Clean Hydrogen Investment Tax Credit: Carbon Intensity Modelling Guidance Document

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I. Foreword

This document provides instructions on how to characterize cradle-to-gate life cycle greenhouse gas emissions of the hydrogen pathway (mass basis) that is included in the Government of Canada's Fuel Life Cycle Assessment (LCA) Model (the Model) in the support of the Clean Hydrogen investment tax credit.

II. Disclaimer

This document does not in any way supersede or modify the *Income Tax Act* (*ITA*) or offer any legal interpretation of those *Regulations*. Where there are any inconsistencies between this document and the *ITA* or *Regulations*, the *ITA* or *Regulations* take precedence. This document is not to be used for credit creation purposes under the *Clean Fuel Regulations (CFR)*.

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V. Terms and definitions

The definitions in the *Income Tax Act* (ITA) apply. Refer to Subsection 127.48 (1) of the *ITA* for other terms and definitions. This section includes only those additional definitions not found in the *ITA*.

Advanced modelling: is applicable when the hydrogen production process and all supporting equipment and activities could be represented by more than one UP that can include unit processes such as B- Oxygen and nitrogen generation system (AM); C- Carbon dioxide (CO2) capture, at HPS (AM); and D- Electricity and heat generation system (AM) in addition to the A- Hydrogen production, at HPS (AM) UP.

Allocation: partitioning the input or output flows of a process or a product system between the product system under study and one or more other product systems (ISO 14040).

Cradle-to-gate: scope of a carbon intensity which covers all life cycle stages up to the production facility gate.

Distinct feedstock: a feedstock associated with a unique CI value and that is represented by a system process or a UP included in the Fuel LCA Model.

Feedstock type: category of feedstock included in the Fuel LCA Model or specified in section 3.3.2 of this document.

Functional unit: means the quantified performance of a product system for use as a reference unit.

Input: product, material or energy flow that enters a unit process (ISO 14040).

Intermediate output flow: output from a UP that is input to other unit processes that require further transformation within the system (ISO 14040).

openLCA: free and open-source software in which the Fuel LCA Model must be imported.

Output: product, material or energy flow that leaves a unit process (ISO 14040).

Product system: defined as a collection of unit processes with elementary and product flows, performing one or more defined functions, and which models the life cycle of a product (ISO 14040).

Simplified modelling: this modelling approach is applicable when the entire hydrogen production process and all supporting equipment and activities, can be represented by only one UP.

System process: aggregation of unit processes that models the life cycle emission factors of a certain activity.

Unit process: smallest element considered in the life cycle inventory analysis for which input, and output data are quantified (ISO 14040/44).

VI. List of abbreviations

AM	Advanced modelling
AR	Assessment report
ATR	Autothermal reforming
CCUS	Carbon capture, utilization and storage
CFR	*Clean Fuel Regulations*
CH-ITC	Clean Hydrogen investment tax credit
CI	Carbon intensity
CO_2	Carbon dioxide
ECCC	Environment and Climate Change Canada
EHGS	Electricity and heat generation system
GHG	Greenhouse gas
H_2	Hydrogen
HEF	Hydrogen efficiency factor
HHV	High heating value
HPS	Hydrogen product system
IPCC	Intergovernmental panel on climate change
ISO	International organization for standardization
ITA	*Income Tax Act*
kWh	Kilowatthour
LCA	Life cycle assessment
MJ	Megajoule
N_2O	Nitrous oxide
O_2	Oxygen
ONGS	Oxygen and nitrogen generation system
OPS	Other product system
PPA	Power purchase agreement
RNG	Renewable natural gas
SM	Simplified modelling
SMR	Steam methane reforming
TS	Technical specification
UP	Unit process

1 Introduction

1.1 Background

The Clean Hydrogen investment tax credit (CH-ITC) supports projects that produce clean hydrogen through a refundable tax credit. The tax credit rates are based on the assessed carbon intensity (CI) of the hydrogen that is produced. This is represented by a kilogram (kg) of carbon dioxide equivalent (CO_2e) per kg of hydrogen and applied to eligible property that becomes available for use by 2034.

Clean hydrogen projects must assess the CI of the hydrogen that will be produced based on the design of the project using the Government of Canada's Fuel Life Cycle Assessment (LCA) Model (the Model) that is maintained by Environment and Climate Change Canada (ECCC).

Once operating, clean hydrogen projects must demonstrate that the CI of the hydrogen they produced falls into the same tax credit tier that the project was assessed at, or within 0.5 kg CO_2e/kg H_2 of the tier if the actual CI is higher than the expected CI. This must be demonstrated over a 5-year compliance period. The CI of the hydrogen being produced must be assessed each year with the Model, and the CI for the entire compliance period must be verified by an independent third-party after the fifth year of the compliance period.

The Clean Hydrogen Investment Tax Credit – Carbon Intensity Modelling Guidance Document (CI Modelling guidance) is intended for use by taxpayers and provides comprehensive CI modelling instructions for assessing the CI of a clean hydrogen project with the Model.

1.2 Fuel Life Cycle Assessment Model

The Model is a tool used to calculate the life cycle CI of fuels and energy sources used and produced in Canada. The Model helps to support the delivery of regulations and programs as part of Canada's actions on climate change. For example, the *CFR* use the Model to determine the CI of fuels, material inputs, and energy sources for credit creation.

For the purposes of calculating the carbon intensity of hydrogen produced and to be produced by a clean hydrogen project, applicants must use either:

1. The most recent version (published in August 2024, or thereafter) of the Fuel LCA Model at the time of filing by the taxpayer of the most recent related clean hydrogen project plan with the Minister of Natural Resources. No reassessment is required if a new version of the Fuel LCA Model becomes available, unless a revised clean hydrogen project plan is filed electively or is required per Subsection 127.48(8) of the *Income Tax Act (ITA)*.

2. A subsequent version or the most recent version of the Fuel LCA Model that becomes available from when the clean hydrogen project plan is filed to when the annual compliance report is filed, if the taxpayer elects to use a subsequent or the most recent version of the Fuel LCA Model instead of the version used at the time of filing of the final clean hydrogen project plan.

The most recent version of the Fuel LCA Model is available under the "Fuel LCA Model (latest version)" folder on the Environment and Climate Change Canada Data Catalogue.

1.3 CH-ITC CI Modelling Guidance Document and Workbook

The objective of the Clean Hydrogen Investment Tax Credit – Carbon Intensity Modelling Guidance Document is to provide clear CI modelling instructions for CH-ITC applicants to ensure that the CI from any clean hydrogen project is calculated in a fair, consistent and comparable manner, independently of the nature or configuration of the project. It also provides the main instructions to enter data in the CH-ITC Workbook and in the Model.

The CH-ITC Workbook contains spreadsheets that help to convert applicant data into data for input into the Model and document the modelling of the hydrogen product system (HPS). It must be used to carry out all calculations prior to data entry in the Model. This could include unit conversions, weighted average calculations, etc.

Each version of the CH-ITC CI Modelling Guidance Document is associated with a corresponding version of the CH-ITC Workbook that applicants must use together.

The applicants must use the most recent version and subversion of the CH-ITC CI Modelling Guidance Document and CH-ITC Workbook at the time of filing by the taxpayer of the most recent related clean hydrogen project plan with the Minister of Natural Resources. For example, if applicants use the latest subversion of version 1 (for example, version 1.1) of the CH-ITC CI Modelling Guidance, then the version of the CH-ITC Workbook must also be the latest subversion of version 1 available (for example, version 1.2). Please note that the latest versions of the CH-ITC CI Modelling Guidance Document and the CH-ITC Workbook may not necessarily have the same subversion number.

For the purposes of calculating the CI of hydrogen produced (actual CI), applicants must use either:

1. The same version and subversion of the CH-ITC CICI Modelling Guidance and CH-ITC Workbook that were used at the time of filing by the taxpayer of the most recent related clean hydrogen project plan with the Minister of Natural Resources
2. A subsequent version of the CH-ITC CI Modelling Guidance and CH-ITC Workbook that is compatible with the version of the Fuel LCA Model that are listed in the most recent version of the CH-ITC CI Modelling Guidance. In this case, the applicant must use the most recent subversion of the CH-ITC CI modelling guidance and CH-ITC Workbook available.

ECCC will make a table of valid combinations of versions and subversions of the Model, CH-ITC CI Guidance, and CH-ITC Workbook available.

In addition, this version of the CH-ITC CI Modelling Guidance Document (and the corresponding CH-ITC Workbook are to apply conclusively with the **August 2024** version of the Model.

1.4 Associated documents

The ***Clean Fuel Regulations*** **Specifications for Fuel LCA Model CI calculations** is the central document to consult to determine a CI value using the Model under the *CFR*. This CH-ITC CI modelling guidance document is based on the *CFR* Specifications to ensure consistency between the CI modelling within Government of Canada regulations and programs. The *CFR* Specifications may also be required for the CI modelling of some feedstocks and fuel inputs covered by this CI Modelling Guidance.

The **Clean Hydrogen Investment Tax Credit - Technical and Equipment Guidance Document** provides guidance on the types of property that are described under Subsection 127.48 (1) of the *ITA* and applies to engineering and scientific matters only as it pertains to equipment eligibility.

The **Clean Hydrogen Investment Tax Credit – Validation and Verification Guidance Document** outlines requirements for taxpayers, third-party qualified validation firms, and qualified verification firms in preparing CI documentation required for the CH-ITC.

The **Data Library** and **Fuel Pathways** are the main components of the Model that must be uploaded in the openLCA modelling software. The Data Library provides a selection of life cycle emission factors (called system processes) that can be used to populate the hydrogen pathway (mass basis) stored in the Fuel Pathways folder of the Model.
ISO 14040/44 standards: The applicant must always follow the general principles stated in ISO 14040/44 in parallel with this guidance document. It is recommended that the applicant reviews these standards prior to reading the guidance.

The **Fuel LCA Model** has been primarily developed to model the life cycle of liquid and gaseous low-carbon-intensity (CI) fuels and other material inputs and energy sources such as electricity, hydrogen, etc. The following documents and tools should be consulted and used in parallel if applicants are calculating a CI value using the Model in the context of the CH-ITC.

The **Fuel LCA Model Methodology** describes the methodology, data sources, and assumptions that were used in the development of the Model and provides the rationale supporting the methodological approach.

The **Fuel LCA Model User Manual** provides information about the concepts and terms used in this document (CI Modelling Guidance). It also provides technical guidance on how to perform basic operations in the openLCA software that are required for CI calculations. This document (CI Modelling Guidance) includes references to sections of the Fuel LCA Model User Manual.

2 Key concepts of carbon intensity modelling

This section presents key concepts that must be understood to perform CI modelling using the Model under the CH-ITC. It also presents the scope of the CI modelling and outlines the options available for CI calculations. Finally, it provides an overview of the 2 steps required to model a hydrogen pathway: entering applicant data into the CH-ITC Workbook and modelling the pathway in the Model.

2.1 Definitions

The following definitions introduce the key concepts on which CI modelling with the Model is based on. Applicants should familiarize themselves with these concepts before proceeding with the CI modelling of their clean hydrogen project.

2.1.1 Unit process

A unit process (UP) is the smallest element considered in the life cycle inventory analysis for which input and output data are quantified as per ISO 14040/44.

Each UP includes input and output flows to and from a group of process equipment or activities. Each UP boundary should include process equipment and activities and their associated flows of material, energy, and emissions required to perform an LCA in accordance with ISO 14040/44 and this modelling guidance. Also, each process equipment or activity must be accounted for only once, meaning that flows from 1 piece of equipment or activity **cannot** be part of more than 1 UP.

2.1.2 Product system

A product system is defined as a collection of unit processes with elementary and product flows, performing one or more defined functions, and which models the life cycle of a product as per ISO 14040/44.

Under this modelling guidance, there are 2 types of product systems: the hydrogen product system (HPS) and other product systems (OPS), such as ammonia production. The OPS is used for setting up the applicant’s activity map but is not included in the actual modelling in openLCA.

2.1.2.1 Hydrogen product system

The hydrogen product system (HPS) groups one or more-unit processes that are required to produce hydrogen. The HPS represents the hydrogen production facility with all supporting equipment and activities, which constitutes a clean hydrogen project, and can be represented by one or more unit processes. Refer to Figure 1 for an example of a single UP. For example, this could include the treatment of a natural gas feedstock at the hydrogen production facility.

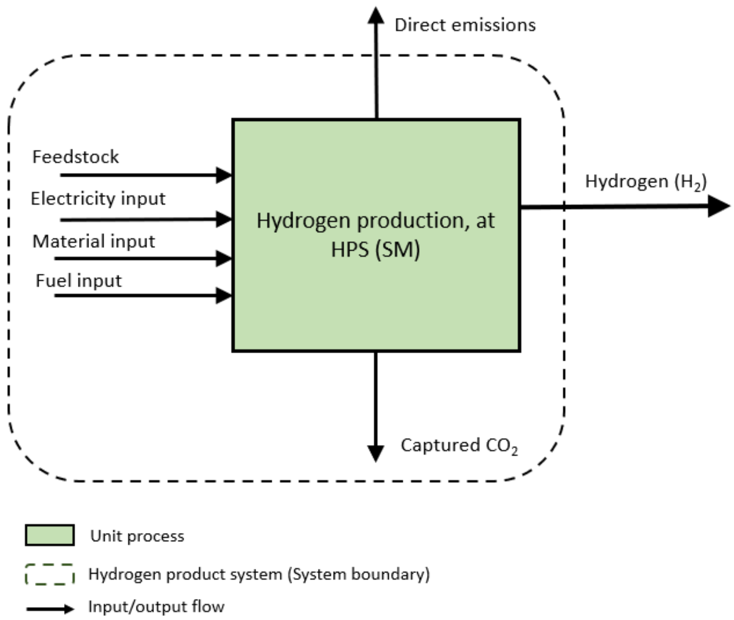

Figure 1: Example of the Hydrogen production, at hydrogen product system (SM) UP included in the hydrogen product system under the simplified modelling approach.

In this CI modelling guidance, the number of unit processes that are part of the HPS and their scope (inclusions and exclusions) are defined by the choice of the modelling approach: simplified or advanced.

Applicants can refer to section 2.4.2 for more information on the simplified and advanced modelling approaches.

2.1.2.2 Other product system

The other product system (OPS) regroups one or more-unit processes that interact with the HPS through the exchange of material or energy flows but are not part of the HPS boundaries. Examples of other product systems can include:

- ammonia production unit such as a Haber Bosch loop that is using hydrogen from the HPS to produce ammonia and exchanging flows such as steam
- processes in a chemical or refinery plant that are using hydrogen from the HPS and exchanging flows such as feedstock, electricity, steam, or fuel inputs

OPS are not covered by this CI modelling guidance, but this concept is used to determine which flows of material or energy leave or enter the HPS.

2.2 Scope of the carbon intensity modelling

This section defines the scope of the life cycle assessment that must be caried out to calculate the CI value of an eligible hydrogen project, using the Model.

2.2.1 Eligible pathways

The CI modelling guidance is applicable to 2 main categories of hydrogen production processes, as defined in Subsection 127.48(1) of the *ITA*:

- from electrolysis of water
- the reforming or partial oxidation of eligible hydrocarbons with carbon dioxide captured using a carbon capture, utilization, and storage (CCUS) process

Applicants should refer to section 3.3 for the list of eligible feedstocks under the CH-ITC.

2.2.2 Functional unit

A functional unit is "the quantified performance of a product system for use as a reference unit" as per ISO 14040/44. When performing an LCA, applicants are required to assess their system's performance by using the same functional unit to ensure that the CI values are consistent for all projects. A consistent functional unit is required to evaluate the cradle-to-gate emissions associated with hydrogen production facilities on a fair and transparent basis. Applicants must declare the pressure, state of hydrogen and purity of the hydrogen produced from their HPS.

For the purposes of the CH-ITC, the functional unit is defined as:

The production of 1 kg of gaseous pure (100%) hydrogen at a pressure between 1 and 30 bar, produced in Canada, at the hydrogen product system gate.

If applicants produce hydrogen (gaseous) between 1-30 bar and at a purity of 100%, then no adjustment is required. In addition, the compression and purification processes to reach the functional unit are included in the HPS.

If the actual purity of the hydrogen produced by an eligible project differs from the functional unit, an adjustment procedure is required to equate it to the functional unit. In addition, if applicants use compression to bring the hydrogen (between 1 and 30 bar) above 30 bar, then an adjustment procedure can be applied.

When hydrogen is in a liquid form, liquefaction is never included in the HPS's system boundaries. It is recommended that applicants apply the adjustment procedure to the electricity use of this equipment if the electricity for liquefaction is already included in their data collection.

2.2.2.1 Adjustment for purity and pressure

The adjustment procedures apply to both the simplified and advanced modelling approach.

Purity adjustment to reach functional unit

For the purposes of modelling, if the purity of the hydrogen is below 100%, the quantity of the hydrogen output flow must be converted to a quantity on a pure (100%) hydrogen basis. Applicants should refer to section 3.2 for instructions on this procedure. The impurities containing carbon will be considered as though fully oxidized and released as CO_2 emissions. However, this adjustment is considered covered by the procedure to calculate direct emissions from the HPS (refer to section 3.6.2.4).

Additional adjustments
If compression is used to bring the hydrogen (between 1 and 30 bar) above 30 bar applicants **can deduct** the electricity use for compression from the total electricity consumption of the HPS if it occurs on-site at the hydrogen production facility. Applicants should refer to section 3.6.3.2 for instructions on this case.

Please note that liquefaction as well as processes for delivering, collecting, recovering, treating, or recirculating water are outside of the system boundary of the HPS, therefore electricity used by these processes **can** be deducted from the total electricity consumption. Applicants should follow the procedure in section 3.6.3.2.

2.2.3 System boundaries

The CI value is determined by assessing the greenhouse gas (GHG) emissions emitted during different stages of the life cycle. As per ISO 14044 section 4.2.3.3, the system boundary “determines which unit processes shall be included within the LCA”. This includes deciding which inputs/outputs are contained in the unit processes. Applicants are encouraged to review this section of the ISO standard before proceeding in the guidance.

Applicants must refer to the detailed modelling guidance in sections 3 (simplified modelling) and 4 (advanced modelling) for an exhaustive list of processes and flows that are included and excluded in the system boundaries.

Under the CH-ITC, the life cycle boundaries of an eligible hydrogen project (and its corresponding product system) are limited to a cradle-to-gate CI value. The term ‘cradle-to-gate CI value’ is defined as the aggregate lifecycle GHG emissions from resource extraction (cradle) until the hydrogen is produced and is ready to be delivered to another product system (gate). The HPS can include an entire facility dedicated to the production of hydrogen or a production unit of hydrogen that is part of a larger facility. In the latter case, special attention must be paid to the definition of the system boundaries. Certain flows or equipment in a larger facility will be excluded from the system boundaries if these are not necessary to produce hydrogen. For instance, flows related to a Haber Bosch loop in an ammonia process would be excluded from the system boundaries, but an air separation unit used by both the hydrogen production and the ammonia process would not be excluded. Please note that the process and property eligibility defined under the Clean Hydrogen Investment Tax Credit - Technical and Equipment Guidance Document does not affect the system boundaries under the Clean Hydrogen Investment Tax Credit – Carbon Intensity Modelling Guidance Document.

This CI value includes the emissions associated with feedstock extraction, processing, and delivery to an HPS. It also includes the emissions associated with the hydrogen production process: electricity, fuel and material inputs used by the HPS and direct emissions from the process. The use of system processes from the Data Library of the Model ensures that upstream life cycle emissions of material and energy inputs are considered in the system boundary.

When CCUS technology is used, this modelling guidance assumes that all CO_2 is released into the air, but the emissions captured from the HPS are subtracted from the total emissions. However, only CO_2 going to an eligible use, as defined in Subsection 127.44(1) of the *ITA,* is subtracted from the total emissions. If the CO_2 is stored or sent to an ineligible use, this will not be considered as captured and is assumed to be released into the air.

When calculating the expected CI, CO_2 can only be subtracted from the total emissions if storage of CO_2 in a geological formation, or use of CO_2 in the production of concrete, meets the requirements of eligible use at the time of calculating the expected CI. For storage in a geological formation, this means that the geological formation must be located in a designated jurisdiction (as defined in Subsection 127.44(1) of the *ITA*) at the time that the expected CI is being calculated.

Additional compression required for on-site storage of hydrogen can be excluded through the procedure for pressure adjustment (refer to section 2.2.2.1) and liquefaction is considered outside of the system boundary. Any other downstream activities or emissions, such as off-site hydrogen storage, transportation, distribution (including leaks), and combustion are outside of the scope of the CH-ITC and therefore excluded. However, impurities containing carbon in the output flow of hydrogen will be considered converted in CO_2 emissions and they will be included in the boundary of the HPS, independently of when and where they occur (refer to section 3.6.2.4).

Under the advanced modelling approach, hydrogen may not always be an output flow of the HPS system boundaries. For example, hydrogen can be entirely consumed for electricity production that is then, in part, used to power the hydrogen production plant. In this case, the CI of hydrogen can still be calculated, but as an intermediate flow within the HPS.

Finally, the benefits of using hydrogen as a material or fuel input by another product system (such as displacing fossil fuels) are also excluded from the boundaries.

In a case where the HPS is highly integrated with the OPS, the Clean Hydrogen Investment Tax Credit - Technical and Equipment Guidance Document can be consulted to help determine which equipment is required for hydrogen production and that should be included.

2.2.3.1 Cut-off criteria

As per ISO 14044, cut-off criteria are required to determine which inputs/outputs should be included in the LCA. Several cut-off criteria can be used in LCA practice, such as mass, energy, and environmental significance. These criteria can be used to reduce the burden associated with data collection but not to exclude readily available information to artificially lower the CI.

In the context of the CH-ITC, the 1% cut-off rule is permitted in relation to environmental significance. This means that processes can be excluded from the LCA if they contribute to less than 1% of the total impacts. For example, if propane is used as a fuel input for the operation of a forklift onsite, then its contribution is considered below the cut-off criteria. Thus, it can be excluded. If an applicant wants to apply the 1% cut-off rule to a process, then they must follow the instructions below.

Applicants can apply the cut-off criteria to quantifiable data that is **not readily available** before modelling their CI. If the contribution of a material or energy flow to the hydrogen's CI value is expected to be lower than 1%, and the aggregate of all such exclusions is not expected to exceed 2%, then it can be excluded.

Applicants must state when 1% cut-off criteria are used within a process by stating, "A 1% cut-off criteria has been applied on the environmental significance" in the data completeness section in openLCA for that process. In addition, life cycle stages, inputs, and emissions that are explicitly excluded in the CI modelling guidance should not be considered in the application of the cut-off criteria.

To determine the environmental significance of an input or output, a contribution analysis using the "Contribution tree" tab from the window entitled, "Results of:" in openLCA can be used to apply cut-off criteria.

2.2.4 Impact assessment method

To obtain the CI value from the life cycle inventory of GHG emissions of the system, applicants must use the impact assessment method from the Assessment Report 6 (AR6) of the Intergovernmental Panel on Climate Change (IPCC). Global warming potential (GWP) values that are based on a 100-year timeframe are used. Further details are listed in section 5.

2.2.5 Temporal boundaries (period of data)

As per the *ITA*, 2 types of CIs must be calculated for applicant's clean hydrogen project: expected CI and actual CI. Please refer to Subsection 127.48 (1) of the *ITA* for more information on the role of each CI.

2.2.5.1 Expected carbon intensity

An expected CI must be calculated for the hydrogen that is expected to be produced by each clean hydrogen project. It must be calculated by using the data included in the applicant's clean hydrogen project plan and using cumulative data that represents the first **20 years** of operation of the eligible project. The project plan must include assumptions on the volume of production (kg H_2) as well as all other input and output flows of the HPS including any eligible power purchase agreements for electricity and agreements to procure eligible renewable hydrocarbons for each year of the first **20 years**. The expected carbon intensity must be validated by a qualified validation firm in accordance with the Clean Hydrogen Investment Tax Credit – Validation and Verification Guidance Document.

2.2.5.2 Actual carbon intensity

An actual CI must be calculated for hydrogen that is produced by a qualified clean hydrogen project based on the actual inputs and emissions. As per the *ITA* (*127.48 (1) actual carbon intensity*), the compliance period for the actual CI is based on a minimum of **5 operating years**. It must be calculated for **each year** of the **5-year compliance period**. The data for each year of the compliance period must be collected directly from the hydrogen facility, and annual compliance reports filed. At the end of the fifth year of the compliance period, the data and actual CI calculation for the entire compliance period must be verified by a qualified verification firm in respect of the project as described in the Clean Hydrogen Investment Tax Credit – Validation and Verification Guidance Document. Additionally, applicants must document each source of electricity and the supplier for their feedstock(s) under each operating year in the CH-ITC Workbook. Please refer to section 3 for more information on modelling feedstocks and energy inputs.

2.3 Carbon intensity modelling with the Fuel LCA Model

ECCC uses the LCA software, openLCA, for the Model's development. The database of the Model is imported into this free, open-source software, and thus, must be downloaded to calculate CI values. The Model is built around fuel and energy pathways that are designed for different types of fuels, material inputs, and energy sources. Chapter 4.2.2 of the Fuel LCA Model Methodology provides a detailed description of these pathways and the Mass basis pathway. In the context of the CH-ITC, only the Processes/Fuel pathways/Hydrogen pathway/**Mass basis** folder in the Model is applicable.

To understand the instructions and explanations provided in this document, applicants should first refer to the Fuel LCA Model User Manual to understand important concepts and elements of the Model. This includes Fuel Pathways, Data Library, unit and system processes, and flows.

