P per truck	10	kg	
Compost			
Total volume of compost	5,268,642	m^3	
Truck trips required	439,053	trips	
Mass of compost per truck	4,843	kg	
Mass of solids per truck	3,618	kg	
Mass of N per truck	44	kg	
Mass of P per truck	10	kg	

Diesel Requirements for Composting

Diesel required to compost	11,880,334	L diesel	See BMP 1-Windrow Sizing tab

Emissions from composting manure

Assuming proper composting techniques, there is not expected to be any emissions from composting beef manure, curing, and storage of the compost (CH_4 and N_2O).

BMP 1 - Windrow Sizing Information

Windrow Sizing	*Available on-site Loader*	*Vermeer Turner CT 1010TX*		
height	3.5	2.7	m	References: below (Co-Composter)
width	7.0	3.0	m	Cambridge Leaf & Yard Waste Composting Pad operations
length	100	100	m	http://www2.vermeer.com/vermeer/AP/en/N/equipment/compost_turners/ct1010tx
Pad Sizing				
Spacing between windrows	3	0.1	m	
Buffer at edge of pad	3	3	m	
		10		

Co-Composter vers. 2a **November 15, 2001** **Cornell University**

Written by Douglas Haith, Thomas Crone, Adam Sherman, Julie Lincoln, Jeffrey Reed, Suzanne Saidi, Joshua Trembley, with assistance from Peter Wright, Jean Bonhotal, Molly Moffe, Ellen Harrison, A. Edward Staehr, Wayne Knoblauch.

Model used for many composting inputs in this tab

Estimation of Fuel Use ***{referred to in Turning & Handling Costs sheet of model above}***

Fuel was estimated using .048 gal/hp-hr. (Downs, 1998) Annual diesel fuel was calculated by multiplying the appropriate horsepower, weekly hours and .048gal/hr-hp. This was then multiplied by 52 to report annual diesel consumption in gallons.

In order to estimate diesel use for the self powered, and self propelled turner (Systems 3.1 & 3.2) the same calculation was made. The horsepower of each turner was known and the same calculation was carried out.

Note: Fuel consumption might not be as efficient with the turner as the tractors. (Downs, 1998)

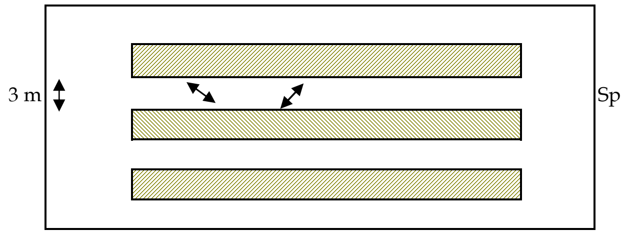
Fuel and Electrical Costs

{See Section N in the Background sheet for sources and explanation of fuel estimates.}

Required Equipment	Type of Fuel	Estimated Use	Units	Estimated fuel Use[a] (gal/hr)[b]	Option #1 Fuel Use (gal/yr)	Option #2 Fuel Use (gal/yr)	Option #3 Fuel Use (gal/yr)	Option #4 Fuel Use (gal/yr)
Diesel Use								
Turning and Handling:								
Front Loader, 135 hp, 3 yd bucket	diesel	6.51	hr/wk	6.615			1525	

a: Calculated with tractors using .049 gal/hp-hr doing average work.

1/ FRONT END LOADER (typical)			**References**	majority of inputs from co-composter model
Equipment Specs			Cambridge Leaf & Yard Waste Composting Pad operations	
Bucket Size	2.29	m^3	Assumes 3 yards	
Operating speed	300	m^3/hr	About 150 tonnes/hr	from co-composter model
Horsepower	135	hp	Typical	from co-composter model
Fuel Consumption	25	L/hr	http://thedieselgarage.com/forums/showthread.php?t=50336	
Windrow Size (Triangular)			Calculated with tractors using .049 gal/hp-hr doing average work.	
Height	3.5		- from co-composter model (6.6 gal/hr)	



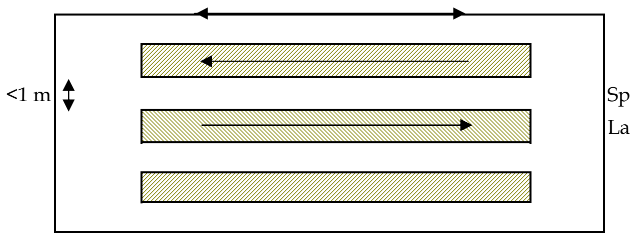
Spacing between windrows - enough aisle room for loader to maneuver

BMP 1 - Windrow Sizing Information

Width	7.0

2/ CT1010TX (SIDE-THROW)

Operating Speed	1,911	m^3/hr	min	http://www2.vermeer.com/vermeer/LA/en/N/equipment/compost_turners/ct1010tx
	3,058	m^3/hr	max	
	2,485	m^3/hr	average	
Horsepower requirements	215	hp		
Fuel Consumption	45	L/hr		Engine option One - 12.1 gal/hr
Windrow Size				
Height	2.7			
Width	3.0			



Spacing between windrows - minimal

Larger space is required at ends for the large turning radius

Estimated Sizing and Operating Requirements

Manure	3,762,900	tonnes
Amendment	1,103,416	tonnes
	4,866,316	**tonnes**

Active composting time	40	days	Curing time	90	days	
	6	weeks		13	weeks	
Density	0.62	tonnes/m3	Density	0.62	tonnes/m3	Assume same density, weight and volume as during active composting time.
Weight	4,866,316	tonnes	Weight	4,866,316	tonnes	
Volume	7,799,092	m3	Volume	7,799,092	m3	
Turning Frequency			Turning Frequency			
Weeks 1-2	5.5	turns per week	Weeks 7-19	0.25	turns per week	Assume operational 7 days per week
Weeks 3-6	1	turn per week				

Windrow Sizing	***Loader***	***CT 1010TX (straddle)***		
height	3.5	2.7	m	
width	7.0	3.0	m	
length	100.0	100.0	m	
Pad Sizing				
Spacing between windrows	3	0	m	Illustrations of pad layouts above
Buffer at edge of pad	3	3	m	For turning radius and operating area
		10	m	

No. of Windrow Piles

Loader	6,367	According to % breakdown in Summary Tab
CT1010TX	0	

Pad Area

Loader	**6,748,920**	**m^2**
	1,667.7	**acres**
CT1010TX	**0**	**m^2**
	0.0	**acres**

Storage

Storage Area	0	m^2	Additional area for storing finished material prior to shipping off-site. Not required, but may be considered.
	0.0	acres	Assumed 0

BMP 1 - Windrow Sizing Information

Total Units Required

Operating Hours	8	hours / day	Assumed
	7	days / week	

Operating Time	*Weeks 1-2* (hrs/day)	*Weeks 3-6* (hrs/day)	*Weeks 7-19* (hrs/day)	**TOTAL**		Max Hrs per period	Required # of Machines to process all manure		**Req'd # of machines based on divide**	
Loader	20,426	3,714	928	25,069	hours	20,426	2,553	units	**2,553**	**units**
CT1010TX (straddle)	2,466	448	112	3,027	hours	2,466	308	units	**0**	**units**

Diesel Fuel Consumption	L/day	L/day	L/day	To process all manure		**Req'd diesel based on divide**	
Loader	511,482	92,997	23,249	12	M Litres/19 wks	**12**	**Million Litres / unit / cycle of 19 weeks**
CT1010TX	112,038	20,370	5,093	3	M Litres/19 wks	**0**	**Million Litres / unit / cycle of 19 weeks**

Comments

Total number of feedlots in Alberta currently 4000 Alberta Beef Producers. Beef Production. Available at: http://albertabeef.org/industry/beef-production-chain/

About 100 feedlots with capacities over 1,000 head produce 75% of the finished beef cattle in the province.

Alberta Bunk Capacity	# of lots
1,000 - 5,000	127
5,001 - 10,000	45
10,001 - 15,000	15
15,001 - 20,000	8
20,000 and over	13

Canada Cattle: Alberta Feedlot Industry Demographics. Available at: www.cattlenetwork.com/Canada-Cattle. Accessed on May 29, 2005.

BMP 1 - Improved manure management practice (2010 Baseline)
Composting of solid managed manure stream produced in fedlots

Assumed Percent Composting On-Site (only affects feedlot)	15%	(% can be adjusted here for the entire model)	
% farms using existing equipment for on-site composting	100%	(% can be adjusted here for the entire model)	(assumed)
% farms purchasing new windrow turners for on-site composting	0%	(updates automatically)	
% farms using clay source on-site for compost pad	0%	(% can be adjusted here for the entire model)	(assumed)
% farms purchasing and shipping clay to site for compost pad	100%	(updates automatically)	
Assumed Percent Composting Off-site **or Off-site Direct Land Application** (only affects feedlots) (only affects feedlot)	85%		
Total number of animals (only affects feedlots)	319,871	animals	
Total weight affected to slaughter (only affects feedlots)	194,459	tonnes	

Provided by ARD
2010 Baseline Scenario

Total GHG emissions	2.12E+10 kg CO2e
Total acidification	3.12E+07 kg SO2-Eq
Total eutrophication	5.74E+06 kg PO4-Eq
Total non-renewable energy	3.53E+11 MJ-Eq

	COW/CALF OPERATIONS								FEEDLOT OPERATIONS							
	BMP 1		Baseline (2001)		Change		Per Unit Market Value	Total Impact	BMP 1		Baseline (2001)		Change		Per Unit Market Value	Total Impact
	(amount)	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*	*($/unit)*	*($ Million)*	*(amount)*	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*	*($/unit)*	*($ Million)*
Inputs with Change																
Production of pesticide/herbicide																
Production of chemical fertilizer																
Production of bedding																
Production of min., trc min., cobalt, protein suppl., vit., antibiotic																
Purchase of chemical fertilizer																
Urea, as N, at regional storehouse																
Ammonia, liquid, at regional storehouse																
Monoammonium phosphate, as P2O5, at regional storehouse																
Monoammonium phosphate, as N, at regional storehouse																
Ammonium sulphate, as N, at regional storehouse																
Purchase of manure for land application																
Purchase of pesticide/herbicide																
Purchase of seed for barley																
Purchase of seed for barlye silage																
Purchase of seed for alfalfa/grass hay																
Purchase of water to irrigate crops																
Purchase of amendment materials (wood waste/wood chips)									7.78E+07	kg	0	kg	7.78E+07	kg	$0.13	$10.29
Purchase of amendment materials (straw)									1.03E+09	kg	0	kg	1.03E+09	kg	$0.06	$59.81
Purchase of composting equipment (Windrow turner)									0	turners	0	turners	0	turners	$175,000	$0.00
Purchase of clay for composting pad and compaction									3.37E+06	m^3	0	m^3	3.37E+06	m^3	$28	$94.48
Compaction of clay (source on-site)									0.00E+00	m^3	0	m^3	0.00E+00	m^3	$15	$0.00
Transportation costs for clay to site (250 km assumed)									4.39E+06	tonne	0	tonne	4.39E+06	tonne	$25	$109.67
Purchase of alfalfa/grass hay	6.59E+09	kg	6.59E+09	kg	0	kg	-	-								
Purchase of barley									4.49E+09	kg	4.49E+09	kg	0	kg	-	-
Purchase of barley silage									7.58E+09	kg	7.58E+09	kg	0	kg	-	-
Purchase of bedding	5.09E+08	kg	5.09E+08	kg	0	kg	-	-	4.22E+08	kg	4.22E+08	kg	0	kg	-	-
Purchase of animal shelters, wind breakers, fencing, etc.	0	units	0	units	0	units	-	-								
Purchase of ionophores	0	kg	0	kg	0	kg	-	-								
Purchase of RAC									0	kg	0	kg	0	kg	-	-
Purchase of min., trc min., cobalt, protein suppl., antibiotic	7.91E+07	kg	7.91E+07	kg	0	kg	-	-	1.45E+08	kg	1.45E+08	kg	0	kg	-	-
Purchase of vitamins	1,684	kg	1,684	kg	0	kg	-	-	1.76E+05		1.76E+05	kg	0	kg	-	-
Purchase of RFI testing (includes transportation)	0	tests	0	tests	0	tests	-	-	0	tests	0	tests	0	tests	-	-
Fuel/energy required to operate composting equipment									1.19E+07	L	0	L	1.19E+07	L	$0.75	$8.89
Fuel consumed to transport barley and barley silage																
Fuel consumed to transport alfalfa/grass hay																
Fuel consumed for cropping activities																
Fuel consumed to bed livestock (change)	0	L	0	L	0	L	-	-	0	L	0	L	0	L	-	-
Fuel consumed to transport garbage (change)	0	L	0	L	0	L	-	-	0	L	0	L	0	L	-	-
Fuel consumed to transport bedding (change)																
Fuel consumed to feed livestock (change)	0	L	0	L	0	L	-	-	0	L	0	L	0	L	-	-
Fuel consumed to collect manure (change)									0	L	0	L	0	L	-	-
Fuel consumed to transport manure off-site for disposal (change)									5.92E+06	L	6.97E+06	L	-1.05E+06	L	$0.75	-$0.78
Fuel cons. to transp. min., trc min., cob., prot. suppl., vit., antibiotic																
Fuel consumed to transport livestock for testing	0	L	0	L	0	L	-	-	0	L	0	L	0	L	-	-
Labour (change)	0	hrs	0	hrs	0	hrs	-	-	4.74.E+05	hrs	0	hrs	4.74.E+05	hrs	$16.22	$7.70
Working capital interest	0	$	0	$	0	$	-	-	0	$	0	$	0	$		$0.00
Total Input Value Change								**$0.00**								**$290.06**
Outputs with Change																
Manure sold for land application									2.13E+10	kg	2.51E+10	kg	-3.76E+09	kg	$0.00	$0.00
Compost sold for land application									2.15E+06	tonne	0	tonne	2.15E+06	tonne	$6.00	$12.89
Sale price for beef to slaughterhouse (change)									0	$	0	$	0	$	-	-
Total Output Value Change								**$0.00**								**$12.89**

CHANGE IN OVERALL GHG EMISSIONS

	COW/CALF OPERATIONS						FEEDLOT OPERATIONS						BEEF INDUSTRY					
	BMP 1		Baseline (2001)		Change		BMP 1		Baseline (2001)		Change		BMP 1		Baseline (2001)		Change	
	(amount)	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*	*(amount)*	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*	*(amount)*	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*
BEEF ACTIVITIES - SOIL AND CROP																		
Manure generation	3.45E+10	kg	3.45E+10	kg	0	kg	1.89E+10	kg	1.89E+10	kg	0	kg						
Methane emissions from stored manure	1.49E+08	kg CO_2e	1.49E+08	kg CO_2e	0	kg CO_2e	1.34E+08	kg CO_2e	1.44E+08	kg CO_2e	-9.97E+06	kg CO_2e						
Enteric fermentation emissions	7.03E+09	kg CO_2e	7.03E+09	kg CO_2e	0	kg CO_2e	3.56E+09	kg CO_2e	3.56E+09	kg CO_2e	0	kg CO_2e						
N_2O emissions from stored manure (direct)	1.83E+09	kg CO_2e	1.83E+09	kg CO_2e	0	kg CO_2e	3.60E+08	kg CO_2e	3.27E+08	kg CO_2e	3.35E+07	kg CO_2e						
N_2O emissions from stored manure (indirect)	4.04E+08	kg CO_2e	4.04E+08	kg CO_2e	0	kg CO_2e	3.06E+08	kg CO_2e	3.06E+08	kg CO_2e	0	kg CO_2e						
N_2O emissions from cropping and land use													9.57E+08	kg CO_2e	9.57E+08	kg CO_2e	0	kg CO_2e
Total P emissions from run-off													4.15E+06	kg PO_4-eq	4.15E+06	kg PO_4-eq	0	kg PO_4-eq
Soil Carbon Change in Soil From Land Use													-2.36E+08	kg CO_2e	-2.36E+08	kg CO_2e	0	kg CO_2e
Direct CO2 emissions from managed soils													1.89E+08	kg CO_2e	1.89E+08	kg CO_2e	0	kg CO_2e
ADDITIONAL ACTIVITIES																		
Construction	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	5.89E+06	kg CO_2e	0	kg CO_2e	5.89E+06	kg CO_2e						
Forage and cereal sub-activities													1.20E+09	kg CO_2e	1.20E+09	kg CO_2e	0	kg CO_2e
Energy generation and consumption activities	2.81E+09	kg CO_2e	2.81E+09	kg CO_2e	0	kg CO_2e	1.10E+09	kg CO_2e	1.04E+09	kg CO_2e	5.74E+07	kg CO_2e						
O&M activities	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e						
Cereal activities													3.38E+08	kg CO_2e	3.38E+08	kg CO_2e	0	kg CO_2e
Forage activities													2.86E+08	kg CO_2e	2.86E+08	kg CO_2e	0	kg CO_2e
Feedlot and pasture activities	3.20E+06	kg CO_2e	3.20E+06	kg CO_2e	0	kg CO_2e	1.39E+08	kg CO_2e	1.40E+08	kg CO_2e	-1.74E+06	kg CO_2e	4.02E+08	kg CO_2e	3.04E+08	kg CO_2e	9.85E+07	kg CO_2e
Cow activities (transportation)	2.49E+07	kg CO_2e	2.49E+07	kg CO_2e	0	kg CO_2e												
Bull activities (transportation)	3.14E+06	kg CO_2e	3.14E+06	kg CO_2e	0	kg CO_2e												
Yearling-fed system activities (transportation)							1.08E+08	kg CO_2e	1.08E+08	kg CO_2e	0	kg CO_2e						
Calf-fed system activities (transportation)							6.59E+07	kg CO_2e	6.59E+07	kg CO_2e	0	kg CO_2e						

Total GWP for BMP

kg CO_2e **1.22E+10** **Cow/Calf** **5.77E+09** **Feedlot** **3.14E+09** **Beef Industry**

Total Change in GWP for BMP

kg CO_2e **0.00E+00** **8.51E+07** **9.85E+07**

Overall Baseline GWP (2001)

kg CO_2e/kg live weight **14.705**

Overall Baseline GWP (2010)

kg CO_2e/kg live weight **14.834** (This is the 2010 baseline model)

Overall BMP GWP

kg CO_2e/kg live weight **14.834** (includes construction emissions)

Change in overall GWP from 2001

kg CO_2e/kg live weight **0.129**

Change in overall GWP from 2010

kg CO_2e/kg live weight **0.000**

Change in GWP per kg of beef affected from 2001

kg CO_2e/kg live weight **0.944** **(total change in GHG emissions divided by total weight of cattle affected)**

Notes:
Energy generation emission changes assumed all to feedlot as only feedlot affected by this BMP
Feedlot and pasture activities assumed all to feedlot and beef industry as cow calf not affected by this BMP

BENEFITS AND COSTS

BMP 1 - Improved manure management practice (BMP 1.1a Windrow and On-site Clay)
Composting of solid managed manure stream produced in fedlots

Assumed Percent Composting On-Site (only affects feedlot)	100%	(% can be adjusted here for the entire model)
% farms using existing equipment for on-site composting	0%	(% can be adjusted here for the entire model)
% farms purchasing new windrow turners for on-site composting	100%	(updates automatically)
% farms using clay source on-site for compost pad	100%	(% can be adjusted here for the entire model)
% farms purchasing and shipping clay to site for compost pad	0%	(updates automatically)
Assumed Percent Composting Off-site **or Off-site Direct Land Application** (only affects feedlots) (only affects feedlot)	0%	
Total number of animals (only affects feedlots)	2,132,470	animals
Total weight affected to slaughter (only affects feedlots)	1,296,392	tonnes

Scenario BMP 1.1a

Total GHG emissions	**2.21E+10 kg CO2e**
Total acidification	**3.42E+07 kg SO2-Eq**
Total eutrophication	**6.83E+06 kg PO4-Eq**
Total non-renewable energy	**3.64E+11 MJ-Eq**

	COW/CALF OPERATIONS								**FEEDLOT OPERATIONS**								
	BMP 1		**Baseline (2010)**		**Change**		**Per Unit Market Value**	**Total Impact**	**BMP 1**		**Baseline (2010)**		**Change**		**Per Unit Market Value**	**Total Impact**	
	(amount)	***(unit)***	***(amount)***	***(unit)***	***(change)***	***(unit)***	***($/unit)***	***($ Million)***	***(amount)***	***(unit)***	***(amount)***	***(unit)***	***(change)***	***(unit)***	***($/unit)***	***($ Million)***	
Inputs with Change																	
Production of pesticide/herbicide																	
Production of chemical fertilizer																	
Production of bedding																	
Production of min., trc min., cobalt, protein suppl., vit., antibiotic																	
Purchase of chemical fertilizer																	
Urea, as N, at regional storehouse																	
Ammonia, liquid, at regional storehouse																	
Monoammonium phosphate, as P2O5, at regional storehouse																	
Monoammonium phosphate, as N, at regional storehouse																	
Ammonium sulphate, as N, at regional storehouse																	
Purchase of manure for land application																	
Purchase of pesticide/herbicide																	
Purchase of seed for barley																	
Purchase of seed for barlye silage																	
Purchase of seed for alfalfa/grass hay																	
Purchase of water to irrigate crops																	
Purchase of amendment materials (wood waste/wood chips)									5.19E+08	kg	7.78E+07	kg	4.41E+08	kg	$0.13	$58.32	
Purchase of amendment materials (straw)									6.84E+09	kg	1.03E+09	kg	5.81E+09	kg	$0.06	$338.92	
Purchase of composting equipment (Windrow turner)									2,055	turners	0	turners	2,055	turners	$175,000	$359.69	**First year only**
Purchase of clay for composting pad and compaction									0.00E+00	m^3	3.37E+06	m^3	-3.37E+06	m^3	$28	-$94.48	**First year only**
Compaction of clay (source on-site)									1.36E+07	m^3	0	m^3	1.36E+07	m^3	$15	$204.14	**First year only**
Transportation costs for clay to site (250 km assumed)									0.00E+00	tonne	4.39E+06	tonne	-4.39E+06	tonne	$25	-$109.67	**First year only**
Purchase of alfalfa/grass hay	6.59E+09	kg	6.59E+09	kg	0	kg	-	-									
Purchase of barley									4.49E+09	kg	4.49E+09	kg	0	kg	-	-	
Purchase of barley silage									7.58E+09	kg	7.58E+09	kg	0	kg	-	-	
Purchase of bedding	5.09E+08	kg	5.09E+08	kg	0	kg	-	-	4.22E+08	kg	4.22E+08	kg	0	kg	-	-	
Purchase of animal shelters, wind breakers, fencing, etc.	0	units	0	units	0	units	-	-									
Purchase of ionophores	0	kg	0	kg	0	kg	-	-									
Purchase of RAC									0	kg	0	kg	0	kg	-	-	
Purchase of min., trc min., cobalt, protein suppl., antibiotic	7.91E+07	kg	7.91E+07	kg	0	kg	-	-	1.45E+08	kg	1.45E+08	kg	0	kg	-	-	
Purchase of vitamins	1,684	kg	1,684	kg	0	kg	-	-	1.76E+05		1.76E+05	kg	0	kg	-	-	
Purchase of RFI testing (includes transportation)	0	tests	0	tests	0	tests	-	-	0	tests	0	tests	0	tests	-	-	
Fuel/energy required to operate composting equipment									1.73E+07	L	1.19E+07	L	5.47E+06	L	$0.75	$4.09	
Fuel consumed to transport barley and barley silage																	
Fuel consumed to transport alfalfa/grass hay																	
Fuel consumed for cropping activities																	
Fuel consumed to bed livestock (change)	0	L	0	L	0	L	-	-	0	L	0	L	0	L	-	-	
Fuel consumed to transport garbage (change)	0	L	0	L	0	L	-	-	0	L	0	L	0	L	-	-	
Fuel consumed to transport bedding (change)																	
Fuel consumed to feed livestock (change)	0	L	0	L	0	L	-	-	0	L	0	L	0	L	-	-	
Fuel consumed to collect manure (change)									0	L	0	L	0	L	-	-	
Fuel consumed to transport manure off-site for disposal (change)									0	L	5.92E+06	L	-5.92E+06	L	$0.75	-$4.43	
Fuel cons. to transp. min., trc min., cob., prot. suppl., vit., antibiotic																	
Fuel consumed to transport livestock for testing	0	L	0	L	0	L	-	-	0	L	0	L	0	L	-	-	
Labour (change)	0	hrs	0	hrs	0	hrs	-	-	3.82.E+05	hrs	4.74.E+05	hrs	-9.25.E+04	hrs	$16.22	-$1.50	
Working capital interest	0	$	0	$	0	$	-	-	0	$	0	$	0	$		$0.00	
Total Input Value Change								**$0.00**								**$755.07**	
Outputs with Change																	
Manure sold for land application									0.00E+00	kg	2.13E+10	kg	-2.13E+10	kg	$0.00	$0.00	
Compost sold for land application									1.43E+07	tonne	2.15E+06	tonne	1.22E+07	tonne	$6.00	$73.05	
Sale price for beef to slaughterhouse (change)									0	$	0	$	0	$	-	-	
Total Output Value Change								**$0.00**								**$73.05**	

CHANGE IN OVERALL GHG EMISSIONS	COW/CALF OPERATIONS						FEEDLOT OPERATIONS						BEEF INDUSTRY					
	BMP 1		Baseline (2010)		Change		BMP 1		Baseline (2010)		Change		BMP 1		Baseline (2010)		Change	
	(amount)	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*	*(amount)*	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*	*(amount)*	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*
BEEF ACTIVITIES - SOIL AND CROP																		
Manure generation	3.45E+10	kg	3.45E+10	kg	0	kg	1.89E+10	kg	1.89E+10	kg	0	kg						
Methane emissions from stored manure	1.49E+08	kg CO_2e	1.49E+08	kg CO_2e	0	kg CO_2e	7.77E+07	kg CO_2e	1.34E+08	kg CO_2e	-5.65E+07	kg CO_2e						
Enteric fermentation emissions	7.03E+09	kg CO_2e	7.03E+09	kg CO_2e	0	kg CO_2e	3.56E+09	kg CO_2e	3.56E+09	kg CO_2e	0	kg CO_2e						
N_2O emissions from stored manure (direct)	1.83E+09	kg CO_2e	1.83E+09	kg CO_2e	0	kg CO_2e	5.50E+08	kg CO_2e	3.60E+08	kg CO_2e	1.90E+08	kg CO_2e						
N_2O emissions from stored manure (indirect)	4.04E+08	kg CO_2e	4.04E+08	kg CO_2e	0	kg CO_2e	3.06E+08	kg CO_2e	3.06E+08	kg CO_2e	0	kg CO_2e						
N_2O emissions from cropping and land use													9.57E+08	kg CO_2e	9.57E+08	kg CO_2e	0	kg CO_2e
Total P emissions from run-off													4.15E+06	kg PO_4-eq	4.15E+06	kg PO_4-eq	0	kg PO_4-eq
Soil Carbon Change in Soil From Land Use													-2.36E+08	kg CO_2e	-2.36E+08	kg CO_2e	0	kg CO_2e
Direct CO2 emissions from managed soils													1.89E+08	kg CO_2e	1.89E+08	kg CO_2e	0	kg CO_2e
ADDITIONAL ACTIVITIES																		
Construction	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	2.58E+08	kg CO_2e	5.89E+06	kg CO_2e	2.52E+08	kg CO_2e						
Forage and cereal sub-activities													1.20E+09	kg CO_2e	1.20E+09	kg CO_2e	0	kg CO_2e
Energy generation and consumption activities	2.81E+09	kg CO_2e	2.81E+09	kg CO_2e	0	kg CO_2e	1.12E+09	kg CO_2e	1.10E+09	kg CO_2e	2.64E+07	kg CO_2e						
O&M activities	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e						
Cereal activities													3.38E+08	kg CO_2e	3.38E+08	kg CO_2e	0	kg CO_2e
Forage activities													2.86E+08	kg CO_2e	2.86E+08	kg CO_2e	0	kg CO_2e
Feedlot and pasture activities	3.20E+06	kg CO_2e	3.20E+06	kg CO_2e	0	kg CO_2e	1.31E+08	kg CO_2e	1.39E+08	kg CO_2e	-8.17E+06	kg CO_2e	9.61E+08	kg CO_2e	4.02E+08	kg CO_2e	5.59E+08	kg CO_2e
Cow activities (transportation)	2.49E+07	kg CO_2e	2.49E+07	kg CO_2e	0	kg CO_2e												
Bull activities (transportation)	3.14E+06	kg CO_2e	3.14E+06	kg CO_2e	0	kg CO_2e												
Yearling-fed system activities (transportation)							1.08E+08	kg CO_2e	1.08E+08	kg CO_2e	0	kg CO_2e						
Calf-fed system activities (transportation)							6.59E+07	kg CO_2e	6.59E+07	kg CO_2e	0	kg CO_2e						

Total GWP for BMP

kg CO_2e 1.22E+10 Cow/Calf 6.18E+09 Feedlot 3.70E+09 Beef Industry

Total Change in GWP for BMP

kg CO_2e 0.00E+00 4.04E+08 5.59E+08

Total change in emissions 962,702 tonnes

Overall Baseline GWP (2001)

kg CO_2e/kg live weight 14.705

Overall Baseline GWP (2010)

kg CO_2e/kg live weight 14.834 Construction activties only for first year of operation
Values without construction activities

Overall BMP GWP

kg CO_2e/kg live weight 15.509 15.332

Change in overall GWP from 2001

kg CO_2e/kg live weight 0.803 0.627

Change in overall GWP from 2010

kg CO_2e/kg live weight 0.675 0.498

Change in GWP per kg of beef affected from 2010
kg CO_2e/kg live weight 0.743 (total change in GHG emissions divided by total weight of cattle affected)

Notes:
Energy generation emission changes assumed all to feedlot as only feedlot affected by this BMP
Feedlot and pasture activities assumed all to feedlot as only feedlot affected by this BMP

BENEFITS AND COSTS

BMP 1 - Improved manure management practice (BMP 1.1b - Windrow Turner and Off-site Clay)
Composting of solid managed manure stream produced in fedlots

Assumed Percent Composting On-Site (only affects feedlot)	100%	(% can be adjusted here for the entire model)
% farms using existing equipment for on-site composting	0%	(% can be adjusted here for the entire model)
% farms purchasing new windrow turners for on-site composting	100%	(updates automatically)
% farms using clay source on-site for compost pad	0%	(% can be adjusted here for the entire model)
% farms purchasing and shipping clay to site for compost pad	100%	(updates automatically)
Assumed Percent Composting Off-site **or Off-site Direct Land Application** (only affects feedlots) (only affects feedlot)	0%	
Total number of animals (only affects feedlots)	2,132,470	animals
Total weight affected to slaughter (only affects feedlots)	1,296,392	tonnes

Scenario BMP 1.1b

Total GHG emissions	2.21E+10 kg CO2e
Total acidification	3.42E+07 kg SO2-Eq
Total eutrophication	6.83E+06 kg PO4-Eq
Total non-renewable energy	3.64E+11 MJ-Eq

	COW/CALF OPERATIONS								FEEDLOT OPERATIONS								
	BMP 1		Baseline (2010)		Change		Per Unit Market Value	Total Impact	BMP 1		Baseline (2010)		Change		Per Unit Market Value	Total Impact	
	(amount)	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*	*($/unit)*	*($ Million)*	*(amount)*	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*	*($/unit)*	*($ Million)*	
Inputs with Change																	
Production of pesticide/herbicide																	
Production of chemical fertilizer																	
Production of bedding																	
Production of min., trc min., cobalt, protein suppl., vit., antibiotic																	
Purchase of chemical fertilizer																	
Urea, as N, at regional storehouse																	
Ammonia, liquid, at regional storehouse																	
Monoammonium phosphate, as P2O5, at regional storehouse																	
Monoammonium phosphate, as N, at regional storehouse																	
Ammonium sulphate, as N, at regional storehouse																	
Purchase of manure for land application																	
Purchase of pesticide/herbicide																	
Purchase of seed for barley																	
Purchase of seed for barlye silage																	
Purchase of seed for alfalfa/grass hay																	
Purchase of water to irrigate crops																	
Purchase of amendment materials (wood waste/wood chips)									5.19E+08	kg	7.78E+07	kg	4.41E+08	kg	$0.13	$58.32	
Purchase of amendment materials (straw)									6.84E+09	kg	1.03E+09	kg	5.81E+09	kg	$0.06	$338.92	
Purchase of composting equipment (Windrow turner)									2,055	turners	0	turners	2,055	turners	$175,000	$359.69	**First year only**
Purchase of clay for composting pad and compaction									1.36E+07	m^3	3.37E+06	m^3	1.02E+07	m^3	$28	$286.58	**First year only**
Compaction of clay (source on-site)									0.00E+00	m^3	0	m^3	0.00E+00	m^3	$15	$0.00	**First year only**
Transportation costs for clay to site (250 km assumed)									1.77E+07	tonne	4.39E+06	tonne	1.33E+07	tonne	$25	$332.63	**First year only**
Purchase of alfalfa/grass hay	6.59E+09	kg	6.59E+09	kg	0	kg	-	-									
Purchase of barley									4.49E+09	kg	4.49E+09	kg	0	kg	-	-	
Purchase of barley silage									7.58E+09	kg	7.58E+09	kg	0	kg	-	-	
Purchase of bedding	5.09E+08	kg	5.09E+08	kg	0	kg	-	-	4.22E+08	kg	4.22E+08	kg	0	kg	-	-	
Purchase of animal shelters, wind breakers, fencing, etc.	0	units	0	units	0	units	-	-									
Purchase of ionophores	0	kg	0	kg	0	kg	-	-									
Purchase of RAC									0	kg	0	kg	0	kg	-	-	
Purchase of min., trc min., cobalt, protein suppl., antibiotic	7.91E+07	kg	7.91E+07	kg	0	kg	-	-	1.45E+08	kg	1.45E+08	kg	0	kg	-	-	
Purchase of vitamins	1,684	kg	1,684	kg	0	kg	-	-	1.76E+05		1.76E+05	kg	0	kg	-	-	
Purchase of RFI testing (includes transportation)	0	tests	0	tests	0	tests	-	-	0	tests	0	tests	0	tests	-	-	
Fuel/energy required to operate composting equipment									1.73E+07	L	1.19E+07	L	5.47E+06	L	$0.75	$4.09	
Fuel consumed to transport barley and barley silage																	
Fuel consumed to transport alfalfa/grass hay																	
Fuel consumed for cropping activities																	
Fuel consumed to bed livestock (change)	0	L	0	L	0	L	-	-	0	L	0	L	0	L	-	-	
Fuel consumed to transport garbage (change)	0	L	0	L	0	L	-	-	0	L	0	L	0	L	-	-	
Fuel consumed to transport bedding (change)																	
Fuel consumed to feed livestock (change)	0	L	0	L	0	L	-	-	0	L	0	L	0	L	-	-	
Fuel consumed to collect manure (change)									0	L	0	L	0	L	-	-	
Fuel consumed to transport manure off-site for disposal (change)									0	L	5.92E+06	L	-5.92E+06	L	$0.75	-$4.43	
Fuel cons. to transp. min., trc min., cob., prot. suppl., vit., antibiotic																	
Fuel consumed to transport livestock for testing	0	L	0	L	0	L	-	-	0	L	0	L	0	L	-	-	
Labour (change)	0	hrs	0	hrs	0	hrs	-	-	3.82.E+05	hrs	4.74.E+05	hrs	-9.25.E+04	hrs	$16.22	-$1.50	
Working capital interest	0	$	0	$	0	$	-	-	0	$	0	$	0	$		$0.00	
Total Input Value Change								**$0.00**								**$1,374.30**	
Outputs with Change																	
Manure sold for land application									0.00E+00	kg	2.13E+10	kg	-2.13E+10	kg	$0.00	$0.00	
Compost sold for land application									1.43E+07	tonne	2.15E+06	tonne	1.22E+07	tonne	$6.00	$73.05	
Sale price for beef to slaughterhouse (change)									0	$	0	$	0	$	-	-	
Total Output Value Change								**$0.00**								**$73.05**	

CHANGE IN OVERALL GHG EMISSIONS	COW/CALF OPERATIONS						FEEDLOT OPERATIONS						BEEF INDUSTRY					
	BMP 1		Baseline (2010)		Change		BMP 1		Baseline (2010)		Change		BMP 1		Baseline (2010)		Change	
	(amount)	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*	*(amount)*	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*	*(amount)*	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*
BEEF ACTIVITIES - SOIL AND CROP																		
Manure generation	3.45E+10	kg	3.45E+10	kg	0	kg	1.89E+10	kg	1.89E+10	kg	0	kg						
Methane emissions from stored manure	1.49E+08	kg CO_2e	1.49E+08	kg CO_2e	0	kg CO_2e	7.77E+07	kg CO_2e	1.34E+08	kg CO_2e	-5.65E+07	kg CO_2e						
Enteric fermentation emissions	7.03E+09	kg CO_2e	7.03E+09	kg CO_2e	0	kg CO_2e	3.56E+09	kg CO_2e	3.56E+09	kg CO_2e	0	kg CO_2e						
N_2O emissions from stored manure (direct)	1.83E+09	kg CO_2e	1.83E+09	kg CO_2e	0	kg CO_2e	5.50E+08	kg CO_2e	3.60E+08	kg CO_2e	1.90E+08	kg CO_2e						
N_2O emissions from stored manure (indirect)	4.04E+08	kg CO_2e	4.04E+08	kg CO_2e	0	kg CO_2e	3.06E+08	kg CO_2e	3.06E+08	kg CO_2e	0	kg CO_2e						
N_2O emissions from cropping and land use													9.57E+08	kg CO_2e	9.57E+08	kg CO_2e	0	kg CO_2e
Total P emissions from run-off													4.15E+06	kg PO_4-eq	4.15E+06	kg PO_4-eq	0	kg PO_4-eq
Soil Carbon Change in Soil From Land Use													-2.36E+08	kg CO_2e	-2.36E+08	kg CO_2e	0	kg CO_2e
Direct CO2 emissions from managed soils													1.89E+08	kg CO_2e	1.89E+08	kg CO_2e	0	kg CO_2e
ADDITIONAL ACTIVITIES																		
Construction	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	2.70E+08	kg CO_2e	5.89E+06	kg CO_2e	2.64E+08	kg CO_2e						
Forage and cereal sub-activities													1.20E+09	kg CO_2e	1.20E+09	kg CO_2e	0	kg CO_2e
Energy generation and consumption activities	2.81E+09	kg CO_2e	2.81E+09	kg CO_2e	0	kg CO_2e	1.12E+09	kg CO_2e	1.10E+09	kg CO_2e	2.64E+07	kg CO_2e						
O&M activities	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e						
Cereal activities													3.38E+08	kg CO_2e	3.38E+08	kg CO_2e	0	kg CO_2e
Forage activities													2.86E+08	kg CO_2e	2.86E+08	kg CO_2e	0	kg CO_2e
Feedlot and pasture activities	3.20E+06	kg CO_2e	3.20E+06	kg CO_2e	0	kg CO_2e	1.31E+08	kg CO_2e	1.39E+08	kg CO_2e	-8.17E+06	kg CO_2e	9.61E+08	kg CO_2e	4.02E+08	kg CO_2e	5.59E+08	kg CO_2e
Cow activities (transportation)	2.49E+07	kg CO_2e	2.49E+07	kg CO_2e	0	kg CO_2e												
Bull activities (transportation)	3.14E+06	kg CO_2e	3.14E+06	kg CO_2e	0	kg CO_2e												
Yearling-fed system activities (transportation)							1.08E+08	kg CO_2e	1.08E+08	kg CO_2e	0	kg CO_2e						
Calf-fed system activities (transportation)							6.59E+07	kg CO_2e	6.59E+07	kg CO_2e	0	kg CO_2e						

Total GWP for BMP

kg CO_2e **1.22E+10 Cow/Calf** **6.19E+09 Feedlot** **3.70E+09 Beef Industry**

Total Change in GWP for BMP

kg CO_2e **0.00E+00** **4.16E+08** **5.59E+08**

Total change in emissions **974,634 tonnes**

Overall Baseline GWP (2001)

kg CO_2e/kg live weight **14.705**

Overall Baseline GWP (2010)

kg CO_2e/kg live weight **14.834** **Construction activties only for first year of operation**

Adjusted to exclude construction emissions for years after implementation

Overall BMP GWP

kg CO_2e/kg live weight **15.517** **15.328**

Change in overall GWP from 2001

kg CO_2e/kg live weight **0.812** **0.622**

Change in overall GWP from 2010

kg CO_2e/kg live weight **0.683** **0.494**

Change in GWP per kg of beef affected from 2010

kg CO_2e/kg live weight **0.752** **(total change in GHG emissions divided by total weight of cattle affected)**

Notes:
Energy generation emission changes assumed all to feedlot as only feedlot affected by this BMP
Feedlot and pasture activities assumed all to feedlot as only feedlot affected by this BMP

BMP 1 - Improved manure management practice (BMP 1.2a - Existing Equipment and On-site Clay)
Composting of solid managed manure stream produced in fedlots

Assumed Percent Composting On-Site (only affects feedlot)	100%	(% can be adjusted here for the entire model)
% farms using existing equipment for on-site composting	100%	(% can be adjusted here for the entire model)
% farms purchasing new windrow turners for on-site composting	0%	(updates automatically)
% farms using clay source on-site for compost pad	100%	(% can be adjusted here for the entire model)
% farms purchasing and shipping clay to site for compost pad	0%	(updates automatically)
Assumed Percent Composting Off-site **or Off-site Direct Land Application** (only affects feedlots) (only affects feedlot)	0%	
Total number of animals (only affects feedlots)	2,132,470	animals
Total weight affected to slaughter (only affects feedlots)	1,296,392	tonnes

Scenario BMP 1.2a

Total GHG emissions	2.22E+10 kg CO2e
Total acidification	3.39E+07 kg SO2-Eq
Total eutrophication	6.91E+06 kg PO4-Eq
Total non-renewable energy	3.95E+11 MJ-Eq

	COW/CALF OPERATIONS					FEEDLOT OPERATIONS					
	BMP 1	Baseline (2010)	Change	Per Unit Market Value	Total Impact	BMP 1	Baseline (2010)	Change	Per Unit Market Value	Total Impact	
	(amount) (unit)	*(amount) (unit)*	*(change) (unit)*	*($/unit)*	*($ Million)*	*(amount) (unit)*	*(amount) (unit)*	*(change) (unit)*	*($/unit)*	*($ Million)*	
Inputs with Change											
Production of pesticide/herbicide											
Production of chemical fertilizer											
Production of bedding											
Production of min., trc min., cobalt, protein suppl., vit., antibiotic											
Purchase of chemical fertilizer											
Urea, as N, at regional storehouse											
Ammonia, liquid, at regional storehouse											
Monoammonium phosphate, as P2O5, at regional storehouse											
Monoammonium phosphate, as N, at regional storehouse											
Ammonium sulphate, as N, at regional storehouse											
Purchase of manure for land application											
Purchase of pesticide/herbicide											
Purchase of seed for barley											
Purchase of seed for barlye silage											
Purchase of seed for alfalfa/grass hay											
Purchase of water to irrigate crops											
Purchase of amendment materials (wood waste/wood chips)						5.19E+08 kg	7.78E+07 kg	4.41E+08 kg	$0.13	$58.32	
Purchase of amendment materials (straw)						6.84E+09 kg	1.03E+09 kg	5.81E+09 kg	$0.06	$338.92	
Purchase of composting equipment (Windrow turner)						0 turners	0 turners	0 turners	$175,000	$0.00	**First year only**
Purchase of clay for composting pad and compaction						0.00E+00 m^3	3.37E+06 m^3	-3.37E+06 m^3	$28	-$94.48	**First year only**
Compaction of clay (source on-site)						2.25E+07 m^3	0 m^3	2.25E+07 m^3	$15	$337.43	**First year only**
Transportation costs for clay to site (250 km assumed)						0.00E+00 tonne	4.39E+06 tonne	-4.39E+06 tonne	$25	-$109.67	**First year only**
Purchase of alfalfa/grass hay	6.59E+09 kg	6.59E+09 kg	0 kg	-	-						
Purchase of barley						4.49E+09 kg	4.49E+09 kg	0 kg	-	-	
Purchase of barley silage						7.58E+09 kg	7.58E+09 kg	0 kg	-	-	
Purchase of bedding	5.09E+08 kg	5.09E+08 kg	0 kg	-	-	4.22E+08 kg	4.22E+08 kg	0 kg	-	-	
Purchase of animal shelters, wind breakers, fencing, etc.	0 units	0 units	0 units	-	-						
Purchase of ionophores	0 kg	0 kg	0 kg	-	-						
Purchase of RAC						0 kg	0 kg	0 kg	-	-	
Purchase of min., trc min., cobalt, protein suppl., antibiotic	7.91E+07 kg	7.91E+07 kg	0 kg	-	-	1.45E+08 kg	1.45E+08 kg	0 kg	-	-	
Purchase of vitamins	1,684 kg	1,684 kg	0 kg	-	-	1.76E+05	1.76E+05 kg	0 kg	-	-	
Purchase of RFI testing (includes transportation)	0 tests	0 tests	0 tests	-	-	0 tests	0 tests	0 tests	-	-	
Fuel/energy required to operate composting equipment						7.92E+07 L	1.19E+07 L	6.73E+07 L	$0.75	$50.39	
Fuel consumed to transport barley and barley silage											
Fuel consumed to transport alfalfa/grass hay											
Fuel consumed for cropping activities											
Fuel consumed to bed livestock (change)	0 L	0 L	0 L	-	-	0 L	0 L	0 L	-	-	
Fuel consumed to transport garbage (change)	0 L	0 L	0 L	-	-	0 L	0 L	0 L	-	-	
Fuel consumed to transport bedding (change)											
Fuel consumed to feed livestock (change)	0 L	0 L	0 L	-	-	0 L	0 L	0 L	-	-	
Fuel consumed to collect manure (change)						0 L	0 L	0 L	-	-	
Fuel consumed to transport manure off-site for disposal (change)						0 L	5.92E+06 L	-5.92E+06 L	$0.75	-$4.43	
Fuel cons. to transp. min., trc min., cob., prot. suppl., vit., antibiotic											
Fuel consumed to transport livestock for testing	0 L	0 L	0 L	-	-	0 L	0 L	0 L	-	-	
Labour (change)	0 hrs	0 hrs	0 hrs	-	-	3.16.E+06 hrs	4.74.E+05 hrs	2.69.E+06 hrs	$16.22	$43.61	
Working capital interest	0 $	0 $	0 $	-	-	0 $	0 $	0 $		$0.00	
Total Input Value Change					**$0.00**					**$620.08**	
Outputs with Change											
Manure sold for land application						0.00E+00 kg	2.13E+10 kg	-2.13E+10 kg	$0.00	$0.00	
Compost sold for land application						1.43E+07 tonne	2.15E+06 tonne	1.22E+07 tonne	$6.00	$73.05	
Sale price for beef to slaughterhouse (change)						0 $	0 $	0 $	-	-	
Total Output Value Change					**$0.00**					**$73.05**	

CHANGE IN OVERALL GHG EMISSIONS	COW/CALF OPERATIONS						FEEDLOT OPERATIONS						BEEF INDUSTRY					
	BMP 1		Baseline (2010)		Change		BMP 1		Baseline (2010)		Change		BMP 1		Baseline (2010)		Change	
	(amount)	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*	*(amount)*	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*	*(amount)*	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*
BEEF ACTIVITIES - SOIL AND CROP																		
Manure generation	3.45E+10	kg	3.45E+10	kg	0	kg	1.89E+10	kg	1.89E+10	kg	0	kg						
Methane emissions from stored manure	1.49E+08	kg CO_2e	1.49E+08	kg CO_2e	0	kg CO_2e	7.77E+07	kg CO_2e	1.34E+08	kg CO_2e	-5.65E+07	kg CO_2e						
Enteric fermentation emissions	7.03E+09	kg CO_2e	7.03E+09	kg CO_2e	0	kg CO_2e	3.56E+09	kg CO_2e	3.56E+09	kg CO_2e	0	kg CO_2e						
N_2O emissions from stored manure (direct)	1.83E+09	kg CO_2e	1.83E+09	kg CO_2e	0	kg CO_2e	5.50E+08	kg CO_2e	3.60E+08	kg CO_2e	1.90E+08	kg CO_2e						
N_2O emissions from stored manure (indirect)	4.04E+08	kg CO_2e	4.04E+08	kg CO_2e	0	kg CO_2e	3.06E+08	kg CO_2e	3.06E+08	kg CO_2e	0	kg CO_2e						
N_2O emissions from cropping and land use													9.57E+08	kg CO_2e	9.57E+08	kg CO_2e	0	kg CO_2e
Total P emissions from run-off													4.15E+06	kg PO_4-eq	4.15E+06	kg PO_4-eq	0	kg PO_4-eq
Soil Carbon Change in Soil From Land Use													-2.36E+08	kg CO_2e	-2.36E+08	kg CO_2e	0	kg CO_2e
Direct CO2 emissions from managed soils													1.89E+08	kg CO_2e	1.89E+08	kg CO_2e	0	kg CO_2e
ADDITIONAL ACTIVITIES																		
Construction	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	1.96E+07	kg CO_2e	5.89E+06	kg CO_2e	1.37E+07	kg CO_2e						
Forage and cereal sub-activities													1.20E+09	kg CO_2e	1.20E+09	kg CO_2e	0	kg CO_2e
Energy generation and consumption activities	2.81E+09	kg CO_2e	2.81E+09	kg CO_2e	0	kg CO_2e	1.42E+09	kg CO_2e	1.10E+09	kg CO_2e	3.25E+08	kg CO_2e						
O&M activities	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e						
Cereal activities													3.38E+08	kg CO_2e	3.38E+08	kg CO_2e	0	kg CO_2e
Forage activities													2.86E+08	kg CO_2e	2.86E+08	kg CO_2e	0	kg CO_2e
Feedlot and pasture activities	3.20E+06	kg CO_2e	3.20E+06	kg CO_2e	0	kg CO_2e	1.31E+08	kg CO_2e	1.39E+08	kg CO_2e	-8.17E+06	kg CO_2e	9.61E+08	kg CO_2e	4.02E+08	kg CO_2e	5.59E+08	kg CO_2e
Cow activities (transportation)	2.49E+07	kg CO_2e	2.49E+07	kg CO_2e	0	kg CO_2e												
Bull activities (transportation)	3.14E+06	kg CO_2e	3.14E+06	kg CO_2e	0	kg CO_2e												
Yearling-fed system activities (transportation)							1.08E+08	kg CO_2e	1.08E+08	kg CO_2e	0	kg CO_2e						
Calf-fed system activities (transportation)							6.59E+07	kg CO_2e	6.59E+07	kg CO_2e	0	kg CO_2e						

