premise

Release 2.0.0

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May 16, 2024

CONTENTS

This user guide will help you navigate the inner workings of *premise*.

CHAPTER

ONE

IN A NUTSHELL

1.1 Purpose

premise enables the alignment of life cycle inventories within the ecoinvent 3.6-3.9.1 database, using either a "cut-off" or "consequential" system model, to match the output results of Integrated Assessment Models (IAMs) such as REMIND or IMAGE. This allows for the creation of life cycle inventory databases under future policy scenarios for any year between 2005 and 2100.

Note: The ecoinvent database is not included in this package. You need to have a valid license for ecoinvent 3.6-3.9.1 to use *premise*. Also, please read carefully ecoinvent's EULA before using *premise*.

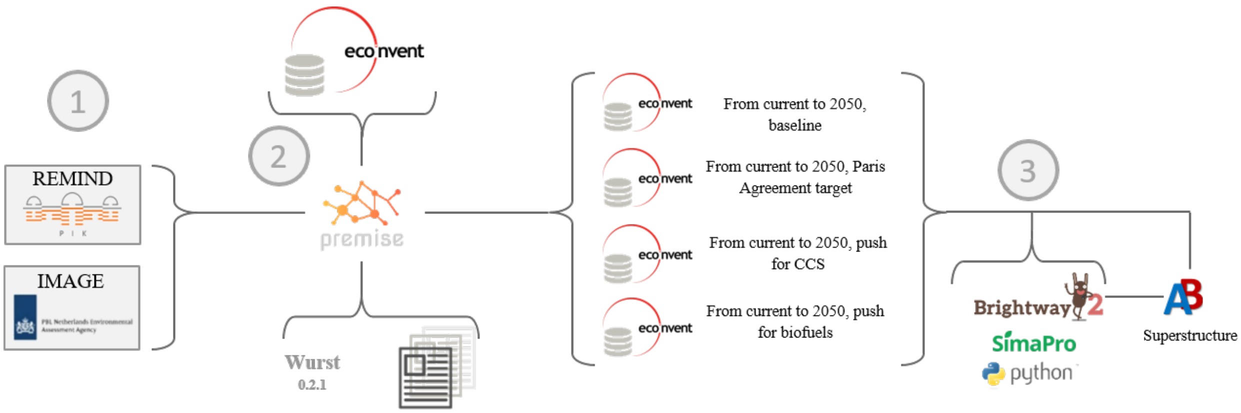
1.2 Publication

The methodology behind *premise* is described in the following publication:

R. Sacchi, T. Terlouw, K. Siala, A. Dirnaichner, C. Bauer, B. Cox, C. Mutel, V. Daioglou, G. Luderer, PRospective EnvironMental Impact asSEment (premise): A streamlined approach to producing databases for prospective life cycle assessment using integrated assessment models, Renewable and Sustainable Energy Reviews, 2022, https://doi.org/10.1016/j.rser.2022.112311.

Note: If you use *premise* in your research, please cite the above publication.

1.3 Workflow



As illustrated in the workflow diagram above, *premise* follows an Extract, Transform, Load (ETL) process:

Extract the ecoinvent database from a Brightway project or from ecospold2 files. Expand the database by adding additional inventories for future production pathways for certain commodities, such as electricity, steel, cement, etc. Modify the ecoinvent database, focusing primarily on process efficiency improvements and market adjustments. Load the updated database back into a Brightway project or export it as a set of CSV files, such as Simapro CSV files.

1.4 Default IAM scenarios

Provided a decryption key (ask the maintainers), the following IAM scenarios are available when installing *premise*:

SSP/RCP scenario	GMST increase by 2100	Society/economy trend	Climate policy	REMIND	IMAGE
SSP1-None	2.3-2.8 °C	Optimistic trends for human develop. and economy, driven by sustainable practices.	None	SSP1-Base	SSP1-Base
SSP1-None	~2.2 °C	Optimistic trends for human develop. and economy, driven by sustainable practices.	National Policies Implemented (NPI).	SSP1-NPi	
SSP1-None	~1.9 °C	Optimistic trends for human develop. and economy, driven by sustainable practices.	Nationally Determined Contributions (NDCs).	SSP1-NDC	
SSP1-RCP2.6	~1.7 °C	Optimistic trends for human develop. and economy, driven by sustainable practices.	Paris Agreement objective.	SSP1-PkBudg11	
SSP1-RCP1.9	~1.3 °C	Optimistic trends for human develop. and economy, driven by sustainable practices.	Paris Agreement objective.	SSP1-PkBudg50	
SSP2-None	~3.5 °C	Extrapolation from historical developments.	None (eq. to RCP6)	SSP2-Base	SSP2-Base
SSP2-None	~3.3 °C	Extrapolation from historical developments.	National Policies Implemented (NPI).	SSP2-NPi	
SSP2-None	~2.5 °C	Extrapolation from historical developments.	Nationally Determined Contributions (NDCs).	SSP2-NDC	
SSP2-RCP2.6	1.6-1.8 °C	Extrapolation from historical developments.	Paris Agreement objective.	SSP2-PkBudg11	SSP2-RCP26
SSP2-RCP1.9	1.2-1.4 °C	Extrapolation from historical developments.	Paris Agreement objective.	SSP2-PkBudg50	SSP2-RCP19
SSP5-None	~4.5 °C	Optimistic trends for human develop. and economy, driven by fossil fuels.	None	SSP5-Base	
SSP5-None	~4.0 °C	Optimistic trends for human develop. and economy, driven by fossil fuels.	National Policies Implemented (NPI).	SSP5-NPi	
SSP5-None	~3.0 °C	Optimistic trends for human develop. and economy, driven by fossil fuels.	Nationally Determined Contributions (NDCs).	SSP5-NDC	
SSP5-RCP2.6	~1.7 °C	Optimistic trends for human develop. and economy, driven by fossil fuels.	Paris Agreement objective.	SSP5-PkBudg11	
SSP5-RCP1.9	~1.0 °C	Optimistic trends for human develop. and economy, driven by fossil fuels.	Paris Agreement objective.	SSP5-PkBudg50	

CarbonBrief wrote a good article explaining the meaning of the SSP/RCP system.

Additionally, we provided a summary of the main characteristics of each scenario here.

You can however use any other scenario files generated by REMIND or IMAGE. If you wish to use an IAM file which has not been generated by either of these two models, you should refer to the **Mapping** section.

1.5 Requirements

- Python language interpreter **>=3.9**
- License for ecoinvent 3
- brightway2 (optional)

1.6 How to install this package?

Two options:

A development version with the latest advancements (but with the risks of unseen bugs), is available on Anaconda Cloud:

```
conda install -c romainsacchi premise
```

For a more stable and proven version, from Pypi:

```
pip install premise
```

This will install the package and the required dependencies.

1.7 How to use it?

1.7.1 Examples notebook

This notebook will show you everything you need to know to use *premise*.

1.7.2 ScenarioLink plugin

There now exists a plugin for Activity Browser, called ScenarioLink, which allows you to directly download IAM scenario-based premise databases from the browser, without the use of premise. You can find it here.

1.8 Main contributors

- Romain Sacchi
- Alois Dirnaichner
- Chris Mutel
- Brian Cox

CHAPTER

TWO

EXTRACT

The **EXTRACT** phase consists of the following steps:

- Extraction and cleaning of the ecoinvent database
- Import and cleaning of additional inventories
- Import and cleaning of user-provided inventories (optional)
- Caching, if these database and inventories are imported for the first time
- Loading of IAM data

2.1 Current IAM scenarios

premise includes several Integrated Assessment Model (IAM) scenarios, but you can also use other scenarios. In *premise*, scenarios are defined by their Shared Socio-economic Pathway (SSP), a climate trajectory—often represented by a Representative Concentration Pathway (RCP)—and a year (e.g., SSP1, Base, 2035).

SSP/RCP scenario	GMST increase by 2100	Society/economy trend	Climate policy	REMIND	IMAGE
SSP1-None	2.3-2.8 °C	Optimistic trends for human develop. and economy, driven by sustainable practices.	None	SSP1-Base	SSP1-Base
SSP1-None	~2.2 °C	Optimistic trends for human develop. and economy, driven by sustainable practices.	National Policies Implemented (NPI).	SSP1-NPi	
SSP1-None	~1.9 °C	Optimistic trends for human develop. and economy, driven by sustainable practices.	Nationally Determined Contributions (NDCs).	SSP1-NDC	
SSP1-RCP2.6	~1.7 °C	Optimistic trends for human develop. and economy, driven by sustainable practices.	Paris Agreement objective.	SSP1-PkBudg11	
SSP1-RCP1.9	~1.3 °C	Optimistic trends for human develop. and economy, driven by sustainable practices.	Paris Agreement objective.	SSP1-PkBudg50	
SSP2-None	~3.5 °C	Extrapolation from historical developments.	None (eq. to RCP6)	SSP2-Base	SSP2-Base
SSP2-None	~3.3 °C	Extrapolation from historical developments.	National Policies Implemented (NPI).	SSP2-NPi	
SSP2-None	~2.5 °C	Extrapolation from historical developments.	Nationally Determined Contributions (NDCs).	SSP2-NDC	
SSP2-RCP2.6	1.6-1.8 °C	Extrapolation from historical developments.	Paris Agreement objective.	SSP2-PkBudg11	SSP2-RCP26
SSP2-RCP1.9	1.2-1.4 °C	Extrapolation from historical developments.	Paris Agreement objective.	SSP2-PkBudg50	SSP2-RCP19
SSP5-None	~4.5 °C	Optimistic trends for human develop. and economy, driven by fossil fuels.	None	SSP5-Base	
SSP5-None	~4.0 °C	Optimistic trends for human develop. and economy, driven by fossil fuels.	National Policies Implemented (NPI).	SSP5-NPi	
SSP5-None	~3.0 °C	Optimistic trends for human develop. and economy, driven by fossil fuels.	Nationally Determined Contributions (NDCs).	SSP5-NDC	
SSP5-RCP2.6	~1.7 °C	Optimistic trends for human develop. and economy, driven by fossil fuels.	Paris Agreement objective.	SSP5-PkBudg11	
SSP5-RCP1.9	~1.0 °C	Optimistic trends for human develop. and economy, driven by fossil fuels.	Paris Agreement objective.	SSP5-PkBudg50	

Note: A summary report of the main variables of the scenarios selected is generated automatically after each database export. There is also an online dashboard. You can also generate it manually:

2.2 Supported versions of ecoinvent

premise currently works with the following ecoinvent database versions:

- v.3.5, cut-off
- v.3.6, cut-off
- v.3.7, cut-off
- v.3.7.1, cut-off
- **v.3.8, cut-off and consequential**
- **v.3.9/3.9.1, cut-off and consequential**

2.3 Supported sources of ecoinvent

premise can extract the ecoinvent database from:

- a brightway2 project that contains the ecoinvent database
- ecosposld2 files, that can be downloaded from the ecoinvent website

Note: The ecoinvent database is not included in *premise*. You need to have a valid license to download and use it. Also, please read carefully ecoinvent's EULA before using *premise*.

2.3.1 From a brightway2 project

To extract from an ecoinvent database located in a brightway2 project, simply indicate the database name in *source_db* and its version in *source_version*:

```
from premise import *
import brightway2 as bw

bw.projects.set_current("my_project)

ndb = NewDatabase(
      scenarios=[
              {"model":"remind", "pathway":"SSP2-Base", "year":2028}
          ],
      source_db="ecoinvent 3.7 cutoff", # <-- this is NEW.
      source_version="3.7.1", # <-- this is NEW
      key='xxxxxxxxxxxxxxxxxxxxxxxxx',
      use_multiprocessing=True, # True by default, set to False if multiprocessing is␣
↪causing troubles
      keep_uncertainty_data=False # False by default, set to True if you want to keep␣
↪ecoinvent's uncertainty data
  )
```

Note that a cache of the database will be created the first time and store in the library folder. Any subsequent creation of databases using the same ecoinvent version will no longer require this extraction step.

If you wish to clear that cache folder, do:

```python
from premise import *

clear_cache()
```

Note: It is recommended to restart your notebook once the data has been cached for the first time, so that the remaining steps can be performed using the cached data (much faster).