There are 3 main components of a fuel pathway in the Model: flows representing inputs and outputs, unit processes, and linked processes (also called providers in the openLCA software). Providers can be system or unit processes that attach a CI value to a given flow. Please refer to chapter 6.2.1 of the Fuel LCA Model User Manual for additional details.

An applicant will perform different kinds of operations with these 3 components when they model their CI:

- determine the amounts of input and output flows for each UP, and enter them in the unit processes of the hydrogen pathway
- link the appropriate processes to input and output flows
- calculate the allocation factor for the UP with multiple intermediate output flows

2.4 Modelling options

This CI modelling guidance includes different modelling options depending on the applicant's HPS configuration. Each modelling option has its own set of instructions. Before starting to model the hydrogen CI value, applicants must determine which option should be applied: simplified or advanced modelling approach. They must also ensure that they follow the applicable instructions through the modelling steps listed in section 3 and/or 4.

2.4.1 Type of carbon intensity values

Under the CH-ITC, 2 types of CI values must be calculated: expected CI and actual CI. Both are cradle-to-gate values and include the lifecycle stages as described previously. They are both calculated using the Model. The differences between the expected and actual CI are the temporal boundaries and the treatments of PPA and renewable hydrocarbons inputs (refer to section 2.2.5), as well as the source of data used to quantify the input and output flows.

1. **Expected CI:** Applicant data that is used to calculate the expected CI can include process model outputs, reasonable assumptions, and other details from a taxpayer's clean hydrogen project plan. This includes quantities that are expected to be used.

2. **Actual CI:** Actual applicant data is used to calculate the actual CI and it must be quantified using operating data from the hydrogen production plant. This must be based on the temporal boundaries (section 2.2.5) for the taxpayer's compliance period.

Note: the general procedure to model and calculate an expected CI value and an actual CI value in the Model is the same.

2.4.2 Simplified vs. advanced modelling

To determine a CI value, applicants must determine which modelling approach is suitable for their HPS. Once a modelling approach is chosen, applicants must adhere to the instructions provided for that specific modelling approach until a final CI value is calculated. There are 2 modelling options that applicants can choose from:

- simplified modelling
- advanced modelling

Specific instructions for the simplified modelling approach are available in section 3, and instructions for the advanced modelling approach are available in section 4. Furthermore, section 5 explains how to calculate the CI value and these instructions apply to both the simplified and advanced modelling approaches.

Under the context of the CH-ITC:

1. **Simplified modelling (SM) -** this modelling approach must be used when the entire hydrogen production process, with all supporting equipment and activities, can be represented by a single UP: Hydrogen production, at HPS (SM). This is further explained in the merging conditions for each UP under advanced modelling below. This corresponds to a case where the HPS is treated as a black box and only the input and outputs flows crossing the boundary of the hydrogen production UP are modelled and internal flows that are not leaving the boundary of this UP are no longer explicitly considered. Please note that this approach was originally developed for the *CFR*. In addition, the simplified modelling approach may use other unit processes such as Carbon dioxide (CO2) capture, at HPS (SM) (if carbon capture occurs at HPS), Feedstock, at hydrogen product system, Fuel input, at hydrogen product system or Electricity, average supply mix, at HPS (SM). This modelling approach is illustrated in Figure 2, which also indicates the sections of this document that provide further guidance regarding the modelling of each flow of the pathway under the simplified modelling approach. The simplified approach is further explained in section 3.

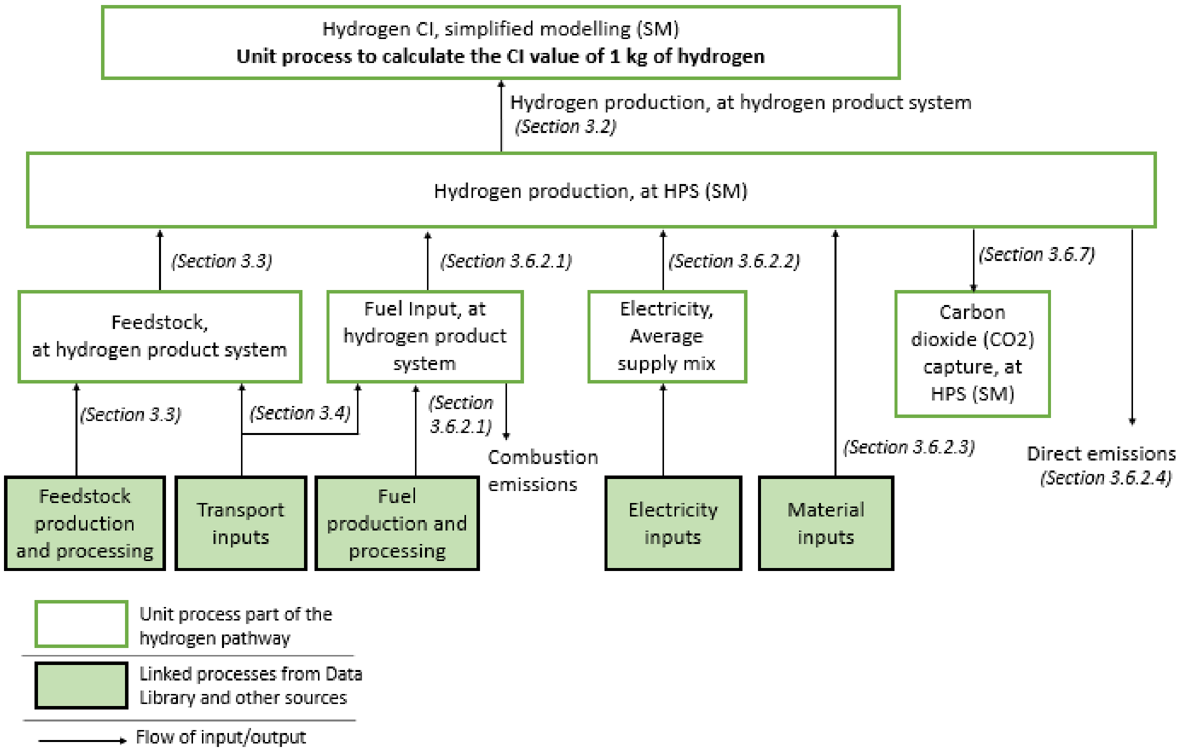

Figure 2: Schematic of the hydrogen pathway for the simplified modelling approach.

2. **Advanced Modelling (AM)** - is applicable when the HPS and all supporting equipment and activities can be represented by more than 1 UP, which can include unit processes such as:
   - B- Oxygen and nitrogen generation system (AM)
   - C- Carbon dioxide (CO2) capture, at HPS (AM)
   - D- Electricity and heat generation system (AM)
   - E- Electricity, average supply mix, at HPS (AM)
   - F- Hydrogen with heat adjustment (AM), in addition to the A- Hydrogen production, at HPS (AM) UP

   Therefore, one or more-unit processes from the HPS are modelled separately from the A- Hydrogen production, at HPS (AM) UP. Take note that apart from steam produced from the combustion of fuel in the D- Electricity and heat generation system (AM) UP, steam flows are only considered at the HPS level and are modelled with the F- Hydrogen with heat adjustment (AM) UP. Section 4.1.1 includes additional definitions for unit processes listed above. Please refer to Figure 3 for a visual representation of this modelling approach (case where all unit processes are modelled separately) with the possible flows exchanged between the unit processes. The figure also indicates the sections of this document that provide further guidance regarding the modelling of each UP (and their associated flows) of the pathway under the advanced modelling approach. The advanced approach is further explained in section 4.

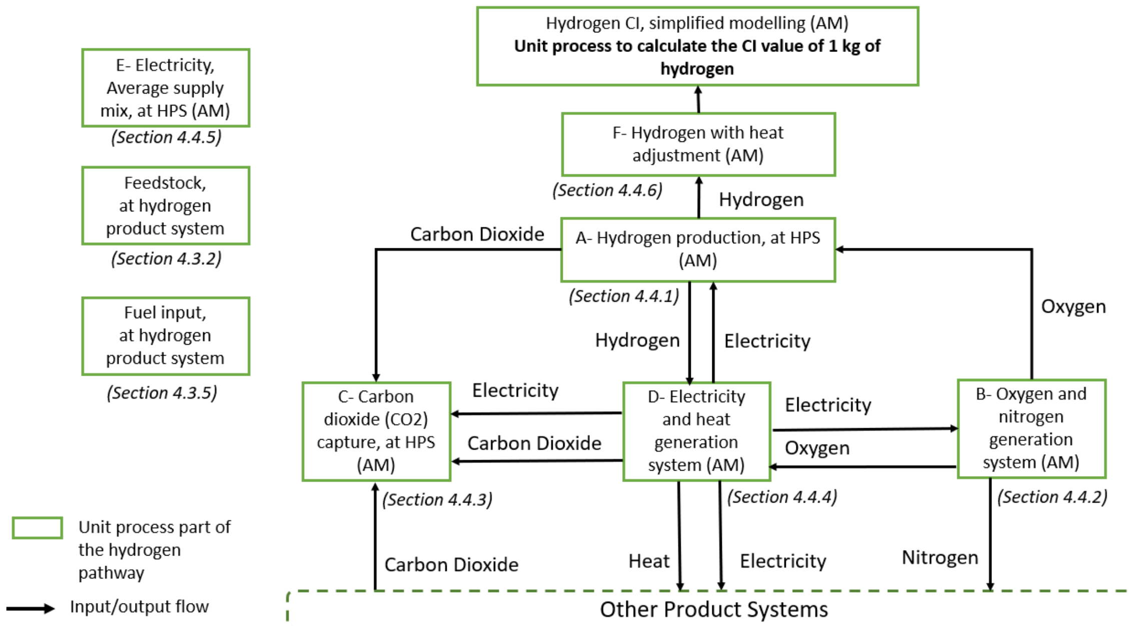

Figure 3: Simplified schematic of the hydrogen pathway for the advanced modelling approach.

The following sections explain the conditions whereby unit processes: B, C and D can be omitted or merged with the A- Hydrogen production, at HPS (AM) UP. If at the end of this procedure all these unit processes are merged with the A- Hydrogen production, at HPS (AM) UP, an applicant must refer to section 3 to apply the simplified modelling approach. Otherwise, the applicant must refer to section 4 to apply the advanced modelling approach.

B- Oxygen and nitrogen generation system (AM) UP

This UP must be **omitted** if:

- oxygen is not required for hydrogen production, or if
- the oxygen is not produced on-site by oxygen and nitrogen generation equipment (in this case oxygen is modelled as a material input with a configurable process from the Model)

This UP must be **merged** with the A- Hydrogen production, at HPS (AM) UP if:

- the oxygen or the nitrogen co-product is not used by another product system or by another UP that is modelled separately in the HPS

Alternatively, applicants can decide to merge this UP with the A- Hydrogen production, at HPS (AM) UP by neglecting the oxygen or nitrogen that is used by another product system or UP and consider that all energy inputs are allocated to the HPS (conservative assumption).

C- Carbon dioxide (CO2) capture, at HPS (AM) UP

This UP must be **omitted** if:

- carbon capture is not required for any element of the HPS
- carbon capture is used for a refinery that is on-site with the hydrogen production, but the carbon capture does not capture CO_2 from the HPS

If carbon capture is required for the HPS, the electricity and fuel inputs within this UP must be **merged** with the A- Hydrogen production, at HPS (AM) UP if:

- the CCUS equipment is not used to capture carbon from another product system or by another UP modelled separately in the HPS
- for example, the CO_2 captured from post combustion for the electricity and heat generation system may not require a separate C- Carbon dioxide (CO2) capture, at HPS (AM) UP if the D- Electricity and heat generation system (AM) UP is merged with A- Hydrogen production, at HPS (AM) UP

Alternatively, applicants can decide to merge this UP with the A- Hydrogen production, at HPS (AM) UP by neglecting the carbon that would have been captured by another product system or UP and consider that all energy inputs are allocated to the HPS as a conservative assumption.

D- Electricity and heat generation system (AM) UP
This UP must be **omitted** if:

- electricity is not generated on-site through the combustion of fuel (including hydrogen, natural gas, certain fuel gases, etc.) or from recovered heat from the taxpayer's production of hydrogen or ammonia

This UP must be **merged** with the A- Hydrogen production, at HPS (AM) UP if:

- neither electricity nor heat produced from the electricity and heat generation system are used by another product system or by another UP that is modelled separately in the HPS

Alternatively, applicants can decide to merge this UP with the A- Hydrogen production, at HPS (AM) UP by assuming that the electricity and/or steam produced are not used by another product system or UP and consider that all inputs and outputs and emissions are allocated to the HPS (conservative assumption).

Finally, this UP must not be merged with the A- Hydrogen production, at HPS (AM) UP if:

- the procedure for adjusting pressure is applied (refer to section 2.2.2.1) and electricity is generated on-site through the combustion of fuel (including hydrogen, natural gas, certain fuel gases, etc.) or from recovered heat from the taxpayer's production of hydrogen or ammonia
- in this case, the adjustment must take into account all sources of electricity (supplied and produced internally)

2.5 Modelling steps

The modelling of each UP presented above is performed by completing the following 3 steps, which are further described in the following subsections. These steps are identical for all modelling options stated in the previous section.

- creating a flow diagram
- step 1: entering applicant data in the CH-ITC Workbook
- step 2: modelling the hydrogen pathway in the Fuel LCA Model

If any error or discrepancy is present in the CH-ITC Workbook or the hydrogen pathway, this guidance document takes precedence.

2.5.1 Creating an activity map

Applicants are required to provide an activity map of their clean hydrogen project which identifies all unit processes and flows modelled. Applicants must modify the relevant modelling diagram (simplified or advanced) on the "Activity Map" worksheet in the CH-ITC Workbook, deleting any flows that are irrelevant to their project and adding additional flows as necessary. The naming conventions used for flows shown in the template should be maintained for new flows. The activity map should include all required unit processes and corresponding interrelationships, which are represented through input/output flows as per instructions provided in the CI modelling guidance and in accordance with ISO 14044.

2.5.2 Step 1: entering applicant data in the CH-ITC Workbook

The next step is to enter the applicant data into the CH-ITC Workbook. Where there are any inconsistencies between this document and the CH-ITC Workbook, this document takes precedence. This is necessary to document and quantify the input and output flows of each UP from applicant's data collection. It is recommended that applicants complete a separate CH-ITC Workbook for each type of CI and for each compliance year. As an example, data for expected and actual CI includes:

- quantities and composition of feedstocks consumed
- quantities and purity of hydrogen outputs from the production process
- amount of material and energy inputs such as fuels, electricity, etc. used in the production process

The list of applicant data that is required for each type of CI value (expected and actual) is detailed in the CH-ITC Workbook and described in sections 3 and 4. It is recommended that all applicant data required in the CH-ITC Workbook and any applicable quantification methods be collected before proceeding with Step 2 of the procedure.

The CH-ITC Workbook uses applicant data to calculate the values of the input and output flows that will be entered in the hydrogen pathway in the Model during step 2: modelling in the Fuel LCA model. Please ensure that the CH-ITC Workbook is in "Automatic" mode under "Calculation Options" in Excel.

Applicants must provide a complete document reference in accordance with the CH-ITC naming convention (including project name, document type, document revision date), page number, stream number/reference. The workbook also documents relevant information and assumptions used to validate the choices of linked processes, such as the choice of the electricity datasets from the Data Library. Applicants must list all assumptions and limitations in the "Side Calculations" worksheet.

All applicant data must be reported in the CH-ITC Workbook in the units in which they have been estimated, measured or collected, except as otherwise specified in the CH-ITC Workbook. The CH-ITC Workbook automatically sums up data over the reporting period to generate total values for each type of input and output flow. Please note that instructions to copy and paste information from the Workbook to openLCA are listed in the cell's comments. In addition, rows that have a grey background only apply to the advanced modelling approach.

For most cases, the CH-ITC Workbook does not prescribe a unit but rather specifies the unit type such as mass-based, energy-based, volume-based in which data must be entered in the hydrogen pathway, unless otherwise specified. openLCA allows the user to choose between many different units for a given flow that are part of the same unit type.

For quantities of gas and liquid that are converted from a unit of volume to other units (mass or energy) using the conversion factors available in the “ECCC Parameters” worksheet in the CH-ITC Workbook, all volume quantities reported in the CH-ITC Workbook must be provided at standard temperature and pressure (temperature of 15°C and pressure of 101.325kPa). This ensures that the unit of the flow will be compatible with the unit of the processes to which the flow will be linked in the hydrogen pathway. This can be done through correction by the metering device, or if such device is not capable of correcting the measurement to standard conditions above, the raw measured data should be converted to standard temperature and pressure. In the second case, each measured data point must be converted first prior to any calculation to account for the different conditions of measurement of each data point. The converted quantities then can be referenced into other pertinent worksheets or calculations within the CH-ITC Workbook.

In the case of a gaseous volume, if the measurement device does not automatically correct for this, the gaseous volume data must be corrected from measured temperature and pressure conditions to the standard temperature and pressure conditions, using the most reliable method to introduce the least amount of error possible.

When unit conversion is necessary, an applicant can use the unit conversion factors and standard properties provided in the “ECCC Parameters” worksheet of the CH-ITC Workbook when these are not available at the plant. In addition, applicants must use the “ECCC Parameters” worksheet for HHV values, densities, etc. in priority of measured amounts.

Numerical values entered into the CH-ITC Workbook and openLCA should be entered with as many significant digits as possible. The values must not be rounded in any of the calculation steps. Furthermore, any calculations performed in the “Side Calculations” worksheet must be appropriately documented and labelled in a clear and concise manner. The applicant must also link any applicable calculations in the “Side Calculations” worksheet to the corresponding worksheet.

For calculations in the CH-ITC Workbook, the use of cell references in formulas, as opposed to copying cell values, is mandatory. This can be done by clicking the cell where the value is to be used, typing “=” (equal sign) in the formula bar, and either selecting the cell that contains the value or typing its cell reference into the formula bar. This is to ensure that no significant digits are lost and allow traceability of work.

2.5.3 Step 2: modelling in the Fuel LCA Model

Once step 1 is completed, the CI value can be modeled and calculated using the Model and the hydrogen pathway in openLCA. To do so, an applicant must:

1. Copy the quantified input and output flows from the CH-ITC Workbook to the Model. These flows are represented as arrows in Figure 2 and Figure 3.

2. Link the output flows of the unit processes within the hydrogen pathway in the Model. These are represented by boxes in Figure 2 and Figure 3.
3. Calculate the allocation factors with the "Allocation" process tab of the appropriate UP of the hydrogen pathway in the Model (if applicable).

Please note that "(AM)" indicates that the flow is for advanced modelling while "(SM)" indicates that the flow is for simplified modelling.

For the purposes of data entry into the hydrogen pathway in openLCA, numerical values entered into the "Inputs/Outputs" tab must be copied directly from the CH-ITC Workbook into the hydrogen pathway and not be rounded. Please note that detailed instructions are included in comments for each flow. When copying values from the CH-ITC Workbook to openLCA, either copy and paste the value displayed on the formula bar into openLCA, or change the format of the cell to "Number" and click "Show More Decimal Places" until the decimal places become repeated zeros and copy and paste that value into openLCA. This will ensure that all the significant digits are copied. Numerical values in openLCA can include up to 17 digits. Applicants can refer to chapter 5.4.1 "Copy/pasting flows from Excel" in the Fuel LCA Model User Manual if they are unfamiliar with this procedure. Please note that applicants can encounter errors if the flow or process names are misspelled.

Furthermore, quantitative reference flows cannot be removed without first changing the quantitative reference for a given process in openLCA. If applicants want to enter data into their unit processes another way, then they can refer to chapter 5.2.2 "Inputting data into a unit process (flow information)" and chapter 5.2.3 "Adding or removing a flow to or from a unit process" of the Fuel LCA Model User Manual for more information. The Fuel LCA Model User Manual also provides detailed instructions on how to perform basic modelling operations in openLCA.

Sections 3 and 4 of this document provide guidance on how to create new processes and link processes in the hydrogen pathway and specify which unit processes must be selected in different cases.

Section 5 describes the steps that an applicant must complete to calculate a final CI value.

3 Simplified approach (cradle-to-gate carbon intensity modelling)

This section includes modelling information with regards to the modelling of a cradle-to-gate CI under the simplified modelling approach for both the expected CI and actual CI. Applicants must refer to section 2.4 for instructions on how to determine the appropriate modelling approach. Applicants who fall under the advanced modelling approach must refer to section 4.

All the flows covered in this section must be quantified using **cumulative 20-year data** from the clean hydrogen project plan for the expected CI. For the actual CI, applicants must use **1 year of operating data** for each year of a given compliance period as per Subsection 127.48 (1) of the *ITA*.

3.1 General information

General information on the hydrogen facility (step 1) such as the name, address, hydrogen pathway, operating year, etc. must be completed. The applicant must also list the start date, end date and reason for any shutdown periods under step 4 (a). The applicant must enter the required information in the "General" worksheet in the CH-ITC Workbook. It is important that the applicant selects both the type of modelling (step 2) and CI (expected or actual - step 3c). These choices will affect the calculation procedure and the results in the workbook.

Applicants can then refer to the "Activity Map" worksheet in the CH-ITC Workbook and follow the instructions in this guidance and the workbook to complete the required worksheets under the simplified approach.

In openLCA, the user will use the processes under Processes/Fuel pathways/Hydrogen pathway/Mass basis/**Hydrogen production, simplified modelling (SM)** for the simplified modelling approach.

3.2 Net hydrogen produced

3.2.1 Summary

This section explains how to determine and document the quantities and characteristics of hydrogen produced from an HPS. This includes the calculation procedure to convert the mass flow rate of gas stream (hydrogen and impurities) to a pure quantity of hydrogen. It also includes instructions for entering this quantity in the CH-ITC Workbook and Model.

3.2.2 Quantification of flows

Under the simplified modelling approach, the flow of hydrogen that is sent to another product system and/or exits the HPS must be quantified. This is referred to as the Hydrogen production, at HPS (SM) flow in the Hydrogen pathway. Hydrogen that is consumed or lost within the HPS is not considered in the calculation of net hydrogen produced. Please refer to the example in Figure 4 below where the quantities of hydrogen that are either consumed internally, or lost, are disregarded. For the purposes of calculating the hydrogen CI, the only valid flow is the net hydrogen produced, which crosses the system boundary of the HPS and is fed to another product system.

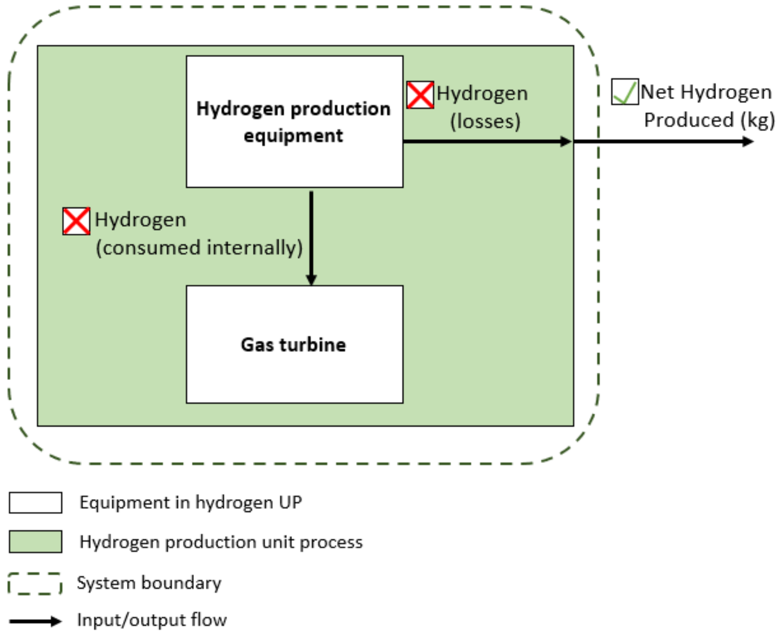

Figure 4: Different flows of hydrogen in a hydrogen product system.

The total quantity of net hydrogen production must always be expressed in terms of mass of pure (100%) hydrogen. If an applicant's gas stream of hydrogen does not meet this criterion, the mass flow rate of the gas stream consisting of hydrogen and impurities must be converted to pure quantity of hydrogen by using Equation 1.

Equation 1: conversion of gas stream to a pure quantity of hydrogen

$$M_{H2\ pure} = M_{Gas\ stream} * a$$

Where:
$M_{H2\ pure}$: Flow rate of pure hydrogen (kg H_2/year)
$M_{Gas\ stream}$: Flow rate of gas stream of hydrogen (kg $_{gas}$/year)
a: purity of the hydrogen gas stream (mass %)

For both expected and actual CI, applicants are instructed to document how they determined the hydrogen purity (mass %) of the hydrogen gas stream. Applicants must use the most reliable method available to introduce the least amount of error possible and document their procedure in the "Side Calculations" worksheet of the CH-ITC Workbook. An example of the method that can be used to determine the parameters of Equation 1 is presented in ISO/TS 19870:2023 Annex K Purity.

In cases where processes such as compression or liquefaction are excluded due to the adjustment process for the functional unit (refer to section 2.2.2.1 and 3.6.3.2), the quantity of net hydrogen must still be determined after these processes. For example, losses of hydrogen during these processes will still be considered losses within the HPS.

3.2.3 Source of the CI value

The flow of Hydrogen production, at HPS (SM) is an output flow of the Hydrogen production, at HPS (SM) UP and no CI value can be selected for the hydrogen output flow. This can be attributed to the fact that once the CI modelling has been completed, the Hydrogen production, at HPS (SM) UP will define the CI value for this flow.