Total GWP for BMP

kg CO_2e **1.22E+10** **Cow/Calf** **6.24E+09** **Feedlot** **3.70E+09** **Beef Industry**

Total Change in GWP for BMP

kg CO_2e **0.00E+00** **4.64E+08** **5.59E+08**

Total change in emissions **1,022,630 tonnes**

Overall Baseline GWP (2001)

kg CO_2e/kg live weight **14.705**

Overall Baseline GWP (2010)

kg CO_2e/kg live weight **14.834** **Construction activties only for first year of operation**

Adjusted to exclude construction emissions for years after implementation

Overall BMP GWP

kg CO_2e/kg live weight **15.551** **15.537**

Change in overall GWP from 2001

kg CO_2e/kg live weight **0.845** **0.832**

Change in overall GWP from 2010

kg CO_2e/kg live weight **0.717** **0.703**

Change in GWP per kg of beef affected from 2010

kg CO_2e/kg live weight **0.789** **(total change in GHG emissions divided by total weight of cattle affected)**

Notes:

Energy generation emission changes assumed all to feedlot as only feedlot affected by this BMP

Feedlot and pasture activities assumed all to feedlot as only feedlot affected by this BMP

BENEFITS AND COSTS

BMP 1 - Improved manure management practice (BMP 1.2b - Existing Equipment and Off-site Clay)
Composting of solid managed manure stream produced in fedlots

Assumed Percent Composting On-Site (only affects feedlot)	100%	(% can be adjusted here for the entire model)
% farms using existing equipment for on-site composting	100%	(% can be adjusted here for the entire model)
% farms purchasing new windrow turners for on-site composting	0%	(updates automatically)
% farms using clay source on-site for compost pad	0%	(% can be adjusted here for the entire model)
% farms purchasing and shipping clay to site for compost pad	100%	(updates automatically)
Assumed Percent Composting Off-site **or Off-site Direct Land Application** (only affects feedlots) (only affects feedlot)	0%	
Total number of animals (only affects feedlots)	2,132,470	animals
Total weight affected to slaughter (only affects feedlots)	1,296,392	tonnes

Scenario BMP 1.2b

Total GHG emissions	**2.22E+10 kg CO2e**
Total acidification	**3.39E+07 kg SO2-Eq**
Total eutrophication	**6.91E+06 kg PO4-Eq**
Total non-renewable energy	**3.95E+11 MJ-Eq**

	COW/CALF OPERATIONS					FEEDLOT OPERATIONS					
	BMP 1	Baseline (2010)	Change	Per Unit Market Value	Total Impact	BMP 1	Baseline (2010)	Change	Per Unit Market Value	Total Impact	
	(amount) (unit)	*(amount) (unit)*	*(change) (unit)*	*($/unit)*	*($ Million)*	*(amount) (unit)*	*(amount) (unit)*	*(change) (unit)*	*($/unit)*	*($ Million)*	
Inputs with Change											
Production of pesticide/herbicide											
Production of chemical fertilizer											
Production of bedding											
Production of min., trc min., cobalt, protein suppl., vit., antibiotic											
Purchase of chemical fertilizer											
Urea, as N, at regional storehouse											
Ammonia, liquid, at regional storehouse											
Monoammonium phosphate, as P2O5, at regional storehouse											
Monoammonium phosphate, as N, at regional storehouse											
Ammonium sulphate, as N, at regional storehouse											
Purchase of manure for land application											
Purchase of pesticide/herbicide											
Purchase of seed for barley											
Purchase of seed for barlye silage											
Purchase of seed for alfalfa/grass hay											
Purchase of water to irrigate crops											
Purchase of amendment materials (wood waste/wood chips)						5.19E+08 kg	7.78E+07 kg	4.41E+08 kg	$0.13	$58.32	
Purchase of amendment materials (straw)						6.84E+09 kg	1.03E+09 kg	5.81E+09 kg	$0.06	$338.92	
Purchase of composting equipment (Windrow turner)						0 turners	0 turners	0 turners	$175,000	$0.00	**First year only**
Purchase of clay for composting pad and compaction						2.25E+07 m^3	3.37E+06 m^3	1.91E+07 m^3	$28	$535.39	**First year only**
Compaction of clay (source on-site)						0 m^3	0 m^3	0 m^3	$15	$0.00	**First year only**
Transportation costs for clay to site (250 km assumed)						2.92E+07 tonne	4.39E+06 tonne	2.49E+07 tonne	$25	$621.43	**First year only**
Purchase of alfalfa/grass hay	6.59E+09 kg	6.59E+09 kg	0 kg	-	-						
Purchase of barley						4.49E+09 kg	4.49E+09 kg	0 kg	-	-	
Purchase of barley silage						7.58E+09 kg	7.58E+09 kg	0 kg	-	-	
Purchase of bedding	5.09E+08 kg	5.09E+08 kg	0 kg	-	-	4.22E+08 kg	4.22E+08 kg	0 kg	-	-	
Purchase of animal shelters, wind breakers, fencing, etc.	0 units	0 units	0 units	-	-						
Purchase of ionophores	0 kg	0 kg	0 kg	-	-						
Purchase of RAC						0 kg	0 kg	0 kg	-	-	
Purchase of min., trc min., cobalt, protein suppl., antibiotic	7.91E+07 kg	7.91E+07 kg	0 kg	-	-	1.45E+08 kg	1.45E+08 kg	0 kg	-	-	
Purchase of vitamins	1,684 kg	1,684 kg	0 kg	-	-	1.76E+05	1.76E+05 kg	0 kg	-	-	
Purchase of RFI testing (includes transportation)	0 tests	0 tests	0 tests	-	-	0 tests	0 tests	0 tests	-	-	
Fuel/energy required to operate composting equipment						7.92E+07 L	1.19E+07 L	6.73E+07 L	$0.75	$50.39	
Fuel consumed to transport barley and barley silage											
Fuel consumed to transport alfalfa/grass hay											
Fuel consumed for cropping activities											
Fuel consumed to bed livestock (change)	0 L	0 L	0 L	-	-	0 L	0 L	0 L	-	-	
Fuel consumed to transport garbage (change)	0 L	0 L	0 L	-	-	0 L	0 L	0 L	-	-	
Fuel consumed to transport bedding (change)											
Fuel consumed to feed livestock (change)	0 L	0 L	0 L	-	-	0 L	0 L	0 L	-	-	
Fuel consumed to collect manure (change)						0 L	0 L	0 L	-	-	
Fuel consumed to transport manure off-site for disposal (change)						0 L	5.92E+06 L	-5.92E+06 L	$0.75	-$4.43	
Fuel cons. to transp. min., trc min., cob., prot. suppl., vit., antibiotic											
Fuel consumed to transport livestock for testing	0 L	0 L	0 L	-	-	0 L	0 L	0 L	-	-	
Labour (change)	0 hrs	0 hrs	0 hrs	-	-	3.16.E+06 hrs	4.74.E+05 hrs	2.69.E+06 hrs	$16.22	$43.61	
Working capital interest	0 $	0 $	0 $	-	-	0 $	0 $	0 $		$0.00	
Total Input Value Change					**$0.00**					**$1,643.63**	
Outputs with Change											
Manure sold for land application						0.00E+00 kg	2.13E+10 kg	-2.13E+10 kg	$0.00	$0.00	
Compost sold for land application						1.43E+07 tonne	2.15E+06 tonne	1.22E+07 tonne	$6.00	$73.05	
Sale price for beef to slaughterhouse (change)						0 $	0 $	0 $	-	-	
Total Output Value Change					**$0.00**					**$73.05**	

CHANGE IN OVERALL GHG EMISSIONS	COW/CALF OPERATIONS						FEEDLOT OPERATIONS						BEEF INDUSTRY					
	BMP 1		Baseline (2010)		Change		BMP 1		Baseline (2010)		Change		BMP 1		Baseline (2010)		Change	
	(amount)	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*	*(amount)*	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*	*(amount)*	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*
BEEF ACTIVITIES - SOIL AND CROP																		
Manure generation	3.45E+10	kg	3.45E+10	kg	0	kg	1.89E+10	kg	1.89E+10	kg	0	kg						
Methane emissions from stored manure	1.49E+08	kg CO_2e	1.49E+08	kg CO_2e	0	kg CO_2e	7.77E+07	kg CO_2e	1.34E+08	kg CO_2e	-5.65E+07	kg CO_2e						
Enteric fermentation emissions	7.03E+09	kg CO_2e	7.03E+09	kg CO_2e	0	kg CO_2e	3.56E+09	kg CO_2e	3.56E+09	kg CO_2e	0	kg CO_2e						
N_2O emissions from stored manure (direct)	1.83E+09	kg CO_2e	1.83E+09	kg CO_2e	0	kg CO_2e	5.50E+08	kg CO_2e	3.60E+08	kg CO_2e	1.90E+08	kg CO_2e						
N_2O emissions from stored manure (indirect)	4.04E+08	kg CO_2e	4.04E+08	kg CO_2e	0	kg CO_2e	3.06E+08	kg CO_2e	3.06E+08	kg CO_2e	0	kg CO_2e						
N_2O emissions from cropping and land use													9.57E+08	kg CO_2e	9.57E+08	kg CO_2e	0	kg CO_2e
Total P emissions from run-off													4.15E+06	kg PO_4-eq	4.15E+06	kg PO_4-eq	0	kg PO_4-eq
Soil Carbon Change in Soil From Land Use													-2.36E+08	kg CO_2e	-2.36E+08	kg CO_2e	0	kg CO_2e
Direct CO2 emissions from managed soils													1.89E+08	kg CO_2e	1.89E+08	kg CO_2e	0	kg CO_2e
ADDITIONAL ACTIVITIES																		
Construction	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	3.93E+07	kg CO_2e	5.89E+06	kg CO_2e	3.34E+07	kg CO_2e						
Forage and cereal sub-activities													1.20E+09	kg CO_2e	1.20E+09	kg CO_2e	0	kg CO_2e
Energy generation and consumption activities	2.81E+09	kg CO_2e	2.81E+09	kg CO_2e	0	kg CO_2e	1.42E+09	kg CO_2e	1.10E+09	kg CO_2e	3.25E+08	kg CO_2e						
O&M activities	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e						
Cereal activities													3.38E+08	kg CO_2e	3.38E+08	kg CO_2e	0	kg CO_2e
Forage activities													2.86E+08	kg CO_2e	2.86E+08	kg CO_2e	0	kg CO_2e
Feedlot and pasture activities	3.20E+06	kg CO_2e	3.20E+06	kg CO_2e	0	kg CO_2e	1.31E+08	kg CO_2e	1.39E+08	kg CO_2e	-7.69E+06	kg CO_2e	9.61E+08	kg CO_2e	4.02E+08	kg CO_2e	5.58E+08	kg CO_2e
Cow activities (transportation)	2.49E+07	kg CO_2e	2.49E+07	kg CO_2e	0	kg CO_2e												
Bull activities (transportation)	3.14E+06	kg CO_2e	3.14E+06	kg CO_2e	0	kg CO_2e												
Yearling-fed system activities (transportation)							1.08E+08	kg CO_2e	1.08E+08	kg CO_2e	0	kg CO_2e						
Calf-fed system activities (transportation)							6.59E+07	kg CO_2e	6.59E+07	kg CO_2e	0	kg CO_2e						

Total GWP for BMP

kg CO_2e **1.22E+10** **Cow/Calf** **6.26E+09** **Feedlot** **3.70E+09** **Beef Industry**

Total Change in GWP for BMP

kg CO_2e **0.00E+00** **4.84E+08** **5.58E+08**

Total change in emissions **1,042,414 tonnes**

Overall Baseline GWP (2001)

kg CO_2e/kg live weight **14.705**

Overall Baseline GWP (2010)

kg CO_2e/kg live weight **14.834**

Construction activties only for first year of operation
Adjusted to exclude construction emissions for years after implementation

Overall BMP GWP

kg CO_2e/kg live weight **15.565** **15.537**

Change in overall GWP from 2001

kg CO_2e/kg live weight **0.859** **0.832**

Change in overall GWP from 2010

kg CO_2e/kg live weight **0.731** **0.703**

Change in GWP per kg of beef affected from 2010

kg CO_2e/kg live weight **0.804** **(total change in GHG emissions divided by total weight of cattle affected)**

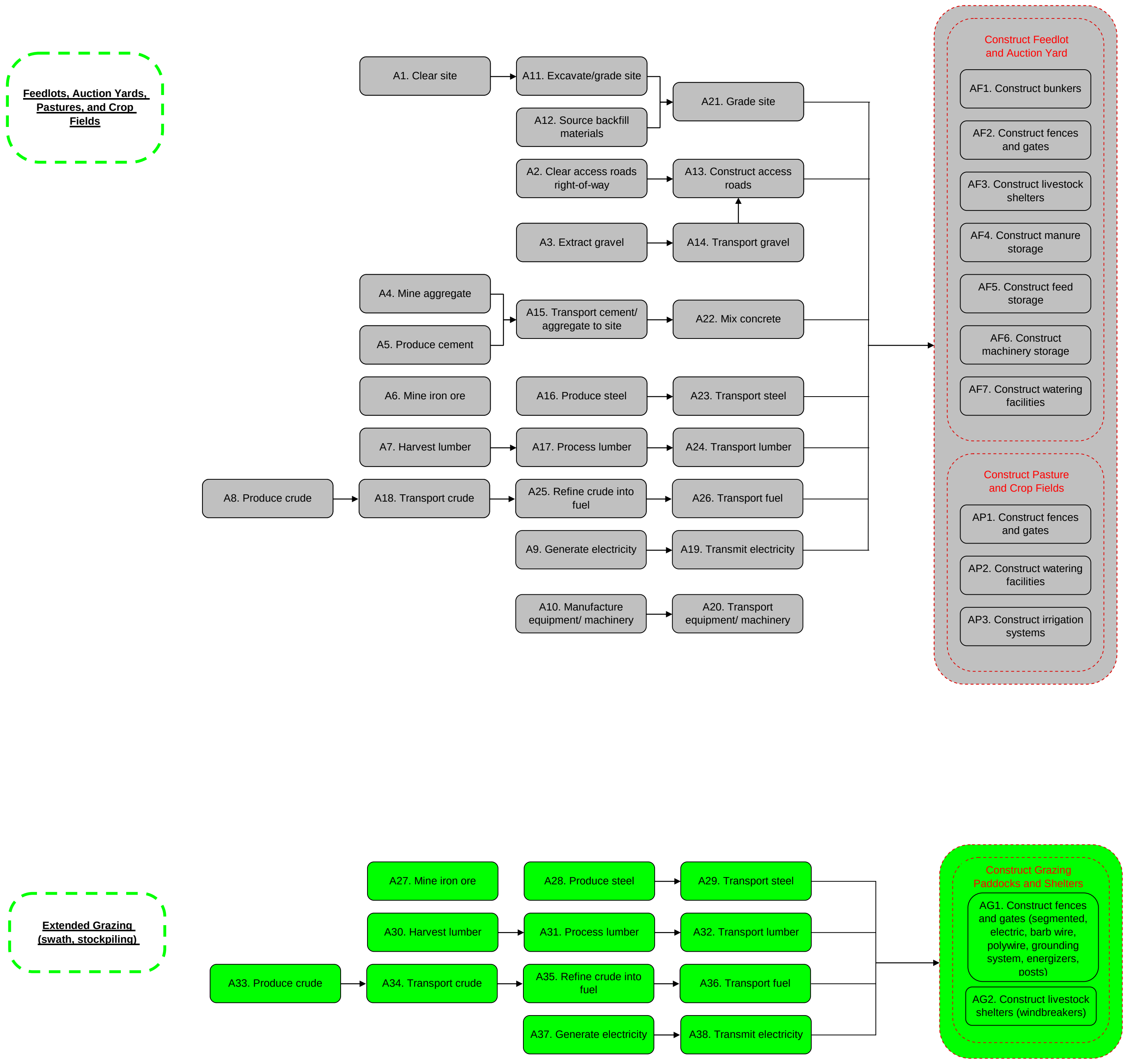
Notes:
Energy generation emission changes assumed all to feedlot as only feedlot affected by this BMP
Feedlot and pasture activities assumed all to feedlot as only feedlot affected by this BMP

APPENDIX F

BMP 2 – INCREASED EFFICIENCY IN COW/CALF FEEDING AND GRAZING

ACTIVITY MAPS AND DATA COLLECTION

A: Construction



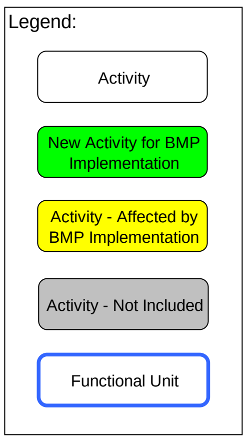


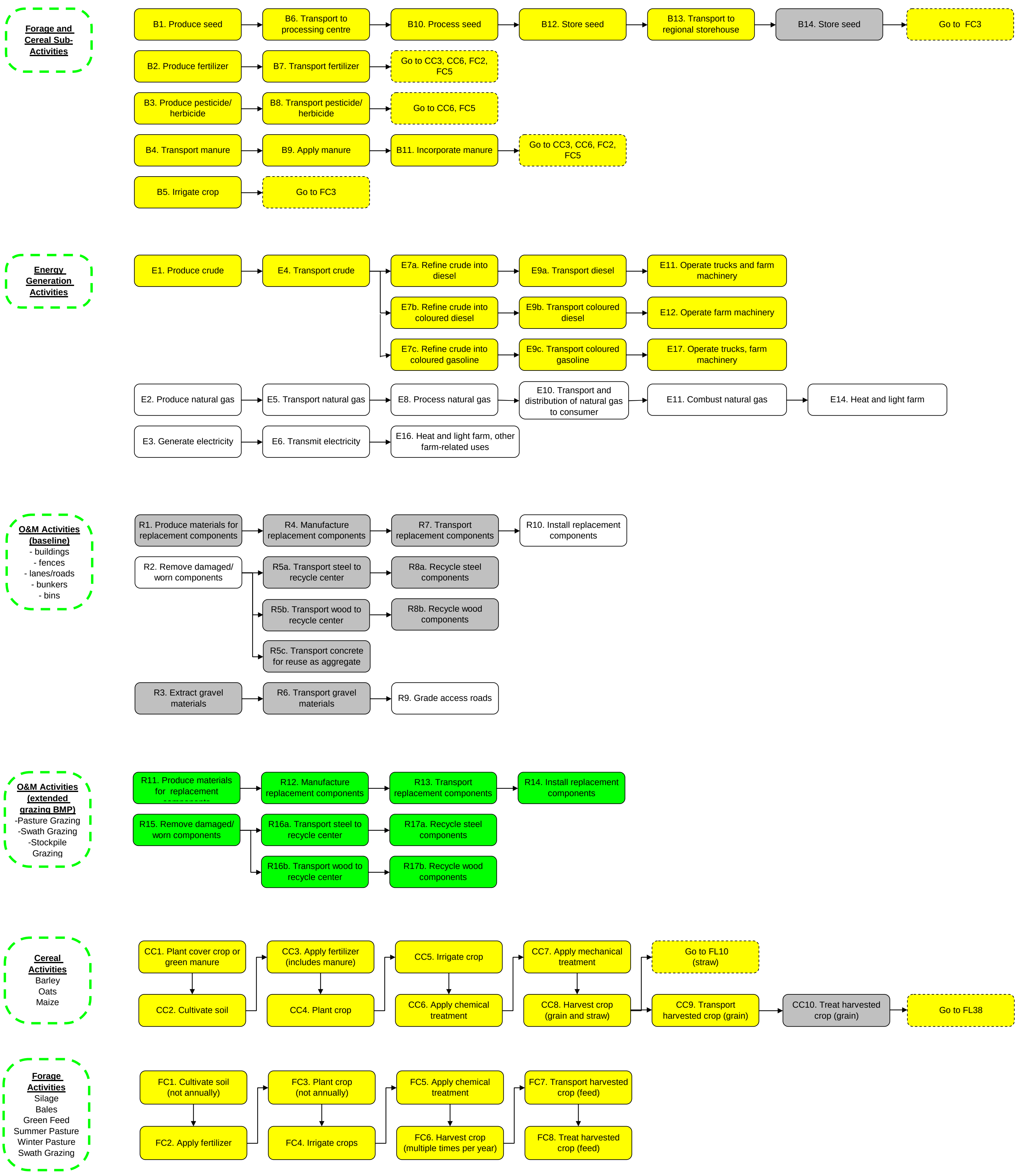
FIGURE BMP 2a

ACTIVITY MAP
BMP #2 - PROMOTION OF INCREASED EFFICIENCY IN COW/CALF FEEDING AND GRAZING SYSTEMS
LIFE CYCLE ASSESSMENT - BEEF
ALBERTA AGRICULTURE AND RURAL DEVELOPMENT
Edmonton, Alberta

CRA

the PEMBINA institute
Sustainable Energy Solutions

B: Operation and Maintenance



The scenarios for this BMP will affect the above yellow-highlighted activities, and are outlined as follows:

BMP 2.1: Winter Pasture - Extended Grazing (Swath Grazing)
BMP 2.2: Winter Pasture - Extended Grazing (Stockpile Grazing)

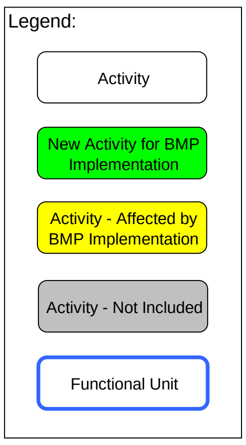
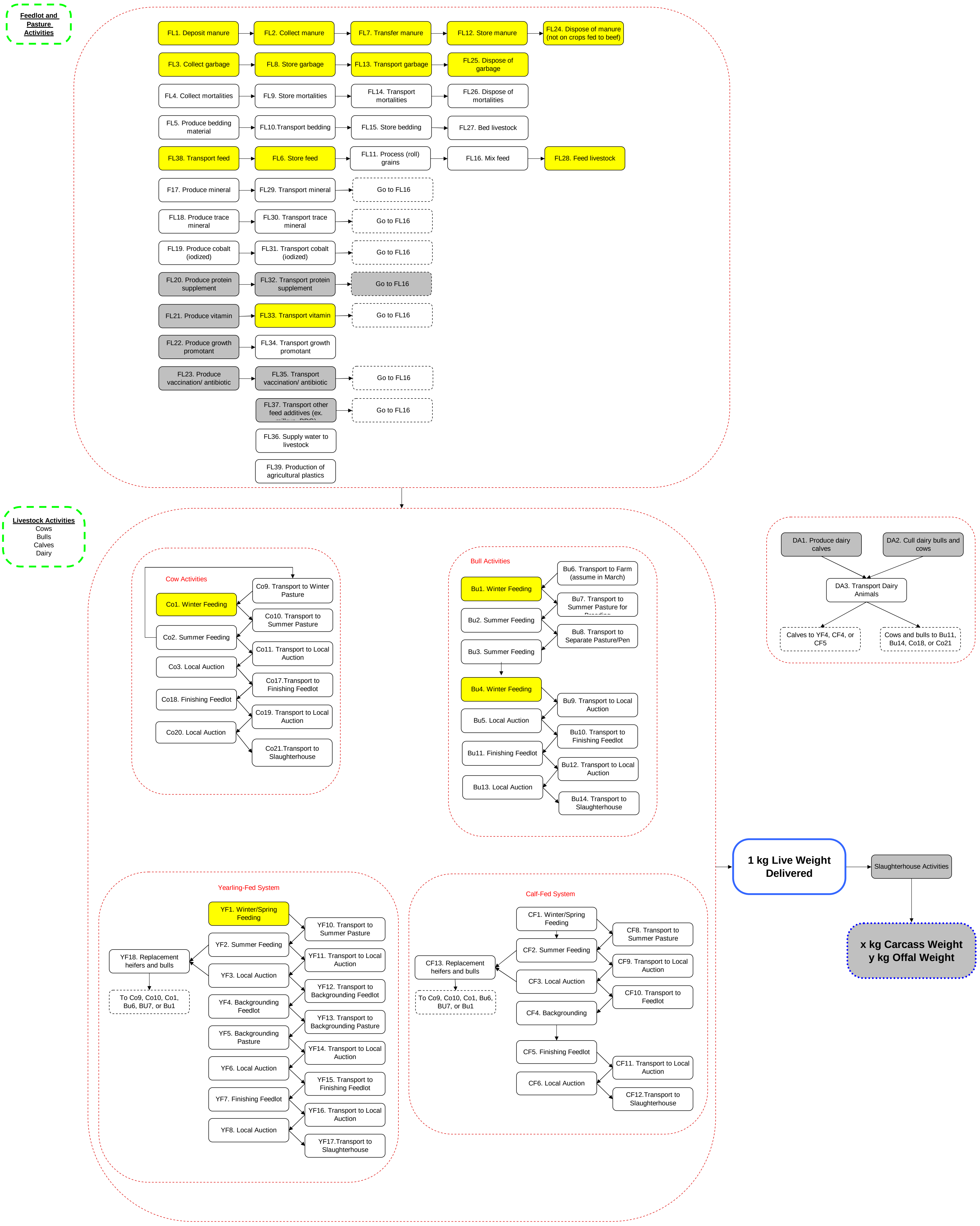


FIGURE BMP 2b

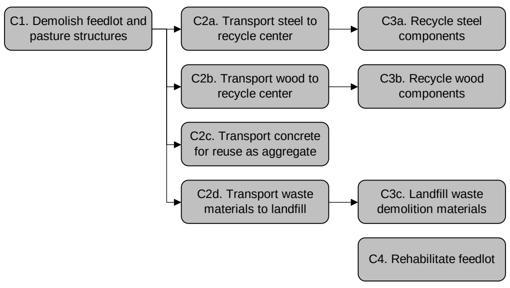
ACTIVITY MAP
BMP #2 - PROMOTION OF INCREASED EFFICIENCY IN COW/CALF FEEDING AND GRAZING SYSTEMS
LIFE CYCLE ASSESSMENT - BEEF
ALBERTA AGRICULTURE AND RURAL DEVELOPMENT
Edmonton, Alberta

Sustainable Energy Solutions

B: Operation and Maintenance



C: Decommissioning



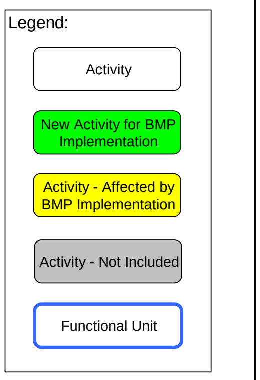


FIGURE BMP 2c

ACTIVITY MAP
BMP #2 - PROMOTION OF INCREASED EFFICIENCY IN COW/CALF FEEDING AND GRAZING SYSTEMS
LIFE CYCLE ASSESSMENT - BEEF
ALBERTA AGRICULTURE AND RURAL DEVELOPMENT
Edmonton, Alberta

CRA

the PEMBINA institute
Sustainable Energy Solutions

Swath Grazing Data

								Source
Available forage coefficient		0.8						Determining your stocking rate. At: http://extension.usu.edu/files/publications/publication/NR_RM_04.pdf
Weight of cattle	cow	454	kg	1000	lbs	606	kg	1335 lbs Beef LCA - Phase 1
	bull	544	kg	1200	lbs	998	kg	2200 lbs Beef LCA - Phase 2
Food intake coefficient		0.75						Using the Animal Unit Month (AUM) Effectively. At: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex1201
Animal units equivalent AU eq - cow, dry		0.92						Using the Animal Unit Month (AUM) Effectively. At: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex1201
Animal units equivalent AU eq - bull		1						Using the Animal Unit Month (AUM) Effectively. At: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex1202

Animal Unit Equivalent (AUE) based on metabolic weight	Animal Live Weight (lbs)	Animal Unit Equivalent	Animal Live Weight (lbs)	Animal Unit Equivalent	
	1000	1	1300	1.217	Llewellyn L. , Animal Unit Equivalent for Beef Cattle Based on Metabolic Weight. At: http://www.ag.ndsu.nodak.edu/dickinso/research/1997/animal.htm
	1200	1.2	2200	1.806	Llewellyn L. , Animal Unit Equivalent for Beef Cattle Based on Metabolic Weight. At: http://www.ag.ndsu.nodak.edu/dickinso/research/1997/animal.htm

1.12
lbs/acre × 1.12 = kg/ha

daily food intake	cow	11.34	kg	
		25.00	lbs	
	bull	13.61	kg	
		30.00	lbs	
Determining stocking rates				http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex113

Note: use for the daily food intake the data provided by the nutritionist

cow	28.00	lbs
bull	28.00	lbs

Swath system					**Crops**	**Source**
Single graze	Cereal	Annual	DP	A	oats	discussion (Febr 25, 2011) and e-mail (March 1, 2011) - Grant lastiwka
Single graze	Cereal	Annual	P	A	oats	discussion (Febr 25, 2011) and e-mail (March 1, 2011) - Grant lastiwka
Single graze	Cereal	Annual	NR	A	oats	discussion (Febr 25, 2011) and e-mail (March 1, 2011) - Grant lastiwka
Single graze	Cereal	Annual	DP	A	triticale	discussion (Febr 25, 2011) and e-mail (March 1, 2011) - Grant lastiwka
Single graze	Cereal	Annual	P	A	triticale	discussion (Febr 25, 2011) and e-mail (March 1, 2011) - Grant lastiwka
Single graze	Cereal	Annual	NR	A	triticale	discussion (Febr 25, 2011) and e-mail (March 1, 2011) - Grant lastiwka

Yield crop - DM					**Crops**	**Yield dry matter** kg/ha	**Yield dry matter** (lb/ac)	**Source: see also comments on cells**
Single graze	Cereal	Annual	DP	A	oats	4704	4200	discussion (Febr 25, 2011) and e-mail (March 1, 2011) - Grant lastiwka
Single graze	Cereal	Annual	P	A	oats	9632	8600	discussion (Febr 25, 2011) and e-mail (March 1, 2011) - Grant lastiwka
Single graze	Cereal	Annual	NR	A	oats	6720	6000	discussion (Febr 25, 2011) and e-mail (March 1, 2011) - Grant lastiwka
Single graze	Cereal	Annual	DP	A	triticale	5040	4500	discussion (Febr 25, 2011) and e-mail (March 1, 2011) - Grant lastiwka
Single graze	Cereal	Annual	P	A	triticale	9856	8800	discussion (Febr 25, 2011) and e-mail (March 1, 2011) - Grant lastiwka
Single graze	Cereal	Annual	NR	A	triticale	6720	6000	discussion (Febr 25, 2011) and e-mail (March 1, 2011) - Grant lastiwka

Days on pasture					**Days**	**Source**
Single graze	Cereal	Annual	DP	A	90	Agri-Facts, October 2004. Swath grazing in Western Canada: An Introduction. Table 1, page 5. At: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex9239/$file/420_56-2.pdf?OpenElement
Single graze	Cereal	Annual	P	A	90	Agri-Facts, October 2004. Swath grazing in Western Canada: An Introduction. Table 1, page 5. At: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex9239/$file/420_56-2.pdf?OpenElement
Single graze	Cereal	Annual	NR	A	90	Agri-Facts, October 2004. Swath grazing in Western Canada: An Introduction. Table 1, page 5. At: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex9239/$file/420_56-2.pdf?OpenElement
Single graze	Cereal	Annual	DP	A	90	Agri-Facts, October 2004. Swath grazing in Western Canada: An Introduction. Table 1, page 5. At: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex9239/$file/420_56-2.pdf?OpenElement
Single graze	Cereal	Annual	P	A	90	Agri-Facts, October 2004. Swath grazing in Western Canada: An Introduction. Table 1, page 5. At: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex9239/$file/420_56-2.pdf?OpenElement
Single graze	Cereal	Annual	NR	A	90	Agri-Facts, October 2004. Swath grazing in Western Canada: An Introduction. Table 1, page 5. At: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex9239/$file/420_56-2.pdf?OpenElement

Area for swath grazing						**Source**
Single graze	Cereal	Annual	DP	A	**698,196**	Statistics Canada. Table 5.1-6 Hay and field crops - Barley, census years 2006 and 2001. 2001 data. At: http://www.statcan.gc.ca/pub/95-629-x/5/4124257-eng.htm#48
Single graze	Cereal	Annual	P	A	**1,039,365**	Statistics Canada. Table 5.1-6 Hay and field crops - Barley, census years 2006 and 2001. 2001 data. At: http://www.statcan.gc.ca/pub/95-629-x/5/4124257-eng.htm#49
Single graze	Cereal	Annual	NR	A	**246,241**	Statistics Canada. Table 5.1-6 Hay and field crops - Barley, census years 2006 and 2001. 2001 data. At: http://www.statcan.gc.ca/pub/95-629-x/5/4124257-eng.htm#50

Note: for swath grazing systems: annual crops as cereals - add more land for grazing (ARD, conference call Nov 30, 2010)

Cattle and crop data

Total number of cattle (includes beef cows, replacement heifers and bulls)		**# cattle**	**% Breakdown per region from total**		**Source**
DP		773,130	30		Statistics Canada. Table 6.1
P		1,303,129	51		Statistics Canada. Table 6.2
NR		493,699	19		Statistics Canada. Table 6.3
	total	**2,569,958**	100	2,569,958	Statistics Canada. Table 19 -May 15, 2001. At: http://www.statcan.gc.ca/pub/95f0301x/t/html/4064782-eng.htm

Number of cattle on winter diet, as per the initial model	days			Comment
	60	cows	2,458,579	59 days from the diet (see Cow Rplc tab) are approximated to 60 days
	60	bulls	109,428	
	60	**total**	**2,568,007**	
	30	cows	2,230,364	
	30	bulls	89,730	
	30	**total**	**2,320,093**	

oats	triticale	Assumption: 50% of cattle graze on oats and 50% on triticale from the total existent crops

Swath Grazing Data

Source

Breakdown per region, based on %	days			50%	50%	100%		
DP	60	cows	739,623	369,812	369,812	739,623		
	60	bulls	32,920	16,460	16,460	32,920		
	60	***total***	***772,543***	***386,272***	***386,272***	***772,543***	0	data check
P	60	cows	1,246,653	623,326	623,326	1,246,653		
	60	bulls	55,487	27,743	27,743	55,487		
	60	***total***	***1,302,140***	***651,070***	***651,070***	***1,302,140***		
NR	60	cows	472,303	236,151	236,151	472,303		
	60	bulls	21,022	10,511	10,511	21,022		
	60	***total***	***493,324***	***246,662***	***246,662***	***493,324***		
			2,568,007					
DP	30	cows	670,969	335,484	335,484	670,969		
	30	bulls	26,994	13,497	13,497	26,994		
	30	***total***	*697,962*	***348,981***	***348,981***	***697,962***		
P	30	cows	1,130,933	565,467	565,467	1,130,933		
	30	bulls	45,499	22,749	22,749	45,499		
	30	***total***	*1,176,432*	***588,216***	***588,216***	***1,176,432***		
NR	30	cows	428,462	214,231	214,231	428,462		
	30	bulls	17,237	8,619	8,619	17,237		
	30	***total***	***445,699***	***222,850***	***222,850***	***445,699***		
			2,320,093					

Seeding rates						**kg/ha**
Single graze	Cereal	Annual	DP	A	oats	143.02
Single graze	Cereal	Annual	P	A	oats	143.02
Single graze	Cereal	Annual	NR	A	oats	143.02
Single graze	Cereal	Annual	DP	A	triticale	111.24
Single graze	Cereal	Annual	P	A	triticale	111.24
Single graze	Cereal	Annual	NR	A	triticale	111.24

Yield of seeds per cultivated ha							
Single graze	Cereal	Annual	DP	A	oats	7,151	kg/ha
Single graze	Cereal	Annual	P	A	oats	7,151	kg/ha
Single graze	Cereal	Annual	NR	A	oats	7,151	kg/ha
Single graze	Cereal	Annual	DP	A	triticale	2225	kg/ha
Single graze	Cereal	Annual	P	A	triticale	2225	kg/ha
Single graze	Cereal	Annual	NR	A	triticale	2225	kg/ha

200 bu/ac=12.713 kg/ha				http://www.extension.iastate.edu/agdm/wholefarm/pdf/c6-80.pdf
1	bu/ac	63.57	kg/ha	

DM intake	Weight of cattle kg	Food intake coefficient month	Food intake kg/month	Food intake kg/day	Food intake lbs/day
Cows	606	0.75	454	15.14	33.37
Bulls	998	0.75	748	24.95	55.00

Change in gas, diesel, and electricity usage on feedlots for reduced feed time, replaced by extended grazing (swath grazing)

Note: Energy required to feed animals in the baseline is included in the total energy used on beef farms in Alberta. Changes to energy requirements to be calculated.

Energy requirements to feed cattle in the feedlot	1785 Mcal/animal			ACRES USA. From Mid-East Oil to London Broil: A Comparison of Energy Inputs in Feedlot versus Grass-Fed Beef. November 2005. Available at: http://www.acresusa.com/magazines/archive
Days on winter feed in feedlot (in reference)	255 days of feed in feedlot			
Days on winter feed in feedlot (in model)	90 days of feed in farm			
Mass of feed per day in feedlot during the winte	28 lbs feed per cow per day			
Energy requirements to feed 1 lb of feed in the feedlot	**1 lb feed = 0.28 Mcal**			
	0.28 Mcal	=	1111.13 Btu	
		=	**1.1723 MJ**	

Note: Assume that diesel is the fuel used to operate the machinery to feed cattle (as per reference)

Change in gas and diesel for manure handling on feedlot for reduced time, replaced by swath grazing on the pasture

Note: Energy required to collect manure in the baseline is included in the total energy used on beef farms in Alberta. Changes to energy requirements to be calculated.

Manure collection and handling			
Diesel consumption for a tractor	16.6	L/hr	Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3
Number of feedlot cattle in reference	50,000	cattle	Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3
Pens with 250 head/pen in reference	200	pens	Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3
times per year	2		Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3
heads per pen	250		Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3
Time to pile up manure in pen in reference	60	min/pen two times per year	Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3
	400	hrs/yr	Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3
Diesel required per year	6,640	L/yr	Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3:
CO_2 emission factor for truck diesel	2,569	g CO_2/L	Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3
CH_4 emission factor for truck diesel	0.21	g CH_4/L	Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3
Total emissions from manure collection (calculated based on data)	17.09	tonnes CO_2e/yr	Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3

Swath Grazing Data

				Source
Total emissions from manure collection (total provided in reference) *reference different than total emissions provided in reference.* *Only raw data from reference will be used to calculate emissions in model.)*	1,172	tonnes CO2e/year		
Quantity of manure (in reference) *(Alberta Beef LCA model used same reference to quantify manure)*	58,700	tonne dry manure/year		Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3
Emission factor for the combustion of diesel in agricultural equipment - Alberta Beef LCA	3.28	kg CO_2e/kg diesel		Intergovernmental Panel on Climate Change (IPCC). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 2. Chapter 3: Mobile Combustion. Available at: http://www.ipcc-nggip.iges.or.jp/pub
Density of diesel	0.885	kg/L		Simetric. Specific Gravity of Liquids. Available at: http://www.simetric.co.uk/si_liquids.htm
	3.71	kg CO_2e/L		
Total emissions from manure collection using the LCA model emission factor *(comparable to emissions calculated using reference data)*	24.61	tonnes/yr		
Total emissions from manure collection per animal per day	0.00135	kg/animal/day	Calculated	

Change in gas and diesel for bedding animals in feedlot for reduced time, replaced by extended swath grazing on the pasture

Note: Energy required to provide bedding in the baseline is included in the total energy used on beef farms in Alberta. Changes to energy requirements to be calculated.

Bedding required for feedlot in Alberta Beef LCA model	422,073	tonnes		
Total mass of barley and barley silage (feedlot diet)	12,061,530	tonnes		
% of bedding mass compared to total feed mass	3.5	%		

Bedding mass negligible compared to feed.

Change in quantity of agricultural plastics for reduced winter feed, replaced by extended swath grazing on the pasture

Current agricultural plastics disposal methods

- Burning is still the most prominent method of getting rid of agricultural plastics (2008)
- There is little industry capacity to handle agricultural plastics in Alberta
- Pilot recycling program conducted in Alberta in 2008 to understand the amount, type, and quality of used agricultural plastics and the capacity of industry to use it
- Alberta Beef LCA baseline model assumed the same as the current situation for the handling of agricultural plastics (burning and
- No change in the disposal of plastics
- Total change in plastics will be calculated based on percentage of total change in feed

Recycling Council of Alberta. Agricultural Plastics Recycling Pilot Project. Summary

Change in labour

Average reduction in days on feedlot	90.0	days		
Average labor time per day cattle on farm	2	hrs/day	Assumption	
Average labor time per day cattle on extended grazing	1	hrs/day	The WFBG showed 44% less labor for swath grazing versus traditional feeding.	YEAR ROUND GRAZING = 365 DAYS http://www.agrireseau.qc.ca/bovinsboucherie/documents/00105%20p.pdf

Price Information

Average farm hand wage	16.22	$/hr		WAGEinfo, Alberta Wage and Salary Survey, 2009 data. Available at: http://alis.alberta.ca/wageinfo/Content/RequestAction.asp?aspAction=GetWageDetail&format=html&RegionID=20&NOC=8431
Purchase of barley	161.38	$/tonne		Lethbridge Barley Price, Alberta Grains Council, Alberta Canola Producers Commission. Weekly Average from 2005 to 2010
	0.16	$/kg		
Purchase of barley silage	40	$/tonne	Based on a conversation with a local dairy farmer on January 3, 2011.	
	0.04	$/kg		
Purchase of bedding (model assumes 100% straw bedding used) (Straw estimate for 2010)				
Wheat straw (fertilizer costs)	24.2	$/ton		What is Straw Worth? - Frequently Asked Questions. Ag-Info Centre, Alberta Agriculture and Rural Development. Available at: www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/faq7514
	26.7	$/tonne		
Barley and oat straw (fertilizer costs)	32	$/ton		What is Straw Worth? - Frequently Asked Questions. Ag-Info Centre, Alberta Agriculture and Rural Development. Available at: www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/faq7514
	35.3	$/tonne		
Pea straw (fertilizer costs)	30	$/ton		What is Straw Worth? - Frequently Asked Questions. Ag-Info Centre, Alberta Agriculture and Rural Development. Available at: www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/faq7514
	33.1	$/tonne		

Swath Grazing Data

						Source
Canola straw (fertilizer costs)	22.6	$/ton				What is Straw Worth? - Frequently Asked Questions. Ag-Info Centre, Alberta Agriculture and Rural Development. Available at: www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/faq7514
	24.9	$/tonne				
Average weight of straw bale	450	kg				Microsoft Word document provided by Alberta Agriculture and Rural Development in an email from Emmanuel Laate to Stephen Ball on November 20, 2009
Baling costs	9.00 - 11.50	$/large round bale				What is Straw Worth? - Frequently Asked Questions. Ag-Info Centre, Alberta Agriculture and Rural Development. Available at: www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/faq7514
	10.25	$/large round bale			Average	
	0.023	$/kg				
	22.78	$/tonne				
Hauling and stacking	2.00 - 3.00	$/large round bale				What is Straw Worth? - Frequently Asked Questions. Ag-Info Centre, Alberta Agriculture and Rural Development. Available at: www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/faq7514
	2.5	$/large round bale			Average	
	0.0056	$/kg				
	5.56	$/tonne				
Average price (wheat straw)	55.01	$/tonne				
Average price (barley and oat straw)	63.61	$/tonne				
Average price (pea straw)	61.40	$/tonne				
Average price (canola straw)	53.25	$/tonne				
Average price for straw	58.32	$ / tonne				
	0.058	$ / kg				
Purchase of alfalfa/grass hay (alfalfa per ton)	124.44	$/ton				Internet Hay Exchange. Hay Price Calculator. Available at: http://www.hayexchange.com/tools/ave_price_calc.php.
	137.17	$/tonne				
	0.14	$ / kg				
Purchase of seed for alfalfa/grass	0.55	$/lb				Source: Historical Turf and Forage Seed Prices in Alberta -- to 2009. At: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/sis6720
	1.21	$/kg				
Purchase of seed for oats	4	$/bu				http://alberta.kijiji.ca/c-buy-and-sell-other-12000-bushels-of-seeding-oats-W0QQAdIdZ261197051
	0.26	$/kg		Canada: 34 lb = 15.4221 kg	http://www.answers.com/topic/bushel	
Purchase of seed for triticale	28	$/50 lb			http://www.geertsonseedfarms.com/Pages/Prices.htm	
	0.56	$/lb				
	1.23	$/kg				
Purchase of chemical fertilizer						
Urea, as N, at regional storehouse	0.45		$/kg			http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/sdd11027
Ammonia, liquid, at regional storehouse	0.88		$/kg			http://www.agr.gc.ca/pol/mad-dam/pubs/rmar/pdf/rmar_02_07_2010-11-26_eng.pdf
Monoammonium phosphate, as P2O5, at regiona	0.62		$/kg			http://www.agr.gc.ca/pol/mad-dam/pubs/rmar/pdf/rmar_02_07_2010-11-26_eng.pdf
Monoammonium phosphate, as N, at regional st	0.62		$/kg			http://www.agr.gc.ca/pol/mad-dam/pubs/rmar/pdf/rmar_02_07_2010-11-26_eng.pdf
Ammonium sulphate, as N, at regional storehou	0.44		$/kg			insert reference
Purchase of pesticide	88.74	$/kg				http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/sdd11027
Purchase of water to irrigate crop	1.22		$/m3			
calculated	1500.00		$/acre foot			http://www.saaep.ca/Irrigation_In_Alberta_2004.pdf
	1.22		$/m3			
Custom rates for agricultural operations						
Tillage						
No till						
Heavy harrow	8	$/ac			http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/inf12992	
	19.77	$/ha				
Reduced till						
Chisel plow (3 inch)	74.67	$/ac			http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/inf12992	
	184.50	$/ha				
Heavy harrow	8	$/ac			http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/inf12992	
	19.77	$/ha				
Full till						
Chisel plow (3 inch)	75	$/ac			http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/inf12992	
	185.33	$/ha				
Field cultivator	10	$/ac			http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/inf12992	
	24.71	$/ha				
Heavy off-set disk	40	$/ac			http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/inf12992	
	98.84	$/ha				
Apply fertilizer						
Broadcasting						
Sprayer	6	$/ac			http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/inf12992	
	14.83	$/ha				
Injected or knifed in						
Anhydrous applicator	17.5	$/ac			http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/inf12992	
	43.24	$/ha				
Plant crop						
Air drill	24	$/ac			http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/inf12992	
	59.30	$/ha				
Apply chemical treatment						
Sprayer	6	$/ac				
	14.83	$/ha			http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/inf12992	
Swath crop						
Swather	10	$/ac			http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/inf12992	

Swath Grazing Data

				Source
	24.71	$/ha		
Harvesting alfalfa hay				
Combine - proxy	16	$/ac	http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/inf12992	
	39.54	$/ha		
Purchase of min., trc min., cobalt, protein suppl., vit., antibiotic for feedlot				
32% Feedlot Supplement (pellets with	11.89	$/25 kg		UFA Limited. Available at: http://ufa.com/products/product.html. Accessed on January 3, 2011.
	0.48	$/kg		
Vitamins (A-D-E Premix) for feedlot				
Mash	24.99	$/20 kg		UFA Limited. Available at: http://ufa.com/products/product.html. Accessed on January 3, 2011.
Crumble	30.00	$/20 kg		UFA Limited. Available at: http://ufa.com/products/product.html. Accessed on January 3, 2011.
Average	27.50	$/20 kg		
	1.37	**$/kg**		
Purchase of manure	0	$/kg		Government of Alberta. Agriculture and Rural Development. Manure and Compost Directory. Available at: http://www.agric.gov.ab.ca/app68/manure. Accessed on January 3, 2011.
Sale price for beef to slaughterhouse (reduction due to younger age)	0	$/kg	Assumed value - only approximately 5 day difference and therefore price shouldn't be affected.	
Fuel consumed to feed livestock (on-farm diesel) - and -				
Fuel consumed to collect manure (on-farm				
Ultra Low Sulphur Diesel (ULSD)				
Calgary, AB	80.7	cents/L (excluding taxes)		UFA Petroleum. Rack Prices. December 18 to December 20, 2010. Available at: www.ufa.net/petroleum/rack_pricing.html
Edmonton, AB	77.5	cents/L (excluding taxes)		UFA Petroleum. Rack Prices. December 18 to December 20, 2010. Available at: www.ufa.net/petroleum/rack_pricing.html
Ultra Low Sulphur Diesel Lite (ULSD-LT)				
Calgary, AB	84.2	cents/L (excluding taxes)		UFA Petroleum. Rack Prices. December 18 to December 20, 2010. Available at: www.ufa.net/petroleum/rack_pricing.html
Edmonton, AB	81.0	cents/L (excluding taxes)		UFA Petroleum. Rack Prices. December 18 to December 20, 2010. Available at: www.ufa.net/petroleum/rack_pricing.html
Average	80.85	cents/L (excluding taxes)		
Fuel tax rates (diesel - all grades) (April 1, 2007 to current)	9	cents/L		Alberta Tax and Revenue Administration - Current and Historic Tax Rates. Available at: www.finance.alberta.ca/publications/tax_rebates/rates/hist1.html#fuel
Alberta Farm Fuel Benefit Program and Farm Fuel Distribution Allowance (taxes)	-15	cents/L		Alberta Tax and Revenue Administration - Current and Historic Tax Rates. Available at: www.finance.alberta.ca/publications/tax_rebates/rates/hist1.html#fuel
Fuel tax is exempted for diesel used on farms and a subsidy of 6 cents per L of diesel is				
Average diesel price minus Alberta programs	**0.75**	**$/L**		
Electric Fencing				
Charger (energizer)	799.00	$/unit		UFA Co-operative Limited. Available at www.ufa.net. Accessed Jan 18, 2011.
High tensile wire - 14 gauge	24.99	$/ 400 m		UFA Co-operative Limited. Available at www.ufa.net. Accessed Jan 18, 2011.
Connectors - wire tensioners	22.49	$/5 units		UFA Co-operative Limited. Available at www.ufa.net. Accessed Jan 18, 2011.
Grounding rod -				
3/4" x 10' Galvanized Pipe	62.34	$/unit		at: http://www.fastenal.com/web/search/products/plumbing/pipe-pipe-accessories/pipe-lengths/_/N-gj4z0iZjudqgqZjucbwsZjudwhl&Nty=0
insulators for wooden posts (for permanent fences)	9.79	$/25		UFA Co-operative Limited. Available at www.ufa.net. Accessed Jan 18, 2011.
Posts - wood	6.69	$/unit		at: http://www.ufa.net/products/Building-Supply/38/Lumber.html
Posts fiberglass - proxy step-in temporary post (poly)	3.59	$/each		UFA Co-operative Limited. Available at www.ufa.net. Accessed Jan 18, 2011.
voltage meter - Gallagher Smart Fix Fault Finder	148.99	$/each		at: http://www.ufa.net/products/Animal-Care/Livestock/Fencing/196/Electric-Fence-Supplies.html
Barbwire Fencing				
Barbed wire	62.99	$/400m		UFA Co-operative Limited. Available at www.ufa.net. Accessed Jan 18, 2011.
Windbreaker	5.00	$/foot		information from Ab Ag (discussion with Emamnuel Latte on February 24, 2011)
	16.40	$/m		

