**300** **DA13**

Projet de construction d'une usine de fabrication d'engrais à Bécancour **6211-10-019**

# IFFCO Canada

## Urea comparative carbon footprint

Carbon footprint report

4 September 2013

Building a better working world

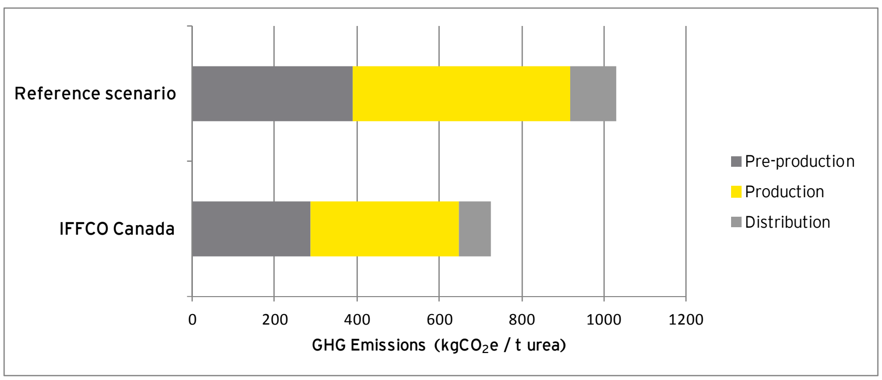
# Executive Summary

In preparation for public hearings concerning its projected urea plant in Bécancour (Québec), IFFCO Canada has undertaken work to evaluate the carbon footprint of urea over its life cycle. In this report, potential life cycle greenhouse gas (GHG) emissions of two different products are compared: IFFCO Canada urea and a reference urea. GHG emissions of both products are assessed using the *GHG Protocol Product Life Cycle Accounting and Reporting Standard* (or "GHG Protocol Product Standard").

Granular urea is most commonly used as a nitrogen fertilizer. However, a smaller but significant portion of the urea produced worldwide serves as an industrial input. While the exact share going to each application is unknown, it is assumed to be equal for both the IFFCO Canada scenario and the reference scenario. Furthermore, the use and end-of-life phases are considered identical for both scenarios. Hence, the type of inventory is cradle-to-gate as the use and end-of-life phases are excluded from the boundary. The life cycle stages included in the inventory boundary are raw material extraction and processing, urea production and transport to the distributor's warehouses.

For the IFFCO Canada scenario, the GHG inventory is calculated for year 2018 based on technical design figures, assuming the plant operates at full capacity (1,300 kt of granular urea par year). IFFCO Canada urea is assumed to be distributed in Quebec, Ontario, Eastern US and Western Europe (the "distribution mix") based on IFFCO Canada's marketing plan. In the reference scenario, for each of these regions, a projected "supply mix" is estimated, based on the current importing countries and market evolution perspectives. In 2018, in the "business-as-usual" scenario (i.e. without production from IFFCO Canada), regions in the distribution mix are thus expected to rely on domestic production (other than IFFCO Canada) and imports from main urea exporters (i.e. Eastern Europe, North Africa and the Middle East).

Inventory results are modelled and expressed in terms of $CO_2$ equivalent ($CO_2e$) based on the latest Global Warming Potentials (GWPs) published by the Intergovernmental Panel on Climate Change (IPCC). Cradle-to-gate GHG emissions by ton of urea are respectively equal to 725 $kgCO_2e$ for the IFFCO Canada scenario and 1029 $kgCO_2e$ for the reference scenario. Results are broken down by life cycle stage in the figure below.




Cradle-to-gate emissions for the IFFCO Canada urea are approximately 30% lower than for the reference scenario. Three main factors explain this difference:

- Lower natural gas use at IFFCO Canada's plant, due to energy efficient technologies and the use of electricity driven auxiliary equipment.
- Low carbon footprint of Québec's grid mix, due to a high reliance on hydroelectricity.
- Reduced distribution distances for most distribution routes.

A critical review was performed by a third party panel and directed by the Interuniversity Research Centre for the Life Cycle of Products, Processes and Services (CIRAIG). The panel came to the conclusion that methods used to carry out the inventory are consistent with the GHG Protocol Product Standard, are scientifically and technically valid and that the data used are appropriate and reasonable for public reporting.

# Sommaire exécutif

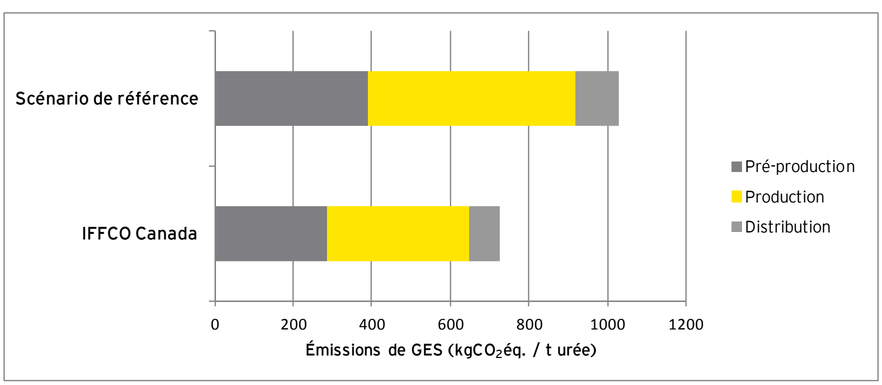
**Mise en garde:** Ce sommaire exécutif est basé sur l'ensemble des hypothèses et sources d'informations présentées de manière détaillée dans le rapport complet intitulé « *IFFCO Canada: Urea comparative carbon footprint - Carbon Footprint report* » daté du 4 Septembre 2013, dont il fait partie intégrante.

En préparation des audiences publiques concernant le projet de construction d'une usine d'urée à Bécancour (Québec), IFFCO Canada a entrepris des travaux pour évaluer l'empreinte carbone de l'urée sur son cycle de vie. Les émissions potentielles de gaz à effet de serre (GES) sur le cycle de vie de deux produits différents sont ainsi comparées: l'urée d'IFFCO Canada et l'urée de référence. Les émissions de GES de ces deux produits sont évaluées selon le *GHG Protocol Product Life Cycle Accounting and Reporting Standard* (ou « GHG Protocol Product Standard »).

L'urée granulaire est le plus couramment utilisée comme engrais azoté, mais une portion non négligeable de la production mondiale sert comme intrant pour divers procédés industriels. Comme la répartition exacte entre ces deux applications est inconnue, elle est supposée être la même pour le scénario IFFCO Canada et le scénario de référence. De plus, les phases d'utilisation de l'urée et de fin de vie sont raisonnablement supposées identiques pour les deux scénarios comparés. Par conséquent, l'utilisation et la fin de vie sont exclues des frontières du système. Les étapes du cycle de vie incluses dans l'analyse comparative sont donc du « berceau à l'entrepôt », soit: l'extraction et la transformation des matières premières, la production d'urée et le transport vers les entrepôts des distributeurs.

Pour le scénario IFFCO Canada, l'empreinte carbone est calculée pour l'année 2018 sur la base des données de conception de l'usine, en supposant que celle-ci fonctionne à capacité nominale (1300 kT d'urée granulaire par année). L'urée d'IFFCO Canada est supposée être distribuée au Québec, en Ontario, dans l'Est des États-Unis et en Europe de l'Ouest, sur la base des plans de commercialisation d'IFFCO Canada. Dans le scénario de référence, pour chacune de ces régions, l'approvisionnement futur est estimé en fonction des pays d'où est actuellement importée l'urée, et des perspectives d'évolution du marché. Dans le scénario de référence, c'est-à-dire en l'absence de production d'IFFCO Canada, l'approvisionnement en urée des régions visées par IFFCO Canada pour l'année 2018 reposerait ainsi à la fois sur la production domestique (autre que IFFCO Canada) et les importations des principaux exportateurs d'urée (Europe de l'Est, Nord de l'Afrique et Moyen-Orient).

Les résultats de l'empreinte carbone sont modélisés et exprimés en termes d'équivalent $CO_2$ ($CO_2$éq.) selon les plus récents potentiels de réchauffement de la planète (PRP) publiés par le Groupe d'experts intergouvernemental sur l'évolution du climat (GIEC). Les émissions de GES « du berceau à l'entrepôt » sont respectivement égales à 725 kg$CO_2$éq. par tonne d'urée pour le scénario IFFCO Canada et 1029 kg$CO_2$éq. par tonne d'urée pour le scénario de référence. Les résultats sont présentés par étape du cycle de vie dans la figure ci-dessous.



Les émissions du « berceau à l'entrepôt » de l'urée IFFCO Canada sont environ 30% inférieures à celles du scénario de référence. Trois facteurs principaux expliquent cette différence:

- Une utilisation plus faible de gaz naturel à l'usine d'IFFCO Canada, en raison de technologies efficaces sur le plan énergétique et de l'utilisation d'équipement auxiliaire électrique.
- La faible empreinte carbone de l'électricité produite au Québec, soit l'hydroélectricité à forte majorité.
- Des distances de distribution réduites pour la plupart des marchés visés.

Une revue critique dirigée par le Centre interuniversitaire de recherche sur le cycle de vie des produits, procédés et services (CIRAIG) a été réalisée par un comité d'experts indépendants. Le comité est arrivé à la conclusion que les méthodes utilisées pour effectuer l'inventaire sont conformes au *GHG Protocol Product Standard*, sont scientifiquement et techniquement valides et que les données utilisées sont appropriées et raisonnables pour une divulgation publique des résultats.

Les résultats présentés dans ce rapport sont uniquement basés sur les hypothèses et pratiques d'IFFCO Canada. Le scénario de référence a été conçu spécifiquement pour être comparé au modèle prévu de production et de distribution d'IFFCO Canada. Les résultats ne sont pas comparables à d'autres entreprises ou d'autres produits. Le lecteur peut se référer au *GHG Protocol Product Standard* pour plus d'informations sur la méthodologie de l'empreinte carbone.

Les travaux que nous avons réalisés ne constituent pas une mission de certification, d'examen ou une autre forme d'attestation selon les normes de comptabilité ou de vérification généralement reconnues. Nous n'avons pas audité ni vérifié les informations qui nous ont été fournies dans le cadre de ce mandat.

Ce rapport a été préparé pour IFFCO Canada. Notre rapport ne considère pas d'éventuels enjeux reliés à son utilisation par des tierces parties. Toute tierce partie qui décidait d'utiliser ce rapport le ferait entièrement à ses propres risques. Ernst & Young décline toute responsabilité liée à l'utilisation de ce rapport par des tiers.

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*NOTE: This report has been prepared to assist IFFCO Canada. Our report has not considered issues relevant to third parties. Any use a third party may choose to make of this report is entirely at its own risk.*

# 1. General information

## 1.1 Context

In preparation for public hearings concerning its projected urea plant in Bécancour (Québec), IFFCO Canada Enterprise Limited (below "IFFCO Canada") has undertaken work to evaluate the carbon footprint of urea over its life cycle. Urea is mainly used as mineral nitrogen fertilizer in agriculture. It can also be used as an input in different industrial processes.

In this report, potential life cycle greenhouse gas (GHG) emissions of two different products are compared: IFFCO Canada urea and a reference urea. The nature of this study is prospective, since IFFCO Canada's plant is expected to start its operations in 2017.

Potential life cycle GHG emissions of both products are assessed from cradle-to-gate using the GHG Protocol Product Life Cycle Accounting and Reporting Standard (below "GHG Protocol Product Standard") (WRI & WBCSD, 2011). The carbon footprint of the reference urea is calculated based on the markets where IFFCO Canada urea is expected to be distributed and the projected supplying countries for these regions in 2018.

The carbon footprint was calculated by Ernst & Young LLP (below "Ernst & Young") for IFFCO Canada. Contact information is provided in Table 1-1.

**Table 1-1 – Contact information**

| Organization | Contact information |
|---|---|
| IFFCO Canada | Manish Gupta (mg@iffcocan.com)<br>Chief Executive Officer |
| | Simon Pillarella (simon@iffcocan.com)<br>Vice President, Business Development |
| | Steve Psutka (sp@iffcocan.com)<br>Senior Vice-President, Technical |
| Ernst & Young | Thibaut Millet (thibaut.millet@ca.ey.com)<br>Associate Partner, Climate Change and Sustainability Services |
| | Stéphane Villemain (stephane.villemain@ca.ey.com)<br>Manager, Climate Change and Sustainability Services |
| | Bruno Gagnon (bruno.gagnon@ca.ey.com)<br>Senior Advisor, Climate Change and Sustainability Services |

## 1.2 Urea production process

Urea is produced from ammonia ($NH_3$) and carbon dioxide ($CO_2$), both outputs of the ammonia production process. Ammonia production consists of two main steps: hydrogen ($H_2$) production from steam reforming of natural gas and ammonia synthesis from hydrogen and atmospheric nitrogen ($N_2$). Urea is synthesized in liquid form (urea melt) and goes through a granulation process before being sold as a final product in granular form.

Main inputs for ammonia and urea production are natural gas (mainly composed of methane or $CH_4$), water ($H_2O$) and air (mainly composed of nitrogen and oxygen). An overview of the production process is provided in Figure 1-1. Readers interested in a more detailed presentation of the ammonia and urea production processes can consult the *Environmental Impact Assessment Study submitted to the Ministry of Sustainable Development, Environment, Wildlife and Parks* (SNC-Lavalin, 2013).

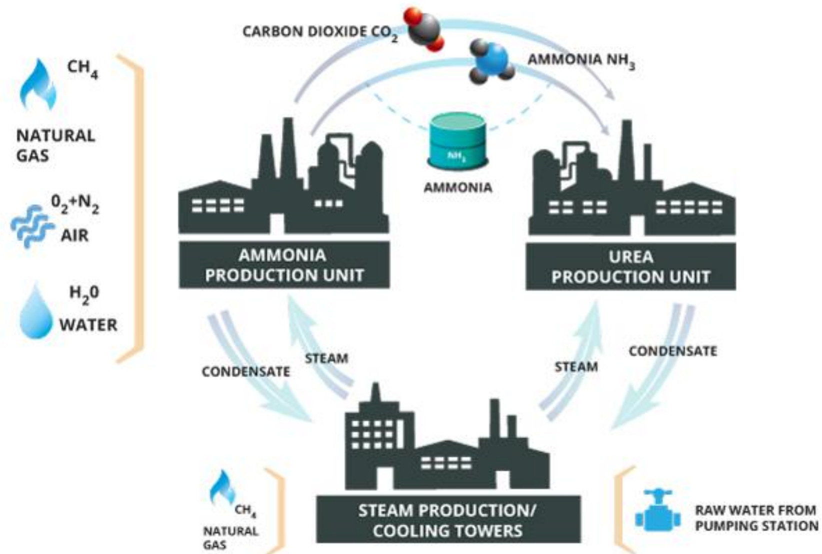


Figure 1-1 – Urea production process

## 1.3 Literature review of urea carbon footprint

A review of studies on urea production, as well as upstream and downstream processes, was performed to estimate typical values for the carbon footprint of urea and to identify main contributing life cycle stages. A detailed description of each life cycle stage of urea can be found in Section 3 of this report.

Figures on GHG emissions occurring during each life cycle stage of urea were taken from references provided in Table 1-2. In cases where values for a specific stage were not directly available, they were estimated based on multiple references. Minimum and maximum values found, as well as corresponding production or use scenarios, are discussed in Table 1-2.

Table 1-2 – Results from the literature review of urea carbon footprint

| Stage | References | Minimum GHG emission value (for 1 kg urea) | Maximum GHG emission value (for 1 kg urea) |
|---|---|---|---|
| Material acquisition and pre-processing* | Forster & Perks (2012), Skone et al. (2011), Stephenson et al. (2011), Zhang et al. (2013). | 0.05 $kgCO_2e$: natural gas extraction, processing and transmission near urea plant in Western Europe. | 0.4 $kgCO_2e$: coal mining, processing and transport to urea plant in China. |
| Production | GHD (2009), Ledgard et al. (2011), Fable et al. (2002), Wood & Cowie (2004), Yara International (2010), Zhang et al. (2013). | 0.4 $kgCO_2e$: modern technology in Western Europe using natural gas as fuel and feedstock. | 1.8 $kgCO_2e$: urea from ammonia produced by coal-gasification in China. |
| Distribution and storage | Ledgard et al. (2011), Fable et al. (2002), Wood & Cowie (2004). | 0.02 $kgCO_2e$: transport from urea plant to field for regional use. | 0.2 $kgCO_2e$: transport from Persian Gulf plant to New Zealand field. |

*Note: emissions for material acquisition and pre-processing are calculated based on energy consumption (in MJ/kg) for ammonia production (IEA, 2007) and urea production (European Commission, 2007) as well as emission factors for fuel extraction, processing and distribution (in $gCO_2e/MJ$).

Unlike other life cycle phases, emissions from fertilizer use are not associated with extraction or transformation processes, but are generated through biochemical reactions that take place in the fields after land application. When used as an industrial input, emissions from the use of urea will depend on the type of product in which it is incorporated.