2.3.2 From ecospold2 files

To extract from a set of ecospold2 files, you need to point to the location of those files in *source_file_path*, as well as indicate the database format in *source_type*:

```python
from premise import *

ndb = NewDatabase(
    scenarios = [
        {"model":"remind", "pathway":"SSP2-Base", "year":2028}
                ],
    source_type="ecospold", # <--- this is NEW
    source_file_path=r"C:\file\path\to\ecoinvent 3.5_cutoff_ecoSpold02\datasets", # <--
↪this is NEW
    source_version="3.5",
)
```

2.4 Import of additional inventories

After the ecoinvent database is extracted and checked, a number of additional inventories are imported, regardless of the year of scenario that is being considered.

2.4.1 Power generation

A number of datasets relating to power generation not originally present in ecoinvent are imported. The next subsections lists such datasets.

2.4.1.1 Power plants with CCS

Datasets for power generation with Carbon Capture and Storage (CCS) are imported. They originate from Volkart et al. 2013, and can be consulted here: LCI_Power_generation. An exception to this are the inventories for biomass-based integrated gasification combined cycle power plants (BIGCCS), which are from Briones-Hidrovo et al, 2020.

The table below lists the names of the new activities (only production datasets are shown).

Power generation with CCS (activities list)	location
electricity production, at power plant/hard coal, IGCC, no CCS	RER
electricity production, at power plant/hard coal, PC, no CCS	RER
electricity production, at power plant/hard coal, oxy, pipeline 200km, storage 1000m	RER
electricity production, at power plant/hard coal, oxy, pipeline 400km, storage 3000m	RER
electricity production, at power plant/hard coal, post, pipeline 200km, storage 1000m	RER
electricity production, at power plant/hard coal, post, pipeline 400km, storage 1000m	RER
electricity production, at power plant/hard coal, post, pipeline 400km, storage 3000m	RER
electricity production, at power plant/hard coal, pre, pipeline 200km, storage 1000m	RER
electricity production, at power plant/hard coal, pre, pipeline 400km, storage 3000m	RER
electricity production, at power plant/lignite, IGCC, no CCS	RER
electricity production, at power plant/lignite, PC, no CCS	RER
electricity production, at power plant/lignite, oxy, pipeline 200km, storage 1000m	RER
electricity production, at power plant/lignite, oxy, pipeline 400km, storage 3000m	RER
electricity production, at power plant/lignite, post, pipeline 200km, storage 1000m	RER
electricity production, at power plant/lignite, post, pipeline 400km, storage 3000m	RER
electricity production, at power plant/lignite, pre, pipeline 200km, storage 1000m	RER
electricity production, at power plant/lignite, pre, pipeline 400km, storage 3000m	RER
electricity production, at power plant/natural gas, ATR H2-CC, no CCS	RER
electricity production, at power plant/natural gas, NGCC, no CCS/kWh	RER
electricity production, at power plant/natural gas, post, pipeline 200km, storage 1000m	RER
electricity production, at power plant/natural gas, post, pipeline 400km, storage 1000m	RER
electricity production, at power plant/natural gas, post, pipeline 400km, storage 3000m	RER
electricity production, at power plant/natural gas, pre, pipeline 200km, storage 1000m	RER
electricity production, at power plant/natural gas, pre, pipeline 400km, storage 3000m	RER
electricity production, at wood burning power plant 20 MW, truck 25km, no CCS	RER
electricity production, at wood burning power plant 20 MW, truck 25km, post, pipeline 200km, storage 1000m	RER
electricity production, at wood burning power plant 20 MW, truck 25km, post, pipeline 400km, storage 3000m	RER

2.4.1.2 Natural gas

Updated inventories relating to natural gas extraction and distribution are imported to substitute some of the original ecoinvent dataset. These datasets originate from ESU Services and come with a report, and can be consulted here: LCI_Oil_NG.

They have been adapted to a brightway2-compatible format. These new inventories have, among other things, higher methane slip emissions along the natural gas supply chain, especially at extraction.

Original dataset	Replaced by
natural gas production (natural gas, high pressure), DE	natural gas, at production (natural gas, high pressure), DE
natural gas production (natural gas, high pressure), DZ	natural gas, at production (natural gas, high pressure), DZ
natural gas production (natural gas, high pressure), US	natural gas, at production (natural gas, high pressure), US
natural gas production (natural gas, high pressure), RU	natural gas, at production (natural gas, high pressure), RU
petroleum and gas production, GB	natural gas, at production (natural gas, high pressure), GB
petroleum and gas production, NG	natural gas, at production (natural gas, high pressure), NG
petroleum and gas production, NL	natural gas, at production (natural gas, high pressure), NL
petroleum and gas production, NO	natural gas, at production (natural gas, high pressure), NO

The original natural gas datasets are preserved, but they do not provide input to any other datasets in the database. The new datasets provide natural gas at high pressure to the original supply chains, which remain unchanged.

The table below lists the names of the new activities (only high pressure datasets are shown).

Natural gas extraction	location
natural gas, at production	AZ
natural gas, at production	RO
natural gas, at production	LY
natural gas, at production	SA
natural gas, at production	IQ
natural gas, at production	RU
natural gas, at production	NL
natural gas, at production	DZ
natural gas, at production	NG
natural gas, at production	DE
natural gas, at production	KZ
natural gas, at production	NO
natural gas, at production	QA
natural gas, at production	GB
natural gas, at production	MX
natural gas, at production	US

Note: This import does not occur when using ecoinvent v.3.9 as those dataset updates are already included.

2.4.1.3 Photovoltaic panels

Photovoltaic panel inventories originate the IEA's Task 12 project IEA_PV. They have been adapted into a brightway2-friendly format. They can be consulted here: LCI_PV.

They consist of the following PV installation types:

PV installation	location
photovoltaic slanted-roof installation, 1.3 MWp, multi-Si, panel, mounted, on roof	CH
photovoltaic flat-roof installation, 156 kWp, multi-Si, on roof	CH
photovoltaic flat-roof installation, 156 kWp, single-Si, on roof	CH
photovoltaic flat-roof installation, 280 kWp, multi-Si, on roof	CH
photovoltaic flat-roof installation, 280 kWp, single-Si, on roof	CH
photovoltaic flat-roof installation, 324 kWp, multi-Si, on roof	DE
photovoltaic slanted-roof installation, 3 kWp, CIS, laminated, integrated, on roof	CH
photovoltaic slanted-roof installation, 3 kWp, CIS, laminated, integrated, on roof	RER
photovoltaic slanted-roof installation, 3 kWp, CdTe, panel, mounted, on roof	CH
photovoltaic slanted-roof installation, 3 kWp, CdTe, panel, mounted, on roof	RER
photovoltaic slanted-roof installation, 3 kWp, micro-Si, laminated, integrated, on roof	RER
photovoltaic slanted-roof installation, 3 kWp, micro-Si, panel, mounted, on roof	RER
photovoltaic flat-roof installation, 450 kWp, single-Si, on roof	DE
photovoltaic open ground installation, 560 kWp, single-Si, on open ground	CH
photovoltaic open ground installation, 569 kWp, multi-Si, on open ground	ES
photovoltaic open ground installation, 570 kWp, CIS, on open ground	RER
photovoltaic open ground installation, 570 kWp, CdTe, on open ground	RER
photovoltaic open ground installation, 570 kWp, micro-Si, on open ground	RER
photovoltaic open ground installation, 570 kWp, multi-Si, on open ground	ES
photovoltaic open ground installation, 570 kWp, multi-Si, on open ground	RER
photovoltaic open ground installation, 570 kWp, single-Si, on open ground	RER
photovoltaic slanted-roof installation, 93 kWp, multi-Si, laminated, integrated, on roof	CH
photovoltaic slanted-roof installation, 93 kWp, multi-Si, panel, mounted, on roof	CH
photovoltaic slanted-roof installation, 93 kWp, single-Si, laminated, integrated, on roof	CH
photovoltaic slanted-roof installation, 93 kWp, single-Si, panel, mounted, on roof	CH

Although these datasets have a limited number of locations (CH, RER, DE, ES), the IEA report provides country-specific load factors:

production [kWh/kWp]	roof-top	façade	central
PT	1427	999	1513
IL	1695	1187	1798
SE	919	643	974
FR	968	678	1026
TR	1388	971	1471
NZ	1240	868	1315
MY	1332	933	1413
CN	971	679	1029
TH	1436	1005	1522
ZA	1634	1144	1733
JP	1024	717	1086
CH	976	683	1040
DE	922	645	978

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Table 1 – continued from previous page

production [kWh/kWp]	roof-top	façade	central
KR	1129	790	1197
AT	1044	731	1111
GR	1323	926	1402
IE	796	557	844
AU	1240	868	1314
IT	1298	908	1376
MX	1612	1128	1709
NL	937	656	994
GB	848	593	899
ES	1423	996	1509
CL	1603	1122	1699
HU	1090	763	1156
CZ	944	661	1101
CA	1173	821	1243
US	1401	981	1485
NO	832	583	882
FI	891	624	945
BE	908	635	962
DK	971	680	1030
LU	908	635	962

In the report, the generation potential per installation type is multiplied by the number of installations in each country, to produce country-specific PV power mix datasets normalized to 1 kWh. The report specifies the production-weighted PV mix for each country, but we further split it between residential (<=3kWp) and commercial (>3kWp) installations (as most IAMs make such distinction):

Production-weighted PV mix	location
electricity production, photovoltaic, residential	PT
electricity production, photovoltaic, residential	IL
electricity production, photovoltaic, residential	SE
electricity production, photovoltaic, residential	FR
electricity production, photovoltaic, residential	TR
electricity production, photovoltaic, residential	NZ
electricity production, photovoltaic, residential	MY
electricity production, photovoltaic, residential	CN
electricity production, photovoltaic, residential	TH
electricity production, photovoltaic, residential	ZA
electricity production, photovoltaic, residential	JP
electricity production, photovoltaic, residential	CH
electricity production, photovoltaic, residential	DE
electricity production, photovoltaic, residential	KR
electricity production, photovoltaic, residential	AT
electricity production, photovoltaic, residential	GR
electricity production, photovoltaic, residential	IE
electricity production, photovoltaic, residential	AU
electricity production, photovoltaic, residential	IT
electricity production, photovoltaic, residential	MX

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Table 2 – continued from previous page

Production-weighted PV mix	location
electricity production, photovoltaic, residential	NL
electricity production, photovoltaic, residential	GB
electricity production, photovoltaic, residential	ES
electricity production, photovoltaic, residential	CL
electricity production, photovoltaic, residential	HU
electricity production, photovoltaic, residential	CZ
electricity production, photovoltaic, residential	CA
electricity production, photovoltaic, residential	US
electricity production, photovoltaic, residential	NO
electricity production, photovoltaic, residential	FI
electricity production, photovoltaic, residential	BE
electricity production, photovoltaic, residential	DK
electricity production, photovoltaic, residential	LU
electricity production, photovoltaic, commercial	PT
electricity production, photovoltaic, commercial	IL
electricity production, photovoltaic, commercial	SE
electricity production, photovoltaic, commercial	FR
electricity production, photovoltaic, commercial	TR
electricity production, photovoltaic, commercial	NZ
electricity production, photovoltaic, commercial	MY
electricity production, photovoltaic, commercial	CN
electricity production, photovoltaic, commercial	TH
electricity production, photovoltaic, commercial	ZA
electricity production, photovoltaic, commercial	JP
electricity production, photovoltaic, commercial	CH
electricity production, photovoltaic, commercial	DE
electricity production, photovoltaic, commercial	KR
electricity production, photovoltaic, commercial	AT
electricity production, photovoltaic, commercial	GR
electricity production, photovoltaic, commercial	IE
electricity production, photovoltaic, commercial	AU
electricity production, photovoltaic, commercial	IT
electricity production, photovoltaic, commercial	MX
electricity production, photovoltaic, commercial	NL
electricity production, photovoltaic, commercial	GB
electricity production, photovoltaic, commercial	ES
electricity production, photovoltaic, commercial	CL
electricity production, photovoltaic, commercial	HU
electricity production, photovoltaic, commercial	CZ
electricity production, photovoltaic, commercial	CA
electricity production, photovoltaic, commercial	US
electricity production, photovoltaic, commercial	NO
electricity production, photovoltaic, commercial	FI
electricity production, photovoltaic, commercial	BE
electricity production, photovoltaic, commercial	DK
electricity production, photovoltaic, commercial	LU