Notes:

A	Applicable
NA	Not Applicable

Please see inserted comments in cells for additional references, details

Additional resources
Winter feeding Beef Cows on Pasture with Bale Grazing and Bale Processing versus Drylot
http://www.angelfire.com/trek/mytravels/nutrientmanagement.html

Estimated manure nutrients. Feedlot management
http://www.extension.iastate.edu/Publications/PM1867.pdf

Swath Grazing Management Data

Grazing management: Fences, including electric fencing, gates, windbreakers. Source: ARECA, November 2006. Year Round Grazing 365 Days, At: http://www.agrireseau.qc.ca/bovinsboucherie/documents/00105%20p.pdf

Items	*Composition*			*Materials used*	*Materials requirements*	*Process*	*Ecoinvent*
Electric fencing (1)	polywire			wire		Production of poly wire	wire drawing, steel
	grounding system	energizers (battery powered or plug-in)		miscellaneous	calculated		
		minimum of three ground rods (http://www.extension.umn.edu/beef/components/homestudy/plesson3.PDF)	galvanized large surface area ground rods that are 6-7 feet in length, to extend below the frost line (e.g. galvanized pipe + 1 ¼" tubing used to frame link fence gates)	galvanized pipe and tubing	calculated	Production of galvanized pipe	drawing of pipes, steel
			One half-inch diameter galvanized steel rods or 3/4" galvanized pipe make the best ground rods. They should be at least 6 feet long and driven 5-1/2 feet into the soil (http://www.extension.umn.edu/beef/components/homestudy/plesson3.PDF))	galvanized pipe	calculated	Production of galvanized pipe	drawing of pipes, steel
		ground rod clamps			calculated	Production of ground rod clamps	connector, clamp connection, at plant
		electric posts (ground rods) see above		-	-		
Fence (1)	barb wire			metal	calculated	Production of barb wire	wire drawing, steel
	posts	3/8" diameter fiberglass posts		fiberglass	calculated	Production of fiberglass	fiberglass, at plant
	posts	wooden		wood	calculated	Production of wood for poles	round wood, hardwood, under bark, u=70%, at forest road
Gates (1)	barb wire			metal	calculated	Production of barb wire	wire drawing, steel
	posts	3/8" diameter fiberglass posts		fiberglass	calculated	Production of fiberglass	fiberglass, at plant
	posts	wooden		wood	calculated	Production of wood for poles	round wood, hardwood, under bark, u=70%, at forest road
Electricity							
Drill (1)	cordless drill with a masonary bit, 24 volt power pack drill with a long masonry drill			units	calculated		
Windbreakers (portable)	frame	steel tubing		steel	calculated	Production of galvanized pipe	drawing of pipes, steel
	planks	wooden		wood	calculated	Production of wood for planks	plywood, outdoor use, at plant

Barbed wire
Barbed wire for agriculture use is typically double-strand 12½-gauge, zinc-coated (galvanized) steel and comes in rolls of 1,320 ft (400 m) length.
http://en.wikipedia.org/wiki/Barbed_wire#Agricultural_fencing

Windbreakers
a variety of models to select from http://www.agriculture.gov.sk.ca/Default.aspx?DN=adb8ecee-7d31-4f72-8d83-c71ac97baba4

as a general rule, one foot of fence (windbreaker) protects enough area for one cow
http://www.agriculture.gov.sk.ca/Default.aspx?DN=adb8ecee-7d31-4f72-8d83-c71ac97baba4

Portable Windbreak Fencing - Sustainable Livestock Wintering: How Can It Work for You?
http://www.gov.mb.ca/agriculture/crops/forages/pdf/bjb05s17.pdf
Calculations of material requirements are based on the total grazing area and the grazing management strategy

Grazing management strategies   Strip grazing
leave 10 to 20 % crop residue each year
source: YEAR ROUND GRAZING = 365 DAYS http://www.agrireseau.qc.ca/bovinsboucherie/documents/00105%20p.pdf

watering: Solar-powered systems. cost of water per cow ranged from $0.03 to $0.15 per day. The cost per gallon of pumped water ranged from $0.002 to $0.007 per gallon.
http://attra.ncat.org/attra-pub/solarlswater.html

http://www.thebeefsite.com/articles/2078/livestock-fencing-systems-for-pasture-management

	2001	2006
Total cattle and calves number	6,615,201	6,369,116
Farms reporting	31,774	28,751
Average number of cattle per farm	208	222

Source: Table 1.3 Selected agricultural data, selected livestock data, Canada and provinces, census years 1921 to 2006. At: http://www.statcan.gc.ca/pub/95-632-x/2007000/t/4129740-eng.htm#48

Tame or seeded pasture	Average area in acres per farm reporting	2001	2006
	acres	229	267

Source: Table 2.5 Total land area and use of farm land, Canada and provinces, census years 1976 to 2006. At: http://www.statcan.gc.ca/pub/95-632-x/2007000/t/4185579-eng.htm#48

Swath Grazing Calculations

				Crops	*Yield dry matter (kg/ha)*	*Number of cattle - cows (50% of total)*	*Number of cattle - bulls (50% of total)*	*Total cow days (# cows * # days)*	*Total bull days (# bulls * # days)*	*Available forage coefficient*	*Weight of cattle - cows (kg)*	*Weight of cattle - bulls (kg)*	*Food intake coefficient*	*AU eq cows*	*AU eq bulls*	*Days on pasture*	*Months on pasture*	*Total cultivated area ha (calculated) (1)*	**Tame or seeded pasture (as per Statistics Canada)**
Single graze	Cereal	Annual	DP	oats	4704	369,812	16,460	21,820,189	971,369	0.8	454	544	0.75	1	1.2	60	2	71,148	672,135
			P	oats	9632	623,326	27,743	36,778,447	1,637,265	0.8	454	544	0.75	1	1.2	60	2	58,566	1,025,787
			NR	oats	6720	236,151	10,511	13,933,757	620,289	0.8	454	544	0.75	1	1.2	60	2	31,803	532,970
						1,284,003											**oats**	**161,516**	
						1,229,290	54,714												

				Crops	*Yield dry matter (kg/ha)*	*Number of cattle - cows (50% of total)*	*Number of cattle - bulls (50% of total)*	*Total cow days (# cows * # days)*	*Total bull days (# bulls * # days)*	*Available forage coefficient*	*Weight of cattle (kg)*	*Weight of cattle - bulls (kg)*	*Food intake coefficient*	*AU eq*	*AU eq bulls*	*Days on pasture*	*Months on pasture*	*Total cultivated area ha (calculated) (1)*
Single graze	Cereal	Annual	DP	oats	4704	335,484	13,497	10,414,966	416,987	0.8	454	544	0.75	1	1.2	30	1	32,085
			P	oats	9632	565,467	22,749	17,554,673	702,842	0.8	454	544	0.75	1	1.2	30	1	26,411
			NR	oats	6720	214,231	8,619	6,650,704	266,276	0.8	454	544	0.75	1	1.2	30	1	14,342
						1,160,047											**oats**	**72,838**
						1,115,182	44,865										**TOTAL OATS**	**234,354**

				Crops	*Yield dry matter (kg/ha)*	*Number of cattle - cows (50% of total)*	*Number of cattle - bulls (50% of total)*	*Total cow days (# cows * # days)*	*Total bull days (# bulls * # days)*	*Available forage coefficient*	*Weight of cattle (kg)*	*Weight of cattle - bulls (kg)*	*Food intake coefficient*	*AU eq*	*AU eq bulls*	*Days on pasture*	*Months on pasture*	*Total cultivated area ha (calculated) (1)*
Single graze	Cereal	Annual	DP	triticale	5040	369,812	16,460	21,820,189	971,369	0.8	454	544	0.75	1	1.2	60	2	66,404
			P	triticale	9856	623,326	27,743	36,778,447	1,637,265	0.8	454	544	0.75	1	1.2	60	2	57,235
			NR	triticale	6720	236,151	10,511	13,933,757	620,289	0.8	454	544	0.75	1	1.2	60	2	31,803
						1,284,003											**triticale**	**155,442**
						1,229,290	54,714											

				Crops	*Yield dry matter (kg/ha)*	*Number of cattle - cows (50% of total)*	*Number of cattle - bulls (50% of total)*	*Total cow days (# cows * # days)*	*Total bull days (# bulls * # days)*	*Available forage coefficient*	*Weight of cattle (kg)*	*Weight of cattle - bulls (kg)*	*Food intake coefficient*	*AU eq*	*AU eq bulls*	*Days on pasture*	*Months on pasture*	*Total cultivated area ha (calculated) (1)*
Single graze	Cereal	Annual	DP	triticale	5040	335,484	13,497	10,414,966	416,987	0.8	454	544	0.75	1	1.2	30	1	29,946
			P	triticale	9856	565,467	22,749	17,554,673	702,842	0.8	454	544	0.75	1	1.2	30	1	25,811
			NR	triticale	6720	214,231	8,619	6,650,704	266,276	0.8	454	544	0.75	1	1.2	30	1	14,342
						1,160,047											**triticale**	**70,099**
						1,115,182	44,865										**TOTAL TRITICALE**	**225,541**

223,535,524

Summary crop areas		ha
	Oats	234,354
	Triticale	225,541

Sources

(1) Pratt, M., and Rasmussen, A., 2001. Determining your stocking rate, Range Management Fact Sheet. At: http://extension.usu.edu/files/publications/publication/NR_RM_04.pdf

Notes

DP	Dry Prairie
P	Parkland
NR	Northern Regions

for swath grazing systems: annual crops as cereals - add more land for grazing; perennial crops as forage - do not add more land, keep the same area (ARD, conference call Nov 30, 2010)

Agri-Facts, September 2008. Agronomic Management of Swath Grazed Pastures:
Very little research done in Western Canada on swath grazing perennial forage crops. Winterkill could be a problem because swath grazing may leave the perennial crop with insufficient snow cover.

Swath Grazing Management Calculations

CALCULATE THE AREA REQUIRED BY ONE DAY OF GRAZING/ONE CATTLE

days on pasture 1

				Crops	*Yield dry matter (kg/ha)*	*Number of cattle - cows (50% of total)*	*Number of cattle - bulls (50% of total)*	*Available forage coefficient*	*Weight of cattle - cows (kg)*	*Weight of cattle - bulls (kg)*	*Food intake coefficient*	*AU eq cows*	*AU eq bulls*	*Days on pasture*	*Months on pasture*	*Total cultivated area ha (calculated) (1)*
Single graze	Cereal	Annual	DP	oats	4704	369,812	16,460	0.8	454	544	0.75	1	1.2	1	0.03	1,186
			P	oats	9632	623,326	27,743	0.8	454	544	0.75	1	1.2	1	0.03	976
			NR	oats	6720	236,151	10,511	0.8	454	544	0.75	1	1.2	1	0.03	530
						1,284,003									**Oats**	**2,692**
						1,229,290	54,714									

Tame or seeded pasture (as per Statistics Canada)
672,135
1,025,787
532,970

Conclusion: the area currently cultivated with these species can support more cattle than in the model

				Crops	*Yield dry matter (kg/ha)*	*Area (ha)*		*Available forage coefficient*	*Weight of cattle (kg)*		*Food intake coefficient*	*AU eq*		*Days on pasture*	*Months on pasture*	*No. of cattle (calculated) (1)*
Single graze	Forage	Perennial	DP	triticale	5040	348,252		0.8	454		0.75	#REF!		90	3.00	#REF!
			P	triticale	9856	767,036		0.8	454		0.75	#REF!		90	3.00	#REF!
			NR	triticale	6720	469,300		0.8	454		0.75	#REF!		90	3.00	#REF!

				Crops	*Yield dry matter (kg/ha)*	*Number of cattle - cows (50% of total)*	*Number of cattle - bulls (50% of total)*	*Available forage coefficient*	*Weight of cattle (kg)*	*Weight of cattle - bulls (kg)*	*Food intake coefficient*	*AU eq*	*AU eq bulls*	*Days on pasture*	*Months on pasture*	*Total cultivated area ha (calculated) (1)*
Single graze	Cereal	Annual	DP	oats	4704	335,484	13,497	0.8	454	544	0.75	1	1.2	1	0.03	1,069
			P	oats	9632	565,467	22,749	0.8	454	544	0.75	1	1.2	1	0.03	880
			NR	oats	6720	214,231	8,619	0.8	454	544	0.75	1	1.2	1	0.03	478
						1,160,047									**Oats**	**2,428**
						1,115,182	44,865								**TOTAL**	**5,120**

				Crops	*Yield dry matter (kg/ha)*	*Number of cattle - cows (50% of total)*	*Number of cattle - bulls (50% of total)*	*Available forage coefficient*	*Weight of cattle (kg)*	*Weight of cattle - bulls (kg)*	*Food intake coefficient*	*AU eq*	*AU eq bulls*	*Days on pasture*	*Months on pasture*	*Total cultivated area ha (calculated) (1)*
Single graze	Forage	Perennial	DP	triticale	5040	369,812	16,460	0.8	454	544	0.75	1	1.2	1	0.03	1,107
			P	triticale	9856	623,326	27,743	0.8	454	544	0.75	1	1.2	1	0.03	954
			NR	triticale	6720	236,151	10,511	0.8	454	544	0.75	1	1.2	1	0.03	530
						1,284,003									**grass as forage**	**2,591**
						1,229,290	54,714									

				Crops	*Yield dry matter (kg/ha)*	*Number of cattle - cows (50% of total)*	*Number of cattle - bulls (50% of total)*	*Available forage coefficient*	*Weight of cattle (kg)*	*Weight of cattle - bulls (kg)*	*Food intake coefficient*	*AU eq*	*AU eq bulls*	*Days on pasture*	*Months on pasture*	*Total cultivated area ha (calculated) (1)*
Single graze	Forage	Perennial	DP	triticale	5040	335,484	13,497	0.8	454	544	0.75	1	1.2	1	0.03	998
			P	triticale	9856	565,467	22,749	0.8	454	544	0.75	1	1.2	1	0.03	860
			NR	triticale	6720	214,231	8,619	0.8	454	544	0.75	1	1.2	1	0.03	478
						1,160,047									**grass as forage**	**2,337**
						1,115,182	44,865								**TOTAL**	**4,927**

number of cattle	1,284,003	head
	1,160,047	head
	1,284,003	head
	1,160,047	head
total	***4,888,100***	head
area 1 day/1 head	**0.002**	**ha**

area for 1 day, all cattle	2,692	ha
	2,428	ha
	2,591	ha
	2,337	ha
total	***10,047***	ha

CALCULATE THE GRAZING AREA PER HERD

Pasture area for swath grazing 459,895 ha

Average number of cattle/farm 208 head

Number of cattle on winter diet, as per the initial model		2,458,579 cows	95.7	% of total cattle
		109,428 bulls	4.3	% of total cattle
	total	**2,568,007** head	100.0	% of total cattle

Average number of cattle per herd and composition of herd	200 head	
	191.48 cows	192 cows
	8.52 bulls	8 bulls

Number of herds, per total, based on average head/herd and total number of cattle 12,840 herds

Daily requirement of forage/herd	2177 kg	cows
	109 kg	bulls

Average number of herds/farm 1 based on average number of cattle/farm and average cattle in a herd

average area/head/day	0.002 ha
area/ 200 head herd/day, based on average area for 1 head per day and number of head in the herd	0.41 ha
	1.02 acres

average area of farm used for grazing/ 90 days, based on area/herd and number of herds per farm 91 acres

Tame or seeded pasture	Average area in acres per farm reporting		
		2001	229 acres
		2006	267 acres

Conclusion: for one farm, the available area for grazing is larger than the minimum grazing area requirements, calculated based on number of head and individual grazing area needs

Swath Grazing Management Calculations

FENCING

at: http://www.hallman.ca/principl.htm

Elements of portable electric fence

Charger (energizer)		1 unit/line	
Power source	outlets	1 unit/energizer	
	12 or 6 volt wet cell DC batteries	1 unit/energizer	
	9 volt dry cell batteries	1 unit/energizer	
Wire	high tensile wire	2 wire lines	
Connecting wire	connectors	3 units/charger	
Grounding rods		3 units/charger	
		1 extra unit/1500 feet of fence	500m
Insulators		1 unit/grounding rod	
Fence posts	wood	1 every 50 feet of fence	15m
	fiber glass	1 every 50 feet of fence	15m
	metal	1 every 50 feet of fence	15m
Gate for portable fence		1 unit/line	
Voltage meter		1 unit/line	

Elements of barbed wire fence for perimeter enclosure

Barbed wire		3 strand lines
Fence posts	wood	1 unit/5 m of fence
	fiber glass	1 unit/5 m of fence
	metal	1 unit/5 m of fence
Gate for fence		2 units/enclosure

CALCULATE FENCING PER FARM

1 quarter section = 160 acres 1 quarter section = 0.5 mile long and 0.5 mile wide

Assumed the total grazing perimeter for a herd for 90 days enclosed with barbed wire. The entire area to be enclosed	91	acres	369979	m2
Length	0.50	miles	805	m
Width	0.29	miles	460	m
Total perimeter of the enclosure	1.57	miles	2529	m

Within the perimeter, portable electric fence is used to delineate grazing of the heard (grazing cell). Assumed lines of portable fence delineating strips 0.5 mile long, moved every 3 days. 2 lines of portable fence
The cell is moved every 3 days, for 30 times, to cover all winter grazing period of 90 days

Summary fencing for one herd and farm

Lines of electric fence	2	units
Length of electric fence	1609	m
Gates for electric fence	2	units
Length of barbed wire fence	2529	m
Gates for barbed wire fence	2	units

Summary /one herd and farm

Charger (energizer)				2	unit
Power source					unit
	outlets	0% use of outlets	0.00	0	unit
	12 or 6 volt wet cell DC batteries	100% use of 12 or 6 volt wet cell DC batteries	1.00	2	unit
	9 volt dry cell batteries	0% use of 9 volt dry cell batteries	0.00	0	unit
Wire	high tensile wire			3219	m
Connecting wire	connectors			6	unit
Grounding rods				6	unit
				4	extra unit
Insulators				10	unit
Electric fence posts	wood post	0% use of wood posts	0.00	0	unit
	fiber glass post	100% use of fiber glass post	1.00	107	unit
	metal post	0% use of metal posts	0.00	0	unit
Gate for portable electric fence					
	wood post	100% use of wood posts	1.00	2	unit
	fiber glass post	assuming 0% use of fiber glass post	0.00	0	unit
	metal post	0% use of metal posts	0.00	0	unit
Voltage meter				1	unit
Barbed wire				7587	m
Barbed wire fence posts	wood post	100% use of wood posts	1.00	506	unit
	metal post	0% use of metal posts	0.00	0	unit
Gate for barbed wire fence	wood post	100% use of wood posts	1.00	2	unit
	metal post	0% use of metal posts	0.00	0	unit

Summary all farms 31,774 (Census data 2001)
Number of farms cow-calf operators 12,840

				material	quantity		Ecoinvent process
Charger (energizer)		25,680	unit	misc	data gap		data gap
Power source	12 or 6 volt wet cell DC batteries	25,680	unit	misc	data gap		data gap
High tensile wire		41,328,066	m	steel wire	5,635,517	kg	wire drawing, steel
Connectors - wire tensioners		77,040	unit	connectors	3,852	kg	connector, clamp connection, at plant
Grounding rods		128,400	unit	galvanized pipe	83,460	kg	drawing of pipes, steel
Insulators		128,400	unit	misc	data gap		data gap
Posts - wood		6,545,647	unit	wood	373,102	m3	round wood, hardwood, under bark, u=70%, at forest road
Posts fiberglass		1,377,602	unit	fiber glass	119,767	kg	fiberglass, at plant
Posts metal		0	unit	metal	0	kg	drawing of pipes, steel
Voltage meter		12,840	unit	misc	data gap		data gap
Barbed wire		97,414,308	m	steel wire	13,283,467	kg	wire drawing, steel

WINDBREAKERS

as a general rule, one foot of fence (windbreaker) protects enough area for one cow			1	foot of windbreaker
Number of cattle on winter grazing	total		2,569,958	head
	60 days	DP	772,543	
	60 days	P	1,302,140	
	60 days	NR	493,324	
	30 days	DP	697,962	
	30 days	P	1,176,432	
	30 days	NR	445,699	
7.5% of the cattle are protected by artificial windbreakers in the DP	8%			
1% of the cattle are protected by artificial windbreakers in the P and NR	1%		75,895	feet of windbreaker

Windbreakers used for the first 60 days are also used for the next 30 days of winter grazing.

With 25% porosity, an 8' long section of fence 8' tall would require 12 1x6" boards and 3 2x6" boards

1 feet windbreaker			material	quantity		Ecoinvent process
1x6" wood board, 8 feet high	1.5	unit				
	0.24	ft3				
	0.006796043	m3	wood	516	m3	plywood, outdoor use, at plant
2x6" wood board, 8 feet high	0.375	unit				
	0.48	ft3				
	0.013592087	m3	wood	1032	m3	plywood, outdoor use, at plant

Swath Grazing Management Calculations

steel pipe	metal components (frame, support, axel, etc), tyres, or wooden bracing is sourced from old machinery or surplus materials already on-farm (old combines, irrigation piping, old tractors, spare fence posts, etc.)				
		83,460	kg	drawing of pipes, steel	**use this number for AG1-a**
TOTALS		**13,283,467**	kg	wire drawing, steel	**use this number for AG1-b**
		5,635,517	kg	wire drawing, steel	**use this number for AG1-c**
		1547	m3	plywood, outdoor use, at plant	**use this number for AG1-d**
		373,102	m3	round wood, hardwood, under bark, u=70%, at forest road	**use this number for AG1-e**
		3,852	kg	connector, clamp connection, at plant	**use this number for AG1-f**
		119,767	kg	fiberglass, at plant	**use this number for AG1-g**

BMP 2 - SWATH GRAZING - BENEFITS AND COSTS

BMP 2 (BMP 2.1 - Swath Grazing)
Extended grazing during winter - swath grazing

Assumed Percent Adoption of BMP 2	**100%**	
(% adoption can be adjusted for the entire model in the source cell)		
Number of cattle affected by this BMP (cow/calf operation only)	2,568,007	cows and bulls affected
Weight of affected cattle (slaughtered cows and bulls)	130,388,870	kg live shrunk weight
Density of diesel	0.885	kg/L

	COW/CALF OPERATIONS										FEEDLOT OPERATIONS									
	BMP 2			**Baseline**			**Change**		**Per Unit Market Value**	**Total Impact**	**BMP 2**			**Baseline**			**Change**		**Per Unit Market Value**	**Total Impact**
	(amount)	*(unit)*		*(amount)*	*(unit)*		*(change)*	*(unit)*	*($/unit)*	*($ Million)*	*(amount)*	*(unit)*		*(amount)*	*(unit)*		*(change)*	*(unit)*	*($/unit)*	*($ Million)*
Inputs with Change																				
Purchase of seed for barley											202,360,278			202,360,278			0			
Purchase of seed for barley silage											82,029,696			82,029,696			0			
Purchase of seed for alfalfa/grass hay	4,661,566	kg	0	8,190,019	kg	0	-3,528,453	kg												
Purchase of seed for oats	33,517,641	kg	0	0	kg	0	33,517,641	kg												
Purchase of seed for triticale	25,088,879	kg	0	0	kg	0	25,088,879	kg												
Purchase of alfalfa/grass hay	3,750,747,349	kg		6,589,779,580	kg		-2,839,032,231	kg												
Production of chemical fertilizer																				
Total urea, as N	820,506	kg	0	0	kg	0	820,506	kg			114,107,963	kg		120,290,430	kg		-6,182,467	kg		
Total ammonia, liquid	642,847	kg	0	0	kg	0	642,847	kg			89,400,826	kg		94,244,639	kg		-4,843,813	kg		
Total monoammonium phosphate as P2O5	0	kg	0	19,131,205	kg	0	-19,131,205	kg			41,555,961	kg		46,773,950	kg		-5,217,990	kg		
Total monoammonium phosphate as N	0	kg	0	4,487,567	kg	0	-4,487,567	kg			9,747,694	kg		10,971,667	kg		-1,223,973	kg		
Total ammonium sulphate as N	2,870,815	kg	0	0	kg	0	2,870,815	kg			11,979,163	kg		11,979,163	kg		0	kg		
Purchase of chemical fertilizer																				
Urea, as N, at regional storehouse	820,506	kg	0	0	kg	0	820,506	kg			114,107,963	kg		120,290,430	kg		-6,182,467	kg		
Ammonia, liquid, at regional storehouse	642,847	kg	0	0	kg	0	642,847	kg			89,400,826	kg		94,244,639	kg		-4,843,813	kg		
Monoammonium phosphate, as P2O5, at regional storehouse	0	kg	0	0	kg	0	0	kg			41,555,961	kg		46,773,950	kg		-5,217,990	kg		
Monoammonium phosphate, as N, at regional storehouse	0	kg	0	0	kg	0	0	kg			9,747,694	kg		10,971,667	kg		-1,223,973	kg		
Ammonium sulphate, as N, at regional storehouse	2,870,815	kg	0	0	kg	0	2,870,815	kg			11,979,163	kg		11,979,163	kg		0	kg		
Fuel consumed to transport fertilizer	60,529	L		0	L		60,529	L			2,061,626	kg		1,934,516	kg		127,110	kg		
Fuel consumed to transport manure as soil amendment for application	2,000,740	L		0	L		2,000,740	L			11,179,009	kg		9893423.126	kg		1285586.056	kg		
Production of pesticide/herbicide	382,775	kg	0	0	kg	0	382,775	kg			4,136,235	kg		3,660,568	kg		475667.0575	kg		
Purchase of pesticide/herbicide	382,775	kg	0	0	kg	0	382,775	kg			4,136,235	kg	0	3,660,568	kg	0	475,667	kg		
Fuel consumed to transport pesticide	689	L			kg		689	L			5,829	kg		5,829	kg		475,667			
Fuel consumed for forage activities																				
Fuel consumed to cultivate soil	3,690,386	L		0	L		3,690,386	L			5,920,675	L		5,920,675	L		0	L		
Fuel consumed to apply fertilizer	1,269,703	L		0	L		1,269,703	L			2,037,050	L		2,037,050	L		0	L		
Fuel consumed to plant crop	1,875,956	L		0	L		1,875,956	L			3,009,693	L		3,009,693	L		0	L		
Fuel consumed to irrigate crop	98,780	L		0	L		98,780	L			158,478	L		158,478	L		0	L		
Fuel consumed to apply chemical treatment to crop	415,724	L		0	L		415,724	L			666,968	L		666,968	L		0	L		
Fuel consumed to harvest crop	2,611,269	L		0	L		2,611,269	L			8,378,784	L		8,378,784	L		0	L		
Fuel consumed to transport forage	0	L		0	L		0	L			1,160,473	L		1,160,473	L		0	L		
Purchase of water to irrigate crop	13,876,276	m3		0	m3		13,876,276	m3			44,524,839	kg		44,524,839	kg		0	kg		
Fuel consumed to collect manure during winter feeding																				
Fuel consumed to transfer manure on site- included above																				
Fuel consumed to transport manure off-site - not applicable																				
Production of bedding	409,313,507	kg		509,445,174	kg		-100,131,666	kg			422,073,796	kg		422,073,796	kg		0	kg		
Fuel consumed to transport bedding	290,450,715	L		361,504,598	L		-71,053,883	L			299,505,473	L		299,505,473	L		0	L		
Fuel consumed to feed livestock (change)							-44,640,145	L												
Fuel consumed to bed livestock (no change)																				
Production of min., trc min., cobalt, protein suppl., vit., antibiotic (no change)																				
Production of vitamins (no change)																				
Purchase of min., trc min., cobalt, protein suppl., antibiotic (no change)																				
Purchase of vitamins (no change)																				
Fuel cons. to transp. min., trc min., cob., prot. suppl., vit., antibiotic (no change)																				
Fuel consumed for transport of vitamin (no change)																				
Purchase of fencing elements																				
Charger (energizer)	25680	unit		0			25680	unit												
Power source - included in the price of energizer																				
High tensile wire - 14 gauge	41328066	m		0			41328066	m												
Connectors - wire tensioners	77040	unit		0			77040	unit												
Grounding rod	128400	unit		0			128400	unit												
Insulators	128400	unit		0			128400	unit												
Posts - wood	6545647	unit		0			6545647	unit												
Posts fiberglass	1377602	unit		0			1377602	unit												
Voltage meter	12840	unit		0			12840	unit												
Barbed wire	97414308	m		0			97414308	m												
Windbreakers	75,895	feet of windbreaker		0			75895.36898	feet of windbreaker												
Labour (change)	12,840	hrs		25,680	hrs		-12,840	hrs	$ 16.22	-0.21										
Cropping costs (change)										135.12										
Working capital interest																				
Total Input Value Change																				
Outputs with Change																				
Manure sold for land application																				
Compost sold for land application																				
Total Output Value Change																				

CHANGE IN OVERALL GHG EMISSIONS	COW/CALF OPERATIONS						FEEDLOT OPERATIONS						BEEF INDUSTRY					
	BMP 2		Baseline		Change		BMP 2		Baseline		Change		BMP 2		Baseline		Change	
	(amount)	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*	*(amount)*	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*	*(amount)*	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*
BEEF ACTIVITIES - SOIL AND CROP																		
Manure generation																		
Methane emissions from stored manure	1.49E+08	kg CO_2eq	1.49E+08	kg CO_2eq	0.00E+00	kg CO_2eq	1.44E+08	kg CO_2eq	1.44E+08	kg CO_2eq	0.00E+00	kg CO_2eq						
Enteric fermentation emissions	7.03E+09	kg CO_2eq	7.03E+09	kg CO_2eq	0.00E+00	kg CO_2eq	3.56E+09	kg CO_2eq	3.56E+09	kg CO_2eq	0.00E+00	kg CO_2eq						
N2O emissions from stored manure (direct)	1.83E+09	kg CO_2eq	1.83E+09	kg CO_2eq	0.00E+00	kg CO_2eq	3.27E+08	kg CO_2eq	3.27E+08	kg CO_2eq	0.00E+00	kg CO_2eq						
N2O emissions from stored manure (indirect)	4.04E+08	kg CO_2eq	4.04E+08	kg CO_2eq	0.00E+00	kg CO_2eq	3.06E+08	kg CO_2eq	3.06E+08	kg CO_2eq	0.00E+00	kg CO_2eq						
N_2O emissions from cropping and land use	1.48E+08	kg CO_2eq	0.00E+00	kg CO_2eq	1.48E+08	kg CO_2eq							8.16E+08	kg CO_2eq	9.57E+08	kg CO_2eq	-1.41E+08	kg CO_2eq
Total P emissions from run-off	6.28E+05	kg PO_4-eq	0.00E+00	kg PO_4-eq	6.28E+05	kg PO_4-eq							3.70E+06	kg PO_4-eq	4.15E+06	kg PO_4-eq	-4.43E+05	kg PO_4-eq
Soil Carbon Change in Soil From Land Use	-3.90E+07	kg CO2eq	0.00E+00	kg CO2eq	-3.90E+07	kg CO2eq							-2.28E+08	kg CO2eq	-2.36E+08	kg CO2eq	7.84E+06	kg CO2eq
Direct CO2 emissions from managed soils	1.29E+06	kg CO2eq	0.00E+00	kg CO2eq	1.29E+06	kg CO2eq							1.79E+08	kg CO2eq	1.89E+08	kg CO2eq	-9.71E+06	kg CO_2eq
OVERALL SUMMARY																		
Construction	1.44E+07	kg CO_2e	0	kg CO_2e	1.44E+07	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e						
Forage and cereal sub-activities	2.24E+08	kg CO_2e	0.00E+00	kg CO_2e	2.24E+08	kg CO_2e							1.03E+09	kg CO2eq	1.20E+09	kg CO2eq	-1.78E+08	kg CO2eq
Energy generation and consumption activities	2.59E+09	kg CO_2eq	2.81E+09	kg CO_2eq	-2.16E+08	kg CO_2eq	1.04E+09	kg CO_2eq	1.04E+09	kg CO_2eq	0	kg CO_2eq						
O&M activities	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e						
Cereal activities													3.38E+08	kg CO2eq	3.38E+08	kg CO2eq	0.00E+00	kg CO2eq
Forage activities	5.48E+07	kg CO_2eq	0.00E+00	kg CO_2eq	5.48E+07	kg CO_2eq							2.11E+08	kg CO2eq	2.86E+08	kg CO2eq	-7.45E+07	kg CO2eq
Feedlot and pasture activities	4.19E+07	kg CO2eq	3.20E+06	kg CO2eq	3.87E+07	kg CO2eq	1.40E+08	kg CO_2eq	1.40E+08	kg CO_2eq	0.00E+00	kg CO_2eq	2.54E+08	kg CO2eq	3.04E+08	kg CO2eq	-4.96E+07	kg CO2eq
Cow activities (transportation)	2.49E+07	kg CO2eq	2.49E+07	kg CO2eq	0.00E+00	kg CO2eq												
Bull activities (transportation)	3.14E+06	kg CO2eq	3.14E+06	kg CO2eq	0.00E+00	kg CO2eq												
Yearling-fed system activities (transportation)							1.08E+08	kg CO_2eq	1.08E+08	kg CO_2eq	0.00E+00	kg CO_2eq						
Calf-fed system activities (transportation)							6.59E+07	kg CO_2eq	6.59E+07	kg CO_2eq	0.00E+00	kg CO_2eq						

Total GWP for BMP

kg CO_2e **1.25E+10** **Cow/Calf** **5.69E+09** **Feedlot** **2.60E+09** **Beef Industry**

Total Change in GWP for BMP

kg CO_2e **2.27E+08** **0.00E+00** **-4.45E+08**

Overall Baseline GWP (2001)

kg CO_2e/kg live weight **14.705**

Overall BMP GWP

kg CO_2e/kg live weight **14.552**

Change in overall GWP from 2001

kg CO_2e/kg live weight **-0.153**

Change in GWP per kg of beef affected from 2001

kg CO_2e/kg live weight **-1.673** **(total change in GHG emissions divided by total weight of cattle affected)**

Notes:
Energy generation emissions divided by the number of cattle on cow/calf vs feedlot
Feedlot and pasture activities are divided appropriately.

Stockpiling Data								**References**
Available forage coefficient		0.8						Determining your stocking rate. At: http://extension.usu.edu/files/publications/publication/NR_RM_04.pdf
								YEAR ROUND GRAZING = 365 DAYS http://www.agrireseau.qc.ca/bovinsboucherie/documents/00105%20p.pdf
Weight of cattle	cow	**454**	kg	1000	lbs	606	kg	Beef LCA - Phase 1
	bull	**544**	kg	1200	lbs	998	kg	Beef LCA - Phase 1
Food intake coefficient body weight/month		0.75						Using the Animal Unit Month (AUM) Effectively. At: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex1201
Animal units equivalent AU eq - cow, dry		0.92						
Animal units equivalent AU eq - bull		1						Using the Animal Unit Month (AUM) Effectively. At: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex1201
Animal Unit Equivalent (AUE) based on metabolic weight	Animal Live Weight (lbs)	Animal Unit Equivalent				Animal Live Weight (lbs)	Animal Unit Equivalent	
	1000	1				1300	1.217	Llewellyn L. , Animal Unit Equivalent for Beef Cattle Based on Metabolic Weight. At: http://www.ag.ndsu.nodak.edu/dickinso/research/1997/animal.htm
	1200	1.2				2200	1.806	Llewellyn L. , Animal Unit Equivalent for Beef Cattle Based on Metabolic Weight. At: http://www.ag.ndsu.nodak.edu/dickinso/research/1997/animal.htm
lbs/acre × 1.12 = kg/ha		1.12						
daily food intake	cow	11.34	kg					
		25.00	lbs					
	bull	13.61	kg					
		30.00	lbs					
Note: use for the daily food intake the data provided by the nutritionist								
	cow	28.00	lbs					
	bull	28.00	lbs					

Stockpiling system - Cultivated crops					**Crops**	**Source**
						The single-graze system is suited to the drier prairie regions where low summer rainfall prevents good regrowth.
	Grass	Perennial	DP	A	grass mix	discussion (Febr 25, 2011) and e-mail (March 1, 2011) - Grant Lawstika
	Grass	Perennial	DP	A	grass mix	discussion (Febr 25, 2011) and e-mail (March 1, 2011) - Grant Lawstika
	Grass	Perennial	DP	A	grass mix	discussion (Febr 25, 2011) and e-mail (March 1, 2011) - Grant Lawstika
	Grass	Perennial	P	A	meadow brome	discussion (Febr 25, 2011) and e-mail (March 1, 2011) - Grant Lawstika
	Grass	Perennial	NR	A	meadow brome	discussion (Febr 25, 2011) and e-mail (March 1, 2011) - Grant Lawstika

Yield - Cultivated crops					**Crops**	**Yield dry matter (kg/ha)**	**Yield dry matter (lb/ac)**	**Source: see comments on cells**
	Grass	Perennial	DP	A	grass mix	2800	2500	discussion (Febr 25, 2011) and e-mail (March 1, 2011) - Grant Lawstika
	Grass	Perennial	DP	A	grass mix	2800	2500	discussion (Febr 25, 2011) and e-mail (March 1, 2011) - Grant Lawstika
	Grass	Perennial	DP	A	grass mix	2800	2500	discussion (Febr 25, 2011) and e-mail (March 1, 2011) - Grant Lawstika
	Grass	Perennial	P	A	meadow brome	3360	3000	discussion (Febr 25, 2011) and e-mail (March 1, 2011) - Grant Lawstika
	Grass	Perennial	NR	A	meadow brome	3920	3500	discussion (Febr 25, 2011) and e-mail (March 1, 2011) - Grant Lawstika

Note: for stockpile grazing systems: keep the same area as current for grazing (ARD, conference call Nov 30, 2010)

Hay and field crops - All other tame hay and fodder crops					**ha**	**Source**
	Grass	Perennial	DP	A	152,360	Statistics Canada. Table 5.1-23 Hay and field crops - All other tame hay and fodder crops, census years 2006 and 2001. At: http://www.statcan.gc.ca/pub/95-629-x/2007000/4123849-eng.htm#hay
	Grass	Perennial	P	A	487,091	Statistics Canada. Table 5.1-23 Hay and field crops - All other tame hay and fodder crops, census years 2006 and 2001. At: http://www.statcan.gc.ca/pub/95-629-x/2007000/4123849-eng.htm#hay
	Grass	Perennial	NR	A	283,139	Statistics Canada. Table 5.1-23 Hay and field crops - All other tame hay and fodder crops, census years 2006 and 2001. At: http://www.statcan.gc.ca/pub/95-629-x/2007000/4123849-eng.htm#hay

Stockpiling system - Native crops (species)	Crops	Source
For stockpiling, native species are not better than tame forage species. The native species, western wheatgrass, had similar nutritive value to the tame species, meadow bromegrass, and was superior to another native, green needle grass.		At: http://www.mbforagecouncil.mb.ca/resources/forage-grassland-manual/9-extended-grazing/94-plan-your-stockpiling-program-now/#Native vs. Tame Species

		The single-graze system is suited to the drier prairie regions where low summer rainfall prevents good regrowth.
Cattle on cultivated crops (assumption applied to the total number of cattle on pasture, below)		conversation with Emmanuel Latte on February 23, 2011
DP	0.075	
P	1	
NR	1	

Total number of cattle	**Jan.1-Feb.28**	all cattle	cows	bulls
DP		773,130	737,823	35,307
P		1,303,129	1,246,517	56,612
NR		493,699	474,239	19,460
totals				

Stockpiling Data

References

Number of cattle on cultivated crops **Jan.1-Feb.28**

number of cattle from Statistics Canada. □Census 2001

								% breakdown by regions		% breakdown by regions- all cattle, including cattle on native pasture			
					all cattle	cows	bulls	cows	bulls	cows	bulls		
DP - total # of cattle	**57,985**	grass	perennial	0.33	**19,328**	18,446	883						
DP - # of cows	55,337	grass	perennial	0.33	**19,328**	18,446	883						
DP - # of bulls	2,648	grass	perennial	0.33	**19,328**	18,446	883	3.12	3.36	30.01	31.70		
P - total # of cattle	1,303,129	grass	perennial	1	**1,303,129**	1,246,517	56,612	70.18	71.92	50.70	50.83	0	data check
P - # of cows	1,246,517												
P - # of bulls	56,612												
NR - total # of cattle	493,699	grass	perennial	1	**493,699**	474,239	19,460	26.70	24.72	19.29	17.47	0	data check
NR - # of cows	474,239												
NR - # of bulls	19,460												
Total # of cattle on cultivated crops	**Jan.1-Feb.28**				**1,854,813**	1,776,093	78,720	***100***	***100***	***100***	***100***		
						2,458,579	*109,428*						

Total number of cattle	**Dec.2-Dec.31**	all cattle	cows	bulls
DP		697,779	669,335	28,444
P		1,176,418	1,130,810	45,608
NR		445,896	430,218	15,677
totals		**2,320,093**	2,230,364	89,730

Number of cattle on cultivated crops **Dec.2-Dec.31**

				cows	bulls
DP - total # of cattle				50,200	2,133
DP - # of cows	grass	perennial	0.33	16,733	711
DP - # of bulls	grass	perennial	0.33	16,733	711
	grass	perennial	0.33	16,733	711
P	grass	perennial	1	1,130,810	45,608
NR	grass	perennial	1	430,218	15,677
Total cows/bulls				2,230,364	89,730
Total all cattle				2,320,093	

Days on stockpiling grazing					**Days**	**Source**
	Grass	Perennial	DP	A	30	ARECA, November 2006. Year round grazing 365 days, page 4. At: http://www.agrireseau.qc.ca/bovinsboucherie/documents/00105%20p.pdf
	Grass	Perennial	DP	A	30	ARECA, November 2006. Year round grazing 365 days, page 4. At: http://www.agrireseau.qc.ca/bovinsboucherie/documents/00105%20p.pdf
	Grass	Perennial	DP	A	30	ARECA, November 2006. Year round grazing 365 days, page 4. At: http://www.agrireseau.qc.ca/bovinsboucherie/documents/00105%20p.pdf
						ARECA, November 2006. Year round grazing 365 days, page 4. At: http://www.agrireseau.qc.ca/bovinsboucherie/documents/00105%20p.pdf
	Grass	Perennial	P	A	30	ARECA, November 2006. Year round grazing 365 days, page 4. At: http://www.agrireseau.qc.ca/bovinsboucherie/documents/00105%20p.pdf
	Grass	Perennial	NR	A	30	ARECA, November 2006. Year round grazing 365 days, page 4. At: http://www.agrireseau.qc.ca/bovinsboucherie/documents/00105%20p.pdf

Seeding rates						**kg/ha**
	Grass	Perennial	DP	A	grass mix	6.05
	Grass	Perennial	DP	A	grass mix	6.05
	Grass	Perennial	DP	A	grass mix	6.05
	Grass	Perennial	P	A	meadow brome	11.20
	Grass	Perennial	NR	A	meadow brome	11.20

Yield of seeds per cultivated ha						**kg/ha**
	Grass	Perennial	DP	A	grass mix	217
	Grass	Perennial	DP	A	grass mix	217
	Grass	Perennial	DP	A	grass mix	217
	Grass	Perennial	P	A	meadow brome	196
	Grass	Perennial	NR	A	meadow brome	196

Pesticide requirements						kg/ha
	Grass	Perennial	DP	A	grass mix	0.8
	Grass	Perennial	DP	A	grass mix	0.8
	Grass	Perennial	DP	A	grass mix	0.8
	Grass	Perennial	P	A	meadow brome	0.8
	Grass	Perennial	NR	A	meadow brome	0.8

Notes:

A	Applicable
NA	Not Applicable

Please see inserted comments in cells for additional references, details

Stockpiling Data

References

Change in gas, diesel, and electricity usage on feedlots for reduced feed time, replaced by extended grazing (swath grazing)

Note: Energy required to feed animals in the baseline is included in the total energy used on beef farms in Alberta. Changes to energy requirements to be calculated.

Energy requirements to feed cattle in the feed	1785	Mcal/animal		ACRES USA. From Mid-East Oil to London Broil: A Comparison of Energy Inputs in Feedlot versus Grass-Fed Beef. November 2005. Available at: http://www.acresusa.com/magazines/archives		
Days on winter feed in feedlot (in reference)	255	days of feed in feedlot				
Days on winter feed in feedlot (in model)	0	days of feed in farm				
Mass of feed per day in feedlot during the wi	0	lbs feed per cow per day				
Energy requirements to feed 1 lb of feed in the feedlot	**1**	**lb feed = 0.28 Mcal**				
	0.28	Mcal	=	1111.13	Btu	
			=	**1.1723**	**MJ**	

Note: Assume that diesel is the fuel used to operate the machinery to feed cattle (as per reference)

Change in gas and diesel for manure handling on feedlot for reduced time, replaced by swath grazing on the pasture

Note: Energy required to collect manure in the baseline is included in the total energy used on beef farms in Alberta. Changes to energy requirements to be calculated.

Manure collection and handling				
Diesel consumption for a tractor	16.6	L/hr		Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of G
Number of feedlot cattle in reference	50,000	cattle		Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of G
Pens with 250 head/pen in reference	200	pens		Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of G
times per year	2			Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of G
heads per pen	250			Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of G
Time to pile up manure in pen in reference	60	min/pen two times per year		Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of G
	400	hrs/yr		Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of G
Diesel required per year	6,640	L/yr		Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Gr
CO_2 emission factor for truck diesel consumption	2,569	g CO_2/L		Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of G
CH_4 emission factor for truck diesel consumption	0.21	g CH_4/L		Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of G
Total emissions from manure collection (calculated based on data)	17.09	tonnes CO_2e/yr		Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of G
Total emissions from manure collection (total provided in reference)	1,172	tonnes CO2e/year		
(Total emissions calculated using data from reference different than total emissions provided in reference. *Only raw data from reference will be used to calculate emissions in model.)*				
Quantity of manure (in reference) *(Alberta Beef LCA model used same reference to quantify manure)*	58,700	tonne dry manure/year		Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of G
Emission factor for the combustion of diesel in agricultural equipment - Alberta Beef LCA model	3.28	kg CO_2e/kg diesel		Intergovernmental Panel on Climate Change (IPCC). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 2. Chapter 3: Mobile Combustion. Available at: http://www.ipcc-nggip
Density of diesel	0.885	kg/L		Simetric. Specific Gravity of Liquids. Available at: http://www.simetric.co.uk/si_liquids.htm
	3.71	kg CO_2e/L		
Total emissions from manure collection using the LCA model emission factor *(comparable to emissions calculated using reference data)*	24.61	tonnes/yr		
Total emissions from manure collection per animal per day	**0.00135**	kg/animal/day	Calculated	

Change in gas and diesel for bedding animals in feedlot for reduced time, replaced by extended swath grazing on the pasture

Note: Energy required to provide bedding in the baseline is included in the total energy used on beef farms in Alberta. Changes to energy requirements to be calculated.

Bedding required for feedlot in Alberta Beef LCA model	422,073	tonnes

Stockpiling Data				References
Total mass of barley and barley silage (feedlot diet)	12,061,530	tonnes		
% of bedding mass compared to total feed mass	3.5	%		

Bedding mass negligible compared to feed.