Cradle-to-gate emissions (including fuel extraction, processing, transport, ammonia and urea production) are highly influenced by the fuel from which ammonia is derived. The highest emissions correspond to urea production in China from coal feedstock while lowest emissions are observed with energy efficient ammonia plants using natural gas feedstock (e.g., Canada or Western Europe). Urea from Eastern Europe stands between both scenarios. While natural gas serves as feedstock in Eastern Europe, plants are less energy efficient and higher fugitive emissions occur during natural gas transmission. GHG emissions from distribution have a low relative contribution to the overall carbon footprint of urea.

Soil emissions, which occur between land application and plant uptake, also contribute to the total carbon footprint of urea. Due to the composition of urea ($NH_2$-CO-$NH_2$), $CO_2$ emissions from hydrolysis (0.733kg$CO_2$ for 1 kg of urea) are added to $N_2O$ emissions associated with nitrification and denitrification which occur afterwards. $N_2O$ emissions from nitrification and denitrification are usually higher than $CO_2$ emissions from urea hydrolysis. Other types of nitrogen fertilizers which contain ammonium ($NH_4$) or nitrate ($NO_3$) do not release $CO_2$ emissions after land application.

$N_2O$ emissions associated with nitrogen fertilizers are highly influenced by local and regional factors (e.g., climate, topography and soil characteristics. While emissions can be influenced by the type of nitrogen fertilizer applied, the models proposed by the IPCC (2006b) and Rochette et al. (2008) to calculate emissions for national GHG inventories do not allow such differentiation. This approach is consistent with the results from the meta-analysis performed by Bouwman et al. (2002), which shows no significant difference between main fertilizer types such as ammonium nitrate (AN), calcium ammonium nitrate (CAN), urea ammonium nitrate (UAN), urea and organic fertilizers.

Based on Rochette et al. (2008), IPCC (2006b) and FAO & IFA (2001), the average emission factor for fertilizer use in the semi-arid brown soils of the Canadian Prairies is equal to 2.9kg$CO_2$e per kg of N applied and is equal to 7.7kg$CO_2$e per kg of N applied for the Québec-Ontario region. Hence, for urea with a nitrogen content of 46%, emissions from the use phase in Canada will typically vary between 1.5kg$CO_2$e and 3.5 kg$CO_2$e per kg of urea. Emissions resulting from the use of nitrogen fertilizers can be reduced through the implementation of best agricultural practices.

# 2. Scope

IFFCO Canada's plant in Bécancour is expected to start its operations in 2017. Both granular urea and diesel exhaust fluid (or "DEF", a solution with 32.5% urea) will be produced at IFFCO Canada's plant. Since most of the urea (approximately 85%) will be transformed into granules, the current study focuses on granular urea only.

The studied products are:

- Urea in granular form (nutrient content: 46-0-0) to be produced in 2018 at IFFCO Canada's projected plant in Bécancour, Québec and distributed in North America and Western Europe ("IFFCO Canada scenario" or "IFFCO Canada urea").
- Urea in granular form produced by other plants, distributed in 2018 in North America and Europe, in the same markets as IFFCO Canada's projected markets ("reference scenario" or "reference urea").

Granular urea is most commonly used as a nitrogen fertilizer. However, a significant portion of the urea produced serves as an industrial input, namely for the fabrication of urea-formaldehyde resin. While the exact share going to each application is unknown, it is assumed to be equal for the IFFCO Canada scenario and the reference scenario. Hence, the type of inventory is cradle-to-gate as the use and end-of-life phases are excluded from the boundary. The life cycle stages included in the inventory boundary are raw material extraction and processing, urea production and transport to the distributor's warehouses.

Coated urea is also available on the market, but is mostly destined for non-agricultural use (golf courses, horticulture, landscaping, etc.) and production volumes are low compared to non-coated urea (Landels, 2003) therefore not relevant for the purpose of this study.

As required by the GHG Protocol Product Standard, the inventory is developed following an attributional approach, i.e. using primary data provided by IFFCO Canada or average industry data.

The GHGs included in the inventory are: carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$), sulfur hexafluoride ($SF_6$), perfluorocarbons (PFCs) and hydrofluorocarbons (HFCs).

## 2.1 Unit of analysis

The unit of analysis is defined through the identification of the **function**, the **functional unit** and the **reference flow** (Table 2-1).

**Table 2-1 – Unit of analysis**

| | |
|---|---|
| **Function** | Support plant growth by increasing the level of bioavailable nitrogen in the soil or serve as an input in industrial processes |
| **Functional unit** | 1 tonne of granular urea at the distributor's warehouse for IFFCO Canada's distribution mix (North America and Western Europe) in 2018 |
| **Reference flow** | 1 tonne of granular urea |

For more details on regions in which IFFCO Canada urea is expected to be distributed, refer to Section 3. The identification of the functional unit and the reference flow are coherent with recommendations in the GHG Protocol Product Standard for cradle-to-gate inventories. In the present case, the exact share between agricultural use and industrial use of urea is unknown, but does not differ between the IFFCO Canada scenario and the reference scenario.

No product category rules (PCR) or sector-specific guidance is used to calculate the carbon footprint because none were developed for mineral fertilizers in conformance with the GHG Protocol Product Standard.

## 2.2 Inventory date and version

This is the first version of the inventory, for both IFFCO Canada urea and the reference urea. The inventory was completed in July 2013. For IFFCO Canada urea, the inventory is based on design data for the projected plant expected to begin operations in 2017. For the reference urea, the inventory is based on recent industrial and market data.

## 2.3 Limitations

The results presented in this report are unique to the assumptions and practices of IFFCO Canada. The reference scenario has been specifically developed to be compared to IFFCO Canada's planned distribution model. The results are not meant to be a platform for comparability to other companies and/or products. Hence, the results for IFFCO Canada urea or the reference scenario urea should not be used by a third party for comparisons outside the scope of this study.

Even for similar products, differences in unit of analysis, use and end-of-life stage profiles, and data quality may produce incomparable results. The reader may refer to the GHG Protocol Product Life Cycle Accounting and Reporting Standard (WRI & WBCSD, 2011) for a glossary and additional insight into the GHG inventory process.

The procedures we performed do not constitute an audit, examination or a review in accordance with generally accepted auditing standards or attestation standards. We have not audited or otherwise verified the information supplied to us in connection with this engagement.

Future events are inherently unpredictable. It is not possible to predict future events or anticipate all potential circumstances. As such, actual results achieved for the periods covered in this document may vary.

# 3. Boundary setting

The life cycle stages of urea fertilizer are described in Table 3-1. Natural gas is the most widely used feedstock and fuel globally for ammonia production. While coal and naphtha are used in some countries (e.g., China and India), urea exports from these countries to Eastern North America and Western Europe are marginal. Hence, the description focuses on natural gas based urea only.

**Table 3-1 – Life cycle stage of urea fertilizer**

| Stages | Sub-stages | Description |
|---|---|---|
| Material acquisition and pre-processing | Natural gas extraction and processing | Extraction includes site preparation, well drilling and well completion. Afterwards, natural gas is treated to eliminate impurities (water, oil, hydrocarbons and sulfur). The extraction process is influenced by the type of natural gas: conventional gas, coalbed methane, tight sand gas or shale gas. Conventional gas can either be "associated" (found along with oil) or "non-associated" (isolated in distinct reservoirs). North American natural gas production consists of a mix of conventional and unconventional gas, while a large portion of natural gas produced worldwide comes from conventional sources. |
| | Natural gas transport and distribution | Following processing, natural gas is transported in long distance pipelines before reaching regional and local distribution networks. Urea plants are typically connected to high pressure distribution networks, near pipelines. Natural gas will be supplied to the IFFCO Canada's plant by Gaz Métro. |
| | Water withdrawal and treatment | Water is required for steam reforming, but also for cooling and other purposes. Water used in the ammonia and urea production process needs to be demineralized. |
| | Production of electricity and other auxiliary materials | Electricity and chemicals (e.g., metallic catalysts, lime, caustic soda, sulfuric acid, activated methyl diethanolamine) are required for the ammonia and urea production process. |
| Production | Ammonia production | Ammonia is synthesized from hydrogen and nitrogen. The former is extracted from natural gas through the steam-reforming process while the latter comes from air. While natural gas is the most widely used hydrocarbon for ammonia production, coal and heavier hydrocarbons can also serve as feedstock. These feedstock are excluded because they are used in countries which do not typically export urea in Eastern North America or Western Europe. |
| | Urea production | Urea is synthesized by combining ammonia and carbon dioxide. Carbon dioxide is extracted from process gases during ammonia production and reused during urea production. Urea is concentrated, then granulated or diluted in water. |
| | Other auxiliary operations | Various systems are used for steam production, energy recovery, atmospheric pollution control and wastewater treatment. Includes the treatment of waste resulting from operations (catalysts, oils, sludge). |
| Distribution and storage | Transport from plant to distributor's warehouses | Through various modes (conveyor, barge, ship, train or truck) urea is transferred from the plant to the distributor's warehouses and stored. |
| | Transport from distributor's warehouses to final user (excluded) | Urea is shipped from the warehouses to the final user, for agricultural or industrial applications. |
| Use (excluded) | Agricultural applications | Urea is applied to the land and converted to nitrate by microorganisms before being assimilated by plants. |
| | Industrial applications | In solid form, urea can be used to produce various resins, including urea-formaldehyde. |
| End-of-life (excluded) | Agricultural applications | Surface run-off and leaching. |
| | Industrial applications | Depends on the end-of-life of materials and products made from urea. |
| | Packaging disposition | The majority of urea produced is bulk shipped and do not require packaging. No bagging system is planned for IFFCO Canada's plant. |

## 3.1 Boundary for urea product life cycle

The processes, as well as the associated GHG emissions and removals, included in the inventory are identified through the boundary setting. Only the processes corresponding to the cradle-to-gate life cycle stages are included in the boundary, as represented in Figure 3-1.

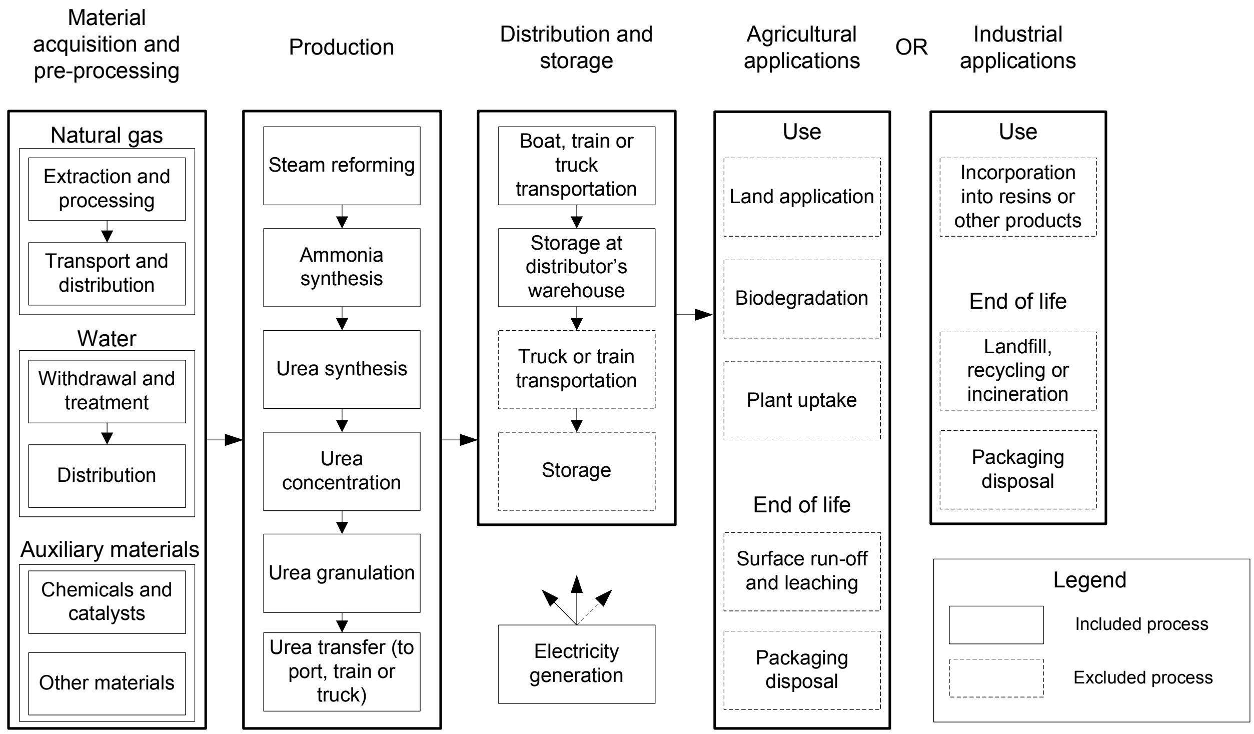


Figure 3-1 - Inventory boundary for granular urea

Non-attributable processes (i.e., processes not directly connected to the studied product) are not included in the boundary. Non-attributable processes include infrastructure and equipment, corporate activities, transport of employees to and from work, etc. In both scenarios, the urea form will be the same (granular urea with anti-caking agent, such as urea-formaldehyde)

The boundary is set for a cradle-to-gate inventory and life cycle stages from the distributor's warehouse until the end of life are excluded. For agricultural applications, $N_2O$ emissions following land application of urea are likely to be a main contributor to the cradle-to-grave carbon footprint, as shown in Section 1.3. However, the use phase is expected to be identical for both the IFFCO Canada scenario and the reference scenario.

## 3.2 IFFCO Canada scenario and reference scenario

For the IFFCO Canada scenario, urea will be produced in Québec and distributed by La Coop Fédérée or other distributors in North America or Western Europe. The production capacities for granular urea and DEF are provided in Table 3-2 (SNC-Lavalin, 2013).

For the first full year of operation (2018), the plant is expected to produce only granular urea at the average design capacity (1,300 kt per year).

Table 3-2 – IFFCO Canada's urea production capacity

| Production scenarios | Operating days per year | Total production (kiloton per year) | Projected production (kiloton per year) | |
|---|---|---|---|---|
| | | Granular urea eq. | Granular urea | DEF (32,5% urea) |
| Annual average design capacity | 340 | 1,300 | 1,100 | 630 |
| Annual average expected capacity (design +20%) | 340 | 1,600 | 1,300 | 760 |

We assume the urea from Bécancour will be distributed to various regional markets, as broken down in Table 3-3. Those values are in line with the marketing plan developed for IFFCO Canada by a third party based on current and projected urea consumption, current distribution routes as well as production and distribution cost considerations.

Table 3-3 – Projected distribution regions and yearly quantities for IFFCO Canada

| Scenarios | Québec | Ontario | Eastern US[1] | Western Europe[2] |
|---|---|---|---|---|
| Base case | 250 kt (20%) | 200 kt (15%) | 600 kt (45%) | 250 kt (20%) |
| North America focused | 325 kt (25%) | 200 kt (15%) | 650 kt (50%) | 125 kt (10%) |
| Europe focused | 250 kt (20%) | 125 kt (10%) | 525 kt (40%) | 350 kt (30%) |

At the moment, there is some level of uncertainty associated with the values in Table 3-3, mainly because market conditions in 2018 will depend on many factors. A sensitivity analysis based on two alternative scenarios (Table 3-3) is performed to account for this uncertainty. For the "North America focused" scenario, a higher share of the total production is shipped to Québec and Eastern US while a lower share is shipped to Western Europe. The "Europe focused" scenario corresponds to the opposite situation, where shipped quantities are transferred from Ontario and Eastern US to Western Europe. The current import countries for the same regional markets (where La Coop Fédérée and other distributors are expected to sell IFFCO Canada urea) are listed in Table 3-4. The values correspond to average quantities imported over the 2010–2012 period.

Table 3-4 – Current urea supply mix for Eastern Canada and North Eastern US (average 2010-2012)

| Québec | | | Ontario | | | Eastern US[3] | | |
|---|---|---|---|---|---|---|---|---|
| Country | Urea (kt) | % | Country | Urea (kt) | % | Country | Urea (kt) | % |
| Russia | 115.1 | 27.4 | Canada | 44.6 | 24.2 | Oman | 696.5 | 13.7 |
| Germany | 60.2 | 14.3 | US | 37.6 | 20.3 | Canada | | 12,8 |
| Egypt | 54.4 | 13.0 | Egypt | 26.6 | 14.4 | Saudi Arabia | 582.0 | 11.5 |
| Ukraine | 39.1 | 9.3 | Russia | 17.0 | 9.2 | Egypt | 573.8 | 11.3 |
| Venezuela | 35.9 | 8.6 | Ukraine | 9.0 | 4.9 | Kuwait | 486.8 | 9.6 |
| Libya | 33.3 | 7.9 | Lithuania | 6.0 | 3.3 | Qatar | 458.6 | 9.1 |
| Qatar | 11.9 | 2.8 | Switzerland | 6.0 | 3.3 | Trinidad | 396.6 | 7.8 |
| Oman | 10.4 | 2.5 | Venezuela | 5.5 | 3.0 | Bahrain | 367.1 | 7.2 |
| Lithuania | 9.8 | 2.3 | UK | 4.6 | 2.5 | Venezuela | 356.4 | 7.0 |
| Others | 50.0 | 11.9 | Others | 27.6 | 15.0 | Others | | 12.8 |

Sources: Canada: (Statistics Canada, 2012), (Statistics Canada, 2013); US: (USDA, 2013), (Prud'homme, 2012).