3.2.4 Step 1: entering data into the CH-ITC Workbook

Applicants must enter data related to the hydrogen produced from the Hydrogen production, at HPS (SM) UP in the "Hydrogen from HPS (H1,H2)" worksheet of the CH-ITC Workbook for the H1 flow. Applicants must enter information regarding their hydrogen production quantities such as the unit of the hydrogen production data and quantity of hydrogen produced.

Please note that applicants must use the "Side Calculations" worksheet to document how the hydrogen purity of the hydrogen gas stream is determined.

Once the applicant has entered all required information then they will obtain the cumulative quantity of hydrogen for the first 20 years of operation from the hydrogen project plan (expected CI) or for 1 year of operation (actual CI) that can be used in step 2: modelling in the Fuel LCA Model.

3.2.5 Step 2: modelling in the Fuel LCA Model

The process Processes/Fuel Pathways/Hydrogen pathway/Mass basis/Hydrogen production, simplified modelling (SM)/**Hydrogen production, at HPS (SM)** is used to model the production of hydrogen.

Applicants must follow the modelling steps below for hydrogen produced:

1. In openLCA, open the UP Hydrogen production, at HPS (SM).
2. In the CH-ITC Workbook, follow step 3 of the "Hydrogen from HPS (H1,H2)" worksheet. This includes instructions to copy and paste rows from the CH-ITC Workbook to the Hydrogen production, at HPS (SM) process in openLCA.
3. Applicants must ensure that the reference flow copied and pasted from the CH-ITC Workbook is made as the reference flow in openLCA by:
    a. Right clicking on the pasted Hydrogen production, at HPS (SM) flow.
    b. Select "set as quantitative reference".
    c. Once this is done then applicants can remove the old reference flow.
    d. This procedure can be applied in all instances where the applicant must set the copied/pasted flow as the new reference flow.
4. Save and close the UP.

3.3 Feedstock production

3.3.1 Summary

The feedstock for a hydrogen pathway is the primary material that is transformed to produce hydrogen. Feedstock amounts are quantified separately from fuel inputs. For example, a HPS can use natural gas as both a feedstock to be transformed into hydrogen, and as a fuel input for heating purposes. Therefore, only the portion of natural gas sent to the reactor to be transformed into hydrogen is considered as a feedstock.

This section describes the different types of feedstocks permitted under the CH-ITC, how to quantify these flows, the source of the CI values associated to them, as well as modelling instructions for the feedstock.

Steps 1 and 2 consist of documenting and modelling the feedstock production and processing inputs in one of the unit processes of the “Feedstock, at hydrogen product system” folder of the Model.

This section is only relevant for eligible pathways associated with the production of hydrogen from the reforming or partial oxidation of eligible hydrocarbons, with carbon dioxide captured using a CCUS process.

The impact of supplying water as a feedstock to produce hydrogen is considered to have a contribution to the carbon intensity below the 1% cut-off criteria, and thus, section 3.3 and 3.4 are to be skipped for the electrolysis pathway.

3.3.2 Quantification of flows

3.3.2.1 Distinct feedstock

A distinct feedstock is a feedstock defined by a unique CI value that is represented by a system process or a UP included in the Model. In addition, renewable hydrocarbon feedstocks from different origins (and different CI values) would also be considered as distinct feedstocks.

In the context of the CH-ITC, the feedstock types for which a distinct feedstock can be modelled are:

- fossil-based natural gas (section 3.3.2.2)
- fossil-based hydrocarbons, other than natural gas, which includes 1) a substance sourced all or substantially all from raw natural gas (including methane, ethane, propane, butane and pentane) or 2) a substance that is a by-product from processing natural gas or one or more of the substances sourced from raw natural gas (section 3.3.2.3)
- eligible renewable hydrocarbons that are produced from non-fossil carbon and for which a *Clean Fuel Regulations* carbon intensity can be determined under the *CFR* (section 3.3.2.4)

Applicants must consult the subsections in the list above to determine which feedstock(s) is applicable to their HPS. Once a feedstock type is chosen, applicants must follow the corresponding instructions in sections 3.3 and 3.4 (if applicable). If applicants have more than one distinct feedstock used by their HPS, then they must model each one by following instructions provided in section 3.3.

To model a project’s expected CI, the contribution of each distinct feedstock used to produce hydrogen are to be calculated in proportion to the quantity of feedstock that is expected to be used over the first 20 years of the project’s operations, based on the most recent clean hydrogen project plan. The total quantity of feedstock that is expected to be used must be reported on an annual basis. Further instructions are included in the CH-ITC Workbook.

To model a project's actual CI, only the actual quantity of each distinct feedstock consumed during each operating year of the compliance period is to be considered. As previously mentioned, this quantity does not include the amount of fuel consumed, if for example, some of the feedstock is used as a fuel.

3.3.2.2 Natural gas

Fossil-based natural gas is gas supplied by the natural gas transmission and distribution system in Canada or directly delivered by a gas plant with similar specifications.

Applicants must determine the amount of natural gas (feedstock) that is used in their HPS to produce hydrogen and convert it in unit of energy on a HHV basis. The energy density and the carbon content of the feedstock is based on predefined data (available in the "ECCC Parameters" worksheet of the CH-ITC Workbook).

3.3.2.3 Eligible fossil-based hydrocarbons (other than natural gas)

The list of **eligible substances sourced all or substantially all from fossil-based raw natural gas** are:

- methane
- ethane
- propane (including isopropane)
- butane (including isobutane)
- pentane (including isopentane)

This also includes **eligible substances that are by-products from processing fossil-based natural gas (by-products),** or one or more substances sourced all or substantially all from fossil-based natural gas.

In addition, the by-products must be part of the following list of processes:

- off-gas from the production of ethylene or ethylene derivative

For each eligible fossil-based hydrocarbon used, applicants must determine:

- the amount of eligible substances and by-products (feedstock) that are used in their HPS to produce hydrogen
- the energy density of the feedstock (eligible substance or by-product) to convert quantities in unit of energy on an HHV basis
- the fossil carbon content of the feedstock to calculate the direct emissions associated with the use of this feedstock (refer to section 3.6.4.4 for modelling of direct emissions)

For both expected and actual CI, applicants are instructed to document how they determined these parameters. Applicants must use the most reliable method available to introduce the least amount of error possible and document their procedure in the "Side Calculations" worksheet of the CH-ITC Workbook. An example of the method that can be used to determine the carbon content is listed in section 10.B of Canada's greenhouse gas quantification requirements/ Greenhouse Gas Reporting Program.

Since these substances and by-products can be used alone or in combination with different ratios, there are 2 options for applicants to determine the amount, energy density, and carbon content of the feedstock:

1. Model 1 distinct feedstock per year based on the average composition of substances that is calculated from the cumulative amount of each substance used during a year.
2. Model a distinct feedstock for each portion of all the feedstocks that has a constant composition, energy density and carbon content that is used during a year.

Applicants must indicate which option was selected and document how the distinct feedstocks were defined in the "Side Calculations" worksheet.

3.3.2.4 Eligible renewable hydrocarbons

To be considered in the CI calculation under the CH-ITC program, an eligible renewable hydrocarbon feedstock must meet the criteria set out in the definition of an eligible renewable hydrocarbon as defined by Subsection 127.48 (1) of the *ITA*:

- *(a) that is produced from non-fossil carbon*
- *(b) in respect of which a CFR carbon intensity can be determined under the Clean Fuel Regulations*
- *(c) that is included in the Clean Hydrogen Investment Tax Credit – Carbon Intensity Modelling Guidance Document published by the Government of Canada at the time that the taxpayer files its most recent clean hydrogen project plan with the Minister of Natural Resources;*
- *(d) that is sourced from a facility that first commenced production of the substance on or after both*
    - *i. November 3, 2022, and*
    - *ii. the earlier of the day that is*
        - *A. 24 months before the taxpayer's first clean hydrogen project plan is filed with the Minister of Natural Resources, and*
        - *B. 36 months before the day on which hydrogen is first produced by the relevant clean hydrogen project of the taxpayer;*
- *(e) that, if acquired by the taxpayer under an agreement, the agreement grants, or will grant, the taxpayer the sole and exclusive right to the environmental attributes associated with the substance; and*
- *(f) that is acquired or produced by the taxpayer for the sole purpose of operating the clean hydrogen project during all or any portion of the first 20 years of the project's operations.*

The list of eligible renewable hydrocarbon feedstocks that are included in this CI modelling guidance is:

- renewable natural gas, biogas, renewable propane as defined under the *CFR*:
    - produced on-site, or
    - produced offsite and physically supplied, or supplied by means of contractual agreements, if the hydrogen producer provides the supporting documentation required

- other renewable hydrocarbons included in a new pathway approved under the *CFR* and produced on-site or offsite, if physically supplied

Applicants can refer to section 3.3.3.4 for detailed descriptions of the options for CI determination for these sources of renewable feedstock. In addition, applicants are encouraged to refer to the *CFR* and *CFR* Specifications for additional information on a *CFR* CI.

3.3.3 Source of the CI value

A distinct feedstock is modelled using a cradle-to-gate or cradle-to-grave (includes all lifecycle stages) feedstock CI value, which can be determined using one of the following 4 options:

- system process for the feedstock from the Data Library of the Model
- a transferred CI from a carbon-intensity contributor as determined and approved under the *CFR*
- CI value calculated in accordance with the *CFR* Supplemental Specifications for RNG, biogas or renewable propane
- CI value determined with an approved new pathway under the *CFR*

The following sections present the list of CI value sources for each feedstock type.

3.3.3.1 Natural gas

When natural gas (fossil-based) is used as a feedstock, for both expected and actual CI, applicants must select the system process: Processes/Data Library/Fossil fuels/Non-combusted fossil fuels, at end user/**Natural gas, at end user**

- no customization of the life cycle stages of natural gas production, transmission and distribution are allowed
- the system process is valid for all provinces and territories in Canada

3.3.3.2 Eligible substance sourced all or substantially all from raw natural gas

When an eligible substance is used as a feedstock, for both expected and actual CI, applicants must select the system process: Processes/Data Library/Fossil fuels/Non-combusted fossil fuels, at production gate/**Propane, at fuel production gate,** if the feedstock is produced on-site and Processes/Data Library/Fossil fuels/Non-combusted fossil fuels, at end user/**Propane, at end user,** if the feedstock is produced off-site

- no customization of the life cycle stage of the feedstock production, transmission and distribution are allowed
- the system process is valid for all provinces and territories in Canada

3.3.3.3 Eligible by-products from processing natural gas

When an eligible substance that is a by-product from processing natural gas or substances sourced all or substantially all from raw natural gas is used as a feedstock, for both expected and actual CI, applicants must select the system process: Processes/Data Library/Fossil fuels/Non-combusted fossil fuels, at end user/**Natural gas, at end user**

- no customization of the life cycle stages of the feedstock production, transmission and distribution are allowed (note: it is assumed that this feedstock is always produced on-site)

- the system process is valid for all provinces and territories in Canada

3.3.3.4 Eligible renewable hydrocarbon

Applicants must provide a reasonable estimate of their CI with the best information available at the date that the clean hydrogen project plan is filed by the taxpayer when an eligible renewable hydrocarbon is used as a feedstock (for the expected CI) based on *CFR* (and *CFR* Specifications) methodology. It is the responsibility of the applicant to provide an estimate of the CI and confirm that a CI can be determined under the *CFR* at the date of filing the compliance reports.

For the actual CI, there are 3 main sources of CI that can be determined under the *CFR* that are described below:

1. **Transferred CI from a carbon-intensity contributor**
    - this option can be used if the renewable natural gas, biogas, renewable propane, as defined under the *CFR*, is not produced at the hydrogen facility
    - the renewable natural gas, biogas or renewable propane must be used as a feedstock in the production of clean hydrogen and be physically supplied or supplied by means of a contractual agreement
    - only applicable for a final CI determined with the Model (existing and new pathway) with input data for a period of 24 consecutive months
    - can be determined with different life cycle boundaries: cradle-to-gate or cradle-to-grave

2. **CI value calculated in accordance with the *CFR* Supplemental Specifications for RNG, biogas or renewable propane**
    - this option can only be used if the RNG, biogas, or renewable propane is produced on-site at the hydrogen facility or if the applicant for the CI of hydrogen determines the CI of the RNG, biogas, or renewable propane feedstock which is produced at another production facility
    - the renewable natural gas, biogas or renewable propane must be used as a feedstock in the production of clean hydrogen and be physically supplied or supplied by means of a contractual agreement
    - can be determined as a temporary CI (with the Model with input data for a period between 3 months to 24 months) or final CI with the appropriate life cycle boundaries

3. **CI value determined with an approved new pathway under the *CFR***
    - this option can only be used if the RNG, biogas, renewable propane, or other renewable hydrocarbon is produced on-site at the hydrogen facility or if the applicant for the CI of hydrogen determines the CI of the RNG, biogas, renewable propane or other renewable hydrocarbon which is produced at another production facility
    - the renewable natural gas, biogas or renewable propane must be used as a feedstock in the production of clean hydrogen and be physically supplied or supplied by means of a contractual agreement
    - the other renewable hydrocarbon must be used as a feedstock in the production of clean hydrogen and be physically supplied

- can be determined as a temporary CI or final CI with the appropriate life cycle boundaries

For the actual CI, applicants must use the most recent CI that is determined under the *CFR* at the date of filing a compliance report by using one of the following options:

1. **Transferred CI from a carbon-intensity contributor for the feedstock quantity supplied to the hydrogen production facility**
    - a CI that has been specified in the most recent CI pathway report referred to in the *CFR* in respect of which a verification report was submitted and resulted in an unqualified opinion or a qualified opinion in accordance with the *CFR*
    - if not available, the approved CI under the *CFR* that is still valid

2. **CI value calculated in accordance with the *CFR* Supplemental Specifications for RNG, biogas or renewable propane**
    - the CI of RNG, biogas or renewable propane that has been determined as part of the CI of hydrogen or as part of the CI of a low-CI fuel using hydrogen as an input where the CI of hydrogen or the CI of the low-CI fuel is specified in the most recent CI pathway report referred to in the *CFR* in respect of which a verification report was submitted and resulted in an unqualified opinion or a qualified opinion in accordance with the *CFR*
    - if not available, the CI of RNG, biogas or renewable propane that has been determined as part of a CI application where the CI of hydrogen is determined, if the approved CI of hydrogen or of the low-CI fuel for which the application relates is still valid under the *CFR* at the date of filing the compliance report

3. **CI value determined with an approved new pathway under the *CFR***
    - the CI of RNG, biogas, renewable propane or other renewable hydrocarbon that has been determined as part of the CI of hydrogen or as part of the CI of a low-CI fuel using hydrogen as an input where the CI of hydrogen or the CI of the low-CI fuel is specified in the most recent CI pathway report referred to in the *CFR* in respect of which a verification report was submitted and resulted in an unqualified opinion or a qualified opinion in accordance with the *CFR*
    - if not available, the CI of RNG, biogas, renewable propane or other renewable hydrocarbon that has been determined as part of a CI application where the CI of hydrogen is determined, if the approved CI of hydrogen or of the low-CI fuel for which the application relates is still valid under the *CFR* at the date of filing the compliance report
    - in the case the CI for hydrogen or the CI of a low-CI fuel using hydrogen as an input has not yet been approved, a CI that was determined for RNG, biogas, renewable propane, or another renewable hydrocarbon in a new pathway that was approved and is still valid at the date of filling the compliance report

For a transferred CI, the alphanumeric identifier assigned to the approved CI of the RNG, biogas or renewable propane under the *CFR*, for the feedstock quantity supplied at the hydrogen production facility, must be provided.

For a CI value calculated in accordance with the *CFR* Supplemental Specifications for RNG, biogas or renewable propane, the alphanumeric identifier assigned to the approved CI of the hydrogen or of the low-CI fuel under the *CFR* must be provided.

For a CI value calculated in accordance with an approved new pathway under the *CFR*, the alphanumeric identifier assigned to the approved new pathway under the *CFR* as well as the alphanumeric identifier assigned to the approved CI of the hydrogen or of the low-CI fuel under the *CFR*, if any, must be provided.

In a case where a CI determined under the *CFR*, as described above, is not available at the date of filing a compliance report, applicants must select the system process:

- Processes/Data Library/Fossil fuels/Non-combusted fossil fuels, at end user/**Natural gas, at end user**

3.3.4 Step 1: entering applicant data in the CH-ITC Workbook

For each distinct feedstock, applicants must complete a distinct “Feedstock input (FD1)” worksheet. Applicants must enter information regarding their feedstock, such as the feedstock type, supplier, fossil carbon content of feedstock and feedstock quantities.

If a supplier procures feedstock from 2 different locations, it must be treated as 2 distinct suppliers and therefore 2 distinct feedstocks. In this case, an applicant will have a “Feedstock input (FD1)” and a “Feedstock input (FD2)” worksheet. Each worksheet in the CH-ITC Workbook should have its own unique name. Please consult section 3.3 for additional information.

Once the applicant has entered all required information then they will obtain the cumulative quantity of feedstock for the first 20 years of operation from the hydrogen project plan (expected CI) or for 1 year of operation (actual CI) that can be used in step 2: modelling in the Fuel LCA Model.

3.3.5 Step 2: modelling in the Fuel LCA Model

If the source of CI value is a system process:
One of the processes in the Processes/Fuel Pathways/Hydrogen pathway/Mass basis/**Feedstock, at hydrogen product system** folder is used to model the feedstock production. One UP must be selected for each distinct feedstock, and they must be entered as inputs in the hydrogen production, at HPS (SM) UP.

Applicants must follow the modelling steps below for natural gas, eligible substances sourced all or substantially all from raw natural gas, or eligible by-products from processing natural gas:

1. In openLCA, open the folder “Feedstock, at hydrogen product system”. The folder already includes distinct feedstock unit processes. For example, “Feedstock A, at hydrogen product system”, “Feedstock B, at hydrogen product system”, “Feedstock C, at hydrogen product system”.
2. For each distinct feedstock, open a UP such as “Feedstock A, at hydrogen product system” and follow these steps:

- rename the UP and the corresponding output flow with the name of the feedstock generated in the CH-ITC Workbook like Natural gas, at fuel production gate, at hydrogen product system[1]
- in the CH-ITC Workbook, follow step 6 of the corresponding feedstock worksheet "Feedstock input (FD1)", "Feedstock input (FD2)", etc.

3. For feedstock transportation, refer to section 3.4. If applicable, this step must be completed before proceeding forward.
4. Save and close the UP.
5. If more unit processes for a feedstock need to be added to the folder "Feedstock, at hydrogen product system", create a new UP and a corresponding flow and follow the procedure described in step 2.

Please note that the feedstock production and transportation is modelled for 1 MJ (or per unit of energy), rather than with the total amount(s) of feedstock.

If the source of CI value is a *CFR* CI:

1. Applicants must first create a new UP with the procedure described in section 6 (Annex A).
2. Once the *CFR* CI UP is added to the hydrogen pathway, the steps above for a system process can be applied with the *CFR* CI UP equivalent to the system process from the Data library.

3.4 Feedstock transportation

3.4.1 Summary

This section describes the quantification and modelling of feedstock transportation which includes the transport between the production site of the feedstock and the production site of the hydrogen.

The modelling of feedstock transportation is only required when applicants are modelling an eligible renewable hydrocarbon feedstock with a *CFR* CI that doesn't already include all the transportation steps between the feedstock supplier and the hydrogen plant. For example, this could include an applicant who only has access to a cradle-to-gate *CFR* CI for a feedstock that is not produced on site. Therefore, the *CFR* CI would not include feedstock transportation so in this case it would need to be modelled. Please refer to section 6 (Annex A) and the *CFR* Specifications for additional information on a *CFR* CI. Otherwise, all other feedstocks covered by this guidance (including natural gas and other fossil-based eligible hydrocarbon feedstocks) use a system process where the feedstock transportation is already included so the modelling of feedstock transportation is not required and section 3.4 can be skipped.

This section also provides instructions for documenting and modelling the transportation inputs in the Feedstock, at hydrogen product system unit processes under the Hydrogen Pathway of the Model.

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[1] Applicants can refer to chapter 5.2.6 Renaming a unit process or flow in the Fuel LCA Model User Manual.

In some instances, this section may also be relevant to the modelling of an eligible renewable hydrocarbon when a *CFR* CI is used as a fuel input (if the modelling of transportation is required).

3.4.2 Quantification of flows

For any feedstock other than eligible renewable hydrocarbons modelled with a *CFR* CI, the modelling of feedstock transportation is never required and section 3.4 can be skipped.

For an eligible renewable hydrocarbon modelled with a *CFR* CI, the transportation of the feedstock to the hydrogen production facility may not be required in the following cases:

- if the eligible renewable hydrocarbons are produced on site, or
- if the *CFR* CI is a cradle-to-grave (or end user) value (the distribution will already be included in the CI), or
- if the applicant demonstrates that the contribution of the distribution life cycle stage to the CI of the RNG, biogas, renewable propane, or other renewable hydrocarbon is less than 1%

If the criteria indicated above are not met, the following instructions must be followed:

- for RNG, biogas, renewable propane, or other renewable hydrocarbon which is physically supplied: the applicant must follow the instructions entitled "RNG, biogas, renewable propane, or other renewable hydrocarbon feedstock transported by dedicated pipeline" or "RNG, biogas, renewable propane or, other renewable hydrocarbon feedstock transported using other transport mode(s)" in section 3.4.4
- for RNG, biogas or renewable propane supplied by means of a contractual agreement: the applicant must follow the instructions entitled "RNG, biogas, or renewable propane supplied by means of a contractual agreement" in section 3.4.4

If the modelling of the feedstock transportation is required, applicants must use information collected from either their clean hydrogen project plan for the expected CI, or actual data for their actual CI. For each distinct feedstock, applicants must provide the travelling distance (km) for each transportation mode required to transport the feedstock from the supplier (feedstock production site) to the HPS. Applicants must also ensure that the correct conversion factors are used in the CH-ITC Workbook when feedstock quantity are entered in units of energy (MJ) or volume (m^3). The feedstock transportation flows are quantified as mass-distance units of t.km in the CH-ITC Workbook and in the hydrogen pathway.

3.4.3 Source of the CI value

For each transport mode used for feedstock transportation, applicants are instructed to select the corresponding system process from the Data Library from the list below.

Truck transport (t.km):

- Processes/Data library/Transport/Generic Transport/ **Truck transport, diesel, 25 tonnes**
- Processes/Data library/Transport/Generic Transport/ **Truck transport, diesel, 45 tonnes**
- Processes/Data library/Transport/Natural gas transport/**Truck transport, of compressed RNG**
- Processes/Data library/Transport/Propane transport/ **Truck transport, of liquid propane**

Train transport (t.km)

- Processes/Data library/Transport/Generic Transport/**Train transport, diesel**

Pipeline transport (t.km):

- Processes/Data library/Transport/Generic Transport/**Pipeline transport, of gas**
- Processes/Data Library/Transport/Natural gas transport/**Pipeline transport, of RNG, dedicated pipeline**
- Processes/Data Library/Transport/Natural gas transport/**Pipeline transport, of RNG, injection in natural gas pipeline**
- Processes/Data Library/Transport/Propane transport/**Pipeline transport, of renewable propane, dedicated pipeline, including flaring emissions**

Ship transport (t.km):

- Processes/Data library/Transportation/Generic Transport/**Ship transport**

3.4.4 Step 1: entering data into the CH-ITC Workbook

Applicants must complete the transportation section in step 4 of the "Feedstock input (FD1)" worksheet for each feedstock worksheet created (according to section 3.3) that requires the modelling of feedstock transportation.

In the "Feedstock input (FD1)" worksheet (or a copy thereof), under the Feedstock transportation section, applicants must enter the total number of kilometers (km) for each transport mode based on data from the supply chain (except for fossil-based eligible hydrocarbons). The distances must be determined in accordance with the instructions for each type of feedstock. Applicants must also enter the parameters such as HHV, density, etc. for converting in a mass basis the quantity of feedstock entered from either the "ECCC Parameters" or "Side Calculations" worksheet. This is required to calculate the mass-distance parameter used by the transportation system process in the Data Library.

Afterwards, the cumulative quantity of feedstock for the first 20 years of operation from the hydrogen project plan (expected CI) or for 1 year of operation (actual CI) is multiplied by the distance of each transportation mode to obtain the final t-km parameter that applicants can use for step 2: modelling in the Fuel LCA Model.

3.4.4.1 RNG, biogas, renewable propane or other renewable hydrocarbon feedstock transported by dedicated pipeline

Applicants must use applicant data to model the feedstock transportation in a dedicated pipeline (RNG, biogas, renewable propane and other renewable hydrocarbons).

Applicants must enter the dedicated pipeline distance traveled between the RNG, biogas, renewable propane or other renewable hydrocarbon production facility and the hydrogen facility. The distance should be based on the real distance between the 2 facilities. If the distance is not known, it should be approximated using either the physical distance between the 2 points or using the driving distance as calculated using navigation software.

3.4.4.2 RNG, biogas, renewable propane or other renewable hydrocarbon feedstock, transported using other transport mode(s)

For any transport modes other than a dedicated pipeline where the RNG, biogas, renewable propane or other renewable hydrocarbon is physically supplied (by train, truck, or ship – generic processes), applicants must use applicant data to model the transportation of RNG, biogas, renewable propane, other renewable hydrocarbon feedstock as described below.

Applicants must enter the distance traveled between the RNG, biogas, renewable propane or other renewable hydrocarbon production facility and the hydrogen production facility for each transport mode. The distance should be based on the real distance between the RNG, biogas, renewable propane or other renewable hydrocarbon production facility and the hydrogen production facility. If the distance is not known, it should be approximated using either the physical distance between the 2 points or using the driving distance as calculated using navigation software.