Change in quantity of agricultural plastics for reduced winter feed, replaced by extended swath grazing on the pasture

Current agricultural plastics disposal methods

- Burning is still the most prominent method of getting rid of agricultural plastics
- There is little industry capacity to handle agricultural plastics in Alberta
- Pilot recycling program conducted in Alberta in 2008 to understand the amount, type, and quality of used agricultural plastics and the capacity of industry to use it
- Alberta Beef LCA baseline model assumed the same as the current situation for the handling of agricultural plastics (burning and burying)
- No change in the disposal of plastics
- Total change in plastics will be calculated based on percentage of total change in feed

Recycling Council of Alberta. Agricultural Plastics Recycling Pilot Project. Summary

Change in labour

Average reduction in days on feedlot	35.0	days		
Average labor time per day cattle on farm	2	hrs/day	Assumption	
Average labor time per day cattle on extended grazing	1	hrs/day	The WFBG showed 44% less labor for swath grazing versus traditional feeding.	YEAR ROUND GRAZING = 365 DAYS http://www.agrireseau.qc.ca/bovinsboucherie/documents/00105%20p.pdf
Total time saved	72,012,896	hrs	Calculated, based on cattle days	

Price Information

Average farm hand wage	16.22	$/hr		WAGEinfo, Alberta Wage and Salary Survey, 2009 data. Available at: http://alis.alberta.ca/wageinfo/Content/RequestAction.asp?aspAction=GetWageDetail&format=html&RegionID=20&NOC=84
Purchase of barley	161.38 0.16	$/tonne $/kg		Lethbridge Barley Price, Alberta Grains Council, Alberta Canola Producers Commission. Weekly Average from 2005 to 2010
Purchase of barley silage	40 0.04	$/tonne $/kg	Based on a conversation with a local dairy farmer on January 3, 2011.	
Purchase of bedding (model assumes 100% straw bedding used) (Straw estimate for Wheat straw (fertilizer costs)	24.2 26.7	$/ton $/tonne		What is Straw Worth? - Frequently Asked Questions. Ag-Info Centre, Alberta Agriculture and Rural Development. Available at: www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/faq7514
Barley and oat straw (fertilizer costs)	32 35.3	$/ton $/tonne		What is Straw Worth? - Frequently Asked Questions. Ag-Info Centre, Alberta Agriculture and Rural Development. Available at: www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/faq7514
Pea straw (fertilizer costs)	30 33.1	$/ton $/tonne		What is Straw Worth? - Frequently Asked Questions. Ag-Info Centre, Alberta Agriculture and Rural Development. Available at: www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/faq7514
Canola straw (fertilizer costs)	22.6 24.9	$/ton $/tonne		What is Straw Worth? - Frequently Asked Questions. Ag-Info Centre, Alberta Agriculture and Rural Development. Available at: www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/faq7514
Average weight of straw bale	450	kg		
Baling costs	9.00 - 11.50 10.25	$/large round bale $/large round bale	Average	What is Straw Worth? - Frequently Asked Questions. Ag-Info Centre, Alberta Agriculture and Rural Development. Available at: www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/faq7514
Hauling and stacking	2.00 - 3.00 2.5	$/large round bale $/large round bale	Average	What is Straw Worth? - Frequently Asked Questions. Ag-Info Centre, Alberta Agriculture and Rural Development. Available at: www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/faq7514
Average price (wheat straw)	26.68	$/tonne		
Average price (barley and oat straw)	35.27	$/tonne		
Average price (pea straw)	33.07	$/tonne		
Average price (canola straw)	24.91	$/tonne		
Average price for straw	29.98 0.030	$ / tonne $ / kg		
Purchase of alfalfa/grass hay (alfalfa per ton	124.44 137.17 0.14	$/ton $/tonne $ / kg		Internet Hay Exchange. Hay Price Calculator. Available at: http://www.hayexchange.com/tools/ave_price_calc.php.

Stockpiling Data				References
Purchase of alfalfa seeds	0.55	$/lb		Source: Historical Turf and Forage Seed Prices in Alberta -- to 2009. At: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/sis6720
	1.21	$/kg		
Purchase of meadow brome	2.71	$/lb		http://www.utahseed.com/page12.html
	5.97	$/kg		
Purchase of Russian wild rye	6.34	$/lb		http://www.utahseed.com/page12.html
	13.98	$/kg		
Purchase of Pubescent wheat grass	2.71	$/lb		http://www.utahseed.com/page12.html
	5.97	$/kg		
Purchase of mix of meadow brome, russian wild rye and pubescen wheat grass	8.64	$/kg		
Purchase of chemical fertilizer				
Urea, as N, at regional storehouse	0.45	$/kg		http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/sdd11027
Ammonia, liquid, at regional storehouse	0.88	$/kg		http://www.agr.gc.ca/pol/mad-dam/pubs/rmar/pdf/rmar_02_07_2010-11-26_eng.pdf
Monoammonium phosphate, as P2O5, at regi	0.62	$/kg		http://www.agr.gc.ca/pol/mad-dam/pubs/rmar/pdf/rmar_02_07_2010-11-26_eng.pdf
Monoammonium phosphate, as N, at regiona	0.62	$/kg		http://www.agr.gc.ca/pol/mad-dam/pubs/rmar/pdf/rmar_02_07_2010-11-26_eng.pdf
Ammonium sulphate, as N, at regional storeh	0.44	$/kg		insert reference
Purchase of pesticide	88.74	$/kg		http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/sdd11027
Purchase of water to irrigate crop	1.22	$/m3		
calculated	1500.00	$/acre foot		http://www.saaep.ca/Irrigation_In_Alberta_2004.pdf
	1.22	$/m3		
Custom rates for agricultural operations				
Tillage				
No till				
Heavy harrow	8	$/ac	http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/inf12992	
	19.77	$/ha		
Reduced till				
Chisel plow (3 inch)	75	$/ac	http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/inf12992	
	185.33	$/ha		
Heavy harrow	8	$/ac	http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/inf12992	
	19.77	$/ha		
Full till				
Chisel plow (3 inch)	75	$/ac	http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/inf12992	
	185.33	$/ha		
Field cultivator	10	$/ac	http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/inf12992	
	24.71	$/ha		
Heavy off-set disk	40	$/ac	http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/inf12992	
	98.84	$/ha		
Apply fertilizer				
Broadcasting				
Sprayer	6	$/ac	http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/inf12992	
	14.83	$/ha		
Injected or knifed in				
Anhydrous applicator	17.5	$/ac	http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/inf12992	
	43.24	$/ha		
Plant crop				
Air drill	24	$/ac	http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/inf12992	
	59.30	$/ha		
Apply chemical treatment				
Sprayer	6	$/ac		
	14.83	$/ha	http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/inf12992	
Swath crop				
Windrower	6	$/ac		
	14.83	$/ha		

Stockpiling Data				References
Purchase of min., trc min., cobalt, protein suppl., vit., antibiotic for feedlot				
32% Feedlot Supplement (pellets with monensin)	11.89	$/25 kg		UFA Limited. Available at: http://ufa.com/products/product.html. Accessed on January 3, 2011.
	0.48	$/kg		
Vitamins (A-D-E Premix) for feedlot				
Mash	24.99	$/20 kg		UFA Limited. Available at: http://ufa.com/products/product.html. Accessed on January 3, 2011.
Crumble	30.00	$/20 kg		UFA Limited. Available at: http://ufa.com/products/product.html. Accessed on January 3, 2011.
Average	27.50	$/20 kg		
	1.37	$/kg		
Purchase of manure	0	$/kg		Government of Alberta. Agriculture and Rural Development. Manure and Compost Directory. Available at: http://www.agric.gov.ab.ca/app68/manure. Accessed on January 3, 2011.
Sale price for beef to slaughterhouse (reduction due to younger age)	0	$/kg	Assumed value - only approximately 5 day difference and therefore price shouldn't be affected.	
Fuel consumed to feed livestock (on-farm diesel) - and -				
Fuel consumed to collect manure (on-farm diesel)				
Ultra Low Sulphur Diesel (ULSD)				
Calgary, AB	80.7	cents/L (excluding taxes)		UFA Petroleum. Rack Prices. December 18 to December 20, 2010. Available at: www.ufa.net/petroleum/rack_pricing.html
Edmonton, AB	77.5	cents/L (excluding taxes)		UFA Petroleum. Rack Prices. December 18 to December 20, 2010. Available at: www.ufa.net/petroleum/rack_pricing.html
Ultra Low Sulphur Diesel Lite (ULSD-LT)				
Calgary, AB	84.2	cents/L (excluding taxes)		UFA Petroleum. Rack Prices. December 18 to December 20, 2010. Available at: www.ufa.net/petroleum/rack_pricing.html
Edmonton, AB	81.0	cents/L (excluding taxes)		UFA Petroleum. Rack Prices. December 18 to December 20, 2010. Available at: www.ufa.net/petroleum/rack_pricing.html
Average	80.85	cents/L (excluding taxes)		
Fuel tax rates (diesel - all grades) (April 1, 2007 to current)	9	cents/L		Alberta Tax and Revenue Administration - Current and Historic Tax Rates. Available at: www.finance.alberta.ca/publications/tax_rebates/rates/hist1.html#fuel
Alberta Farm Fuel Benefit Program and Farm Fuel Distribution Allowance (taxes)	-15	cents/L		Alberta Tax and Revenue Administration - Current and Historic Tax Rates. Available at: www.finance.alberta.ca/publications/tax_rebates/rates/hist1.html#fuel
Fuel tax is exempted for diesel used on farms and a subsidy of 6 cents per L of diesel is provided				
Average diesel price minus Alberta	0.75	$/L		
Electric Fencing				
energizer	799.00	$/unit		UFA Co-operative Limited. Available at www.ufa.net. Accessed Jan 18, 2011.
High tensile wire - 14 gauge	24.99	$/ 400 m		UFA Co-operative Limited. Available at www.ufa.net. Accessed Jan 18, 2011.
Connectors - wire tensioners	22.49	$/5 units		UFA Co-operative Limited. Available at www.ufa.net. Accessed Jan 18, 2011.
Grounding rod -				
3/4" x 10' Galvanized Pipe	62.34	$/each		at: http://www.fastenal.com/web/search/products/plumbing/pipe-pipe-accessories/pipe-lengths/_/N-gj4z0iZjudqgqZjucbwsZjudwhl&Nty=0
insulators for wooden posts (for permanent fences)	9.79	$/25		UFA Co-operative Limited. Available at www.ufa.net. Accessed Jan 18, 2011.
Posts - wood	6.69	$/each		at: http://www.ufa.net/products/Building-Supply/38/Lumber.html
Posts fiberglass - proxy step-in temporary post (poly)	3.59	$/each		UFA Co-operative Limited. Available at www.ufa.net. Accessed Jan 18, 2011.
voltage meter - Gallagher Smart Fix Fault Fin	148.99	$/each		at: http://www.ufa.net/products/Animal-Care/Livestock/Fencing/196/Electric-Fence-Supplies.html
Barbwire Fencing				
Barbed wire	62.99	$/400m		UFA Co-operative Limited. Available at www.ufa.net. Accessed Jan 18, 2011.
Windbreaker	5.00	$/foot		AT: http://www.mindfulservices.ca/pbe/files/AgriPark03/Final%20Document%20final.doc
	16.40	$/m		

Summary of data gaps

Yield dry matter	barley: Selection of the most appropriate data. The available yield value encompass a wide range of variation.	Agri-Facts, September 2008. Agronomic Management of Swath Grazed Pastures. At: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex12419/$file/420_56-3.pdf?OpenElement
Yield dry matter	barley-oat	
perennial forage crops for grazing	Very little research done in Western Canada on swath grazing perennial forage crops	Agri-Facts, September 2008. Agronomic Management of Swath Grazed Pastures:

Overall, selection of the most appropriate species for swath grazing crops. The selection should cover an average range, to support the available data and structure of the model.
yield, dry matter, for most of the species selected in the current model, such as: winter wheat, green needlegrass, western wheatgrass
DM yields adjusted for second/multiple pass
What % of cattle stockpile grazing on cultivated crops/native species?
How much grazing (%) on grass out of the total grazing (grass and legumes) ?
How much grazing (%) on annual/perennial grass and legumes?

Notes:

A	Applicable
NA	Not Applicable

Please see inserted comments in cells for additional references, details

Stockpiling Data **References**

Additional resources

Agri-Facts, October 2008. Agronomic management of stockpiled pastures:
Depth of snow cover frequently limits winter grazing of standing forage in the Parkland and Boreal forest regions. However, the grazing season may be extended by several weeks by using stockpiled forage in late fall and early spring.
Winter grazing on the prairie works best with little or no snow cover. Supplemental feed is needed if snow cover is too deep and forage yields are low.

seeding native grass	http://www.gov.mb.ca/agriculture/crops/forages/pdf/sodseeding.pdf
native grass mixes	http://www.viterra.ca/static/agri_products/MasterBlendsSection.pdf
seeding rate winter wheat	http://www.gov.mb.ca/agriculture/crops/forages/bjb00s40.html

Winter feeding Beef Cows on Pasture with Bale Grazing and Bale Processing versus Drylot
http://www.angelfire.com/trek/mytravels/nutrientmanagement.html

Estimated manure nutrients. Feedlot management
http://www.extension.iastate.edu/Publications/PM1867.pdf

Winter feeding Beef Cows on Pasture with Bale Grazing and Bale Processing versus Drylot

Stockpile Grazing Management Data

Total area	394,820	ha
Total no of cattle	2,569,958	head

Grazing management: Fences, including electric fencing, gates, windbreakers. Source: ARECA, November 2006. Year Round Grazing 365 Days, At: http://www.agrireseau.qc.ca/bovinsboucherie/documents/00105%20p.pdf

Items	*Composition*			*Materials used*	*Materials requirements*	*Process*	*Ecoinvent*
Electric fencing (1)	polywire			wire		Production of poly wire	wire drawing, steel
	grounding system	energizers (battery powered or plug-in)		miscellaneous	calculated		
		minimum of three ground rods (http://www.extension.umn.edu/beef/components/homestudy/plesson3.PDF)	galvanized large surface area ground rods that are 6-7 feet in length, to extend below the frost line (e.g. galvanized pipe + 1 ¼" tubing used to frame link fence gates)	galvanized pipe and tubing	calculated	Production of galvanized pipe	drawing of pipes, steel
			One half-inch diameter galvanized steel rods or 3/4" galvanized pipe make the best ground rods. They should be at least 6 feet long and driven 5-1/2 feet into the soil (http://www.extension.umn.edu/beef/components/homestudy/plesson3.PDF))	galvanized pipe	calculated	Production of galvanized pipe	drawing of pipes, steel
		ground rod clamps			calculated	Production of ground rod clamps	connector, clamp connection, at plant
		electric posts (ground rods) see above		-	-		
Fence (1)	barb wire			metal	calculated	Production of barb wire	wire drawing, steel
	posts	3/8" diameter fiberglass posts		fiberglass	calculated	Production of fiberglass	fiberglass, at plant
	posts	wooden		wood	calculated	Production of wood for poles	round wood, hardwood, under bark, u=70%, at forest road
Gates (1)	barb wire			metal	calculated	Production of barb wire	wire drawing, steel
	posts	3/8" diameter fiberglass posts		fiberglass	calculated	Production of fiberglass	fiberglass, at plant
	posts	wooden		wood	calculated	Production of wood for poles	round wood, hardwood, under bark, u=70%, at forest road

Electricity

Drill (1)	cordless drill with a masonary bit, 24 volt power pack drill with a long masonry dr	units	calculated		
Windbreakers (por	frame	steel tubing	steel	calculated	Production of galvanized pipe	drawing of pipes, steel
	planks	wooden	wood	calculated	Production of wood for planks	plywood, outdoor use, at plant

Barbed wire

Barbed wire for agriculture use is typically double-strand 12½-gauge, zinc-coated (galvanized) steel and comes in rolls of 1,320 ft (400 m) length.
http://en.wikipedia.org/wiki/Barbed_wire#Agricultural_fencing

Windbreakers

a variety of model: http://www.agriculture.gov.sk.ca/Default.aspx?DN=adb8ecee-7d31-4f72-8d83-c71ac97baba4

as a general rule, one foot of fence (windbreaker) protects enough area for one cow
http://www.agriculture.gov.sk.ca/Default.aspx?DN=adb8ecee-7d31-4f72-8d83-c71ac97baba4

Portable Windbreak Fencing - Sustainable Livestock Wintering: How Can It Work for You?
http://www.gov.mb.ca/agriculture/crops/forages/pdf/bjb05s17.pdf
Calculations of material requirements are based on the total grazing area and the grazing management strategy

Grazing management strategies Strip grazing

leave 10 to 20 % crop residue each year
source: YEAR ROUND GRAZING = 365 DAYS http://www.agrireseau.qc.ca/bovinsboucherie/documents/00105%20p.pdf

watering: Solar-powered systems. cost of water per cow ranged from $0.03 to $0.15 per day. The cost per gallon of pumped water ranged from $0.002 to $0.007 per gallon.
http://attra.ncat.org/attra-pub/solarlswater.html

http://www.thebeefsite.com/articles/2078/livestock-fencing-systems-for-pasture-management

	2001	2006
Total cattle and calves number	6,615,201	6,369,116
Farms reporting	31,774	28,751
Average number of cattle per farm	208	222

Source: Table 1.3 Selected agricultural data, selected livestock data, Canada and provinces, census years 1921 to 2006. At: http://www.statcan.gc.ca/pub/95-632-x/2007000/t/4129740-eng.htm#48

Tame or seeded pasture	Average area in acres per farm reporting	2001	2006
	acres	229	267

Source: Table 2.5 Total land area and use of farm land, Canada and provinces, census years 1976 to 2006. At: http://www.statcan.gc.ca/pub/95-632-x/2007000/t/4185579-eng.htm#48

Stockpiling Calculations

484,357

			Cultivated Crops	*Yield dry matter cultivated species (kg/ha)*	*Number of cattle on cultivated species - cows*	*Number of cattle on cultivated species - bulls*	*Total cow days (# cows * # days)*	*Total bull days (# bulls * # days)*	*Available forage coefficient*	*Weight of cattle - cows (kg)*	*Weight of cattle - bulls (kg)*	*Food intake coefficient*	*AU eq cows*	*AU eq bulls*	*Days on pasture*	*Months on pasture*	*Total cultivated area ha (calculated) (1)*
Grass	Perennial	DP	grass mix	2800	16,733	711	519,481	21,970	0.8	454	544	0.75	1	1.2	30	1.00	5,083
Grass	Perennial	DP	grass mix	2800	16,733	711	519,481	21,970	0.8	454	544	0.75	1	1.2	30	1.00	5,083
Grass	Perennial	DP	grass mix	2800	16,733	711	519,481	21,970	0.8	454	544	0.75	1	1.2	30	1.00	5,083
Grass	Perennial	P	meadow brome	3360	1,130,810	45,608	35,105,519	1,409,066	0.8	454	544	0.75	1	1.2	30	1.00	286,232
Grass	Perennial	NR	meadow brome	3920	430,218	15,677	13,355,940	484,357	0.8	454	544	0.75	1	1.2	30	1.00	93,340
				Total cattle	**1,674,647**		**50,019,902**	**1,959,332**								**Total area**	**394,820**
																Area Grass DP	15,248
																Area Grass P	286,232
																Area Grass NR	93,340

Sources

(1) Pratt, M., and Rasmussen, A., 2001. Determining your stocking rate, Range Management Fact Sheet. At: http://extension.usu.edu/files/publications/publication/NR_RM_04.pdf

Notes

DP	Dry Prairie
P	Parkland
NR	Northern Regions

Stockpiling Grazing Management Calculations

CALCULATE THE AREA REQUIRED BY ONE DAY OF GRAZING/ONE CATTLE

days on pasture 1

			Crops	*Yield dry matter (kg/ha)*	*Number of cattle - cows*	*Number of cattle - bulls*	*Available forage coefficient*	*Weight of cattle - cows (kg)*	*Weight of cattle - bulls (kg)*	*Food intake coefficient*	*AU eq cows*	*AU eq bulls*	*Days on pasture*	*Months on pasture*	*Total cultivated area ha (calculated) (1)*
Grass	Perennial	DP	grass mix	2800	50,200	2,133	0.8	454	544	0.75	1	1.2	1	0.03	270
					52,333									**grass DP**	270

Tame or seeded pasture (as per Statistics Canada)
672,135

Conclusion: the area currently cultivated with these species can support more cattle than in the model

			Crops	*Yield dry matter (kg/ha)*	*Number of cattle - cows*	*Number of cattle - bulls*	*Available forage coefficient*	*Weight of cattle - cows (kg)*	*Weight of cattle - bulls (kg)*	*Food intake coefficient*	*AU eq*	*AU eq bulls*	*Days on pasture*	*Months on pasture*	*Total cultivated area ha (calculated) (1)*
Grass	Perennial	P	meadow brome	3360	1,130,810	45,608	0.8	454	544	0.75	1	1.2	1	0.03	5,048
Grass	Perennial	NR	meadow brome	3920	430,218	15,677	0.8	454	544	0.75	1	1.2	1	0.03	1,637
					1,622,314									**grass P and NR**	6,685

Conclusion: the area currently cultivated with these species can support more cattle than in the model

number of cattle	52,333	heads
	1,622,314	heads
total	1674647	heads
area 1 day/1 head	0.004	ha

total area for 1 day, all catt **6,955**

CALCULATE THE GRAZING AREA PER HERD

Pasture area for stockpile grazing on cultivated species	394,820	ha		
Average number of cattle/farm	208	head		
Number of cattle on winter diet, as per the initial model	2,230,364	cows	96.1	% of total cattle
	89,730	bulls	3.9	% of total cattle
total	**2,320,093**	heads	100.0	% of total cattle

Note: calculations for winter grazing logistics apply for all cattle, both on native and cultivated species.
Assumption: the area 1/day/1 head is the same for native/cultivated species.

Average number of cattle per herd and composition of herd	200	heads		
	192.26	cows	192	cows
	7.74	bulls	8	bulls
Number of herds, per total, based on average heads/herd and total number of cattle	11,600	herds		
Daily requirement of forage/herd	2177	kg		cows
	109	kg		bulls
Average number of herds/farm	1			based on average number of cattle/farm and average cattle in a herd
average area/head/day	0.004	ha		
area/ 200 heads herd/day, based on average area for 1 head per day and number of heads in the herd	0.83	ha		
	2.05	acres		
average area of farm used for grazing/ 30 days, based on area/herd and number of herds per farm	62	acres		

Tame or seeded pasture	Average area in acres per farm reporting	2001	229	acres
		2006	267	acres

Conclusion: for one farm, the available area for grazing is larger than the minimum grazing area requirements, calculated based on number of heads and individual grazing area needs

Stockpiling Grazing Management Calculations

FENCING

Elements of portable electric fence

Charger (energizer)		1	unit/line	
Power source	outlets	1	unit/energizer	
	12 or 6 volt wet cell DC batteries	1	unit/energizer	
	9 volt dry cell batteries	1	unit/energizer	
Wire	high tensile wire	2	wire lines	
Connecting wire	connectors	3	units/charger	
Grounding rods		3	units/charger	
		1	extra unit/1500 feet of fence	500m
Insulators		1	unit/grounding rod	
Fence posts	wood	1	every 50 feet of fence	15m
	fiber glass	1	every 50 feet of fence	15m
	metal	1	every 50 feet of fence	15m
Gate for portable fence		1	unit/line	
Voltage meter		1	unit/line	

Elements of barbed wire fence for perimeter enclosure

Barbed wire		3	strand lines
Fence posts	wood	1	unit/5 m of fence
	fiber glass	1	unit/5 m of fence
	metal	1	unit/5 m of fence
Gate for fence		2	units/enclosure

CALCULATE FENCING PER FARM

1 quarter section = 160 acres 1 quarter section = 0.5 mile long and 0.5 mile wide

Assumed the total grazing perimeter for a herd for 90 days enclosed with barbed wire. The entire area to be enclosed	62	acres	249172	m2
Length	0.50	miles	805	m
Width	0.19	miles	310	m
Total perimeter of the enclosure	1.38	miles	2229	m

Within the perimeter, portable electric fence is used to delineate grazing of the heard (grazing cell). Assumed lines of portable fence delineating strips 0.5 mile long, moved every 3 days. 2 lines of portable fence
The cell is moved every 3 days, for 10 times, to cover all winter grazing period of 30 days

Summary fencing for one herd and farm

Lines of electric fence	2	units
Length of electric fence	1609	m
Gates for electric fence	2	units
Length of barbed wire fence	2229	m
Gates for barbed wire fence	2	units

Summary /one herd and farm

Charger (energizer)				**2**	unit
Power source					unit
	outlets	0% use of outlets	0.00	0	unit
	12 or 6 volt wet cell DC batteries	100% use of 12 or 6 volt wet cell DC batteries	1.00	**2**	unit
	9 volt dry cell batteries	0% use of 9 volt dry cell batteries	0.00	0	unit
Wire	high tensile wire			**3219**	m
Connecting wire	connectors			**6**	unit
Grounding rods				6	unit
				4	extra unit
Insulators				**10**	unit
Electric fence posts	wood post	0% use of wood posts	0.00	0	unit
	fiber glass post	100% use of fiber glass post	1.00	**107**	unit
	metal post	0% use of metal posts	0.00	0	unit
Gate for portable electric fence					
	wood post	100% use of wood posts	1.00	**2**	unit
	fiber glass post	assuming 0% use of fiber glass post	0.00	0	unit
	metal post	0% use of metal posts	0.00	0	unit
Voltage meter				**1**	unit
Barbed wire				**6686**	m
Barbed wire fence posts	wood post	100% use of wood posts	1.00	**446**	unit
	metal post	0% use of metal posts	0.00	**0**	unit
Gate for barbed wire fence	wood post	100% use of wood posts	1.00	2	unit
	metal post	0% use of metal posts	0.00	**0**	unit

Summary all farms **31,774** (Census data 2001)
Number of farms 11,600

				material	quantity		Ecoinvent process
Charger		23,201	unit	misc	data gap		data gap
Power source	12 or 6 volt wet cell DC batteries	23,201	unit	misc	data gap		data gap
High tensile wire		37,338,284	m	steel wire	5,091,469	kg	wire drawing, steel
connectors		69,603	unit	connectors	3,480	kg	connector, clamp connection, at plant
Grounding rods		116,005	unit	galvanized pi	75,403	kg	drawing of pipes, steel
Insulators		116,005	unit	misc	data gap		data gap
Posts - wood		5,217,094	unit	wood	297,374	m3	round wood, hardwood, under bark, u=70%, at forest road
Posts fiberglass		1,244,609	unit	fiber glass	108,205	kg	fiberglass, at plant
Posts metal		0	unit	metal	0	kg	drawing of pipes, steel
Voltage meter		11,600	unit	misc	data gap		data gap
Barbed wire		77,560,378	m	steel wire	10,576,175	kg	wire drawing, steel

Stockpiling Grazing Management Calculations

WINDBREAKERS

as a general rule, one foot of fence (windbreaker) protects enough area for one cow			1	foot of windbreaker
Number of cattle on winter grazing	total		2,320,093	head
	30 days	DP	697,779	
	30 days	P	1,176,418	
	30 days	NR	445,896	
7.5% of the cattle are protected by artificial windbreakers in the DP		0.075		
1% of the cattle are protected by artificial windbreakers in the P and NR		0.01		
			68,557	feet of windbreaker

With 25% porosity, an 8' long section of fence 8' tall would require 12 1x6" boards and 3 2x6" boards

1 feet windbreaker			**material**	**quantity**		**Ecoinvent process**
1x6" wood board, 8 feet high	1.5	unit				
	0.24	ft3				
	0.006796043	m3	wood	466	m3	plywood, outdoor use, at plant
2x6" wood board, 8 feet high	0.375	unit				
	0.48	ft3				
	0.013592087	m3	wood	932	m3	plywood, outdoor use, at plant

steel pipe metal components (frame, support, axel, etc), tyres, or wooden bracing is sourced from old machinery or surplus materials already on-farm (old combines, irrigation piping, old tractors, spare fence posts, etc.)

	75,403	kg	drawing of pipes, steel	**use this number for AG1-a**
TOTALS	**10,576,175**	kg	wire drawing, steel	**use this number for AG1-b**
	5,091,469	kg	wire drawing, steel	**use this number for AG1-c**
	1398	m3	plywood, outdoor use, at plant	**use this number for AG1-d**
	297,374	m3	round wood, hardwood, under bark, u=70%, at forest road	**use this number for AG1-e**
	3,480	kg	connector, clamp connection, at plant	**use this number for AG1-f**
	108,205	kg	fiberglass, at plant	**use this number for AG1-g**

BMP 2 (BMP 2.2 - Stockpile Grazing)
Approach 2: Extended grazing during winter - swath grazing

Assumed Percent Adoption of BMP 2 **100** %
(% adoption can be adjusted for the entire model in the source cell)
Number of cattle affected by this BMP 2,568,007 cows and bulls affected
(cow/calf operation only)
Weight of affected cattle (slaughtered cows and bulls) 130,388,870 kg live shrunk weight

Density of diesel 0.885 kg/L

	COW/CALF OPERATIONS										FEEDLOT OPERATIONS								BEEF INDUSTRY							
	BMP 2			Baseline			Change		Per Unit Market Value	Total Impact	BMP 2		Baseline		Change		Per Unit Market Value	Total Impact	BMP 2		Baseline		Change		Per Unit Market Value	Total Impact
	(amount)	(unit)		(amount)	(unit)		(change)	(unit)	($/unit)	($ Million)	(amount)	(unit)	(amount)	(unit)	(change)	(unit)	($/unit)	($ Million)	(amount)	(unit)	(amount)	(unit)	(change)	(unit)	($/unit)	($ Million)
Inputs with Change																										
Purchase of seed for alfalfa/grass	7,053,313	kg		8,190,019	kg	0	-1,136,706	kg																		
Purchase of seed for Grass DP	92,220	kg		0	kg	0	92,220	kg																		
Purchase of seed for Grass P	1,731,128	kg		0	kg	0	1,731,128	kg																		
Purchase of seed for Grass NR	1,045,413	kg		0	kg		1,045,413	kg																		
Purchase of alfalfa/grass hay	5,675,173,575	kg		6,589,779,580	kg		-914,606,005	kg																		
Production of chemical fertilizer																										
Total urea, as N	19,166,611	kg		0	kg	0	19,166,611	kg											118,449,660	kg	120,290,430	kg	-1,840,770	kg		
Total ammonia, liquid	55,950,352	kg		0	kg	0	55,950,352	kg											92,802,440	kg	94,244,639	kg	-1,442,199	kg		
Total monoammonium phosphate as P2O5	48,482,123	kg		0	kg	0	45,379,737	kg											45,220,344	kg	46,773,950	kg	-1,553,606	kg		
Total monoammonium phosphate as N	11,372,350	kg		0	kg	0	10,644,630	kg											10,607,241	kg	10,971,667	kg	-364,426	kg		
Total ammonium sulphate as N	0	kg		0	kg	0	0	kg											11,979,163	kg	11,979,163	kg	0	kg		
Purchase of chemical fertilizer																										
Urea, as N, at regional storehouse	19,166,611	kg		0	kg	0	19,166,611	kg											118,449,660	kg	120,290,430	kg	-1,840,770	kg		
Ammonia, liquid, at regional storehouse	55,950,352	kg		0	kg	0	55,950,352	kg											92,802,440	kg	94,244,639	kg	-1,442,199	kg		
Monoammonium phosphate, as P2O5, at regional storehouse	48,482,123	kg		0	kg	0	48,482,123	kg											45,220,344	kg	46,773,950	kg	-1,553,606	kg		
Monoammonium phosphate, as N, at regional storehouse	11,372,350	kg		0	kg	0	11,372,350	kg											10,607,241	kg	10,971,667	kg	-364,426	kg		
Ammonium sulphate, as N, at regional storehouse	0	kg		0	kg	0	0	kg											11,979,163	kg	11,979,163	kg	0	kg		
Fuel consumed to transport fertilizer	858,087	L	2,070,232	0	kg		858,087	L											2,148,894	L	2,185,894	L	-36,999.64	L		
Fuel consumed to transport manure	1,686,961	L		0	kg		1,686,961	L											11,179,009	L	11,179,009	L	0	L		
Production of pesticide/herbicide	322,744	kg	0	0	kg	0	322,744	kg											3,660,568	L	3,660,568	L	0	L		
Purchase of pesticide/herbicide	322,744	kg	0	0	kg	0	322,744	kg											3,660,568	L	3,660,568	L	0	L		
Fuel consumed to transport pesticide	581	L		0	kg		581	L											6,586	L	6,586	L	0	L		
Fuel consumed for forage activities																										
Fuel consumed to cultivate soil	528,033	L		0	L		528,033	kg											5,920,675	L	5,920,675	L	0	kg		
Fuel consumed to apply fertilizer	1,090,040	L		0	L		1,090,040	kg											2,037,050	L	2,037,050	L	0	kg		
Fuel consumed to plant crop	268,418	L		0	L		268,418	kg											3,009,693	L	3,009,693	L	0	kg		
Fuel consumed to irrigate crop	84,803	L		0	L		84,803	kg											50,310,552	L	50,310,552	L	0	kg		
Fuel consumed to apply chemical treatment to crop	356,899	L		0	L		356,899	kg											666,968	L	666,968	L	0	kg		
Fuel consumed to harvest crop	0	L		0	L		0	kg											1,160,473	L	1,160,473	L	0	kg		
Fuel consumed to transport forage	0	L		0	L		0	kg											1,160,473	L	1,160,473	L	0	kg		
Purchase of water to irrigate crop	11,912,784	m3			m3		11,912,784	m3											44,524,839	kg	44,524,839	kg	0	kg		
Fuel consumed to collect manure during winter feeding							-18,912	L																		
Production of bedding	486,161,325	kg		509,445,174	kg		-23,283,848	kg											422,073,796	kg	422,073,796	kg	0	kg		
Fuel consumed to transport bedding	344,982,274	L		361,504,598	L		-16,522,324	kg											299,505,473	L	299,505,473	L	0	kg		
Fuel consumed to feed livestock (change)							-10,380,276	L																		
Fuel consumed to bed livestock (no change)																										
Production of min., trc min., cobalt, protein suppl., vit., antibiotic (no change)																										
Production of vitamins (no change)																										
Purchase of min., trc min., cobalt, protein suppl., antibiotic (no change)																										
Purchase of vitamins (no change)																										
Fuel cons. to transp. min., trc min., cob., prot. suppl., vit., antibiotic (no change)																										
Fuel consumed for transport of vitamin (no change)																										
Purchase of fencing elements																										
Charger (energizer)	23,201	unit		0			23,201	unit																		
Power source - included in the price of energizer	0			0			0	0																		
High tensile wire - 14 gauge	37,338,284	m		0			37,338,284	m																		
Connectors - wire tensioners	69,603	unit		0			69,603	unit																		
Grounding rod	116,005	unit		0			116,005	unit																		
Insulators	116,005	unit		0			116,005	unit																		
Posts - wood	5,217,094	unit		0			5,217,094	unit																		
Posts fiberglass	1,244,609	unit		0			1,244,609	unit																		
Voltage meter	11,600	unit		0			11,600	unit																		
Barbed wire	77,560,378	m		0			77,560,378	m																		
Windbreakers	68,557	feet of windbreaker		0			68,557	feet of windbreaker																		
Labour (change)	11,600	hr		23,201	hr		-11,600	hr																		
Cropping activities										32.01																
Working capital interest																										
Total Input Value Change																										
Outputs with Change																										
Manure sold for land application																										
Compost sold for land application																										
Total Output Value Change																										

CHANGE IN OVERALL GHG EMISSIONS	COW/CALF OPERATIONS						FEEDLOT OPERATIONS						BEEF INDUSTRY					
	BMP 2		Baseline		Change		BMP 2		Baseline		Change		BMP 2		Baseline		Change	
	(amount)	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*	*(amount)*	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*	*(amount)*	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*
BEEF ACTIVITIES - SOIL AND CROP																		
Methane emissions from stored manure	1.49E+08	kg CO_2e	1.49E+08	kg CO_2e	0.00E+00	kg CO_2e	1.44E+08	kg CO_2e	1.44E+08	kg CO_2e	0.00E+00	kg CO_2e						
Enteric fermentation emissions	7.03E+09	kg CO_2e	7.03E+09	kg CO_2e	0.00E+00	kg CO_2e	3.56E+09	kg CO_2e	3.56E+09	kg CO_2e	0.00E+00	kg CO_2e						
N2O emissions from stored manure (direct)	1.83E+09	kg CO_2e	1.83E+09	kg CO_2e	0.00E+00	kg CO_2e	3.27E+08	kg CO_2e	3.27E+08	kg CO_2e	0.00E+00	kg CO_2e						
N2O emissions from stored manure (indirect)	4.04E+08	kg CO_2e	4.04E+08	kg CO_2e	0.00E+00	kg CO_2e	3.06E+08	kg CO_2e	3.06E+08	kg CO_2e	0.00E+00	kg CO_2e						
N_2O emissions from cropping and land use	6.60E+08	kg CO_2e	0.00E+00	kg CO_2e	6.60E+08	kg CO_2e							9.07E+08	kg CO_2e	9.57E+08	kg CO_2e	-5.06E+07	kg CO_2e
Total P emissions from run-off	6.42E+05	kg PO_4-eq	0.00E+00	kg PO_4-eq	6.42E+05	kg PO_4-eq							4.00E+06	kg PO_4-eq	4.15E+06	kg PO_4-eq	-1.43E+05	kg PO_4-eq
Soil Carbon Change in Soil From Land Use	-5.48E+06	kg CO_2e	0.00E+00	kg CO_2e	-5.48E+06	kg CO_2e							-2.34E+08	kg CO_2e	-2.36E+08	kg CO_2e	2.53E+06	kg CO_2e
Direct CO2 emissions from managed soils	3.01E+07	kg CO_2e	0.00E+00	kg CO_2e	3.01E+07	kg CO_2e							1.86E+08	kg CO_2e	1.89E+08	kg CO_2e	-2.89E+06	kg CO_2e
OVERALL SUMMARY																		
Construction	1.18E+07	kg CO_2e	0.00E+00	kg CO_2e	1.18E+07	kg CO_2e	0.00E+00	kg CO_2e	0.00E+00	kg CO_2e	0.00E+00	kg CO_2e						
Forage and cereal sub-activities	3.29E+08	kg CO_2e	0.00E+00	kg CO_2e	3.29E+08	kg CO_2e							1.17E+09	kg CO_2e	1.20E+09	kg CO_2e	-3.19E+07	kg CO_2e
Energy generation and consumption activities	2.76E+09	kg CO_2e	2.81E+09	kg CO_2e	-5.01E+07	kg CO_2e	1.04E+09	kg CO_2e	1.04E+09	kg CO_2e	0.00E+00	kg CO_2e						
O&M activities	0.00E+00	kg CO_2e	0.00E+00	kg CO_2e	0.00E+00	kg CO_2e	0.00E+00	kg CO_2e	0.00E+00	kg CO_2e	0.00E+00	kg CO_2e						
Cereal activities													3.38E+08	kg CO_2e	3.38E+08	kg CO_2e	0.00E+00	kg CO_2e
Forage activities	1.72E+07	kg CO_2e	0.00E+00	kg CO_2e	1.72E+07	kg CO_2e							2.62E+08	kg CO_2e	2.86E+08	kg CO_2e	-2.40E+07	kg CO_2e
Feedlot and pasture activities	3.05E+06	kg CO_2e	3.20E+06	kg CO_2e	-1.47E+05	kg CO_2e	1.40E+08	kg CO_2e	1.40E+08	kg CO_2e	0.00E+00	kg CO_2e	3.02E+08	kg CO_2e	3.04E+08	kg CO_2e	-2.40E+06	kg CO_2e
Cow activities (transportation)	2.49E+07	kg CO_2e	2.49E+07	kg CO_2e	0.00E+00	kg CO_2e												
Bull activities (transportation)	3.14E+06	kg CO_2e	3.14E+06	kg CO_2e	0.00E+00	kg CO_2e												
Yearling-fed system activities (transportation)							1.08E+08	kg CO_2e	1.08E+08	kg CO_2e	0.00E+00	kg CO_2e						
Calf-fed system activities (transportation)							6.59E+07	kg CO_2e	6.59E+07	kg CO_2e	0.00E+00	kg CO_2e						
Total GWP for BMP																		
kg CO_2e	**1.32E+10**	**Cow/Calf**					**5.69E+09**	**Feedlot**					**2.93E+09**	**Beef Industry**				
Total Change in GWP for BMP																		
kg CO_2e					**9.92E+08**						**0.00E+00**						**-1.09E+08**	

Overall Baseline GWP (2001)

kg CO_2e/kg live weight 14.705

Overall BMP GWP

kg CO_2e/kg live weight **15.324**

Change in overall GWP from 2001

kg CO_2e/kg live weight **0.619**

4.2% change from 2001

Change in GWP per kg of beef affected from 2001

kg CO_2e/kg live weight **0.007** **(total change in GHG emissions divided by total weight of cattle affected)**

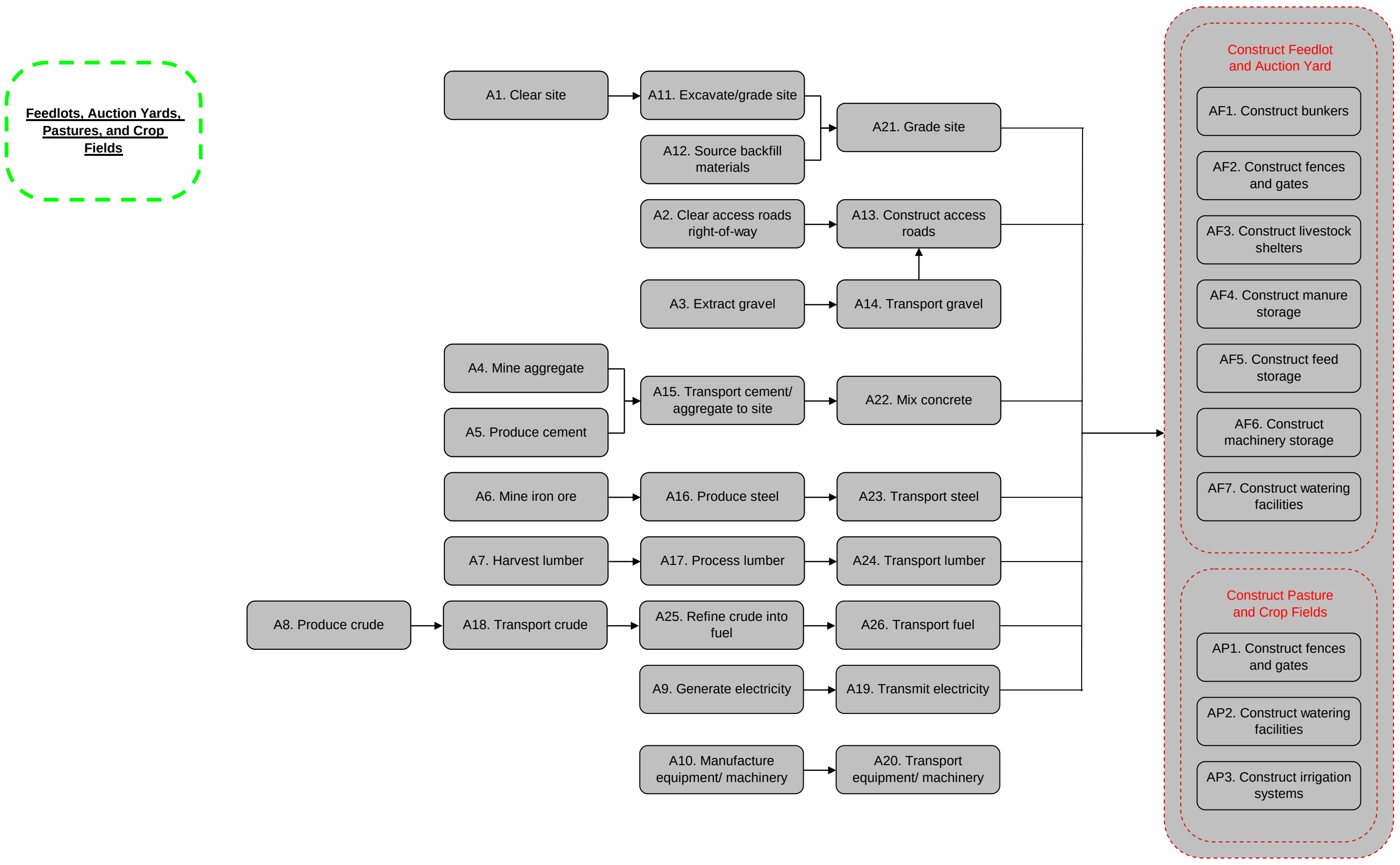
Notes:
Energy generation emissions divided by the number of cattle on cow/calf vs feedlot
Feedlot and pasture activities are divided appropriately.

APPENDIX G

BMP 3 – USE OF IONOPHORES IN COW AND HEIFER DIETS

ACTIVITY MAPS AND DATA COLLECTION

A: Construction



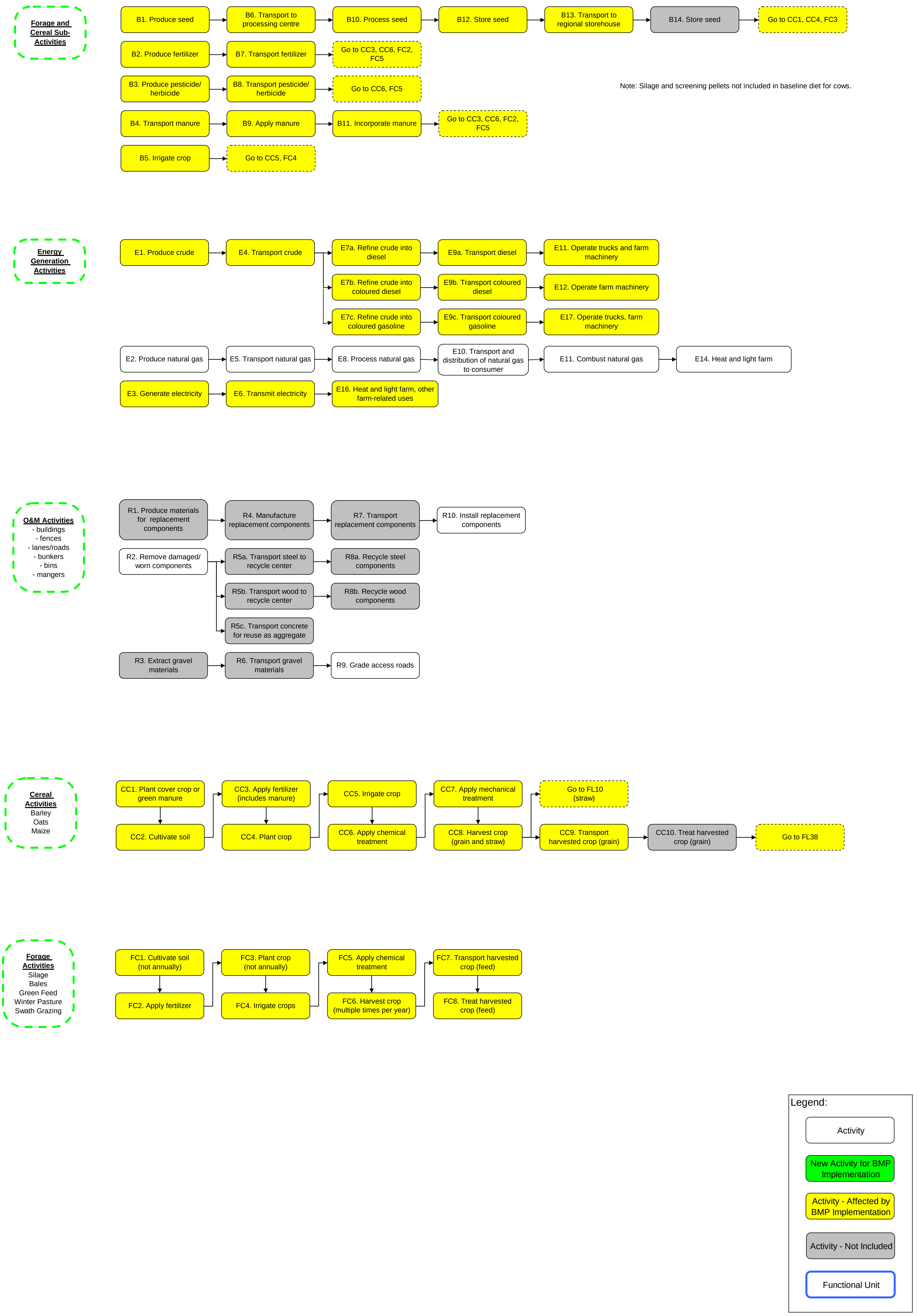
Legend:

- Activity
- New Activity for BMP Implementation
- Activity - Affected by BMP Implementation
- Activity - Not Included
- Functional Unit

FIGURE BMP 3a

ACTIVITY MAP
BMP #3 - USE OF IONOPHORES IN COW DIETS TO IMPROVE FEED EFFICIENCY
LIFE CYCLE ASSESSMENT - BEEF
ALBERTA AGRICULTURE AND RURAL DEVELOPMENT
Edmonton, Alberta

B: Operation and Maintenance



Note: Silage and screening pellets not included in baseline diet for cows.