[1] Mainly in the US East North Central division (WI, IL, MI, IN, OH) and to neighboring States (NY, PA, MN).

[2] Mainly France, Spain, Italy and the United Kingdom (largest urea importers in Western Europe).

[3] Based on total imports for the US, from which are subtracted quantities from countries supplying Western US regions (mainly China and Indonesia). Share of Canadian imports based on total values for the US. Does not include domestic supply, which accounts for 45% of total US consumption for the 2010-2012 period.

Unlike for Canada and the United States, detailed data for Western Europe is not publicly available. In 2011, the region relied on imports for approximately 40% of its consumption (Agrium, 2012). The main trading route is from Egypt to France (Agrium, 2012). Western Europe countries also import from Eastern Europe and the Middle East (Yara International, 2012).

Overall, urea production will mostly increase in regions where demand is following an upward trend (e.g., China and India) and in regions or countries where natural gas is abundant (e.g., Middle East, Algeria, Nigeria and Russia). Hence it is reasonable to expect that current trade partners for the US and Canada will in general remain the same. However, due to an increase in production capacity, these countries should rely less on imported urea for their supply in 2018. In Western Europe, both demand and production capacity are expected to remain stable (Heffer, 2013; Harrisson, 2013) and no major shift in the urea market is projected.

The reference urea will likely come from the Middle East, Eastern Europe, US, South America and Western Europe. Urea plants in those regions use natural gas as a feedstock. The projected share in 2018 for each region is provided in Table 3-5.

**Table 3-5 – Projected supply mix for Eastern Canada, North Eastern US and Western Europe (2018)**

| **Québec** | | |
|---|---|---|
| Region | Supply | Comments |
| Eastern Europe | 50% | Slight increase compared to 2010–2012 following the recent trend observed. |
| North Africa | 35% | Similar to pre-2010 situation, due to a return to normal production levels in Egypt or increase of imports from Algeria from new production capacity. |
| Middle East | 5% | No change compared to 2010-2012, Middle East (Persian Gulf countries) to remain one of the main exporting regions in the World. |
| Western Europe | 10% | Similar to pre-2010 situation, production in Western Europe mainly to supply regional market. |
| South America | 0% | Production from Venezuela and Trinidad & Tobago expected to supply the US market as well as the expanding South American market. |
| **Ontario** | | |
| Region | Supply | Comments |
| Canada | 30% | No change compared to 2010-2012, increased capacity projected in Western Canada mostly to supply the Prairies or Western US. |
| United States | 25% | No change compared to 2010-2012, increased capacity projected in the United States mostly to supply regional market. |
| Eastern Europe | 25% | Slight increase compared to 2010–2012 following the recent trend observed. |
| North Africa | 20% | Similar to pre-2010 situation, due to a return to normal production levels in Egypt or increase of imports from Algeria due to new production capacity. |
| **North Eastern US** | | |
| Region | Supply | Comments |
| United States | 55% | Reduced reliance on imports for the US when compared to 2010–2012 due to increased local production capacity. Projected level of imports in North Eastern US similar to the level for the entire country. |
| Middle East | 25% | Small reduction compared to 2010-2012, Middle East (Persian Gulf countries) to remain one of the main exporting regions in the World. |
| Canada | 10% | No change when compared to 2010-2012. Imports from Canada in Eastern US slightly lower than for the entire US because Canadian urea is mostly destined for North Western States. |
| South America | 5% | No change compared to 2010-2012, South American production mostly going to US and regional markets. |
| Eastern Europe | 5% | No change compared to 2010-2012, Eastern Europe (Russia and Ukraine) to remain one of the main exporting regions in the World. |

Table 3-5 (continued)

| **Western Europe** | | |
|---|---|---|
| Region | Supply | Comments |
| Western Europe | 60% | No change compared to 2010–2012 situation, projected consumption and production capacity to remain approximately the same. |
| North Africa | 20% | The major trade route for incoming urea in Europe is from Egypt and production capacity from Algeria will increase between 2012 and 2018. |
| Middle East | 10% | Approximate value, Middle East (Persian Gulf countries) to remains of the main exporting region in the World. |
| Eastern Europe | 10% | Approximate value, Eastern Europe (Russia and Ukraine) to remain of the main exporting region in the World. |

Based on the proposed marketing mix (Table 3-3) and the supply mix (Table 3-5), the average reference urea to which IFFCO Canada is compared is primarily composed of urea manufactured in the US (29%), Eastern Europe (18%) the Middle East (17%) and Western Europe (14%).

## 3.3 Time period of the inventory

The inventory time period is dependent upon the use and end-of-life stages. In the case of urea, distribution, storage and use cover a period of approximately 3 to 12 months. Carbon stored in urea (0.2 kg of C per kg of urea) will be released during use in agricultural applications and can be released at the end-of-life of products made from urea in industrial applications.

The inventory results are calculated for the year 2018, both for the IFFCO Canada urea and the reference urea. This corresponds to the expected first full year of operation for the IFFCO Canada plant in Bécancour. Production is expected to rise during subsequent and reach 20% over the design capacity level. However, this is not expected to influence GHG emissions intensity in terms of $kgCO_2e$ by ton of urea produced. Furthermore, a shorter time frame was preferred because mid to long term market conditions are hard to predict and lead to a higher uncertainty for both IFFCO Canada's marketing mix and the projected supply mix for the reference scenario.

## 3.4 Land-use change impacts

Since the product’s life cycle under study does not include biogenic materials (at least to a significant level), no land-use change is taken into account. Furthermore, no land-use change is associated with the construction of the plant since it will be located on a previously developed lot.

# 4. Allocation

Allocation is required when a single process has multiple valuable products as outputs (e.g., the refining of crude oil into various petroleum co-products). In these situations, inputs and emissions for the entire process need to be allocated to the various co-products following appropriate methods.

IFFCO Canada's projected plant at Bécancour is designed to allow the production of granular urea and DEF. After concentration, urea melt can either go through the granulation process or be mixed with demineralized water to obtain DEF.

For the present study, the plant capacity and inventory values are given in a scenario where all the concentrated urea goes through the granulation process. Therefore, no allocation is required for the ammonia and urea production life cycle stage.

For transport processes, mass allocation is used (i.e. emissions are calculated based on factors for the transportation of 1 ton of freight over 1 km). For waste generated at the IFFCO Canada plant, the cut-off approach is used (i.e. the impacts and credits for recycled materials are allocated to user of these materials and not to IFFCO Canada urea).

# 5. Data collection and quality

According to the GHG Protocol Product Standard, the assessment of a life cycle GHG inventory typically requires three types of data:

- **Direct emissions data**, which are determined through continuous monitoring, stochiometric equation balancing, mass balance approaches or other similar methods.
- **Activity data**, which capture the physical inputs, outputs and other metrics for processes (e.g., energy consumption, material consumption, distance travelled, etc.)
- **Emission factors**, used to calculate GHG emissions from activity data (e.g., kg$CO_2$ for 1 kWh of energy or 1 kg of material).

Depending on its source, data can either be classified as primary or secondary:

- **Primary data** is specific to the processes included in the product's life cycle boundary. It can be collected in the reporting company or from its suppliers.
- **Secondary data** are not specific to the product under study and is taken from commercial databases, industry reports, literature, etc.

## 5.1 Data sources

Main data sources for both IFFCO Canada urea and the reference urea are listed in Table 5-1. Additional data sources are considered to evaluate scenario uncertainty (see Section 7).

**Table 5-1 – Data sources for significant processes**

| Stages | Sub-stages | Data sources |
|---|---|---|
| Material acquisition and pre-processing | Natural gas extraction and processing | ‣ Canada and US: GHGenius (S&T[2] Consultants, 2012).<br>‣ Western Europe: ecoinvent (Faist Emmenegger et al., 2007) and ESU-services (Schori and Frischknecht, 2012).<br>‣ Russia, North Africa and Middle East: ESU-services (Schori and Frischknecht, 2012).<br>‣ South America: based on Russia data as proxy. |
| | Natural gas transport and distribution | ‣ Canada and US: GHGenius (S&T[2] Consultants, 2012).<br>‣ Western Europe: ecoinvent (Faist Emmenegger et al., 2007) and ESU-services (Schori and Frischknecht, 2012).<br>‣ Russia, North Africa and Middle East: ESU-services (Schori and Frischknecht, 2012).<br>‣ South America: based on Russia data as proxy.<br>‣ Transmission and distribution distances: location of natural gas reserves (US Energy Information Administration, 2013a) and location of urea plants (ICIS, 2013) for each region. |
| | Water withdrawal and treatment | ‣ Ecoinvent (Althaus et al., 2007). |
| | Electricity production | ‣ Ecoinvent (Dones et al., 2007).<br>‣ Grid mix for Québec and other urea supplying countries, states or provinces (Alberta, US, Venezuela, Trinidad and Tobago, Russia, Germany, Egypt, Oman, Saudi Arabia and Kuwait) are adapted using recent statistics covering the 2009-2012 period. |
| | Production of other auxiliary materials | ‣ Ecoinvent (Althaus et al., 2007). |

| Stages | Sub-stages | Data sources |
|---|---|---|
| Production | Ammonia production | ▸ IFFCO Canada: design data and SEIA report (SNC-Lavalin, 2013).<br>▸ Reference scenario: IEA (2007), Natural Resources Canada (2008) and IFA (2009) for energy and ecoinvent (Althaus et al., 2007) for other inputs. |
| | Urea production | ▸ IFFCO Canada: design data and SEIA report (SNC-Lavalin, 2013).<br>▸ Reference scenario: European Commission (2007) and ecoinvent (Nemecek and Kägi, 2007). |
| | Other auxiliary operations | ▸ IFFCO Canada: design data and SEIA report (SNC-Lavalin, 2013).<br>▸ Reference scenario: included in ammonia production and urea production. |
| Distribution and storage | Transport from the plant to the distributor's warehouses | ▸ IFFCO Canada: distances based on La Coop Fédérée current distribution model and IFFCO Canada's projected marketing mix for North America and Western Europe.<br>▸ Reference scenario: distances based on the location of urea plants (ICIS, 2013) for each region, the approximate location of warehouses and the projected suppliers for North American and Western Europe regional markets.<br>▸ Emissions from transportation: ecoinvent (Spielmann et al., 2007). |

Direct emissions, activity data and emission factors used for both the IFFCO Canada and the reference scenarios are provided in Appendix A for main contributing processes.

## 5.2 Data quality

Data quality for each process in the inventory boundary is assessed using the data quality indicators described in Table 5-2 (WRI & WBCSD, 2011).

**Table 5-2 – Data quality indicators**

| Data quality indicators | Description |
|---|---|
| Technological representativeness | The degree to which the data reflects the actual technologies used. |
| Temporal representativeness | The degree to which the data reflects the actual time (e.g., year) or age of the activity. |
| Geographical representativeness | The degree to which the data reflects the actual geographic location of the activity (e.g., country or site). |
| Completeness | The degree to which the data are statistically representative of the relevant activity. Completeness depends on many factors including the percentage of sites for which data is used out of the total number of relevant sites, coverage of seasonal and other fluctuations in data, etc. |
| Reliability | The degree to which the sources, data collection methods and verification procedures used to obtain the data are dependable |

The qualitative evaluation for each data quality indicator is based on the scoring scheme presented in Table 5-3, adapted from WRI & WBCSD (2011). It is worth mentioning that the reference year for evaluating time representativeness is 2018, which corresponds to the projected full year of operation for IFFCO Canada's plant in Bécancour.

As recommended in the GHG Protocol Product Standard, specific circumstances are considered when applying the data quality scoring criteria, especially for time representativeness. This is reflected in using a higher age range when evaluating time representativeness for processes associated with energy infrastructures (mainly electricity and natural gas production). Since those infrastructures have a long lifespan, their overall performance is not expected to change quickly over time, given that production modes remain the same. Furthermore, fuel combustion emission factors are considered to be of good quality even if they are more than 10 years old, because they do not change significantly over time.

**Table 5-3 – Data quality scoring criteria**

| Score | Technology | Time | Geography | Completeness | Reliability |
|---|---|---|---|---|---|
| Very good | Data for the same technology | Data with less than 3 (or 5*) years of difference | Data from the same area | Data from all relevant sites over an adequate time period | Verified data based on measurements |
| Good | Data for a similar but different technology | Data with less than 6 (or 10*) years of difference | Data from a similar area | Data from more than 50% of sites over an adequate time period | Verified data partly based on assumptions or non-verified data based on measurements |
| Fair | Data for a different technology | Data with less than 10 (or 15*) years of difference | Data from a different area | Data from less than 50% of sites over an adequate time period or from less than 50% of sites for a short time period | Non-verified data partly based on assumptions or a qualified estimate |
| Poor | Data for an unknown technology | Data with more than 10 (or 15*) years of difference or age unknown | Data from an area that is unknown | Data from less than 50% of sites over a short time period | Non-qualified estimate |

*Note: for energy processes.

For significant processes (i.e. contributing to 5% or more of the total carbon footprint of IFFCO Canada urea or the reference urea) a descriptive statement on the sources, data quality and the efforts to improve data quality are reported in the following sections.

## 5.2.1 IFFCO Canada scenario

Data quality for processes contributing significantly to IFFCO Canada urea carbon footprint is discussed in Table 5-4.

For the Canadian natural gas process, data on shale gas extraction is based on a limited number of sites. However, shale gas is not expected to contribute significantly to the production mix in 2018 and the impact on data quality is considered low. The situation is different in the US, where shale gas is expected to contribute to approximately 40% of the total natural gas production in 2018 (Energy Information Administration, 2013b).

Emissions from natural gas extraction in the US are calculated in the GHGenius model, which integrates the 2010 emission factors recently from the US Environmental Protection Agency (USEPA). Those factors were criticized by the industry as they appear to be based on a limited amount of data. Hence, they were updated in the GHGenius model based on the more recent 2011 USEPA emission factors for natural gas. Emissions taken for the US in the updated GHGenius model for natural gas extraction and processing in the US (9,3kg$CO_2$e/GJ) sit between figures reported in Skone et al. (2011) for tight gas and shale gas (11kg$CO_2$e/GJ) and Stephenson et al. (2011) for shale gas (between 5.1 and 7.1 kg$CO_2$e/GJ) .

**Table 5-4 – Data quality for the IFFCO Canada scenario**

| Significant process | Data sources | Data quality | Efforts made to improve data quality |
|---|---|---|---|
| Ammonia and urea production | **Activity data:** natural gas and electricity use based on technical design.<br><br>**Emission factors:** IPCC (2006a) values for natural gas combustion. | Very good for all indicators, except for reliability, which is considered good because it partly relies on assumptions made during the design and it is not based on measurements at IFFCO Canada's plant. | None required. |
| Natural gas extraction, processing and transmission (Canada) | **Activity data and emission factors:** industry data and government statistics compiled in the GHGenius model (S&T$^2$ Consultants, 2012). | Data on conventional and non-conventional extraction methods are considered in the model.<br>Industry data (2000-2010) is combined with government statistics (2009-2011). The GHGenius model provides forecasted data (projected production mix, venting, flaring and fugitive emissions). | Use of forecasted data in 2018 provided in the GHGenius model for natural gas from Alberta delivered to Québec. |
| Natural gas extraction, processing and transmission (US) | **Activity data and emission factors:** industry data and government statistics compiled in the GHGenius model (S&T$^2$ Consultants, 2012). | No differentiation of extraction methods.<br>Government statistics are mostly used (2009-2011).<br>The GHGenius model provides forecasted data (venting, flaring and fugitive emissions). | Use of forecasted data to 2018 provided in the GHGenius model for natural gas from Central US.<br><br>Transmission distances adjusted to take into account the urea plant location (800km in the US and 1000km in Canada). |

The evaluation of each data quality criteria for significant processes in the IFFCO Canada scenario, based on preceding comments, is provided in Table 5-5.

**Table 5-5 – Evaluation of data quality criteria for the IFFCO Canada scenario**

| Process | Data | Tech. | Time | Geo. | Comp. | Rel. |
|---|---|---|---|---|---|---|
| Ammonia and urea production | Activity data | Very good | Very good | Very good | Very good | Good |
| | Emissions | Very good | Very good | Very good | Very good | Good |
| Natural gas (Canada) | Activity data | Very good | Good | Very good | Very good | Very good |
| | Emissions | Very good | Good | Very good | Good | Very good |
| Natural gas (US) | Activity data | Good | Good | Very good | Very good | Very good |
| | Emissions | Good | Fair | Very good | Fair | Good |

In general, data quality is considered good or very good, to the exception of a few data quality criteria for natural gas extraction, processing and transmission in the US.

### 5.2.2 Reference scenario

Data quality for processes contributing significantly to the reference urea carbon footprint is discussed in Table 5-6.