3.4.4.3 RNG, biogas, or renewable propane by means of a contractual agreement

For RNG, biogas, or renewable propane, which is supplied by means of a contractual agreement, the transportation should be modelled using applicant data, including:

1. The transportation from the RNG, biogas or renewable propane production facility to the pipeline injection point or to the distribution network (as applicable).
2. The transportation through the pipeline or distribution network from the injection point to the hydrogen production facility.

The distances should be based on the real distance between the two points referred to in (1) or (2), above. If the distance is not known, it should be approximated using either the physical distance between the two points or using the driving distance as calculated using a navigation software.

Applicants must use applicant data to model the feedstock transportation by truck, train, or pipeline (refer to section 3.4.3).

3.4.5 Step 2: modelling in the Fuel LCA Model

The processes in the folder Processes/Fuel Pathways/Hydrogen pathway/Mass basis/**Feedstock, at hydrogen product system** are used to model feedstock transportation. Each applicable transportation UP from the data library must be entered as an input in each feedstock UP, using applicant data.

For each feedstock requiring the modelling of feedstock transportation, open the corresponding UP from the folder "Feedstock, at hydrogen product system" and insert into the "Input/Output" tab:

1. In openLCA, select the corresponding transport system process from the Processes/Data library/**Transportation** folder of the Data Library for each transport mode used for feedstock transportation.
2. In the CH-ITC Workbook, follow step 6 of "Feedstock input (FD1)" worksheet for that transportation mode (system process) and corresponding quantities (t.km). Please note that transportation amounts are modelled for 1 MJ (or per unit of energy) of feedstock, rather than for total amounts of feedstock.

3. Repeat steps 1 and 2 for each transport mode used for the feedstock.
4. Save and close the process.

3.5 Co-products produced

3.5.1 Summary

Co-products are products or services that are generated by the HPS but are either consumed or used by other product systems.

Potential co-products from a HPS are:

- oxygen and nitrogen exported or sold to other product systems
- excess electricity, steam, off-gas (including tail gas, and other fuel gas) exported or sold to other product systems
- carbon from other product systems captured by a CCUS process that is part of the HPS

This section explains that no allocation is allowed under the simplified modelling approach and also states which co-products can be considered for allocation under the advanced modelling approach (section 4).

3.5.2 Quantification of flows

Under the simplified modelling approach, no allocation for a product or service can be performed. Therefore, if the HPS has any of the co-product's list above in section 3.5.1, then these must be neglected (conservative assumption), or the applicant must use the advanced modelling approach (section 4).

However, allocation is never applicable for some co-products even under the advanced modelling approach.

It is assumed that the oxygen co-product by electrolysis is entirely dependent on hydrogen production, so all inputs and outputs of the electrolysis process are allocated to hydrogen; the flow of oxygen can be neglected[2], and no allocation can be performed.

Oxygen produced from oxygen and nitrogen equipment, part of the HPS for reforming or partial oxidation of eligible hydrocarbons, is assumed to be used entirely by the hydrogen production process and any excess oxygen sold or exported to other product systems is neglected.

Excess steam not generated from the electricity and heat generation system and part of the HPS must always be neglected and no allocation or system expansion is allowed. This ensures that hydrogen product systems are optimized to produce hydrogen and not excess steam.

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[2] When an input/output flow is neglected, we assume that it is included in the hydrogen product system and does not need to be quantified.

For off-gas (including tail gas, and other fuel gas) from the hydrogen production, this modelling guidance (for both the simplified and advanced modelling approach) assumes that emissions associated with the combustion of these co-products must always be allocated to the HPS, even in the case where they are sold or exported to another product system. This also ensures that hydrogen product systems are optimized to produce hydrogen and not fuel gas.

3.6 Energy, material inputs and direct emissions

3.6.1 Summary

This section includes instructions on how to quantify and document input and output flows that describe energy and material inputs and direct emissions of an HPS.

Section 3.6.2 lists all the types of input and output flows that can be considered in the modelling of the HPS which includes:

- 3.6.2.1 Fuel inputs
- 3.6.2.2 Electricity inputs
- 3.6.2.3 Materials inputs
- 3.6.2.4 Direct emissions

In addition to these general instructions, applicants should consult section 3.6.3 for additional modelling instructions regarding specific cases related to energy and material inputs at the HPS. The list of specific cases includes the following:

- 3.6.3.1 Case 1: steam purchased or imported from another product system
- 3.6.3.2 Case 2: liquefaction/compression adjustment
- 3.6.3.3 Case 3: purchased fuel gas

Section 3.6.4 explains which CI value can be used depending on the type of flow. This can include using system processes from the Data Library, a configurable process, or a *CFR* CI for renewable hydrocarbons.

Section 3.6.5 explains how quantities for each type of input and output flows must be entered in the CH-ITC Workbook in their respective worksheet. Take note that for fuel inputs only, a similar approach to feedstock modelling is applied where one of the unit processes of the “Fuel input, at hydrogen product system” folder of the Model must be used.

Finally, the CH-ITC Workbook will calculate the final flow value that must be entered into the UP Hydrogen production, at HPS (SM) of the Hydrogen pathway in the Model as explained in section 3.6.6.

3.6.2 Quantification of flows

In the quantification of energy, material inputs and direct emission flows, the HPS is treated as a “black box”. Figure 5 demonstrates how inputs/outputs may be modelled using the black box approach for an ATR plant producing hydrogen under the simplified modelling approach.

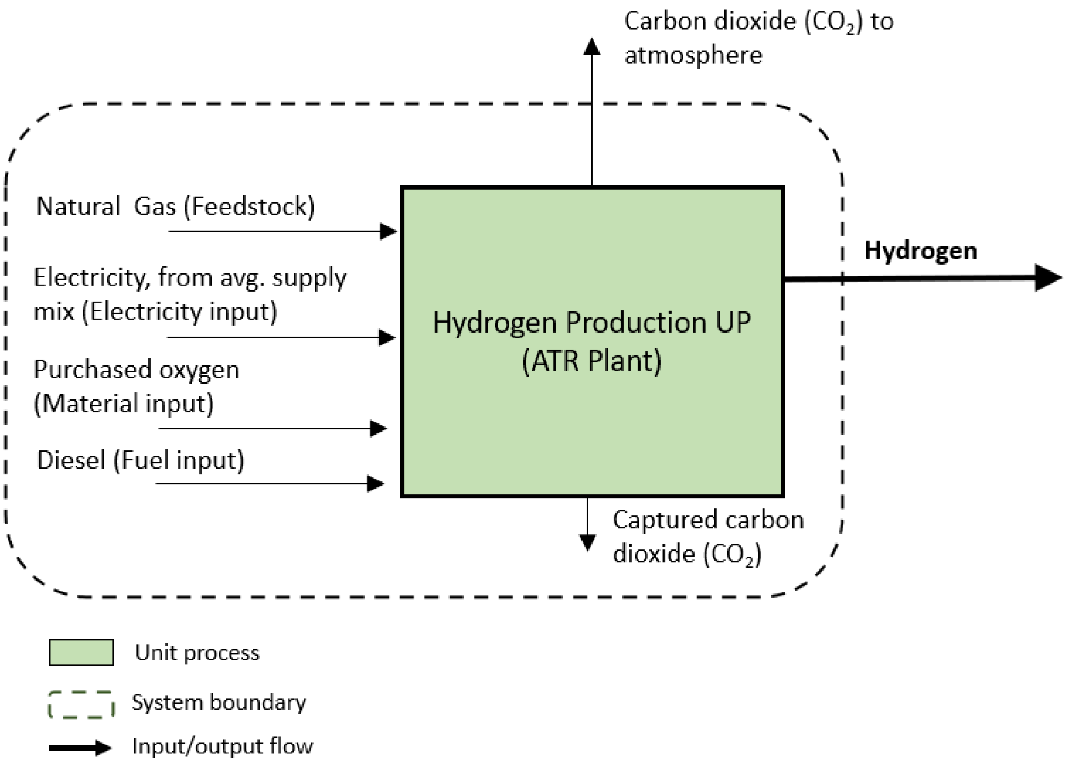

Figure 5: Example of input and output flows using the black box approach for an ATR plant.

The following section presents a description for each category of flows that must be included or excluded for energy and material inputs and direct emissions.

3.6.2.1 Fuel inputs

An applicant must follow the instructions described in sections 3.6.4, 3.6.5, and 3.6.6 to enter applicant data into the CH-ITC Workbook and the hydrogen pathway for the following categories of fuel inputs consumed by the HPS.

The *ITA* imposes restrictions on the use of fuel inputs by the HPS used for the generation of electricity and heat. It is recommended that applicants review this prior to modelling.

It is important to note that if applicants use a fuel to produce electricity and/or heat on-site (and used by the HPS), then the fuel input must be from natural gas, eligible hydrocarbons (section 3.3.2.3) with CCUS, eligible renewable hydrocarbon (section 3.3.2.4), or heat recovered from the taxpayer's hydrogen or ammonia production equipment. The same restrictions apply for fuel or energy inputs used by another product system to generate steam that is purchased or imported by the HPS. If these rules are not applied, the CI of the project will be deemed greater than 4.5 kg CO_2e/kg hydrogen. Please refer to Subsection 127.48 (6) of the *ITA* for more information.

Main fuel inputs:

- natural gas

- eligible fossil-based hydrocarbons, including (descriptions and rules in section 3.3.2.3 apply):
    - eligible substance sourced all or substantially all from raw natural gas
    - eligible substance that is a by-product from processing natural gas or substances sourced all or substantially all from raw natural gas
    - for these two types of fuel inputs, applicants must include the combustion emission factors by following the procedure in section 3.6.2.4
- eligible renewable hydrocarbons (descriptions and rules in section 3.3.2.4 apply, except that the fuel must be physically supplied or produced on-site, and excludes those supplied by means of contractual agreements)
- steam purchased or imported from another product system generated from one of the main fuel inputs or recovered heat from taxpayer's ammonia production equipment (refer to instructions on this specific case in section 3.6.3.1)

Other fuel inputs with additional restrictions:
The following list of fuel inputs should not be used to produce electricity and/or heat on-site (except to support a generator for startup or emergency backup operations).

- other fossil fuels (diesel, heavy and light fuel oil, etc.)
- purchased low-CI fuel in liquid state at standard conditions
- other renewable fuels (wood chips and pellets)
- waste produced outside of the production facility that is used as a fuel and has non-biogenic carbon content that is not derived from biomass
    - for example, municipal solid waste that would be used as a fuel
- fuel gas purchased or imported from another product system (refer to instructions on this specific case in section 3.6.3.3)

Fuel input quantities exclude:

- fuel input quantities used for feedstock transportation (which are already included in the system processes for transport and distribution in the Data Library)
- fuel quantities used as feedstock like renewable hydrocarbons used to produce hydrogen, which must be quantified as feedstocks following the instructions described in section 3.3
- solid and liquid co-products and waste materials produced on-site and used as fuel inputs are excluded, as long as their combustion emissions are considered biogenic. Otherwise, an applicant must enter the quantity (dry mass) of co-product or waste in the CH-ITC Workbook and consider them under the fuel category "non-biogenic waste" which represents waste produced outside of the production facility that is used as a fuel and has non-biogenic carbon content that is not derived from biomass
- gaseous co-products such as off-gas, tail gas and other fuel gases produced and combusted within the HPS are considered under the direct emissions category (refer to instructions in section 3.6.2.4)
- hydrogen produced and consumed at the production facility in the production process is excluded because no GHG emissions are associated with the combustion emissions of the hydrogen
- steam produced from the HPS (including from recovered heat)
- fuel gas imported from OPS for which the carbon content of the fuel is associated with emissions that have already been accounted for as direct emissions (section 3.6.2.4)

- only the energy associated with that carbon content must be excluded, other portions are treated as fuel gas purchased or imported from another product system
- an example is purge gas from ammonia production, where the carbon content comes from the feedstock for hydrogen production

A category of fuel input can be excluded if its contribution to the total fuel inputs of the production facility (in MJ on a HHV basis and without the quantity of excess steam sold) is expected to be lower than 1% and the aggregate of all such exclusions is not expected to exceed 2%. This option can be used to decrease the burden of data collection for small contributors to the CI value.

3.6.2.2 Electricity inputs

Applicants must follow the instructions described in sections 3.6.4, 3.6.5, and 3.6.6 to enter applicant data into the CH-ITC Workbook and the hydrogen pathway for the following categories of electricity inputs consumed by the HPS:

- purchased electricity from the Canadian grid
- electricity from an eligible generation source generated, or to be generated by the taxpayer (behind the meter) that is sourced from:
    - wind, solar, hydro, or nuclear
- eligible power purchase agreements (PPA) (refer to definition of eligible power purchase agreement in Subsection 127.48 (1) of the *ITA*) that are sourced from:
    - wind, solar, hydro, or nuclear
    - if the PPA is considered ineligible, then the applicant must model these quantities of electricity as purchased electricity from the grid and follow the instructions for this category of electricity inputs

Electricity input quantities exclude:

- excess electricity sold to the grid or electricity directly supplied to another product system
    - if excess electricity is produced by the HPS, it must either be neglected (simplified approach) or treated as specified in the advanced modelling approach (refer to section 4.3.6). This means that the applicant must follow the complete instructions under section 4 advanced modelling instead of using the simplified modelling approach
- electricity produced from on-site generation equipment part of the HPS
    - only the fuel input(s) quantities used to produce this electricity need to be entered into the CH-ITC Workbook following the instructions for fuel inputs (section 3.6.2.1)
    - if electricity produced from on-site generation equipment is used by other product systems, applicants may consider the advanced modelling approach that would allow for allocation of the electricity generation impact to other product systems

Applicants should carefully review the rules and limitations on electricity generated or purchased (or proposed to generate or purchase) in Subsection 127.48 (6) of the *ITA*. The generation or purchase of electricity from a generation source other than those described in that section will deem the carbon intensity to be greater than 4.5 kg CO_2e/kg hydrogen.

In addition, if the adjustment procedure for compression/liquefaction is applied, then please refer to case 2 (section 3.6.3.2) for additional instructions. Electricity use for this case can be subtracted from the total electricity consumption of the HPS.

Applicants are instructed to use the Electricity, average supply mix, at HPS (SM) UP that contains the total quantity of the different electricity inputs supplied to the HPS. Applicants should refer to Subsection 127.48 (6)(f) of the *ITA* regarding the rules for determining the quantities of electricity from various sources. It also has a reference flow corresponding to the total quantity of electricity consumed at the HPS and is used as an input for the Hydrogen production, at HPS (SM) UP. This will ensure that any electricity consumption adjustment for compression, liquefaction or purification will be applied to all electricity inputs proportionally.

3.6.2.3 Material inputs

An applicant must follow the instructions described in sections 3.6.4, 3.6.5, and 3.6.6 to enter applicant data into the CH-ITC Workbook and the hydrogen pathway for the following categories of material inputs consumed by the HPS:

- purchased oxygen or oxygen supplied by another product system

Material input quantities exclude:

- oxygen produced onsite within the HPS from a process like an air separation unit and used for hydrogen production
- excess oxygen or nitrogen produced onsite within the HPS, which is sold to a third party or exported to another product system
    - if excess nitrogen or oxygen is produced by the HPS, it must either be neglected under the simplified approach or treated under the advanced modelling approach (which allows only for mass allocation of nitrogen sold to third party or directly supplied to another product system)
- other chemicals and material inputs such as amine (MDEA solvent), electrolytes, catalysts, softened water, rapeseed methyl ester and other material inputs
    - the impact of supplying these material inputs is considered to have a contribution to the carbon intensity below the 1% cut-off criteria

3.6.2.4 Direct emissions

An applicant must follow the instructions described in sections 3.6.4, 3.6.5, and 3.6.6 to enter applicant data into the CH-ITC Workbook and the hydrogen pathway for the following category of direct emissions produced by the HPS:

- CO_2 emissions from the fossil carbon content of the feedstock

Applicants should assume that all the carbon content in the feedstock will be at some point oxidized into CO_2 and emitted into the air. Independently of how and when these emissions occur, they will systematically be attributed to the HPS. If some of this carbon is captured and stored in an "eligible use" (as defined in Subsection 127.44 (1) of the *ITA* for the purposes of Carbon Capture, Utilization and Storage investment tax credit), adjustment for captured emissions will be determined in section 3.7.

If eligible renewable hydrocarbons are used as a feedstock, carbon content associated with this feedstock should not be accounted for in the calculation of CO_2 emissions. Hence, hydrogen produced solely from renewable hydrocarbons is assumed to not have any direct emissions because the resulting emissions are biogenic CO_2.

Direct emissions exclude:

- all other direct emissions from CH_4 (fossil and biogenic), N_2O and other GHG emissions from the HPS such as emissions from an industrial process, waste, wastewater venting, flaring, and leakage
  - the impact of these direct emissions is considered to have a contribution to the carbon intensity below the 1% cut-off criteria
- all combustion emissions that are already included under the "fuel inputs" category (section 3.6.2.1)
  - combustion emissions of this category will already be accounted in the system processes from the Data Library (or other sources of CI) used to model fuel inputs

Direct emissions associated with the combustion of a fuel produced as a co- or by-product of the hydrogen production process like syngas or tail gas combustion will be included in CO_2 emissions from the carbon content of the feedstock. These emissions must be attributed to the HPS even if these fuels are consumed by another product system.

To determine the direct emissions, applicants must:

1. Determine the total quantity of fossil carbon contained in each feedstock used by the HPS (in kg of C) in accordance with instructions in section 3.3.2.

2. Convert the quantity of carbon into direct emissions (kg CO_2) using the following equation:

Equation 2: determination of the direct emissions of a hydrogen product system

$$\text{Direct emissions (kg } CO_2\text{)} = \sum (C_i \text{ x feedstock quantity}_i \text{ (kg)})*(44/12)$$

Where:
C_i = fossil carbon content of feedstock i (kg C/kg feedstock)

3. Add the resulting CO_2 calculated in this procedure as an elementary flow (as an output to the HPS).

An applicant can use multiple feedstocks such as natural gas and renewable natural gas for their HPS. The applicant must only consider fossil-based carbon content. The CH-ITC Workbook will then proceed to calculate the sum of CO_2 direct emissions for all feedstocks. Applicants are instructed to refer to section 3.6.5.4 for information on entering data into the CH-ITC Workbook.

3.6.3 Case-specific instructions on energy and material inputs

The Model can model a large array of cases and configurations at a hydrogen production facility. This section provides additional modelling instructions for specific cases related to energy and material inputs. While this document does not provide a step-by-step description of the CI calculation procedure for each of these cases, the general principles related to data entry in the CH-ITC Workbook and CI value modelling in the Model described in sections 3.6.4, 3.6.5, and 3.6.6 must be applied.

3.6.3.1 Case 1: steam purchased or imported from another product system

The heat exchanges between the HPS and other product systems can take many forms, through exchanges of fluids or gases. However, in the context of this CI modelling guidance, only imported steam (includes purchased steam) from or excess steam exported to another product system are considered. Imported steam will contribute to an increase in the CI of the HPS because the production of the steam will be allocated to it. Excess steam can be considered as a co-product from the HPS. However, to ensure that hydrogen product systems are optimized to produce hydrogen and not excess steam, no allocation or system expansion is allowed for exported excess steam under the simplified modelling approach.

Applicants must determine the total thermal energy imported (T_{imp}): this corresponds to a cumulative quantity for the first 20 years of operation from the hydrogen project plan (expected CI) or measured for 1 year of operation (actual CI).

The amount of thermal energy is determined using the enthalpy method, where the point of measurement i is at the boundary of the HPS. Thermal energy exchanges within the HPS would not be considered.

Equation 3: determination of the thermal energy in a flow

$$\text{Thermal energy flow (T)} = F_i*(h_i-h_{ref})$$

Where:
F_i = Mass flow of steam (kg/h)
h_i = the specific enthalpy of the steam flow (kJ/kg)
h_{ref} = the specific enthalpy of steam at reference conditions (100 °C,1 atm), (kJ/kg)
Thermal energy flow = energy contained in the steam flow (kJ/h)

T_{imp} can be a sum of multiple points of measurement i of thermal energy exchanges. Applicants must use the most reliable method available to introduce the least amount of error possible and document their procedure in the “Side Calculations” worksheet of the CH-ITC Workbook.

The resulting amount must be modelled as a positive quantity of purchased steam as part of the fuel inputs to the HPS.

Take note that the procedure assumes that all the thermal energy generated from the combustion of hydrogen or fuels and from waste heat recovered from the HPS are used by the HPS.

If this approach is judged too conservative by an applicant, then there is the possibility to apply the advanced modelling approach that allows for a more detailed modelling of the impact associated with thermal energy produced from hydrogen and fuels, including energy allocation of this thermal energy that is exported to other product systems. Applicants can refer to section 4 for more information.

Finally, applicants must be cognizant of the conditions that apply with the production of imported steam (section 3.6.2.1).

3.6.3.2 Case 2: compression/liquefaction adjustment

As stated in section 2.2.2, the functional unit has been set as **1 kg of pure (100%) gaseous hydrogen at a pressure between 1 and 30 bar, at the hydrogen product system gate**.

If applicants produce hydrogen (gaseous) above 30 bar, applicants can deduct the electricity use for compression used to bring the hydrogen (between 1 and 30 bar) above 30 bar. These energy input quantities need to be reported separately from the hydrogen facility's energy use data. This calculation is illustrated in Figure 6 and can be done in the CH-ITC Workbook on the "Elec input for HP (E0.1, E0.4)" worksheet through the E0.4 flow.

If the hydrogen is in liquid form, then applicants can deduct the electricity use for liquefaction from the total electricity consumption of the HPS if it occurs on-site at the hydrogen production facility. Therefore, this adjustment can only be made when the electricity for liquefaction comes from the HPS electricity input. The same rule applies for electricity used for processes for delivering, collecting, recovering, treating, or recirculating water. In these cases, applicants can follow the same procedure as compression.

If electricity is produced on-site (within the HPS) from the combustion of fuel inputs or from hydrogen that is directly produced by the HPS, the simplified modelling approach cannot be used for this adjustment procedure and the advanced modelling approach must be used with at least the modelling of Step D: D- Electricity and heat generation system (AM) UP (refer to section 4.4.4) and Step E: E- Electricity, average supply mix, at HPS (AM) (refer to section 4.4.5).

If further hydrogen processing occurs offsite at an external treatment facility, the energy inputs would not be included in the HPS.

If applicants decide to recover heat from the processes for which electricity consumption has been deducted and use it within the HPS then they must treat this as heat recovered from an OPS and as such, it must be modelled as steam purchased or imported from another product system.

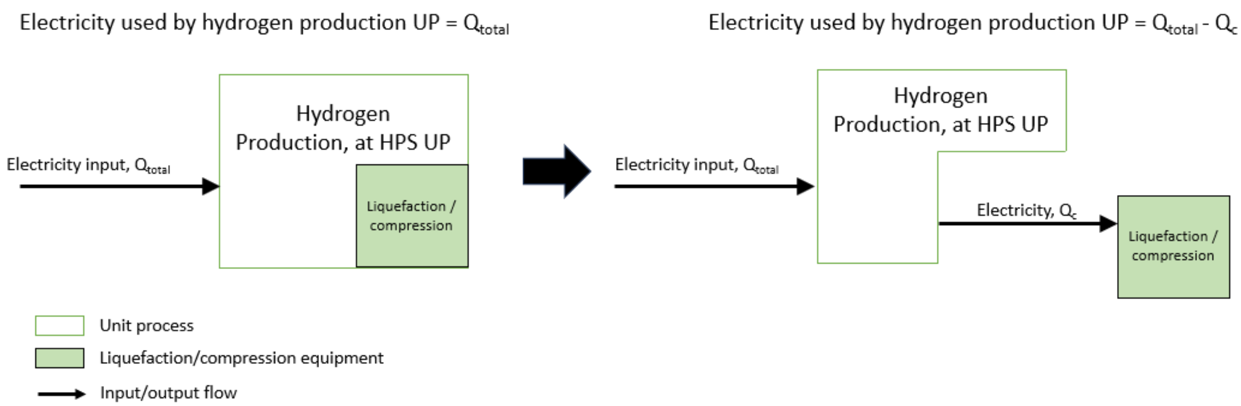

Figure 6: Illustration of the liquefaction and compression calculation.

3.6.3.3 Case 3: purchased fuel gas

A fuel gas is a gas or gas mix other than fossil gaseous fuels already included in the list of fuel input categories (such as natural gas or eligible fossil-based hydrocarbons) that is imported from another product system and used as a fuel within the HPS.

When a fuel gas is used as an input, the quantity must be converted into megajoules (MJ) HHV to be modelled using "Fuel gas combustion" system process (refer to section 3.6.4.1).

The conversion can be done based on the conversion of the individual substances that compose the fuel gas and their contribution to the total mass or volume of the fuel gas. For a given substance within the fuel gas, the assumptions on density and HHV found in the "ECCC Parameters" worksheet in the CH-ITC Workbook should be used as a priority. Otherwise, applicants must document in the "Side Calculations" worksheet the assumptions and calculations used for converting the measured flow of fuel gas in MJ HHV.

3.6.4 Source of the CI value

For each type of energy and material input and direct emission flow, an applicant may be able to choose a source of CI values. The instructions for selecting the appropriate CI values for each type of energy and material input and direct emission flow are listed below. Instructions for the conversion of these units are included in section 3.6.5.

1. System Process from the Data Library

This is the primary source of CI values for energy and material inputs that are purchased or supplied by other product systems. For fuel inputs, the system process will also provide the direct combustion emissions associated with the combustion of purchased or imported fuels at the HPS. When available and applicable, it must always be used before any other CI value source. The list of system processes available for the different types of energy and material inputs and direct emissions at the production facility is available in section 3.6.4.