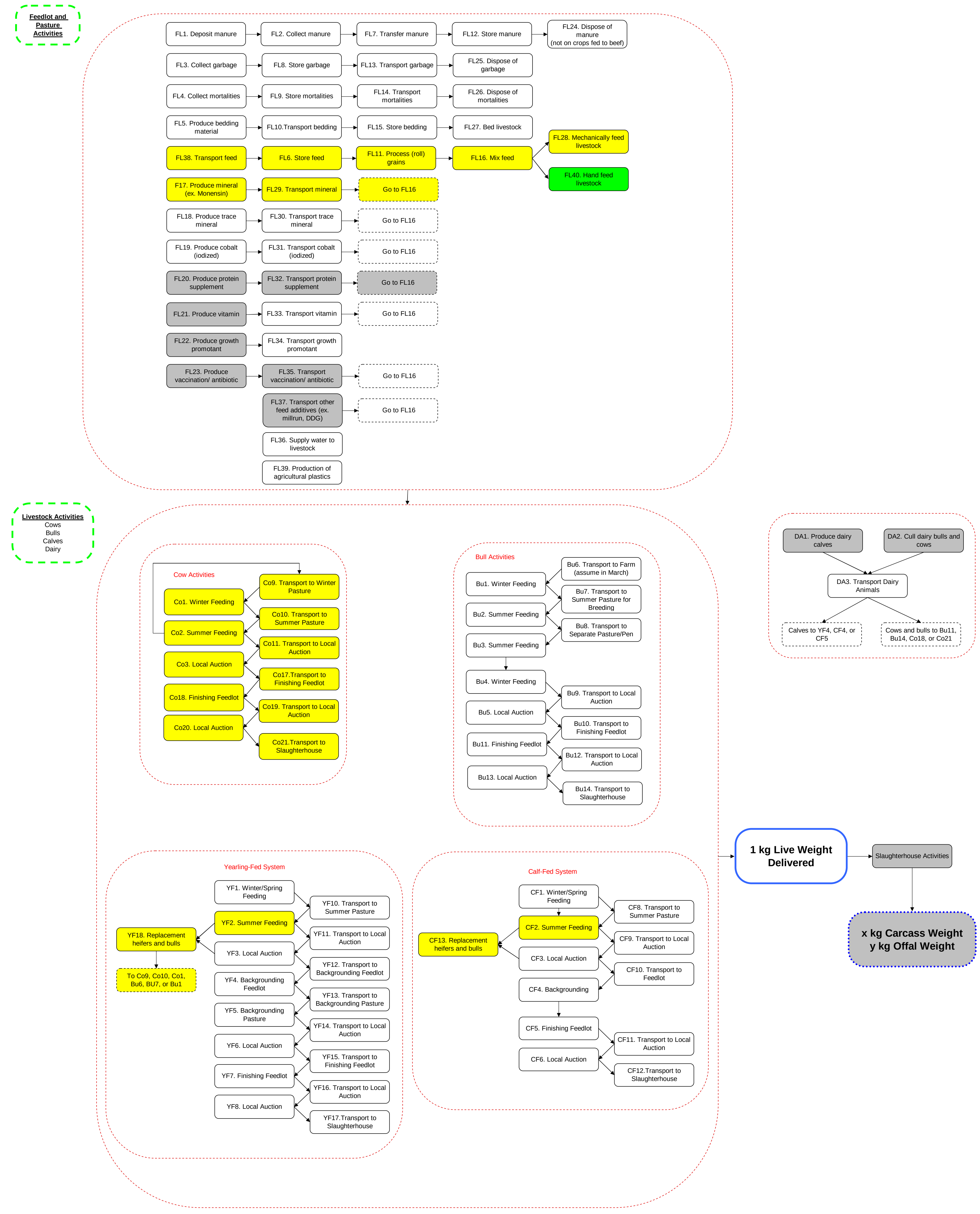
FIGURE BMP 3b

ACTIVITY MAP
BMP #3 - USE OF IONOPHORES IN COW DIETS TO IMPROVE FEED EFFICIENCY
LIFE CYCLE ASSESSMENT - BEEF
ALBERTA AGRICULTURE AND RURAL DEVELOPMENT
Edmonton, Alberta

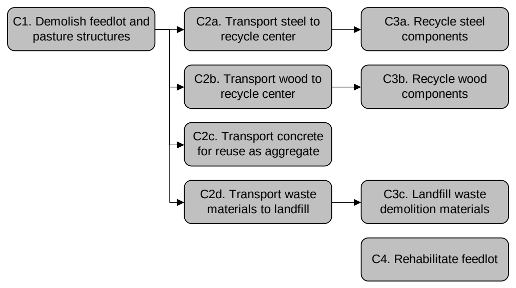
CRA

the PEMBINA institute
Sustainable Energy Solutions

B: Operation and Maintenance



C: Decommissioning



Legend:
- Activity
- 🟩 New Activity for BMP Implementation
- 🟨 Activity - Affected by BMP Implementation
- ▨ Activity - Not Included
- Functional Unit

FIGURE BMP 3c

ACTIVITY MAP
BMP #3 - USE OF IONOPHORES IN COW DIETS TO IMPROVE FEED EFFICIENCY
LIFE CYCLE ASSESSMENT - BEEF
ALBERTA AGRICULTURE AND RURAL DEVELOPMENT
Edmonton, Alberta

CRA

the PEMBINA institute
Sustainable Energy Solutions

BMP 3 – USE OF IONOPHORES IN ROUGHAGE DIETS

Cows: 9.9% reduction in DMI intake during late gestation and early lactation (Sprott et al., 1988)
Late gestation: during 60 days of Winter Feeding, from January 1 to February 28
Early lactation: first 60 days of the Calving period, starting March 1

Bulls			
Winter feeding, last 60 days	Jan.1-Feb.28	109,428	head
Calving, first 60 days	Mar.1-April 30	109,428	head
Cows			
Winter Feeding, last 60 days	Jan.1-Feb.28	2,458,579	head
Calving, first 60 days	Mar.1-April 30	2,458,579	head
Calves	May 1-Jul 31	2,113,345	head

Assumed gestating cows equal to number of born calves + 4.5% calf mortality — Source:http://www.ncbi.nlm.nih.gov/pubmed/8407482

Assumed ionophores will be given unselectively, to all cows and bulls on pasture. An increase on feed efficiency will be applied only to gestating/early lactating cows. The model will be adjusted accordingly.

gestating/lactating cows	2,208,446	head
Reduction in DMI intake during late gestation and early lactation	9.90%	

Weight of cattle	cow	**454**	kg	1000	lbs	606	kg	1335	lbs	Beef LCA - Phase 1
	bull	**544**	kg	1200	lbs	998	kg	2200	lbs	Beef LCA - Phase 2

	2001	2006
Total cattle and calves number	6,615,201	6,369,116
Farms reporting	31,774	28,751
Average number of cattle per farm	208	222

Source: Table 1.3 Selected agricultural data, selected livestock data, Canada and provinces, census years 1921 to 2006. At: http://www.statcan.gc.ca/pub/95-632-x/2007000/t/4129740-eng.htm#48

Change in gas and diesel for manure handling

Note: Energy required to collect manure in the baseline is included in the total energy used on beef farms in Alberta. Changes to energy requirements to be calculated.

Manure collection and handling

Diesel consumption for a tractor	16.6	L/hr	Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3: 3, 257-270.
Number of feedlot cattle in reference	50,000	cattle	Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3: 3, 257-270.
Pens with 250 head/pen in reference	200	pens	Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3: 3, 257-270.
times per year	2		Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3: 3, 257-270.
heads per pen	250		Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3: 3, 257-270.
Time to pile up manure in pen in reference	60	min/pen two times per year	Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3: 3, 257-270.
	400	hrs/yr	Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3: 3, 257-270.
Diesel required per year	6,640	L/yr	Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3: 3, 257-270.
CO_2 emission factor for truck diesel consumption	2,569	g CO_2/L	Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3: 3, 257-270.
CH_4 emission factor for truck diesel consumption	0.21	g CH_4/L	Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3: 3, 257-270.
Total emissions from manure collection (calculated based on data)	17.09	tonnes CO_2e/yr	Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3: 3, 257-270.
Total emissions from manure collection (total provided in reference)	1,172	tonnes CO2e/year	
(Total emissions calculated using data from reference different than total emissions provided in reference. *Only raw data from reference will be used to calculate emissions in model.)*			
Quantity of manure (in reference) *(Alberta Beef LCA model used same reference to quantify manure)*	58,700	tonne dry manure/year	Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3: 3, 257-270.
Emission factor for the combustion of diesel in agricultural equipment - Alberta Beef LCA model	3.28	kg CO_2e/kg diesel	Intergovernmental Panel on Climate Change (IPCC). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 2. Chapter 3: Mobile Combustion. Available at: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_3_Ch3_Mobile_Combustio
Density of diesel	0.885	kg/L	Simetric. Specific Gravity of Liquids. Available at: http://www.simetric.co.uk/si_liquids.htm
	3.71	kg CO_2e/L	
Total emissions from manure collection using the LCA model emission factor *(comparable to emissions calculated using reference data)*	24.61	tonnes/yr	
Total emissions from manure collection per animal per day			

Change in gas, diesel, and electricity usage on feedlots for reduced feed time, replaced by extended grazing (swath grazing)

Note: Energy required to feed animals in the baseline is included in the total energy used on beef farms in Alberta. Changes to energy requirements to be calculated.

Energy requirements to feed cattle in the feedl	1785	Mcal/animal				ACRES USA. From Mid-East Oil to London Broil: A Comparison of Energy Inputs in Feedlot versus Grass-Fed Beef. November 2005. Available at: http://www.acresusa.com/magazines/archives/1105Inputs.htm
Days on winter feed in feedlot (in reference)	255	days of feed in feedlot				
Energy requirements to feed 1 lb of feed in the feedlot	**1**	**lb feed = 0.28 Mcal**				
	0.28	Mcal	=	1111.13	Btu	
			=	**1.1723**	**MJ**	

Note: Assume that diesel is the fuel used to operate the machinery to feed cattle (as per reference)

Labour during winter diet	9.62E-03	hours/head/day		
Reduced labour due to reduced feeding	9.42E-03	hours/head/day		
Purchase of alfalfa/grass hay (alfalfa per ton)	124.44	$/ton		Internet Hay Exchange. Hay Price Calculator. Available at: http://www.hayexchange.com/tools/ave_price_calc.php.
	112.89	$/tonne		
	0.11	$/kg		
Consumption of mineral supplement without ionophores	0.06	kg/100 kg animal		
	0.27	kg/head/day	assuming 1AU	
	0.60	lbs/head/day	assuming 1AU	
Price of mineral supplement for animals on pasture without ionophore	128	$/102 kg	8:4 beef mineral tub, Meant to be consumed at a rate of 0.06kg/100 kg (of animal w	UFA
	1.25	**$/kg**		
Consumption mineral with ionophores/head/day	100	g/head/day		(Phone conversation with Alberta Feed and Consulting Ltd. 403-346-8312
	0.22	lbs/head/day		
Price of mineral loaded with ionophores	45	$/25kg	for 25kg bag which is meant to be consumed at a rate of 100g per head per day	(Phone conversation with Alberta Feed and Consulting Ltd. 403-346-8312
	1.8	**$/kg**		

BMP 3 - IONOPHORES

Assumed Adoption of BMP 3 (adoption can be adjusted for the entire model in the source cell)	100%	cattle on ionophores
Density of diesel	0.885	kg/L

Total GHG emissions	**2.07E+10**	**kg CO2e**
Total acidification	**3.06E+07**	**kg SO2-Eq**
Total eutrophication	**5.47E+06**	**kg PO4-Eq**
Total non-renewable energy	**3.44E+11**	**MJ-Eq**

	COW/CALF OPERATIONS								**FEEDLOT OPERATIONS**								**SLAUGHTERHOUSE**					
	BMP 3		**Baseline**		**Change**		**Per Unit Market Value**	**Total Impact**	**BMP 3**		**Baseline**		**Change**		**Per Unit Market Value**	**Total Impact**	**BMP 3**		**Baseline (2001)**		**Change**	
	(amount)	***(unit)***	***(amount)***	***(unit)***	***(change)***	***(unit)***	***($/unit)***	***($ Million)***	***(amount)***	***(unit)***	***(amount)***	***(unit)***	***(change)***	***(unit)***	***($/unit)***	***($ Million)***	***(amount)***	***(unit)***	***(amount)***	***(unit)***	***(change)***	***(unit)***
Inputs with Change																						
Purchase of seed for alfalfa/grass hay	7,724,118	kg	8,190,019	kg	-465,901	kg																
Purchase of alfalfa/grass hay	6,214,910,655	kg	6,589,779,580	kg	-374,868,925	kg																
Production of chemical fertilizer																						
Total urea, as N																						
Total ammonia, liquid																						
Total monoammonium phosphate as P2O5																						
Total monoammonium phosphate as N																						
Total ammonium sulphate as N																						
Purchase of chemical fertilizer																						
Urea, as N, at regional storehouse																						
Ammonia, liquid, at regional storehouse																						
Monoammonium phosphate, as P2O5, at regional storehouse																						
Monoammonium phosphate, as N, at regional storehouse																						
Ammonium sulphate, as N, at regional storehouse																						
Purchase of supplement without ionophores	169,836,765	kg	253,033,086	kg	-83,196,320	kg																
Purchase of supplement with ionophores	30,569,415	kg	0	kg	30,569,415	kg																
Fuel consumed to transport fertilizer																						
Fuel consumed to transport manure																						
Production of pesticide/herbicide																						
Purchase of pesticide/herbicide																						
Fuel consumed to transport pesticide																						
Fuel consumed for forage activities																						
Fuel consumed to cultivate soil																						
Fuel consumed to apply fertilizer																						
Fuel consumed to plant crop																						
Fuel consumed to irrigate crop																						
Fuel consumed to apply chemical treatment to crop																						
Fuel consumed to harvest crop																						
Fuel consumed to transport harvest crop																						
Purchase of water to irrigate crop																						
Fuel consumed to collect manure during winter feeding																						
Fuel consumed to transfer manure on site- included above																						
Fuel consumed to transport manure off-site (no change)																						
site																						
Production of bedding (no change)																						
Fuel consumed to bed livestock (no change)																						
Fuel consumed to transport bedding (no change)																						
Fuel consumed to feed livestock (change)	184,605,290	L	185,668,985	L	-1,063,695	L																
Production of min., trc min., cobalt, protein suppl., vit., antibiotic (no change)																						
Production of vitamins (no change)																						
Purchase of min., trc min., cobalt, protein suppl., antibiotic (no change)																						
Purchase of vitamins (no change)																						
Fuel cons. to transp. min., trc min., cob., prot. suppl., vit., antibiotic (no change)																						
Fuel consumed for transport of vitamin (no change)					0	kg																
Purchase of manure for land application																						
Fuel consumed to transport barley and barley silage (no change)																						
Fuel consumed to transport alfalfa																						
Labour (change)	8,888,567	hr	8,939,783	hr	-51,216	hr																
Working capital interest	0	$	0	$	0	$																
Total Input Value Change																						
Outputs with Change																						
Manure sold for land application																						
Compost sold for land application																						
Total Output Value Change																						

CHANGE IN OVERALL GHG EMISSIONS	**COW/CALF OPERATIONS**						**FEEDLOT OPERATIONS**						**BEEF INDUSTRY**					
	BMP 3		**Baseline**		**Change**		**BMP 3**		**Baseline**		**Change**		**BMP 3**		**Baseline**		**Change**	
	(amount)	***(unit)***	***(amount)***	***(unit)***	***(change)***	***(unit)***	***(amount)***	***(unit)***	***(amount)***	***(unit)***	***(change)***	***(unit)***	***(amount)***	***(unit)***	***(amount)***	***(unit)***	***(change)***	***(unit)***
BEEF ACTIVITIES - SOIL AND CROP																		
Manure generation	3.35E+10	kg	3.45E+10	kg	-9.66E+08	kg	1.89E+10	kg	1.89E+10	kg	0.00E+00	kg						
Methane emissions from stored manure	1.45E+08	kg CO_2eq	1.49E+08	kg CO_2eq	-3.85E+06	kg CO_2eq	1.44E+08	kg CO_2eq	1.44E+08	kg CO_2eq	0.00E+00	kg CO_2eq						
Enteric fermentation emissions	6.85E+09	kg CO_2eq	7.03E+09	kg CO_2eq	-1.82E+08	kg CO_2eq	3.56E+09	kg CO_2eq	3.56E+09	kg CO_2eq	0.00E+00	kg CO_2eq						
N2O emissions from stored manure (direct)	1.77E+09	kg CO_2eq	1.83E+09	kg CO_2eq	-5.10E+07	kg CO_2eq	3.27E+08	kg CO_2eq	3.27E+08	kg CO_2eq	0.00E+00	kg CO_2eq						
N2O emissions from stored manure (indirect)	3.93E+08	kg CO_2eq	4.04E+08	kg CO_2eq	-1.13E+07	kg CO_2eq	3.06E+08	kg CO_2eq	3.06E+08	kg CO_2eq	0.00E+00	kg CO_2eq						
N_2O emissions from cropping and land use													9.41E+08	kg CO_2eq	9.57E+08	kg CO_2eq	-1.66E+07	kg CO_2eq
Total P emissions from run-off													4.09E+06	kg PO_4-eq	4.15E+06	kg PO_4-eq	-5.85E+04	kg PO_4-eq
Soil Carbon Change in Soil From Land Use													-2.35E+08	kg CO_2eq	-2.36E+08	kg CO_2eq	1.04E+06	kg CO_2eq
Direct CO2 emissions from managed soils													1.88E+08	kg CO_2eq	1.89E+08	kg CO_2eq	-1.16E+06	kg CO_2eq
OVERALL SUMMARY																		
Construction	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e						
Forage and cereal sub-activities													1.19E+09	kg CO2eq	1.20E+09	kg CO2eq	-1.30E+07	kg CO2eq
Energy generation and consumption activities	2.80E+09	kg CO2eq	2.81E+09	kg CO2eq	-5.14E+06	kg CO2eq	1.04E+09	kg CO_2eq	1.04E+09	kg CO_2eq	0.00E+00	kg CO_2eq						
O&M activities	0.00E+00	kg CO2eq	0.00E+00	kg CO2eq	0.00E+00	kg CO2eq	0.00E+00	kg CO2eq	0.00E+00	kg CO2eq	0.00E+00	kg CO2eq						
Cereal activities													3.38E+08	kg CO_2eq	3.38E+08	kg CO_2eq	0.00E+00	kg CO_2eq
Forage activities													2.76E+08	kg CO_2eq	2.86E+08	kg CO_2eq	-9.84E+06	kg CO_2eq
Feedlot and pasture activities	3.19E+06	kg CO_2eq	3.20E+06	kg CO_2eq	-1.18E+04	kg CO_2eq	1.40E+08	kg CO_2eq	1.40E+08	kg CO_2eq	0.00E+00	kg CO_2eq	3.04E+08	kg CO_2eq	3.04E+08	kg CO_2eq	-1.68E+04	kg CO_2eq
Cow activities (transportation)	2.49E+07	kg CO_2eq	2.49E+07	kg CO_2eq	0.00E+00	kg CO_2eq												
Bull activities (transportation)	3.14E+06	kg CO_2eq	3.14E+06	kg CO_2eq	0.00E+00	kg CO_2eq												
Yearling-fed system activities (transportation)							1.08E+08	kg CO_2eq	1.08E+08	kg CO_2eq	0.00E+00	kg CO_2eq						
Calf-fed system activities (transportation)							6.59E+07	kg CO_2eq	6.59E+07	kg CO_2eq	0.00E+00	kg CO_2eq						
Total GWP for BMP																		
kg CO_2e	**1.20E+10**	**Cow/Calf**					**5.69E+09**	**Feedlot**					**3.00E+09**	**Beef Industry**				
Total Change in GWP for BMP																		
kg CO_2e					**-2.53E+08**						**0.00E+00**						**-3.96E+07**	

Total change in emissions **-292,611** **tonnes**

Overall Baseline GWP (2001)
kg CO_2e/kg live weight **14.705**

Overall BMP GWP
kg CO_2e/kg live weight **14.500**

Change in overall GWP from 2001
kg CO_2e/kg live weight **-0.205**

Change in GWP per kg of beef affected from 2001
kg CO_2e/kg live weight **-2.244** **(total change in GHG emissions divided by total weight of cattle affected)**

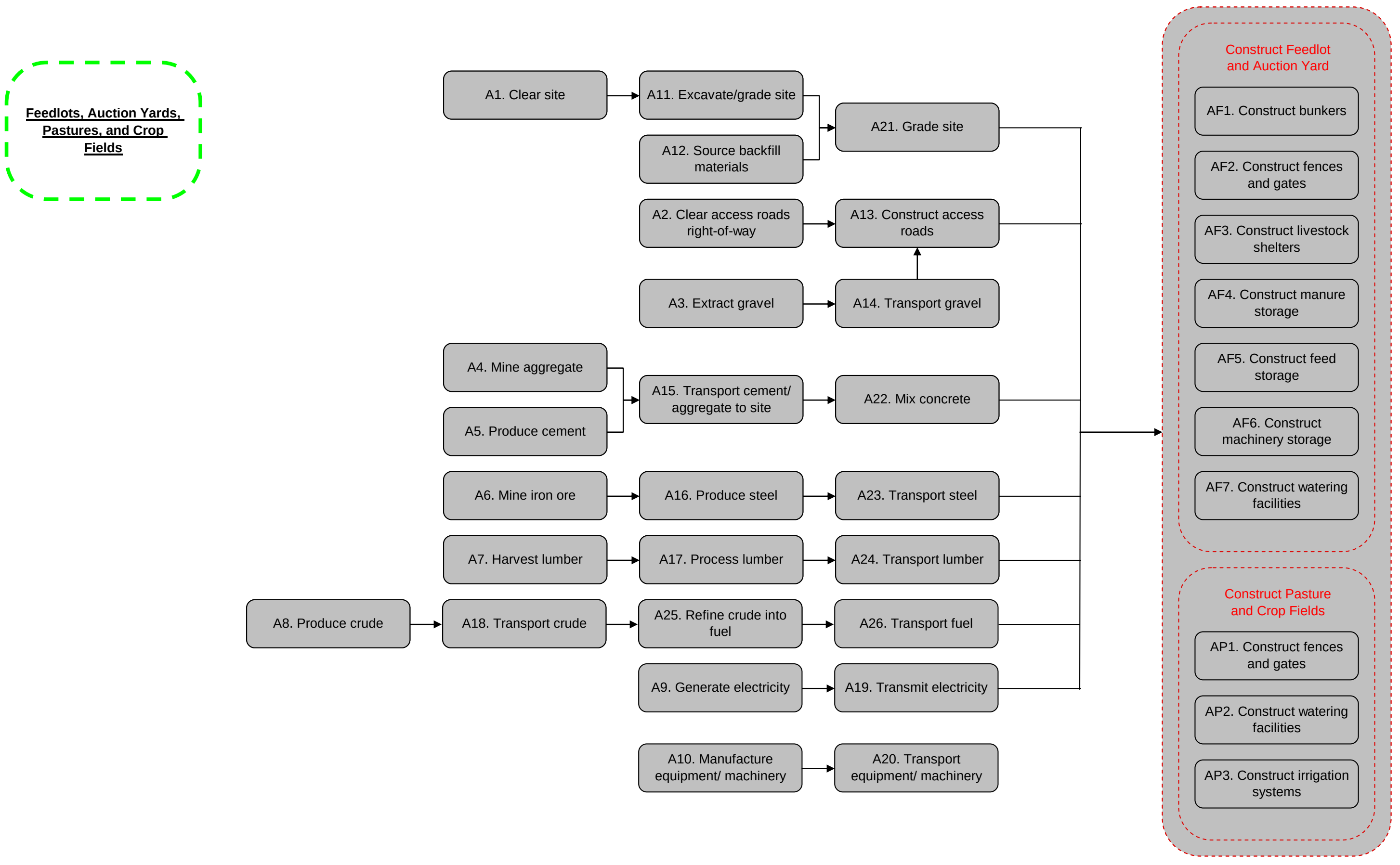
Notes:
Energy generation emissions divided by the number of cattle on cow/calf vs feedlot
Feedlot and pasture activities are divided appropriately.

APPENDIX H

BMP 4 – REDUCED AGE TO SLAUGHTER

ACTIVITY MAPS AND DATA COLLECTION

A: Construction



Legend:

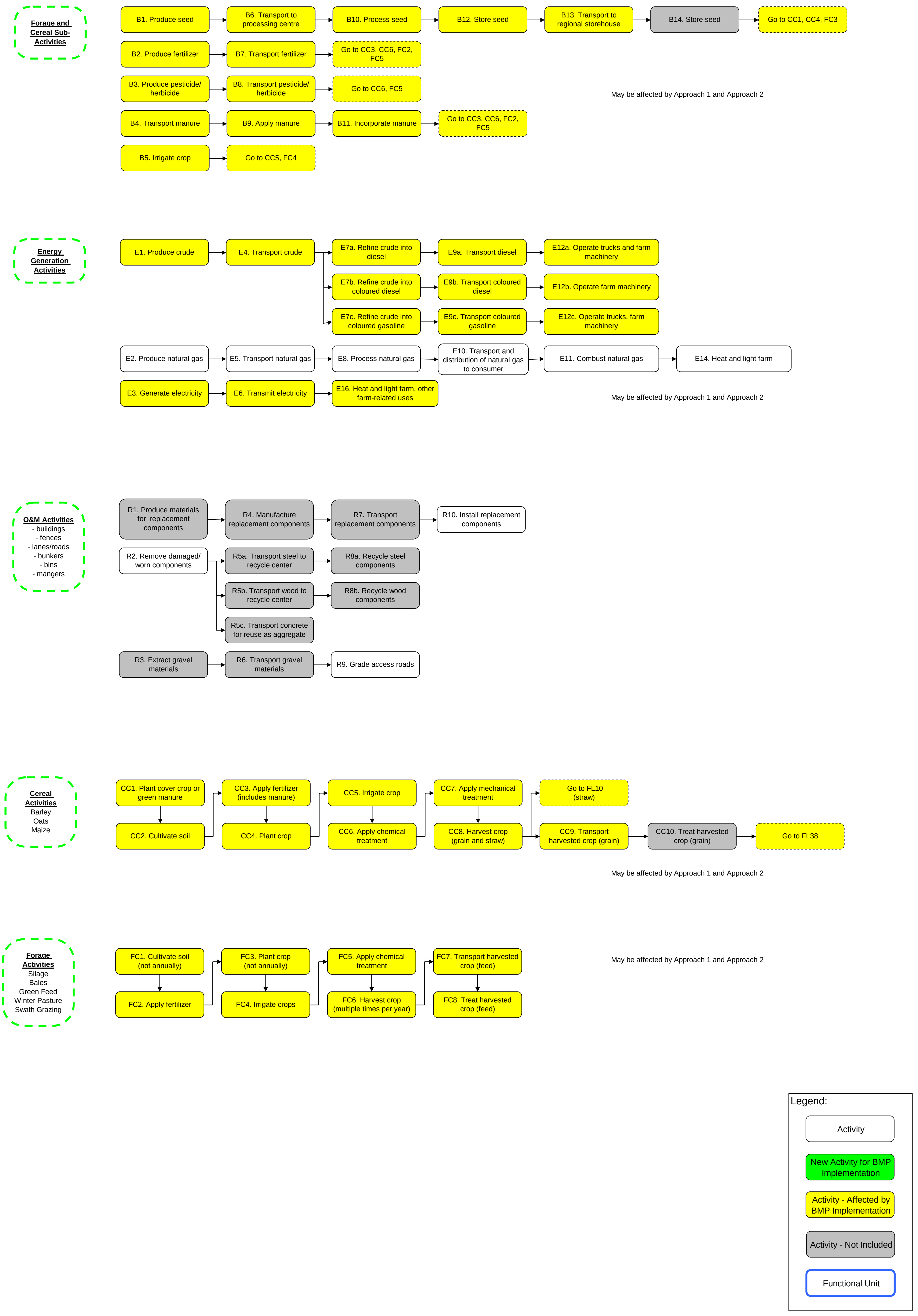
- Activity
- 🟩 New Activity for BMP Implementation
- 🟨 Activity - Affected by BMP Implementation
- ▨ Activity - Not Included
- Functional Unit

FIGURE BMP 4a

ACTIVITY MAP
BMP #4 - REDUCING AGE AT SLAUGHTER
LIFE CYCLE ASSESSMENT - BEEF
ALBERTA AGRICULTURE AND RURAL DEVELOPMENT
Edmonton, Alberta

the PEMBINA institute
Sustainable Energy Solutions

B: Operation and Maintenance



Notes:

Approach 1: Reduce the number of days on feed in feedlot during the final stages of growth

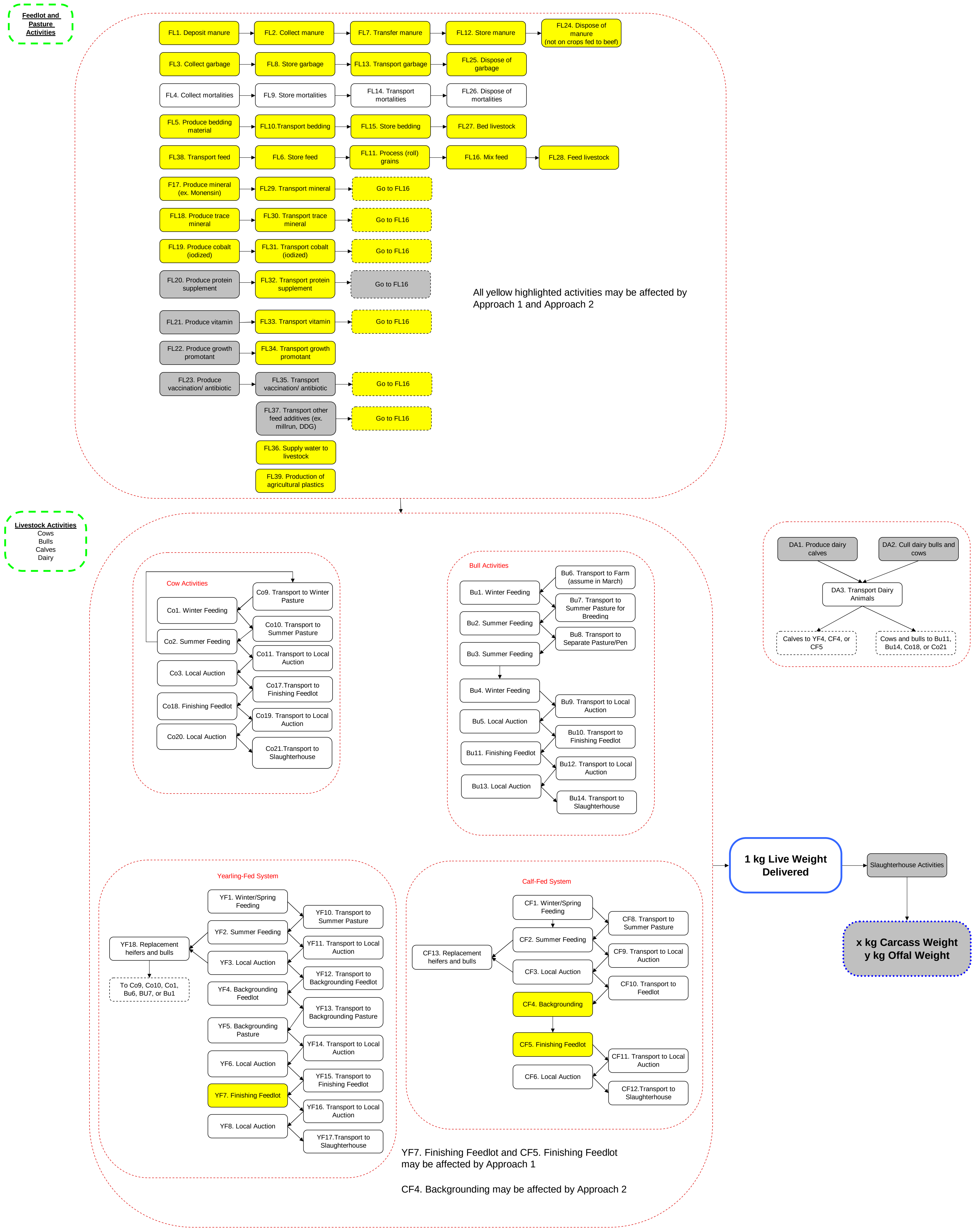
Approach 2: Reduce age at harvest by adjusting the diet to introduce feeder diets sooner

FIGURE BMP 4b

ACTIVITY MAP
BMP #4 - REDUCING AGE AT SLAUGHTER
LIFE CYCLE ASSESSMENT - BEEF
ALBERTA AGRICULTURE AND RURAL DEVELOPMENT
Edmonton, Alberta

the PEMBINA institute
Sustainable Energy Solutions

B: Operation and Maintenance



Feedlot and Pasture Activities

FL1. Deposit manure → FL2. Collect manure → FL7. Transfer manure → FL12. Store manure → FL24. Dispose of manure (not on crops fed to beef)
FL3. Collect garbage → FL8. Store garbage → FL13. Transport garbage → FL25. Dispose of garbage
FL4. Collect mortalities → FL9. Store mortalities → FL14. Transport mortalities → FL26. Dispose of mortalities
FL5. Produce bedding material → FL10.Transport bedding → FL15. Store bedding → FL27. Bed livestock
FL38. Transport feed → FL6. Store feed → FL11. Process (roll) grains → FL16. Mix feed → FL28. Feed livestock
FL17. Produce mineral (ex. Monensin) → FL29. Transport mineral → Go to FL16
FL18. Produce trace mineral → FL30. Transport trace mineral → Go to FL16
FL19. Produce cobalt (iodized) → FL31. Transport cobalt (iodized) → Go to FL16
FL20. Produce protein supplement → FL32. Transport protein supplement → Go to FL16
FL21. Produce vitamin → FL33. Transport vitamin → Go to FL16
FL22. Produce growth promotant → FL34. Transport growth promotant
FL23. Produce vaccination/ antibiotic → FL35. Transport vaccination/ antibiotic → Go to FL16
FL37. Transport other feed additives (ex. millrun, DDG) → Go to FL16
FL36. Supply water to livestock
FL39. Production of agricultural plastics

All yellow highlighted activities may be affected by Approach 1 and Approach 2

Livestock Activities
Cows
Bulls
Calves
Dairy

Cow Activities

Co1. Winter Feeding
Co2. Summer Feeding
Co3. Local Auction
Co18. Finishing Feedlot
Co20. Local Auction
Co9. Transport to Winter Pasture
Co10. Transport to Summer Pasture
Co11. Transport to Local Auction
Co17.Transport to Finishing Feedlot
Co19. Transport to Local Auction
Co21.Transport to Slaughterhouse

Bull Activities

Bu1. Winter Feeding
Bu2. Summer Feeding
Bu3. Summer Feeding
Bu4. Winter Feeding
Bu5. Local Auction
Bu11. Finishing Feedlot
Bu13. Local Auction
Bu6. Transport to Farm (assume in March)
Bu7. Transport to Summer Pasture for Breeding
Bu8. Transport to Separate Pasture/Pen
Bu9. Transport to Local Auction
Bu10. Transport to Finishing Feedlot
Bu12. Transport to Local Auction
Bu14. Transport to Slaughterhouse

DA1. Produce dairy calves
DA2. Cull dairy bulls and cows
DA3. Transport Dairy Animals
Calves to YF4, CF4, or CF5
Cows and bulls to Bu11, Bu14, Co18, or Co21

Yearling-Fed System

YF1. Winter/Spring Feeding
YF2. Summer Feeding
YF3. Local Auction
YF4. Backgrounding Feedlot
YF5. Backgrounding Pasture
YF6. Local Auction
YF7. Finishing Feedlot
YF8. Local Auction
YF10. Transport to Summer Pasture
YF11. Transport to Local Auction
YF12. Transport to Backgrounding Feedlot
YF13. Transport to Backgrounding Pasture
YF14. Transport to Local Auction
YF15. Transport to Finishing Feedlot
YF16. Transport to Local Auction
YF17.Transport to Slaughterhouse
YF18. Replacement heifers and bulls
To Co9, Co10, Co1, Bu6, BU7, or Bu1

Calf-Fed System

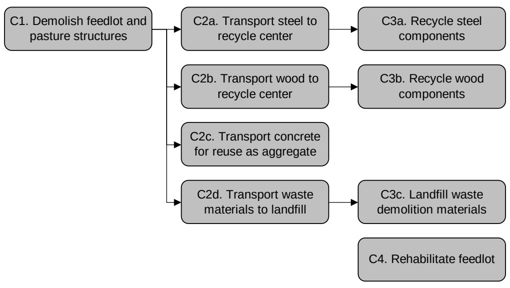
CF1. Winter/Spring Feeding
CF2. Summer Feeding
CF3. Local Auction
CF4. Backgrounding
CF5. Finishing Feedlot
CF6. Local Auction
CF8. Transport to Summer Pasture
CF9. Transport to Local Auction
CF10. Transport to Feedlot
CF11. Transport to Local Auction
CF12.Transport to Slaughterhouse
CF13. Replacement heifers and bulls

YF7. Finishing Feedlot and CF5. Finishing Feedlot may be affected by Approach 1

CF4. Backgrounding may be affected by Approach 2

1 kg Live Weight Delivered → Slaughterhouse Activities → **x kg Carcass Weight y kg Offal Weight**

C: Decommissioning



C1. Demolish feedlot and pasture structures
C2a. Transport steel to recycle center → C3a. Recycle steel components
C2b. Transport wood to recycle center → C3b. Recycle wood components
C2c. Transport concrete for reuse as aggregate
C2d. Transport waste materials to landfill → C3c. Landfill waste demolition materials
C4. Rehabilitate feedlot

Notes:

Approach 1: Reduce the number of days on feed in feedlot during the final stages of growth

Approach 2: Reduce age at harvest by adjusting the diet to introduce feeder diets sooner

Legend:
- Activity
- 🟩 New Activity for BMP Implementation
- Activity - Affected by BMP Implementation
- Activity - Not Included
- Functional Unit

FIGURE BMP 4c

ACTIVITY MAP
BMP #4 - REDUCING AGE AT SLAUGHTER
LIFE CYCLE ASSESSMENT - BEEF
ALBERTA AGRICULTURE AND RURAL DEVELOPMENT
Edmonton, Alberta

BMP 4 APPROACH 1 - DATA

Dosage, weight gain and other effects with RAC (ractopamine) addition in the feedlot

		References
Dosage		
200 mg/hd/day for 28 days typical dosage. No significant affect shown by the addition of ractopamine.	200 mg/head/day for 28 days	Gonzalez, John Michael et al. Effect of Optaflexx 45 (Ractopamine-HCl) on Live and Carcass Performance when Fed to Steers During the Final 28 Days of Feeding. 2009 Florida Beef Report. Available at: http://www.animal.ufl.edu/extension/beef/2009-beef-report/pdf/k-EffectOptaflex.pdf
FDA approved Type C medicated feed - Feeding Directions. Feed minimum of 1.0 lb per head per day of Ractopamine Finishing Cattle Feed Concentrate TD - Type C Medicated Top Dress Feed continuously to cattle fed in confinement for slaughter to provide 70 to 400 mg/head/day for the last 28 to 42 days on feed. Elanco and Optaflexx are brands and trademarks of Eli Lilly.	70-400 mg/head/day	N-141221-C-0022 Ractopamine Finishing Cattle Feed Concentrate - TD, Type B Medicated Feed. September 29, 2009. Available at: http://www.fda.gov/downloads/AnimalVeterinary/Products/AnimalFoodFeeds/MedicatedFeed/BlueBirdLabels/UCM203119.pdf
Additional Weight Gain		
The additional weight gain is about 14.2 lbs when fed with 200 mg per head per day. Feed efficiency is also said to improve by up to 15.9 percent.	14.2 lbs/28 days	TheCattleSite.com. The Codex Perspective on Ractopamine. August 2009. Available at: http://www.thecattlesite.com/articles/2082/the-codex-perspective-on-ractopamine
When Optaflexx is fed to steers during the last 28-42 days of the feeding period, there was an increase in weight gain of 10 to 20 lbs and improved feed efficiency between 14 and 21 percent.	10-20 lbs/28 days	Texas Cooperative Extension. The Texas A&M University System. The Facts about Optaflexx: Ractopamine for Cattle. ASWeb-116 6-04. Available at: http://animalscience.tamu.edu/images/pdf/beef/beef-optaflexx.pdf
ADG increased by 0.24 kg/day for calf-fed steers fed 200 mg/day for final 28 to 38 days. Feed efficiency improved by 14.4% Carcasses were 4.7% heavier.	0.24 kg/day	Vogel, G. J. et al. Effect of Ractopamine Hydrochloride on Growth Performance and Carcass Traits in Calf-Fed and Yearling Holstein Steers Fed to Slaughter. The Professional Animal Scientist. 2009. Available at: http://pas.fass.org/content/25/1/26.full.pdf+html
	0.48 lbs/28 days	
The feeding of RAC during the last 28 to 42 days before slaughter has been shown to improve ADG and G:F ratio by 20%, final slaughter weight by 1.2-2.1% carcass weight by 1.9-2.8% with no effect on DMI. Reduce total number of days required to bring cattle to market. Case study used baseline of 178 days for final finishing period and project of 172.4 days to reach desired final weight for slaughter.	1.2-2.1 % greater final weight	Draft Guidance Document for Reducing the Number of Days in Feed of Beef Cattle. June 2010. Version 7. Government of Alberta. Alberta Agriculture and Rural Development. Emailed to CRA from Emmanuel Laate on October 20, 2010.
	1.65 % greater final weight (average)	
	20 % increase in ADG	

Notes:
RAC is typically added to increase weight to slaughterhouse, not reduce time on feedlots.
Guidance Document weight gain is high compared to other literature but not unrealistic (See Table 4.1b for diet and weight gain calculations - 22 to 24 lbs additional weight gain over 28 days).
Reduction in number of days on feedlot is similar for the Alberta Beef LCA model assuming 28 days of RAC and the weight gain estimated in the case study in the Guidance Document
(4.9 to 5.4 days compared to 5.6 days in the Guidance Document).
Alberta data used from the Guidance Document for the Alberta Beef LCA model, assuming 200 mg/hd/day for the last 28 days in the feedlot.

Other Effects

RAC supplementation slightly decreases LM tenderness	Gruber, S.L. et al. Effects of ractopamine supplementation and postmortem aging on longissimus muscle palatability of beef steers differing in biological type. Journal of Animal Science. 2008. 86:2005-201. Available at: http://jas.fass.org/cgi/reprint/86/1/205
Red meat yield is increased with no effect on marbling	TheCattleSite.com. The Codex Perspective on Ractopamine. August 2009. Available at: http://www.thecattlesite.com/articles/2082/the-codex-perspective-on-ractopamine
Growth performance and HCW improved in both calf-fed and yearling-fed Holstein **steers** having minimal impact on quality grade (i.e. minimal change in yield grade and marbling score, but no effect on yield grade grouping and quality grade grouping - still in Canada 2 yield group and Canada AAA grade) (200 mg/day for 28 to 38 d).	Vogel, G. J. et al. Effect of Ractopamine Hydrochloride on Growth Performance and Carcass Traits in Calf-Fed and Yearling Holstein Steers Fed to Slaughter. The Professional Animal Scientist. 2009. Available at: http://pas.fass.org/content/25/1/26.full.pdf+html
Decrease of 7% Choice and Prime Quality Grade, decrease of 0.8% Prime Quality Grade, decrease of 0.9% Average-High Choice Quality Grade, decrease of 5.3% Low Choice Quality Grade, increase of 6.4% Select Quality Grade, increase of 0.7% Standard Quality Grade.	
Increase of 1.5% Yield Grade 1, increase of 5.6% Yield Grade 2, decrease of 6.7% Yield Grade 3, decrease of 0.5% Yield Grade 4.	

BMP 4 APPROACH 1 - DATA

Differences by sex in response to ractopamine may exist.

Exp. 1: Marbling score with Optaflexx slightly lower than control with 200 mg/day for 28 days **(heifers)** but does not affect quality grade (still slight 300-399). Slight increase in USDA Choice or greater (4.4%), slight decrease in USDA Select (1.8%) and Standard (2.6%). Slight decrease in Yield Grade 1 (5.2%) and 4 (2.8%), and slight increase in Yield Grade 2 (6.7%) and 3 (2%). Minimal differences in colouring.

Exp 2: 200 mg/day for 28 days - similar dresing percentage, slight decrease in marbling score but does not affect quality grade (still small 400 to 499), increase in USDA Choice or greater by 10%, decrease in USDA Select by 11%, and increase in USDA Standard by 1.6%.

Both experiments support to conclusion that USDA Choice or greater grade is anticipated with feeding 200 mg/day for last 28 days before slaughter, with a slight change in Select and Standard grades. Slight change in yield grade was observed in experiment 1.

References

Quinn, M.J. et al. The effects of ractopamine-hydrogen chloride (Optaflexx) on performance, carcass characteristics, and meat quality on finishing feedlot heifers. Department of Animal Sciences and Industry, Kansas State University, Manhattan 66506-1600. J. Anim. Sci. 2008. 86:902-908.

Results of both studies above may reveal the differences in impact of Optaflexx on sex.

	Typ. % in Canadian beef	Difference from control with optaflexx for 28 days before slaughter (%)		
		Heifers	Steers	
Prime (Assumed similar to Canada Prime)	2	4.4	-7.0	From above studies
Choice (Assumed similar to Canada AAA)	50			
Select (Assumed similar to Canada AA)	45	-1.8	6.4	
Standard (Assumed similar to Canada A)	3	-2.6	0.7	
	Reference to the right			

Beef Quality. The Canadian Beef Industry is devoted to producing Beef Products which deliver on our Customers Expectations for Outstanding Eating Quality. Available at: http://www.cbef.com/beefquality.html. Accessed January 10, 2011.

Approximately 40 to 50% of feedlots in Alberta are currently using Optaflexx on their cattle for the last X days to slaughter.

Phone conversation with Scott Entz from Cargill High River regarding Optaflexx and reduced age to slaughter. January 18, 2011 (M. Murphy).

Since the Draft Guidance Document for Reducing the Number of Days in Feed of Beef Cattle was released in June 2010, it is assumed that Optaflexx is currently in use to reduce the number of days on feedlot **(assume that the BMP is implemented at 45% in 2010)**.

This is not showing an impact currently, but if the usage increased to 100%, there would be a significant decrease in quality of beef at the slaughterhouse.

Financially, there is no impact with the current practices.

Assume that the decreases in quality if the majority of the Alberta beef production were to implement the usage of Optaflexx (more than 50%) will reflect the results of the two studies above for steers and heifers fed 200 mg/day for the last 28 days in the feedlot.

Heifers

Shrunk live weight	588	kg	From Slaughterhouse tab
Average warm carcass weight	359	kg	From Beef Data tab
% reduction in weight from shrunk live weight to warm carcass weight	39.0	%	
Dressing percentage	61.0	%	
Total warm carcass weight at slaughterhouse	412,397	tonnes	
Total Canada AAA and better beef from heifers	214,446	tonnes	
% adoption of BMP	45%		From Summary Tab
Total revised Canada AAA and better beef from heifers with BMP implementation	218,692	tonnes	
Change in Canada AAA and better beef from heifers	4,246	tonnes	
Total Canada AA/A beef from heifers	197,950	tonnes	
% adoption of BMP	45%		
Total revised Canada AA/A beef from heifers with BMP implementation	194,031	tonnes	
Change in Canada AA/A beef from heifers	-3,919	tonnes	

Steers

Shrunk live weight	631	kg	From Slaughterhouse tab
Average warm carcass weight	378	kg	From Beef Data tab
% reduction in weight from shrunk live weight to warm carcass weight	40.2	%	
Dressing percentage	59.8	%	
Total warm carcass weight at slaughterhouse - steers	371,221	tonnes	
Total Canada AAA and better beef from steers	193,035	tonnes	

BMP 4 APPROACH 1 - DATA

			References
% adoption of BMP	45%		
Total revised Canada AAA and better beef from steers with BMP implementation	186,954	tonnes	
Change in Canada AAA and better beef from steers	-6,081	tonnes	
Total Canada AA/A beef from steers	178,186	tonnes	
% adoption of BMP	45%		
Total revised Canada AA/A beef from steers with BMP implementation	183,879	tonnes	
Change in Canada AA/A beef from steers	5,693	tonnes	
Total change in Canada AAA beef	**-1,835**	**tonnes**	
Total change in Canada AA/A beef	**1,774**	**tonnes**	

Optaflexx increased ribeye area by up to 1/2 inch, but didn't affect backfat thickness, marbling score or quality grade.	Texas Cooperative Extension. The Texas A&M University System. The Facts about Optaflexx: Ractopamine for Cattle. ASWeb-116 6-04. Available at: http://animalscience.tamu.edu/images/pdf/beef/beef-optaflexx.pdf

Change in gas, diesel, and electricity usage on feedlots for reduced feed time

Note: Energy required to feed animals in the baseline is included in the total energy used on beef farms in Alberta. Changes to energy requirements to be calculated.

Total diesel used on all beef farms (cow/calf and feedlot)	8,361	TJ	From Beef Data tab
Total reduction in feed requirements (Cow/calf and feedlot)	0.39%		From Diets tab
Assumesame reduction in diesel fuel used on feedlots	32.2	TJ reduced	
Revised diesel energy requirements	**8,329**	**TJ used**	

Note: Assume that diesel is the fuel used to operate the machinery to feed cattle and this will be the main source of energy that is reduced

Change in gas and diesel for manure handling on feedlot for reduced time

Note: Energy required to collect manure in the baseline is included in the total energy used on beef farms in Alberta. Changes to energy requirements to be calculated.

<u>Manure collection and handling</u>			
Diesel consumption for a tractor	16.6	L/hr	Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3: 3, 257-270.
Number of feedlot cattle in reference	50,000	cattle	Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3: 3, 257-270.
Pens with 250 head/pen in reference	200	pens	Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3: 3, 257-270.
Time to pile up manure in pen in reference	60	min/pen two times per year	Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3: 3, 257-270.
	400	hrs/yr	
Diesel required per year	6,640	L/yr	
CO_2 emission factor for truck diesel consumption	2,569	g CO_2/L	Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3: 3, 257-270.
CH_4 emission factor for truck diesel consumption	0.21	g CH_4/L	Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3: 3, 257-270.
Total emissions from manure collection (calculated based on data)	17.09	tonnes CO_2e/yr	
Total emissions from manure collection (total provided in reference)	1,172	tonnes CO2e/year	Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3: 3, 257-270.

(Total emissions calculated using data from reference different than total emissions provided in reference.
Only raw data from reference will be used to calculate emissions in model.)

Quantity of manure (in reference)	58,700	tonne dry manure/year	Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3: 3, 257-270.

(Alberta Beef LCA model used same reference to quantify manure)

Emission factor for the combustion of diesel in agricultural equipment - Alberta Beef LCA model	3.28	kg CO_2e/kg diesel	Intergovernmental Panel on Climate Change (IPCC). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 2. Chapter 3: Mobile Combustion. Available at: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_3_Ch3_Mobile_Combustion.pdf
Density of diesel	0.885	kg/L	Simetric. Specific Gravity of Liquids. Available at: http://www.simetric.co.uk/si_liquids.htm
	3.71	kg CO_2e/L	
Total emissions from manure collection using the LCA model emission factor	24.61	tonnes/yr	

BMP 4 APPROACH 1 - DATA

			References
(comparable to emissions calculated using reference data)			
Total emissions from manure collection per animal per day	**0.00135**	**kg/animal/day**	Calculated

Change in gas and diesel for bedding animals in feedlot for reduced time

Note: Energy required to provide bedding in the baseline is included in the total energy used on beef farms in Alberta. Changes to energy requirements to be calculated.