Table 5-6 – Data quality for the reference scenario

| Significant process | Data sources | Data quality | Efforts to improve data quality |
|---|---|---|---|
| Ammonia and urea production | **Activity data**: natural gas use based on industry data (IEA, 2007), (Natural Resources Canada, 2008).<br><br>**Emission factors**: IPCC (2006a) values for natural gas combustion. | Average industry data on each region in the supply mix was available for the steam methane reforming process. Data corresponding to the mid-2000's period. | Energy consumption in 2018 estimated based on past trends for energy efficiency improvement IFA (2009). |
| Natural gas extraction, processing and transmission (US) | **Activity data and emission factors**: same as for the IFFCO Canada scenario. | Same as for the IFFCO Canada scenario. | Transmission distances adjusted to take into account the urea plants locations (400km). |
| Natural gas extraction, processing and transmission (Russia) | **Activity data and emission factors**: industry data and government statistics compiled in Schori and Frischknecht (2012). | The data set is an update to ecoinvent dataset by ESU-services based on recent industry data and government statistics (mostly 2009-2011). | Transmission distances adjusted to take into account urea plants locations (3000 km). |
| Electricity (US) | **Activity data:** average grid mix for the 2010–2012 period from government statistics.<br><br>**Emission factors**: fuel use and emissions for each type of power plant from the ecoinvent database (Dones et al., 2007). | Average grid mix over the period considered representative for 2018.<br><br>Data sets in ecoinvent for main production modes (coal, natural gas and nuclear) based on US specific data from 2003-2006. | The grid mix was updated using recent government statistics. |
| Transoceanic freight transportation | **Activity data:** transportation distances based on the marketing mix, the supply mix and the location of urea plants.<br><br>**Emission factors**: fuel use and emissions from the ecoinvent database (Spielmann et al., 2007). | Transportation distances and modes were modeled for each supplying region – destination combination. Based on average ship capacity.<br>Emission factors in the ecoinvent database based on literature data (late 1990's). | No effort was made to improve the ecoinvent data for emission factors. However, emissions are calculated using two other data sources (DEFRA and USLCI) for uncertainty analysis. |

The evaluation of each data quality criteria for significant processes in the reference scenario, based on preceding comments, is provided in Table 5-7.

Table 5-7 – Evaluation of data quality criteria for the reference scenario

| Process | Data | Tech. | Time | Geo. | Comp. | Rel. |
|---|---|---|---|---|---|---|
| Ammonia and urea production | Activity data | Very good | Very good | Very good | Good | Fair |
| | Emissions | Very good | Very good | Very good | Good | Fair |
| Natural gas (US) | Activity data | Very good | Good | Very good | Very good | Very good |
| | Emissions | Very good | Good | Very good | Fair | Good |
| Natural gas (Russia) | Activity data | Very good | Good | Very good | Very good | Good |
| | Emissions | Very good | Good | Very good | Good | Good |
| Electricity (US) | Activity data | Good | Good | Very good | Very good | Very good |
| | Emissions | Good | Fair | Very good | Fair | Good |
| Transoceanic freight transportation | Activity data | Good | Very good | Good | Very good | Fair |
| | Emissions | Good | Poor | Good | Good | Good |

In general, data quality is considered good or very good, to the exception of a few data quality criteria for natural gas extraction, processing and transmission in the US and transoceanic freight transportation.

## 5.3 Data adaptation and estimation

Throughout the data collection process, activity data and emissions values found in the literature or in life cycle databases were sometimes adapted to improve data quality. In addition, data had to be developed specifically for the present study, mainly to model the distribution routes. Main assumptions on which rely data adaptation and estimation are presented in following sections.

### 5.3.1 Regional models

Urea pre-production, production and distribution for each region included in the reference scenario is modeled based on the countries contributing the most to the supply mix. Impacts associated with natural gas extraction, processing and distribution as well as electricity production and distribution are estimated based on the countries and plant locations provided in Table 5-8.

**Table 5-8 – Regional models for the reference scenario**

| Region | Country, State or Province | Average plant location |
|---|---|---|
| Canada | Alberta | Medicine Hat, AB |
| US | Southeast US | Memphis, TN |
| South America | Venezuela, Trinidad & Tobago | Point Lisas, TD |
| Western Europe | Germany | Lutherstadt Wittenberg, DE |
| Eastern Europe | Russia | Novomskosk, RU |
| North Africa | Egypt | Damietta, EG |
| Middle East | Bahrain, Oman, Kuwait | Sitra, BHR |

### 5.3.2 Electricity production

Electricity is required by the ammonia and urea production process to operate different equipments (compressors, pumps, refrigeration, etc.). It is also used in a lesser extent in other stages of the urea life cycle. The production mix or "grid mix" refers to the relative contribution of electricity production modes to the total generation in a given region. The grid mix for Québec and countries listed in Table 5-8 are provided in Table 5-9.

**Table 5-9 – Grid mix for countries in the reference scenario**

| Country or Province | Coal and lignite | Oil | Gas | Nuclear | Hydro | Others |
|---|---|---|---|---|---|---|
| Québec | 0.3% | 0.0% | 0.2% | 2.6% | 95.3% | 1.6% |
| Alberta | 72.6% | 0.9% | 18.4% | 0.0% | 2.9% | 5.2% |
| US | 41.8% | 0.4% | 26.6% | 19.3% | 6.8% | 5.1% |
| Venezuela | 0.0% | 12.5% | 14.7% | 0.0% | 72.8% | 0.0% |
| Trinidad & Tobago | 0.0% | 0.3% | 99.4% | 0.0% | 0.0% | 0.3% |
| Germany | 44.9% | 1.3% | 11.3% | 16.1% | 3.4% | 22.8% |
| Russia | 16.5% | 1.6% | 47.3% | 16.5% | 17.8% | 0.3% |
| Egypt | 0.0% | 21.3% | 68.7% | 0.0% | 9.3% | 0.7% |
| Saudi Arabia | 0.0% | 55.2% | 44.8% | 0.0% | 0.0% | 0.0% |
| Oman | 0.0% | 18.0% | 82.0% | 0.0% | 0.0% | 0.0% |
| Kuwait | 0.0% | 71.2% | 28.8% | 0.0% | 0.0% | 0.0% |

Data for Québec (Hydro-Québec, 2011; Hydro-Québec, 2012; Hydro-Québec, 2013) and US (US Energy Information Administration, 2013c) for the 2010–2012 period. Data for Alberta (Environment Canada, 2013) for the 2009-2011 period. Data for Germany (DEStatis, 2013) for 2012. Data for other countries (IEA, 2012) for 2009.

### 5.3.3 Natural gas transmission and distribution

For regions where natural gas is extracted near urea plants (e.g., Middle East, North Africa, Southern US and Alberta), the distance for natural gas transmission by pipeline is assumed to be equal to 400km. In Russia, natural gas is estimated to travel by pipeline for 3,000km. For the specific case of US natural gas distributed in Québec, transmission distance from Central US or Eastern US to the Dawn hub (located in Southern Ontario near the US border) is estimated at 800km, the remaining distance to reach Québec users being 1,000km. These values are based on the location of urea plants in each of the regions (ICIS, 2013) and the location of main natural gas fields (US Energy Information Administration, 2013).

Furthermore, high pressure distribution is assumed to be equal to 250km, except for North America (Canada and US) where distribution is modeled in the GHGenius model as if it was supplied to natural gas power plants. This is justified by the fact that urea plants have natural gas consumption levels similar to power plants and are usually located near pipelines, which leads to a minimal high pressure distribution.

Emissions from natural gas processing depends on the level of impurities (e.g., hydrogen sulfide, water, heavy hydrocarbons, etc.) found in the gas. "Sour gas" (with high levels of hydrogen sulfide) will require a more energy intensive purification process than "sweet gas" (with low levels of hydrogen sulfide). Significant emissions are also associated with long distance (pipeline) natural gas transport. Obviously, longer transportation distances are associated with higher energy use and fugitive emissions. For almost all urea producing regions considered in this study, plants are located relatively near gas fields, with the exception of Québec and Russia. Compressors used along the pipelines are usually driven by gas turbines or natural gas fired reciprocating engines. While pipeline transport in Canada mostly relies on turbines, engines are more frequently used in the United States. Since engines have higher fugitive emissions than turbines, estimates of GHG emissions from natural gas transport are higher in the United States than in Canada.

### 5.3.4 Urea and ammonia production

Typical energy consumption for ammonia production for regions in the supply mix found in the literature applies to the mid-2000's period (IEA, 2007; Natural Resources Canada, 2008). In order to improve data quality and comparability with the IFFCO Canada scenario, future energy use was estimated based on energy efficiency improvements observed in ammonia plants over the last decade. According to IFA (2009), energy use for ammonia production approximately decreased 9% per decade over the last three decades. This factor is applied to all regions in the default scenario (Table 5-10).

**Table 5-10 – Energy use for ammonia production**

| Region | Average mid-2000's ($MJ/kgNH_3$) | Default 2018 ($MJ/kgNH_3$) | Low 2018 ($MJ/kgNH_3$) | High 2018 ($MJ/kgNH_3$) |
|---|---|---|---|---|
| Canada | 33.1 | 30.1 | 30.1 | 31.1 |
| Western Europe | 33.5 | 30.5 | 30.5 | 31.5 |
| Middle East* | 36.0 | 32.8 | 31.7 | 33.3 |
| South America | 38.0 | 34.6 | 32.3 | 34.6 |
| US | 37.9 | 34.5 | 32.2 | 34.5 |
| Eastern Europe | 40.0 | 36.4 | 34.0 | 36.4 |

*Note: Middle East considered representative for North Africa

However, one could expect gains to be higher in regions where energy consumption is initially higher. This is reflected in the low and high energy use scenarios in Table 5-10. For the low energy scenario, a 15% improvement is assumed in high consumption regions (Eastern Europe, US, South America), while the default value (9%) is taken for low consumption regions (Western, Canada) and 12% for the Middle East. For the high energy scenario, the default value (9%) is taken for high consumption regions, while a 6% improvement is assumed for low consumption regions and 7.5% for the Middle East.

Energy use for urea production in Western Europe is approximately 3.5MJ/kg urea according to the European Commission (2007) and the ecoinvent database (Nemecek and Kägi, 2007). Values for other regions were estimated based on the regional differences observed for ammonia production. Furthermore, energy use for urea production in 2018 was estimated following the same approach as for ammonia production. Since approximately 85% of natural gas is used for ammonia synthesis and 15% for urea synthesis in combined ammonia-urea plants, energy use for urea production is a parameter less sensitive than energy use for ammonia production.

$CO_2$ required for urea synthesis is typically recycled from the ammonia production process. It is removed from the steam-methane reformer exhaust gases prior to ammonia synthesis. $CO_2$ emissions from ammonia production are based on total natural gas use (fuel and feedstock) and the IPCC emission factor for natural gas combustion (56.1kg$CO_2$/GJ). $CO_2$ use for urea synthesis is subsequently subtracted from that value.

### 5.3.5 Distribution

For the IFFCO Canada scenario, all the production is shipped from Bécancour, Québec (Canada). The plant will have access to a port by a conveyor system as well as train and truck loading stations. Distribution routes to Québec and Ontario are modeled following the current and forecasted distribution activities of La Coop Fédérée, an important fertilizer distributor in Eastern Canada. For shipments to North Eastern US, distribution by State and preferred transportation modes are based on the marketing plan developed for IFFCO Canada by a third party. A brief description of each distribution route is provided in Table 5-11.

**Table 5-11 – Distribution routes for the IFFCO Canada scenario**

| Destination | Distribution route |
|---|---|
| Québec | Freight train to warehouses located near Montréal and Québec (a majority of shipments). Limited volumes can be shipped to nearby warehouses or directly to users by truck. |
| Ontario | Freight train to warehouses located in Southern Ontario (mainly near London, ON to La Coop Fédérée warehouse). |
| Eastern US | Freight train to rail terminals for half the shipments and ship (Great Lakes vessels or "Lakers") to water terminals for the other half of shipments. Additional transportation by truck from the terminals to the warehouses. |
| Western Europe | Transoceanic freight ship to ports overseas, then freight train to warehouses. |

For the reference scenario, the average location of urea plants in each supplying region was defined based on a worldwide plant list (ICIS, 2013). Typical destinations for each market are the same as those used for the IFFCO Canada scenario. Distribution routes are described in Table 5-12.

Table 5-12 – Distribution routes for the reference scenario

| Supplying region | Destinations | Typical distribution route |
|---|---|---|
| Canada | Ontario<br>Eastern US | Freight train to warehouses located in Southern Ontario and to Eastern US rail terminals. Additional transportation by truck from the terminals to the warehouses. |
| US | Ontario<br>Eastern US | Freight train to warehouses located in Southern Ontario.<br>By barge from urea plants in Southern US to water terminals on the Mississippi River. Additional transportation by truck from the terminals to the warehouses. |
| South America | Eastern US | Transoceanic freight ship from Venezuela or Trinidad and Tobago to Port of South Louisiana (urea plants located near the Caribbean Sea). By barge from Port of South Louisiana to water terminals on the Mississippi River. Additional transportation by truck for from the terminals to the warehouses. |
| Western Europe | Québec<br>Western Europe | Freight train from German urea plant to a port on the North Sea, then transoceanic freight ship to the port of Québec or Montreal where La Coop Fédérée's warehouses are located.<br>Intra-European transport from urea plants to warehouses by freight train. |
| Eastern Europe | Québec<br>Ontario<br>Eastern US<br>Western Europe | Freight train from Russian urea plant to a port on the Baltic Sea, then transoceanic freight ship to North American ports. For Eastern US, by barge from Port of South Louisiana to water terminals on the Mississippi River. Additional transportation by truck from ports or water terminals to warehouses in Ontario and Eastern US. Transport from Russian urea plants to Western Europe warehouses by freight train. |
| North Africa | Québec<br>Ontario<br>Western Europe | Freight train from Egyptian urea plant to the Alexandria port, then transoceanic freight ship to Canadian or Western Europe ports. For Ontario, additional transportation by truck from the port to the warehouse. For Western Europe, freight train from the port to the warehouse. |
| Middle East | Québec<br>Ontario<br>Eastern US<br>Western Europe | Transoceanic freight ship from the Arabian Peninsula to North American or Western Europe ports (urea plants located near the Persian Gulf, Gulf of Oman or Red Sea). For Eastern US, by barge from Port of South Louisiana to water terminals on the Mississippi River. Additional transportation by truck from ports or water terminals to warehouses in Ontario and Eastern US. For Western Europe, freight train from the port to the warehouse. |

More details on the distribution routes for both the IFFCO Canada scenario and the reference scenario are available in Appendix B.

# 6. Inventory results

GHG inventory results are calculated based on the global warming potentials (GWP) published by the Intergovernmental Panel for Climate Change (IPCC) for a 100-year time period (Forster et al., 2007). The GWPs for the main GHGs are: 1kg$CO_2$e for 1kg$CO_2$, 25kg$CO_2$e for 1kg$CH_4$ and 298kg$CO_2$ for 1kg$N_2O$. The inventory does not include weighting factors for delayed emissions, offsets and avoided emissions. Inventory results were calculated using the SimaPro software (version 7.3.3.).

Total inventory results (in $CO_2$e) are reported for the unit of analysis in Table 6-1. Due to the nature of the product and the inventory boundary, the results only include non-biogenic emissions from cradle-to-gate as no emissions or removals are associated with biogenic sources and land-use change impacts. These values are calculated on the basis of IFFCO Canada's marketing mix (Table 3-3) and projected suppliers for the regions included in the supply mix (Table 3-5).

**Table 6-1 – Inventory results**

| Unit of analysis | IFFCO Canada scenario | Reference scenario |
|---|---|---|
| 1 tonne of granular urea at the distributor's warehouse | 725kg$CO_2$e | 1029kg$CO_2$e |

Inventory results for each region included in the marketing mix are provided in Table 6-2. The total carbon footprint varies from one region to another for each scenario because of differences between distribution routes and projected supply mix (.

**Table 6-2 – Inventory results by destination region**

| Results (kg$CO_2$e/t urea) | Marketing mix | To Québec | To Ontario | To US | To Europe |
|---|---|---|---|---|---|
| IFFCO Canada | 725 | 658 | 692 | 768 | 719 |
| Reference | 1029 | 1081 | 1054 | 1075 | 855 |

The percentage of total emissions by life cycle stage is also reported, with gate-to-gate inventory results and the carbon content of the product.

**Table 6-3 – Contribution of life cycle stages to the inventory results**

| Stage | IFFCO Canada scenario | | Reference scenario | |
|---|---|---|---|---|
| | GHG emissions (kg$CO_2$e/t urea) | Share (%) | GHG emissions (kg$CO_2$e/t urea) | Share (%) |
| Material acquisition and pre-processing | 288 | 39.7% | 391 | 38.0% |
| Production (gate-to-gate) | 360 | 49.6% | 528 | 51.3% |
| Distribution | 77 | 10.7% | 110 | 10.7% |
| Total (cradle-to-gate) | 725 | 100% | 1029 | 100% |

The carbon content of urea is approximately 20%, which corresponds to 733kg$CO_2$e of potential emissions by ton of urea during the use phase. While total emissions for the IFFCO Canada scenario are significantly lower than those for the reference scenario (-29.6%), the relative importance of each life cycle stage is similar from one scenario to another.