2. Configurable Process

This UP is partially modelled and allows the user to replace certain flows with other flows representing their situation. This is applicable for the Oxygen, gaseous, from cryogenic air separation, configurable A (purchased oxygen) flow, where applicants can replace the dummy flow for electricity with an electricity flow that represents the grid mix of their geographical location.

3. *CFR* CI for a fuel input

For renewable hydrocarbons purchased from an external supplier or produced on site and used by the HPS as a fuel input, a *CFR* CI determined under the *CFR* can be used and linked to the hydrogen pathway as a fuel input flow. A *CFR* CI can be:

- transferred CI from a carbon-intensity contributor as determined and approved under the *CFR*
- a CI value calculated in accordance with the *CFR* Supplemental Specifications for RNG, biogas or renewable propane
- a CI value determined with an approved new pathway under the *CFR*

Please refer to section 3.3.2.4 for more information.

3.6.4.1 Fuel inputs

A fuel input is modelled with one of the processes from the Processes/Fuel Pathways/Hydrogen pathway/Mass basis/**Fuel input, at hydrogen product system** folder. This approach is similar to the one used for feedstock but must also consider combustion emissions.

Main fuel inputs:

Natural gas

- applicants must select the system process: Processes/Data Library/Fossil fuels/Combusted fossil fuels/**Natural gas combustion** located in the Data Library
- this system process can be used regardless of the geographical location where fuels are produced

Eligible substance sourced all or substantially all from raw natural gas

- applicants must select the system process: Processes/Data Library/Fossil fuels/Non-combusted fossil fuels/**Propane, at fuel production gate** (for fuel produced on-site) or Processes/Data Library/Fossil fuels/Non-combusted fossil fuels, at end user/**Propane, at end user** (for fuel produced off-site) to model upstream emissions
- the combustion emissions are added directly as a Flows/Elementary flows/Emission to air/Unspecified/**Carbon dioxide (CO2), fossil** output flow

Eligible substance that is a by-product from processing natural gas or substances sourced all or substantially all from raw natural gas

- applicants must select the system process: Processes/Data Library/Fossil fuels/Non-combusted fossil fuels, at end user/**Natural gas, at end user** to model upstream emissions
- the combustion emissions are added directly as a **Carbon dioxide (CO2), fossil** output flow

Eligible renewable hydrocarbons

- upstream emissions are modelled with a *CFR* CI (refer to instructions in section 3.3.3.4 and procedure described in section 6)
- the combustion emissions can be neglected

- if transportation is required, instructions in section 3.4 for the same type of feedstock must be followed
- in a case where the *CFR* CI is not available at the date of filing a compliance report, applicants must select the system process: Processes/Data Library/Fossil fuels/Combusted fossil fuels/**Natural gas combustion**

Steam purchased or imported from another product system generated from one of the main fuel inputs or recovered heat from taxpayer's ammonia production equipment

- applicants must select the system process: Processes/Data library/Other energy/**Purchased steam** located in the Data library
- this system process can be used regardless of the geographical location where steam is produced

Other fuel inputs with additional restrictions:
Other fossil fuels

- applicants must select the corresponding system process from the folder: Processes/Data Library/Fossil fuels/**Combusted fossil fuels** located in the Data Library
- these system processes can be used regardless of the geographical location of where the fuels are produced

Purchased low-CI fuel that is in a liquid state at standard conditions

- applicants must select the system process with the most similar option to the purchased low-CI fuel available in the folder Processes/Data library/Fossil Fuels/**Combusted fossil fuels** located in the Data Library. Some examples are:
    - "gasoline combustion" for renewable naphtha
    - "diesel combustion" for HDRD
    - "heavy fuel oil combustion" for pyrolysis oil

Other renewable fuels (wood chips and pellets)

- applicants must select the corresponding system process from the folder Processes/Data library/Renewable fuels/**Combusted renewable fuels** located in the Data library
- these system processes can be used regardless of the geographical location where fuels are produced
- if there is no system process that corresponds to the type of renewable fuel input at the production facility, applicants must select the "natural gas combustion" system process
    - the equivalence between the 2 fuel inputs must be based on their HHV

Waste (produced outside the production facility) with non-biogenic carbon content

- applicants must select the system process: Processes/Data library/Energy sources/**Non-biogenic waste combustion** located in the Data Library
- this system process can be used regardless of the geographical location of where the waste is produced

Fuel gas purchased or imported from another product system

- applicants must select the system process: Processes/Data library/Other energy sources/**Fuel gas combustion** located in the Data library
- this system process can be used regardless of the geographical location of where the purchased fuel is produced
- please refer to 3.6.3.3 for case specific instructions for purchased fuel gas

3.6.4.2 Electricity inputs

Electricity inputs are modelled by using an Electricity, average supply mix, at HPS (SM) UP. Within this UP, electricity inputs can be modelled by selecting the appropriate system process for the electricity input from the Data Library in the Model.

Purchased electricity from the grid

- applicants must select the system process corresponding to the province or territory where the electricity is being sourced from by choosing the folder Processes/Data Library/Electricity/Grid electricity/**Canadian grid electricity** located in the Data Library
- it is assumed that the electricity comes from the provincial or territorial grid that the project's electricity is sourced from

Electricity from an eligible generation source generated, or to be generated by the taxpayer (behind the meter)

- applicants must select the system process corresponding to the type of electricity generation associated with the electricity input from the folder Processes/Data Library/Electricity/Technology specific electricity/**Onsite generation** located in the Data Library:
    - Electricity, from hydro, reservoir, onsite generation
    - Electricity, from hydro, run-of-river, onsite generation
    - Electricity, from nuclear, CANDU, onsite generation
    - Electricity, from solar, concentrated solar power, onsite generation
    - Electricity, from solar, photovoltaic, onsite generation
    - Electricity, from wind, onshore, onsite generation (can be used as a proxy for offshore)
- this electricity input type applies to electricity produced on site, not supplied through an electrical network

Eligible power purchase agreements (PPA)

- for electricity from an eligible power purchase agreement, applicants must select the system process corresponding to the type of electricity generation associated with the electricity input from the folder Processes/Data Library/Electricity/Technology specific electricity/**Offsite generation** in the Data Library:
    - Electricity, from hydro, reservoir, offsite generation
    - Electricity, from hydro, run-of-river, offsite generation
    - Electricity, from nuclear, CANDU, offsite generation
    - Electricity, from solar, concentrated solar power, offsite generation
    - Electricity, from solar, photovoltaic, offsite generation
    - Electricity, from wind, onshore, offsite generation (can be used as a proxy for offshore)

3.6.4.3 Material inputs

Purchased oxygen inputs are modelled with a configurable process:

- applicants must select and configure, in accordance with instructions in section 3.6.6.3, one of the configurable unit processes from the folder Processes/Fuel Pathway/Fuel Pathways/Configurable processes/**Oxygen**

3.6.4.4 Direct emissions

To model the direct emissions from a HPS, applicants are instructed to add the resulting quantity of CO_2 calculated in section 3.6.2.4 through an elementary flow as an output (Flows/Elementary flows/Emission to air/**Carbon dioxide (CO2), fossil**) in the Hydrogen production, at HPS (SM) UP process. There is no CI value required for the elementary flow as an output, which contributes directly to the final carbon intensity value.

3.6.5 Step 1: entering data into the CH-ITC Workbook

3.6.5.1 Fuel inputs

An applicant must complete the "Fuel input for HP (FL1)" worksheet according to the instructions given in the CH-ITC Workbook and change the name of the worksheet to the name of the fuel input. For example, an applicant could rename their sheet to "Natural gas fuel for HP (FL1)". Applicants must enter information such as the type of fuel and fuel quantities.

Each "Fuel input for HP (FL1)" worksheet must contain information on a single fuel input. If more than 1 fuel input type is used at the production facility, a new worksheet must be created for each additional fuel input. To create a new worksheet, copy the "Fuel input for HP (FL1)" worksheet and complete it by following the same instructions outlined above. For fuel inputs for which a *CFR* CI value is used, refer to section 6 (Annex A) for additional instructions.

Once the applicant has entered all required information, they will then obtain the cumulative quantity of fuel for the first 20 years of operation from the hydrogen project plan (expected CI) or for 1 year of operation (actual CI) that can be used in step 2: modelling in the Fuel LCA Model.

3.6.5.2 Electricity inputs

An applicant must complete the "Electricity input (Ea)" worksheet according to the instructions given in the CH-ITC Workbook and change the name of the worksheet to the name of the electricity input. For example, a sheet could be renamed from "Electricity input (Ea)" to "Electricity, from grid CA-BC". Each "Electricity input (Ea)" worksheet must contain information for a single electricity source which can include the electricity type, technology, and quantities. If more than 1 electricity input type is used at the production facility, a new worksheet must be created for each additional electricity input and renamed as "Electricity input (Eb)", "Electricity input (Ec)", etc. To create a new worksheet, copy the "Electricity input (Ea)" worksheet and complete it by following the same instructions outlined above.

Once all the electricity input worksheets have been completed, the applicant must complete the "Elec avg. supply mix (E0)" worksheet according to the instructions given in the CH-ITC Workbook. This includes entering information from the "Electricity input (Ea)" worksheet(s) such as the electricity amount. This worksheet will ensure that the electricity, average supply mix correctly combines all the electricity inputs at the hydrogen production facility.

Finally, an applicant must complete the "Elec input for HP (E0.1, E0.4)" worksheet according to the instructions given in the CH-ITC Workbook. This worksheet ensures that the electricity inputs are connected to the Hydrogen production, at HPS (SM) UP. If applicable, applicants will also be able to deduct the electricity use for compression (for pressure above 30 bar) or liquefaction from the total electricity consumption in accordance with the instructions of section 3.6.3.2.

Furthermore, if electricity is produced onsite (in the HPS) then the quantity of electricity consumed by the Hydrogen production, at HPS (SM) UP must not consider the electricity produced on-site. Therefore, this quantity remains internal, and the quantity of electricity entered into the CH-ITC Workbook should represent the amount of electricity received by the HPS via flow E0.1.

Once the applicant has entered all required information, then they will obtain a quantity of electricity from the Electricity, average supply mix, at HPS (SM) UP that can be used in step 2: modelling in the Fuel LCA Model.

3.6.5.3 Material inputs
An applicant must complete the "Purchased oxygen (O1, O4)" worksheet to model purchased oxygen according to the instructions given in the CH-ITC Workbook. This includes entering information such as the quantities of oxygen and corresponding units.

Once the applicant has entered all required information then they will obtain the cumulative quantity of purchase oxygen for the first 20 years of operation from the hydrogen project plan (expected CI) or for 1 year of operation (actual CI) that can be used in step 2: modelling in the Fuel LCA Model.

3.6.5.4 Direct emissions
An applicant must complete the "Direct emissions (DE)" worksheet to model direct emissions according to the instructions given in the CH-ITC Workbook. This includes entering information such as the fossil carbon content of each feedstock used to produce hydrogen, feedstock type and feedstock quantity.

Once the applicant has entered all required information, they will obtain the total direct emissions from all feedstocks that can be used in step 2: modelling in the Fuel LCA Model.

3.6.6 Step 2: modelling in the Fuel LCA Model
Each energy input, material input and direct emissions must be modeled directly in the main UP Hydrogen production, at HPS (SM) from the folder Processes/Fuel Pathways/Hydrogen pathway/Mass basis/**Hydrogen production, simplified modelling (SM)**. Each energy input and material input must be set as inputs of the main process. Each direct emission must be set as an output of the main process, as an emission to air.

Note: Consult section 3.6.3 for additional modelling instructions regarding specific cases related to energy and material inputs at a production facility.

In the Processes/Fuel Pathways/Hydrogen pathway/Mass basis/**Hydrogen production, simplified modelling (SM)** folder, open the UP Hydrogen production, at HPS (SM), go to the "Input/Output" tab and follow the steps below depending on the data source used as detailed in section 3.6.4.

- system process from the Data Library: enter the system processes from the Data Library as inputs, along with the total amounts reported in the "Amount" column of the appropriate worksheet
- *CFR* CI: enter the unit processes as inputs along with the total amounts reported in the "Amount" column of the appropriate worksheet
- save and close the UP (or process)

3.6.6.1 Fuel inputs

If the source of CI value is a system process:
One of the processes of the Processes/Fuel Pathways/Hydrogen pathway/Mass basis/**Fuel input, at hydrogen product system** folder is used to model the fuel inputs. One UP must be selected for each distinct fuel input, and they must be entered as inputs in the hydrogen production, at HPS (SM) UP.

Applicants must follow the modelling steps below for fuel inputs:

1. In openLCA, open the folder "Fuel input, at hydrogen product system". The folder already includes fuel input unit processes. For example, "Fuel input, A, at hydrogen product system", "Fuel input, B, at hydrogen product system", "Fuel input, C, at hydrogen product system".
2. For each fuel input, open a UP (such as "Fuel input, A, at hydrogen product system") and follow these steps:
    a) Rename the UP and the corresponding output flow with the name of the fuel input generated in the CH-ITC Workbook like "Fuel, **natural gas**, at hydrogen product system", or as shown in the workbook.
    b) Follow the instructions under step 6 of the corresponding fuel input worksheet "Fuel input for HP (FL1)", "Fuel input for HP (FL2) etc. of the CH-ITC Workbook.
3. If applicable, applicants must complete the modelling of fuel transportation by following steps 3a-b below before proceeding. Applicants can refer to section 3.6.4.1 to confirm if transportation is required.
    a) The processes in the folder Processes/Fuel Pathways/Hydrogen pathway/Mass basis/**Fuel input, at hydrogen product system** are used to model the transportation of fuel inputs. Each applicable transportation system process from the data library must be entered as an input in each fuel input UP, using applicant data.
    b) For each fuel input, applicants must open the corresponding UP from the folder "Fuel input, at hydrogen product system" and insert in the "Input/Output" tab:
        i. For each transport mode used for fuel transportation, select the corresponding transport system process from the Processes/Data library/**Transportation** folder of the Data Library.
        ii. In the CH-ITC Workbook, follow step 4 of "Fuel input for HP (FL1)" worksheet for that transportation mode (system process).

iii. Repeat steps 1 and 2 for each transport mode used for the fuel.

4. If applicable, applicants must complete the modelling of fuel combustion emission factors by following steps 4a-b below. Applicants can refer to section 3.6.4.1 to confirm if the modelling of combustion emission factors is required.
   a) The processes in the folder Processes/Fuel Pathways/Hydrogen pathway/Mass basis/**Fuel input, at hydrogen product system** are used to model the combustion emission factors of fuel inputs.
   b) For each fuel input, applicants must copy the Carbon dioxide (CO2), fossil quantity (kg) from "Fuel input for HP (FL1)" worksheet under step 6.
5. Save and close the UP.
6. If more unit processes for a fuel input need to be added to the folder "Fuel input, at hydrogen product system", create a new UP and a corresponding flow, and follow the procedure described in step 2.

If the source of CI value is a *CFR* CI:
Applicants must first create a new UP with the procedure described in section 6 (Annex A).

Once the *CFR* CI UP is added to the hydrogen pathway, the steps above for a system process can be applied with the *CFR* CI UP equivalent to the system process from the Data library.

3.6.6.2 Electricity inputs
Applicants must follow the modelling steps below for electricity inputs:
1. In openLCA, open the Electricity, average supply mix, at HPS (SM) UP.
2. In the CH-ITC Workbook, follow step 4 of "Electricity input (Ea)" worksheet from the Workbook.
3. Repeat steps 1-2 for each other electricity input (such as Eb, Ec).
4. Save and close the UP.
5. In openLCA, open the Electricity, average supply mix, at HPS (SM) UP. In the CH-ITC Workbook, follow step 3 of "Elec. Avg. supply mix (E0)" worksheet.
6. Save and close the UP.
7. In openLCA, open the Hydrogen production, at HPS (SM) UP. In the CH-ITC Workbook, follow step 4 of "Elec input for HP (E0.1, E0.4)" worksheet. This includes instructions to copy and paste rows from the CH-ITC Workbook to the Hydrogen production, at HPS (SM) process in openLCA.
8. Save and close the UP.

3.6.6.3 Material inputs
Material inputs use a configurable UP for purchased oxygen.

Purchased oxygen supplied to the HPS must be modelled via the Oxygen, gaseous, from cryogenic air separation, configurable A process. This allows users to define their electricity mix using provincial/territorial grid electricity corresponding to the region where oxygen is produced. This UP has a functional unit of 1 kg of oxygen.

To configure the Oxygen, gaseous, from cryogenic air separation, configurable A process with the electricity mix using provincial/territorial grid electricity that corresponds to the region where oxygen is produced, applicants must:

1. Move one of the applicable processes from the folder Processes/Fuel Pathways/Configurable processes/Oxygen to the Fuel Pathways/Hydrogen pathway/Mass basis/**Hydrogen Production, simplified modelling (SM)** folder.
    a) To move unit processes, refer to chapter 5.2.7 of the Fuel LCA Model User Manual.
2. In the "Input/Output" tab of the Oxygen, gaseous, from cryogenic air separation process, configurable A:
    a) Make sure the amount of the output flow (reference flow) is 1 kg of Oxygen, gaseous, from cryogenic air separation, configurable A.
    b) Enter the system process corresponding to the province or territory where the oxygen is produced in the inputs section. These must be taken from the folder Processes/Data library/Electricity/Grid electricity/**Canadian grid electricity**.
    c) Enter the same amount of electricity used by the Electricity, dummy, to be replaced flow (0.40502 kWh) and erase this flow.
3. Save and close the configurable UP.

Applicants must follow the modelling steps below to model the Hydrogen production, at HPS (SM) UP:

1. In openLCA, open the Hydrogen production, at HPS (SM) UP.
2. In the CH-ITC Workbook, follow step 3 of "Purchased oxygen (O1, O4)" worksheet. This includes instructions to copy and paste rows from the CH-ITC Workbook to the Hydrogen production, at HPS (SM) process in openLCA.
3. Save and close the UP.

3.6.6.4 Direct emissions

Applicants must follow the modelling steps below for direct emissions:

1. In openLCA, open the Hydrogen production, at HPS (SM) UP.
2. In the CH-ITC Workbook, follow step 3 of "Direct emissions (DE)" worksheet. This includes instructions to copy and paste rows from the CH-ITC Workbook to the Hydrogen production, at HPS (SM) process in openLCA.
3. Save and close the UP.

3.7 Carbon dioxide (CO2) capture, at HPS (SM)

3.7.1 Summary

This section includes instructions on how to quantify and document flows of captured CO_2.

For purposes of measuring CIs, captured CO_2 would need to be stored via an "eligible use", as defined in Subsection 127.44(1) of the *ITA* for purposes of the CCUS investment tax credit (which would include dedicated geological storage or use in concrete). CO_2 that is stored or used in any other way (including for enhanced oil recovery) would be treated as if it were released into the atmosphere for the purposes of assessing the CI of hydrogen.

In this CI modelling guidance, only energy inputs associated to the CO_2 transportation and storage are considered, while storage efficiency and CO_2 leaks are not taken into account. Although, these unaccounted emissions are potentially above the cut-off criteria, and would typically be included in the boundaries of the product system based on the scope of the Model and principles in ISO 14040/14044, they are excluded for purposes of the CH-ITC.

3.7.2 Quantification of flows

The total quantity of CO_2 captured at the hydrogen plant must be considered, accounting for any leaks at the capture unit. In other words, this amount must correspond to the quantity of CO_2 leaving the plant and being transported for storage or use.

For the expected CI, carbon quantities are to be calculated in proportion to the quantity of captured CO_2 the project is expected to support for storage or use in an "eligible use" during the first 20 years of the project's operations based on the most recent clean hydrogen project plan. The total quantity of captured CO_2 that is expected to be achieved must be reported on an annual basis. Further instructions are included in the CH-ITC Workbook.

To model a project's actual CI, only the actual quantity of captured CO_2 during each operating year of the compliance period is to be considered.

If the capture unit is used to capture CO_2 from other product systems and not exclusively from the hydrogen production product system, please refer to section 4 for instructions on advanced modelling. Applicants also have the option to use the simplified modelling approach and neglect these other captured CO_2 flows (conservative assumption).

With the simplified modelling approach, energy and material inputs related to the capture of CO_2 at the plant should already be accounted for in the inputs entered for the HPS and do not need to be added separately. Please refer to section 3.6.2.4 for information on how to enter these amounts.

As described previously in section 3.6.2.4, production facilities with CO_2 emissions capture must model their hydrogen as if the CO_2 emissions were not captured. The captured CO_2 will be subtracted in a separate UP, as described in this section.

3.7.3 Source of CI Value

Applicants must model the carbon captured and stored via an "eligible use" as a waste flow using the appropriate UP: Processes/Fuel Pathways/Hydrogen pathway/Mass basis/Hydrogen production, simplified modelling (SM)/**Carbon dioxide (CO2) capture, at HPS (SM)**

- the UP will provide a credit corresponding to the fraction of CO_2 captured and going to an eligible use for each kg CO_2 captured (negative emission of fossil CO_2)
- for example, if 80% of the CO_2 captured is sent to an eligible use, a credit of -0.8 kg will be applied for each kg of CO_2 captured. In addition, electricity use for injection of CO_2 is applied
- the latter corresponds to a default value for injection of CO_2 into geological storage and is used as a proxy for storage in concrete

- the electricity source used will correspond to the provincial grid mix of where the storage occurs

Unlike product flows, waste flows are added as an output to a given process, and not as an input. Furthermore, the reference flow for a waste process is in the inputs of the process, and not in the outputs. For more information on this procedure, please consult section 5.2.2 of the Fuel LCA Model User Manual.

3.7.4 Step 1: entering data into the CH-ITC Workbook

The applicant must fill in the “CCUS at HPS (C1,C2,Cimp)” worksheet according to the instructions provided in the CH-ITC Workbook. This includes entering information such as quantities of carbon captured from the HPS, and other on-site systems and the provincial grid mix used.

Once the applicant has entered all required information then they will obtain the cumulative quantities of CO_2 for the first 20 years of operation from the hydrogen project plan (expected CI) or for 1 year of operation (actual CI) that can be used in step 2: modelling in the Fuel LCA Model.

3.7.5 Step 2: modelling in the Fuel LCA Model

All of the carbon captured must be modeled directly in the main UP Hydrogen production, at HPS (SM) from the folder Processes/Fuel Pathways/Hydrogen pathway/Mass basis/**Hydrogen production, simplified modelling (SM)**. The total quantity must be set as a negative output flow.

Applicants must follow the modelling steps below for CO_2 capture:

1. In openLCA, open the Hydrogen production, at HPS (SM) UP and follow the applicable instructions in step 3 on the “CCUS at HPS (C1,C2,Cimp)” worksheet.
2. Save and close the UP.
3. Open the Carbon dioxide (CO2) capture, at HPS (SM) UP and follow the applicable instructions in step 3 on the “CCUS at HPS (C1,C2,Cimp)” worksheet. Ensure that the Carbon dioxide (CO2), fossil flow is modelled as a negative output flow since it represents captured CO_2 for eligible storage.
4. Copy the flow of electricity corresponding to the appropriate provincial or territorial electricity grid with the amount calculated in the worksheet as an input flow to the UP.
5. Save and close the UP.

4 Advanced approach (cradle-to-gate CI modelling)

This section includes modelling information with regards to the modelling of a cradle-to-gate CI under the advanced modelling approach for both the expected CI and actual CI. Applicants must refer to section 2.4 for instructions on how to determine the appropriate modelling approach for their clean hydrogen project.

Section 4 details how applicants can apply advanced modelling to specific unit processes so that they can model their clean hydrogen project. Each modelling step will include:

- a brief description of the UP
- rules regarding the input/output flows – which flows must, can and cannot be included and how they should be treated
- allocation (if applicable) – how allocation must be performed
- how to enter the data into the CH-ITC Workbook – what information should be entered into the workbook and how it is inputted
- modelling in the Fuel LCA Model – how does the applicant perform the modelling of this UP in openLCA with the pre-determined processes

4.1 General information

General information on the hydrogen facility such as the name, address, hydrogen pathway, operating year, etc. must be completed. The applicant must also list the start date, end date and reason for any shutdown periods under step 4 (a). The applicant must enter the required information in the “General” worksheet in the CH-ITC Workbook. It is important that the applicant selects both the type of modelling (step 2) and CI (expected or actual - step 3c). These choices will affect the calculation procedure and the result in the workbook.

All instructions for step 1: entering data in the CH-ITC Workbook are provided in the CH-ITC Workbook under the “Activity Map” worksheet. The workbook and this guidance provide detailed instructions to fill out each flow/worksheet in the CH-ITC Workbook under the advanced modelling approach.

In openLCA, the user will use the processes under Processes/Fuel pathways/Hydrogen pathway/Mass basis/**Hydrogen production, advanced modelling (AM)** for the advanced modelling approach. This folder contains specific unit processes for advanced modelling, which are described below.

4.1.1 Unit processes for advanced modelling

In the context of the advanced modelling approach, there are 6 types of unit processes.

A- Hydrogen production, at HPS (AM): must include all feedstocks, fuel, electricity, and material inputs, as well as direct emissions associated with equipment that is used to produce hydrogen and that are not already included by the other unit processes. This can include equipment covered under the Clean Hydrogen Investment Tax Credit – Technical and Equipment Guidance Document and eligible property listed in Subsection 127.48 (1) of the *ITA* under “eligible clean hydrogen property”.