Bedding required for feedlot in Alberta Beef LCA model	422,073	tonnes
Total mass of barley and barley silage (feedlot diet)	12,061,530	tonnes
% of bedding mass compared to total feed mass	3.5	%

Bedding mass negligible compared to feed. Will still be included in the analysis as this will calculate through with the change in animal* days for the feed, but actual change in bedding of the livestock is a data gap.

Change in quantity of agricultural plastics for reduced feed

Current agricultural plastics disposal methods

- Burning is still the most prominent method of getting rid of agricultural plastics (2008)

Recycling Council of Alberta. Agricultural Plastics Recycling Pilot Project. Summary Report, September 2009. Available at: http://www.recycleyourplastic.ca/pdf/Ag_Plastics_Pilot_Report.pdf

- There is little industry capacity to handle agricultural plastics in Alberta
- Pilot recycling program conducted in Alberta in 2008 to understand the amount, type, and quality of used agricultural plastics and the capacity of industry to use it
- Alberta Beef LCA baseline model assumed the same as the current situation for the handling of agricultural plastics (burning and burying)
- No change in the disposal of plastics
- Total change in plastics will be calculated based on percentage of total change in feed

Change in labour

Calculate average reduction in days on feedlot	5.1	days	Calculated
Average time per day to feed cattle	4	hrs/day	Assumption
Total number of feedlots in Alberta (2008 data)	85	feedlots	Summed from Beef Data tab
Total time saved from reducing days to slaughter across Alberta	1,724.01	hrs/all feedlots	Calculated

Price Information

Average farm hand wage	16.22	$/hr	WAGEinfo, Alberta Wage and Salary Survey, 2009 data. Available at: http://alis.alberta.ca/wageinfo/Content/RequestAction.asp?aspAction=GetWageDetail&format=html&RegionID=20&NOC=8431
Purchase of barley	161.38	$/tonne	Lethbridge Barley Price, Alberta Grains Council, Alberta Canola Producers Commission. Weekly Average from 2005 to 2010
	0.16	$/kg	
Purchase of barley silage	40	$/tonne	Based on a conversation with a local dairy farmer on January 3, 2011.
	0.04	$/kg	
Purchase of bedding (model assumes 100% straw bedding used) (Straw estimate for 2010)			
Wheat straw (fertilizer costs)	24.2	$/ton	What is Straw Worth? - Frequently Asked Questions. Ag-Info Centre, Alberta Agriculture and Rural Development. Available at: www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/faq7514
	26.7	$/tonne	
Barley and oat straw (fertilizer costs)	32	$/ton	What is Straw Worth? - Frequently Asked Questions. Ag-Info Centre, Alberta Agriculture and Rural Development. Available at: www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/faq7514
	35.3	$/tonne	
Pea straw (fertilizer costs)	30	$/ton	What is Straw Worth? - Frequently Asked Questions. Ag-Info Centre, Alberta Agriculture and Rural Development. Available at: www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/faq7514
	33.1	$/tonne	
Canola straw (fertilizer costs)	22.6	$/ton	What is Straw Worth? - Frequently Asked Questions. Ag-Info Centre, Alberta Agriculture and Rural Development. Available at: www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/faq7514
	24.9	$/tonne	
Average weight of straw bale	450	kg	Microsoft Word document provided by Alberta Agriculture and Rural Development in an email from Emmanuel Laate to Stephen Ball on November 20, 2009

BMP 4 APPROACH 1 - DATA

			References
Baling costs	9.00 - 11.50	$/large round bale	What is Straw Worth? - Frequently Asked Questions. Ag-Info Centre, Alberta Agriculture and Rural Development. Available at: www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/faq7514
	10.25	$/large round bale	Average
	0.023	$/kg	
	22.78	$/tonne	
Hauling and stacking	2.00 - 3.00	$/large round bale	What is Straw Worth? - Frequently Asked Questions. Ag-Info Centre, Alberta Agriculture and Rural Development. Available at: www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/faq7514
	2.5	$/large round bale	Average
	0.0056	$/kg	
	5.56	$/tonne	
Average price (wheat straw)	55.01	$/tonne	
Average price (barley and oat straw)	63.61	$/tonne	
Average price (pea straw)	61.40	$/tonne	
Average price (canola straw)	53.25	$/tonne	
Average price for straw	**58.32**	**$ / tonne**	
	0.058	**$ / kg**	
Purchase of RAC			
2011 Distributor Price (bulk price)	13.85	$/25 lb	Call with Elanco on January 4, 2011.
	0.55	$/lb	
	1.22	$/kg	
2011 Distributor Price (non-bulk price)	55.40	$/lb	Call with Elanco on January 4, 2011.
	122.14	$/kg	
Used the bulk price as it is much cheaper and would most likely be the choice of farmers	**1.22**	**$/kg**	
Purchase of min., trc min., cobalt, protein suppl., vit., antibiotic for feedlot			
32% Feedlot Supplement (pellets with monensin)	11.89	$/25 kg	UFA Limited. Available at: http://ufa.com/products/product.html. Accessed on January 3, 2011 and phone call with UFA on January 4, 2011.
	0.48	**$/kg**	
Vitamins (A-D-E Premix) for feedlot			
Mash	24.99	$/20 kg	UFA Limited. Available at: http://ufa.com/products/product.html. Accessed on January 3, 2011.
Crumble	30.00	$/20 kg	UFA Limited. Available at: http://ufa.com/products/product.html. Accessed on January 3, 2011.
Average	27.50	$/20 kg	
	1.37	**$/kg**	
Purchase of manure	0	$/kg	Government of Alberta. Agriculture and Rural Development. Manure and Compost Directory. Available at: http://www.agric.gov.ab.ca/app68/manure. Accessed on January 3, 2011.
Sale price for beef to slaughterhouse			
Baseline - steers (lbs at slaughterhouse)	1,392	lbs	from model
	631	kg	
Baseline - heifers (lbs at slaughterhouse)	1,296	lbs	from model
	588	kg	
Central Alberta 850 lb steer monthly averages (2005-2010)	weight not applicable for model		Canfax. Central Alberta 850 pound Steer - Monthly Averages. 2005 - 2010.
Central Alberta 550 lb steer monthly averages (2005-2010)	weight not applicable for model		Canfax. Central Alberta 550 pound Steer - Monthly Averages. 2005 - 2010.
Alberta weekly fed steer prices (2005-2010)			Canfax. Alberta Weekly Fed Steer Prices. 2005-2010
Average - Entire Year (2005-2010) (no weight given)	87.52	$/100 lb	
Average - September to November (2005-2010) (no weight given) (calf-fed cattle sent to slaughterhouse end of October) - baseline	86.85	$/100 lb	
Average - May to July (2005-2010) (no weight given) (calf-fed cattle sent to slaughterhouse in June) - BMP	87.73	$/100 lb	
Change in price of fed steers from Sept-Nov to May-Jul	**0.88**	**$/100 lb**	
	0.0040	**$/kg**	
	2.52	**$/steer**	

BMP 4 APPROACH 1 - DATA

			References
Alberta fed heifer monthly averages (2005-2010)			Canfax. Alberta Weekly Fed Heifer Prices. 2005-2010
Average - Entire Year (2005-2010) (no weight given)	87.22	$/100 lb	
Average - September to November (2005-2010) (no weight given) (calf-fed cattle sent to slaughterhouse end of October) - baseline	86.53	$/100 lb	
Average - May to July (2005-2010) (no weight given) (calf-fed cattle sent to slaughterhouse in June) - BMP	87.45	$/100 lb	
Change in price of heifers from Sept-Nov to May-Jul	**0.92**	**$/100 lb**	
	0.0042	**$/kg**	
	2.45	**$/heifer**	

Assume that the decrease in revenue for the slaughterhouse to the market is directly proportional to the decrease in revenue for the feedlots from the slaughterhouse with the usage of RAC above 50% of entire Alberta beef production system (based on discussions with Scott Entz from Cargill High River). Assuming the beef demand stays the same.

Sale price for beef from slaughterhouse to market			
Average 2008 price for Canada AAA beef	3.110	$/lb	CanFax. Boxed beef pricing. 2008. Available at: http://www.canfax.ca/BoxedBeefReports/BeefCarcassBreakdown.aspx
	6.856	$/kg	
Average 2008 price for Canada AA/A beef	2.850	$/lb	CanFax. Boxed beef pricing. 2008. Available at: http://www.canfax.ca/BoxedBeefReports/BeefCarcassBreakdown.aspx
	6.283	$/kg	
Average 2009 price for Canada AAA beef	3.030	$/lb	CanFax. Boxed beef pricing. 2009. Available at: http://www.canfax.ca/BoxedBeefReports/BeefCarcassBreakdown.aspx
	6.680	$/kg	
Average 2009 price for Canada AA/A beef	2.770	$/lb	CanFax. Boxed beef pricing. 2009. Available at: http://www.canfax.ca/BoxedBeefReports/BeefCarcassBreakdown.aspx
	6.107	$/kg	
Average 2010 price for Canada AAA beef	2.860	$/lb	CanFax. Boxed beef pricing. 2010. Available at: http://www.canfax.ca/BoxedBeefReports/BeefCarcassBreakdown.aspx
	6.305	$/kg	
Average 2010 price for Canada AA/A beef	2.730	$/lb	CanFax. Boxed beef pricing. 2010. Available at: http://www.canfax.ca/BoxedBeefReports/BeefCarcassBreakdown.aspx
	6.019	$/kg	
Average price for Canada AAA beef (2008-2010)	**6.614**	**$/kg**	
Average price for Canada AA/A beef (2008-2010)	**6.136**	**$/kg**	

Fuel consumed to feed livestock (on-farm diesel) - and - Fuel consumed to collect manure (on-farm diesel)			
Ultra Low Sulphur Diesel (ULSD)			
Calgary, AB	80.7	cents/L (excluding taxes)	UFA Petroleum. Rack Prices. December 18 to December 20, 2010. Available at: www.ufa.net/petroleum/rack_pricing.html
Edmonton, AB	77.5	cents/L (excluding taxes)	UFA Petroleum. Rack Prices. December 18 to December 20, 2010. Available at: www.ufa.net/petroleum/rack_pricing.html
Ultra Low Sulphur Diesel Lite (ULSD-LT)			
Calgary, AB	84.2	cents/L (excluding taxes)	UFA Petroleum. Rack Prices. December 18 to December 20, 2010. Available at: www.ufa.net/petroleum/rack_pricing.html
Edmonton, AB	81.0	cents/L (excluding taxes)	UFA Petroleum. Rack Prices. December 18 to December 20, 2010. Available at: www.ufa.net/petroleum/rack_pricing.html
Average	80.85	cents/L (excluding taxes)	
Fuel tax rates (diesel - all grades) (April 1, 2007 to current)	9	cents/L	Alberta Tax and Revenue Administration - Current and Historic Tax Rates. Available at: www.finance.alberta.ca/publications/tax_rebates/rates/hist1.html#fuel
Alberta Farm Fuel Benefit Program and Farm Fuel Distribution Allowance (taxes)	-15	cents/L	Alberta Finance and Enterprise. Taxes & Rebates - Fuel Tax Overview. November 23, 2010. Available at: www.finance.alberta.ca/publications/tax_rebates/fuel/overview.html

Fuel tax is exempted for diesel used on farms and a subsidy of 6 cents per L of diesel is provided

Average diesel price minus Alberta programs	**0.75**	**$/L**

Calculation changes to the model

- Reduce time for last feedlot diet based on "BMP 4 Approach 1-Day Reduction" tab, which will reduce feed and supplement requirements assuming all of Alberta will implement this BMP
- Calculate less garbage for less feed used
- Reduce time in feedlot for enteric fermentation emissions and manure emissions
- Reduce time in feedlot for total manure generation
- Reduce energy requirements for feeding cattle and manure collection
- Emissions associated with the production and transportation of RAC
- Include RAC in the Diet Supplements tab

BMP 4 APPROACH 1 - REDUCTION IN DAYS IN FEEDLOT BEFORE SLAUGHTER

Average increase in weight gain with the addition of RAC	1.2-2.1	% greater final weight
(from tab "BMP 4 Approach 1-Data)	1.65	% greater final weight (average)
Improvement in Average Daily Gain (ADG)	20	% increase in ADG

		Steer Yearlings	**Heifer Yearlings**	**Steer Calf-Fed**	**Heifer Calf-Fed**
Last Diet in Feedlot before Slaughter (from ruminant nutritionist)	***Units***	***Diet 7***	***Diet 7***	***Diet 7***	***Diet 7***
RATION (DRY MATTER BASIS)					
Barley	%	86.0	86.0	86.0	86.0
Barley Silage	%	10.0	10.0	10.0	10.0
Barley Straw	%	0	0	0	0
Supplement	%	4.0	4.0	4.0	4.0
Total	%	100	100	100	100
RATION (AS FED BASIS)					
Barley	%	75.3	75.3	75.3	75.3
Barley Silage	%	21.3	21.3	21.3	21.3
Barley Straw	%	0.0	0	0	0
Supplement	%	3.4	3.4	3.4	3.4
Total	%	100	100	100	100
Barley	lbs	2977.8	3036.1	3760.7	3552.7
Barley Silage	lbs	842.2	858.7	1063.7	1004.8
Supplement	lbs	135.5	138.1	171.1	161.6
ANALYSIS					
Date In	-	9-Oct	9-Oct	25-Oct	25-Oct
Date Out	-	11-Feb	27-Feb	22-Apr	19-Apr
Days on feed	d	126	142	180	176
Start Weight	lbs	935	820	790	710
End Weight	lbs	1450	1350	1450	1350
Gain	lbs	515	530	660	640
ADG	lbs/d	4.10	3.73	3.67	3.64
DMI	lbs/d	24.76	22.33	21.86	21.12
Increased Final Weight with RAC	lbs	1474	1372	1474	1372
Improved ADG	lbs/d	4.92	4.48	4.40	4.36
Additional Final Weight Gain	lbs	24	22	24	22
Reduction in days on feedlot	**d**	**4.9**	**5.0**	**5.4**	**5.1**

(assuming same weight to slaughterhouse as in baseline model - reduced number of days on feed)

Notes:

% - percent
ADG - Average daily gain
DMI - Dry matter intake
lbs - pounds
lbs/d - pounds per day
d - day

BMP 4 - Reducing Age to Slaughter (Approach 1) (2010 Baseline)

Approach 1: Add RAC (ractopamine - growth promotant) to diet of steers and heifers for the last 28 days in the feedlot to increase weight gain quicker and reduce age at slaughter

Assumed Percent Adoption of BMP 4 (feedlot only)	45%	(% adoption can be adjusted here for the entire model) **YEAR 2010**
Total number of animals affected by BMP (calf-fed steers and heifers, yearling-fed steers and heifers)	959,612 animals to slaughter (2002)	

Reduction in days on feedlot

Calf-fed steers	5.4 days	Yearling-fed steers	4.9 days
Calf-fed heifers	5.1 days	Yearling-fed heifers	5.0 days

Total weight affected to slaughter 583,376 tonnes

(calf-fed steers and heifers, yearling-fed steers and heifers -live weight)

Scenario BMP 4.1

Total GHG emissions	**2.09E+10 kg CO2e**
Total acidification	**3.07E+07 kg SO2-Eq**
Total eutrophication	**5.50E+06 kg PO4-Eq**
Total non-renewable energy	**3.44E+11 MJ-Eq**

	COW/CALF OPERATIONS								FEEDLOT OPERATIONS								SLAUGHTERHOUSE							
	BMP 4		Baseline (2001)		Change		Per Unit Market Value	Total Impact	BMP 4		Baseline (2001)		Change		Per Unit Market Value	Total Impact	BMP 4		Baseline (2001)		Change		Per Unit Market Value	Total Impact
	(amount)	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*	*($/unit)*	*($ Million)*	*(amount)*	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*	*($/unit)*	*($ Million)*	*(amount)*	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*	*($/unit)*	*($ Million)*
Inputs with Change																								
Production of pesticide/herbicide																								
Production of chemical fertilizer																								
Production of bedding																								
Production of min., trc min., cobalt, protein suppl., vit., antibiotic																								
Purchase of chemical fertilizer																								
Urea, as N, at regional storehouse																								
Ammonia, liquid, at regional storehouse																								
Monoammonium phosphate, as P2O5, at regional storehouse																								
Monoammonium phosphate, as N, at regional storehouse																								
Ammonium sulphate, as N, at regional storehouse																								
Purchase of manure for land application																								
Purchase of pesticide/herbicide																								
Purchase of seed for barley																								
Purchase of seed for barley silage																								
Purchase of seed for alfalfa/grass hay																								
Purchase of water to irrigate crops																								
Purchase of amendment materials									0	kg	0	kg	0	kg	-	-								
Purchase of composting equipment (Windrow turner)									0	turners	0	turners	0	turners	-	-								
Purchase of construction supplies for composting (clay for pad)									0	units	0	units	0	units	-	-								
Purchase of alfalfa/grass hay	6.59E+09	kg	6.59E+09	kg	0	kg	-	-																
Purchase of barley									4.43E+09	kg	4.49E+09	kg	-5.60E+07	kg	$0.16	-$9.04								
Purchase of barley silage									7.56E+09	kg	7.58E+09	kg	-1.58E+07	kg	$0.04	-$0.63								
Purchase of bedding	5.09E+08	kg	5.09E+08	kg	0	kg	-	-	4.20E+08	kg	4.22E+08	kg	-2.41E+06	kg	$0.06	-$0.14								
Purchase of animal shelters, wind breakers, fencing, etc.	0	units	0	units	0	units	-	-																
Purchase of ionophores	0	kg	0	kg	0	kg	-	-																
Purchase of RAC									6.33E+03	kg	0	kg	6,332	kg	$1.22	$0.01								
Purchase of min., trc min., cobalt, protein suppl., antibiotic	7.91E+07	kg	7.91E+07	kg	0	kg	-	-	1.44E+08	kg	1.45E+08	kg	-9.44E+05	kg	$0.48	-$0.45								
Purchase of vitamins	1,684	kg	1,684	kg	0	kg	-	-	1.74E+05	kg	1.76E+05	kg	-1.40E+03	kg	$1.37	-$0.0019								
Purchase of RFI testing (includes transportation)	0	tests	0	tests	0	tests	-	-	0	tests	0	tests	0	tests	-	-								
Fuel/energy required to operate composting equipment									0	kWh or L	0	kWh or L	0	kWh or L	-	-								
Fuel consumed to transport barley and barley silage																								
Fuel consumed to transport alfalfa/grass hay																								
Fuel consumed for cropping activities																								
Fuel consumed to bed livestock (change)	0	L	0	L	0	L	-	-	0	L	0	L	0	L	-	-								
Fuel consumed to transport garbage (change)	0	L	0	L	0	L	-	-	0	L	0	L	0	L	-	-								
Fuel consumed to transport bedding (change)																								
Fuel consumed to feed livestock (change)	0	L	0	L	0	L	-	-	-9.19E+05	L	0	L	-9.19E+05	L	$0.75	-$0.69								
Fuel consumed to collect manure (change)									-9,059	L	0	L	-9,059	L	$0.75	-$0.01								
Fuel cons. to transp. min., trc min., cob., prot. suppl., vit., antibiotic																								
Fuel consumed to transport livestock for testing	0	L	0	L	0	L	-	-	0	L	0	L	0	L	-	-								
Labour (change)	0	hrs	0	hrs	0	hrs	-	-	-1.72E+03	hrs	0	hrs	-1,724	hrs	$16.22	-$0.03								
Working capital interest	0	$	0	$	0	$	-	-	0	$	0	$	0	$	-	-								
Total Input Value Change								**$0.00**								**-$10.98**								
Outputs with Change																								
Manure sold for land application									2.50E+10	kg	2.51E+10	kg	-6.82E+07	kg	$0.00	$0.00								
Compost sold for land application									0	kg	0	kg	0	kg	-	-								
Sold beef on RAC to slaughterhouse (live weight)									5.83E+05	kg	0	kg	583,376	kg	not available	$0.00								
Sold meat from slaughterhouse as Canada AAA or better (carcass)																	4.06E+08	kg	4.07E+08	kg	-1.83E+06	kg	$6.614	-$12.13
Sold meat from slaughterhouse as Canada AA/A (carcass)																	3.78E+08	kg	3.76E+08	kg	1.77E+06	kg	$6.136	$10.88
Total Output Value Change								**$0.00**								**$0.00**								**-$1.25**

CHANGE IN OVERALL GHG EMISSIONS	COW/CALF OPERATIONS						FEEDLOT OPERATIONS						BEEF INDUSTRY					
	BMP 4		Baseline (2001)		Change		BMP 4		Baseline (2001)		Change		BMP 4		Baseline (2001)		Change	
	(amount)	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*	*(amount)*	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*	*(amount)*	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*
BEEF ACTIVITIES - SOIL AND CROP																		
Manure generation	3.45E+10	kg	3.45E+10	kg	0	kg	1.88E+10	kg	1.89E+10	kg	-1.45E+08	kg						
Methane emissions from stored manure	1.49E+08	kg CO_2e	1.49E+08	kg CO_2e	0	kg CO_2e	1.43E+08	kg CO_2e	1.44E+08	kg CO_2e	-7.89E+05	kg CO_2e						
Enteric fermentation emissions	7.03E+09	kg CO_2e	7.03E+09	kg CO_2e	0	kg CO_2e	3.55E+09	kg CO_2e	3.56E+09	kg CO_2e	-1.46E+07	kg CO_2e						
N_2O emissions from stored manure (direct)	1.83E+09	kg CO_2e	1.83E+09	kg CO_2e	0	kg CO_2e	3.24E+08	kg CO_2e	3.27E+08	kg CO_2e	-2.54E+06	kg CO_2e						
N_2O emissions from stored manure (indirect)	4.04E+08	kg CO_2e	4.04E+08	kg CO_2e	0	kg CO_2e	3.04E+08	kg CO_2e	3.06E+08	kg CO_2e	-2.38E+06	kg CO_2e						
N_2O emissions from cropping and land use													9.52E+08	kg CO_2e	9.57E+08	kg CO_2e	-4.87E+06	kg CO_2e
Total P emissions from run-off													4.12E+06	kg PO_4-eq	4.15E+06	kg PO_4-eq	-2.97E+04	kg PO_4-eq
Soil Carbon Change in Soil From Land Use													-2.34E+08	kg CO_2e	-2.36E+08	kg CO_2e	2.07E+06	kg CO_2e
Direct CO2 emissions from managed soils													1.87E+08	kg CO_2e	1.89E+08	kg CO_2e	-1.52E+06	kg CO_2e
OVERALL SUMMARY																		
Construction	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e						
Forage and cereal sub-activities													1.20E+09	kg CO_2e	1.20E+09	kg CO_2e	-8.89E+06	kg CO_2e
Energy generation and consumption activities	2.81E+09	kg CO_2e	2.81E+09	kg CO_2e	0	kg CO_2e	1.03E+09	kg CO_2e	1.04E+09	kg CO_2e	-8.96E+06	kg CO_2e						
O&M activities	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e						
Cereal activities													3.34E+08	kg CO_2e	3.38E+08	kg CO_2e	-4.22E+06	kg CO_2e
Forage activities													2.86E+08	kg CO_2e	2.86E+08	kg CO_2e	-2.36E+05	kg CO_2e
Feedlot and pasture activities	3.20E+06	kg CO_2e	3.20E+06	kg CO_2e	0	kg CO_2e	1.39E+08	kg CO_2e	1.40E+08	kg CO_2e	-1.52E+06	kg CO_2e	3.04E+08	kg CO_2e	3.04E+08	kg CO_2e	-3.74E+05	kg CO_2e
Cow activities (transportation)	2.49E+07	kg CO_2e	2.49E+07	kg CO_2e	0	kg CO_2e												
Bull activities (transportation)	3.14E+06	kg CO_2e	3.14E+06	kg CO_2e	0	kg CO_2e												
Yearling-fed system activities (transportation)							1.08E+08	kg CO_2e	1.08E+08	kg CO_2e	0	kg CO_2e						
Calf-fed system activities (transportation)							6.59E+07	kg CO_2e	6.59E+07	kg CO_2e	0	kg CO_2e						

Total GWP for BMP

kg CO_2e **1.22E+10** **Cow/Calf** **5.66E+09** **Feedlot** **3.03E+09** **Beef Industry**

Total Change in GWP for BMP

kg CO_2e **0.00** **-3.08E+07** **-1.80E+07**

Overall Baseline GWP (2001)

kg CO_2e/kg live weight **14.705**

Overall Baseline GWP (2010)

kg CO_2e/kg live weight **14.671**

Overall BMP GWP

kg CO_2e/kg live weight **14.671**

Change in overall GWP from 2001

kg CO_2e/kg live weight **-0.034**

Change in overall GWP from 2010

kg CO_2e/kg live weight **0.000**

Change in GWP per kg of beef affected from 2001

kg CO_2e/kg live weight **-0.084** **(total change in GHG emissions divided by total weight of cattle affected)**

Notes:
Energy generation emissions divided by the number of cattle on cow/calf vs feedlo
Feedlot and pasture activities are divided as per below.

BMP 4 - Reducing Age to Slaughter (Approach 1) (2011 and after)

Approach 1: Add RAC (ractopamine - growth promotant) to diet of steers and heifers for the last 28 days in the feedlot to increase weight gain quicker and reduce age at slaughter.

Assumed Percent Adoption of BMP 4 100% (% adoption can be adjusted here for the entire model)
(feedlot only) **AFTER 2010**

Total number of animals affected by BMP 2,132,470 animals to slaughter (2002)
(calf-fed steers and heifers, yearling-fed steers and heifers)

Reduction in days on feedlot

Calf-fed steers	5.4 days	Yearling-fed steers	4.9 days
Calf-fed heifers	5.1 days	Yearling-fed heifers	5.0 days

Total weight affected to slaughter 1,296,392 tonnes
(calf-fed steers and heifers, yearling-fed steers and heifers -live weight)

Scenario BMP 4.1

Total GHG emissions	**2.09E+10 kg CO2e**
Total acidification	**3.05E+07 kg SO2-Eq**
Total eutrophication	**5.46E+06 kg PO4-Eq**
Total non-renewable energy	**3.43E+11 MJ-Eq**

	COW/CALF OPERATIONS					FEEDLOT OPERATIONS					SLAUGHTERHOUSE				
	BMP 4	Baseline (2010)	Change	Per Unit Market Value	Total Impact	BMP 4	Baseline (2010)	Change	Per Unit Market Value	Total Impact	BMP 4	Baseline (2010)	Change	Per Unit Market Value	Total Impact
	(amount) (unit)	*(amount) (unit)*	*(change) (unit)*	*($/unit)*	*($ Million)*	*(amount) (unit)*	*(amount) (unit)*	*(change) (unit)*	*($/unit)*	*($ Million)*	*(amount) (unit)*	*(amount) (unit)*	*(change) (unit)*	*($/unit)*	*($ Million)*
Inputs with Change															
Production of pesticide/herbicide															
Production of chemical fertilizer															
Production of bedding															
Production of min., trc min., cobalt, protein suppl., vit., antibiotic															
Purchase of chemical fertilizer															
Urea, as N, at regional storehouse															
Ammonia, liquid, at regional storehouse															
Monoammonium phosphate, as P2O5, at regional storehouse															
Monoammonium phosphate, as N, at regional storehouse															
Ammonium sulphate, as N, at regional storehouse															
Purchase of manure for land application															
Purchase of pesticide/herbicide															
Purchase of seed for barley															
Purchase of seed for barley silage															
Purchase of seed for alfalfa/grass hay															
Purchase of water to irrigate crops															
Purchase of amendment materials						0 kg	0 kg	0 kg	-	-					
Purchase of composting equipment (Windrow turner)						0 turners	0 turners	0 turners	-	-					
Purchase of construction supplies for composting (clay for pad)						0 units	0 units	0 units	-	-					
Purchase of alfalfa/grass hay	6.59E+09 kg	6.59E+09 kg	0 kg	-	-										
Purchase of barley						4.36E+09 kg	4.43E+09 kg	-6.84E+07 kg	$0.16	-$11.05					
Purchase of barley silage						7.54E+09 kg	7.56E+09 kg	-1.94E+07 kg	$0.04	-$0.77					
Purchase of bedding	5.09E+08 kg	5.09E+08 kg	0 kg	-	-	4.17E+08 kg	4.20E+08 kg	-2.94E+06 kg	$0.06	-$0.17					
Purchase of animal shelters, wind breakers, fencing, etc.	0 units	0 units	0 units	-	-										
Purchase of ionophores	0 kg	0 kg	0 kg	-	-										
Purchase of RAC						1.41E+04 kg	6.33E+03 kg	7,740 kg	$1.22	$0.009					
Purchase of min., trc min., cobalt, protein suppl., antibiotic	7.91E+07 kg	7.91E+07 kg	0 kg	-	-	1.43E+08 kg	1.44E+08 kg	-1.28E+06 kg	$0.48	-$0.61					
Purchase of vitamins	1,684 kg	1,684 kg	0 kg	-	-	1.73E+05 kg	1.74E+05 kg	-1.71E+03 kg	$1.37	-$0.0024					
Purchase of RFI testing (includes transportation)	0 tests	0 tests	0 tests	-	-	0 tests	0 tests	0 tests	-	-					
Fuel/energy required to operate composting equipment						0 kWh or L	0 kWh or L	0 kWh or L	-	-					
Fuel consumed to transport barley and barley silage															
Fuel consumed to transport alfalfa/grass hay															
Fuel consumed for cropping activities															
Fuel consumed to bed livestock (change)	0 L	0 L	0 L	-	-	0 L	0 L	0 L	-	-					
Fuel consumed to transport garbage (change)	0 L	0 L	0 L	-	-	0 L	0 L	0 L	-	-					
Fuel consumed to transport bedding (change)															
Fuel consumed to feed livestock (change)	0 L	0 L	0 L	-	-	-2.04E+06 L	-9.19E+05 L	-1.12E+06 L	$0.75	-$0.84					
Fuel consumed to collect manure (change)						-20,132 L	-9.06E+03 L	-1.11E+04 L	$0.75	-$0.008					
Fuel cons. to transp. min., trc min., cob., prot. suppl., vit., antibiotic															
Fuel consumed to transport livestock for testing	0 L	0 L	0 L	-	-	0 L	0 L	0 L	-	-					
Labour (change)	0 hrs	0 hrs	0 hrs	-	-	-3.83E+03 hrs	-1.72E+03 hrs	-2,107 hrs	$16.22	-$0.03					
Working capital interest	0 $	0 $	0 $	-	-	0 $	0 $	0 $	-	-					
Total Input Value Change					**$0.00**					**-$13.48**					
Outputs with Change															
Manure sold for land application						2.49E+10 kg	2.50E+10 kg	-8.33E+07 kg	$0.00	$0.00					
Compost sold for land application						0 kg	0 kg	0 kg	-	-					
Sold beef on RAC to slaughterhouse (live weight)						1.30E+06 kg	5.83E+05 kg	7.13E+05 kg	not available	-$1.53					
Sold meat from slaughterhouse as Canada AAA or better (carcass)											4.03E+08 kg	4.06E+08 kg	-2.24E+06 kg	$6.614	-$14.83
Sold meat from slaughterhouse as Canada AA/A (carcass)											3.80E+08 kg	3.78E+08 kg	2.17E+06 kg	$6.136	$13.30
Total Output Value Change					**$0.00**					**-$1.53**					**-$1.53**

CHANGE IN OVERALL GHG EMISSIONS	**COW/CALF OPERATIONS**						**FEEDLOT OPERATIONS**						**BEEF INDUSTRY**					
	BMP 4		**Baseline (2010)**		**Change**		**BMP 4**		**Baseline (2010)**		**Change**		**BMP 4**		**Baseline (2010)**		**Change**	
	(amount)	***(unit)***	***(amount)***	***(unit)***	***(change)***	***(unit)***	***(amount)***	***(unit)***	***(amount)***	***(unit)***	***(change)***	***(unit)***	***(amount)***	***(unit)***	***(amount)***	***(unit)***	***(change)***	***(unit)***
BEEF ACTIVITIES - SOIL AND CROP																		
Manure generation	3.45E+10	kg	3.45E+10	kg	0	kg	1.86E+10	kg	1.88E+10	kg	-1.77E+08	kg						
Methane emissions from stored manure	1.49E+08	kg CO_2e	1.49E+08	kg CO_2e	0	kg CO_2e	1.42E+08	kg CO_2e	1.43E+08	kg CO_2e	-9.65E+05	kg CO_2e						
Enteric fermentation emissions	7.03E+09	kg CO_2e	7.03E+09	kg CO_2e	0	kg CO_2e	3.53E+09	kg CO_2e	3.55E+09	kg CO_2e	-1.78E+07	kg CO_2e						
N_2O emissions from stored manure (direct)	1.83E+09	kg CO_2e	1.83E+09	kg CO_2e	0	kg CO_2e	3.21E+08	kg CO_2e	3.24E+08	kg CO_2e	-3.11E+06	kg CO_2e						
N_2O emissions from stored manure (indirect)	4.04E+08	kg CO_2e	4.04E+08	kg CO_2e	0	kg CO_2e	3.01E+08	kg CO_2e	3.04E+08	kg CO_2e	-2.91E+06	kg CO_2e						
N_2O emissions from cropping and land use													9.47E+08	kg CO_2e	9.52E+08	kg CO_2e	-5.95E+06	kg CO_2e
Total P emissions from run-off													4.08E+06	kg PO_4-eq	4.12E+06	kg PO_4-eq	-3.63E+04	kg PO_4-eq
Soil Carbon Change in Soil From Land Use													-2.31E+08	kg CO_2e	-2.34E+08	kg CO_2e	2.53E+06	kg CO_2e
Direct CO2 emissions from managed soils													1.86E+08	kg CO_2e	1.87E+08	kg CO_2e	-1.86E+06	kg CO_2e
OVERALL SUMMARY																		
Construction	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e						
Forage and cereal sub-activities													1.19E+09	kg CO_2e	1.20E+09	kg CO_2e	-1.09E+07	kg CO_2e
Energy generation and consumption activities	2.81E+09	kg CO_2e	2.81E+09	kg CO_2e	0	kg CO_2e	1.02E+09	kg CO_2e	1.03E+09	kg CO_2e	-1.10E+07	kg CO_2e						
O&M activities	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e						
Cereal activities													3.29E+08	kg CO_2e	3.34E+08	kg CO_2e	-5.16E+06	kg CO_2e
Forage activities													2.85E+08	kg CO_2e	2.86E+08	kg CO_2e	-2.89E+05	kg CO_2e
Feedlot and pasture activities	3.20E+06	kg CO_2e	3.20E+06	kg CO_2e	0	kg CO_2e	1.37E+08	kg CO_2e	1.39E+08	kg CO_2e	-1.86E+06	kg CO_2e	3.03E+08	kg CO_2e	3.04E+08	kg CO_2e	-4.57E+05	kg CO_2e
Cow activities (transportation)	2.49E+07	kg CO_2e	2.49E+07	kg CO_2e	0	kg CO_2e												
Bull activities (transportation)	3.14E+06	kg CO_2e	3.14E+06	kg CO_2e	0	kg CO_2e												
Yearling-fed system activities (transportation)							1.08E+08	kg CO_2e	1.08E+08	kg CO_2e	0	kg CO_2e						
Calf-fed system activities (transportation)							6.59E+07	kg CO_2e	6.59E+07	kg CO_2e	0	kg CO_2e						

Total GWP for BMP

kg CO_2e **1.22E+10** **Cow/Calf** **5.62E+09** **Feedlot** **3.00E+09** **Beef Industry**

Total Change in GWP for BMP

kg CO_2e **0.00** **-3.76E+07** **-2.21E+07**

Total change in emissions **-59,659** **tonnes**

Overall Baseline GWP (2001)

kg CO_2e/kg live weight **14.705**

Overall Baseline GWP (2010)

kg CO_2e/kg live weight **14.671**

Overall BMP GWP

kg CO_2e/kg live weight **14.629**

Change in overall GWP from 2001

kg CO_2e/kg live weight **-0.076**

Change in overall GWP from 2010

kg CO_2e/kg live weight **-0.042**

Change in GWP per kg of beef affected from 2010

kg CO_2e/kg live weight **-0.046** **(total change in GHG emissions divided by total weight of cattle affected)**

Notes:
Energy generation emissions divided by the number of cattle on cow/calf vs feedlot
Feedlot and pasture activities are divided as per below.

BMP 4 APPROACH 2 - DATA

References

Diet changes See BMP 4 App2-Diet tab for changes to diet

Effects on Beef Quality and Market

If 100% of the Alberta beef system were to implement this BMP, it would be catastrophic to the industry.

The slaughterhouses would have to try and process all cattle (or at least the calf-fed cattle because that is what is considered in the model here) in 2 to 3 months, which couldn't be done.

The customers also want access to beef all year round and it is important to have non-frozen beef to fill the orders.

As for quality, as long as the cattle are the same weight at the slaughterhouse, the prices are not likely to change. Reduced marbling is likely which may be offset by increased tenderness, which in turn may result in a reduction in quality grade.

It is also likely that there will be a reduction in carcass yield (smaller animals).

It is anticipated that the quality grade will be reduced, but there is no literature indicating that this is the case, only discussions with people in the industry.

Therefore, a **reduction in carcass weight** will be assumed to account for the reduced age at harvest and a **slight decrease in AAA beef and a slight increase in AA/A** will be assumed.

Phone conversation with Scott Entz from Cargill High River regarding reduced age to slaughter. January 18, 2011 (M. Murphy)

Reduction in weight for reduced age at harvest cattle (3% decrease)	20 kg	Assumption
Total weight reduced from feedlot to slaughterhouse and slaughterhouse to market (calf-fed)	19,192,230 kg	

	Typ. % in Canadian beef	Assumed change in quality from calf-fed cattle (%)
Prime (Assumed similar to Canada Prime)	2	-5%
Choice (Assumed similar to Canada AAA)	50	
Select (Assumed similar to Canada AA)	45	5% (from AAA)
Standard (Assumed similar to Canada A)	3	

Beef Quality. The Canadian Beef Industry is devoted to producing Beef Products which deliver on our Customers Expectations for Outstanding Eating Quality. Available at: http://www.cbef.com/beefquality.html. Accessed January 10, 2011.
Quality change % is assumption only

Calf-fed Heifers

Shrunk live weight	568 kg	From Slaughterhouse tab
Average warm carcass weight	341 kg	From Beef Data tab
% reduction in weight from shrunk live weight to warm carcass weight	40.0 %	Assumed (from data in Beef data tab)
Dressing percentage	60.0 %	Assumed (from data in Beef data tab)
Total warm carcass weight at slaughterhouse from calf-fed heifers	176,228 tonnes	
Total Canada AAA and better beef from calf-fed heifers	91,638 tonnes	
% adoption of BMP	100%	From Summary Tab
Total revised Canada AAA and better beef from calf-fed heifers with BMP	87,057 tonnes	
Change in Canada AAA and better beef from calf-fed heifers	-4,582 tonnes	
Total Canada AA/A beef from calf-fed heifers	84,589 tonnes	
% adoption of BMP	100%	
Total revised Canada AA/A beef from calf-fed heifers with BMP implementation	89,171 tonnes	
Change in Canada AA/A beef from calf-fed heifers	4,582 tonnes	

Calf-fed Steers

Shrunk live weight	611 kg	From Slaughterhouse tab
Average warm carcass weight	367 kg	From Beef Data tab
% reduction in weight from shrunk live weight to warm carcass weight	40.0 %	Assumed (from data in Beef data tab)
Dressing percentage	60.0 %	Assumed (from data in Beef data tab)
Total warm carcass weight at slaughterhouse from calf-fed steers	162,283 tonnes	
Total Canada AAA and better beef from calf-fed steers	84,387 tonnes	
% adoption of BMP	100%	
Total revised Canada AAA and better beef from calf-fed steers with BMP	80,168 tonnes	
Change in Canada AAA and better beef from calf-fed steers	-4,219 tonnes	
Total Canada AA/A beef from calf-fed steers	77,896 tonnes	
% adoption of BMP	100%	

BMP 4 APPROACH 2 - DATA

			References
Total revised Canada AA/A beef from calf-fed steers with BMP implementation	82,115	tonnes	
Change in Canada AA/A beef from calf-fed steers	4,219	tonnes	
Total change in Canada AAA beef	**-8,801**	**tonnes**	
Total change in Canada AA/A beef	**8,801**	**tonnes**	

Change in gas, diesel, and electricity usage on feedlots for reduced feed time

Note: Energy required to feed animals in the baseline is included in the total energy used on beef farms in Alberta. Changes to energy requirements to be calculated.

Total diesel used on all beef farms (cow/calf and feedlot)	8,361	TJ	From Beef Data tab
Total reduction in feed requirements (Cow/calf and feedlot)	9.62%		From Diets tab
Assume same reduction in diesel fuel used on feedlots	804.2	TJ reduced	
Revised diesel energy requirements	**7,557**	**TJ used**	

Note: Assume that diesel is the fuel used to operate the machinery to feed cattle and this will be the main source of energy that is reduced

Change in gas and diesel for manure handling on feedlot for reduced time

Note: Energy required to collect manure in the baseline is included in the total energy used on beef farms in Alberta. Changes to energy requirements to be calculated.
Assume same for backgrounding feedlots.

Manure collection and handling

Diesel consumption for a tractor	16.6	L/hr	Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3: 3,
Number of feedlot cattle in reference	50,000	cattle	Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3: 3,
Pens with 250 head/pen in reference	200	pens	Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3: 3,
Time to pile up manure in pen in reference	60	min/pen two times per year	Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3: 3,
	400	hrs/yr	
Diesel required per year	6,640	L/yr	
CO_2 emission factor for truck diesel consumption	2,569	g CO_2/L	Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3: 3,
CH_4 emission factor for truck diesel consumption	0.21	g CH_4/L	Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3: 3,
Total emissions from manure collection (calculated based on data)	17.09	tonnes CO_2e/yr	
Total emissions from manure collection (total provided in reference)	1,172	tonnes CO_2e/year	Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3: 3,

(Total emissions calculated using data from reference different than total emissions provided in reference.
Only raw data from reference will be used to calculate emissions in model.)

Quantity of manure (in reference)	58,700	tonne dry manure/year	Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3: 3,

(Alberta Beef LCA model used same reference to quantify manure)

Emission factor for the combustion of diesel in agricultural equipment - Alberta Beef LCA model	3.28	kg CO_2e/kg diesel	Intergovernmental Panel on Climate Change (IPCC). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 2. Chapter 3: Mobile Combustion. Available at: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_3_Ch3_Mobile_Combustion.pdf
Density of diesel	0.885	kg/L	Simetric. Specific Gravity of Liquids. Available at: http://www.simetric.co.uk/si_liquids.htm
	3.71	kg CO_2e/L	
Total emissions from manure collection using the LCA model emission factor *(comparable to emissions calculated using reference data)*	24.61	tonnes/yr	
Total emissions from manure collection per animal per day	**0.00135**	**kg/animal/day**	

BMP 4 APPROACH 2 - DATA

References

Change in gas and diesel for bedding animals in feedlot for reduced time

Note: Energy required to provide bedding in the baseline is included in the total energy used on beef farms in Alberta. Changes to energy requirements to be calculated.
Assume same for backgrounding feedlots.

Bedding required for feedlot in Alberta Beef LCA model	422,073	tonnes
Total mass of barley and barley silage (feedlot diet)	12,061,530	tonnes
% of bedding mass compared to total feed mass	3.5	%

Bedding mass negligible compared to feed. Will still be included in the analysis as this will calculate through with the change in animal* days for the feed, but actual change in bedding of the livestock is a data gap.

Change in quantity of agricultural plastics for change in feed

Current agricultural plastics disposal methods

- Burning is still the most prominent method of getting rid of agricultural plastics (2008)

Recycling Council of Alberta. Agricultural Plastics Recycling Pilot Project. Summary Report, September 2009. Available at: http://www.recycleyourplastic.ca/pdf/Ag_Plastics_Pilot_Report.pdf

- There is little industry capacity to handle agricultural plastics in Alberta
- Pilot recycling program conducted in Alberta in 2008 to understand the amount, type, and quality of used agricultural plastics and the capacity of industry to use it
- Alberta Beef LCA baseline model assumed the same as the current situation for the handling of agricultural plastics (burning and burying)
- No change in the disposal of plastics
- Total change in plastics will be calculated based on percentage of total change in feed

Change in labour

Calculate average reduction in days on feedlot (calf-fed)	106.9	days	Calculated (see BMP 4 App2-Diet tab - average reduction in days for calf-fed steers and heifers)
Average time per day to feed cattle	4	hrs/day	Assumption
Total number of feedlots in Alberta (2008 data)	188	feedlots	Summed from Beef Data tab
Total time saved from reducing days to slaughter across Alberta	80,357.24	hrs/all feedlots	Calculated

Price Information

Average farm hand wage	16.22	$/hr	WAGEinfo, Alberta Wage and Salary Survey, 2009 data. Available at: http://alis.alberta.ca/wageinfo/Content/RequestAction.asp?aspAction=GetWageDetail&format=html&RegionID=20&NOC=8431
Purchase of barley	161.38	$/tonne	Lethbridge Barley Price, Alberta Grains Council, Alberta Canola Producers Commission. Weekly Average from 2005 to 2010
	0.16	$/kg	
Purchase of barley silage	40	$/tonne	Based on a conversation with a local dairy farmer on January 3, 2011.
	0.04	$/kg	
Purchase of bedding (model assumes 100% straw bedding used) (Straw estimate for 2010)			
Wheat straw (fertilizer costs)	24.2	$/ton	What is Straw Worth? - Frequently Asked Questions. Ag-Info Centre, Alberta Agriculture and Rural Development. Available at: www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/faq7514
	26.7	$/tonne	
Barley and oat straw (fertilizer costs)	32	$/ton	What is Straw Worth? - Frequently Asked Questions. Ag-Info Centre, Alberta Agriculture and Rural Development. Available at: www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/faq7514
	35.3	$/tonne	
Pea straw (fertilizer costs)	30	$/ton	What is Straw Worth? - Frequently Asked Questions. Ag-Info Centre, Alberta Agriculture and Rural Development. Available at: www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/faq7514
	33.1	$/tonne	
Canola straw (fertilizer costs)	22.6	$/ton	What is Straw Worth? - Frequently Asked Questions. Ag-Info Centre, Alberta Agriculture and Rural Development. Available at: www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/faq7514
	24.9	$/tonne	
Average weight of straw bale	450	kg	Microsoft Word document provided by Alberta Agriculture and Rural Development in an email from Emmanuel Laate to Stephen Ball on November 20, 2009
Baling costs	9.00 - 11.50	$/large round bale	What is Straw Worth? - Frequently Asked Questions. Ag-Info Centre, Alberta Agriculture and Rural Development. Available at: www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/faq7514
	10.25	$/large round bale	Average

BMP 4 APPROACH 2 - DATA

		References
	0.023 $/kg	
	22.78 $/tonne	
Hauling and stacking	2.00 - 3.00 $/large round bale	What is Straw Worth? - Frequently Asked Questions. Ag-Info Centre, Alberta Agriculture and Rural Development. Available at: www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/faq7514
	2.5 $/large round bale	Average
	0.0056 $/kg	
	5.56 $/tonne	
Average price (wheat straw)	55.01 $/tonne	
Average price (barley and oat straw)	63.61 $/tonne	
Average price (pea straw)	61.40 $/tonne	
Average price (canola straw)	53.25 $/tonne	
Average price for straw	**58.32 $/ tonne**	
	0.058 $/ kg	
Purchase of min., trc min., cobalt, protein suppl., vit., antibiotic for feedlot		
32% Feedlot Supplement (pellets with monensin)	11.89 $/25 kg	UFA Limited. Available at: http://ufa.com/products/product.html. Accessed on January 3, 2011 and phone call with UFA on January 4, 2011.
	0.48 $/kg	
Vitamins (A-D-E Premix) for feedlot		
Mash	24.99 $/20 kg	UFA Limited. Available at: http://ufa.com/products/product.html. Accessed on January 3, 2011.
Crumble	30.00 $/20 kg	UFA Limited. Available at: http://ufa.com/products/product.html. Accessed on January 3, 2011.
Average	27.50 $/20 kg	
	1.37 $/kg	
Purchase of manure	0 $/kg	Government of Alberta. Agriculture and Rural Development. Manure and Compost Directory. Available at: http://www.agric.gov.ab.ca/app68/manure. Accessed on January 3, 2011.
Sale price for beef to slaughterhouse		
Baseline - steers (lbs at slaughterhouse)	1,392 lbs	from model
	631 kg	
Baseline - heifers (lbs at slaughterhouse)	1,296 lbs	from model
	588 kg	
Central Alberta 850 lb steer monthly averages (2005-2010)	weight not applicable for model	Canfax. Central Alberta 850 pound Steer - Monthly Averages. 2005 - 2010.
Central Alberta 550 lb steer monthly averages (2005-2010)	weight not applicable for model	Canfax. Central Alberta 550 pound Steer - Monthly Averages. 2005 - 2010.
Alberta weekly fed steer prices (2005-2010)		Canfax. Alberta Weekly Fed Steer Prices. 2005-2010
Average - Entire Year (2005-2010) (no weight given)	87.52 $/100 lb	
Average - September to November (2005-2010) (no weight given) (calf-fed cattle sent to slaughterhouse end of October) - baseline	86.85 $/100 lb	
Average - May to July (2005-2010) (no weight given) (calf-fed cattle sent to slaughterhouse in June) - BMP	87.73 $/100 lb	
Change in price of fed steers from Sept-Nov to May-Jul	**0.88 $/100 lb**	
	0.0040 $/kg	
	2.52 $/steer	
Alberta fed heifer monthly averages (2005-2010)		Canfax. Alberta Weekly Fed Heifer Prices. 2005-2010
Average - Entire Year (2005-2010) (no weight given)	87.22 $/100 lb	
Average - September to November (2005-2010) (no weight given) (calf-fed cattle sent to slaughterhouse end of October) - baseline	86.53 $/100 lb	
Average - May to July (2005-2010) (no weight given) (calf-fed cattle sent to slaughterhouse in June) - BMP	87.45 $/100 lb	
Change in price of heifers from Sept-Nov to May-Jul	**0.92 $/100 lb**	
	0.0042 $/kg	
	2.45 $/heifer	
Sale price for beef from slaughterhouse to market		
Average 2008 price for Canada AAA beef	3.110 $/lb	CanFax. Boxed beef pricing. 2008. Available at: http://www.canfax.ca/BoxedBeefReports/BeefCarcassBreakdowr
	6.856 $/kg	
Average 2008 price for Canada AA/A beef	2.850 $/lb	CanFax. Boxed beef pricing. 2008. Available at: http://www.canfax.ca/BoxedBeefReports/BeefCarcassBreakdowr

BMP 4 APPROACH 2 - DATA

		References
	6.283 $/kg	
Average 2009 price for Canada AAA beef	3.030 $/lb	CanFax. Boxed beef pricing. 2009. Available at: http://www.canfax.ca/BoxedBeefReports/BeefCarcassBreakdowr
	6.680 $/kg	
Average 2009 price for Canada AA/A beef	2.770 $/lb	CanFax. Boxed beef pricing. 2009. Available at: http://www.canfax.ca/BoxedBeefReports/BeefCarcassBreakdowr
	6.107 $/kg	
Average 2010 price for Canada AAA beef	2.860 $/lb	CanFax. Boxed beef pricing. 2010. Available at: http://www.canfax.ca/BoxedBeefReports/BeefCarcassBreakdowr
	6.305 $/kg	
Average 2010 price for Canada AA/A beef	2.730 $/lb	CanFax. Boxed beef pricing. 2010. Available at: http://www.canfax.ca/BoxedBeefReports/BeefCarcassBreakdowr
	6.019 $/kg	
Average price for Canada AAA beef (2008-2010)	**6.614 $/kg**	
Average price for Canada AA/A beef (2008-2010)	**6.136 $/kg**	
Prime, AAA, AA, A represent 98% of all youthful graded Canadian beef carcasses. Prime/AAA represent 52% of that total, and AA/A represent 48%.		Beef Quality. The Canadian Beef Industry is devoted to producing Beef Products which deliver on our Customers Expectations for Outstanding Eating Quality. Available at: http://www.cbef.com/beefquality.html. Accessed January 10, 2011.
Average price for youthful graded Canadian beef carcasses (2008-2010)	**6.385 $/kg**	

Assume that the decrease in revenue for the slaughterhouse to the market is directly proportional to the decrease in revenue for the feedlots from the slaughterhouse with the implementation of reduced days to harvest for calf-fed cattle (reduction in quality based on discussions with Scott Entz from Cargill High River). Assuming the beef demand stays the same.