Hence, inside the *residential* PV mix of Spain ("electricity production, photovoltaic, residential"), one will find the following inputs for the production of 1kWh:

name	amount	location	unit
Energy, solar, converted	3.8503		megajoule
Heat, waste	0.25027		megajoule
photovoltaic slanted-roof installation, 3 kWp, CIS, laminated, integrated, on roof	2.48441E-08	CH	unit
photovoltaic slanted-roof installation, 3 kWp, CdTe, panel, mounted, on roof	4.99911E-07	CH	unit
photovoltaic slanted-roof installation, 3 kWp, micro-Si, laminated, integrated, on roof	3.93869E-09	RER	unit
photovoltaic slanted-roof installation, 3 kWp, micro-Si, panel, mounted, on roof	6.55186E-08	RER	unit
photovoltaic facade installation, 3kWp, multi-Si, laminated, integrated, at building	2.10481E-07	RER	unit
photovoltaic facade installation, 3kWp, multi-Si, panel, mounted, at building	2.10481E-07	RER	unit
photovoltaic facade installation, 3kWp, single-Si, laminated, integrated, at building	1.11463E-07	RER	unit
photovoltaic facade installation, 3kWp, single-Si, panel, mounted, at building	1.11463E-07	RER	unit
photovoltaic flat-roof installation, 3kWp, multi-Si, on roof	2.20794E-06	RER	unit
photovoltaic flat-roof installation, 3kWp, single-Si, on roof	1.17025E-06	RER	unit
photovoltaic slanted-roof installation, 3kWp, CIS, panel, mounted, on roof	4.12805E-07	CH	unit
photovoltaic slanted-roof installation, 3kWp, CdTe, laminated, integrated, on roof	3.00704E-08	CH	unit
photovoltaic slanted-roof installation, 3kWp, multi-Si, laminated, integrated, on roof	1.08693E-07	RER	unit
photovoltaic slanted-roof installation, 3kWp, multi-Si, panel, mounted, on roof	1.81407E-06	RER	unit
photovoltaic slanted-roof installation, 3kWp, single-Si, laminated, integrated, on roof	5.75655E-08	RER	unit
photovoltaic slanted-roof installation, 3kWp, single-Si, panel, mounted, on roof	9.6195E-07	RER	unit

with, for example, 2.48E-8 units of "photovoltaic slanted-roof installation, 3 kWp, CIS, laminated, integrated, on roof" being calculated as:

```
1 / (30 [years] * 1423 [kWh/kWp] * 0.32% [share of PV capacity of such type installed in Spain])
```

Note that commercial PV mix datasets provide electricity at high voltage, unlike residential PV mix datasets, which supply at low voltage only.

2.4.1.4 Geothermal

Heat production by means of a geothermal well are not represented in ecoinvent. The geothermal power plant construction inventories are from Maeder Bachelor Thesis.

The co-generation unit has been removed and replaced by heat exchanger and district heating pipes. Gross heat output of 1,483 TJ, with 80% efficiency.

The inventories can be consulted here: LCIgeothermal.

They introduce the following datasets (only heat production datasets shown):

Geothermal heat production	location
heat production, deep geothermal	RAS
heat production, deep geothermal	GLO
heat production, deep geothermal	RAF
heat production, deep geothermal	RME
heat production, deep geothermal	RLA
heat production, deep geothermal	RU
heat production, deep geothermal	CA
heat production, deep geothermal	JP
heat production, deep geothermal	US
heat production, deep geothermal	IN
heat production, deep geothermal	CN
heat production, deep geothermal	RER

2.4.2 Hydrogen

premise imports inventories for hydrogen production via the following pathways:

- Steam Methane Reforming, using natural gas
- Steam Methane Reforming, using natural gas, with Carbon Capture and Storage
- Steam Methane Reforming, using bio-methane
- Steam Methane Reforming, using bio-methane, with Carbon Capture and Storage
- Auto Thermal Reforming, using natural gas
- Auto Thermal Reforming, using natural gas, with Carbon Capture and Storage
- Auto Thermal Reforming, using bio-methane
- Auto Thermal Reforming, using bio-methane, with Carbon Capture and Storage
- Woody biomass gasification, using a fluidized bed
- Woody biomass gasification, using a fluidized bed, with Carbon Capture and Storage
- Woody biomass gasification, using an entrained flow gasifier
- Woody biomass gasification, using an entrained flow gasifier, with Carbon Capture and Storage
- Coal gasification
- Coal gasification, with Carbon Capture and Storage
- Electrolysis
- Thermochemical water splitting

- Pyrolysis

Inventories using Steam Methane Reforming are from Antonini et al. 2021. They can be consulted here: LCI_SMR. Inventories using Auto Thermal Reforming are from Antonini et al. 2021. They can be consulted here: LCI_ATR. Inventories using Woody biomass gasification are from Antonini2 et al. 2021. They can be consulted here: LCI_woody. Inventories using coal gasification are from Wokaun et al. 2015, but updated with Li et al. 2022, which also provide an option with CCS. They can be consulted here: LCI_coal. Inventories using electrolysis are from Niklas Gerloff. 2021. They can be consulted here: LCI_electrolysis. Inventories for thermochemical water splitting are from Zhang2 et al. 2022. Inventories for pyrolysis are from Al-Qahtani et al. 2021, completed with data from Postels et al., 2016.

The new datasets introduced are listed in the table below (only production datasets are shown).

Hydrogen production	location
hydrogen production, steam methane reforming of natural gas, 25 bar	CH
hydrogen production, steam methane reforming of natural gas, with CCS (MDEA, 98% eff.), 25 bar	CH
hydrogen production, steam methane reforming, from biomethane, high and low temperature, with CCS (MDEA, 98% eff.), 26 bar	CH
hydrogen production, steam methane reforming, from biomethane, high and low temperature, 26 bar	CH
hydrogen production, auto-thermal reforming, from biomethane, 25 bar	CH
hydrogen production, auto-thermal reforming, from biomethane, with CCS (MDEA, 98% eff.), 25 bar	CH
hydrogen production, gaseous, 25 bar, from heatpipe reformer gasification of woody biomass with CCS, at gasification plant	CH
hydrogen production, gaseous, 25 bar, from heatpipe reformer gasification of woody biomass, at gasification plant	CH
hydrogen production, gaseous, 25 bar, from gasification of woody biomass in entrained flow gasifier, with CCS, at gasification plant	CH
hydrogen production, gaseous, 25 bar, from gasification of woody biomass in entrained flow gasifier, at gasification plant	CH
hydrogen production, gaseous, 30 bar, from hard coal gasification and reforming, at coal gasification plant	RER
hydrogen production, gaseous, 30 bar, from PEM electrolysis, from grid electricity	RER
hydrogen production, gaseous, 20 bar, from AEC electrolysis, from grid electricity	RER
hydrogen production, gaseous, 1 bar, from SOEC electrolysis, from grid electricity	RER
hydrogen production, gaseous, 1 bar, from SOEC electrolysis, with steam input, from grid electricity	RER
hydrogen production, gaseous, 25 bar, from thermochemical water splitting, at solar tower	RER
hydrogen production, gaseous, 100 bar, from methane pyrolysis	RER

2.4.2.1 Hydrogen storage and distribution

A number of datasets relating to hydrogen storage and distribution are also imported.

They are necessary to model the distribution of hydrogen:

- via re-assigned transmission and distribution CNG pipelines, in a gaseous state
- via dedicated transmission and distribution hydrogen pipelines, in a gaseous state
- as a liquid organic compound, by hydrogenation

- via truck, in a liquid state
- hydrogen refuelling station

Small and large storage solutions are also provided: * high pressure hydrogen storage tank * geological storage tank

These datasets originate from the work of Wulf et al. 2018, and can be consulted here: LCI_H2_distr. For re-assigned CNG pipelines, which require the hydrogen to be mixed together with oxygen to limit metal embrittlement, some parameters are taken from the work of Cerniauskas et al. 2020.

The datasets introduced are listed in the table below.

Hydrogen distribution	location
hydrogen refuelling station	GLO
high pressure hydrogen storage tank	GLO
pipeline, hydrogen, low pressure distribution network	RER
compressor assembly for transmission hydrogen pipeline	RER
pipeline, hydrogen, high pressure transmission network	RER
zinc coating for hydrogen pipeline	RER
hydrogenation of hydrogen	RER
dehydrogenation of hydrogen	RER
dibenzyltoluene production	RER
solution mining for geological hydrogen storage	RER
geological hydrogen storage	RER
hydrogen embrittlement inhibition	RER
distribution pipeline for hydrogen, reassigned CNG pipeline	RER
transmission pipeline for hydrogen, reassigned CNG pipeline	RER

2.4.2.2 Hydrogen turbine

A dataset for a hydrogen turbine is also imported, to model the production of electricity from hydrogen, with an efficiency of 51%. The efficiency of the H2-fed gas turbine is based on the parameters of Ozawa et al. (2019), accessible here: LCI_H2_turbine.

2.4.3 Biofuels

Inventories for energy crops- and residues-based production of bioethanol and biodiesel are imported, and can be accessed here: LCI_biofuels. They include the farming of the crop, the conversion of the biomass to fuel, as well as its distribution. The conversion process often leads to the production of co-products (dried distiller's grain, electricity, CO2, bagasse.). Hence, energy, economic and system expansion partitioning approaches are available. These inventories originate from several different sources (Wu et al. 2006 (2020 update), Cozzolino 2018, Pereira et al. 2019 and Gonzalez-Garcia et al. 2012), Cavalett & Cherubini 2022, as indicated in the table below.

The following datasets are introduced:

Activity	Location	Source
Farming and supply of switchgrass	US	Wu et al. 2006 (2020 update)
Farming and supply of poplar	US	Wu et al. 2006 (2020 update)
Farming and supply of willow	US	Wu et al. 2006 (2020 update)
Supply of forest residue	US	Wu et al. 2006 (2020 update)
Farming and supply of miscanthus	US	Wu et al. 2006 (2020 update)
Farming and supply of corn stover	US	Wu et al. 2006 (2020 update)