Three main factors explain the differences between the IFFCO Canada scenario and the reference scenario:

- Lower natural gas use at IFFCO Canada's plant, due to higher electricity use for auxiliary equipment which leads to an overall electricity power requirement of 65 MW.

- Low carbon footprint of Québec's grid mix, due to a high reliance on hydroelectricity.
- Reduced distribution distances for most distribution routes towards the Québec, Ontario and Eastern US major markets.

## 6.1 Contribution analysis

GHG emissions and the relative contribution to the overall carbon footprint are provided for main contributing processes in Table 6-4 (IFFCO Canada scenario) and Table 6-5 (reference scenario).

In both scenarios, the process contributing the most to lifecycle GHG emissions is the production of ammonia and urea, mostly because of the use of natural gas as fuel and feedstock (49.6% of the carbon footprint for the IFFCO Canada and 51.3% for the reference scenario)

**Table 6-4 – Main contributing processes for the IFFCO Canada scenario**

| Stage | Process | GHG emissions ($kgCO_2e$/t urea) | Share (%) |
|---|---|---|---|
| Material acquisition and pre-processing | Natural gas extraction, processing and transport (US) | 135 | 18.6% |
| | Natural gas extraction, processing and transport (Canada) | 113 | 15.7% |
| Production (gate-to-gate) | Urea and ammonia production | 360 | 49.6% |
| Distribution | Transport by freight rail | 25 | 3.4% |
| | Transport by barge | 24 | 3.3% |

Direct emissions from ammonia and urea production are entirely dependent on energy efficiency, e.g., lower natural gas use will result in lower $CO_2$ emissions. As shown in Table 5-10, energy efficiency varies significantly from a region to another.

**Table 6-5 – Main contributing processes for the reference scenario**

| Stage | Process | GHG emissions ($kgCO_2e$/t urea) | Share (%) |
|---|---|---|---|
| Material acquisition and pre-processing | Natural gas extraction, processing and transport (US) | 81 | 7.9% |
| | Natural gas transport (Eastern Europe) | 47 | 4.5% |
| | Electricity production and distribution (US) | 42 | 4.0% |
| | Natural gas production (Eastern Europe) | 29 | 2.8% |
| | Electricity production and distribution (Europe) | 27 | 2.6% |
| | Electricity production and distribution (Russia) | 22 | 2.1% |
| | Electricity production and distribution (Middle East) | 21 | 2.0% |
| Production (gate-to-gate) | Urea and ammonia production (US) | 168 | 16.4% |
| | Urea and ammonia production (Eastern Europe) | 115 | 11.2% |
| | Urea and ammonia production (Middle East) | 72 | 7.0% |
| | Urea and ammonia production (North Africa) | 71 | 6.9% |
| | Urea and ammonia production (Western Europe) | 59 | 5.7% |
| | Urea and ammonia production (Canada) | 36 | 3.5% |
| Distribution | Transport by transoceanic freight ship | 53 | 5.1% |

The second highest contributing process for both scenarios is natural gas production, which entails the stages of extraction, processing and transport of natural gas (34.3% of the carbon footprint for the IFFCO Canada and 23.7% for the reference scenario).

The magnitude of emissions from natural gas production is influenced by several factors. Typically energy use (natural gas combustion) and fugitive emissions (methane) associated with extraction are higher for non-conventional gas resources (e.g., shale gas and tight gas) than for conventional gas. While the United States, and to smaller extent Canada, increasingly rely on non-conventional gas resources, global natural gas production is still dominated by conventional extraction techniques.

# 7. Uncertainty

Inventory uncertainty is assessed on a qualitative and quantitative basis. Following the GHG Protocol Product Standard, three types of uncertainty are addressed: parameter uncertainty, scenario uncertainty and model uncertainty (Table 7-1).

**Table 7-1 – Uncertainty types**

| Uncertainty types | Sources | Description |
|---|---|---|
| Parameter uncertainty | ▸ Direct emissions data<br>▸ Activity data<br>▸ Emission factor data<br>▸ GWP factors | Uncertainty on the accuracy of values used in the inventory. Parameter uncertainty can be assessed through the evaluation of data quality indicators. |
| Scenario uncertainty | ▸ Methodological choices | Uncertainty related to assumptions or methods used for allocation or to model product use or product end-of-life. Scenario uncertainty is assessed via sensitivity analysis. |
| Model uncertainty | ▸ Model limitations | Uncertainty associated with the use of simplified models to represent real life phenomena. Model uncertainty can partly be evaluated with data quality indicators or sensitivity analysis. However, some aspects are very difficult to quantify. |

## 7.1 Parameter uncertainty

Parameter uncertainty for direct emissions data, activity data and emission factor data were discussed for significant processes based on the data quality indicators described at section 5. In general, data quality was very good or good for main contributing processes, both for activity data and emission factors.

## 7.2 Scenario uncertainty

Due to the nature of the product and the inventory boundary, typical sources of scenario uncertainty (e.g., use profile, end-of-life profile, allocation methods and recycling allocation methods) are not assessed through sensitivity analysis, as no assumptions were made regarding those aspects.

Sensitivity analysis was performed on key assumptions, namely the relative share of each region in the marketing mix and the origin of natural gas supplied to IFFCO Canada by Gaz Métro. The significant process for which data quality was considered the lowest, transoceanic freight transportation, was also subject to a sensitivity analysis. The results are presented in the following sub-sections.

### 7.2.1 Marketing mix

In Table 3-4, three scenarios were defined for the marketing mix. While the default scenario corresponds to current best estimates, based on a marketing study realized for IFFCO Canada by a third party, two other scenarios were also developed. In the "North America" scenario, urea volumes distributed are higher and in the "Europe" scenario, volumes distributed to Western Europe are higher. The carbon footprint of both IFFCO Canada urea and the reference urea are given in Table 7-2.

Table 7-2 – Results of the sensitivity analysis on the marketing mix

| Results ($kgCO_2e/t$ urea) | Default | North America focused | Europe focused |
|---|---|---|---|
| IFFCO Canada urea | 724.7 | 724.1 | 723.6 |
| Reference urea | 1029 | 1052 | 1008 |
| Difference | 305 (-29.6%) | 328 (-31.1%) | 285 (-28.2%) |

The difference between IFFCO Canada urea and the reference urea is slightly higher in the "North America focused" scenario and slightly less in the "Europe focused" scenario. This is due to the fact that amongst the different supplying regions considered, urea from Western Europe has the lowest carbon footprint. However, the impact on the overall results does not appear to be significant.

### 7.2.2 Natural gas supply

The origin of natural gas to be supplied by Gaz Métro to its customers in 2018 is uncertain and depends on a multitude of factors. The North American natural gas market is currently going through a transition period. Before 2008, natural gas consumption in Canada was mostly covered by domestic production and natural gas was delivered from Alberta to Québec via the TransCanada pipeline. A decline in Canadian production, combined with higher natural gas use in Western Canada and increased production of shale gas in Eastern US leads to increased imports from the US to Eastern Canada (Gaz Métro, 2013). In this context, Gaz Métro is planning to shift its supply point from Empress (in Alberta) to the Dawn hub (in Ontario).

In 2010, natural gas imports from the US represented approximately 20% of the total consumption in Canada and 75% of the gas consumption in Ontario ($S\&T^2$ Consultants, 2012). At the moment, the supply plan of Gaz Métro in 2018 has not yet been defined and the influence of future US shale gas production on the North American natural gas market is hard to estimate. For the present study, it is assumed that Gaz Métro will be supplied in equal shares by Canadian and US natural gas. Due to a high level of uncertainty, scenarios where the natural gas distributed by Gaz Métro is made of 75% Canadian gas and 75% US gas were also investigated. The results are provided in Table 7-3.

Table 7-3 – Results of the sensitivity analysis on natural gas supply

| Results ($kgCO_2e/t$ urea) | Default (50% Canada-50% US) | Canada (75% Canada-25% US) | US (75% US-25% Canada) |
|---|---|---|---|
| IFFCO Canada urea | 725 | 714 | 735 |
| Reference urea | 1029 | 1029 | 1029 |
| Difference | 305 (-29.6%) | 315 (-28.6%) | 294 (-30.6%) |

An increase in US natural gas supply to Québec has a negative impact on IFFCO Canada's carbon footprint, although marginal. This is explained by the fact GHG emissions associated with natural gas extraction and transmission are higher in the US than in Canada ($S\&T^2$ Consultants, 2012).The influence on the overall results does not appear to be significant.

### 7.2.3 Transportation emission factors

Issues regarding data quality for transportation emission factors, especially transoceanic freight transportation, were identified in Section 5.2.2. To assess the uncertainty associated with the emission factors provided in the ecoinvent database, inventory results were calculated using two other sources: the 2012 Guidelines to Defra / DECC's GHG Conversion Factors for Company Reporting (Defra, 2012) and the USLCI database (NREL, 2007). Results are provided in Table 7-4.

Table 7-4 – Results of the sensitivity analysis on transportation emission factors

| Results ($kgCO_2e/t$ urea) | Ecoinvent | Defra | USLCI |
|---|---|---|---|
| IFFCO Canada urea | 725 | 701 | 708 |
| Reference urea | 1029 | 997 | 1055 |
| Difference | 305 (-29.6%) | 296 (-29.7%) | 347 (-32.9%) |

In the case of IFFCO Canada urea carbon footprint, results are slightly higher using the ecoinvent database than the two other sources. This can, in part, be explained by the fact that the infrastructures are included in the ecoinvent database, while they are not for the Defra emission factors and the USLCI database.

For the reference urea, life cycle GHG emissions calculated using the Defra emission factors are also lower, while the use of the USLCI database leads to higher results. This is mostly due to the fact that fuel consumption in the USLCI transoceanic transportation process is higher than with the ecoinvent process. During the development of transport processes for the ecoinvent database, Spielmann et al. (2007) had identified that values reported in the literature for fuel consumption by bulk carrier freight ship differed significantly. Since distribution only contributes to approximately 10% of the total footprint for both compared products, the uncertainty associated with transportation emission factors is considered to be limited.

## 7.3 Model uncertainty

Natural gas use is a key parameter in the calculation of the carbon footprint of urea. Most life cycle GHG emissions occur at the plant, where natural gas is used as fuel and feedstock, and upstream, during extraction, processing and transport. To reflect the uncertainty associated with the model used to estimate natural gas use in the reference scenario, two alternative scenarios were developed in Section 5.3.4. Inventory results are provided in Table 7-5 for the default, low and high energy use scenarios.

Table 7-5 – Results of the sensitivity analysis on energy use for the reference scenario

| Results ($kgCO_2e/t$ urea) | Projected natural gas use (2018) | Low natural gas use (2018) | High natural gas use (2018) |
|---|---|---|---|
| IFFCO Canada urea | 725 | 725 | 725 |
| Reference urea | 1029 | 963 | 1044 |
| Difference | 305 (-29.6%) | 238 (-24.7%) | 319 (-30.6%) |

As expected, higher energy efficiency for urea production in the reference scenario results in a smaller difference between the two compared products. However, even under the assumption that energy use decreases at a faster pace than that observed in the last decades, the carbon footprint of IFFCO Canada urea is still significantly lower than the carbon footprint of the reference urea.

A last source of uncertainty, which is not specific to the product under study, is associated with the estimation of global warming potentials (GWP) of GHGs. According to the IPCC, there is a ±35% uncertainty associated with the conversion of GHG emissions in $CO_2e$. However, the IPCC is globally considered to be providing the most robust GWP estimates and the most recent latest GWPs from the IPCC over a 100-year time period are used in the present study. Also, more than 85% of the total carbon footprint is associated with $CO_2$ emissions for the two compared products, reducing the impact of this uncertainty.

# 8. Critical review

A critical review was performed by a third party review panel. The review process was directed by the Interuniversity Research Centre for the Life Cycle of Products, Processes and Services (CIRAIG). The members of the review panel are listed in Table 8-1.

**Table 8-1 – Members of the critical review panel**

| Member | Title and organization | Role | Competencies |
|---|---|---|---|
| Jean-François Ménard | Senior analyst, CIRAIG | President of the review panel | Experience in LCA and carbon footprint (performed several studies in various sectors and participated to the carbon footprint pilot project in Québec) |
| Dominique Maxime | Research associate, CIRAIG | LCA expert | Experience in LCA and carbon footprint in the agricultural sector and involved in the Québec life cycle inventory database project |
| Don O'Connor | President, S&T Squared Consultant Inc. | LCA expert | Experience in carbon footprint of transportation fuels (developer of the GHGenius model for Natural Resources Canada) |
| Marzouk Benali | Scientific researcher, CanMET (Natural Resources Canada) | Industrial energy efficiency expert | Experience in industrial process optimization, including ammonia production |

The critical review was performed according to the applicable guidelines of the GHG Protocol Product Standard. The steps of the critical review process are described in Table 8-2.

**Table 8-2 – Critical review process**

| Step | Description | Outcome |
|---|---|---|
| Goal and scope report review | Review of the goal and scope report by a member of the CIRAIG | First review note sent by the CIRAIG and update of the goal and scope report by EY |
| Carbon footprint report review | Review of the carbon footprint report by all members of the critical review panel | Second review note sent by the CIRAIG and update of the carbon footprint report by EY |
| Preparation of the critical review report | Summary of comments, remarks and questions made by the review panel throughout the process as well as the answers and modifications proposed by EY | Critical review report sent by the CIRAIG to be attached to the final carbon footprint report |

The panel came to the conclusion that methods used to carry out the inventory are consistent with the GHG Protocol Product Standard, are scientifically and technically valid and that the data used are appropriate and reasonable for public reporting. Furthermore, the inventory report is considered transparent and consistent.

The critical review report prepared by the CIRAIG is available in its entirety in Appendix C.

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# Appendix A Activity data and emissions factors

## A.1 Ammonia and urea production for IFFCO Canada

| Outputs to technosphere (products) | | | | | |
|---|---|---|---|---|---|
| Name | Amount | Unit | Process | | Reference |
| Urea, granulated at plant | 1 | kg | | | |
| **Inputs from technosphere (materials and energy)** | | | | | |
| Name | Quantity | Unit | Process | Database | Reference |
| Natural gas | 19.9996 | MJ | NG at Power | GHGenius | SNC-Lavalin |
| Electricity | 0.403 | kWh | Electricity, medium voltage, at grid/QC | Ecoinvent (adapted) | IFFCO Canada |
| Nickel catalyst | 5.4e-6 | kg | Nickel, 99.5%, at plant/GLO | Ecoinvent | SNC-Lavalin |
| Copper catalyst | 1.9e-4 | kg | Copper oxide, at plant/RER | Ecoinvent | SNC-Lavalin |
| Iron catalyst | 4.9e-5 | kg | Chromium steel 18/8, at plant/RER | Ecoinvent | SNC-Lavalin |
| Activated alumina | 1.0e-5 | kg | Alumina, at plant/US | USLCI | SNC-Lavalin |
| aMDEA | 2.4e-5 | kg | Dimethylamine, at plant/RER | Ecoinvent | SNC-Lavalin |
| Urea formaldehyde | 0.01 | kg | Urea formaldehyde resin, at plant/RER | Ecoinvent (adapted) | SNC-Lavalin |
| Water | 4.27 | L | Tap water, at user/RER | Ecoinvent | SNC-Lavalin |
| Lime | 3.15e-5 | kg | Lime, hydrated, packed, at plant/CH | Ecoinvent | SNC-Lavalin |
| Caustic soda | 4.0e-4 | kg | Sodium hydroxide, 50% in H2O, production mix, at plant/RER | Ecoinvent | SNC-Lavalin |
| Resins | 7.1e-5 | kg | Cationic resin, at plant/CH | Ecoinvent | SNC-Lavalin |
| Sulfuric acid | 0.0023 | kg | Sulphuric acid, liquid, at plant/kg/RER | Ecoinvent | SNC-Lavalin |
| Transport by truck | 0.497 | t.km | Transport, lorry >16t, fleet average/RER | Ecoinvent | Estimation |
| Transport by train | 7.45 | t.km | Transport, freight, rail, diesel/tkm/US | Ecoinvent | Estimation |
| **Outputs to nature (emissions)** | | | | | |
| Name | Quantity | Unit | Compartment | Factor (LHV) | Reference |
| $CO_2$ | 0.35713 | kg | Atmosphere | n.a. | SNC-Lavalin |
| $CH_4$ | 2.0e-5 | kg | Atmosphere | 1g/GJ | IPCC (2006) |
| $N_2O$ | 6.2e-6 | kg | Atmosphere | n.a. | SNC-Lavalin |
| **Outputs to technosphere (wastes)** | | | | | |
| Name | Quantity | Unit | Process or comment | Database | Reference |
| Catalysts | 8.5e-5 | kg | Recycled by supplier (cut-off) | n.a. | SNC-Lavalin |
| Used oil | 1.2e-6 | kg | Disposal, used mineral oil, 10% water, to hazardous waste incineration/CH | Ecoinvent | IFFCO Canada |
| Sludge | 2.8e-5 | kg | Disposal, sludge from pulp and paper production, 25% water, to landfill/CH | Ecoinvent | SNC-Lavalin |
| Containers | 1.2e-5 | kg | Recycled by IFFCO Canada (cut-off) | n.a. | SNC-Lavalin |