Fuel consumed to feed livestock (on-farm diesel) - and -
Fuel consumed to collect manure (on-farm diesel)

Ultra Low Sulphur Diesel (ULSD)		
Calgary, AB	80.7 cents/L (excluding taxes)	UFA Petroleum. Rack Prices. December 18 to December 20, 2010. Available at: www.ufa.net/petroleum/rack_pricing.html
Edmonton, AB	77.5 cents/L (excluding taxes)	UFA Petroleum. Rack Prices. December 18 to December 20, 2010. Available at: www.ufa.net/petroleum/rack_pricing.html
Ultra Low Sulphur Diesel Lite (ULSD-LT)		
Calgary, AB	84.2 cents/L (excluding taxes)	UFA Petroleum. Rack Prices. December 18 to December 20, 2010. Available at: www.ufa.net/petroleum/rack_pricing.html
Edmonton, AB	81.0 cents/L (excluding taxes)	UFA Petroleum. Rack Prices. December 18 to December 20, 2010. Available at: www.ufa.net/petroleum/rack_pricing.html
Average	80.85 cents/L (excluding taxes)	
Fuel tax rates (diesel - all grades) (April 1, 2007 to current)	9 cents/L	Alberta Tax and Revenue Administration - Current and Historic Tax Rates. Available at: www.finance.alberta.ca/publications/tax_rebates/rates/hist1.html#fuel
Alberta Farm Fuel Benefit Program and Farm Fuel Distribution Allowance (taxes)	-15 cents/L	Alberta Finance and Enterprise. Taxes & Rebates - Fuel Tax Overview. November 23, 2010. Available at: www.finance.alberta.ca/publications/tax_rebates/fuel/overview.html
Fuel tax is exempted for diesel used on farms and a subsidy of 6 cents per L of diesel is provided		
Average diesel price minus Alberta programs	**0.75 $/L**	

Calculation changes to the model

- Reduce time to harvest by reducing backgrounding in calf-fed cattle based on BMP 4- App2-Diet tab, which will change feed and supplement requirements assuming all of Alberta will implement this BMP
- Adjust energy requirements for feeding cattle and manure collection
- Calculate change in garbage for change in feed used
- Adjust total enteric fermentation emissions and manure emissions for calf-fed feedlot cattle. Time on each diet will change only; DMI, the energy density of feed, and methane conversion factor will remain consistent with the baseline (based on IPCC Tier 2 values).
- Adjust total manure generation for calf-fed feedlot cattle. Manure generated will be reduced by the number of days reduced on the feedlot.

BMP 4 APPROACH 2 - COMPARISON OF QUANTIFICATION PROTOCOL TO BASELINE MODEL

Draft Guidance Document for the Quantification Protocol for Reducing Age at Harvest, June 2010, Version 7

Table 4: Typical Feeding Regimes for Beef Cattle in Alberta

Feeding Regime	Age at Harvest (months)			
	12	14	18	21
	Typical Duration of Days on Feed for Animals			
1. 100% Milk - baby calf suckling cow,	91	91	91	91
2. Forage: milk - suckling calf on pasture with cow, days	31	92	92	92
3. Backgrounding on pasture and/or drylot - high roughage diet (e.g., 100% barley silage on a DM basis), days	0	0	212	212
4. Backgrounding on tame and/or native pasture, days	0	0	0	153
5. Step-up diet to final finishing diet, days	31	31	0	0
6. Finishing in a feedlot (>= 85% concentrate diet on a DM basis), days	212	212	153	92
Total Days	365	426	548	640
Total Months	12	14	18	21

Notes:
18 months of age at harvest corresponds to cattle in calf-fed system in Alberta.
BMP 4 Approach 2 will only apply to calf-fed cattle (as per guidance from ARD).
The 18 months of age at harvest for the calf-fed cattle will be reduced to 14 months for this BMP (ARD).

Alberta LCA Model (Baseline) for Calf-Fed System (18 months to harvest)

Cow/calf time	188	days	5 days more than table above
Backgrounding and feedlot time with <85% concentrate diet	180	days	32 days less than table above
Feedlot time with >85% concentrate diet	178	days	25 days more than table above
Total time	546	days	2 days less than table above
Total months	18.0	months	

Notes for altering diet to match 14 months to harvest diet:
- Remove backgrounding and feedlot diet with <85% concentrates as stated in table above.
- Increase feedlot time with >85% concentrates to match feedlot time in table above.
- Include a step-up diet for the time allotted in the table above.

Additional days required on feedlot diet with >85% concentrates to match time in table above
34 days
Step-up diet to be included for period stated in table above
31 days

Adjusted Diet for BMP Implementation - Calf-Fed System (from 18 to 14 months to harvest)

Cow/calf time	188	days	no change
Backgrounding and feedlot time with <85% concentrate diet	0	days	removed from diet
Step-up diet to final finishing diet	31	days	not included in baseline
Feedlot time with >85% concentrate diet	212	days	adjusted to match table above
Total time	431	days	5 days more than table above
Total months	14.2	months	0.2 months longer than table above

Notes:
- Diet will be adjusted based on information above to reduce age at harvest in the Alberta Beef LCA baseline model for calf-fed cattle from 18.0 months to 14.2 months, using diet information in the baseline for each diet (i.e. ADG, ingredients).
- Final weight will remain the same as in the baseline.

BMP 4 APPROACH 2 - APPLICATION OF QUANTIFICATION PROTOCOL TO MODEL TO ADJUST DIET

Draft Guidance Document for the Quantification Protocol for Reducing Age at Harvest, June 2010, Version 7

LCA Model Diet

Table 4: Typical Feeding Regimes for Beef Cattle in Alberta	
Feeding Regime	Age at Harvest (mths)
	18
1. 100% Milk - baby calf suckling cow, days	91
2. Forage: milk - suckling calf on pasture with cow, days	92
3. Backgrounding on pasture and/or drylot - high roughage diet (e.g., 100% barley silage on a DM basis), days	212
4. Backgrounding on tame and/or native pasture, days	0
5. Step-up diet to final finishing diet, days	0
6. Finishing in a feedlot (>= 85% concentrate diet on a DM basis), days	153
Total Days	548
Total Months	18.0

LCA Model Baseline Diet for Calf-Fed Steers and Heifers (% of diet on DM basis)

	Days on feed (days)	Milk	Alfalfa-meadow brome grass	Barley silage	Barley grain	Beef supplement (Mineral / Vitamin)	Total	
	94	100	0	0	0	0	100	From Guidance Document
	94	43	57	0	0	0	100	From Guidance Document
Backgrounding	96	0	0	81.7	14.3	4	100	
Feedlot diet 3	14	0	0	67.3	28.7	4	100	
Feedlot diet 4	14	0	0	53.0	43.0	4	100	
Feedlot diet 5	28	0	0	38.7	57.3	4	100	
Feedlot diet 6	28	0	0	24.3	71.7	4	100	
	-	-	-	-	-	-	-	Not included in baseline
	-	-	-	-	-	-	-	Not included in baseline
Feedlot diet 7	178	0	0	10.0	86.0		96	
Total Days	546							
Total Months	18.0							

Table 4: Typical Feeding Regimes for Beef Cattle in Alberta	
Feeding Regime	Age at Harvest (mths)
	14
1. 100% Milk - baby calf suckling cow, days	91
2. Forage: milk - suckling calf on pasture with cow, days	92
3. Backgrounding on pasture and/or drylot - high roughage diet (e.g., 100% barley silage on a DM basis), days	0
4. Backgrounding on tame and/or native pasture, days	0
5. Step-up diet to final finishing diet, days	31
6. Finishing in a feedlot (>= 85% concentrate diet on a DM basis), days	212
Total Days	426
Total Months	14.0

Altered Diet for BMP 4 Implementation for Calf-Fed Steers and Heifers (% of diet on DM basis)

	Days on feed (days)	Milk	Alfalfa-meadow brome grass	Barley silage	Barley grain	Beef supplement (Mineral / Vitamin)	Total	
	94	100	0	0	0	0	**100**	No change from baseline
	94	43	57	0	0	0	**100**	No change from baseline
	-	-	-	-	-	-	**-**	Removed from baseline
	-	-	-	-	-	-	**-**	Not included in baseline
Adjusted diet	**see below**					4	**-**	
Adjusted diet	**see below**					4	**-**	

Supplement unchanged for project as baseline

BMP 4 APPROACH 2 - APPLICATION OF QUANTIFICATION PROTOCOL TO MODEL TO ADJUST DIET

5. Step-up diet (calf-fed steer)

	Baseline							**Project**							
	Start weight (lbs)	End weight (lbs)	ADG (lbs/d)	Barley (% DM)	Barley silage (% DM)	supplement (% DM)	Baseline days	Start weight (lbs)	**Calculated End weight (lbs)**	ADG (lbs/d)	Barley (% DM)	Barley silage (% DM)	supplement (% DM)	**Assumed Project days**
Backgrounding	500	600	1.04	14.3	81.7	4	96	500	**503.12**	1.04	14.3	81.7	4	**3**
Feedlot diet 3	550	560	0.71	28.7	67.3	4	14	503.12	**505.25**	0.71	28.7	67.3	4	**3**
Feedlot diet 4	560	600	2.86	43.0	53.0	4	14	505.25	**516.69**	2.86	43	53	4	**4**
Feedlot diet 5	600	690	3.21	57.3	38.7	4	28	516.69	**529.53**	3.21	57.3	38.7	4	**4**
Feedlot diet 6	690	790	3.57	71.7	24.3	4	28	529.53	**590.22**	3.57	71.7	24.3	4	**17**
	Notes:													**31**

Step-up diet typically starts at a high roughage level and moves to the finishing diets over a 30-60 day period (DM basis), where a high grain level is finally incorporated (>85% concentrate)

From nutritionist for Alberta Beef LCA model: steers are 550 lbs after backgrounding and heifers are 500 lbs. Backgrounding diet only used for diet and not start-end weights.

6. Finishing diet (calf-fed steer)

	Baseline							**Project**							
	Start weight (lbs)	End weight (lbs)	ADG (lbs/d)	Barley (% DM)	Barley silage (% DM)	supplement (% DM)	Baseline days	Start weight (lbs)	**Calculated End weight (lbs)**	ADG (lbs/d)	Barley (% DM)	Barley silage (% DM)	supplement (% DM)	**Assumed Project days**
Feedlot diet 7	790	1450	3.67	86	10	4	178	590.22	**1449**	3.67	86	10	4	**234**
								Required weight	1450					

** adjusted diet to reach same end weight as baseline

Total days for steers **453** 95 day reduction

Total months for steers **14.9**

5. Step up diet (calf-fed heifer)

	Baseline							**Project**							
	Start weight (lbs)	End weight (lbs)	ADG (lbs/d)	Barley (% DM)	Barley silage (% DM)	supplement (% DM)	Baseline days	Start weight (lbs)	**Calculated End weight (lbs)**	ADG (lbs/d)	Barley (% DM)	Barley silage (% DM)	supplement (% DM)	**Assumed Project days**
Backgrounding	500	600	1.04	14.3	81.7	4	96	500	**503.12**	1.04	14.3	81.7	4	**3**
Feedlot diet 3	500	510	0.71	28.7	67.3	4	14	503.12	**505.25**	0.71	28.7	67.3	4	**3**
Feedlot diet 4	510	540	2.14	43.0	53.0	4	14	505.25	**513.81**	2.14	43	53	4	**4**
Feedlot diet 5	540	620	2.86	57.3	38.7	4	28	513.81	**525.25**	2.86	57.3	38.7	4	**4**
Feedlot diet 6	620	710	3.21	71.7	24.3	4	28	525.25	**579.82**	3.21	71.7	24.3	4	**17**
														31

Step-up diet typically starts at a high roughage level and moves to the finishing diets over a 30-60 day period (DM basis), where a high grain level is finally incorporated (>85% concentrate)

From nutritionist for Alberta Beef LCA model: steers are 550 lbs after backgrounding and heifers are 500 lbs. Backgrounding diet only used for diet and not start-end weights.

6. Finishing diet (calf-fed heifer)

	Baseline							**Project**							
	Start weight (lbs)	End weight (lbs)	ADG (lbs/d)	Barley (% DM)	Barley silage (% DM)	supplement (% DM)	Baseline days	Start weight (lbs)	**Calculated End weight (lbs)**	ADG (lbs/d)	Barley (% DM)	Barley silage (% DM)	supplement (% DM)	**Assumed Project days**
Feedlot diet 7	710	1350	3.64	86	10	4	178	579.82	**1351.5**	3.64	86	10	4	212
								Required weight	1350					

** adjusted diet to reach same end weight as baseline

Total days for heifers **431** 117 day reduction

Total months for heifers **14.2**

Note: CRA does not promote the use and stages in the diets above.

BMP 4 - Reducing Age to Slaughter (Approach 2)
Approach 2: Reduce the number of days to harvest by introducing feedlot diet sooner to reach final weight to slaughter sooner

Assumed Percent Adoption of BMP 4 100% (% adoption can be adjusted here for the entire model)
(calf-fed cattle in feedlot only) (only adjusts calf-fed cattle)
(not currently implemented in Alberta)

Reduction in days to slaughter

Calf-fed steers	95 days	3.1 months
Calf-fed heifers	117 days	3.8 months

Total number of animals affected by BMP 959,612 animals to slaughter (2002)
(calf-fed steers and heifers)

Total weight affected to slaughter 564,184 tonnes
(calf-fed steers and heifers - live weight)

Scenario BMP 4.2

Total GHG emissions	**2.01E+10**	**kg CO2e**
Total acidification	**3.03E+07**	**kg SO2-Eq**
Total eutrophication	**5.23E+06**	**kg PO4-Eq**
Total non-renewable energy	**3.19E+11**	**MJ-Eq**

	COW/CALF OPERATIONS								FEEDLOT OPERATIONS								SLAUGHTERHOUSE							
	BMP 4		Baseline (2001/2010)		Change		Per Unit Market Value	Total Impact	BMP 4		Baseline (2001/2010)		Change		Per Unit Market Value	Total Impact	BMP 4		Baseline (2001/2010)		Change		Per Unit Market Value	Total Impact
	(amount)	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*	*($/unit)*	*($ Million)*	*(amount)*	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*	*($/unit)*	*($ Million)*	*(amount)*	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*	*($/unit)*	*($ Million)*
Inputs with Change																								
Production of pesticide/herbicide																								
Production of chemical fertilizer																								
Production of bedding																								
Production of min., trc min., cobalt, protein suppl., vit., antibiotic																								
Purchase of chemical fertilizer																								
Urea, as N, at regional storehouse																								
Ammonia, liquid, at regional storehouse																								
Monoammonium phosphate, as P2O5, at regional storehouse																								
Monoammonium phosphate, as N, at regional storehouse																								
Ammonium sulphate, as N, at regional storehouse																								
Purchase of manure for land application																								
Purchase of pesticide/herbicide																								
Purchase of seed for barley																								
Purchase of seed for barley silage																								
Purchase of seed for alfalfa/grass hay																								
Purchase of water to irrigate crops																								
Purchase of amendment materials									0	kg	0	kg	0	kg	-	-								
Purchase of composting equipment (Windrow turner)									0	turners	0	turners	0	turners	-	-								
Purchase of construction supplies for composting (clay for pad)									0	units	0	units	0	units	-	-								
Purchase of alfalfa/grass hay	6.59E+09	kg	6.59E+09	kg	0	kg	-	-																
Purchase of barley									4.53E+09	kg	4.49E+09	kg	4.16E+07	kg	$0.16	$6.71								
Purchase of barley silage									5.74E+09	kg	7.58E+09	kg	-1.84E+09	kg	$0.04	-$73.43								
Purchase of bedding	5.09E+08	kg	5.09E+08	kg	0	kg	-	-	3.71E+08	kg	4.22E+08	kg	-5.07E+07	kg	$0.06	-$2.96								
Purchase of animal shelters, wind breakers, fencing, etc.	0	units	0	units	0	units	-	-																
Purchase of ionophores	0	kg	0	kg	0	kg	-	-																
Purchase of RAC									0	kg	0	kg	0	kg	-	-								
Purchase of min., trc min., cobalt, protein suppl., antibiotic	7.91E+07	kg	7.91E+07	kg	0	kg	-	-	1.31E+08	kg	1.45E+08	kg	-1.34E+07	kg	$0.48	-$6.37								
Purchase of vitamins	1,684	kg	1,684	kg	0	kg	-	-	1.58E+05	kg	1.76E+05	kg	-1.80E+04	kg	$1.37	-$0.025								
Purchase of RFI testing (includes transportation)	0	tests	0	tests	0	tests	-	-	0	tests	0	tests	0	tests	-	-								
Fuel/energy required to operate composting equipment									0	kWh or L	0	kWh or L	0	kWh or L	-	-								
Fuel consumed to transport barley and barley silage																								
Fuel consumed to transport alfalfa/grass hay																								
Fuel consumed for cropping activities																								
Fuel consumed to bed livestock (change)	0	L	0	L	0	L	-	-	0	L	0	L	0	L	-	-								
Fuel consumed to transport garbage (change)	0	L	0	L	0	L	-	-	0	L	0	L	0	L	-	-								
Fuel consumed to transport bedding (change)																								
Fuel consumed to feed livestock (change)	0	L	0	L	0	L	-	-	-2.29E+07	L	0	L	-2.29E+07	L	$0.75	-$17.17								
Fuel consumed to collect manure (change)									-184,111	L	0	L	-184,111	L	$0.75	-$0.14								
Fuel cons. to transp. min., trc min., cob., prot. suppl., vit., antibiotic																								
Fuel consumed to transport livestock for testing	0	L	0	L	0	L	-	-	0	L	0	L	0	L	-	-								
Labour (change)	0	hrs	0	hrs	0	hrs	-	-	-8.04E+04	hrs	0	hrs	-80,357	hrs	$16.22	-$1.30								
Working capital interest	0	$	0	$	0	$	-	-	0	$	0	$	0	$	-	-								
Total Input Value Change								**$0.00**								**-$94.69**								
Outputs with Change																								
Manure sold for land application									2.43E+10	kg	2.51E+10	kg	-7.51E+08	kg	$0.00	$0.00								
Compost sold for land application									0	kg	0	kg	0	kg	-	-								
Sold beef to slaughterhouse (changed slaughter month - Sept./Nov. to May/Jul.) (live wt)									5.64E+08	kg	0	kg	5.64E+08	kg	$0.004	$2.31								
Sold beef to slaughterhouse (reduction in carcass weight-Sept./Nov.) (live wt)									-1.92E+07	kg	0	kg	-1.92E+07	kg	$1.911	-$36.67								
Sold beef to slaughterhouse (reduction in quality grade) (live wt)									5.64E+08	kg	0	kg	5.64E+08	kg	not available	-$4.20								
Sold beef from slaughterhouse to market (reduction in carcass weight) (carcass)																	-1.92E+07	kg	0	kg	-1.92E+07	kg	$6.385	-$122.53
Sold meat from slaughterhouse as Canada AAA or better (carcass) (calf-fed only)																	1.67E+08	kg	1.76E+08	kg	-8.80E+06	kg	$6.614	-$58.21
Sold meat from slaughterhouse as Canada AA/A (carcass) (calf-fed only)																	1.71E+08	kg	1.62E+08	kg	8.80E+06	kg	$6.136	$54.01
Total Output Value Change								**$0.00**								**-$38.57**								**-$126.74**
																					-1.56E+00			

CHANGE IN OVERALL GHG EMISSIONS

	COW/CALF OPERATIONS						FEEDLOT OPERATIONS						BEEF INDUSTRY					
	BMP 4		Baseline (2001/2010)		Change		BMP 4		Baseline (2001/2010)		Change		BMP 4		Baseline (2001/2010)		Change	
	(amount)	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*	*(amount)*	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*	*(amount)*	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*
BEEF ACTIVITIES - SOIL AND CROP																		
Manure generation	3.45E+10	kg	3.45E+10	kg	0	kg	1.73E+10	kg	1.89E+10	kg	-1.60E+09	kg						
Methane emissions from stored manure	1.49E+08	kg CO_2e	1.49E+08	kg CO_2e	0	kg CO_2e	1.31E+08	kg CO_2e	1.44E+08	kg CO_2e	-1.30E+07	kg CO_2e						
Enteric fermentation emissions	7.03E+09	kg CO_2e	7.03E+09	kg CO_2e	0	kg CO_2e	3.06E+09	kg CO_2e	3.56E+09	kg CO_2e	-5.02E+08	kg CO_2e						
N2O emissions from stored manure (direct)	1.83E+09	kg CO_2e	1.83E+09	kg CO_2e	0	kg CO_2e	3.01E+08	kg CO_2e	3.27E+08	kg CO_2e	-2.56E+07	kg CO_2e						
N2O emissions from stored manure (indirect)	4.04E+08	kg CO_2e	4.04E+08	kg CO_2e	0	kg CO_2e	2.82E+08	kg CO_2e	3.06E+08	kg CO_2e	-2.40E+07	kg CO_2e						
N_2O emissions from cropping and land use													9.08E+08	kg CO_2e	9.57E+08	kg CO_2e	-4.98E+07	kg CO_2e
Total P emissions from run-off													3.93E+06	kg PO_4-eq	4.15E+06	kg PO_4-eq	-2.21E+05	kg PO_4-eq
Soil Carbon Change in Soil From Land Use													-2.22E+08	kg CO_2e	-2.36E+08	kg CO_2e	1.38E+07	kg CO_2e
Direct CO2 emissions from managed soils													1.91E+08	kg CO_2e	1.89E+08	kg CO_2e	1.71E+06	kg CO_2e
OVERALL SUMMARY																		
Construction	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e						
Forage and cereal sub-activities													1.20E+09	kg CO_2e	1.20E+09	kg CO_2e	-2.39E+05	kg CO_2e
Energy generation and consumption activities	2.81E+09	kg CO_2e	2.81E+09	kg CO_2e	0	kg CO_2e	8.15E+08	kg CO_2e	1.04E+09	kg CO_2e	-2.23E+08	kg CO_2e						
O&M activities	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e						
Cereal activities													3.41E+08	kg CO_2e	3.38E+08	kg CO_2e	3.13E+06	kg CO_2e
Forage activities													2.59E+08	kg CO_2e	2.86E+08	kg CO_2e	-2.74E+07	kg CO_2e
Feedlot and pasture activities	3.20E+06	kg CO_2e	3.20E+06	kg CO_2e	0	kg CO_2e	1.40E+08	kg CO_2e	1.40E+08	kg CO_2e	-4.66E+05	kg CO_2e	2.97E+08	kg CO_2e	3.04E+08	kg CO_2e	-6.70E+06	kg CO_2e
Cow activities (transportation)	2.49E+07	kg CO_2e	2.49E+07	kg CO_2e	0	kg CO_2e												
Bull activities (transportation)	3.14E+06	kg CO_2e	3.14E+06	kg CO_2e	0	kg CO_2e												
Yearling-fed system activities (transportation)							1.08E+08	kg CO_2e	1.08E+08	kg CO_2e	0	kg CO_2e						
Calf-fed system activities (transportation)							6.59E+07	kg CO_2e	6.59E+07	kg CO_2e	0	kg CO_2e						

Total GWP for BMP

kg CO_2e 1.22E+10 Cow/Calf 4.90E+09 Feedlot 2.98E+09 Beef Industry

Total Change in GWP for BMP

kg CO_2e 0.00 -7.88E+08 -6.54E+07

Total change in emissions -853,667 tonnes

Overall Baseline GWP (2001)

kg CO_2e/kg live weight 14.705

Overall Baseline GWP (2010)

kg CO_2e/kg live weight 14.705 This BMP not currently adopted

Overall BMP GWP

kg CO_2e/kg live weight 14.299

Change in overall GWP from 2001

kg CO_2e/kg live weight -0.406

Change in overall GWP from 2010

kg CO_2e/kg live weight -0.406

Change in GWP per kg of beef affected from 2010

kg CO_2e/kg live weight -1.513 **(total change in GHG emissions divided by total weight of cattle affected)**

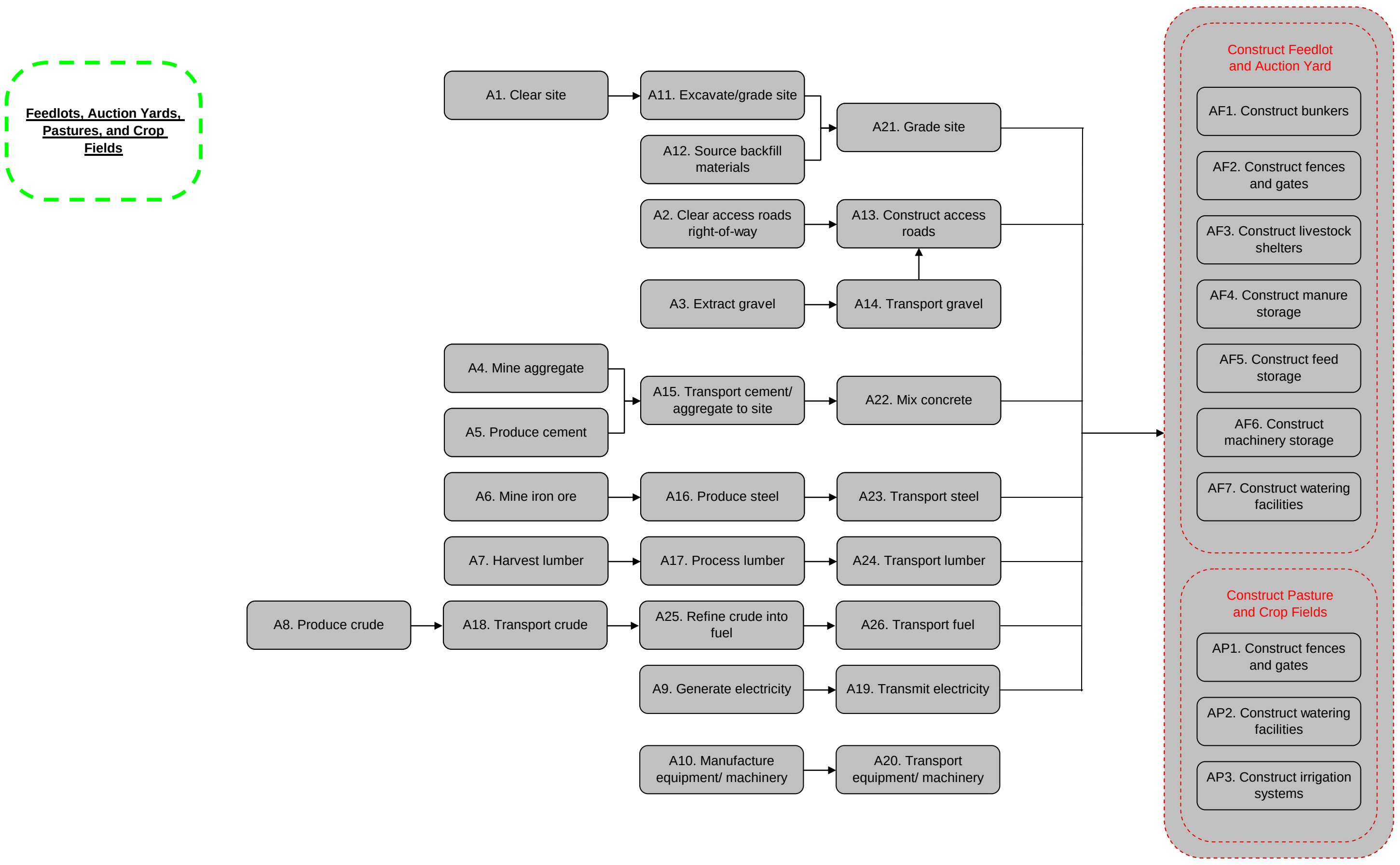
Notes:
Energy generation emissions divided by the number of cattle on cow/calf vs feedlot
Feedlot and pasture activities are divided as per below.

APPENDIX I

BMP 5 – USE OF BEEF ANIMALS POSSESSING SUPERIOR RESIDUAL FEED INTAKE GENETICS

ACTIVITY MAPS AND DATA COLLECTION

A: Construction



Legend:

- Activity
- 🟩 New Activity for BMP Implementation
- 🟨 Activity - Affected by BMP Implementation
- Activity - Not Included
- Functional Unit

FIGURE BMP 5a

ACTIVITY MAP
BMP #5 - SUPERIOR RESIDUAL FEED INTAKE GENETICS IN BREEDING ANIMALS
LIFE CYCLE ASSESSMENT - BEEF
ALBERTA AGRICULTURE AND RURAL DEVELOPMENT
Edmonton, Alberta

Sustainable Energy Solutions

B: Operation and Maintenance

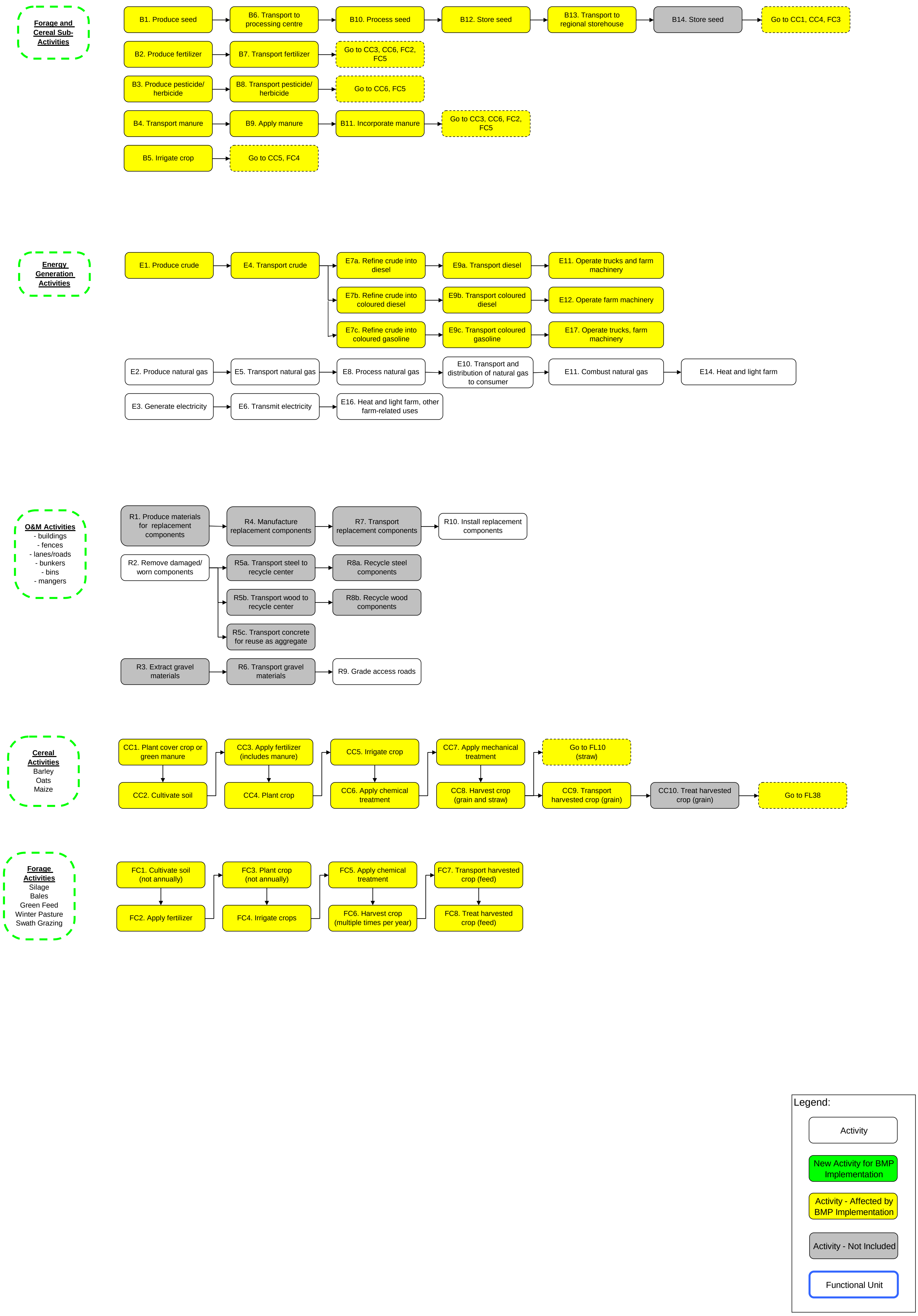


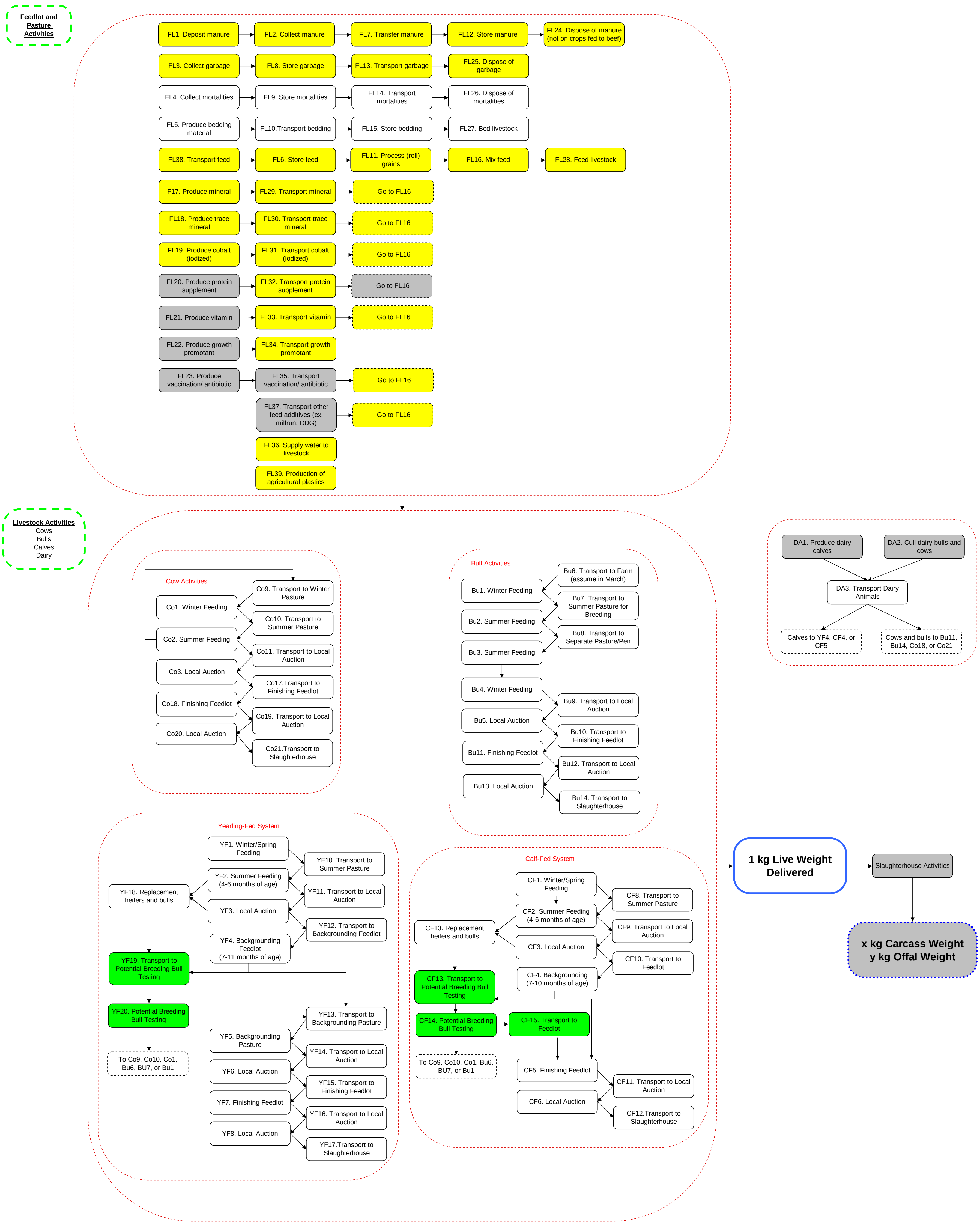
FIGURE BMP 5b

ACTIVITY MAP
BMP #5 - SUPERIOR RESIDUAL FEED INTAKE GENETICS IN BREEDING ANIMALS
LIFE CYCLE ASSESSMENT - BEEF
ALBERTA AGRICULTURE AND RURAL DEVELOPMENT
Edmonton, Alberta

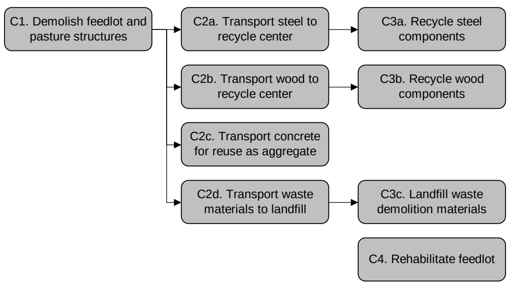
CRA

the PEMBINA institute
Sustainable Energy Solutions

B: Operation and Maintenance



C: Decommissioning



Legend:
- Activity
- Pointer to Activities
- Activity - Not-Included
- Functional Unit

FIGURE BMP 5c

ACTIVITY MAP
BMP #5 - SUPERIOR RESIDUAL FEED INTAKE GENETICS IN BREEDING ANIMALS
LIFE CYCLE ASSESSMENT - BEEF
ALBERTA AGRICULTURE AND RURAL DEVELOPMENT
Edmonton, Alberta

the PEMBINA institute
Sustainable Energy Solutions

BMP 5 - DATA

Cattle tested and capacity of existing testing facilities

			References
Cattle tested for RFI from 2000 to end of 2008 in Alberta (steers, heifers, cows, bulls)	4,300		Technical Protocol Plan (TPP) for Selection for residual feed intake in beef cattle quantification protocol. Part B. Received from Emmanuel Laate via email on October 20, 2010.
Potential breeding bulls tested for RFI in Alberta from 2000 to November 2008	1,220		Technical Protocol Plan (TPP) for Selection for residual feed intake in beef cattle quantification protocol. Part B. Received from Emmanuel Laate via email on October 20, 2010.
Yearly average (2000 - 2008)	136	avg potential breeding bulls tested/yr	
Tested animals from 2000 to 2010 (estimate):			
2000	111	Assumed average for 2000-2008 for year 2004, and increased/decreased average to assume values for other years	
2001	117		
2002	123		
2003	129		
2004	136		
2005	143		
2006	150		
2007	157		
2008	165		
total	1,231	similar to above total	
2009	174	Assumed based on above increase	
2010	182	Assumed based on above increase	

Existing Testing Facilities	*Primary Purpose*	*Number of Nodes*	*Annual Capacity* (head of cattle)
Lacombe Research Centre, Lacombe (ARD)	Research	16	224
Kinsella Ranch, Kinsella (University of Alberta)	Research	20	280
Lethbridge Research Centre, Lethbridge (Agriculture and Agri-Food Canada)	Research	36	504
Cattleland Feedyards, Strathmore	Commercial	40	560
Namaka Farms, Strathmore	Commercial	28	392
Olds College, Olds	Commercial	10	140
Morrison's Feedlot, Airdrie	Commercial	29	406

Arthur, Paul. Science Discussion Paper: Reduction in greenhouse gas emissions associated with selection for residual feed intake in beef cattle in Alberta. Submitted to: Alberta Environment and Alberta Agriculture and Rural Development.

Notes: This is a conservative annual estimate.

The Kinsella Ranch is expected to expand to 140 nodes with an annual capacity of 1,000 head of cattle (research testing facility - won't affect the model).

Estimated potential breeding animals tested in 2010/2011	110	bulls	
(numbers for Namaka Farms and Olds College only)	320	steers	
(numbers unknown for Cattleland Feedyards and Morrison's Feedlot)	180	heifers	
Percent of genetic improvement in a herd that comes from the sires	80-90	%	Agri-Facts. Residual Feed Intake (Net Feed Efficiency) in Beef Cattle. July 2006. Available at: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex10861/$file/420_11-1.pdf
Assume all future cattle tested are potential breeding bulls as this is the majority.			Discussions with John Basarab (ARD, Industry Expert), November 19, 2010.
Estimated potential breeding bulls tested in 2010	430	potential bulls to be tested in 2010	
(bulls and steers anticipated to be tested at Namaka Farms and Olds College, from above)			
Assume that testing occurs before the breeding cycle in June/July every year (post-weaning)			
Test period length	21	days pre-conditioning	
	70	days testing	

Cattle tested after weaning. Assume right before backgrounding.

* * cow/calf operation to pay for testing

Rate of Adoption of Practice

Currently no reliable available data on adoption levels and rates for the Alberta Beef Sector (for both the cow/calf and feedlot sectors)
Calculations to be based on capacity of existing facilities, not anticipated rate of adoption.

Arthur, Paul. Science Discussion Paper: Reduction in greenhouse gas emissions associated with selection for residual feed intake in beef cattle in Alberta. Submitted to: Alberta Environment and Alberta Agriculture and Rural Development.

BMP 5 - DATA

			References
Annual capacity of commercial testing facilities	1,498	potential bulls	
(assuming 2 tests per year at each facility, and assumes this is the only testing being conducted at these facilities year round)			
% of capacity currently being tested for (2010)	28.7	%	
Assume that total capacity is being utilized as of 2010	**1,498**	**potential breeding bulls tested/year (after 2009)**	

Percentage of tested cattle with low RFI and low RFI values

Every group of cattle tested will show 10-15% of cattle with good (low) RFI values			
Assumed percentage of cattle tested with low RFI	12.5	%	Discussions with John Basarab (ARD, Industry Expert), November 19, 2010.
Potential breeding bulls - assumed low RFI value (minimum)	-0.5	kg DM/day	Discussions with John Basarab (ARD, Industry Expert), November 19, 2010.
Potential breeding bulls - assumed low RFI value (maximum)	-1.0	kg DM/day	Discussions with John Basarab (ARD, Industry Expert), November 19, 2010.
Run 1 scenario assuming max value			
Postweaned cattle - low RFI value (8-12 months of age)	-0.54	kg DM/day	Herd et al. Reducing the cost of beef production through genetic improvement in residual feed intake: Opportunity and challenges to application. J. Anim. Sci. 2003, 81: E9-17.
(actual values to be calculated)			
Cows - consumed no more feed with low RFI - **no change in model**			Herd et al. Reducing the cost of beef production through genetic improvement in residual feed intake: Opportunity and challenges to application. J. Anim. Sci. 2003, 81: E9-17. Arthur, Paul. Science Discussion Paper: Reduction in greenhouse gas emissions associated with selection for residual feed intake in beef cattle in Alberta. Submitted to: Alberta Environment and Alberta Agriculture and Rural Development.
There are very few studies on RFI in cattle on pasture because it's difficult to measure. In one study, low RFI females had lower DMI as pregnant heifers and as cows with calves, however the differences were not significant relative to the high RFI females. Assume that the DMI of cows on pasture is not lower for low RFI cows than for high RFI cows.			
Steers on pasture - daily pasture intake the same but slightly higher daily gain - **assume no change to model**			Herd et al. Reducing the cost of beef production through genetic improvement in residual feed intake: Opportunity and challenges to application. J. Anim. Sci. 2003, 81: E9-17.
Steers in feedlot - low RFI value - no compromise in retail meat yield (actual values to be calculated)	-0.2	kg DM/day	Herd et al. Reducing the cost of beef production through genetic improvement in residual feed intake: Opportunity and challenges to application. J. Anim. Sci. 2003, 81: E9-17.

Calculations for the model

- Model to be run assuming -0.5 kg DM/day and -1.0 kg DM/day for bulls (min and max low RFI values) (2 scenarios)
- Low RFI values for bulls assumed to be certified RFI EBV, as no actual data available for Alberta to date
- Apply the low, medium and high heritability to the progeny of the low RFI sires (3
- Dam RFI EBV are not known, therefore to be assumed zero
- Calculate the RFI EBV for the steers and heifers from the low RFI bulls assumed to have inherited the trait
  (add the sire RFI EBV with the dam RFI EBV and then divide by 2 to get the steer/heifer RFI EBV)
  (use the RFI EBV for the heifer/steer and apply it to the diet to calculate the reduction in feed required)
- Calculate the reduction in feed intake by the bulls

Effect on later generations

Number of bulls in 2001 model	109,428		
Number of calves in 2001 model	2,113,345		
Number of calves to one bull	19	calves from 1 bulls per calf crop	Assume this will remain constant
Methane abatement resulting from anticipated adoption of RFI in breeding programs within the Australian beef industry over the next 25 years (genetic-based simulation for Australia over the next 25 years):			Alford, A.R. et al. The impact of breeding to reduce residual feed intake on enteric methane emissions from the Australian beef industry. Australian Journal of Experimental Agriculture, 2006, 46, 813-820.
- Rate of genetic improvement in the northern beef herd	0.38	% per year	

BMP 5 - DATA

		References
- Rate of genetic improvement in the southern beef herd	0.76 % per year	
- Maximum adoption percentage achieved by year 11	30 %	
Note: exponential increase from year 1 to year 11, then plateaus when adoption levels stop at 30%		
- Reduction in RFI in commercial herd in southern Australia for various classes of beef cattle	11.22-21.48 %	
Note: values are sensitive to the level of annual genetic gain and the pattern of adoption among Australian beef producers		
- Cumulative decrease in enteric methane production over the 25 year simulation period	7.4 %	
- Annual methane reduction over an unimproved herd for year 25	15.9 %	

Calculations for the model:

- cannot assume similar benefit over time for Alberta when selecting breeding animals based on superior genetics as proven in this simulation model, but anticipated to occur

Transportation to testing facility	200 km (average, maximum)	Discussions with John Basarab (ARD, Industry Expert), November 19, 2010.
- assumed for all transportation distances involved with the testing of cattle		

Heritability to include high, medium and low values

Range of low RFI heritability	16 - 39 %	Notter, David R. Defining Biological Efficiency of Beef Production. Department of Animal and Poultry Sciences. Virginia Polytechnic Institute and State University; and, Arthur et al., Residual fed intake in beef cattle. R. Bras. Zootec., v.37, supplemento especial p269-279, 2008.
Assumed low heritability	**16 %**	
Assumed medium heritability	**27.5 %**	
Assumed high heritability	**39 %**	
Assume high heritability only in model		

Change in gas, diesel, and electricity usage on feedlots for reduced feed time

Note: Energy required to feed animals in the baseline is included in the total energy used on beef farms in Alberta. Changes to energy requirements to be calculated.

Total diesel used on all beef farms (cow/calf and feedlot)	8,361 TJ	From Beef Data tab
Total reduction in feed requirements (Cow/calf and feedlot)	0.000664%	From Diets tab
Assume same reduction in diesel fuel used on feedlots	0.1 TJ reduced	
Revised diesel energy requirements	**8,361 TJ used**	

Note: Assume that diesel is the fuel used to operate the machinery to feed cattle and this will be the main source of energy that is reduced

Change in gas and diesel for manure handling on feedlot

Note: Energy required to collect manure in the baseline is included in the total energy used on beef farms in Alberta. Changes to energy requirements to be calculated.
Assume same for backgrounding feedlots.

Manure collection and handling

Diesel consumption for a tractor	16.6 L/hr	Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3: 3, 257-270.
Number of feedlot cattle in reference	50,000 cattle	Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3: 3, 257-270.
Pens with 250 head/pen in reference	200 pens	Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3: 3, 257-270.