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Activity	Location	Source
Farming and supply of sugarcane	US	Wu et al. 2006 (2020 update)
Farming and supply of Grain Sorghum	US	Wu et al. 2006 (2020 update)
Farming and supply of Sweet Sorghum	US	Wu et al. 2006 (2020 update)
Farming and supply of Forage Sorghum	US	Wu et al. 2006 (2020 update)
Farming and supply of corn	US	Wu et al. 2006 (2020 update)
Farming and supply of sugarcane	BR	Pereira et al. 2019/RED II
Farming and supply of sugarcane straw	BR	Pereira et al. 2019
Farming and supply of eucalyptus	ES	Gonzalez-Garcia et al. 2012
Farming and supply of wheat grains	RER	Cozzolino 2018
Farming and supply of wheat straw	RER	Cozzolino 2018
Farming and supply of corn	RER	Cozzolino 2018/RED II
Farming and supply of sugarbeet	RER	Cozzolino 2018
Supply of forest residue	RER	Cozzolino 2018
Supply and refining of waste cooking oil	RER	Cozzolino 2018
Farming and supply of rapeseed	RER	Cozzolino 2018/RED II
Farming and supply of palm fresh fruit bunch	RER	Cozzolino 2018
Farming and supply of dry algae	RER	Cozzolino 2018
Ethanol production, via fermentation, from switchgrass	US	Wu et al. 2006 (2020 update)
Ethanol production, via fermentation, from poplar	US	Wu et al. 2006 (2020 update)
Ethanol production, via fermentation, from willow	US	Wu et al. 2006 (2020 update)
Ethanol production, via fermentation, from forest residue	US	Wu et al. 2006 (2020 update)
Ethanol production, via fermentation, from miscanthus	US	Wu et al. 2006 (2020 update)
Ethanol production, via fermentation, from corn stover	US	Wu et al. 2006 (2020 update)
Ethanol production, via fermentation, from sugarcane	US	Wu et al. 2006 (2020 update)
Ethanol production, via fermentation, from grain sorghum	US	Wu et al. 2006 (2020 update)
Ethanol production, via fermentation, from sweet sorghum	US	Wu et al. 2006 (2020 update)
Ethanol production, via fermentation, from forage sorghum	US	Wu et al. 2006 (2020 update)
Ethanol production, via fermentation, from corn	US	Wu et al. 2006 (2020 update)
Ethanol production, via fermentation, from corn, with carbon capture	US	Wu et al. 2006 (2020 update)
Ethanol production, via fermentation, from sugarcane	BR	Pereira et al. 2019
Ethanol production, via fermentation, from sugarcane straw	BR	Pereira et al. 2019
Ethanol production, via fermentation, from eucalyptus	ES	Gonzalez-Garcia et al. 2012
Ethanol production, via fermentation, from wheat grains	RER	Cozzolino 2018
Ethanol production, via fermentation, from wheat straw	RER	Cozzolino 2018
Ethanol production, via fermentation, from corn starch	RER	Cozzolino 2018
Ethanol production, via fermentation, from sugarbeet	RER	Cozzolino 2018
Ethanol production, via fermentation, from forest residue	RER	Cozzolino 2018
Ethanol production, via fermentation, from forest residues	RER	Cavalett & Cherubini 2022
Ethanol production, via fermentation, from forest product (non-residual)	RER	Cavalett & Cherubini 2022
Biodiesel production, via transesterification, from used cooking oil	RER	Cozzolino 2018
Biodiesel production, via transesterification, from rapeseed oil	RER	Cozzolino 2018
Biodiesel production, via transesterification, from palm oil, energy allocation	RER	Cozzolino 2018
Biodiesel production, via transesterification, from algae, energy allocation	RER	Cozzolino 2018
Biodiesel production, via Fischer-Tropsch, from forest residues	RER	Cavalett & Cherubini 2022
Biodiesel production, via Fischer-Tropsch, from forest product (non-residual)	RER	Cavalett & Cherubini 2022
Kerosene production, via Fischer-Tropsch, from forest residues	RER	Cavalett & Cherubini 2022
Kerosene production, via Fischer-Tropsch, from forest product (non-residual)	RER	Cavalett & Cherubini 2022

2.4.4 Synthetic fuels

premise imports inventories for the synthesis of hydrocarbon fuels following two pathways:

- *Fischer-Tropsch*: it uses hydrogen and CO (from CO2 via a reverse water gas shift process) to produce "syncrude", which is distilled into diesel, kerosene, naphtha and lubricating oil and waxes. Inventories are from van der Giesen et al. 2014.
- *Methanol-to-liquids*: methanol is synthesized from hydrogen and CO2, and further distilled into gasoline, diesel, LGP and kerosene. Synthetic methanol inventories are from Hank et al. 2019. The methanol to fuel process specifications are from FVV 2013.
- *Electro-chemical methanation*: methane is produced from hydrogen and CO2 using a Sabatier methanation reactor. Inventories are from Zhang et al, 2019.

In their default configuration, these fuels use hydrogen from electrolysis and CO2 from direct air capture (DAC). However, *premise* builds different configurations (i.e., CO2 and hydrogen sources) for these fuels, for each IAM region:

Fuel production dataset
Diesel production, synthetic, from Fischer Tropsch process, hydrogen from coal gasification, at fuelling station
Diesel production, synthetic, from Fischer Tropsch process, hydrogen from coal gasification, with CCS, at fuelling station
Diesel production, synthetic, from Fischer Tropsch process, hydrogen from electrolysis, at fuelling station
Diesel production, synthetic, from Fischer Tropsch process, hydrogen from wood gasification, at fuelling station
Diesel production, synthetic, from Fischer Tropsch process, hydrogen from wood gasification, with CCS, at fuelling station
Diesel production, synthetic, from methanol, hydrogen from coal gasification, at fuelling station
Diesel production, synthetic, from methanol, hydrogen from coal gasification, with CCS, at fuelling station
Diesel production, synthetic, from methanol, hydrogen from electrolysis, CO2 from cement plant, at fuelling station
Diesel production, synthetic, from methanol, hydrogen from electrolysis, CO2 from DAC, at fuelling station
Gasoline production, synthetic, from methanol, hydrogen from coal gasification, at fuelling station
Gasoline production, synthetic, from methanol, hydrogen from coal gasification, with CCS, at fuelling station
Gasoline production, synthetic, from methanol, hydrogen from electrolysis, CO2 from cement plant, at fuelling station
Gasoline production, synthetic, from methanol, hydrogen from electrolysis, CO2 from DAC, at fuelling station
Kerosene production, from methanol, hydrogen from coal gasification
Kerosene production, from methanol, hydrogen from electrolysis, CO2 from cement plant
Kerosene production, from methanol, hydrogen from electrolysis, CO2 from DAC
Kerosene production, synthetic, Fischer Tropsch process, hydrogen from coal gasification
Kerosene production, synthetic, Fischer Tropsch process, hydrogen from coal gasification, with CCS
Kerosene production, synthetic, Fischer Tropsch process, hydrogen from electrolysis
Kerosene production, synthetic, Fischer Tropsch process, hydrogen from wood gasification
Kerosene production, synthetic, Fischer Tropsch process, hydrogen from wood gasification, with CCS
Lubricating oil production, synthetic, Fischer Tropsch process, hydrogen from coal gasification
Lubricating oil production, synthetic, Fischer Tropsch process, hydrogen from electrolysis
Lubricating oil production, synthetic, Fischer Tropsch process, hydrogen from wood gasification
Lubricating oil production, synthetic, Fischer Tropsch process, hydrogen from wood gasification, with CCS
Methane, synthetic, gaseous, 5 bar, from coal-based hydrogen, at fuelling station
Methane, synthetic, gaseous, 5 bar, from electrochemical methanation (H2 from electrolysis, CO2 from DAC using heat pump h
Methane, synthetic, gaseous, 5 bar, from electrochemical methanation (H2 from electrolysis, CO2 from DAC using waste heat),
Methane, synthetic, gaseous, 5 bar, from electrochemical methanation, at fuelling station
Naphtha production, synthetic, Fischer Tropsch process, hydrogen from coal gasification
Naphtha production, synthetic, Fischer Tropsch process, hydrogen from electrolysis
Naphtha production, synthetic, Fischer Tropsch process, hydrogen from wood gasification
Naphtha production, synthetic, Fischer Tropsch process, hydrogen from wood gasification, with CCS
Liquefied petroleum gas production, synthetic, from methanol, hydrogen from electrolysis, CO2 from DAC, at fuelling station

In the case of wood and coal gasification-based fuels, the CO2 needed to produce methanol or syncrude originates from the gasification process itself. This also implies that in the methanol and/or RWGS process, a carbon balance correction is applied to reflect the fact that a part of the CO2 from the gasification process is redirected into the fuel production process.

If the CO2 originates from:

- a gasification process without CCS, a negative carbon correction is added to

reflect the fact that part of the CO2 has not been emitted but has ended in the fuel instead. * the gasification process with CCS, no carbon correction is necessary, because the CO2 is stored in the fuel instead of being stored underground, which from a carbon accounting standpoint is similar.

2.4.5 Carbon Capture

Two sets of inventories for Direct Air Capture (DAC) are available in *premise*. One for a solvent-based system, and one for a sorbent-based system. The inventories were developed by Qiu and are available in the LCI_DAC spreadsheet. For each, a variant including the subsequent compression, transport and storage of the captured CO2 is also available.

They can be consulted here: LCI_DAC.

Additional, two datasets for carbon capture at point sources are available: one at cement plant from Meunier et al, 2020, and another one at municipal solid waste incineration plant (MSWI) from Bisinella et al, 2021.

They introduce the following datasets:

Activity	Location
carbon dioxide, captured from atmosphere, with a sorbent-based direct air capture system, 100ktCO2	RER
carbon dioxide, captured from atmosphere and stored, with a sorbent-based direct air capture system, 100ktCO2	RER
carbon dioxide, captured from atmosphere, with a solvent-based direct air capture system, 1MtCO2	RER
carbon dioxide, captured from atmosphere and stored, with a solvent-based direct air capture system, 1MtCO2	RER
carbon dioxide, captured at municipal solid waste incineration plant, for subsequent reuse	RER
carbon dioxide, captured at cement production plant, for subsequent reuse	RER

Using the transformation function *update("dac")*, *premise* creates various configurations of these processes, using different sources for heat (industrial steam heat, high-temp heat pump heat and excess heat), which are found under the following names, for each IAM region:

name	location
carbon dioxide, captured from atmosphere, with a solvent-based direct air capture system, 1MtCO2, with industrial steam heat, and grid electricity	all IAM regions
carbon dioxide, captured from atmosphere, with a solvent-based direct air capture system, 1MtCO2, with heat pump heat, and grid electricity	all IAM regions
carbon dioxide, captured from atmosphere, with a sorbent-based direct air capture system, 100ktCO2, with waste heat, and grid electricity	all IAM regions
carbon dioxide, captured from atmosphere, with a sorbent-based direct air capture system, 100ktCO2, with industrial steam heat, and grid electricity	all IAM regions
carbon dioxide, captured from atmosphere, with a sorbent-based direct air capture system, 100ktCO2, with heat pump heat, and grid electricity	all IAM regions

Note that only solid sorbent DAC can use waste heat, as the heat requirement for liquid solvent DAC is too high (~900 C)

2.4.6 Li-ion batteries

When using ecoinvent 3.8 as a database, *premise* imports new inventories for lithium-ion batteries. NMC-111, NMC-6222 NMC-811 and NCA Lithium-ion battery inventories are originally from Dai et al. 2019. They have been adapted to ecoinvent by Crenna et al, 2021. LFP and LTO Lithium-ion battery inventories are from Schmidt et al. 2019. Li-S battery inventories are from Wickerts et al. 2023. Li-O2 battery inventories are from Wang et al. 2020. Finally, SIB battery inventories are from Zhang22 et al. 2024.

They introduce the following datasets:

Battery components	location	source
battery management system production, for Li-ion battery	GLO	Schmidt et al. 2019
battery cell production, Li-ion, NMC111	GLO	Dai et al. 2019, Crenna et al. 2021
battery cell production, Li-ion, NMC622	GLO	Dai et al. 2019, Crenna et al. 2021
battery cell production, Li-ion, NMC811	GLO	Dai et al. 2019, Crenna et al. 2021
battery cell production, Li-ion, NCA	GLO	Dai et al. 2019, Crenna et al. 2021
battery cell production, Li-ion, LFP	GLO	Schmidt et al. 2019
battery cell production, Li-ion, LTO	GLO	Schmidt et al. 2019
battery cell production, Li-S	GLO	Wickerts et al. (2023)
battery cell production, Li-O2	GLO	Wang et al. (2020)
battery cell production, SIB	GLO	Zhang et al. (2024)

These battery inventories are mostly used by battery electric vehicles, stationary energy storage systems, etc. (also imported by *premise*).

NMC-111, NMC-811, LFP and NCA inventories can be found here: LCI_batteries1. NMC-622 and LTO inventories can be found here: LCI_batteries2. Li-S inventories can be found here: LCI_batteries3. Li-O2 inventories can be found here: LCI_batteries4. And SIB inventories can be found here: LCI_batteries5.

When using ecoinvent 3.9 and above, the NMC-111, NMC-811, LFP and NCA battery inventories are not imported (as are already present the ecoinvent database).

2.4.7 Graphite

premise includes new inventories for:

- natural graphite, from Engels et al. 2022,
- synthetic graphite, from Surovtseva et al. 2022,

forming a new market for graphite, with the following datasets:

Activity	Location	
market for graphite, battery grade		1.0
graphite, natural	CN	0.8
graphite, synthetic	CN	0.2

to represent a 80:20 split between natural and synthetic graphite, according to Surovtseva et al, 2022.

These inventories can be found here: LCI_graphite.

2.4.8 Cobalt

New inventories of cobalt are added, from the work of Dai, Kelly and Elgowainy, 2018. They are available under the following datasets:

Activity	Location
cobalt sulfate production, from copper mining, economic allocation	CN
cobalt sulfate production, from copper mining, energy allocation	CN
cobalt metal production, from copper mining, via electrolysis, economic allocation	CN
cobalt metal production, from copper mining, via electrolysis, energy allocation	CN

We recommend using those rather than the original ecoinvent inventories for cobalt, provided by the Cobalt Development Institute (CDI) since ecoinvent 3.7, which seem to lack transparency.