## A.2 Ammonia and urea production for the reference scenario

| **Outputs to technosphere (products)** | | | | | |
|---|---|---|---|---|---|
| Name | Amount | Unit | Process | | Reference |
| Ammonia, at plant | 1 | kg | | | |
| **Inputs from technosphere (materials and energy)** | | | | | |
| Name | Quantity | Unit | Process | Database | Reference |
| Natural gas | Variable [30.1-36.4] | MJ | NG, at power (AB and Central US) Natural gas, high pressure, at consumer/DE, RU, DZ, RME, RER | GHGenius, ecoinvent, ESU | Table 5-1 and Table 5-8 |
| Electricity | Variable [0.07-0.14] | kWh | Electricity, medium voltage, at grid/AB, US, SA, RU, DZ, RME, RER | Ecoinvent, (adapted), ESU | Althaus et al. (2007), NREL (2007) Table 5-9 for grid mixes |
| Nickel and other catalysts | 3.5e-4 | kg | Nickel, 99.5%, at plant/GLO | Ecoinvent | Althaus et al. (2007) |
| Chemicals and solvents | 1.9e-4 | kg | Solvents, organic, unspecified, at plant / GLO U | Ecoinvent | Althaus et al. (2007) |
| Water | 4.27 | L | Tap water, at user/RER | Ecoinvent | Althaus et al. (2007) |
| Transport by truck | 0.497 | t.km | Transport, lorry >16t, fleet average/RER | Ecoinvent | Althaus et al. (2007) |
| Transport by train | 7.45 | t.km | Transport, freight, rail, diesel/tkm/US | Ecoinvent | Althaus et al. (2007) |
| **Outputs to nature (emissions)** | | | | | |
| Name | Quantity | Unit | Compartment | Factor (LHV) | Reference |
| $CO_2$ | From NG | kg | Atmosphere and technosphere (to urea production) | 56.1kg/GJ | IPCC (2006) |
| $CH_4$ | From NG | kg | Atmosphere | 1g/GJ | IPCC (2006) |
| $N_2O$ | 1.5e-6 | kg | Atmosphere | n.a. | Althaus et al. (2007) |
| **Outputs to technosphere (wastes)** | | | | | |
| Name | Quantity | Unit | Process or comment | Database | Reference |
| Various | 0.002 | kg | Disposal, municipal soild waste, 22,9% water, to sanitary landfill/CH | n.a. | SNC-Lavalin |

| **Outputs to technosphere (products)** | | | | | |
|---|---|---|---|---|---|
| Name | Amount | Unit | Process | | Reference |
| Urea, granulated at plant | 1 | kg | | | |
| **Inputs from technosphere (materials and energy)** | | | | | |
| Name | Quantity | Unit | Process | Database | Reference |
| CO2 (from ammonia prod.) | 0.735 | kg | n.a. | n.a. | European Commission (2007) |
| Ammonia | 0.568 | kg | Ammonia production process | n.a. | Nemecek and Kägi (2007), European Commission (2007) |
| Natural gas | Variable [3.15-3.80] | MJ | NG, at power (AB and Central US) Natural gas, high pressure, at consumer/DE, RU, NAC, RME, RER | GHGenius, ecoinvent, ESU | Table 5-1 |
| Electricity | 0.12 | kWh | Electricity, medium voltage, at grid/AB, US, SA, RU, EG, RME, RER | Ecoinvent, (adapted), | Nemecek and Kägi (2007) |
| Urea formaldehyde | 0.01 | kg | Urea formaldehyde resin, at plant/RER | Ecoinvent (adapted) | Similar to IFFCO Canada |
| Transport by truck | 0.497 | t.km | Transport, lorry >16t, fleet average/RER | Ecoinvent | Nemecek and Kägi (2007) |
| Transport by train | 7.45 | t.km | Transport, freight, rail, diesel/tkm/US | Ecoinvent | Nemecek and Kägi (2007) |
| **Outputs to nature (emissions)** | | | | | |
| Name | Quantity | Unit | Compartment | Factor (LHV) | Reference |
| $CO_2$ | From NG | kg | Atmosphere | 56.1kg/GJ | IPCC (2006) |
| $CH_4$ | From NG | kg | Atmosphere | 1g/GJ | IPCC (2006) |
| $N_2O$ | From NG | kg | Atmosphere | 0.1g/GJ (LHV) | Althaus et al. (2007) |
| **Outputs to technosphere (wastes)** | | | | | |
| Name | Quantity | Unit | Process or comment | Database | Reference |
| None | | | | | |

## A.3 Emission factors for the main contributing processes

(i.e. processes contributing to more than 1% of the total GHG emissions for the IFFCO Canada or the reference scenarios)

| **Pre-production** | | | | | |
|---|---|---|---|---|---|
| Natural gas | Database | Quantity | Unit | Emissions | Unit |
| NG to Power (from Canada to Québec) | GHGenius | 1 | MJ | 0.0113 | $kgCO_2e$ |
| NG to Power (from US to Québec) | GHGenius (adapted) | 1 | MJ | 0.0135 | $kgCO_2e$ |
| NG to Power (from US to Central US) | GHGenius | 1 | MJ | 0.0118 | $kgCO_2e$ |
| Natural gas, at production onshore/NAC | ESU-Services | 1 | $m^3$ | 0.241 | $kgCO_2e$ |
| Natural gas, at production onshore/RME | ESU-Services | 1 | $m^3$ | 0.241 | $kgCO_2e$ |
| Natural gas, at production onshore/RU | ESU-Services | 1 | $m^3$ | 0.188 | $kgCO_2e$ |
| Transport, natural gas, pipeline, long distance/RU | ESU-Services | 1 | t.km | 0.0853 | $kgCO_2e$ |
| Electricity | Database | Quantity | Unit | Emissions | Unit |
| Electricity, medium voltage, at grid/AB | Ecoinvent (adapted) | 1 | kWh | 1.026 | $kgCO_2e$ |
| Electricity, medium voltage, at grid/EG | Ecoinvent (adapted) | 1 | kWh | 0.649 | $kgCO_2e$ |
| Electricity, medium voltage, at grid/QC | Ecoinvent (adapted) | 1 | kWh | 0.039 | $kgCO_2e$ |
| Electricity, medium voltage, at grid/RME | Ecoinvent (adapted) | 1 | kWh | 0.810 | $kgCO_2e$ |
| Electricity, medium voltage, at grid/RU | Ecoinvent (adapted) | 1 | kWh | 0.666 | $kgCO_2e$ |
| Electricity, medium voltage, at grid/UCTE | Ecoinvent (adapted) | 1 | kWh | 0.531 | $kgCO_2e$ |
| Electricity, medium voltage, at grid/US | Ecoinvent (adapted) | 1 | kWh | 0.706 | $kgCO_2e$ |
| Chemicals | Database | Quantity | Unit | Emissions | Unit |
| Urea formaldehyde resin, at plant/RNA | Ecoinvent (adapted) | 1 | kg | 2.19 | $kgCO_2e$ |
| **Distribution** | | | | | |
| Transport | Database | Quantity | Unit | Emissions | Unit |
| Transport, freight, rail, diesel/US | Ecoinvent | 1 | t.km | 0.0497 | $kgCO_2e$ |
| Transport, freight, rail/RER | Ecoinvent | 1 | t.km | 0.0394 | $kgCO_2e$ |
| Transport, barge/RER | Ecoinvent | 1 | t.km | 0.0463 | $kgCO_2e$ |
| Transport, transoceanic freight ship/OCE | Ecoinvent | 1 | t.km | 0.0107 | $kgCO_2e$ |
| Transport, lorry >32t, EURO3/RER | Ecoinvent | 1 | t.km | 0.1210 | $kgCO_2e$ |

# Appendix B Description of distribution routes

| | | Transport leg 1 | | | | | Transport leg 2 | | | | | Transport leg 3 | | | | | Transport leg 4 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Plant | User | Origin | Destination | Mode | Dist. | Unit | Origin | Destination | Mode | Dist. | Unit | Origin | Destination | Mode | Dist. | Unit | Origin | Destination | Mode | Dist. | Unit |
| Eastern Europe | Quebec | Novomskosk, RU | Primorsk, RU | Train | 1200 | km | Primorsk, RU | Montreal, CA | Boat | 7600 | km | | | | | | | | | | |
| Eastern Europe | Ontario | Novomskosk, RU | Primorsk, RU | Train | 1200 | km | Primorsk, RU | Hamilton, CA | Boat | 7600 | km | Montreal, CA | Warehouse | Truck | 130 | km | | | | | |
| Eastern Europe | Eastern US | Novomskosk, RU | Primorsk, RU | Train | 1200 | km | Primorsk, RU | Port of South Louisiana, LA | Boat | 10600 | km | Port of South Louisiana, LA | Local port (St-Louis, MI) | Barge | 1100 | km | Local port (St-Louis, MI) | Warehouse (Preoria, IL or Keokuk IO or Danville IL) | Truck | 250 | km |
| Eastern Europe | Western Europe | Novomskosk, RU | Orléans, FR (Warehouse) | Train | 3000 | km | | | | | | | | | | | | | | | |
| Middle East | Quebec | Sitra, BHR | Montreal, CA | Boat | 15300 | km | | | | | | | | | | | | | | | |
| Middle East | Eastern US | Sitra, BHR | Port of South Louisiana, LA | Boat | 17900 | km | Port of South Louisiana, LA | Local port (St-Louis, MI) | Barge | 200 | km | Local port (St-Louis, MI) | Warehouse (Preoria, IL or Keokuk IO or Danville IL) | Truck | 250 | km | | | | | |
| Middle East | Western Europe | Sitra, BHR | Marseille, FR | Boat | 8700 | km | Marseille, FR | Warehouse | Train | 700 | km | | | | | | | | | | |
| North Africa | Quebec | Damietta, EG | Alexandria, EG | Train | 200 | km | Alexandria, EG | Montreal, CA | Boat | 9300 | km | | | | | | | | | | |
| North Africa | Ontario | Damietta, EG | Alexandria, EG | Train | 200 | km | Alexandria, EG | Hamilton, CA | Boat | 9300 | km | Montreal, CA | Warehouse | Truck | 130 | km | | | | | |
| North Africa | Western Europe | Damietta, EG | Alexandria, EG | Train | 200 | km | Alexandria, EG | Marseille, FR | Boat | 2700 | km | Marseille, FR | Orléans, FR (Warehouse) | Train | 700 | km | | | | | |
| Western Europe | Western Europe | Regional plant | Regional warehouse | Train | 500 | km | | | | | | | | | | | | | | | |
| Western Europe | Quebec | Lutherstadt Wittenberg, DE | Bremerhaven, DE | Train | 450 | km | Bremerhaven, DE | Montreal, CA | Boat | 6300 | km | | | | | | | | | | |
| South America | Eastern US | Point Lisas, TD | Port of South Louisiana, LA | Boat | 3500 | km | Port of South Louisiana, LA | Local port (St-Louis, MI) | Barge | 1100 | km | Local port (St-Louis, MI) | Warehouse (Preoria, IL or Keokuk IO or Danville IL) | Truck | 200 | km | | | | | |
| US | Ontario | Memphis, TN | London, ON | Train | 1400 | km | | | | | | | | | | | | | | | |
| US | Eastern US | Memphis, TN | Regional port (Saint-Louis, MS) | Barge | 450 | km | Regional port (Saint-Louis, MS) | Regional warehouse (Preoria, IL or Keokuk IO or Danville IL) | Truck | 250 | km | | | | | | | | | | |
| Canada | Ontario | Medicine Hat, AB | London, ON | Train | 3300 | km | | | | | | | | | | | | | | | |
| Canada | Eastern US | Medicine Hat, AB | Regional train terminal (Chicago) | Train | 2300 | km | Regional train terminal (Chicago) | Warehouse (Preoria, IL or Madison, WI or Indianapolis IN or Coldwater MI) | Truck | 250 | km | | | | | | | | | | |

| | | Transport leg 1 | | | | | | Transport leg 2 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Plant | Warehouse | Origin | Destination | Mode | Dist. | Unit | Comments and assumptions | Origin | Destination | Mode | Dist. | Unit | Comments and assumptions |
| IFFCO Canada | Quebec | Becancour, QC | Trois-Rivières | Truck | 120 | km | Deliveries directly to farmers near IFFCO Canada's plant (25% of total to QC). | | | | | | |
| IFFCO Canada | Quebec | Becancour, QC | Montreal, QC Quebec, QC | Train | 180 | km | Main warehouse of La Coop Fédérée. Ports in Quebec, Montreal (75% of total to QC). | | | | | | |
| IFFCO Canada | Ontario | Becancour, QC | London, ON | Train | 900 | km | Main warehouse of La Coop Fédérée. Ontario (St-Thomas, near London). | | | | | | |
| IFFCO Canada | Eastern US | Becancour, QC | Regional train terminal (Springfield, OH) | Train | 1500 | km | Average use location in the Eastern US (50% of total to Eastern US). | Regional train terminal (Springfield, OH) | Warehouse (Indianapolis IN or Coldwater MI) | Truck | 250 | km | Average use location in the Eastern US |
| IFFCO Canada | Eastern US | Becancour, QC | Regional port (Burns Harbor) | Vessel | 2300 | km | Average use location in the Eastern US. Boat transport through the Great Lakes with small capacity vessels ("lakers") (50% of total to Eastern US).. | Regional port (Burns Harbor) | Warehouse (Preoria, IL or Madison, WI or Indianapolis IN or Coldwater MI) | Truck | 250 | km | Average use location in the Eastern US |
| IFFCO Canada | Western Europe | Becancour, QC | Le Havre, FR | Boat | 5600 | km | France between Spain, Italy and UK (4 main Western Europe importers for urea) | Le Havre, FR | Orléans, FR (Warehouse) | Train | 300 | km | Typical distance from Port to warehouse in Western Europe |

# Appendix C Critical review report


**CRITICAL REVIEW REPORT**

**CRITICAL REVIEW OF THE UREA COMPARATIVE CARBON FOOTPRINT BY ERNST & YOUNG FOR IFFCO CANADA**

August 23, 2013 (Final Review Report)

*Prepared for*


**Thibaut Millet**
Senior Manager, Climate Change and Sustainability Services

Ernst & Young LLP

*By :*

**Dominique Maxime, Ph.D.**
Analyst
(Review of the Goal &scope report)

*and*

**Jean-François Ménard, ing.**
Analyst
(President of the critical review committee for the Final report)

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# 1 Critical review Context

This report is provided by CIRAIG to Ernst & Young LLP (below "Ernst & Young") as part of the process of critical review of a carbon footprint comparative study of urea production.

The critical review has been performed by:

- Dominique Maxime (DM), analyst at CIRAIG, reviewer of the Goal and scope report;
- Jean-François Ménard (JFM). Analyst at CIRAIG, president of the review committee for the Final report;
- Don O'Connor (DOC), President of S&T Squared Consultant Inc., member of the review committee for the Final report;
- Marzouk Benali (MB), Research scientist at CanmetENERGY, Natural Resources Canada, member of the review committee for the Final report.

# 2 Critical review process

The critical review was conducted iteratively between CIRAIG and Ernst & Young, the consulting company mandated by IFFCO Canada Enterprise Limited (below "IFFCO Canada") to perform the carbon footprint study. The critical review proceeded as follows:

1. The Goal and scope report was sent to CIRAIG by Ernst & Young on July 10, 2013;
2. The review of the Goal and scope report has been performed by Dominique Maxime and the review report was sent to the authors on July 12, 2013;
3. The draft of Final report was sent to CIRAIG by Ernst & Young on July 26, 2013;
4. The review of the draft of the Final report has been performed by the review committee and the review report was sent to the authors on August 6, 2013;
5. The revised version of the Final report was sent by Ernst & Young on August 16, 2012;
6. The review of the revised version of the Final report has been performed by the review committee and the final review report was sent to the authors on August 23, 2013.

# 3 Content of the critical review

The critical review report consists of:

1. The overall assessment of the quality of the study;
2. The check list used to ensure conformity with the requirements of the *Greenhouse Gas Protocol – Product Life Cycle Accounting and Reporting Standard*

(GHGP-PS), and all comments, remarks and questions from the reviewer for the Goal and scope report and corresponding answers from the authors;

3. The check list used to ensure conformity with the requirements of the *Greenhouse Gas Protocol – Product Life Cycle Accounting and Reporting Standard* (GHGP-PS), and all comments, remarks and questions from the review committee for the Final report and corresponding answers from the authors

# 4 OVERALL ASSESSMENT OF THE QUALITY OF THE STUDY

The critical review process ensures that:

- Methods used to carry out the product inventory are consistent with the GHGP-PS;
- Methods used to carry out the product inventory are scientifically and technically valid;
- Data used are appropriate and reasonable for public reporting;
- The inventory report and any conclusions based on the results are appropriate for GHG-only inventories;
- The inventory report is transparent and consistent.