BMP 5 - DATA

			References
Time to pile up manure in pen in reference	60	min/pen two times per year	Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3: 3, 257-270.
	400	hrs/yr	
Diesel required per year	6,640	L/yr	
CO_2 emission factor for truck diesel consumption	2,569	g CO_2/L	Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3: 3, 257-270.
CH_4 emission factor for truck diesel consumption	0.21	g CH_4/L	Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3: 3, 257-270.
Total emissions from manure collection (calculated based on data)	17.09	tonnes CO_2e/yr	
Total emissions from manure collection (total provided in reference)	1,172	tonnes CO_2e/year	Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3: 3, 257-270.

(Total emissions calculated using data from reference different than total emissions provided in reference. Only raw data from reference will be used to calculate emissions in model.)

Quantity of manure (in reference)	58,700	tonne dry manure/year	Ghafoori, Emad, Flynn, Peter C. and Checkel, M. David (2006). Global Warming Potential of Electricity Generation from Beef Cattle Manure: A Life Cycle Assessment Study. International Journal of Green Energy, 3: 3, 257-270.

(Alberta Beef LCA model used same reference to quantify manure)

Emission factor for the combustion of diesel in agricultural equipment - Alberta Beef LCA model	3.28	kg CO_2e/kg diesel	Intergovernmental Panel on Climate Change (IPCC). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 2. Chapter 3: Mobile Combustion. Available at: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_3_Ch3_Mobile_Combustion.pdf
Density of diesel	0.885	kg/L	Simetric. Specific Gravity of Liquids. Available at: http://www.simetric.co.uk/si_liquids.htm
	3.71	kg CO_2e/L	
Total emissions from manure collection using the LCA model emission factor *(comparable to emissions calculated using reference data)*	24.61	tonnes/yr	
Total emissions from manure collection per animal per day	**0.00135**	**kg/animal/day**	

Change in quantity of agricultural plastics for change in feed

Current agricultural plastics disposal methods

- Burning is still the most prominent method of getting rid of agricultural plastics (2008) — Recycling Council of Alberta. Agricultural Plastics Recycling Pilot Project. Summary Report, September 2009. Available at: http://www.recycleyourplastic.ca/pdf/Ag_Plastics_Pilot_Report.pdf
- There is little industry capacity to handle agricultural plastics in Alberta
- Pilot recycling program conducted in Alberta in 2008 to understand the amount, type, and quality of used agricultural plastics and the capacity of industry to use it
- Alberta Beef LCA baseline model assumed the same as the current situation for the handling of agricultural plastics (burning and burying)
- No change in the disposal of plastics
- Total change in plastics will be calculated based on percentage of total change in feed

Additional Assumptions

An animal assessed early in life to be efficient (low RFI) will be efficient throughout its life.

Linear responses up to 38 generations were reported for a mice experiment at the University of Nebraska with feed efficiency selection.
It is expected that responses due to superior RFI genetics in beef cattle will be seen for a long time.
Assume responses for selection during entire analysis time.

Arthur, Paul. Science Discussion Paper: Reduction in greenhouse gas emissions associated with selection for residual feed intake in beef cattle in Alberta. Submitted to: Alberta Environment and Alberta Agriculture and Rural Development.

Cows that produced low RFI progeny calved 5-6 days later than cows that produced high RFI progeny.

BMP 5 - DATA

References

Assumed to have minimal effect on the overall model. Not included.

It will be assumed that the sector in which raises the cattle will be able to obtain carbon credits for the time the cattle is spent at this location. This is not specified in the Draft RFI Selection Protocol.

Effects on Meat Yield and Market with BMP Implementation

Significant differences in body composition between low RFI and high RFI cattle 1. Internal organs (increase by approximately 0.5%) 2. Carcass fat (decrease by approximately 1.4%) 3. Bone (increase by approximately 0.4%)	Arthur, Paul. Science Discussion Paper: Reduction in greenhouse gas emissions associated with selection for residual feed intake in beef cattle in Alberta. Submitted to: Alberta Environment and Alberta Agriculture and Rural Development.
Significant differences in meat attributes between low RFI and high RFI cattle 1. 12/13th rib fat depth (decrease by approximately 0.9mm) 2. Calpastatin (increase by approximately 0.6 units/g tissue)	Arthur, Paul. Science Discussion Paper: Reduction in greenhouse gas emissions associated with selection for residual feed intake in beef cattle in Alberta. Submitted to: Alberta Environment and Alberta Agriculture and Rural Development.
Conclusion: there is a significant difference in percent carcass fat but not in percent retail beef. Assume no change in final slaughter weight or market value.	Arthur, Paul. Science Discussion Paper: Reduction in greenhouse gas emissions associated with selection for residual feed intake in beef cattle in Alberta. Submitted to: Alberta Environment and Alberta Agriculture and Rural Development.
Profitability is maximized when 10 to 20% of the potential breeding bulls are measured.	Arthur, Paul. Science Discussion Paper: Reduction in greenhouse gas emissions associated with selection for residual feed intake in beef cattle in Alberta. Submitted to: Alberta Environment and Alberta Agriculture and Rural Development.

Change in labour

Average reduction in feed based on reduced feed intake by low RFI cattle

barley	-0.00065	%	From Diets tab
barley silage	-0.00070	%	From Diets tab
alfalfa	-0.00063	%	From Diets tab
overall	-0.00066	%	From Diets tab

Reduction in feed overall is significantly less than 1%; therefore, assume that there would be minimal change in labour if any.

Price Information

Average farm hand wage	16.22	$/hr	WAGEinfo, Alberta Wage and Salary Survey, 2009 data. Available at: http://alis.alberta.ca/wageinfo/Content/RequestAction.asp?aspAction=GetWageDetail&format=html&RegionID=20&NOC=8431
Purchase of barley	161.38	$/tonne	Lethbridge Barley Price, Alberta Grains Council, Alberta Canola Producers Commission. Weekly Average from 2005 to 2010
	0.16	$/kg	
Purchase of barley silage	40	$/tonne	Based on a conversation with a local dairy farmer on January 3, 2011.
	0.04	$/kg	
Purchase of alfalfa/grass hay (alfalfa per ton)	124.44	$/ton	Internet Hay Exchange. Hay Price Calculator. Available at: http://www.hayexchange.com/tools/ave_price_calc.php.
	137.17	$/tonne	
	0.14	**$/kg**	
Purchase of bedding (model assumes 100% straw bedding used) (Straw estimate for 2010)			
Wheat straw (fertilizer costs)	24.2	$/ton	What is Straw Worth? - Frequently Asked Questions. Ag-Info Centre, Alberta Agriculture and Rural Development. Available at: www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/faq7514

BMP 5 - DATA

			References
	26.7	$/tonne	
Barley and oat straw (fertilizer costs)	32	$/ton	What is Straw Worth? - Frequently Asked Questions. Ag-Info Centre, Alberta Agriculture and Rural Development. Available at: www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/faq7514
	35.3	$/tonne	
Pea straw (fertilizer costs)	30	$/ton	What is Straw Worth? - Frequently Asked Questions. Ag-Info Centre, Alberta Agriculture and Rural Development. Available at: www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/faq7514
	33.1	$/tonne	
Canola straw (fertilizer costs)	22.6	$/ton	What is Straw Worth? - Frequently Asked Questions. Ag-Info Centre, Alberta Agriculture and Rural Development. Available at: www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/faq7514
	24.9	$/tonne	
Average weight of straw bale	450	kg	0
Baling costs	9.00 - 11.50	$/large round bale	What is Straw Worth? - Frequently Asked Questions. Ag-Info Centre, Alberta Agriculture and Rural Development. Available at: www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/faq7514
	10.25	$/large round bale	Average
	0.023	$/kg	
	22.78	$/tonne	
Hauling and stacking	2.00 - 3.00	$/large round bale	What is Straw Worth? - Frequently Asked Questions. Ag-Info Centre, Alberta Agriculture and Rural Development. Available at: www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/faq7514
	2.5	$/large round bale	Average
	0.0056	$/kg	
	5.56	$/tonne	
Average price (wheat straw)	55.01	$/tonne	
Average price (barley and oat straw)	63.61	$/tonne	
Average price (pea straw)	61.40	$/tonne	
Average price (canola straw)	53.25	$/tonne	
Average price for straw	**58.32**	**$/tonne**	
	0.058	**$/kg**	
Purchase of min., trc min., cobalt, protein suppl., vit., antibiotic for feedlot			
32% Feedlot Supplement (pellets with monensin)	11.89	$/25 kg	UFA Limited. Available at: http://ufa.com/products/product.html. Accessed on January 3, 2011 and phone call with UFA on January 4, 2011.
	0.48	**$/kg**	
Vitamins (A-D-E Premix) for feedlot			
Mash	24.99	$/20 kg	UFA Limited. Available at: http://ufa.com/products/product.html. Accessed on January 3, 201
Crumble	30.00	$/20 kg	UFA Limited. Available at: http://ufa.com/products/product.html. Accessed on January 3, 201
Average	27.50	$/20 kg	
	1.37	**$/kg**	
Purchase of manure	0	$/kg	Government of Alberta. Agriculture and Rural Development. Manure and Compost Directory. Available at: http://www.agric.gov.ab.ca/app68/manure. Accessed on January 3, 2011.

Fuel consumed to feed livestock (on-farm diesel) - and -
Fuel consumed to collect manure (on-farm diesel)
Ultra Low Sulphur Diesel (ULSD)

BMP 5 - DATA

			References
Calgary, AB	80.7	cents/L (excluding taxes)	UFA Petroleum. Rack Prices. December 18 to December 20, 2010. Available at: www.ufa.net/petroleum/rack_pricing.html
Edmonton, AB	77.5	cents/L (excluding taxes)	UFA Petroleum. Rack Prices. December 18 to December 20, 2010. Available at: www.ufa.net/petroleum/rack_pricing.html
Ultra Low Sulphur Diesel Lite (ULSD-LT)			
Calgary, AB	84.2	cents/L (excluding taxes)	UFA Petroleum. Rack Prices. December 18 to December 20, 2010. Available at: www.ufa.net/petroleum/rack_pricing.html
Edmonton, AB	81.0	cents/L (excluding taxes)	UFA Petroleum. Rack Prices. December 18 to December 20, 2010. Available at: www.ufa.net/petroleum/rack_pricing.html
Average	80.85	cents/L (excluding taxes)	
Fuel tax rates (diesel - all grades) (April 1, 2007 to current)	9	cents/L	Alberta Tax and Revenue Administration - Current and Historic Tax Rates. Available at: www.finance.alberta.ca/publications/tax_rebates/rates/hist1.html#fuel
Alberta Farm Fuel Benefit Program and Farm Fuel Distribution Allowance (taxes)	-15	cents/L	Alberta Finance and Enterprise. Taxes & Rebates - Fuel Tax Overview. November 23, 2010. Available at: www.finance.alberta.ca/publications/tax_rebates/fuel/overview.html
Fuel tax is exempted for diesel used on farms and a subsidy of 6 cents per L of diesel is provided			
Average diesel price minus Alberta programs	**0.75**	**$/L**	
Fuel consumption (Lorry >32t EURO4)	244.00	g/km	Ecoinvent. Transport Services. Data v2.0. Report No. 14. December 2007.

Testing costs

Alberta Environment. Selection for residual feed intake in beef cattle quantification protocol. Draft Version 2.0. September 2009.

Seedstock breeder - breed low RFI breeding animals or semen for sale to cow/calf operations
- assuming no AI for this model as this is not the most prevalent method for breeding used in Alberta

Cow/calf operation - purchase low RFI breeding stock and uses them in matings
- majority of progeny sold to backgrounding/finishing feedlots for a premium

Model lumps cow/calf operations and seedstock producers together as the number of bulls is much lower than the number of cows in the Alberta beef system.

Cattle tested between 8 and 13 months of age. Assume all tested in January at 8 months of age - assume that all cattle sent and paid for by cow/calf operation.

Carbon credits - available for first progeny only and for low RFI EBV bulls.
- ownership/title to emission reduction offsets are established through contracts
- if credits are included in this analysis, assume that the owner of the cattle at the time where credits can be achieved will obtain those credits

RFI testing cost in Alberta (2009 cost)	1	$ CAD/head/day	Technical Protocol Plan (TPP) for Selection for residual feed intake in beef cattle quantification protocol. Part B. Received from Emmanuel Laate via email on October 20, 2010.
Testing period	91	days	
Total testing cost	**91**	**$ CAD/head**	

Premiums for low RFI cattle

Low RFI bull - premium price over standard bull (equivalent to recoup the cost of testing in 2-stage selection program and paying AUD 300 for testing each bull for RFI)	153	$ AUD	Technical Protocol Plan (TPP) for Selection for residual feed intake in beef cattle quantification protocol. Part B. Received from Emmanuel Laate via email on October 20, 2010.
1 Australian dollar =	0.982755387	Canadian dollars	Google website. January 17, 2011.
1 Australian dollar =	0.84	Canadian dollars	Australian Dollar. Exchange Rates. March 18, 2009. Available at: http://aud.exchangerates24.com/cad/history/2009-03-18/
2009 conversion	129	$ CAD/head	

US Data:

BMP 5 - DATA

			References
Premium paid for bulls with low RFI in the US (this includes the savings from all the potential calves born from this bull over his life)	124	$ US/lb of improvement per day	McDonald, Tyrel James. Searching for the ultimate cow: the economic value of RFI at bull sales. Masters Thesis for Montana State University, Bozeman, Montana. March 2010. Available at: http://etd.lib.montana.edu/etd/2010/mcdonald/McDonaldT0510.pdf.
	273	$ US/kg of improvement per day	
Low RFI value for this model	-1.0	kg DM/day	
Premium for low RFI bull	273	$ US/head	
1 US dollar =	0.987098621	Canadian dollars	Google website. January 17, 2011.
	270	$ CAD/head	
Average premium for low RFI bulls from Australia and US	199	$ CAD/head	Calculated
Reduction in price to feed calves from low RFI sires for finishing diet	8.50	$ CAD/head	AGCanada.com Study Says Low RFI Bulls Sire Feed-Efficient Calves. December 7, 2009. Available at: http://www.agcanada.com/Article.aspx?ID=14638
	50 - 70	$ US/head	Progressive Cattleman. The quest for efficiency: South Dakota breeder sees big potential with RFI system. Available at: http://www.progressivecattle.com/index.php?option=com_content&view=article&id=3554:the-quest-for-efficiency-south-dakota-breeder-sees-big-potential-with-rfi-system&catid=93:featured-main-page

Currently, there are no premiums being paid in Alberta for low RFI cattle. Cattleland Feedyards have had 2 years of decreases in the number of clients requesting RFI testing because of insufficient economic incentive. Other characteristics are being pursued in Alberta right now such as carcass quality or breed characteristics, where premiums could be achieved.

The interest in this breeding scheme has not grown over the past couple of years; however, if the Alberta Protocol for greenhouse gas offsets gets approved, the economics for RFI testing may change the way beef is produced in Alberta.

Phone call with William (research manager at Cattleland Feedyards) on January 17, 2011.

" As a cow-calf producer and feeder, Stuart Thiessen of Namala Farms near Strathmore, has already installed GrowSafe feed bunks to test their own calves. 'I really hope RFI will work and we can make it fit into the production system. The challenge will be how the market will reward low RFI cattle,' he says. 'If the market pulls it, cow-calf producers will look for low RFI bulls.'

He foresees the day when buyers will be willing to pay more for low RFI calves. But to get there from here, he says, will require some sort of cross-herd scoring system to understand which herds are different from others.

'Assuming RFI works, we will be able to improve production and not hurt what our customers want. At the end of the day - though there's something to be said for good marketing - you have to have good production numbers.' "

AGCanada.com Study Says Low RFI Bulls Sire Feed-Efficient Calves. December 7, 2009. Available at: http://www.agcanada.com/Article.aspx?ID=14638

Negative cash flow anticipated for the first 10 years of investing in RFI superior genetics.
Cost of testing is expected to decrease over time.

Technical Protocol Plan (TPP) for Selection for residual feed intake in beef cattle quantification protocol. Part B. Received from Emmanuel Laate via email on October 20, 2010.

Calculation changes to the model

- Adjust feed requirements based on the above information for steers, heifers, replacement heifers, and bulls
- Calculate less garbage for less feed used
- Adjust enteric fermentation emissions and manure emissions calculations to account for reduced DMI of steers, heifers, replacement heifers, and bulls
- Reduce total manure generation based on feed intake
- Reduce energy requirements for feeding cattle and manure collection
- Modify transportation for calf-fed and yearling-fed systems to exclude cattle to be tested
- Include additional transportation for cattle to be tested

BMP 5 - CALCULATIONS FOR MODEL **Adjust everything on the Summary Tab to Update these Calculations**

According to the Alberta Environment (September 2009), Selection for Residual Feed Intake in Beef Cattle Quantification Protocol Draft Version 2.0:
- Credit duration - first generation only within Alberta's eight year crediting period.
- Reductions may be claimed on the animals with low RFI EBV's and their first generation progeny only.
- Animals in the project condition have EBVs computed using a specified year as the base year or beginning of the project. The mean EBV of a particular trait is set to zero for all the animals born in that year or earlier.
  - Therefore, EBVs for 2002 are set to zero (baseline year for protocol).

Culling/replacement rate for bulls (US)	25	%
Culling/replacement rate for beef cows (from model)	17	%
Assume both bulls and cows are in the beef system for 4 years		
Replacement rate of calf crop	12	%

Low RFI Values

Assumed minimum low RFI value	-0.5	kg DM/day
Assumed maximum low RFI value	-1.0	kg DM/day

Heritability

Assumed low heritability	16	%
Assumed medium heritability	27.5	%
Assumed high heritability	39	%

Breeding bulls

Low RFI value (reduction in DMI)	**-1**	**kg DM/day**	assumed average certified RFI_p EBV of sires
Estimated mean DMI (from model) (base year)	13.61	kg DM/day	
Percent change in DMI between project and baseline	-7.35	%	
Project DMI	12.61	kg DM/day	assumed this remains constant for every year for bulls
Assumed dam RFI_p EBV	0.00	kg DM/day	
Heritability	**39**	**%**	

Example Calculation (-0.5 kg DM/day RFI for sire):

Assigned RFI_p EBV to steers and heifers = [(Sire RFI_p EBV) + Dam RFI_p EBV)] / 2
r steers and heifers with low RFI genetics) = [(-0.5 kg DM/day) + (0 kg DM/day)] / 2
= -0.25 kg DM/day
% Change = [(RFI_p EBV) / (Base Year mean DMI)] * 100
= [(-0.25 kg DM/day) / (13.61 kg DM/day)] * 100
= -1.8 %

Model Calculation:

Calculated RFI EBV for steers and heifers = **-0.5 kg DM/day**
% Change = **-3.7 %**

For this model:		
Calf Crop (birth year)	2010	
Calf Crop (slaughter year)	2011	
Bulls		
# bulls tested	182	
# bulls tested with low RFI	23	
Total bulls with low RFI in system	85	
Bull RFI RBV	-1.0	kg DM/day
% reduction in DMI	-7.35	%
Replacement Bulls		
# replacement bulls with low RFI	13	
Replacement bull RFI EBV	-0.50	kg DM/day
% reduction in DMI	-3.67	%
Cows/Replacement Heifers		
# cows/replacement heifers with low RFI	254	
Replacement heifer RFI EBV	-0.50	kg DM/day
% reduction in DMI	-3.67	%
Calves		
Calf-fed steers born with low RFI	128	
Calf-fed heifers born with low RFI	109	
Yearling-fed steers born with low RFI	156	
Yearling-fed heifers born with low RFI	133	
Calf RFI EBV	-0.5	kg DM/day
% reduction in DMI for calves	-3.67	%

				kg DM/day	%	CALVES BORN FROM		kg DM/day	%					LOW RFI - CALF-FED CATTLE						LOW RFI - YEARLING-FED CATTLE					
		LOW RFI - BULLS				LOW RFI BULLS	LOW RFI - CALVES BORN			LOW RFI - REPLACEMENT HEIFERS		LOW RFI - REPLACEMENT BULLS		STEERS			HEIFERS			STEERS			HEIFERS		
Year	# bulls tested	# bulls tested with low RFI	Total bulls with low RFI in beef system (cull rate 25%)	Calculated RFI EBV	% reduction in DMI	# of calves (1st generation) from low RFI bulls (calf crop from bulls-4 yrs)	# of calves (1st generation) from low RFI bulls with low RFI genetics	Calculated RFI EBV 1st generation calves with low RFI genetics	% reduction in DMI for calves born	# 1st generation calves used for replacement heifers	Cows/Replacement heifers with low RFI adjust diet - total 4 yrs	# 1st generation calves used for replacement bulls	Replacement bulls with low RFI (adjust diet - total 4 yrs)	# 1st generation calves calf-fed steers	Low RFI Calf-fed steers Birth Year	Low RFI Calf-fed steers Slaughter Year	# 1st generation calves calf-fed heifers	Low RFI Calf-fed heifers Birth Year	Low RFI Calf-fed heifers Slaughter Year	# 1st generation calves yearling-fed steers	Low RFI Yearling-fed steers Birth Year	Low RFI Yearling-fed steers Slaughter Year	# 1st generation calves yearling-fed steers	Low RFI Yearling-fed heifers Birth Year	Low RFI Yearling-fed heifers Slaughter Year
2000	111	14	14	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2001	117	15	28	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2002	123	15	30	-1.0	-7.35	540	210	-0.5	-3.67	24	24	1	1	45	45	0	38	38	0	55	55	0	47	47	0
2003	129	16	31	-1.0	-7.35	568	221	-0.5	-3.67	25	25	1	1	47	47	45	40	40	38	58	58	55	49	49	47
2004	136	17	48	-1.0	-7.35	598	233	-0.5	-3.67	27	52	1	2	50	50	47	43	43	40	61	61	58	52	52	49
2005	143	18	66	-1.0	-7.35	921	359	-0.5	-3.67	41	93	2	4	77	77	50	66	66	43	94	94	61	80	80	52
2006	150	19	70	-1.0	-7.35	1,260	491	-0.5	-3.67	56	149	3	7	105	105	77	90	90	66	128	128	94	110	110	80
2007	157	20	73	-1.0	-7.35	1,325	516	-0.5	-3.67	59	183	3	9	110	110	105	94	94	90	135	135	128	115	115	110
2008	165	21	77	-1.0	-7.35	1,392	542	-0.5	-3.67	62	218	3	11	116	116	110	99	99	94	141	141	135	121	121	115
2009	174	22	81	-1.0	-7.35	1,461	569	-0.5	-3.67	65	242	3	12	122	122	116	104	104	99	149	149	141	127	127	121
2010	182	23	85	-1.0	-7.35	1,534	598	-0.5	-3.67	68	254	4	13	128	128	122	109	109	104	156	156	149	133	133	127
2011	1,498	187	252	-1.0	-7.35	1,611	628	-0.5	-3.67	71	266	4	14	134	134	128	115	115	109	164	164	156	140	140	133
2012	1,498	187	419	-1.0	-7.35	4,795	1,870	-0.5	-3.67	213	417	11	22	399	399	134	341	341	115	488	488	164	417	417	140
2013	1,498	187	585	-1.0	-7.35	7,960	3,104	-0.5	-3.67	353	705	18	37	663	663	399	567	567	341	810	810	488	693	693	417
2014	1,498	187	749	-1.0	-7.35	11,106	4,331	-0.5	-3.67	493	1,130	26	59	925	925	663	791	791	567	1,130	1,130	810	967	967	693
2015	1,498	187	749	-1.0	-7.35	14,231	5,550	-0.5	-3.67	631	1,690	33	88	1,185	1,185	925	1,014	1,014	791	1,448	1,448	1,130	1,239	1,239	967
2016	1,498	187	749	-1.0	-7.35	14,231	5,550	-0.5	-3.67	631	2,108	33	110	1,185	1,185	1,185	1,014	1,014	1,014	1,448	1,448	1,448	1,239	1,239	1,239
2017	1,498	187	749	-1.0	-7.35	14,231	5,550	-0.5	-3.67	631	2,386	33	125	1,185	1,185	1,185	1,014	1,014	1,014	1,448	1,448	1,448	1,239	1,239	1,239
2018	1,498	187	749	-1.0	-7.35	14,231	5,550	-0.5	-3.67	631	2,524	33	132	1,185	1,185	1,185	1,014	1,014	1,014	1,448	1,448	1,448	1,239	1,239	1,239
2019	1,498	187	749	-1.0	-7.35	14,231	5,550	-0.5	-3.67	631	2,524	33	132	1,185	1,185	1,185	1,014	1,014	1,014	1,448	1,448	1,448	1,239	1,239	1,239
2020	1,498	187	749	-1.0	-7.35	14,231	5,550	-0.5	-3.67	631	2,524	33	132	1,185	1,185	1,185	1,014	1,014	1,014	1,448	1,448	1,448	1,239	1,239	1,239
2021	1,498	187	749	-1.0	-7.35	14,231	5,550	-0.5	-3.67	631	2,524	33	132	1,185	1,185	1,185	1,014	1,014	1,014	1,448	1,448	1,448	1,239	1,239	1,239
2022	1,498	187	749	-1.0	-7.35	14,231	5,550	-0.5	-3.67	631	2,524	33	132	1,185	1,185	1,185	1,014	1,014	1,014	1,448	1,448	1,448	1,239	1,239	1,239
2023	1,498	187	749	-1.0	-7.35	14,231	5,550	-0.5	-3.67	631	2,524	33	132	1,185	1,185	1,185	1,014	1,014	1,014	1,448	1,448	1,448	1,239	1,239	1,239
2024	1,498	187	749	-1.0	-7.35	14,231	5,550	-0.5	-3.67	631	2,524	33	132	1,185	1,185	1,185	1,014	1,014	1,014	1,448	1,448	1,448	1,239	1,239	1,239
2025	1,498	187	749	-1.0	-7.35	14,231	5,550	-0.5	-3.67	631	2,524	33	132	1,185	1,185	1,185	1,014	1,014	1,014	1,448	1,448	1,448	1,239	1,239	1,239
2026	1,498	187	749	-1.0	-7.35	14,231	5,550	-0.5	-3.67	631	2,524	33	132	1,185	1,185	1,185	1,014	1,014	1,014	1,448	1,448	1,448	1,239	1,239	1,239
2027	1,498	187	749	-1.0	-7.35	14,231	5,550	-0.5	-3.67	631	2,524	33	132	1,185	1,185	1,185	1,014	1,014	1,014	1,448	1,448	1,448	1,239	1,239	1,239
2028	1,498	187	749	-1.0	-7.35	14,231	5,550	-0.5	-3.67	631	2,524	33	132	1,185	1,185	1,185	1,014	1,014	1,014	1,448	1,448	1,448	1,239	1,239	1,239
2029	1,498	187	749	-1.0	-7.35	14,231	5,550	-0.5	-3.67	631	2,524	33	132	1,185	1,185	1,185	1,014	1,014	1,014	1,448	1,448	1,448	1,239	1,239	1,239
2030	1,498	187	749	-1.0	-7.35	14,231	5,550	-0.5	-3.67	631	2,524	33	132	1,185	1,185	1,185	1,014	1,014	1,014	1,448	1,448	1,448	1,239	1,239	1,239
	Note 1		Note 2	Note 3			Note 4	Note 5	Note 5	Note 6		Note 6													

Notes:

1. Tested postweaning before breeding period. Calves born the following year.
2. Assumes 19 calves per bull (as per model) (constant over time)
3. Constant value over time. EBVs for replacement heifers cannot be certified as it is assumed that they are not tested (as per Alberta protocol).
4. Only first generation calves are included in low RFI calculations (as per protocol). Diets will be adjusted for entire life of animal.
5. Values assumed to be constant. No increase in genetics superiority included (too complex for this model).
6. Cows are 95% of breeding herd and bulls are 5% (model)

Protocol states that 2002 is the baseline year; therefore, diets before 2002 cannot be adjusted for emissions reductions.

BMP 5 - Superior Residual Feed Intake (RFI) Genetics in Breeding Animals

Post-weaned animals selected for potential replacement bulls will be tested for RFI in yearling-fed and calf-fed systems. Bulls with low RFI will be used as breeding animals to reduce feed intake while keeping weight gain constant.

Low RFI value assumed	-1.0 kg DM/day	(value can be adjusted here for entire model)
Heritability percentage value assumed	39 %	(value can be adjusted here for entire model)
Calf Crop (birth year)	2010	(value can be adjusted here for entire model)
Calf Crop (slaughter year)	2011	(value can be adjusted here for entire model)

Total number of animals	
(number of bulls tested this year)	182 bulls
(number of bulls tested with low RFI this year)	23 bulls
(total number of breeding bulls with low RFI this year)	85 bulls
(total number of calves born this year with low RFI)	598 calves
(total number of calves born per year based on 2001 model)	2,113,345 calves
(percentage of calves born with low RFI to total this year)	0.03 %
Total weight affected by BMP (to slaughter)	322 tonnes
(total slaughter weight not affected) (model has an affect on cow/calf and feedlot operations)	

Low RFI Values	
Minimum low RFI value	-0.5 kg DM/day
Maximum low RFI value	-1.0 kg DM/day
Heritability	
Low heritability	16 %
Medium heritability	27.5 %
High heritability	39 %

Total GHG emissions	**2.0981E+10 kg CO2e**
Total acidification	**3.0760E+07 kg SO2-Eq**
Total eutrophication	**5.5380E+06 kg PO4-Eq**
Total non-renewable energy	**3.4516E+11 MJ-Eq**

	COW/CALF OPERATIONS								FEEDLOT OPERATIONS							
	BMP 5		Baseline (2001)		Change		Per Unit Market Value	Total Impact	BMP 5		Baseline (2001)		Change		Per Unit Market Value	Total Impact
	(amount)	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*	*($/unit)*	*($ Million)*	*(amount)*	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*	*($/unit)*	*($ Million)*
Inputs with Change																
Production of pesticide/herbicide																
Production of chemical fertilizer																
Production of bedding																
Production of min., trc min., cobalt, protein suppl., vit., antibiotic																
Purchase of chemical fertilizer																
Urea, as N, at regional storehouse																
Ammonia, liquid, at regional storehouse																
Monoammonium phosphate, as P2O5, at regional storehouse																
Monoammonium phosphate, as N, at regional storehouse																
Ammonium sulphate, as N, at regional storehouse																
Purchase of manure for land application																
Purchase of pesticide/herbicide																
Purchase of seed for barley																
Purchase of seed for barley silage																
Purchase of seed for alfalfa/grass hay																
Purchase of water to irrigate crops																
Purchase of amendment materials									0	kg	0	kg	0	kg	-	-
Purchase of composting equipment (Windrow turner)									0	turners	0	turners	0	turners	-	-
Purchase of construction supplies for composting (clay for pad)									0	units	0	units	0	units	-	-
Purchase of bull with low RFI for breeding (cow-calf) (premium)	23	head	0	head	23	head	$0	$0.000								
Sale of bull with low RFI for breeding (seedstock producer) (premium)	-23	head	0	head	-23	head	$0	$0.000								
Purchase of alfalfa/grass hay	6.59E+09	kg	6.59E+09	kg	-6.59E+04	kg	$0.14	-$0.009								
Purchase of barley									4.49E+09	kg	4.49E+09	kg	-3.50E+04	kg	$0.16	-$0.006
Purchase of barley silage									7.58E+09	kg	7.58E+09	kg	-2.80E+05	kg	$0.04	-$0.011
Purchase of bedding	5.09E+08	kg	5.09E+08	kg	0.0	kg	$0.06	$0.00	4.22E+08	kg	4.22E+08	kg	0.0	kg	$0.06	$0.00
Purchase of animal shelters, wind breakers, fencing, etc.	0	units	0	units	0	units	-	-								
Purchase of ionophores	0	kg	0	kg	0	kg	-	-								
Purchase of RAC									0	kg	0	kg	0	kg	-	-
Purchase of min., trc min., cobalt, protein suppl., antibiotic	7.90E+07	kg	7.91E+07	kg	-3.09E+04	kg	$0.48	-$0.015	1.45E+08	kg	1.45E+08	kg	-2.79E+03	kg	$0.48	-$0.0013
Purchase of vitamins	1.68E+03	kg	1,684	kg	-9.75E-01	kg	$1.37	-$0.0000013	1.76E+05	kg	1.76E+05	kg	-3.61E+00	kg	$1.37	-$0.000005
Purchase of RFI testing	182	tests	0	tests	182	tests	$91	$0.02	0	tests	0	tests	0	tests	-	-
Fuel/energy required to operate composting equipment									0	kWh or L	0	kWh or L	0	kWh or L	-	-
Fuel consumed to transport barley and barley silage																
Fuel consumed to transport alfalfa/grass hay																
Fuel consumed for cropping activities																
Fuel consumed to bed livestock (change)	0	L	0	L	0	L	$0.75	$0.00	0	L	0	L	0	L	$0.75	$0.00
Fuel consumed to transport garbage (change)	0	L	0	L	0	L	$0.75	$0.00	0	L	0	L	0	L	$0.75	$0.00
Fuel consumed to transport bedding (change)																
Fuel consumed to feed livestock (change)	-559	L	0	L	-559	L	$0.75	-$0.000419	-1,024	L	0	L	-1,024	L	$0.75	-$0.000766
Fuel consumed to collect manure (change)									-11.68	L	0	L	-11.68	L	$0.75	-$0.0000087
Fuel cons. to transp. min., trc min., cob., prot. suppl., vit., antibiotic																
Fuel consumed to transport livestock for testing	291	L	0	L	291	L	$0.75	$0.0002	0	L	0	L	0	L	-	-
Labour (change)	0	hrs	0	hrs	0	hrs	-	-	0	hrs	0	hrs	0	hrs	-	-
Working capital interest	0	$	0	$	0	$	-	-	0	$	0	$	0	$	-	-
Total Input Value Change								**-$0.01**								**-$0.02**
Outputs with Change																
Manure sold for land application									2.51E+10	kg	2.51E+10	kg	-8.80E+05	kg	$0.00	$0.00
Compost sold for land application									0	kg	0	kg	0	kg	-	-
Price for beef to feedlot (purchase or sale) (change)	-598	head	0	head	-598	head	$0.00	$0.00	598	head	0	head	598	head	$0.00	$0.00
Total Output Value Change								**$0.00**								**$0.00**

CHANGE IN OVERALL GHG EMISSIONS	COW/CALF OPERATIONS						FEEDLOT OPERATIONS						BEEF INDUSTRY					
	BMP 5		Baseline (2001)		Change		BMP 5		Baseline (2001)		Change		BMP 5		Baseline (2001)		Change	
	(amount)	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*	*(amount)*	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*	*(amount)*	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*
BEEF ACTIVITIES - SOIL AND CROP																		
Manure generation	3.45E+10	kg	3.45E+10	kg	-228,579	kg	1.89E+10	kg	1.89E+10	kg	-145,385	kg						
Methane emissions from stored manure	1.49E+08	kg CO_2e	1.49E+08	kg CO_2e	-972	kg CO_2e	1.44E+08	kg CO_2e	1.44E+08	kg CO_2e	-13,458	kg CO_2e						
Enteric fermentation emissions	7.03E+09	kg CO_2e	7.03E+09	kg CO_2e	-45,844	kg CO_2e	3.56E+09	kg CO_2e	3.56E+09	kg CO_2e	-276,956	kg CO_2e						
N_2O emissions from stored manure (direct)	1.83E+09	kg CO_2e	1.83E+09	kg CO_2e	-12,756	kg CO_2e	3.27E+08	kg CO_2e	3.27E+08	kg CO_2e	-2,482	kg CO_2e						
N_2O emissions from stored manure (indirect)	4.04E+08	kg CO_2e	4.04E+08	kg CO_2e	-2,824	kg CO_2e	3.06E+08	kg CO_2e	3.06E+08	kg CO_2e	-2,327	kg CO_2e						
N_2O emissions from cropping and land use													9.57E+08	kg CO_2e	9.57E+08	kg CO_2e	-8,821	kg CO_2e
Total P emissions from run-off													4.15E+06	kg PO_4-eq	4.15E+06	kg PO_4-eq	-27	kg PO_4-eq
Soil Carbon Change in Soil From Land Use													-2.36E+08	kg CO_2e	-2.36E+08	kg CO_2e	1,556	kg CO_2e
Direct CO2 emissions from managed soils													1.89E+08	kg CO_2e	1.89E+08	kg CO_2e	-1,155	kg CO_2e
OVERALL SUMMARY																		
Construction	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e						
Forage and cereal sub-activities													1.20E+09	kg CO_2e	1.20E+09	kg CO_2e	-7,470	kg CO_2e
Energy generation and consumption activities	2.81E+09	kg CO_2e	2.81E+09	kg CO_2e	-11,243	kg CO_2e	1.04E+09	kg CO_2e	1.04E+09	kg CO_2e	-4,159	kg CO_2e						
O&M activities	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e						
Cereal activities													3.38E+08	kg CO_2e	3.38E+08	kg CO_2e	-2,181	kg CO_2e
Forage activities													2.86E+08	kg CO_2e	2.86E+08	kg CO_2e	-1,888	kg CO_2e
Feedlot and pasture activities	3.20E+06	kg CO_2e	3.20E+06	kg CO_2e	-379	kg CO_2e	1.40E+08	kg CO_2e	1.40E+08	kg CO_2e	-1,413	kg CO_2e	3.04E+08	kg CO_2e	3.04E+08	kg CO_2e	-62,809	kg CO_2e
Cow activities (transportation)	2.49E+07	kg CO_2e	2.49E+07	kg CO_2e	0	kg CO_2e												
Bull activities (transportation)	3.14E+06	kg CO_2e	3.14E+06	kg CO_2e	0	kg CO_2e												
Yearling-fed system activities (transportation)							1.08E+08	kg CO_2e	1.08E+08	kg CO_2e	963	kg CO_2e						
Calf-fed system activities (transportation)							6.59E+07	kg CO_2e	6.59E+07	kg CO_2e	611	kg CO_2e						

Total GWP for BMP

kg CO_2e **1.22E+10** Cow/Calf **5.69E+09** Feedlot **3.04E+09** Beef Industry

Total Change in GWP for BMP

kg CO_2e **-7.40E+04** **-2.99E+05** **-8.28E+04**

Overall Baseline GWP (2001)

kg CO_2e/kg live weight **14.7052**

Overall Baseline GWP (2010)

kg CO_2e/kg live weight **14.7049** (calculated from this model - for 2010/2011 calf crop)

Overall BMP GWP

kg CO_2e/kg live weight **14.7049**

Change in overall GWP from 2001

kg CO_2e/kg live weight **-0.00032**

Change in overall GWP from 2010

kg CO_2e/kg live weight **0**

Change in GWP per kg of beef affected from 2001

kg CO_2e/kg live weight **-1.418** **(total change in GHG emissions divided by total weight of cattle affected)**

Notes:
Energy generation emissions divided by the number of cattle on cow/calf vs feedlo
Feedlot and pasture activities are divided as per below

BMP 5 - Superior Residual Feed Intake (RFI) Genetics in Breeding Animals

Post-weaned animals selected for potential replacement bulls will be tested for RFI in yearling-fed and calf-fed systems. Bulls with low RFI will be used as breeding animals to reduce feed intake while keeping weight gain constant.

Low RFI value assumed	**-1.0 kg DM/day**	(value can be adjusted here for entire model)
Heritability percentage value assumed	**39 %**	(value can be adjusted here for entire model)
Calf Crop (birth year)	**2029**	(value can be adjusted here for entire model)
Calf Crop (slaughter year)	**2030**	(value can be adjusted here for entire model)

Total number of animals

(number of bulls tested this year)	1,498	bulls
(number of bulls tested with low RFI this year)	187	bulls
(total number of breeding bulls with low RFI this year)	749	bulls
(total number of calves born this year with low RFI)	5550	calves
(total number of calves born per year based on 2001 model)	2,113,345	calves
(percentage of calves born with low RFI to total this year)	0.26	%
Total weight affected by BMP (to slaughter)	2,987	tonnes

(total slaughter weight not affected) (model has an affect on cow/calf and feedlot operations)

Low RFI Values

Minimum low RFI value	-0.5	kg DM/day
Maximum low RFI value	-1.0	kg DM/day

Heritability

Low heritability	16	%
Medium heritability	27.5	%
High heritability	39	%

Total GHG emissions	**2.0977E+10**	**kg CO2e**
Total acidification	**3.0752E+07**	**kg SO2-Eq**
Total eutrophication	**5.5377E+06**	**kg PO4-Eq**
Total non-renewable energy	**3.4514E+11**	**MJ-Eq**

	COW/CALF OPERATIONS								FEEDLOT OPERATIONS							
	BMP 5		Baseline (2010)		Change		Per Unit Market Value	Total Impact	BMP 5		Baseline (2010)		Change		Per Unit Market Value	Total Impact
	(amount)	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*	*($/unit)*	*($ Million)*	*(amount)*	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*	*($/unit)*	*($ Million)*
Inputs with Change																
Production of pesticide/herbicide																
Production of chemical fertilizer																
Production of bedding																
Production of min., trc min., cobalt, protein suppl., vit., antibiotic																
Purchase of chemical fertilizer																
Urea, as N, at regional storehouse																
Ammonia, liquid, at regional storehouse																
Monoammonium phosphate, as P2O5, at regional storehouse																
Monoammonium phosphate, as N, at regional storehouse																
Ammonium sulphate, as N, at regional storehouse																
Purchase of manure for land application																
Purchase of pesticide/herbicide																
Purchase of seed for barley																
Purchase of seed for barley silage																
Purchase of seed for alfalfa/grass hay																
Purchase of water to irrigate crops																
Purchase of amendment materials									0	kg	0	kg	0	kg	-	-
Purchase of composting equipment (Windrow turner)									0	turners	0	turners	0	turners	-	-
Purchase of construction supplies for composting (clay for pad)									0	units	0	units	0	units	-	-
Purchase of bull with low RFI for breeding (cow-calf) (premium)	187	head	23	head	164	head	$0	$0.00								
Sale of bull with low RFI for breeding (seedstock producer) (premium)	-187	head	-23	head	-164	head	$0	$0.00								
Purchase of alfalfa/grass hay	6.59E+09	kg	6.59E+09	kg	-5.30E+05	kg	$0.14	-$0.073								
Purchase of barley									4.48E+09	kg	4.49E+09	kg	-2.84E+05	kg	$0.16	-$0.0458
Purchase of barley silage									7.57E+09	kg	7.58E+09	kg	-2.08E+06	kg	$0.04	-$0.083
Purchase of bedding	5.09E+08	kg	5.09E+08	kg	0.0	kg	$0.06	$0.00	4.22E+08	kg	4.22E+08	kg	0.0	kg	$0.06	$0.00
Purchase of animal shelters, wind breakers, fencing, etc.	0	units	0	units	0	units	-	-								
Purchase of ionophores	0	kg	0	kg	0	kg	-	-								
Purchase of RAC									0	kg	0	kg	0	kg	-	-
Purchase of min., trc min., cobalt, protein suppl., antibiotic	7.88E+07	kg	7.90E+07	kg	-2.76E+05	kg	$0.48	-$0.1311	1.45E+08	kg	1.45E+08	kg	-2.13E+04	kg	$0.48	-$0.0101
Purchase of vitamins	1.67E+03	kg	1.68E+03	kg	-8.17E+00	kg	$1.37	-$0.0000112	1.76E+05	kg	1.76E+05	kg	-2.75E+01	kg	$1.37	-$0.000038
Purchase of RFI testing	1,498	tests	182	tests	1,316	tests	$91	$0.12	0	tests	0	tests	0	tests	-	-
Fuel/energy required to operate composting equipment									0	kWh or L	0	kWh or L	0	kWh or L	-	-
Fuel consumed to transport barley and barley silage																
Fuel consumed to transport alfalfa/grass hay																
Fuel consumed for cropping activities																
Fuel consumed to bed livestock (change)	0	L	0	L	0	L	$0.75	$0.00	0	L	0	L	0	L	$0.75	$0.00
Fuel consumed to transport garbage (change)	0	L	0	L	0	L	$0.75	$0.00	0	L	0	L	0	L	$0.75	$0.00
Fuel consumed to transport bedding (change)																
Fuel consumed to feed livestock (change)	-5,244	L	-559	L	-4,685	L	$0.75	-$0.004	-9,599	L	-1,024	L	-8,575	L	$0.75	-$0.006
Fuel consumed to collect manure (change)									-108.46	L	-11.68	L	-96.78	L	$0.75	-$0.00007244
Fuel cons. to transp. min., trc min., cob., prot. suppl., vit., antibiotic																
Fuel consumed to transport livestock for testing	2,394	L	291	L	2,103	L	$0.75	$0.0016	0	L	0	L	0	L	-	-
Labour (change)	0	hrs	0	hrs	0	hrs	-	-	0	hrs	0	hrs	0	hrs	-	-
Working capital interest	0	$	0	$	0	$	-	-	0	$	0	$	0	$	-	-
Total Input Value Change								**-$0.086**								**-$0.15**
Outputs with Change																
Manure sold for land application									2.51E+10	kg	2.51E+10	kg	-8.18E+06	kg	$0.00	$0.00
Compost sold for land application									0	kg	0	kg	0	kg	-	-
Price for beef to feedlot (purchase or sale) (change)	-5550	head	0	head	-5550	head	$0.00	$0.00	5550	head	598	head	4952	head	$0.00	$0.00
Total Output Value Change								**$0.00**								**$0.00**

CHANGE IN OVERALL GHG EMISSIONS	COW/CALF OPERATIONS						FEEDLOT OPERATIONS						BEEF INDUSTRY					
	BMP 5		Baseline (2010)		Change		BMP 5		Baseline (2010)		Change		BMP 5		Baseline (2010)		Change	
	(amount)	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*	*(amount)*	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*	*(amount)*	*(unit)*	*(amount)*	*(unit)*	*(change)*	*(unit)*
BEEF ACTIVITIES - SOIL AND CROP																		
Manure generation	3.44E+10	kg	3.45E+10	kg	-1,938,417	kg	1.89E+10	kg	1.89E+10	kg	-1,204,972	kg						
Methane emissions from stored manure	1.49E+08	kg CO_2e	1.49E+08	kg CO_2e	-8,249	kg CO_2e	1.44E+08	kg CO_2e	1.44E+08	kg CO_2e	-111,677	kg CO_2e						
Enteric fermentation emissions	7.03E+09	kg CO_2e	7.03E+09	kg CO_2e	-389,200	kg CO_2e	3.56E+09	kg CO_2e	3.56E+09	kg CO_2e	-2,297,311	kg CO_2e						
N_2O emissions from stored manure (direct)	1.83E+09	kg CO_2e	1.83E+09	kg CO_2e	-108,316	kg CO_2e	3.27E+08	kg CO_2e	3.27E+08	kg CO_2e	-20,614	kg CO_2e						
N_2O emissions from stored manure (indirect)	4.04E+08	kg CO_2e	4.04E+08	kg CO_2e	-23,976	kg CO_2e	3.06E+08	kg CO_2e	3.06E+08	kg CO_2e	-19,325	kg CO_2e						
N_2O emissions from cropping and land use													9.57E+08	kg CO_2e	9.57E+08	kg CO_2e	-73,630	kg CO_2e
Total P emissions from run-off													4.15E+06	kg PO_4-eq	4.15E+06	kg PO_4-eq	-228	kg PO_4-eq
Soil Carbon Change in Soil From Land Use													-2.36E+08	kg CO_2e	-2.36E+08	kg CO_2e	12,948	kg CO_2e
Direct CO2 emissions from managed soils													1.89E+08	kg CO_2e	1.89E+08	kg CO_2e	-9,634	kg CO_2e
OVERALL SUMMARY																		
Construction	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e						
Forage and cereal sub-activities													1.20E+09	kg CO_2e	1.20E+09	kg CO_2e	-62,407	kg CO_2e
Energy generation and consumption activities	2.81E+09	kg CO_2e	2.81E+09	kg CO_2e	-94,155	kg CO_2e	1.04E+09	kg CO_2e	1.04E+09	kg CO_2e	-34,827	kg CO_2e						
O&M activities	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e	0	kg CO_2e						
Cereal activities													3.38E+08	kg CO_2e	3.38E+08	kg CO_2e	-18,126	kg CO_2e
Forage activities													2.86E+08	kg CO_2e	2.86E+08	kg CO_2e	-15,903	kg CO_2e
Feedlot and pasture activities	3.20E+06	kg CO_2e	3.20E+06	kg CO_2e	-3,389	kg CO_2e	1.40E+08	kg CO_2e	1.40E+08	kg CO_2e	-11,731	kg CO_2e	3.03E+08	kg CO_2e	3.04E+08	kg CO_2e	-561,316	kg CO_2e
Cow activities (transportation)	2.49E+07	kg CO_2e	2.49E+07	kg CO_2e	0	kg CO_2e												
Bull activities (transportation)	3.14E+06	kg CO_2e	3.14E+06	kg CO_2e	0	kg CO_2e												
Yearling-fed system activities (transportation)							1.08E+08	kg CO_2e	1.08E+08	kg CO_2e	6,954	kg CO_2e						
Calf-fed system activities (transportation)							6.59E+07	kg CO_2e	6.59E+07	kg CO_2e	4,410	kg CO_2e						

Total GWP for BMP

kg CO_2e **1.22E+10** **Cow/Calf** **5.69E+09** **Feedlot** **3.04E+09** **Beef Industry**

Total Change in GWP for BMP

kg CO_2e **-6.27E+05** **-2.48E+06** **-7.28E+05**

Total change in emissions **-3,839** **tonnes**

Overall Baseline GWP (2001)

kg CO_2e/kg live weight **14.70524**

Overall Baseline GWP (2010)

kg CO_2e/kg live weight **14.70492**

Overall BMP GWP

kg CO_2e/kg live weight **14.70223**

Change in overall GWP from 2001

kg CO_2e/kg live weight **-0.0030**

Change in overall GWP from 2010

kg CO_2e/kg live weight **-0.0027**

Change in GWP per kg of beef affected from 2010

kg CO_2e/kg live weight **-1.285** **(total change in GHG emissions divided by total weight of cattle affected)**

Notes:
Energy generation emissions divided by the number of cattle on cow/calf vs feedlo
Feedlot and pasture activities are divided as per below