These inventories can be found here: LCI_cobalt.

2.4.9 Lithium

New inventories for lithium extraction are also added, from the work of Schenker et al., 2022. They cover lithium extraction from five different locations in Chile, Argentina and China. They are available under the following datasets for battery production:

Activity	Location
market for lithium carbonate, battery grade	GLO
market for lithium hydroxide, battery grade	GLO

These inventories can be found here: LCI_lithium.

2.4.10 Vanadium Redox Flow Batteries

premise imports inventories for the production of a vanadium redox flow battery, used for grid-balancing, from the work of Weber et al. 2021. It is available under the following dataset:

- vanadium-redox flow battery system assembly, 8.3 megawatt hour

The dataset providing electricity is the following:

- electricity supply, high voltage, from vanadium-redox flow battery system

The power capacity for this application is 1MW and the net storage capacity 6 MWh. The net capacity considers the internal inefficiencies of the batteries and the min Sate-of-Charge, requiring a certain oversizing of the batteries. For providing net 6 MWh, a nominal capacity of 8.3 MWh is required for the VRFB with the assumed operation parameters. The assumed lifetime of the stack is 10 years. The lifetime of the system is 20 years or 8176 cycle-life (49,000 MWh).

These inventories can be found here: LCI_vanadium_redox_flow_batteries.

This publication also provides LCIs for Vanadium mining and refining from iron ore. The end product is vanadium pentoxide, which is available under the following dataset:

- vanadium pentoxide production

These inventories can be found here: LCI_vanadium.

2.4.11 Road vehicles

premise imports inventories for different types of on-road vehicles.

2.4.11.1 Two-wheelers

The following datasets for two-wheelers are imported. Inventories are from Sacchi et al. 2022. The vehicles are available for different years and emission standards. *premise* will only import vehicles which production year is equal or inferior to the scenario year considered. The inventories can be consulted here: LCItwowheelers.

Two-wheeler datasets	location
transport, Kick Scooter, electric, <1kW	all IAM regions
transport, Bicycle, conventional, urban	all IAM regions
transport, Bicycle, electric (<25 km/h)	all IAM regions
transport, Bicycle, electric (<45 km/h)	all IAM regions
transport, Bicycle, electric, cargo bike	all IAM regions
transport, Moped, gasoline, <4kW, EURO-3	all IAM regions
transport, Moped, gasoline, <4kW, EURO-4	all IAM regions
transport, Moped, gasoline, <4kW, EURO-5	all IAM regions
transport, Scooter, gasoline, <4kW, EURO-3	all IAM regions
transport, Scooter, gasoline, <4kW, EURO-4	all IAM regions
transport, Scooter, gasoline, <4kW, EURO-5	all IAM regions
transport, Scooter, gasoline, 4-11kW, EURO-3	all IAM regions
transport, Scooter, gasoline, 4-11kW, EURO-4	all IAM regions
transport, Scooter, gasoline, 4-11kW, EURO-5	all IAM regions
transport, Scooter, electric, <4kW	all IAM regions
transport, Scooter, electric, 4-11kW	all IAM regions
transport, Motorbike, gasoline, 4-11kW, EURO-3	all IAM regions
transport, Motorbike, gasoline, 4-11kW, EURO-4	all IAM regions
transport, Motorbike, gasoline, 4-11kW, EURO-5	all IAM regions
transport, Motorbike, gasoline, 11-35kW, EURO-3	all IAM regions
transport, Motorbike, gasoline, 11-35kW, EURO-4	all IAM regions
transport, Motorbike, gasoline, 11-35kW, EURO-5	all IAM regions
transport, Motorbike, gasoline, >35kW, EURO-3	all IAM regions
transport, Motorbike, gasoline, >35kW, EURO-4	all IAM regions
transport, Motorbike, gasoline, >35kW, EURO-5	all IAM regions
transport, Motorbike, electric, <4kW	all IAM regions
transport, Motorbike, electric, 4-11kW	all IAM regions
transport, Motorbike, electric, 11-35kW	all IAM regions
transport, Motorbike, electric, >35kW	all IAM regions

These inventories do not supply inputs to other activities in the LCI database. As such, they are optional.

2.4.11.2 Passenger cars

The following datasets for passenger cars are imported.

Passenger car datasets	location
transport, passenger car, gasoline, Large, EURO-2	all IAM regions
transport, passenger car, gasoline, Large, EURO-3	all IAM regions
transport, passenger car, gasoline, Large, EURO-4	all IAM regions
transport, passenger car, gasoline, Large, EURO-6ab	all IAM regions
transport, passenger car, gasoline, Large, EURO-6d-TEMP	all IAM regions
transport, passenger car, gasoline, Large, EURO-6d	all IAM regions
transport, passenger car, diesel, Large, EURO-2	all IAM regions
transport, passenger car, diesel, Large, EURO-3	all IAM regions
transport, passenger car, diesel, Large, EURO-4	all IAM regions
transport, passenger car, diesel, Large, EURO-6ab	all IAM regions
transport, passenger car, diesel, Large, EURO-6d-TEMP	all IAM regions

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Passenger car datasets	location
transport, passenger car, diesel, Large, EURO-6d	all IAM regions
transport, passenger car, compressed gas, Large, EURO-2	all IAM regions
transport, passenger car, compressed gas, Large, EURO-3	all IAM regions
transport, passenger car, compressed gas, Large, EURO-4	all IAM regions
transport, passenger car, compressed gas, Large, EURO-6ab	all IAM regions
transport, passenger car, compressed gas, Large, EURO-6d-TEMP	all IAM regions
transport, passenger car, compressed gas, Large, EURO-6d	all IAM regions
transport, passenger car, plugin gasoline hybrid, Large, EURO-6ab	all IAM regions
transport, passenger car, plugin gasoline hybrid, Large, EURO-6d-TEMP	all IAM regions
transport, passenger car, plugin gasoline hybrid, Large, EURO-6d	all IAM regions
transport, passenger car, plugin diesel hybrid, Large, EURO-6ab	all IAM regions
transport, passenger car, plugin diesel hybrid, Large, EURO-6d-TEMP	all IAM regions
transport, passenger car, plugin diesel hybrid, Large, EURO-6d	all IAM regions
transport, passenger car, fuel cell electric, Large	all IAM regions
transport, passenger car, battery electric, NMC-622 battery, Large	all IAM regions
transport, passenger car, gasoline hybrid, Large, EURO-6ab	all IAM regions
transport, passenger car, gasoline hybrid, Large, EURO-6d-TEMP	all IAM regions
transport, passenger car, gasoline hybrid, Large, EURO-6d	all IAM regions
transport, passenger car, diesel hybrid, Large, EURO-6ab	all IAM regions
transport, passenger car, diesel hybrid, Large, EURO-6d-TEMP	all IAM regions
transport, passenger car, diesel hybrid, Large, EURO-6d	all IAM regions
transport, passenger car, gasoline, Large SUV, EURO-2	all IAM regions
transport, passenger car, gasoline, Large SUV, EURO-3	all IAM regions
transport, passenger car, gasoline, Large SUV, EURO-4	all IAM regions
transport, passenger car, gasoline, Large SUV, EURO-6ab	all IAM regions
transport, passenger car, gasoline, Large SUV, EURO-6d-TEMP	all IAM regions
transport, passenger car, gasoline, Large SUV, EURO-6d	all IAM regions
transport, passenger car, diesel, Large SUV, EURO-2	all IAM regions
transport, passenger car, diesel, Large SUV, EURO-3	all IAM regions
transport, passenger car, diesel, Large SUV, EURO-4	all IAM regions
transport, passenger car, diesel, Large SUV, EURO-6ab	all IAM regions
transport, passenger car, diesel, Large SUV, EURO-6d-TEMP	all IAM regions
transport, passenger car, diesel, Large SUV, EURO-6d	all IAM regions
transport, passenger car, compressed gas, Large SUV, EURO-2	all IAM regions
transport, passenger car, compressed gas, Large SUV, EURO-3	all IAM regions
transport, passenger car, compressed gas, Large SUV, EURO-4	all IAM regions
transport, passenger car, compressed gas, Large SUV, EURO-6ab	all IAM regions
transport, passenger car, compressed gas, Large SUV, EURO-6d-TEMP	all IAM regions
transport, passenger car, compressed gas, Large SUV, EURO-6d	all IAM regions
transport, passenger car, plugin gasoline hybrid, Large SUV, EURO-6ab	all IAM regions
transport, passenger car, plugin gasoline hybrid, Large SUV, EURO-6d-TEMP	all IAM regions
transport, passenger car, plugin gasoline hybrid, Large SUV, EURO-6d	all IAM regions
transport, passenger car, plugin diesel hybrid, Large SUV, EURO-6ab	all IAM regions
transport, passenger car, plugin diesel hybrid, Large SUV, EURO-6d-TEMP	all IAM regions
transport, passenger car, plugin diesel hybrid, Large SUV, EURO-6d	all IAM regions
transport, passenger car, fuel cell electric, Large SUV	all IAM regions
transport, passenger car, battery electric, NMC-622 battery, Large SUV	all IAM regions
transport, passenger car, gasoline hybrid, Large SUV, EURO-6ab	all IAM regions
transport, passenger car, gasoline hybrid, Large SUV, EURO-6d-TEMP	all IAM regions
transport, passenger car, gasoline hybrid, Large SUV, EURO-6d	all IAM regions

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Table 5 – continued from previous page

Passenger car datasets	location
transport, passenger car, diesel hybrid, Large SUV, EURO-6ab	all IAM regions
transport, passenger car, diesel hybrid, Large SUV, EURO-6d-TEMP	all IAM regions
transport, passenger car, diesel hybrid, Large SUV, EURO-6d	all IAM regions
transport, passenger car, gasoline, Lower medium, EURO-2	all IAM regions
transport, passenger car, gasoline, Lower medium, EURO-3	all IAM regions
transport, passenger car, gasoline, Lower medium, EURO-4	all IAM regions
transport, passenger car, gasoline, Lower medium, EURO-6ab	all IAM regions
transport, passenger car, gasoline, Lower medium, EURO-6d-TEMP	all IAM regions
transport, passenger car, gasoline, Lower medium, EURO-6d	all IAM regions
transport, passenger car, diesel, Lower medium, EURO-2	all IAM regions
transport, passenger car, diesel, Lower medium, EURO-3	all IAM regions
transport, passenger car, diesel, Lower medium, EURO-4	all IAM regions
transport, passenger car, diesel, Lower medium, EURO-6ab	all IAM regions
transport, passenger car, diesel, Lower medium, EURO-6d-TEMP	all IAM regions
transport, passenger car, diesel, Lower medium, EURO-6d	all IAM regions
transport, passenger car, compressed gas, Lower medium, EURO-2	all IAM regions
transport, passenger car, compressed gas, Lower medium, EURO-3	all IAM regions
transport, passenger car, compressed gas, Lower medium, EURO-4	all IAM regions
transport, passenger car, compressed gas, Lower medium, EURO-6ab	all IAM regions
transport, passenger car, compressed gas, Lower medium, EURO-6d-TEMP	all IAM regions
transport, passenger car, compressed gas, Lower medium, EURO-6d	all IAM regions
transport, passenger car, plugin gasoline hybrid, Lower medium, EURO-6ab	all IAM regions
transport, passenger car, plugin gasoline hybrid, Lower medium, EURO-6d-TEMP	all IAM regions
transport, passenger car, plugin gasoline hybrid, Lower medium, EURO-6d	all IAM regions
transport, passenger car, plugin diesel hybrid, Lower medium, EURO-6ab	all IAM regions
transport, passenger car, plugin diesel hybrid, Lower medium, EURO-6d-TEMP	all IAM regions
transport, passenger car, plugin diesel hybrid, Lower medium, EURO-6d	all IAM regions
transport, passenger car, fuel cell electric, Lower medium	all IAM regions
transport, passenger car, battery electric, NMC-622 battery, Lower medium	all IAM regions
transport, passenger car, gasoline hybrid, Lower medium, EURO-6ab	all IAM regions
transport, passenger car, gasoline hybrid, Lower medium, EURO-6d-TEMP	all IAM regions
transport, passenger car, gasoline hybrid, Lower medium, EURO-6d	all IAM regions
transport, passenger car, diesel hybrid, Lower medium, EURO-6ab	all IAM regions
transport, passenger car, diesel hybrid, Lower medium, EURO-6d-TEMP	all IAM regions
transport, passenger car, diesel hybrid, Lower medium, EURO-6d	all IAM regions
transport, passenger car, gasoline, Medium, EURO-2	all IAM regions
transport, passenger car, gasoline, Medium, EURO-3	all IAM regions
transport, passenger car, gasoline, Medium, EURO-4	all IAM regions
transport, passenger car, gasoline, Medium, EURO-6ab	all IAM regions
transport, passenger car, gasoline, Medium, EURO-6d-TEMP	all IAM regions
transport, passenger car, gasoline, Medium, EURO-6d	all IAM regions
transport, passenger car, diesel, Medium, EURO-2	all IAM regions
transport, passenger car, diesel, Medium, EURO-3	all IAM regions
transport, passenger car, diesel, Medium, EURO-4	all IAM regions
transport, passenger car, diesel, Medium, EURO-6ab	all IAM regions
transport, passenger car, diesel, Medium, EURO-6d-TEMP	all IAM regions
transport, passenger car, diesel, Medium, EURO-6d	all IAM regions
transport, passenger car, compressed gas, Medium, EURO-2	all IAM regions
transport, passenger car, compressed gas, Medium, EURO-3	all IAM regions
transport, passenger car, compressed gas, Medium, EURO-4	all IAM regions