B- Oxygen and nitrogen generation system (AM): must include all electricity inputs for equipment that provides/generates oxygen and nitrogen material to both the hydrogen and ammonia product systems. This also includes equipment covered under the Clean Hydrogen Investment Tax Credit - Technical and Equipment Guidance Document and eligible property listed in Subsection 127.48 (1) of the *ITA* under "dual-use hydrogen and ammonia".

C- Carbon dioxide (CO2) capture, at HPS (AM): must include all fuel and electricity inputs for equipment that is used to capture CO_2 from the hydrogen and other product systems. This also includes equipment covered by the 1) Clean Hydrogen Investment Tax Credit - Technical and Equipment Guidance Document, 2) Carbon Capture, Utilization, and Storage investment tax credit and 3) eligible property listed in Subsection 127.48 (1) of the *ITA*.

D- Electricity and heat generation system (AM): must include all hydrogen, fuel and electricity inputs for equipment that is used to generate, distribute, and transmit electricity and/or heat energy to produce hydrogen. This can also include equipment that is covered by the Clean Hydrogen Investment Tax Credit - Technical and Equipment Guidance Document and eligible property listed in Subsection 127.48 (1) of the *ITA* under "dual-use heat and electricity equipment".

E- Electricity, average supply mix, at HPS (AM): this UP has individual electricity inputs such as "Electricity, from grid [CA-ON]" and is used to deliver electricity as an input to other unit processes.

F- Hydrogen with heat adjustment (AM): this UP is used for step F of the advanced modelling approach whereby the user quantifies the relationship between thermal energy flows that interact with the HPS.

As a visual example, Figure 3 shows the 6-unit processes and the exchanges of flows between them and other product systems.

4.2 Scope

Section 2 includes information such as key concepts, scope of the CI modelling, functional unit, modelling options and modelling steps. These concepts can be re-applied under advanced modelling. This section also describes in which situations unit processes can be merged for advanced modelling.

4.2.1 System boundary

The system boundary under the advanced modelling approach can include up to 6 unit processes listed in section 4.1.1 whereas the simplified modelling approach has all flows and unit processes merged within the Hydrogen production, at HPS (SM), Electricity, average supply mix, at HPS (SM) and Carbon dioxide (CO2) capture, at HPS (SM) unit processes.

4.3 Quantification of flows

This section includes instructions on how to quantify and document input and output flows that describe energy, material inputs, and direct emissions of unit processes in an HPS. It also lists instructions in addition to section 3 for the advanced modelling approach. Thus, describing applicable differences in the treatment of flows between sections and additional considerations for applicants.

All the flows covered in sections 3 and 4.3 must be quantified using a cumulative 20-year data from the clean hydrogen project plan for the expected CI. For the actual CI, applicants must use 1 year of operating data for each year of a given compliance period as per Subsection 127.48 (1) of the *ITA*.

4.3.1 Hydrogen produced

This output flow is only applicable for the A- Hydrogen production, at HPS (AM) UP.

The main distinction between the simplified and advanced modelling approach is that the quantity of hydrogen that is produced from the Hydrogen production, at HPS UP includes quantities exported to other product systems and consumed within the HPS, such as flows named Hydrogen production, at HPS, exported to OPS (AM) and Hydrogen production, at HPS, used by HPS (AM). Hydrogen that is lost within the HPS is not considered in the calculation of net hydrogen produced. Please refer to the example in Figure 7 below where the quantities of hydrogen that are exported to other product systems and consumed internally are included.

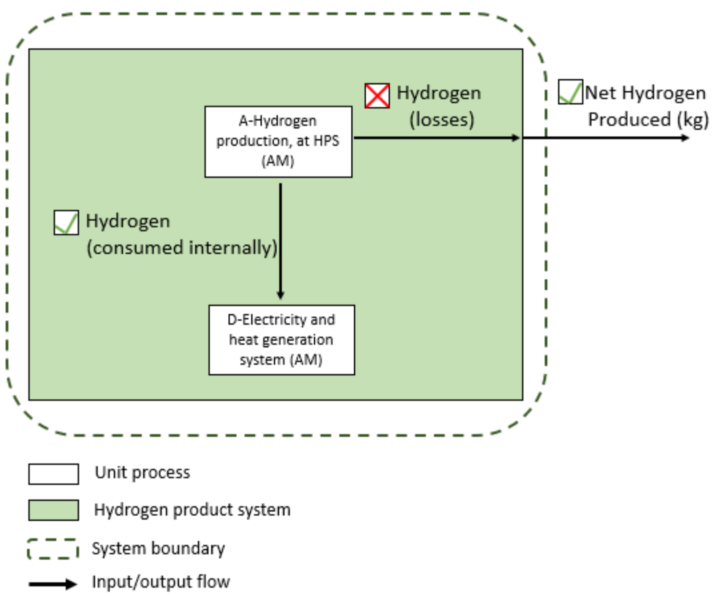

Figure 7: Different flows of hydrogen in a hydrogen product system.

The total quantity of hydrogen produced must always be expressed in terms of pure (100%) hydrogen on a mass basis. This quantity is measured at the gate of the hydrogen system process (for hydrogen exported to OPS) or at the gate of equipment consuming hydrogen that are part of the D- Electricity and heat generation system (AM) UP (for hydrogen used internally). Applicants can refer to section 7 (Annex B) for information on the modelling of the electricity and heat generation system.

Applicants must refer to Equation 1 and the procedure in section 3.2 to convert all applicant's gas streams of hydrogen into a pure quantity of hydrogen.

4.3.2 Feedstock input

Feedstocks must be modelled in accordance with section 3.3. However, the created feedstock unit processes must be entered as inputs in the A- Hydrogen production, at HPS (AM) UP instead of Hydrogen production, at HPS (SM) UP.

4.3.3 Feedstock transportation

Feedstock transportation must be modelled in accordance with section 3.4.

4.3.4 Co-products produced

Potential co-products that will be covered in 4.4 modelling steps are:

- hydrogen exported to OPS or used internally (4.4.1)
- nitrogen exported to OPS or oxygen used internally (4.4.2)
- electricity and heat exported to OPS or used internally (4.4.4)
- CO_2 from other product systems or from unit processes that are part of the HPS and captured by a CCUS system that is part of the HPS such as a service of carbon capture as a co-product (4.4.3)

The total quantity of a co-product that is exported to OPS must be measured at the gate of the HPS. However, the quantity must always be defined by the quantity that is useful to other product systems. Hence, quantities that are wasted or unused by the OPS must be subtracted from the total quantity of co-product exported to OPS. For example, nitrogen cannot be considered as a co-product if vented to atmosphere.

The losses associated with hydrogen and oxygen used internally must be considered in the quantity of these co-products produced and used. This means that if the quantity of these co-products used is measured at the gate of the equipment consuming the co-product, this quantity must be adjusted for the losses in a way that the sum of a co-product output must be adjusted so it is equal to the sum of the co-product inputs to all unit processes (refer to steps A and B in section 4.4 for more information on the modelling of these flows). A similar logic applies to CO_2 capture where the sum of captured CO_2 outputs must be adjusted, so it is equal to the sum of captured CO_2 input to the CCUS UP. Any adjustment of input flows must be documented in the "Side Calculations" worksheet of the CH-ITC Workbook.

Quantities of nitrogen, oxygen, and CO_2 must always be expressed in terms of pure (100%) substance on a mass basis. Applicants must apply the same procedure as for hydrogen (refer to Equation 1 and the procedure in section 3.2) to convert applicant's gas streams of co-product in a pure quantity of co-product.

Allocation between co-products must be performed on either a mass or energy basis. Section 4.4 details when this is applicable, and section 4.5 demonstrates how applicants can perform allocation in openLCA.

For off-gas (including tail gas, and other fuel gas) from the hydrogen production, this modelling guidance (for both the simplified and advanced modelling approach) assumes that emissions associated with the eventual combustion of these co-products must always be allocated to the HPS, even in the case where they are sold or exported to another product system. Hence, quantification of the flows related to these fuels is not required.

4.3.5 Fuel inputs

Fuel inputs are only applicable for the A- Hydrogen production, at HPS (AM); C- Carbon dioxide (CO2) capture, at HPS (AM); and D- Electricity and heat generation system (AM) unit processes. Applicants should model the actual fuel used by the equipment of each category of UP. For example, they cannot use an average fuel input like the E- Electricity, average supply mix, at HPS (AM).

Fuel inputs must be modelled in accordance with section 3.6.2.1 and any differences listed below supersede the instructions in section 3.6.2.1.

Applicable differences between 3.6.2.1 and 4.3.5:

- purchased or imported steam from another product system
  - applicants must refer to step F (section 4.4.6) for the treatment of thermal energy flows
- applicants must declare the quantity of hydrogen **produced and consumed** at the production facility in the production process, even though there are no GHGs associated with the combustion emissions
  - this quantity will be used later in the modelling of the D- Electricity and heat generation system (AM) UP

4.3.6 Electricity inputs

Electricity inputs are applicable for A- Hydrogen production, at HPS (AM); B- Oxygen and nitrogen generation system (AM); C- Carbon dioxide (CO2) capture, at HPS (AM); D- Electricity and heat generation system (AM); and E- Electricity, average supply mix, at HPS (AM) unit processes.

Applicants are instructed to use the E- Electricity, average supply mix, at HPS (AM) UP that contains the total quantity of the different electricity inputs supplied to or produced by the HPS. Applicants should refer to Subsection 127.48 (6)(f) of the *ITA* regarding the rules for determining the quantities of electricity from various sources. The E- Electricity, average supply mix, at HPS (AM) UP also has a reference flow corresponding to the total quantity of electricity consumed at the HPS and will be used as an input for other unit processes that have electricity as an input to enter the total amount used by each UP. Detailed modelling instructions for this UP are available in section 4.4.5 and in the CH-ITC Workbook. This will ensure that any electricity consumption adjustment for compression or liquefaction will be applied to all electricity inputs proportionally.

In the case of a discrepancy between the total amount of electricity output from the E- Electricity, average supply mix, at HPS (AM) UP and the sum of electricity inputs to the A to D unit processes due to losses or measurement uncertainty, the input of the A to D unit processes must be adjusted to eliminate the discrepancy. Therefore, the adjustment of each UP should result in a value that is proportional to the UP's contribution to the sum of the electricity inputs. This calculation must be documented in the "Side Calculations" worksheet of the CH-ITC Workbook.

Electricity inputs must be modelled in accordance with section 3.6.2.2 and any differences listed below supersede the instructions in section 3.6.2.2.

Applicable differences between 3.6.2.2 and 4.3.6:

- electricity produced on-site (within the HPS) from the combustion of fuel inputs (refer to section 3.6.2.1) or from hydrogen that is directly produced by the HPS is included and modelled in accordance with section 4.4.4
- if electricity is exported from the HPS, then applicants must quantify the total amount of electricity
    - this is referred to as Electricity, from electricity and heat generation system, exported to OPS, and this flow of electricity will be considered as a co-product so energy allocation will be applied as described in section 4.4.4

In addition, if the adjustment for purity and pressure procedure is applied, then please refer to case 2 (section 3.6.3.2) for additional instructions.

4.3.7 Material inputs

Material inputs are only applicable for the A- Hydrogen production, at HPS (AM) and D- Electricity and heat generation system, at HPS (AM) unit processes and must be modelled in accordance with section 3.6.2.3.

4.3.8 Direct emissions

Direct emissions are only applicable for the A- Hydrogen production, at HPS (AM) UP and must be modelled in accordance with section 3.6.2.4.

4.3.9 Thermal energy flows

If a net amount of thermal energy is imported into the product system from another product system or exported out of the HPS, the amount of steam imported or exported must be determined using the enthalpy method. This amount includes the thermal energy recovered from equipment from inside the HPS and the amount of thermal energy that is produced from the combustion of fuels such as hydrogen and fuel inputs in section 4.3.5. Like section 3, only heat contained in steam flows will be considered for the calculations. Applicants can refer to Equation 3 to determine the thermal energy in a flow. This equation can also be applied to all steam flows entering and leaving the HPS to determine the total amount of heat entering and leaving the HPS.

If thermal energy is generated through the combustion of fuels, this amount must also be determined using the enthalpy method, following the same method presented in Equation 3 for flows entering and leaving the heat generation unit. This corresponds to thermal energy generated from burning fuels such as additional natural gas with a portion of the hydrogen produced within the HPS, or from other purchased fuel inputs entering the product system. This amount corresponds to the net thermal energy generated from combustion of fuels within the production unit of heat and electricity. However, please note that input flows entering this system may not be steam, but water in a liquid state. For the purposes of evaluating the thermal energy generated from the combustion of fuels only, these can be considered. Applicants can refer to section 7 (Annex B) for the combustion of fuels and corresponding thermal energy flows.

Applicants must refer to section 4.4.6 and section 7 (Annex B) for a detailed description on the modelling of thermal energy flows under the advanced modelling approach.

4.3.10 Carbon Dioxide (CO_2) captured

The Carbon dioxide (CO2) capture, at OPS (AM) flow represents CO_2 captured that can come from another product system. The Carbon dioxide (CO2) capture, at HPS (AM) flow represents CO_2 captured that comes from applicable unit processes inside of the HPS. Please refer to step C for modelling instructions.

4.3.11 Special cases

Section 3.6.3 contains 3 special cases for the treatment of certain material, energy, and fuel inputs. These may or may not apply to the advanced modelling approach, as detailed below:

- case 1 (section 3.6.3.1) does not apply under the advanced modelling approach
    - steam produced from the D- Electricity and heat generation system (AM) UP under the advanced modelling approach is dealt with through the heat adjustment procedure (step F in section 4.4.6)
- case 2 (section 3.6.3.2) applies to the advanced modelling approach
    - applicants must refer to sections 4.3.6 and 4.4.1 for additional instructions
- case 3 (section 3.6.3.3) applies to the advanced modelling approach
    - applicants must refer to that section for instructions

4.4 Modelling steps

The modelling steps presented below will instruct applicants to define several unit processes that are part of the advanced modelling approach by quantifying input and output flows for these unit processes. This includes instructions on which flows must, can and cannot be included under a specific UP.

The advanced modelling approach is required in a limited number of cases. Applicants are encouraged to consult section 2.4.2 if they are unsure which modelling approach is most suitable for their HPS.

Even though the advanced modelling approach is different from the simplified modelling approach, applicants may have to apply information presented in section 3 of the modelling guidance to model specific flows under each step. For example, in most cases, fuel inputs will be modelled in accordance with the procedure listed in section 3.6.2.1.

This section will present the steps that need to be done to model all situations (under the CH-ITC) using the advanced modelling approach. The steps are as follows:

- step A: model the A- Hydrogen production, at HPS (AM) UP

- step B: model the B- Oxygen and nitrogen generation system (AM) UP
- step C: model the C- Carbon dioxide (CO2) capture, at HPS (AM)UP
- step D: model the D- Electricity and heat generation system (AM) UP
- step E: model the E- Electricity, average supply mix, at HPS (AM) UP
- step F: apply the heat adjustment procedure, calculate the hydrogen efficiency factor and model with the F- Hydrogen with heat adjustment (AM) UP
- step G: ensure that all the reference flows of the unit processes in the HPS are connected

4.4.1 Step A: A- Hydrogen production, at HPS (AM) UP

4.4.1.1 Summary

The A- Hydrogen production, at HPS (AM) UP regroups all equipment that are essential to produce hydrogen such as a reformer, an electrolyser, etc.

Additionally, one or more of the unit processes described in steps B to D, covering supporting equipment to hydrogen production, can be merged with the A- Hydrogen production, at HPS (AM) UP.

When another UP is merged with the A- Hydrogen production, at HPS (AM) UP, all the input and output flows related to that other UP must be aggregated and added to the flows of the A- Hydrogen production, at HPS (AM) UP. Flows that are not leaving/crossing the boundary of the UP will not be considered.

Unit processes and equipment that fall under this UP might not require the advanced modelling approach. Applicants are encouraged to consult section 2.4 if they are unsure which modelling approach is most suitable for their HPS.

In Figure 8, there are 2 unit processes: B- Oxygen and nitrogen generation system (AM) UP and A- Hydrogen production, at HPS (AM) UP on the left-hand side and 1 UP (merged A- Hydrogen production, at HPS (AM)) on the righthand side. This means that the 2-unit processes were merged and the input flows for electricity are aggregated as a result (5+2kWh=7kWh) because they cross the UP boundary and represent the same flow of electricity for the A- Hydrogen production, at HPS (AM) UP. The flow of oxygen between the unit processes is disregarded because it does not leave the UP boundary (dotted line). Furthermore, the flows for CO_2, hydrogen and natural gas remain the same because they were already attributed to the hydrogen production UP. Also, in cases where this B- Oxygen and nitrogen generation system (AM) UP was also producing a flow of nitrogen used by another product system, this flow will have to be neglected (and included in the HPS) after the merging of the unit processes. This would lead to a more conservative CI for hydrogen produced, since impact of the B- Oxygen and nitrogen generation system (AM) UP will no longer be allocated between oxygen and nitrogen co-products.

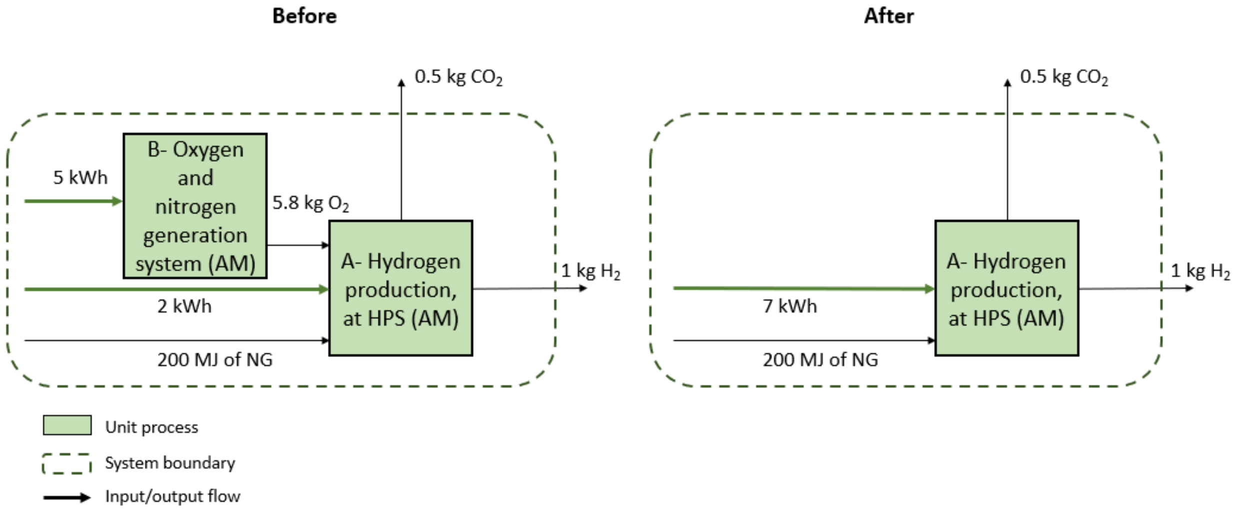

Figure 8: Example of merging unit processes and flows together.

The A- Hydrogen production, at HPS (AM) UP should include all flows associated with equipment as specified in section 4.1.1, but exclude any flows that are included in another UP (modelled in steps B to D) or product system. The A- Hydrogen production, at HPS (AM) UP (Figure 9) will also include all input/output flows that may be required to produce hydrogen.

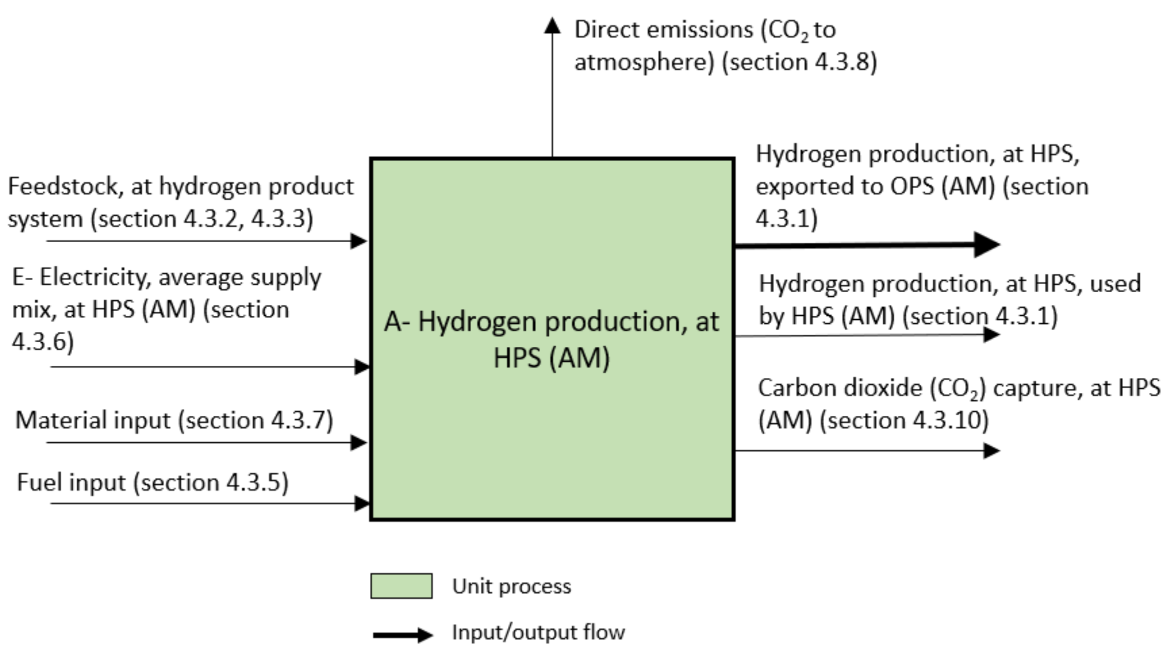

Figure 9: Diagram showing the input/output flows of a A- Hydrogen production, at HPS (AM) UP.

4.4.1.2 Input flows

In the case of advanced modelling, the A- Hydrogen production, at HPS (AM) UP **must** include at least one of the following input flows:

- eligible feedstock types that are used for hydrogen production and the feedstocks must be modelled in accordance with section 4.3.2
- fuel inputs used by the equipment in this UP and the fuel inputs must be modelled in accordance with section 4.3.5
- material inputs must be modelled in accordance with section 4.3.7. There are 2 options:
  - flow of oxygen from the B- Oxygen and nitrogen generation system (AM) UP. If this applies to your hydrogen project, then please refer to section 4.4.2 step B for more information
  - flow of purchased oxygen from another product system
- electricity inputs used by the equipment in this UP must be modelled in accordance with section 4.3.6
  - if liquefaction or compression adjustment is used, then applicants must refer to 3.6.3.2 for modelling instructions

The A- Hydrogen production, at HPS (AM) UP **cannot** include the following input flows:

- flows of steam inputs from another UP or product system, as they will be considered in the heat adjustment procedure (refer to step F)

4.4.1.3 Output flows

The A- Hydrogen production, at HPS (AM) UP **must** include these output flows:

- flow of Hydrogen production, at HPS, exported to OPS (AM), modelled in accordance with section 4.3.1, and/or
- flow of Hydrogen production, at HPS, used by HPS (AM) that goes into the D- Electricity and heat generation system (AM) UP, modelled in accordance with section 4.3.1

The A- Hydrogen production, at HPS (AM) UP **can** also include the following output flows:

- elementary flow of CO_2, modelled in accordance with section 4.3.8
- flow of C- Carbon dioxide (CO2) capture, at HPS (AM) to the C- Carbon dioxide (CO2) capture, at HPS (AM) UP. This is modelled as a waste flow in accordance with section 4.3.10

The A- Hydrogen production, at HPS (AM) UP **cannot include** the following output flows:

- excess electricity or heat sold or exported to another product system
- excess material sold or exported to another product system

4.4.1.4 Allocation

Mass allocation is used for the flows of hydrogen exported and used internally. Applicants can refer to section 4.5 for more information on how to perform mass allocation.

4.4.1.5 Step 1: entering data into the CH-ITC Workbook

Once applicants have quantified their flows, they can begin to enter information into the CH-ITC Workbook for each UP under the advanced modelling approach. Each worksheet contains detailed instructions for the applicant to follow. Applicants can also refer to subsections (step 1: entering data into the CH-ITC Workbook) in section 3 for additional information.

To cover all the flows linked to the A- Hydrogen production, at HPS (AM) UP, applicants must complete the following worksheets, as applicable:

- Elec input for HP (E0.1,0.4) – this includes information regarding the quantities of electricity that are used as inputs to the A- Hydrogen production, at HPS (AM) UP
- Feedstock input (FD1) – this includes information regarding the feedstock(s) that is used to produce hydrogen
- Fuel input for HP (FL1)- this includes information regarding the fuel(s) that is used for the A- Hydrogen production, at HPS (AM) UP
- Purchased oxygen (O1,O4)- if applicable, this includes information regarding the oxygen that is used for the A- Hydrogen production, at HPS (AM) UP
- Hydrogen from HPS (H1,H2) - this includes information regarding the hydrogen that is produced from the A- Hydrogen production, at HPS (AM) UP
- Direct emissions (DE) - this includes information regarding the direct emissions that occur from the production of hydrogen via A- Hydrogen production, at HPS (AM) UP
- CCUS at HPS (C1,C2,Cimp) – this includes information regarding the quantity of carbon that is captured and stored from the HPS

4.4.1.6 Step 2: modelling in the Fuel LCA Model

By following instructions provided in the section “Information to copy in openLCA” of each applicable worksheets listed above, applicants can begin to model the A- Hydrogen production, at HPS (AM) UP. The applicant can use the steps below to verify that the modelling has been correctly performed.