From the GHGP-PS (Appendix A), for performance claims:

- The unit of analysis should be identical;
- The system boundaries and temporal boundary should be equivalent;
- The same allocation methods should be used for similar processes;
- The data types used and the data quality and uncertainty of data should be reported and assessed to determine if a fair comparison can be made;
- The temporal and geographical representativeness of the inventories should be assessed to determine if a fair comparison can be made.

The review committee is unanimous in stating that the study generally satisfies all the elements listed above. There are a few new comments that need to be addressed (see section 6.2) but these essentially touch on the report transparency and do not affect the overall favorable opinion on the quality of the study.

It should be noted that only the study report was made available to the review committee, no detailed examination of the inventory data or the Simapro model was done.

# 5 REVIEW OF THE GOAL AND SCOPE REPORT

## 5.1 Greenhouse Gas Protocol – Product Life Cycle Accounting and Reporting Standard's Check List

This check list has been prepared to ensure conformity with all requirements of the guidelines of the *Product Life Cycle Accounting and Reporting Standard* of the *Greenhouse Gas Protocol*.

The checkbox in the left column is checked when the specific requirement is met and unchecked when it appeared that the requirement was not fulfilled (see comment).

| Requirements | Reviewer's comments | Authors' answers | Reviewer's answers |
|---|---|---|---|
| **a) General Information and Scope:**<br>☒Contact information of applicant(s) and author(s) of the inventory;<br>☒Date and version of the inventory;<br>☐Studied product name and description;<br>☒Unit of analysis and reference flow<br>☒Type of inventory: cradle-to-grave or cradle-to-gate, and justification of a cradle-to-gate boundary, when applicable<br>☒GHGs included in the inventory<br>☒Any product rules or sector-specific guidance used<br>☐For subsequent inventories, a link to previous inventory reports and description of any methodological changes;<br>☒Disclaimer stating the limitations of various potential uses of the report including product comparison | Needs a clear phrasing of studied products and the mention that the scope is a comparative study (see comment #1 in section 5.2) | See answer in section 5.2. | OK |
| **b) Boundary Setting:**<br>☐Life cycle-stage definitions and descriptions;<br>☒Process map including attributable processes in the inventory;<br>☒Non-attributable processes included in the inventory;<br>☒Excluded attributable processes and justification for their | See comments #2 and #3 in section 5.2 | See answers in section 5.2. | OK |

| | | | |
|---|---|---|---|
| exclusion<br>☒Time period;<br>☒Method used to calculate land-use change impacts, when applicable | | | |
| **c) Data Collection and Quality**<br>☐For significant processes included within boundaries, a descriptive statement on the data sources, data quality, and any efforts taken to improve data quality<br><br>☒Collection of primary data for all processes under the ownership or control of the applicant. | To be completed: although sources are described, data quality description is missing as well as efforts taken towards improving data quality. In addition, dating ecoinvent data and reports as of 2012 in table 5.1 and in references section is fallacious with respect to temporal representativeness. Ecoinvent data are quite old: end of 90s'-beginning of 2000's: they are de facto of low quality for a prospective scenario in 2018. Hence, effort towards higher quality data for the reference scenario is expected.<br>See other comments #6 and 7 in section 5.2 | Description of data quality is provided in the carbon footprint report.<br>In the goal and scope report, the ecoinvent database is cited as a whole according to the ecoinvent centre code of practice.<br>The exact time period for used datasets is taken in consideration to evaluate temporal representativeness.<br>Amongst the efforts taken to improve data quality figure:<br>• Estimation of projected energy use for ammonia and urea production for each supplying region based on latest data available and trends for efficiency improvement.<br>• Comparison of ecoinvent data for freight transportation with more recent emissions factors from DEFRA (including scope 3 emissions).<br>• National and regional grid mixes are updated using 2010-2012 data (US, AB, QC) | OK |

| | | | |
|---|---|---|---|
| | | or 2009 data (UE, DE, RU, South America, Middle East, Egypt). | |
| **d) Allocation :**<br>☒Disclosure and justification of the methods used to avoid or perform allocation due to co-products or recycling<br>☐When using the closed loop approximation method, any displaced emissions and removals separately from the end-of-life stage | | | |
| **e) Uncertainty:**<br>☒Qualitative statement on inventory uncertainty and methodological choices (Use and end-of-life profile, Allocation methods, including allocation due to recycling, Source of global warming potential (GWP) factors used, Calculation models) | | | |
| **f) Carbon footprint calculation:**<br>☒Source and date of the GWP factors used;<br>☒Total inventory results in units of CO2e per unit of analysis, which includes all emissions and removals included in the boundary from biogenic sources, non-biogenic sources, and land-use change impacts;<br>☒Percentage of total inventory results by life cycle stage;<br>☐Biogenic and non-biogenic emissions and removals separately, when applicable<br>☒Land use impacts separately, when applicable<br>☒Cradle-to-gate and gate-to-gate inventory results separately (or a clear statement that confidentiality is a limitation to providing this information);<br>☐Companies shall not include the following when quantifying inventory results: weighting factors for delayed emissions; offsets; and avoided emissions;<br>☒Amount of carbon contained in the product or its components that is not released to the atmosphere during waste treatment, when applicable OR, for cradle-to-gate inventories, the amount of carbon contained in the | Statement not mentioned | The statement is added: “the inventory does not include weighting factors for delayed emissions, offsets and avoided emissions”. | OK |

| | | | |
|---|---|---|---|
| intermediate product. | | | |
| **g) Quality Assurance**<br>The assurance statement including::<br>☐Whether the assurance was performed by a first or third party; | Rephrase the statement : "A critical review will be performed by a review panel of interested parties": …by a review panel of third party. | Statement rephrased: "A critical review will be performed by a third party review panel." | OK |
| ☐Assurance providers (names, affiliation, and relevant competencies); | To be completed : Don O'Connor (Canada) and Stewart Ledgard (New Zealand). See full information in email from Sophie Fallaha to E&Y (July 2, 2013) | The names are added. | OK |
| ☐How any potential conflicts of interests were avoided for first party assurance;<br>☒ A summary of the assurance process; | | | |
| ☐ Level of assurance achieved (limited or reasonable) and assurance opinion or the critical review findings. | *This will be addressed after completion of the study.* | | |

## 5.2 Reviewer's comments and authors' answers

| # | Page | Reviewers' comments | Authors' answers | Reviewers' answers |
|---|---|---|---|---|
| 1 | 2 | 1) Please, mention from the start this is a comparative study of 2 different products/scenarios. 2) Description of the two studied products: the IFFCO urea is also distributed: this is not stated. | The comparative nature of the study is stated from the start (general information section). The reference scenario is described in more details:<br>• Distribution mix, with ranges for each region.<br>• Projected supply mix for each region in the distribution mix (based on current supplying | OK |

| | | | | |
|---|---|---|---|---|
| | | | countries and projected trends in global urea production and consumption).<br>The distribution phase for IFFCO Canada urea is mentioned. | |
| 2 | 4 | Improvement in Table 3.1: some stages need to be explicitly mentioned as excluded, to conform with text scope and UF previously mentioned and to next figure (e.g. liquid urea, coal and naphtha feedstock, distribution to user, use, and packaging waste).<br>Also, it would be welcome to provide a figure for the "small amount" of packaging waste to justify exclusion | Exclude life cycle stages are explicitly mentioned in Table 3.1.<br><br>The exclusion of packaging is justified by the fact that the majority of urea produced is bulk shipped and do not require packaging. No bagging system is planned for IFFCO Canada's plant. | OK<br><br>OK |
| 3 | 5 | It is stated: "In particular, the use of urea is excluded, as it is based primarily on client operations (agricultural or industrial applications), and the impacts occurring during this phase are not affected by the origin of urea". Actually, some forms of fertilizer granulation and/or adjuvant addition do exist that can influence impacts from use of fertilizer (e.g. slow release, hence reduced volatilization/leaching, etc...). So, instead of such a statement, it would be preferable to mention (and possibly justify) that in both scenarios the urea form will be (in 2018) the same and will not affect the use phase. | The statement has been modified according to the recommendation.<br>The urea that will be produced at IFFCO Canada's plant in Bécancour will be in granulated form with urea-formaldehyde additive. The urea for the reference scenario (2018) is considered to be in the same form. Hence, the use phase will be identical. In 2018, it is expected that most urea in IFFCO Canada's market will be under granulated form (new urea plants use the granulation process instead of the prilling process and existing plants using the prilling process are retrofitted to use the granulation process. | OK |
| 4 | 6-7 | Section 3.2: A sensitivity analysis on the supply mix will likely to be performed if the step is high contributing. Authors may already propose one, as they did for the projected distribution markets of IFFCO urea. | Scenarios for the marketing mix and the supply mix are proposed. | OK |
| 5 | 7 | Section 3.3: the C stored in urea and released from fertilizer use depends on the amount actually fixed in the process. The 0.2 C/kg urea is | The C stored in urea depends on its composition (state chemical formula). Hence, the amount fixed is very stable from one plant to another (ref UE?). | OK |

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| | | from IPCC (it is not sourced but I presume so…) and might need to be adjusted according to the process modelled. | | |
| 6 | 2 | It is about data quality: In 2.2, the statement “For the reference urea, the inventory is based on recent industrial and market data” is fallacious: 1) market for product distribution is prospective (2018); and 2) industrial data inventory might not be "recent" (this will be judged later on sections 3.2 and 5.1). | The statement is modified.<br>The exact time period for each dataset is taken into account for data quality evaluation. | OK |
| 7 | 9 | Table 5-1 on data sources: change every reference “ecoinvent 2012” for the reference of the specific ecoinvent report, with its specific year; Adapt the References section accordingly. | References to specific ecoinvent reports are provided. | OK |
| | | A discussion on the quality of the raw data used for ecoinvent database would be worthwhile even at the time of this Goal & Scope report, for an expected representativeness of the 2018 context. A quick screening footprint may help identify contributing steps/flows, for spotting those data that will need further refinement. | Based on a literature review, stages with the highest contribution to the carbon footprint are already known: ammonia production, distribution (in the case long distances are travelled) and natural gas transmission (in the case of long distances travelled through pipelines with high leakage). | OK |
| | | There is no mention of Natural resources Canada’s study on energy benchmarking in ammonia industry (of relevance for the reference scenario with supply from Canada plants to Ontario market, as mentioned in Table 3-4, provided it still applies for 2018). | The NRCAN study is used as a data source for Canadian plants. The citation is added. | OK |
| | | Other sources: Ammonia energy efficiency (Int. Fertilizer Association 2008) | The IFA document is used to estimate general increase in energy efficiency and project energy consumption in 2018. | OK |

# 6 Final Report Review

## 6.1 Greenhouse Gas Protocol – Product Life Cycle Accounting and Reporting Standard's Check List

This check list has been prepared to ensure conformity with all requirements of the guidelines of the *Product Life Cycle Accounting and Reporting Standard* of the *Greenhouse Gas Protocol*.

The checkbox in the left column is checked when the specific requirement is met and unchecked when it appeared that the requirement was not fulfilled (see comment).

| Requirements | Reviewer's comments | Authors' answers | Reviewer's answers |
|---|---|---|---|
| **a) General Information and Scope:** | | | |
| ☒Contact information of applicant(s) and author(s) of the inventory; | | | |
| ☒Date and version of the inventory; | | | |
| ☒Studied product name and description; | See comment #29 in section 6.2 | | |
| ☒Unit of analysis and reference flow | See comment #2 in section 6.2 | | |
| ☒Type of inventory: cradle-to-grave or cradle-to-gate, and justification of a cradle-to-gate boundary, when applicable | See comment #19 in section 6.2 | | |
| ☒GHGs included in the inventory | | | |
| ☒Any product rules or sector-specific guidance used | | | |
| ☐For subsequent inventories, a link to previous inventory reports and description of any methodological changes; | | | |
| ☒Disclaimer stating the limitations of various potential uses of the report including product comparison | See comment #28 in section 6.2 | | |
| **b) Boundary Setting:** | | | |
| ☒Life cycle-stage definitions and descriptions; | See comment #30 in section 6.2 | | |
| ☒Process map including attributable processes in the inventory; | See comment #4 in section 6.2 | | |
| ☒Non-attributable processes included in the inventory; | See comment #31 in section 6.2 | | |
| ☐Excluded attributable processes and justification for their exclusion | See comment #21 in section 6.2 | | |
| ☒Time period; | See comment #34 in section 6.2 | | |
| ☐Method used to calculate land-use change impacts, when | | | |

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| applicable | | | |
| **c) Data Collection and Quality**<br>☒For significant processes included within boundaries, a descriptive statement on the data sources, data quality, and any efforts taken to improve data quality<br>☒Collection of primary data for all processes under the ownership or control of the applicant. | See comment #36 in section 6.2<br><br>See comment #23 in section 6.2 | | |
| **d) Allocation :**<br>☒Disclosure and justification of the methods used to avoid or perform allocation due to co-products or recycling<br>☐When using the closed loop approximation method, any displaced emissions and removals separately from the end-of-life stage | See comments #9 and #35 in section 6.2 | | |
| **e) Uncertainty:**<br>☒Qualitative statement on inventory uncertainty and methodological choices (Use and end-of-life profile, Allocation methods, including allocation due to recycling, Source of global warming potential (GWP) factors used, Calculation models) | See comments #25 and #38 in section 6.2 | | |
| **f) Carbon footprint calculation:**<br>☒Source and date of the GWP factors used;<br>☒Total inventory results in units of CO2e per unit of analysis, which includes all emissions and removals included in the boundary from biogenic sources, non-biogenic sources, and land-use change impacts;<br>☒Percentage of total inventory results by life cycle stage;<br>☐Biogenic and non-biogenic emissions and removals separately, when applicable<br>☐Land use impacts separately, when applicable<br>☒Cradle-to-gate and gate-to-gate inventory results separately (or a clear statement that confidentiality is a limitation to providing this information);<br>☒Companies shall not include the following when quantifying inventory results: weighting factors for delayed emissions; offsets; and avoided emissions; | See comment #13 in section 6.2<br><br>See comment #35 in section 6.2 | | |

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| ☒Amount of carbon contained in the product or its components that is not released to the atmosphere during waste treatment, when applicable OR, for cradle-to-gate inventories, the amount of carbon contained in the intermediate product. | | | |
| **g) Quality Assurance**<br>The assurance statement including::<br>☒Whether the assurance was performed by a first or third party;<br>☒Assurance providers (names, affiliation, and relevant competencies);<br>☐How any potential conflicts of interests were avoided for first party assurance;<br>☒A summary of the assurance process;<br>☒Level of assurance achieved (limited or reasonable) and assurance opinion or the critical review findings. | | | |

## 6.2 Reviewer's comments and authors' answers

| # | Reviewer | Page of report | Reviewers' comments | Authors' answers | Reviewers' answers |
|---|---|---|---|---|---|
| 1 | JFM | General | Although all requirements from the GHGP-PS are essentially met, there is a lack in transparency in the actual data (primary and secondary) used in the calculation of the GHG inventory that makes it hard to clearly understand the choices made and assess the results of the study. | Activity data is provided for ammonia and urea production, for both the IFFCO Canada scenario and the reference scenario at Appendix A. Emission factors are also provided for other main contributing processes (natural gas extraction, processing and transportation; transportation) at Appendix A. | OK |
| 2 | JFM | 4 | Since there are several possible functions for urea (agricultural fertilizer or industrial input), its exact function is unknown, thus according to the GHGP-PS | While urea can be used as an industrial input, most of the production is destined for agricultural use. | For a cradle-to-gate study there is no need for a functional unit, a |

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| | | | for an intermediate product whose final function is not known, the unit of analysis is the reference flow and not a functional unit.<br>However, there are several instances in the following sections of the report where the urea seems to be clearly identified as an agricultural fertilizer and in that case, a functional unit, and associated reference flow, could be defined as unit of analysis and the scope of the study would then need to be cradle-to-grave (the fact the use stage is assumed to be identical for the IFFCO Canada urea and the reference urea does not affect the unit of analysis definition according to the GHGP-PS, it may be referred to reduce the scope of the study and exclude this stage from the boundaries since the goal of the study is the comparison of the two scenarios and not the simple calculation of their respective GHG inventories). If it is clear that the granulated urea produced by the IFFCO Canada plant will be for agricultural use then the appropriate changes need to be made, if it is not clear and some uncertainty remains as to its function then those instances need to be removed. | The relative proportion going to each type of use, as well as the exact use mode in each situation is considered identical for both scenarios.<br>Both applications are mentioned in sections 1, 2 and 3.1. No references are made to use phase in subsequent sections. | reference flow is sufficient. |
| 3 | JFM | Table 3-1 | End-of-life: the end-of-life of urea as 1) fertilizer, is either uptake by plants or emissions of N2O and CO2 and run-offs in surface waters or aquifers, 2) industrial inputs, depends on the actual use but is linked with the end-of-life of the final product.<br>The operation of the urea plant will most probably generate various types of waste (chemical packaging, used catalyst and other chemicals), how will they be disposed of and is this included? | Details on the end-of-life of urea is added in Table 3-1.<br>The treatment of production waste is included in the production phase (comment added in Table 3-1). | OK |
| 4 | JFM | Figure 3-1 | The use stage only considers urea as agricultural fertilizer, either indicate that this is an illustrative example, don't show this detail at all, or include other possible uses as an intermediate chemical. | Industrial use is added to Figure 3-1. The Figure is also updated to reflect previous comments. | OK |