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Table 5 – continued from previous page

Passenger car datasets	location
transport, passenger car, compressed gas, Medium, EURO-6ab	all IAM regions
transport, passenger car, compressed gas, Medium, EURO-6d-TEMP	all IAM regions
transport, passenger car, compressed gas, Medium, EURO-6d	all IAM regions
transport, passenger car, plugin gasoline hybrid, Medium, EURO-6ab	all IAM regions
transport, passenger car, plugin gasoline hybrid, Medium, EURO-6d-TEMP	all IAM regions
transport, passenger car, plugin gasoline hybrid, Medium, EURO-6d	all IAM regions
transport, passenger car, plugin diesel hybrid, Medium, EURO-6ab	all IAM regions
transport, passenger car, plugin diesel hybrid, Medium, EURO-6d-TEMP	all IAM regions
transport, passenger car, plugin diesel hybrid, Medium, EURO-6d	all IAM regions
transport, passenger car, fuel cell electric, Medium	all IAM regions
transport, passenger car, battery electric, NMC-622 battery, Medium	all IAM regions
transport, passenger car, gasoline hybrid, Medium, EURO-6ab	all IAM regions
transport, passenger car, gasoline hybrid, Medium, EURO-6d-TEMP	all IAM regions
transport, passenger car, gasoline hybrid, Medium, EURO-6d	all IAM regions
transport, passenger car, diesel hybrid, Medium, EURO-6ab	all IAM regions
transport, passenger car, diesel hybrid, Medium, EURO-6d-TEMP	all IAM regions
transport, passenger car, diesel hybrid, Medium, EURO-6d	all IAM regions
transport, passenger car, gasoline, Medium SUV, EURO-2	all IAM regions
transport, passenger car, gasoline, Medium SUV, EURO-3	all IAM regions
transport, passenger car, gasoline, Medium SUV, EURO-4	all IAM regions
transport, passenger car, gasoline, Medium SUV, EURO-6ab	all IAM regions
transport, passenger car, gasoline, Medium SUV, EURO-6d-TEMP	all IAM regions
transport, passenger car, gasoline, Medium SUV, EURO-6d	all IAM regions
transport, passenger car, diesel, Medium SUV, EURO-2	all IAM regions
transport, passenger car, diesel, Medium SUV, EURO-3	all IAM regions
transport, passenger car, diesel, Medium SUV, EURO-4	all IAM regions
transport, passenger car, diesel, Medium SUV, EURO-6ab	all IAM regions
transport, passenger car, diesel, Medium SUV, EURO-6d-TEMP	all IAM regions
transport, passenger car, diesel, Medium SUV, EURO-6d	all IAM regions
transport, passenger car, compressed gas, Medium SUV, EURO-2	all IAM regions
transport, passenger car, compressed gas, Medium SUV, EURO-3	all IAM regions
transport, passenger car, compressed gas, Medium SUV, EURO-4	all IAM regions
transport, passenger car, compressed gas, Medium SUV, EURO-6ab	all IAM regions
transport, passenger car, compressed gas, Medium SUV, EURO-6d-TEMP	all IAM regions
transport, passenger car, compressed gas, Medium SUV, EURO-6d	all IAM regions
transport, passenger car, plugin gasoline hybrid, Medium SUV, EURO-6ab	all IAM regions
transport, passenger car, plugin gasoline hybrid, Medium SUV, EURO-6d-TEMP	all IAM regions
transport, passenger car, plugin gasoline hybrid, Medium SUV, EURO-6d	all IAM regions
transport, passenger car, plugin diesel hybrid, Medium SUV, EURO-6ab	all IAM regions
transport, passenger car, plugin diesel hybrid, Medium SUV, EURO-6d-TEMP	all IAM regions
transport, passenger car, plugin diesel hybrid, Medium SUV, EURO-6d	all IAM regions
transport, passenger car, fuel cell electric, Medium SUV	all IAM regions
transport, passenger car, battery electric, NMC-622 battery, Medium SUV	all IAM regions
transport, passenger car, gasoline hybrid, Medium SUV, EURO-6ab	all IAM regions
transport, passenger car, gasoline hybrid, Medium SUV, EURO-6d-TEMP	all IAM regions
transport, passenger car, gasoline hybrid, Medium SUV, EURO-6d	all IAM regions
transport, passenger car, diesel hybrid, Medium SUV, EURO-6ab	all IAM regions
transport, passenger car, diesel hybrid, Medium SUV, EURO-6d-TEMP	all IAM regions
transport, passenger car, diesel hybrid, Medium SUV, EURO-6d	all IAM regions
transport, passenger car, battery electric, NMC-622 battery, Micro	all IAM regions

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Table 5 – continued from previous page

Passenger car datasets	location
transport, passenger car, gasoline, Mini, EURO-2	all IAM regions
transport, passenger car, gasoline, Mini, EURO-3	all IAM regions
transport, passenger car, gasoline, Mini, EURO-4	all IAM regions
transport, passenger car, gasoline, Mini, EURO-6ab	all IAM regions
transport, passenger car, gasoline, Mini, EURO-6d-TEMP	all IAM regions
transport, passenger car, gasoline, Mini, EURO-6d	all IAM regions
transport, passenger car, diesel, Mini, EURO-2	all IAM regions
transport, passenger car, diesel, Mini, EURO-3	all IAM regions
transport, passenger car, diesel, Mini, EURO-4	all IAM regions
transport, passenger car, diesel, Mini, EURO-6ab	all IAM regions
transport, passenger car, diesel, Mini, EURO-6d-TEMP	all IAM regions
transport, passenger car, diesel, Mini, EURO-6d	all IAM regions
transport, passenger car, compressed gas, Mini, EURO-2	all IAM regions
transport, passenger car, compressed gas, Mini, EURO-3	all IAM regions
transport, passenger car, compressed gas, Mini, EURO-4	all IAM regions
transport, passenger car, compressed gas, Mini, EURO-6ab	all IAM regions
transport, passenger car, compressed gas, Mini, EURO-6d-TEMP	all IAM regions
transport, passenger car, compressed gas, Mini, EURO-6d	all IAM regions
transport, passenger car, plugin gasoline hybrid, Mini, EURO-6ab	all IAM regions
transport, passenger car, plugin gasoline hybrid, Mini, EURO-6d-TEMP	all IAM regions
transport, passenger car, plugin gasoline hybrid, Mini, EURO-6d	all IAM regions
transport, passenger car, plugin diesel hybrid, Mini, EURO-6ab	all IAM regions
transport, passenger car, plugin diesel hybrid, Mini, EURO-6d-TEMP	all IAM regions
transport, passenger car, plugin diesel hybrid, Mini, EURO-6d	all IAM regions
transport, passenger car, fuel cell electric, Mini	all IAM regions
transport, passenger car, battery electric, NMC-622 battery, Mini	all IAM regions
transport, passenger car, gasoline hybrid, Mini, EURO-6ab	all IAM regions
transport, passenger car, gasoline hybrid, Mini, EURO-6d-TEMP	all IAM regions
transport, passenger car, gasoline hybrid, Mini, EURO-6d	all IAM regions
transport, passenger car, diesel hybrid, Mini, EURO-6ab	all IAM regions
transport, passenger car, diesel hybrid, Mini, EURO-6d-TEMP	all IAM regions
transport, passenger car, diesel hybrid, Mini, EURO-6d	all IAM regions
transport, passenger car, gasoline, Small, EURO-2	all IAM regions
transport, passenger car, gasoline, Small, EURO-3	all IAM regions
transport, passenger car, gasoline, Small, EURO-4	all IAM regions
transport, passenger car, gasoline, Small, EURO-6ab	all IAM regions
transport, passenger car, gasoline, Small, EURO-6d-TEMP	all IAM regions
transport, passenger car, gasoline, Small, EURO-6d	all IAM regions
transport, passenger car, diesel, Small, EURO-2	all IAM regions
transport, passenger car, diesel, Small, EURO-3	all IAM regions
transport, passenger car, diesel, Small, EURO-4	all IAM regions
transport, passenger car, diesel, Small, EURO-6ab	all IAM regions
transport, passenger car, diesel, Small, EURO-6d-TEMP	all IAM regions
transport, passenger car, diesel, Small, EURO-6d	all IAM regions
transport, passenger car, compressed gas, Small, EURO-2	all IAM regions
transport, passenger car, compressed gas, Small, EURO-3	all IAM regions
transport, passenger car, compressed gas, Small, EURO-4	all IAM regions
transport, passenger car, compressed gas, Small, EURO-6ab	all IAM regions
transport, passenger car, compressed gas, Small, EURO-6d-TEMP	all IAM regions
transport, passenger car, compressed gas, Small, EURO-6d	all IAM regions

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Table 5 – continued from previous page