1. Open the A- Hydrogen production, at HPS (AM) UP and under inputs, verify that the following flows are added (if applicable) with the correct amount, unit, and provider.
    a) E- Electricity, average supply mix, at HPS (AM)
    b) Feedstock (all flows)
    c) Fuel inputs (all flows)
    d) Material inputs (oxygen)
2. Under the outputs, verify that the following flows are added (if applicable) with the correct quantity and unit.
    a) Elementary flow of CO2, fossil
    b) Hydrogen production, at HPS, exported to OPS (AM) – reference flow
    c) Hydrogen production, at HPS, used by HPS (AM)
    d) Carbon dioxide (CO2) capture, at HPS (AM) – waste flow
3. Under the “Allocation” tab verify that allocation factors have been calculated and the physical allocation method has been selected (section 4.5).
4. Save and close the UP.

4.4.2 Step B: B- Oxygen and nitrogen generation system (AM) UP

4.4.2.1 Summary

Section 2.4.2 describes when this UP can be merged with the A- Hydrogen production, at HPS (AM) UP as a conservative assumption. If this UP is merged with the A- Hydrogen production, at HPS (AM) UP, the modelling steps here can be skipped, and any flows associated with this equipment are considered under the A- Hydrogen production, at HPS (AM) UP.

This UP should include electricity and fuels flows associated with equipment required for the operation of a B- Oxygen and nitrogen generation system (AM) UP (refer to Figure 10).

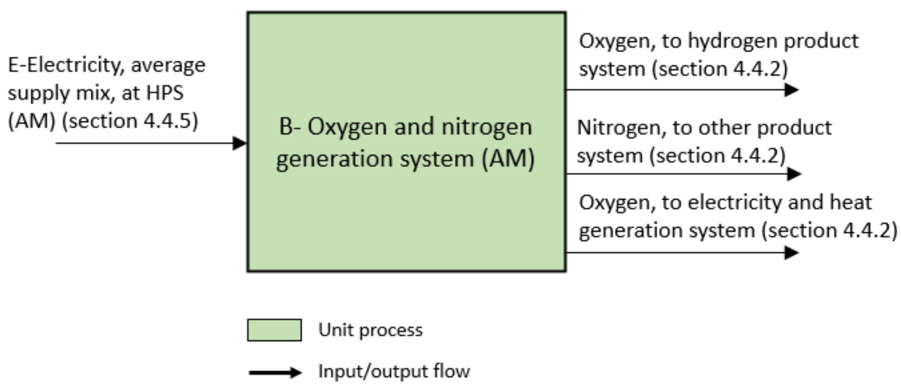

Figure 10: Diagram showing the input/output flows of a B- Oxygen and nitrogen generation system (AM) UP.

4.4.2.2 Input flows

The B- Oxygen and nitrogen generation system (AM) UP **must** include this input flow:

- flow of electricity used by the equipment covered under this UP, modelled in accordance with section 4.3.6

4.4.2.3 Output flows

The B- Oxygen and nitrogen generation system (AM) UP **must** include the following output flows:

- flow of total oxygen production used for hydrogen production

The B- Oxygen and nitrogen generation system (AM) UP **can** also include the following output flows:

- flow of nitrogen production exported to other product systems
- flow of oxygen used by the D- Electricity and heat generation system UP

These flows can also be neglected and included in the HPS as a conservative assumption. For example, if an air separation unit has 95% oxygen that is used by the HPS and 5% useful nitrogen that is used for an ammonia product system, then it might not be worth the time and effort to allocate the impacts of the 5% useful nitrogen to the ammonia product system. Therefore, the applicant can assume both the 95% oxygen and 5% nitrogen are allocated to the A- Hydrogen production, at HPS (AM) UP. This will result in a slightly higher CI because now the nitrogen is included in the hydrogen CI calculation, whereas if it were separated then the impacts would've been partitioned to the OPS.

The B- Oxygen and nitrogen generation system (AM) UP **cannot include** the following output flows:

- flow of oxygen production exported to other product systems
- excess electricity sold or exported to another product system
- flows of steam outputs to another UP or product system (they will be considered in the heat adjustment procedure – refer to step F in section 4.4.5)

4.4.2.4 Allocation

Mass allocation is used for the nitrogen and oxygen co-products. Applicants can refer to section 4.5 for more information on how to perform mass allocation.

4.4.2.5 Step 1: entering data into the CH-ITC Workbook

Applicants must complete the following worksheets specifically for the oxygen and nitrogen generation system UP:

- Elec input for ONGS (E0.2) - this includes information regarding the quantity of electricity that is used for the B- Oxygen and nitrogen generation system (AM) UP
- Nitrogen from ONGS (N1) - this includes information regarding the quantity of nitrogen that is produced from the B- Oxygen and nitrogen generation system (AM) UP
- Oxygen from ONGS (O2,O3) - this includes information regarding the quantities of oxygen that is produced from the B- Oxygen and nitrogen generation system (AM) UP

4.4.2.6 Step 2: modelling in the Fuel LCA Model

By following instructions provided in the section "Information to copy in openLCA" of each applicable worksheets listed above, applicants can begin to model the B- Oxygen and nitrogen generation system (AM) UP. The applicant can use the steps below to verify that the modelling has been correctly performed.

1. Open the B- Oxygen and nitrogen generation system (AM) UP and under inputs verify that the following flows are added (if applicable) with the correct amount, unit, and provider.
    a) E- Electricity, average supply mix, at HPS (AM)
2. Under the outputs, verify that the following flows are added (if applicable) with the correct quantity and unit.
    a) Oxygen, from onsite generation, used by HPS
    b) Nitrogen, from onsite generation, exported to OPS
    c) Oxygen, from onsite generation, used by EHGS
3. Under the "Allocation" tab verify that allocation factors have been calculated and the physical allocation method has been selected (section 4.5).
4. Save and close the UP.

4.4.3 Step C: C- Carbon dioxide (CO_2) capture, at HPS (AM) UP

4.4.3.1 Summary

This UP should include electricity and fuels flows associated with equipment required for the operation of a C- Carbon dioxide (CO_2) capture, at HPS (AM) UP.

Section 2.4.2 describes when the separate modelling of this UP is not required. Even if the separate modelling of C- Carbon dioxide (CO2) capture, at HPS (AM) is not required, a C- Carbon dioxide (CO2) capture, at HPS (AM) UP must be modelled in accordance with section 3.7 but will **not include the fuel and energy requirement for this specific process**. These flows can also be merged as a conservative assumption, where all fuel and energy requirements for the capture unit will be merged with the A- Hydrogen production, at HPS (AM) UP.

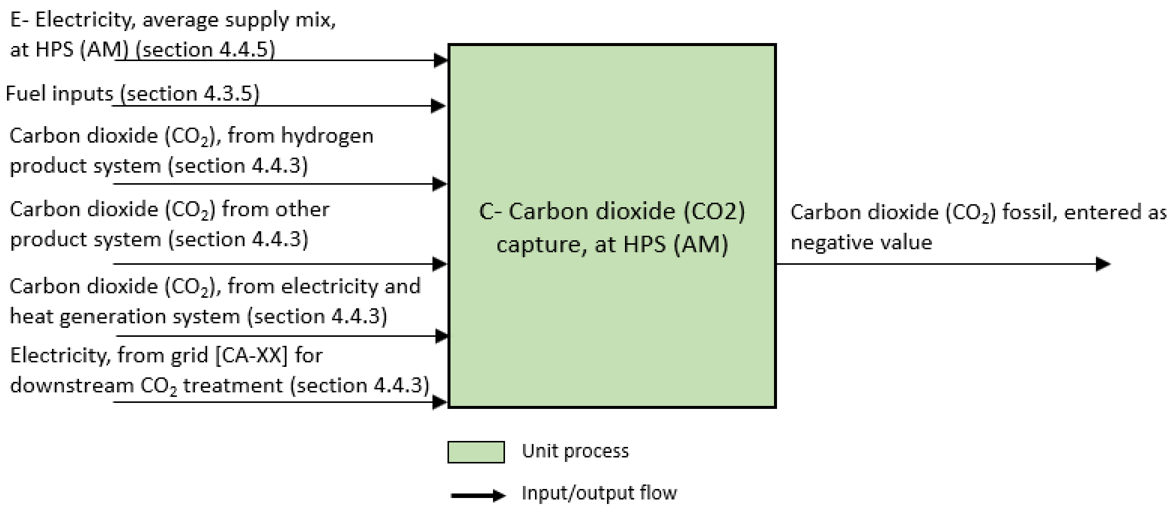

Figure 11: Diagram showing the input/output flows of a C- Carbon dioxide (CO2) capture, at HPS (AM) UP.

4.4.3.2 Input flows

The C- Carbon dioxide (CO2) capture, at HPS (AM) UP **must** include the following input flows:

- flow of the total CO_2 captured from the hydrogen production (modelled as waste flows in openLCA)
- flow of electricity for downstream injection of CO_2 (this corresponds to a default value)

The C- Carbon dioxide (CO2) capture, at HPS (AM) UP **can** also include the following input flows if the capture unit for the HPS is also used by another product system:

- electricity inputs used by the equipment covered under this UP must be modelled in accordance with section 4.3.6
- fuel inputs that are modelled in accordance with section 4.3.5
- flow of the total CO_2 captured from all other product systems
- flow of the total CO_2 captured from electricity and heat generation system

4.4.3.3 Output flows

The C- Carbon dioxide (CO2) capture, at HPS (AM) UP should include the following output flow:

- a negative quantity of CO_2 fossil emissions that corresponds to the total quantity of CO_2 captured from all product systems (hydrogen and others)

The C- Carbon dioxide (CO2) capture, at HPS (AM) UP **cannot include** the following output flows:

- excess electricity sold or exported to other product systems or unit processes
- flows of steam output from another UP or product system (they will be considered in the heat adjustment procedure – refer to step F)

4.4.3.4 Allocation

Mass allocation must be performed between the flows of CO_2 captured. Applicants can refer to section 4.5 for more information on how to perform mass allocation.

4.4.3.5 Step 1: entering data into the CH-ITC Workbook

Applicants must fill out the following flows/worksheets.

- Elec input for CCUS (E0.3) - this includes information regarding the quantity of electricity that is used for the C- Carbon dioxide (CO2) capture, at HPS (AM) UP
- CCUS at HPS (C1,C2,Cimp)- this includes information regarding the quantity of carbon that is captured by the A- Hydrogen production, at HPS (AM) UP (C1), D- Electricity and heat generation system UP (C2), and quantity of carbon captured by the OPS (Cimp)
    - electricity input (for downstream injection) – this includes information regarding the provincial grid mix used where a default value for electricity consumption is applied
- Fuel input for CCUS (FL3) – this includes information regarding the quantity of fuel that is used for C- Carbon dioxide (CO2) capture, at HPS (AM)

4.4.3.6 Step 2: modelling in the Fuel LCA Model

By following instructions provided in the section "Information to copy in openLCA" of each applicable worksheets listed above, applicants can begin to model the C- Carbon dioxide (CO2) capture, at HPS (AM) UP. The applicant can use the steps below to verify that the modelling has been correctly performed.

1. Open the C- Carbon dioxide (CO2) capture, at HPS (AM) UP and under inputs verify that the following flows or waste flows are added (if applicable) with the correct amount, unit, and provider (if applicable).
    a) E- Electricity, average supply mix, at HPS (AM)
    b) Fuel inputs (all flows)
    c) Carbon dioxide (CO2) capture, at OPS (AM)
    d) Carbon dioxide (CO2) capture, at HPS (AM) – reference flow
    e) Carbon dioxide (CO2) capture, at EHSG (AM)
    f) Electricity, from grid [CA-XX]
2. Under the outputs, verify that the following flow is added (if applicable) with the correct quantity and unit.
    a) Flow of Carbon dioxide (CO2), fossil – this flow's amount should have a negative value.
3. Under the "Allocation" tab verify that allocation factors have been calculated and the physical allocation method has been selected (section 4.5).
4. Save and close the UP.

4.4.4 Step D: D- Electricity and heat generation system (AM) UP

4.4.4.1 Summary

Section 2.4.2 describes when this UP can be merged with the A- Hydrogen production, at HPS (AM) UP and is not necessary. This UP can also be merged as a conservative assumption. If this is the case, the modelling steps here can be skipped, and any flows associated with this equipment are considered under the A- Hydrogen production, at HPS (AM) UP.

This UP includes all heat (steam) and electricity flows going into and out of the equipment, such as a combined heat and power unit, a co-generator, an organic rankine cycle system, a boiler, etc. For example, hydrogen, purchased fuels, or heat flows may be sent to this UP to generate additional electricity that will be used in other unit processes and thus, reducing the amount of electricity required from other sources, such as PPAs or the grid. This UP must regroup all the electricity and heat generation systems that are part of the HPS and model them as single large equipment.

Both electricity and steam outputs of this UP must be net amounts. This means that any electricity or steam inputs must be deducted from the total electricity and steam outputs. Please refer to the section 7 (Annex B) for more details on how to model this UP.

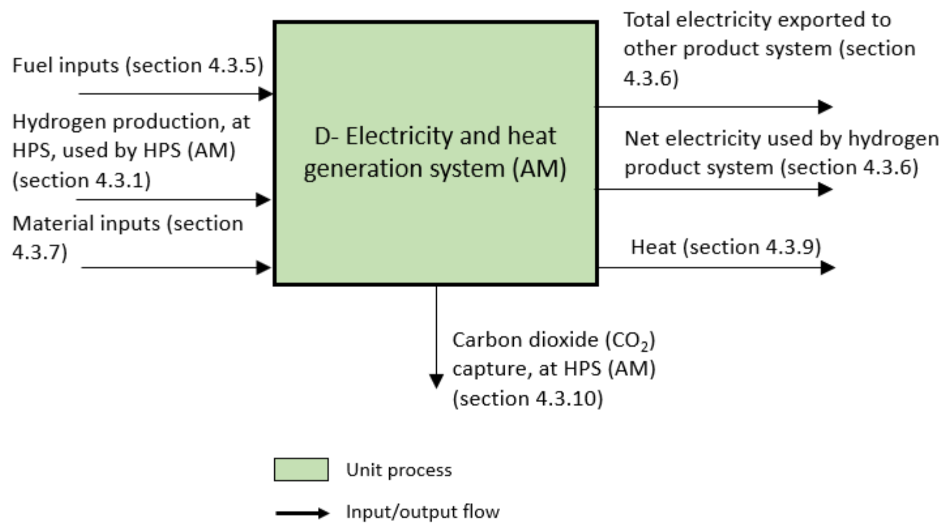

Figure 12: Diagram showing the input/output flows of a D- Electricity and heat generation system (AM) UP.

4.4.4.2 Input flows

The D- Electricity and heat generation system (AM) UP **can** include the following input flows:

- fuel inputs that are modelled in accordance with section 4.3.5
- the flow of hydrogen if it's used as a fuel from the A- Hydrogen production, at HPS (AM) UP
- flow of oxygen, modelled in accordance with section 4.4.2 for oxygen produced on site or section 3.6.2.3 for purchased oxygen/oxygen supplied by another product system
- flow of net electricity used by the D- Electricity and heat generation system (AM) UP which is equivalent to the total electricity used by the D- Electricity and heat generation system (AM) UP

minus the total electricity generated and used by the HPS, if the electricity and heat generation system has a net consumption of electricity

The D- Electricity and heat generation system (AM) UP **cannot include** the following input flow:

- flow of gaseous co-products such as tail gas and other fuel gases produced by the HPS because they are considered under the direct emissions category
- solid and liquid co-products and waste materials produced on-site if their combustion emissions are considered biogenic
- flows of steam/heat/purchased steam from other unit processes or product systems

4.4.4.3 Output flows

The D- Electricity and heat generation system (AM) UP **must** include, at least one of the following output flows:

- flow of net electricity generated and used by the HPS which is the total electricity generated and used by the HPS minus the total electricity used by the D- Electricity and heat generation system (AM) UP, if the electricity and heat generation system generates a net production of electricity
- flow of net steam produced at the D- Electricity and heat generation system (AM) UP (refer to section 7)

The D- Electricity and heat generation system (AM) UP **can** also include the following output flow:

- flow of total electricity generated and exported to all other product systems
- flow of carbon to the Carbon dioxide (CO2) capture, at HPS (AM) process (waste flow) if the Carbon dioxide (CO2) capture, at HPS (AM) is modelled in a separate UP (refer to step C in section 4.4.3)

4.4.4.4 Allocation

Energy allocation must be performed between the flows of electricity and heat. Please consult section 4.5 for instructions on how to perform allocation.

4.4.4.5 Step 1: entering data into the CH-ITC Workbook

Applicants must complete the following worksheets:

- Fuel input for EHGS (FL2) - this includes information regarding the fuel(s) that is used for the D- Electricity and heat generation system (AM) UP
- Elec from EHGS (E0.5,E1,Eexp) – this includes information regarding the quantity of electricity that is produced from the D- Electricity and heat generation system, at HPS (AM) UP and the quantity that is exported outside of the HPS
- Heat from EHGS (T1) – this includes information regarding the quantity of heat (MJ) that is produced from the D- Electricity and heat generation system, at HPS (AM) UP and exported outside of the HPS
- Oxygen from ONGS (O2,O3)- this includes information regarding the quantity of oxygen used for the D- Electricity and heat generation system, at HPS (AM) UP

4.4.4.6 Step 2: modelling in the Fuel LCA Model

By following the instructions provided in the section “Information to copy in openLCA” of each applicable worksheets listed above, applicants can begin to model the D- Electricity and heat generation system (AM) UP. The applicant can use the steps below to verify that the modelling has been correctly performed.

1. Open the D- Electricity and heat generation system (AM) UP and under inputs verify that the following flows are added (if applicable) with the correct amount, unit, and provider.
    a) Fuel inputs (all flows)
    b) Hydrogen production, at HPS, exported to OPS (AM)
    c) Material inputs (oxygen)
    d) E- Electricity, average supply mix, at HPS (AM)
2. Under the outputs, verify that the following flows are added (if applicable) with the correct quantity and unit.
    a) Electricity, from electricity and heat generation system, exported to OPS
    b) Electricity, from electricity and heat generation system, used by HPS – reference flow
    c) Net generated steam, from electricity and heat generation system
3. Under the “Allocation” tab, verify that allocation factors have been calculated and the energy allocation method has been selected (section 4.5).
4. Save and close the UP.

4.4.5 Step E: E- Electricity, average supply mix, at HPS (AM) UP

4.4.5.1 Summary

The E- Electricity, average supply mix, at HPS (AM) UP plays the same role as the Electricity, average supply mix, at HPS (SM) used in the simplified modelling approach but the AM version allows applicants to include the amount of electricity produced on site and modelled in the D- Electricity and heat generation system (AM) UP. The figure below displays this UP and its corresponding input/output flows.

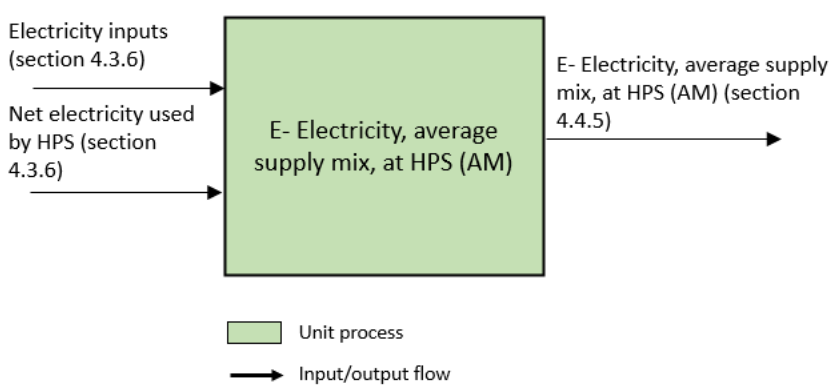

Figure 13: Diagram showing the input/output flows of a E- Electricity, average supply mix, at HPS (AM) UP.

This process cannot be merged with the A- Hydrogen production, at HPS (AM) UP and is mandatory when the advanced modelling approach is used.

The E- Electricity, average supply mix, at HPS (AM) UP has a reference flow corresponding to the total amount of electricity consumed at the HPS and will contain the total amount of the different electricity inputs supplied to or produced by the HPS. The reference flow will be used as an input for other unit processes of steps A to D that have electricity as an input to model the total amount of electricity used by each of these unit processes. Additional instructions are included in the CH-ITC Workbook.

The main role of this UP is to ensure that all unit processes are supplied with the same average electricity mix and any electricity consumption adjustment for compression and liquefaction will be applied to all electricity inputs proportionally.

4.4.5.2 Input flows

The E- Electricity, average supply mix, at HPS (AM) UP **can** include the following input flows:

- electricity inputs that are used to supply the HPS
    - the electricity inputs must be modelled in accordance with section 4.3.6
- electricity produced on-site (within the HPS) from the combustion of fuel inputs or from hydrogen that is directly produced by the HPS and modelled in accordance with section 4.4.4

4.4.5.3 Output flows

The E- Electricity, average supply mix, at HPS (AM) UP **must** include this output flow:

- flow of E- Electricity, average supply mix, at HPS (AM), modelled in accordance with section 4.3.6

4.4.5.4 Allocation

Allocation is not required for this UP.

4.4.5.5 Step 1: entering data into the CH-ITC Workbook

To cover all the flows linked to the E- Electricity, average supply mix, at HPS (AM) UP, applicants must complete the following worksheets, as applicable:

- Electricity input (Ea) - this includes information regarding the different quantities and types of electricity that are used as inputs to the HPS
- Elec avg. supply mix (E0) – this includes information regarding the total electricity consumption from various sources
- Elec from EHGS (E0.5,E1,Eexp) (if not already completed) - this includes information regarding the quantity of electricity that is produced from the D- Electricity and heat generation system, at HPS (AM) UP and the quantity that is exported outside of the HPS

Please note that for each electricity input used, applicants must fill an “Electricity input (Ea)” worksheet according to the instructions in the CH-ITC Workbook. If multiple sources of electricity are used, a separate “Electricity input (Ea)” worksheet must be filled for each source by making copies as needed.

4.4.5.6 Step 2: modelling in the Fuel LCA Model

By following the instructions provided in the section "Information to copy in openLCA" of each applicable worksheet listed above, the modelling of the E- Electricity, average supply mix, at HPS (AM) UP should be completed at this point. The applicant can use the steps below to verify that the modelling has been correctly performed.

1. Open the E- Electricity, average supply mix, at HPS (AM) UP and under inputs verify that the following flows are added (if applicable) with the correct amount, unit, and provider:
    a) Electricity inputs (all flows)
    b) Flow of Electricity, from electricity and heat generation system, used by HPS
2. Under the outputs, verify that the following flows are added (if applicable) with the correct quantity and unit:
    a) Flow of E- Electricity, average supply mix, at HPS (AM) – reference flow
    b) Note: the total amount of this output flow must always correspond to the sum of input flows.
3. Save and close the UP.

4.4.6 Step F: heat adjustment procedure and hydrogen efficiency factor

4.4.6.1 Summary

Heat adjustment procedure

The F- Hydrogen with heat adjustment (AM) UP ensures that the modelling considers thermal energy exchanges between the HPS and other product systems. Figure 14 displays the input/output flows of this UP.

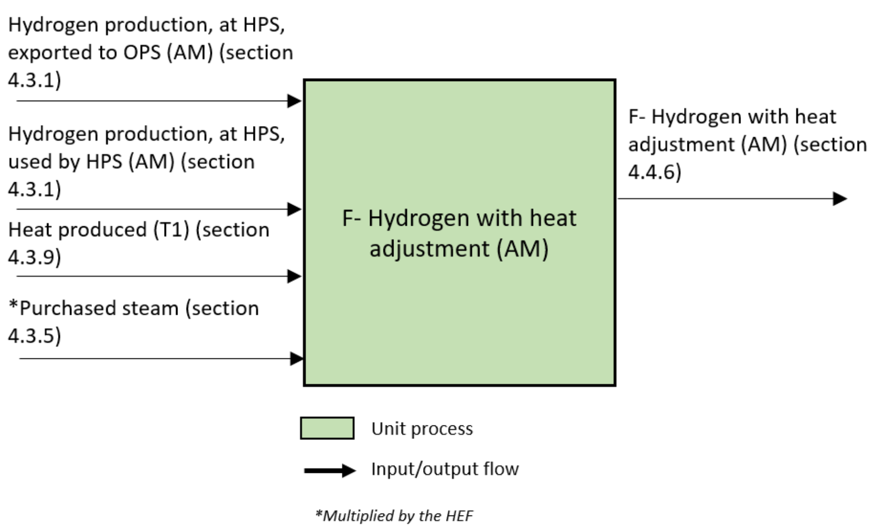

Figure 14: Diagram showing the input/output flows of a F- Hydrogen with heat adjustment (AM) UP.

This procedure is based on the one provided in section 3.6.3.1 but considers additional specificities of the advanced modelling, such as the option to apply energy allocation to the thermal energy generated from the combustion of hydrogen or fuels.

Due to the complexity of exchanges of thermal energy in most production plants, thermal energy flows cannot be modelled at the UP level of the advanced modelling approach. For this reason, the F- Hydrogen with heat adjustment (AM) UP provides the possibility to continue to apply the simplified modelling approach for steam flows alone, in parallel with the multiple unit processes of the advanced modelling.

In addition, for thermal energy exchanges with other product systems, the F- Hydrogen with heat adjustment (AM) UP considers the CI associated with heat generated by the D- Electricity and heat generation system (AM) process that is consumed by the HPS. Under the advanced modelling, allocation of impact between the electricity and heat produced by this D- Electricity and heat generation system (AM) process has been performed and since no heat flows have yet been connected back to any UP of the HPS, the impact of heat is not considered. The F- Hydrogen with heat adjustment (AM) UP is used to reconnect this heat flow to the HPS.