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| 5 | JFM | Table 3-3 | Will the projected distribution regions for DEF urea be the same? | DEF distribution is not considered since it is not planned to be produced in 2018. Only granular urea is included into the scope of the study. | OK |
| 6 | JFM | Table 3-4 | The sum of the indicated contributions for the supplying countries is not 100% but only about 80% for the three regions. | Other countries who are not important suppliers are not included. An additional country is added to lower the proportion of other countries for Quebec, Ontario and Eastern US. The row (others) is added. | OK |
| 7 | JFM | Table 3-5 | The projected numbers do not reflect those in Table 3-4 when you say that essentially no change will occur compared to the 2010-2012 situation. For example, for the Quebec market, Russia, Ukraine and Lithuania account for only 39% and not 50%; Qatar only accounts for 2.8% in Table 3-4 whereas the Middle East is projected to account for 15% of imports; and where is South America, Venezuela accounts for 8.6% in Table 3-4? There is no Middle East country listed in Table 3-4 for the Ontario supply mix.<br>The supply mixes are described in terms of regions whereas the data in Table 3-4 on which the projections are based refers to individual countries. Are the regions model as a single country used as representative, and if so, which one? | Update for Quebec:<br>“No change” changed to “slight increase” for Eastern Europe.<br>Libya was associated with Middle East when it should have been in North Africa. The percentages are corrected accordingly.<br>Production from South America expected to go mainly to the US and South America (comment added).<br>Update for Ontario:<br>The correction was performed for the Middle East, 5% transferred to North Africa.<br>The model for each region is based on countries which contribute the most to the supply mix. Chosen countries and plant locations for each region are given at Table 5-8. | OK |
| 8 | JFM | 10 | N2O emissions associated with use of urea as agricultural fertilizer is the main GHG concern. The carbon and N2O emissions released during the use and end-of-life stages are excluded from the boundaries of the study and this should be clearly stated. | The issue is put forward in section 1.2. A reference is added to section 3.1. | OK |
| 9 | JFM | 11 | Transport processes are multi-functional, i.e. they usually transport more than one good. How will these processes be allocated to each transported good? | Urea is transported in bulk and is usually the only product in trucks, wagons and trains used on a given distribution route. | Mass allocation for the transport processes seem to have been used. According to Appendix A, there is recycling of some |

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| | | | | | of the waste generated at the IFFCO Canada plant, a cut-off approach has been used to treat this multi-functional process. |
| 10 | JFM | Table 5-1 | Not enough details are provided on the data used for the GHG inventory calculation, i.e. the reproducibility of the latter is not assured by the level of detail provided. Most of the data sources indicated are public ones and no confidentiality issues restrict the divulgation of the detailed information. The name of the ecoinvent, US LCI and DEFRA datasets used could at least be indicated. Is the Russia data also used as proxy for the other Eastern Europe countries?<br>In relation to comment #6, grid mixes for many different countries are listed, are these the only countries modeled (they are not all the countries listed in Table 3-4)? What are the sources for those grid mixes? | See answer to comment #1.<br>Countries used as proxies for regional models are provided at Table 5-8.<br>Grid mixes and data sources for each country used as a proxy are provided at Table 5-9. | OK |
| 11 | JFM | Table 5-4 | Only the natural gas combustion to provide the energy to drive the steam reforming, ammonia synthesis and urea synthesis seems to be considered, has the natural gas feedstock (around 0.27 kg $CH_4$/kg urea) been included in the calculation of natural gas use? Also, during steam reforming of natural gas, $CO_2$ is generated and captured to be later used during urea synthesis, what is the assumed yield of the process and efficiency of the capture? If not 100%, is the emitted $CO_2$ included in the inventory calculation? The same thing goes for urea synthesis which combines the ammonia and captured $CO_2$, what is the efficiency/yield of the process, are there any fugitive releases? | Natural gas use is based on data from IFFCO Canada (IFFCO Canada scenario) and industry data (reference scenario). See Table 5-10. It includes both the fuel and feedstock.<br>For IFFCO Canada, emissions are calculated based on combustion emissions and the composition of the flue gas (from the reforming process). It includes uncaptured CO2 from the ammonia production process and venting emissions (refer to SEIA).<br>For the reference scenario, total CO2 emissions from natural gas feedstock are calculated based on the IPCC factor (56.1kg/GJ). The required amount for urea (0.735kg/kg urea) is substracted during urea production. Exceeding CO2 is thus assumed to be vented at one point | OK |

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| | | | | or another of the process. | |
| 12 | JFM | Appendix A | The location of the distributor's warehouse seem to change for the same distribution region depending on the supplying region/country and scenario, why is that? Doesn't that make the unit of analysis and system boundaries for the two scenarios different, the GHGP-PS requires for inventory comparison that they should be the same? | Distribution routes were revised so that only one representative location is considered for each region, with the exception of the US. In this region, a few sites located at equal distances of three terminals (Saint-Louis, MI, Chicago, IL / Burns Harbor IN and Springfield IN) were selected.<br>Each of the sites considered can be supplied by at least two terminals. Hence, distribution routes for both the IFFCO Canada and the reference are considered equivalent. | OK |
| 13 | JFM | 20 | The values of the GWP factors used should be given to make it more transparent and easier for the reader to know which values were used. | The valued are provided. | OK |
| 14 | JFM | 20 | The carbon content of urea is 20% (based on the formula $(NH_2)_2CO$ and a molecular weight of 60). Considering that all the carbon contained is emitted and completely oxidized to $CO_2$ (does this constitute a reasonable hypothesis?), one gets 733 kg $CO_2$ (or eq.)/ton urea and not 773 kg as indicated. This however does not consider the much more problematic emissions of $N_2O$ associated with the use or urea as agricultural fertilizer. | It was a typo. The value was corrected in the text. The value used for activity data is correct. | OK |
| 15 | JFM | 21 | The more detailed contribution analysis would be interesting to have. | The exact contribution for main processes (IFCCO Canada and reference urea) is provided in section 6.1. | OK |
| 16 | JFM | Table 7-2 | The base scenario is understood to be "the-middle-of-the-road" scenario between the two "extreme" ones, so how can the result for the former for the IFFCO Canada urea be higher than the ones for both the alternative scenarios, i.e. focussing on North America for urea produced in Quebec would tend to give lower results but wouldn't focussing on Europe give higher ones?. | The (very marginal) reduction between the base case and North America comes from increased shipments in Quebec (low distribution impacts). The (very marginal) reduction between the base case and Europe are due to the replacement of shipments in North America (train/vessel) to Europe (transoceanic ship / train). | OK |

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| 17 | JFM | 24 | Were all ecoinvent emission factors for the transport processes replaced with DEFRA and US LCI ones or just those for the transoceanic freight transport? SimaPro 7.3.3 provides a way to remove the contributions of the infrastructure processes included in the ecoinvent database, why wasn't this tool used? | All the transport processes were replaced. DEFRA processes are used for the comparison, but by default, it is judged better to include infrastructures in transport processes because they can have a significant impact. | OK but since infrastructures are excluded for most modelled processes, they should have also been excluded from all the ecoinvent modelled processes. |
| 18 | DOC | General | It is really difficult to assess the report since neither the primary data or the calculations for the urea production process are provided. The reason provided for the low emissions is the higher use of electricity but no values are provided for the scenario or the reference case. | See answer to comment #1.<br>On the basis of the activity data, electricity consumption is indeed higher for the IFFCO Canada scenario (0.4kWh / kg urea) than for the reference scenario (approx. 0.18kWh). | OK |
| 19 | DOC | 1 and Table 1-2 | While the work is done for a cradle to gate system, there is some data supplied on product use. This should be removed as I don't think it is correct. In Table 1-2 the figures for use do not include the $CO_2$ from hydrolysis of the urea. The last line of section 1 mentions different emissions with different types of fertilizer. This could be removed but if it stays in it should be referenced as this is not universally accepted and the Bouwmen paper that is the probable reference doesn't have many data points. | The figures in Table 1-2 do include hydrolysis: 0.733kgCO2e for hydrolysis and 3.03kgCOe in ON/QC for N2O or 0.353kgCO2e for Prairies. Calculations are based on the references provided for nitrification, denitrification and indirect from volatilization and leaching. Reference was added to the Bouwman paper. The conclusions of Bouwman are based on the compilation of data from 849 sites.<br>Can a reference be indicated to support the fact that the conclusions in Bouwman paper are controversial? | I am OK with the removal of the suggestion that $N_2O$ emissions are a function of the type of fertilizer. No need to add the reference that suggestions to the contrary are controversial. |
| 20 | DOC | 5 | There should be some discussion of the limitations of the study. It is appropriate for comparison of this nitrogen fertilizer source to other sources of urea but not to other types of nitrogen fertilizers as only urea results in $CO_2$ emissions when it is applied to the soil. | It is already specified that the results are not meant to be a platform for comparability to other companies and/or products. It would not be coherent to mention that the results can be used by others for comparisons between their own urea, but not for other types of nitrogen fertilizer.<br>A comment is added in section 1.2 on the fact that urea is the only N fertilizer with hydrolysis | OK |

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| | | | | CO2 emissions. | |
| 21 | DOC | 7 | Should add rationale for excluding infrastructure, equipment, etc. | According to the GHG Product PS, non-attributable processes (among which figure infrastructure and equipment) must be excluded from the system boundaries. They are excluded for both the IFFCO Canada and the reference scenarios. | OK |
| 22 | DOC | 7 | There needs to be a clearer statement on the system boundaries. The inclusion of some discussion on product use confuses the issue. | See answer to comment 2. | OK |
| 23 | DOC | Table 5-1 | No detail is provided on the primary data that is used. The lack of transparency makes it impossible to judge the overall results. | See answer to comment 1. | OK. Shouldn't the reference for electricity in Table A.1 also be SNC rather than IIFCO? All of the other inputs are SNC. |
| 24 | DOC | Table 5-1 | I have no issues with the data sources used for secondary data. I think that they are generally the best available. | OK | No response required. |
| 25 | DOC | Tables 5-4 and 5-6 | The US EPA revised their emission factors for methane losses in the 2011 NIR that was released in April. These are not yet included in GHGenius. They are lower than previous emission factors. | Emissions from NG extraction, processing and transport have been adjusted in the GHGenius model according to the most recent USEPA inventory. | OK |
| 26 | DOC | Table 6-3 | In section 6, the plant emissions are reported as 340 kg $CO_2$eq/t urea. In the SNC project description supplied to the Canadian Environmental Assessment Agency the emissions are reported as 0.41 t $CO_2$eq/tonne. Why the difference? | An addendum to the SEIA report by SNC-Lavalin will be made public for the public hearings. It will contain the updated GHG emissions for the IFFCO Canada plant.<br>NG consumption is reduced by using more electric motor driven equipment and less steam turbine driven equipment. | OK |
| 27 | MB | General | The authors did not cover specifically all requirements as stated in chapter 12 of the GHGP-PS. However, I do confirm that "Urea comparative carbon footprint" study has been carried out according to the GHGP-PS guidelines.<br>Although the report focuses on carbon footprint | Are there requirements not addressed in the comments?<br>There are no specific requirements in the GHG Protocol PS to address non CO2 emissions. On-site atmospheric emissions are covered in details in the SEIA made public earlier this year. | OK |

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| | | | assessment, it would be more informative for the readers (or the public in general) to complement the report with few words on emissions other than $CO_2$ (e.g., possible leaks and/or effluents of $NH_3$).<br>The assumptions are meaningful and sources of data used in the calculations are well described.<br>If IFFCO Canada has any plan to achieve inventory emissions reduction in the future (e.g., 5-years plan following the first production year), it will be interesting to state the general strategy to do so. | The strategy for further emission reductions (covering the 2018-2022 period) has not yet been defined. Actions were put forward during the design stage to reduce GHG emissions. | |
| 28 | MB | i | A specific disclaimer to limit the endorsement and/or the use of the views, recommendations and the results should be added. It has to appear before the table of contents. | Such a disclaimer will be added, in conformance with the guidelines in place at EY. The exact formulation will be confirmed after review by our legal services, which is planned during the week of Aug. 19$^{th}$. | OK |
| 29 | MB | 1 | Without revealing any strategic information, the technical specifications of the “urea production technology”, selected by IFFCO Canada, should be provided in section 1 “General information”. The idea is to let the readers capture at an early stage the specifics of the Bécancour plant.<br>A summary of the fertilizer sector profile would better position IFFCO Canada’s Bécancour plant, at least in the North-American market context. | A high level description of the urea production is provided.<br>To avoid repeating existing information, readers are referred to the Environmental Impact Assessment (EIA) report prepared by SNC-Lavalin for a more detailed description of the technical specifications.<br>The fertilizer sector is also covered in the EIA report. It was chosen not to duplicate the content in the carbon footprint report. | OK |
| 30 | MB | Table 3-1 | The boundaries are well circumscribed and evidently highlighted.<br>Even though the study is limited to the gate (i.e., the production stage), the five stages of the urea life-cycle have been clearly illustrated. | OK | OK |
| 31 | MB | 7 | The non-attributable processes have been identified. | OK | OK |
| 32 | MB | Table 3-3 | Data presented in Table 3-3 are on yearly basis. Therefore, the caption could be modified as follows: “Projected distribution and yearly quantities for IFFCO Canada”. | The caption was updated. | OK |

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| 33 | MB | 8 | Uncertainties due to seasonal attributes of fertilizer market could be mentioned. | The seasonal attributes of the fertilizer market are not expected to affect the operations at the plant. Production levels are expected to stay relatively constant throughout the year. Stocks are accumulated by distributors during the cold season and sold during the warm season. | OK |
| 34 | MB | 10 | The main issue is the time period which coincides with the starting year of the plant. This is not so convincing. More explications could be added to make it more defensible. | Additional explanations were given in section 3.3. | OK |
| 35 | MB | Section 4 | As the projected plant at Bécancour is targeting only the production of granulated urea as a product output, the allocation of emissions or removals is not mandatory. | OK | OK |
| 36 | MB | Section 5 | The data sources are defined and the data quality assessment is well done. | OK | OK |
| 37 | MB | Section 6.1 | The “Contribution analysis” should be detailed in the final report. | See additions in section 6.1. | OK |
| 38 | MB | Section 7 | The types of uncertainties are described.<br>How do the limiting samplings affect the values of the emission factor?<br>Do the seasonal fluctuations of the fertilizer market affect the production of granulated urea? If yes, how it can be considered as a source of uncertainty? | M. Benali was contacted Aug. 12$^{th}$ to obtain more details on his comment regarding the sampling.<br>See answer to comment #33 for the influence of seasonal fluctuations. | OK |
| 39 | MB | 24 | Following the sub-section 7.3, a clear statement of the principal findings should be added. The general public reader would appreciate to discover the importance of this study. Besides, the reader will look for understanding at what extent the IFFCO Canada urea technology is an advanced one as compared to other plants and established on high environmental performance and high energy efficiency standards. | A section on the summary of findings is not required by the GHG Protocol PS. A one page document is being prepared to present to key findings of the study. It will be disclosed at the same time as the carbon footprint report.<br>The characteristics of IFFCO Canada’s urea production process is disclosed in the EIA report. An addendum will be presented at the beginning of September to explain how the replacement of steam turbines by electric motors significantly reduces GHG emissions. | OK |

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| 40 | MB | Section 6 | As the analysis provided in the report is driven by the "cradle-to-gate" life cycle assessment, there is no need to include evaluation of biogenic and non-biogenic emissions assessment as well as the land use impacts. | It is already specified that no biogenic or land-use emissions / removals occur. Does the sentence need to be clearer? | OK |
| 41 | MB | 30 | An appendix C, in which disaggregation of GHG impacts will be reported, could be of interest for the reader. | M. Benali was contacted Aug. 12th to obtain more details on his comment regarding the detailed presentation of results.<br>The contribution analysis in section 6.1 provides disaggregated results for main contributing processes. | OK |
| 42 | DOC | Appendix A | Tables A.1 and A.2 should be better aligned for comparison. Table A.1 is for an integrated plant, natural gas to urea. Table A.2 is for separate plants, NG to ammonia and then ammonia to urea and it uses different units. Suggest modifying Table A.2 so that it is NG to Urea and using the same units as used in Table A.1. That way an easy comparison between the project data and the reference data can be made. | | |
| 43 | MB | i | An executive summary should be added before section 1 of the report. | | |

**EY** | Assurance | Tax | Transactions | Advisory