Passenger car datasets	location
transport, passenger car, plugin gasoline hybrid, Small, EURO-6ab	all IAM regions
transport, passenger car, plugin gasoline hybrid, Small, EURO-6d-TEMP	all IAM regions
transport, passenger car, plugin gasoline hybrid, Small, EURO-6d	all IAM regions
transport, passenger car, plugin diesel hybrid, Small, EURO-6ab	all IAM regions
transport, passenger car, plugin diesel hybrid, Small, EURO-6d-TEMP	all IAM regions
transport, passenger car, plugin diesel hybrid, Small, EURO-6d	all IAM regions
transport, passenger car, fuel cell electric, Small	all IAM regions
transport, passenger car, battery electric, NMC-622 battery, Small	all IAM regions
transport, passenger car, gasoline hybrid, Small, EURO-6ab	all IAM regions
transport, passenger car, gasoline hybrid, Small, EURO-6d-TEMP	all IAM regions
transport, passenger car, gasoline hybrid, Small, EURO-6d	all IAM regions
transport, passenger car, diesel hybrid, Small, EURO-6ab	all IAM regions
transport, passenger car, diesel hybrid, Small, EURO-6d-TEMP	all IAM regions
transport, passenger car, diesel hybrid, Small, EURO-6d	all IAM regions
transport, passenger car, gasoline, Van, EURO-2	all IAM regions
transport, passenger car, gasoline, Van, EURO-3	all IAM regions
transport, passenger car, gasoline, Van, EURO-4	all IAM regions
transport, passenger car, gasoline, Van, EURO-6ab	all IAM regions
transport, passenger car, gasoline, Van, EURO-6d-TEMP	all IAM regions
transport, passenger car, gasoline, Van, EURO-6d	all IAM regions
transport, passenger car, diesel, Van, EURO-2	all IAM regions
transport, passenger car, diesel, Van, EURO-3	all IAM regions
transport, passenger car, diesel, Van, EURO-4	all IAM regions
transport, passenger car, diesel, Van, EURO-6ab	all IAM regions
transport, passenger car, diesel, Van, EURO-6d-TEMP	all IAM regions
transport, passenger car, diesel, Van, EURO-6d	all IAM regions
transport, passenger car, compressed gas, Van, EURO-2	all IAM regions
transport, passenger car, compressed gas, Van, EURO-3	all IAM regions
transport, passenger car, compressed gas, Van, EURO-4	all IAM regions
transport, passenger car, compressed gas, Van, EURO-6ab	all IAM regions
transport, passenger car, compressed gas, Van, EURO-6d-TEMP	all IAM regions
transport, passenger car, compressed gas, Van, EURO-6d	all IAM regions
transport, passenger car, plugin gasoline hybrid, Van, EURO-6ab	all IAM regions
transport, passenger car, plugin gasoline hybrid, Van, EURO-6d-TEMP	all IAM regions
transport, passenger car, plugin gasoline hybrid, Van, EURO-6d	all IAM regions
transport, passenger car, plugin diesel hybrid, Van, EURO-6ab	all IAM regions
transport, passenger car, plugin diesel hybrid, Van, EURO-6d-TEMP	all IAM regions
transport, passenger car, plugin diesel hybrid, Van, EURO-6d	all IAM regions
transport, passenger car, fuel cell electric, Van	all IAM regions
transport, passenger car, battery electric, NMC-622 battery, Van	all IAM regions
transport, passenger car, gasoline hybrid, Van, EURO-6ab	all IAM regions
transport, passenger car, gasoline hybrid, Van, EURO-6d-TEMP	all IAM regions
transport, passenger car, gasoline hybrid, Van, EURO-6d	all IAM regions
transport, passenger car, diesel hybrid, Van, EURO-6ab	all IAM regions
transport, passenger car, diesel hybrid, Van, EURO-6d-TEMP	all IAM regions
transport, passenger car, diesel hybrid, Van, EURO-6d	all IAM regions

Inventories are from Sacchi2 et al. 2022. The vehicles are available for different years and emission standards and for each IAM region. *premise* will only import vehicles which production year is equal or inferior to the scenario year considered. *premise* will create fleet average vehicles during the *Transport* transformation for each IAM region. The inventories can be consulted here: LCIpasscars.

At the moment. these inventories do not supply inputs to other activities in the LCI database. As such, they are optional.

2.4.11.3 Medium and heavy duty trucks

The following datasets for medium and heavy-duty trucks are imported.

Truck datasets	location
transport, freight, lorry, battery electric, NMC-622 battery, 3.5t gross weight	all IAM regions
transport, freight, lorry, fuel cell electric, 3.5t gross weight	all IAM regions
transport, freight, lorry, diesel hybrid, 3.5t gross weight, EURO-VI	all IAM regions
transport, freight, lorry, diesel, 3.5t gross weight, EURO-III	all IAM regions
transport, freight, lorry, diesel, 3.5t gross weight, EURO-IV	all IAM regions
transport, freight, lorry, diesel, 3.5t gross weight, EURO-V	all IAM regions
transport, freight, lorry, diesel, 3.5t gross weight, EURO-VI	all IAM regions
transport, freight, lorry, compressed gas, 3.5t gross weight, EURO-III	all IAM regions
transport, freight, lorry, compressed gas, 3.5t gross weight, EURO-IV	all IAM regions
transport, freight, lorry, compressed gas, 3.5t gross weight, EURO-V	all IAM regions
transport, freight, lorry, compressed gas, 3.5t gross weight, EURO-VI	all IAM regions
transport, freight, lorry, plugin diesel hybrid, 3.5t gross weight, EURO-VI	all IAM regions
transport, freight, lorry, battery electric, NMC-622 battery, 7.5t gross weight	all IAM regions
transport, freight, lorry, fuel cell electric, 7.5t gross weight	all IAM regions
transport, freight, lorry, diesel hybrid, 7.5t gross weight, EURO-VI	all IAM regions
transport, freight, lorry, diesel, 7.5t gross weight, EURO-III	all IAM regions
transport, freight, lorry, diesel, 7.5t gross weight, EURO-IV	all IAM regions
transport, freight, lorry, diesel, 7.5t gross weight, EURO-V	all IAM regions
transport, freight, lorry, diesel, 7.5t gross weight, EURO-VI	all IAM regions
transport, freight, lorry, compressed gas, 7.5t gross weight, EURO-III	all IAM regions
transport, freight, lorry, compressed gas, 7.5t gross weight, EURO-IV	all IAM regions
transport, freight, lorry, compressed gas, 7.5t gross weight, EURO-V	all IAM regions
transport, freight, lorry, compressed gas, 7.5t gross weight, EURO-VI	all IAM regions
transport, freight, lorry, plugin diesel hybrid, 7.5t gross weight, EURO-VI	all IAM regions
transport, freight, lorry, battery electric, NMC-622 battery, 18t gross weight	all IAM regions
transport, freight, lorry, fuel cell electric, 18t gross weight	all IAM regions
transport, freight, lorry, diesel hybrid, 18t gross weight, EURO-VI	all IAM regions
transport, freight, lorry, diesel, 18t gross weight, EURO-III	all IAM regions
transport, freight, lorry, diesel, 18t gross weight, EURO-IV	all IAM regions
transport, freight, lorry, diesel, 18t gross weight, EURO-V	all IAM regions
transport, freight, lorry, diesel, 18t gross weight, EURO-VI	all IAM regions
transport, freight, lorry, compressed gas, 18t gross weight, EURO-III	all IAM regions
transport, freight, lorry, compressed gas, 18t gross weight, EURO-IV	all IAM regions
transport, freight, lorry, compressed gas, 18t gross weight, EURO-V	all IAM regions
transport, freight, lorry, compressed gas, 18t gross weight, EURO-VI	all IAM regions
transport, freight, lorry, plugin diesel hybrid, 18t gross weight, EURO-VI	all IAM regions
transport, freight, lorry, battery electric, NMC-622 battery, 26t gross weight	all IAM regions
transport, freight, lorry, fuel cell electric, 26t gross weight	all IAM regions
transport, freight, lorry, diesel hybrid, 26t gross weight, EURO-VI	all IAM regions
transport, freight, lorry, diesel, 26t gross weight, EURO-III	all IAM regions
transport, freight, lorry, diesel, 26t gross weight, EURO-IV	all IAM regions
transport, freight, lorry, diesel, 26t gross weight, EURO-V	all IAM regions

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Table 6 – continued from previous page

Truck datasets	location
transport, freight, lorry, diesel, 26t gross weight, EURO-VI	all IAM regions
transport, freight, lorry, compressed gas, 26t gross weight, EURO-III	all IAM regions
transport, freight, lorry, compressed gas, 26t gross weight, EURO-IV	all IAM regions
transport, freight, lorry, compressed gas, 26t gross weight, EURO-V	all IAM regions
transport, freight, lorry, compressed gas, 26t gross weight, EURO-VI	all IAM regions
transport, freight, lorry, plugin diesel hybrid, 26t gross weight, EURO-VI	all IAM regions
transport, freight, lorry, battery electric, NMC-622 battery, 32t gross weight	all IAM regions
transport, freight, lorry, fuel cell electric, 32t gross weight	all IAM regions
transport, freight, lorry, diesel hybrid, 32t gross weight, EURO-VI	all IAM regions
transport, freight, lorry, diesel, 32t gross weight, EURO-III	all IAM regions
transport, freight, lorry, diesel, 32t gross weight, EURO-IV	all IAM regions
transport, freight, lorry, diesel, 32t gross weight, EURO-V	all IAM regions
transport, freight, lorry, diesel, 32t gross weight, EURO-VI	all IAM regions
transport, freight, lorry, compressed gas, 32t gross weight, EURO-III	all IAM regions
transport, freight, lorry, compressed gas, 32t gross weight, EURO-IV	all IAM regions
transport, freight, lorry, compressed gas, 32t gross weight, EURO-V	all IAM regions
transport, freight, lorry, compressed gas, 32t gross weight, EURO-VI	all IAM regions
transport, freight, lorry, plugin diesel hybrid, 32t gross weight, EURO-VI	all IAM regions
transport, freight, lorry, battery electric, NMC-622 battery, 40t gross weight	all IAM regions
transport, freight, lorry, fuel cell electric, 40t gross weight	all IAM regions
transport, freight, lorry, diesel hybrid, 40t gross weight, EURO-VI	all IAM regions
transport, freight, lorry, diesel, 40t gross weight, EURO-III	all IAM regions
transport, freight, lorry, diesel, 40t gross weight, EURO-IV	all IAM regions
transport, freight, lorry, diesel, 40t gross weight, EURO-V	all IAM regions
transport, freight, lorry, diesel, 40t gross weight, EURO-VI	all IAM regions
transport, freight, lorry, compressed gas, 40t gross weight, EURO-III	all IAM regions
transport, freight, lorry, compressed gas, 40t gross weight, EURO-IV	all IAM regions
transport, freight, lorry, compressed gas, 40t gross weight, EURO-V	all IAM regions
transport, freight, lorry, compressed gas, 40t gross weight, EURO-VI	all IAM regions
transport, freight, lorry, plugin diesel hybrid, 40t gross weight, EURO-VI	all IAM regions

Inventories are from Sacchi3 et al. 2021. The vehicles are available for different years and emission standards and for each IAM region. *premise* will only import vehicles which production year is equal or inferior to the scenario year considered. *premise* will create fleet average vehicles during the *Transport* transformation for each IAM region. The inventories can be consulted here: LCItrucks.

2.4.11.4 Buses

The following datasets for city and coach buses are imported.

transport, passenger bus, battery electric - overnight charging, NMC-622 battery, 9m midibus	all IAM regio
transport, passenger bus, battery electric - opportunity charging, LTO battery, 9m midibus	all IAM regio
transport, passenger bus, fuel cell electric, 9m midibus	all IAM regio
transport, passenger bus, diesel hybrid, 9m midibus, EURO-VI	all IAM regio
transport, passenger bus, diesel, 9m midibus, EURO-III	all IAM regio
transport, passenger bus, diesel, 9m midibus, EURO-IV	all IAM regio