Hydrogen efficiency factor (HEF)
If hydrogen is used internally to produce energy used by the HPS, the applicant must calculate the quantity of hydrogen required to produce 1kg of net hydrogen produced with openLCA. This quantity is called the hydrogen efficiency factor and is required to ensure that the modelling of the HPS considers the correct amount of imported steam in the F- Hydrogen with heat adjustment (AM) UP. This manual adjustment applies to the purchased steam process only, as the thermal energy flow generated by the D- Electricity and heat generation system (AM) UP will be dynamically connected to the HPS and already scaled accordingly to the HEF.

If all hydrogen is used by another product system, the hydrogen efficiency factor is considered equal to 1.

Since the HEF is calculated using openLCA, the procedure to determine its value is provided in section 4.4.7.2.

4.4.6.2 Quantification of flows

Heat adjustment procedure
Under the advanced modelling approach, applicants are still required to quantify the flow of imported steam as described in section 3.6.3.1 for the expected and actual CI. If required, the amount of thermal energy exported to other product systems (T_{exp}) and generated from the combustion of fuels or hydrogen (T_1) must also be determined by using the enthalpy method and the procedure described in section 7 (Annex B).

Figure 15 illustrates the thermal energy flows that must be considered in this procedure in the context of the advanced modelling approach.

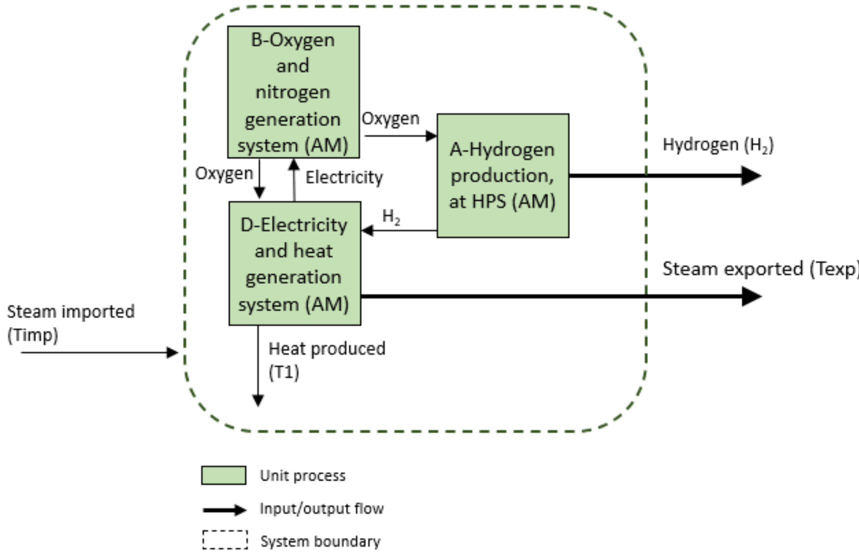

Figure 15: Examples of the heat flows interacting with the hydrogen product system.

These flows must be quantified before proceeding and applicants can refer to section 4.3.9 for instructions on how to quantify thermal energy flows. Please note that imported thermal energy can represent recovered thermal energy from outside of the HPS such as heat from a Haber Bosch loop.

Hydrogen efficiency factor

If no hydrogen flow is used by the D- Electricity and heat generation system (AM) UP or if the net thermal energy balance is a negative value, the hydrogen efficiency factor is equal to 1 or irrelevant and this procedure can be skipped.

Otherwise, to determine this value, applicants must calculate a CI with the F-Hydrogen with heat adjustment (AM) UP with a target amount of 1kg of hydrogen. For detailed instructions on this procedure, applicants can refer to section 5.2 to calculate a CI in openLCA.

Then the applicant must go to the “Inventory results” tab and determine the amount of hydrogen required to produce 1kg of net hydrogen output under “Total requirements”. The HEF is the sum of the 2 amounts below:

- Hydrogen production, at HPS, exported to OPS (AM)
- Hydrogen production, at HPS, used by the HPS (AM)

This value is needed to complete the modelling of the “Heat adjustment(Texp,Timp)” worksheet.

It is important to note that the result of this procedure will change if changes are made to any UP of the HPS. It is important to apply this procedure and update the hydrogen efficiency factor in the F-Hydrogen with heat adjustment (AM) UP after any modification or any correction to ensure the correct final CI is calculated.

4.4.6.3 Procedure

The procedure for calculating the quantity of imported steam from another product system includes 2 main steps as described below. This procedure is included in the calculation of the "Heat adjustment(Texp,Timp)" worksheet of the CH-ITC Workbook.

Step 1:
Applicants must use Equation 4 to determine if the net thermal energy balance (NTEB) of thermal energy exchanges between the HPS and OPS is positive, negative, or null.

Equation 4: determination of net thermal energy balance

$$NTEB\ (MJ) = T_{imp}\ (MJ) - T_{exp}\ (MJ)$$

The net amount of heat in the form of steam generated from the EHGS is represented by the T1 flow "Net generated steam, from electricity and heat generation system" and is connected as an input to the F- Hydrogen with heat adjustment (AM) UP with a quantity corresponding to the output value for this flow in the D- Electricity and heat generation system (AM) UP.

If the net thermal energy balance is null, this means that all the thermal energy generated by the electricity and heat generation system (D- Electricity and heat generation system (AM) UP) is consumed by the HPS. No further action is required.

If the net thermal energy balance is a positive value, this means that in addition to all the heat generated by the electricity and heat generation system that is consumed by the HPS, a net flow of thermal energy is imported to the HPS. The NTEB must be multiplied by the hydrogen efficiency factor that will be calculated using openLCA (refer to section 4.4.6.3.2) and the result must be entered as a positive quantity of purchased steam in the F- Hydrogen with heat adjustment (AM) UP.

If the net thermal energy balance is a negative value, then this means that a net flow of thermal energy is exported from the HPS. The applicant must proceed to step 2 to determine if this flow of net thermal energy is produced by the hydrogen production or by intentional combustion of fuel.

Step 2:
If the net thermal energy balance is a negative value, Equation 5 must be used to determine the amount of thermal energy generated from the combustion of fuels or hydrogen (T1) that is used by the HPS.

Equation 5: determination of quantity of T1 used internally (T1_UI)

$$T1\_UI\ (MJ) = T1\ (MJ) - |NTEB|\ (MJ)\ \text{(entered as a positive value)}$$

If T1_UI is null or a positive value, this means that only a portion of the thermal energy from the combustion of fuels or hydrogen (T1) is exported to other product systems. Hence, "Net generated steam, from electricity and heat generation system" flow T1 must be connected as an input to the F- Hydrogen with heat adjustment (AM) with a quantity corresponding to T1_UI.

If T1_UI is a negative value, this means that all the thermal energy from the combustion of fuels or hydrogen (T1) is exported to other product systems. Hence, “Net generated steam, from electricity and heat generation system” flow T1 must be connected as an input to the F- Hydrogen with heat adjustment (AM) with a value of 0.

4.4.6.3.1 Step 1: entering data into the CH-ITC Workbook

Applicants must complete the “Heat from EHGS (T1)” and “Heat adjustment (Texp,Timp)” worksheets. These worksheets include information such as the quantities of heat produced/exported from the HPS and the quantity of steam that is imported (purchased steam) to the HPS.

Once the applicant has entered all required information, then they will obtain the cumulative quantities of imported steam (multiplied by the HEF) and heat produced for the first 20 years of operation from the hydrogen project plan (expected CI) or for 1 year of operation (actual CI) that can be used in step 2: modelling in the Fuel LCA Model.

4.4.6.3.2 Step 2: modelling in the Fuel LCA model

By following the instructions provided in the section “Information to copy in openLCA” of each applicable worksheet listed above, the modelling of the F- Hydrogen with heat adjustment (AM) UP should be completed at this point. The applicant can use the steps below to verify that the modelling has been correctly performed.

1. Open the F- Hydrogen with heat adjustment (AM) UP and under inputs verify that the following flows are added (if applicable) with the correct amount, unit, and provider.
    a) Net generated steam, from electricity and heat generation system
    b) Hydrogen production, at HPS, used by HPS (AM)
    c) Hydrogen production, at HPS, exported to OPS (AM)
    d) Purchased steam (multiplied by the HEF)
2. Under the outputs, verify that the following flow is added (if applicable) with the correct amount, unit, and provider.
    a) F- Hydrogen with heat adjustment (AM) - reference flow
3. Save and close the UP.

4.4.7 Step G: verify connection of unit processes

4.4.7.1 Summary

All the reference flows of the product system should be connected once steps A to F are completed. Applicants must ensure that the F- Hydrogen with heat adjustment (AM) flow is added to the UP with Hydrogen CI, advanced modelling (AM) as an input.

4.4.7.2 Procedure

It is recommended that the applicant reviews the model graph[3] and individual unit processes, including the “Allocation” tab, in openLCA to validate the connection. The applicant can use the “Step 2: modelling in the Fuel LCA Model” section of each UP as a checklist to confirm that the modelling has been performed correctly.

If the HEF is used in the modelling (refer to section 4.4.6), this value must be recalculated and modified in the CH-ITC Workbook and the Model after any change or correction to the model.

Once the model has been validated, applicants should refer to section 5 to calculate their final CI value.

4.5 Performing allocation in openLCA

All allocation procedures for the advanced modelling approach can be performed in openLCA with the physical allocation method (for mass or energy). The steps for this method are shown below.

Physical allocation method:

1. After entering in all flow information in the process in openLCA, go to the “Allocation” tab of the process.
2. Select the default method “physical allocation”.
3. Note: If you do not select a default method for allocation, then the allocation coefficients will not be included in the CI calculations, even if you fill in the “Allocation” tab. All your products must have the same flow property/unit type for physical allocation to work. Physical allocation will automatically use the flow property that the products are in such as mass, energy, etc.
4. Click the “Calculate factors” button and then click “OK” to calculate the allocation factors.
5. Save the UP.

[3] Applicants can refer to chapter 5.3.1 of the Fuel LCA Model User Manual for instructions on how to use the model graph.

5 Determining a CI value and submitting a report

This section explains the process for generating a CI value and submitting it with the validation information package, clean hydrogen project plan, or compliance report following the completion of the steps described in section 3 and 4. An applicant can calculate the expected or actual CI value of their hydrogen.

5.1 Selecting the appropriate process for CI value calculation in the Fuel LCA Model

The unit processes in the folder Processes/Fuel pathways/Hydrogen pathway/Mass basis/**Hydrogen CI** must be used to calculate the final CI value of the hydrogen produced by the clean hydrogen project assessed. The folder contains 2 different unit processes, 1 for each modelling approach that can be used for your HPS. For both modelling approaches, applicants must verify that the correct flow and provider is selected in the hydrogen CI UP. Applicants should also review their entire CI modelling before running a simulation, including ensuring that input and output flows are entered with the correct quantity and the selected “Provider” match the one described in the CI Modelling guidance and the CH-ITC Workbook.

Simplified modelling approach:

1. Open the Processes/Fuel pathways/Hydrogen pathway/Mass basis/Hydrogen CI/**Hydrogen CI, simplified modelling (SM)** process.
2. Applicants must add Hydrogen production, at HPS (SM) flow with the corresponding provider as an input with the amount of 1 kg.
3. Ensure that the Hydrogen CI, simplified modelling (SM) reference flow is entered as an output with the amount of 1kg.
4. Ensure that all processes linked are correctly entered into the inputs and outputs section of the process based on step 2 instructions provided in section 3.
5. Save and close the process.

Advanced modelling approach:

1. Open Fuel pathways/Hydrogen pathway/ Mass basis/Hydrogen CI/**Hydrogen CI, advanced modelling (AM)** process.
2. Applicants must add F- Hydrogen with heat adjustment (AM) flow with the corresponding provider as input with the quantity of 1 kg.
3. Ensure that the Hydrogen CI, advanced modelling (SM) reference flow is entered as an output with the amount of 1kg.
4. Ensure that all processes linked are correctly entered into the inputs and outputs section of the process based on step 2 instructions provided in section 4.
5. Save and close the process.

5.2 CI value calculation in the Fuel LCA Model

To generate a cradle-to gate CI value for hydrogen, an applicant must create a product system for the Hydrogen CI, simplified modelling (SM) or Hydrogen CI, advanced modelling (AM) UP.

1. In openLCA, open the UP mentioned above and press “Create product system” in the “General information” tab.

2. The options should be kept at their default settings in the "New product system window", as described below:
    a) Auto-link processes: yes
    b) Check multi-provider links (experimental): no
    c) Provider linking: Prefer default providers
    d) Preferred process type: System process
    e) Cut-off: no
3. Click on "Finish".
    a) For more information on how to create a product system, refer to chapter 5.2.9 of the Fuel LCA Model User Manual.

A new product system will now have been created in the folder "*Product systems*".

1. Open the product system (if not already open) and verify that the target amount and unit in the "Reference" section of the "General information" tab are set to "1.0" and "kg".
2. Click on "Calculate".
3. In the "Calculation properties", select the following options:
    a) Allocation method: "As defined in processes"
    b) Impact assessment method: "FuelLCAModelLCIA_AR**6**"
    c) Normalization and weighting set: blank
    d) Calculation type: "Lazy/On-demand" or "Eager/All"
    e) Regionalized calculation: no
    f) Include cost calculation: no
    g) Assess data quality: no
4. Click on "Finish".
    a) For more information on how to calculate a CI value, refer to chapter 5.2.10 of the Fuel LCA Model User Manual.

Once the product system has been created and the CI value has been calculated, the applicant can use several analytical features in the openLCA software to review, analyse, and understand the results. To navigate through the "Result" window and for troubleshooting, refer to chapter 5.3 of the Fuel LCA Model User Manual.

The CI value calculated for 1 kg of hydrogen that must be included in the application or report is the "impact assessment result" for the "Carbon intensity" impact category found in the "Impact analysis" tab of the "Result" window.

5.3 Exporting the hydrogen pathway

An applicant must export the hydrogen pathway for inclusion in the validation information package, clean hydrogen project plan, or compliance report by following the following instructions:

1. In the menu of openLCA, select "File" and then "Export".
2. In the "Select" window, select the "JSON-LD" format (in the "openLCA" category) and click on "Next".
3. In the "Select data sets" window:
    a) Click on "Browse", then select a location and enter a file name for the exported file. Click on "Save".

b) In the section below the file name, select the fuel pathway folder that contains the modelling of the hydrogen pathway in Fuel pathways/Hydrogen pathway/**Mass basis**. All relevant unit processes that have been created or modified during the modelling procedure must be included in this folder (and its sub-folders). Do not select any other folder, including the Data Library.

4. Click on "Finish".
   a) For more information on how to export a fuel pathway, refer to chapter 5.2.1 of the Fuel LCA Model User Manual.

5.4 Submitting an application or report

Applicants should refer to the Clean Hydrogen Investment Tax Credit Validation and Verification Guidance for information on how to submit the CI modelling documents as part of the validation information package (validation) and compliance reports (compliance/verification).

6 Annex A: Use of a CFR carbon intensity

This section describes how to integrate a *CFR* CI value in the hydrogen pathway.

In the CH-ITC Workbook, the applicant must indicate that a *CFR* CI value is being used and select the option that defines how the CI has been determined under the *CFR*:

- transferred CI approved under the *CFR* with an alphanumeric identifier
- CI specified in the most recent CI pathway report referred to in the *CFR,* with the alphanumeric identifier of the CI for which the report relates
- CI determined in accordance with the *CFR* Supplemental Specifications for RNG, biogas or renewable propane, with the alphanumeric identifier assigned to the approved CI of the hydrogen or of the low-CI fuel determined in a new pathway approved under the *CFR*, with the alphanumerical identifier assigned to the approved new pathway and the alphanumerical identifier assigned to the approved CI of the hydrogen or of the low-CI fuel, if any
- CI that is based on a reasonable estimate which is determined based on *CFR* methodology by the applicant (for expected CI only)

The applicant must also select the scope of the *CFR* CI:

- cradle-to-gate (distribution and combustion excluded)
- cradle-to-grave (all lifecycle stages included)

If the *CFR* CI value is used to model a feedstock: this information must be entered in the applicable "Feedstock input (FD1)" worksheets of the CH-ITC Workbook.

If the *CFR* CI value is used to model a fuel input: this information must be entered in the "Fuel input for HP (FL1)", "Fuel input for EHGS (FL2)" or "Fuel input for CCUS (FL3)" worksheet of the CH-ITC Workbook.

To include a *CFR* CI value in the hydrogen pathway, the applicant must first create a new process that contains the *CFR* CI value, following these steps:

1. Create a new process for the CI value in one of the following folders, depending on what the *CFR* CI is to be used for:
    a) if the *CFR* CI value is used to model a feedstock: create a new process in the folder Processes/Fuel Pathways/Hydrogen pathway/Mass basis/**Feedstock, at hydrogen product system**
    b) if the *CFR* CI value is used to model a fuel input: create a new process in the folder Processes/Fuel Pathways/Hydrogen pathway/Mass basis/**Fuel input, at hydrogen product system**
2. The new process must be named using the same name entered in the CH-ITC Workbook.
3. Create a corresponding flow with the same name. The reference flow property must be "Energy".
4. In the "General information" tab of the new process, describe the option of *CFR* CI and its scope with other relevant information such as the unique alphanumeric identifier (if available).
5. In the "Input/Output" tab:
    a) enter the flow created above as an output, and make sure the output amount is exactly 1 MJ

    b) enter an output flow of Carbon dioxide equivalent (CO_2e) and set its amount equal to the *CFR* CI value
6. Save and close the process.

This UP can now be used as an input to other unit processes.

7 Annex B: Heat and electricity generation system

This section describes the modelling of thermal energy and electricity for the D- Heat and electricity generation system (AM) UP.

Scope

The heat and electricity generation system in the facility refers to any combination of steam turbines, gas turbines, burners, boilers, or other equipment that produces heat and/or electricity used by the HPS. This can include multiple types of equipment, or only 1. Please note that only heat under the form of steam is considered for heat used by the HPS, and only thermal energy in water and steam is considered for the calculations.

Figure 16 below illustrates these different heat and electricity generating equipment types, as well as the associated input and output flows. The flows in grey refer to flows not quantified in the modelling approach.

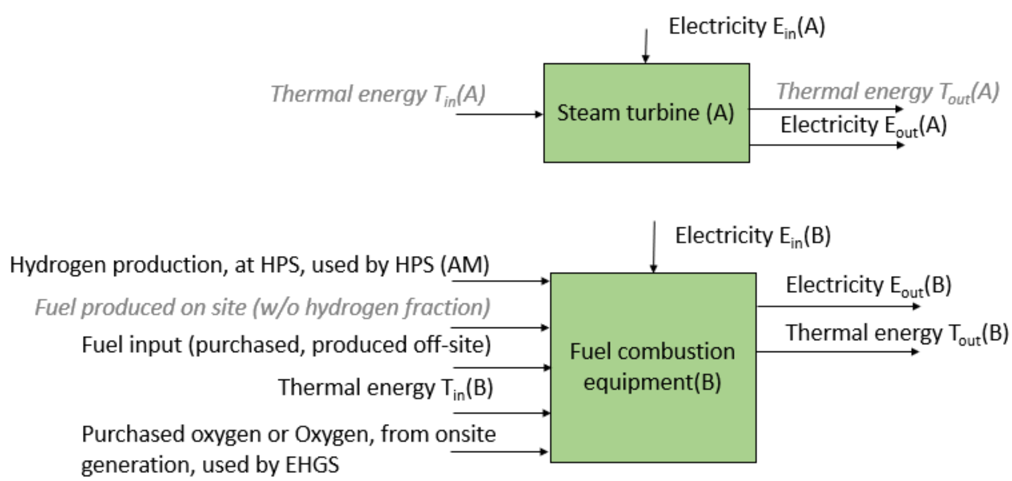

Figure 16: Thermal energy flows.

These are separated into 2 categories, labelled steam turbine (A) and fuel combustion equipment (B) but can refer to different technologies.

Steam turbine (A) refers to a turbine or another equipment type that produces electricity without any direct fuel inputs, the only inputs and outputs are thermal energy under the form of water/steam and electricity. As such, any heat exiting this equipment is not from the combustion of fuels and is not considered. Only the electricity input and output to this equipment are considered.

Fuel combustion equipment (B) refers to any equipment producing electricity and/or heat from the combustion of fuels, whether by burning purchased fuels, hydrogen, gaseous co-products, such as off-gas (including tail gas, and other fuel gas) produced and combusted within the HPS that may or may not contain a fraction of hydrogen. For this equipment, gaseous co-products produced on-site not containing hydrogen are not considered. If hydrogen produced on-site is used as a fuel and is in a fuel gas mix, only the hydrogen fraction of this flow will be considered. Any purchased fuel, hydrogen produced on-site, electricity inputs and outputs, as well as the thermal energy contained in water and steam inputs and outputs are considered. If steam is not produced directly at the equipment where the combustion is taking place, such as a burner, and is paired with a heat exchanger or a similar technology to produce steam, the thermal energy flows will be considered at the heat exchanger, where the steam is produced, and not directly at the equipment where the combustion takes place.

An input flow of either purchased oxygen, or oxygen from the B- Oxygen and nitrogen generation system (AM) UP, can also be added as an input.

Modelling of the D- Electricity and heat generation system (AM) UP
The D- Electricity and heat generation system (AM) UP therefore represents the mass and energy balance of all the type A and B equipment used to produce thermal energy such as steam and/or electricity.

For the flows of hydrogen, fuel inputs and oxygen, the inputs to the D- Electricity and heat generation system (AM) UP is simply the sum of all the inputs to the process of the category B (Fuel combustion equipment). The fuel inputs are modelled in accordance with section 3.6.2.1 (excluding purchased steam, which is considered separately).

For electricity, only the net amount of electricity should be considered for the input or output of the D- Electricity and heat generation system (AM) UP and it is then calculated as follows:

Equation 6: electricity balance

$$\text{Electricity balance} = E_{out\,(A)} - E_{in(A)} + E_{out\,(B)} - E_{in\,(B)}$$

If there is a net electricity production, the resulting amount is then added as an output to the D- Electricity and heat generation system (AM) UP. This net balance of electricity corresponds to the sum of electricity used by the HPS, as well as exported to other product systems, as shown in Figure 17:

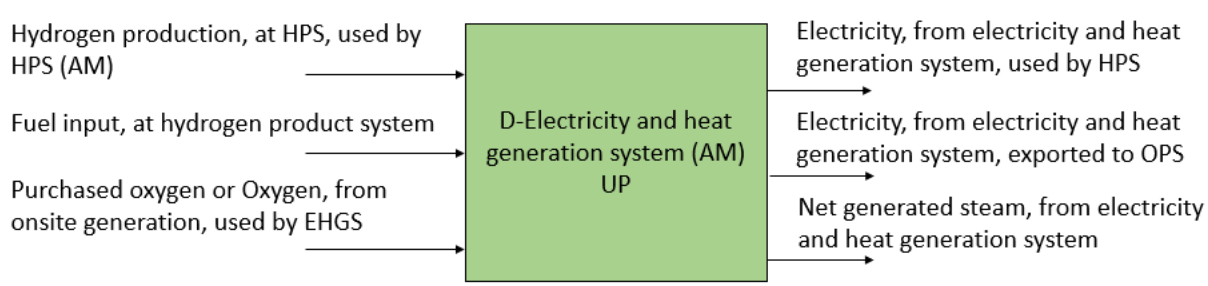

Figure 17: Diagram of the D- Electricity and heat generation system (AM) UP, net electricity production.

If there is a net electricity consumption, the resulting amount is then added as an input to the D- Electricity and heat generation system (AM) UP. This is modelled using a flow of E- Electricity, average supply mix, at HPS (AM), as shown on Figure 18:

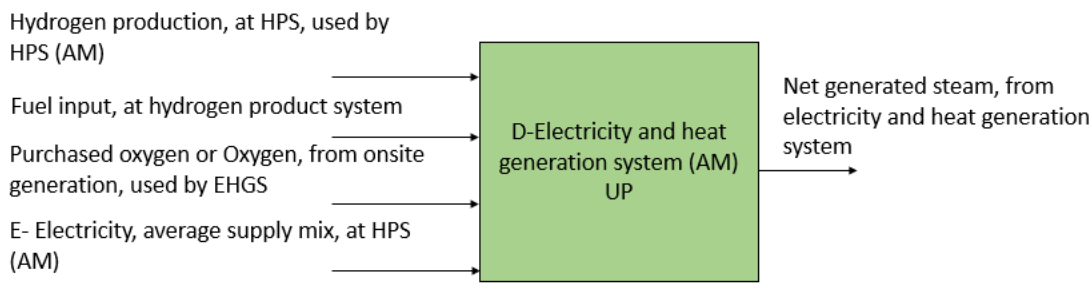

Figure 18: Diagram of the D- Electricity and heat generation system (AM) UP, net electricity consumption.

The definition of the thermal energy output of the D- Electricity and heat generation system (AM) UP is thermal energy that is produced from the combustion of fuels such as hydrogen, purchased fuels, and gaseous co-products such as off-gas (including tail gas, and other fuel gas) produced and combusted within the HPS.

The input and output flows to the gas turbine, or any other equipment producing heat from the combustion of fuels, are considered. This will be modelled with a flow of net generated steam, from electricity and heat generation system when there is a net generation of steam. This net thermal energy output is determined using the enthalpy method and it is calculated as follows:

Equation 7: thermal energy balance

$$T\_out\ (UP) = T\_out\ (B) – T\_in\ (B)$$