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transport, passenger bus, diesel, 9m midibus, EURO-V	all IAM regio
transport, passenger bus, diesel, 9m midibus, EURO-VI	all IAM regio
transport, passenger bus, compressed gas, 9m midibus, EURO-III	all IAM regio
transport, passenger bus, compressed gas, 9m midibus, EURO-IV	all IAM regio
transport, passenger bus, compressed gas, 9m midibus, EURO-V	all IAM regio
transport, passenger bus, compressed gas, 9m midibus, EURO-VI	all IAM regio
transport, passenger bus, battery electric - overnight charging, NMC-622 battery, 13m single deck urban bus	all IAM regio
transport, passenger bus, battery electric - battery-equipped trolleybus, LTO battery, 13m single deck urban bus	all IAM regio
transport, passenger bus, battery electric - opportunity charging, LTO battery, 13m single deck urban bus	all IAM regio
transport, passenger bus, fuel cell electric, 13m single deck urban bus	all IAM regio
transport, passenger bus, diesel hybrid, 13m single deck urban bus, EURO-VI	all IAM regio
transport, passenger bus, diesel, 13m single deck urban bus, EURO-III	all IAM regio
transport, passenger bus, diesel, 13m single deck urban bus, EURO-IV	all IAM regio
transport, passenger bus, diesel, 13m single deck urban bus, EURO-V	all IAM regio
transport, passenger bus, diesel, 13m single deck urban bus, EURO-VI	all IAM regio
transport, passenger bus, compressed gas, 13m single deck urban bus, EURO-III	all IAM regio
transport, passenger bus, compressed gas, 13m single deck urban bus, EURO-IV	all IAM regio
transport, passenger bus, compressed gas, 13m single deck urban bus, EURO-V	all IAM regio
transport, passenger bus, compressed gas, 13m single deck urban bus, EURO-VI	all IAM regio
transport, passenger bus, fuel cell electric, 13m single deck coach bus	all IAM regio
transport, passenger bus, diesel hybrid, 13m single deck coach bus, EURO-VI	all IAM regio
transport, passenger bus, diesel, 13m single deck coach bus, EURO-III	all IAM regio
transport, passenger bus, diesel, 13m single deck coach bus, EURO-IV	all IAM regio
transport, passenger bus, diesel, 13m single deck coach bus, EURO-V	all IAM regio
transport, passenger bus, diesel, 13m single deck coach bus, EURO-VI	all IAM regio
transport, passenger bus, compressed gas, 13m single deck coach bus, EURO-III	all IAM regio
transport, passenger bus, compressed gas, 13m single deck coach bus, EURO-IV	all IAM regio
transport, passenger bus, compressed gas, 13m single deck coach bus, EURO-V	all IAM regio
transport, passenger bus, compressed gas, 13m single deck coach bus, EURO-VI	all IAM regio
transport, passenger bus, battery electric - overnight charging, NMC-622 battery, 13m double deck urban bus	all IAM regio
transport, passenger bus, battery electric - opportunity charging, LTO battery, 13m double deck urban bus	all IAM regio
transport, passenger bus, fuel cell electric, 13m double deck urban bus	all IAM regio
transport, passenger bus, diesel hybrid, 13m double deck urban bus, EURO-VI	all IAM regio
transport, passenger bus, diesel, 13m double deck urban bus, EURO-III	all IAM regio
transport, passenger bus, diesel, 13m double deck urban bus, EURO-IV	all IAM regio
transport, passenger bus, diesel, 13m double deck urban bus, EURO-V	all IAM regio
transport, passenger bus, diesel, 13m double deck urban bus, EURO-VI	all IAM regio
transport, passenger bus, compressed gas, 13m double deck urban bus, EURO-III	all IAM regio
transport, passenger bus, compressed gas, 13m double deck urban bus, EURO-IV	all IAM regio
transport, passenger bus, compressed gas, 13m double deck urban bus, EURO-V	all IAM regio
transport, passenger bus, compressed gas, 13m double deck urban bus, EURO-VI	all IAM regio
transport, passenger bus, fuel cell electric, 13m double deck coach bus	all IAM regio
transport, passenger bus, diesel hybrid, 13m double deck coach bus, EURO-VI	all IAM regio
transport, passenger bus, diesel, 13m double deck coach bus, EURO-III	all IAM regio
transport, passenger bus, diesel, 13m double deck coach bus, EURO-IV	all IAM regio
transport, passenger bus, diesel, 13m double deck coach bus, EURO-V	all IAM regio
transport, passenger bus, diesel, 13m double deck coach bus, EURO-VI	all IAM regio
transport, passenger bus, compressed gas, 13m double deck coach bus, EURO-III	all IAM regio
transport, passenger bus, compressed gas, 13m double deck coach bus, EURO-IV	all IAM regio
transport, passenger bus, compressed gas, 13m double deck coach bus, EURO-V	all IAM regio
transport, passenger bus, compressed gas, 13m double deck coach bus, EURO-VI	all IAM regio
transport, passenger bus, battery electric - overnight charging, NMC-622 battery, 18m articulated urban bus	all IAM regio

continues on next pag

Table 7 – continued from previous page

transport, passenger bus, battery electric - battery-equipped trolleybus, LTO battery, 18m articulated urban bus	all IAM regio
transport, passenger bus, battery electric - opportunity charging, LTO battery, 18m articulated urban bus	all IAM regio
transport, passenger bus, fuel cell electric, 18m articulated urban bus	all IAM regio
transport, passenger bus, diesel hybrid, 18m articulated urban bus, EURO-VI	all IAM regio
transport, passenger bus, diesel, 18m articulated urban bus, EURO-III	all IAM regio
transport, passenger bus, diesel, 18m articulated urban bus, EURO-IV	all IAM regio
transport, passenger bus, diesel, 18m articulated urban bus, EURO-V	all IAM regio
transport, passenger bus, diesel, 18m articulated urban bus, EURO-VI	all IAM regio
transport, passenger bus, compressed gas, 18m articulated urban bus, EURO-III	all IAM regio
transport, passenger bus, compressed gas, 18m articulated urban bus, EURO-IV	all IAM regio
transport, passenger bus, compressed gas, 18m articulated urban bus, EURO-V	all IAM regio
transport, passenger bus, compressed gas, 18m articulated urban bus, EURO-VI	all IAM regio

Inventories are from Sacchi et al. 2021. The vehicles are available for different years and emission standards and for each IAM region. *premise* will only import vehicles which production year is equal or inferior to the scenario year considered. *premise* will create fleet average vehicles during the *Transport* transformation for each IAM region. The inventories can be consulted here: LCIbuses.

At the moment. these inventories do not supply inputs to other activities in the LCI database. As such, they are optional.

2.4.12 Migration between ecoinvent versions

Because the additional inventories that are imported may be composed of exchanges meant to link with an ecoinvent version different than what the user specifies to *premise* upon the database creation, it is necessary to be able to "translate" the imported inventories so that they correctly link to any ecoinvent version *premise* is compatible with.

Therefore, *premise* has a migration map that is used to convert certain exchanges to be compatible with a given ecoinvent version.

This migration map is provided here: migrationmap.

2.5 IAM data collection

After extracting the ecoinvent database and additional inventories, *premise* instantiates the class *IAMDataCollection*, which collects all sorts of data from the IAM output file and store it into multi-dimensional arrays.

2.5.1 Production volumes

Production volumes for different commodities are collected, for the year and scenario specified by the user. Production volumes are used to build regional markets. For example, for the global market, the volume-based shares of each region are used to reflect their respective supply importance. Another example is for building electricity markets: the respective production volumes of each electricity-producing technology is used to determine the gross supply mix of the market.

The table below shows a non-exhaustive list of correspondences between *premise*, REMIND, IMAGE and LCI terminology, regarding electricity producing technologies. *premise* production volumes given for secondary energy carriers for electricity. The mapping file is available in the library root folder: **mappingElec_**.

name in premise	name in REMIND	name in IMAGE	name in LCI database (only first of several shown)
Biomass CHP	SE|Electricity|Bior CCS	Secondary Energy|Electricity|Biomas CCS|3	heat and power co-generation, wood chips
Biomass CHP CCS		Secondary Energy|Electricity|Biomas CCS|2	electricity production, at co-generation power plant/wood, post, pipeline 200km, storage 1000m
Biomass ST		Secondary Energy|Electricity|Biomas CCS|1	electricity production, at wood burning power plant 20 MW, truck 25km, no CCS
Biomass IGCC CCS	SE|Electricity|Bior CCS	Secondary Energy|Electricity|Biomas CCS|1	electricity production, from CC plant, 100% SNG, truck 25km, post, pipeline 200km, storage 1000m
Biomass IGCC	SE|Electricity|Bior CCS	Secondary Energy|Electricity|Biomas CCS|2	electricity production, at BIGCC power plant 450MW, no CCS
Coal PC	SE|Electricity|Coal CCS	Secondary Energy|Electricity|Coal|w/ CCS|1	electricity production, hard coal
Coal IGCC	SE|Electricity|Coal CCS	Secondary Energy|Electricity|Coal|w/ CCS|2	electricity production, at power plant/hard coal, IGCC, no CCS
Coal PC CCS	SE|Electricity|Coal CCS		electricity production, at power plant/hard coal, post, pipeline 200km, storage 1000m
Coal IGCC CCS	SE|Electricity|Coal CCS	Secondary Energy|Electricity|Coal|w/ CCS|1	electricity production, at power plant/hard coal, pre, pipeline 200km, storage 1000m
Coal CHP	SE|Electricity|Coal CCS	Secondary Energy|Electricity|Coal|w/ CCS|3	heat and power co-generation, hard coal
Coal CHP CCS		Secondary Energy|Electricity|Coal|w/ CCS|2	electricity production, at co-generation power plant/hard coal, oxy, pipeline
Gas OC	SE|Electricity|Gas|	Secondary Energy|Electricity|Gas|w/c CCS|1	electricity production, natural gas, conventional power plant
Gas CC	SE|Electricity|Gas| CCS	Secondary Energy|Electricity|Gas|w/c CCS|2	electricity production, natural gas, combined cycle power plant
Gas CHP	SE|Electricity|Gas| CCS	Secondary Energy|Electricity|Gas|w/c CCS|3	heat and power co-generation, natural gas, combined cycle power plant, 400MW electrical
Gas CHP CCS		Secondary Energy|Electricity|Gas|w/ CCS|2	electricity production, at co-generation power plant/natural gas, post, pipeline
Gas CC CCS	SE|Electricity|Gas| CCS	Secondary Energy|Electricity|Gas|w/ CCS|1	electricity production, at power plant/natural gas, pre, pipeline
Geothermal	SE|Electricity|Geo	Secondary Energy|Electricity|Other	electricity production, deep geothermal
Hydro	SE|Electricity|Hyd	Secondary Energy|Electricity|Hydro	electricity production, hydro, reservoir
Nuclear	SE|Electricity|Nucl	Secondary Energy|Electricity|Nuclear	electricity production, nuclear
Oil ST	SE|Electricity|Oil|v CCS	Secondary Energy|Electricity|Oil|w/o CCS|1	electricity production, oil
Oil CC		Secondary En-	electricity production, oil

Note: IAMs do not necessarily display the same variety of technologies. For example, REMIND does not provide a variable for residential PV production while IMAGE does.

Note: Because of a lack of more diverse inventories, wind power is only represented with relatively small installations (< 1MW, 1-3 MW and >3 MW), in respect to today's standard. This can lead to overestimate the associated environmental burden.

The table below shows the correspondence between *premise*, REMIND, IMAGE and LCI terminology, regarding steel and cement producing technologies. The mapping files are available in the library root folder: mappingCement and mappingSteel.

name in premise	name in REMIND	name in IMAGE	name in LCI database
cement	Production|Industry|Cement	Production|Cement	cement production, Portland
steel - primary	Production|Industry|Steel|Primary	Production|Steel|Primary	steel production, converter
steel - secondary	Production|Industry|Steel|Secondary	Production|Steel|Secondary	steel production, electric

The table below shows the correspondence between *premise*, REMIND, IMAGE and LCI terminology, regarding fuel producing technologies. The mapping file is available in the library root folder: mappingFuels.

Warning: Some fuel types are not properly represented in the LCI database. Available inventories for biomass-based methanol production do not differentiate between wood and grass as the feedstock.

Note: **Modelling choice**: *premise* builds several potential supply chains for hydrogen. Because the logistics to supply hydrogen in the future is not known or indicated by the IAM, the choice is made to supply it by truck over 500 km, in a gaseous state.

The production volumes considered for a given scenario can be consulted, like so:

```
ndb.scenarios[0]["iam data"].production_volumes
```

To have an updated overview of the mapping concenring all sectors, refer to this file: mapping.

2.5.2 Efficiencies

The efficiency of the different technologies producing commodities (e.g., electricity, steel, cement, fuel) is modelled to change over time by the IAM. *premise* stores the relative change in efficiency of such technologies.

The table below shows the correspondence between *premise*, REMIND, IMAGE, regarding efficiency variables for electricity producing technologies. The mapping file is available in the library root folder: **mappingElec_**.

name in premise	name in REMIND	name in IMAGE
Biomass CHP	Tech|Electricity|Biomass|CHP|w/o CCS|Efficiency	Efficiency|Electricity|Biomass|w/o CCS|3
Biomass CHP CCS		Efficiency|Electricity|Biomass|w/ CCS|2
Biomass ST		Efficiency|Electricity|Biomass|w/o CCS|1
Biomass IGCC CCS	Tech|Electricity|Biomass|IGCCC|w/ CCS|Efficiency	Efficiency|Electricity|Biomass|w/ CCS|1
Biomass IGCC	Tech|Electricity|Biomass|IGCC|w/o CCS|Efficiency	Efficiency|Electricity|Biomass|w/o CCS|2
Coal PC	Tech|Electricity|Coal|PC|w/o CCS|Efficiency	Efficiency|Electricity|Coal|w/o CCS|1
Coal IGCC	Tech|Electricity|Coal|IGCC|w/o CCS|Efficiency	Efficiency|Electricity|Coal|w/o CCS|2
Coal PC CCS	Tech|Electricity|Coal|PCC|w/ CCS|Efficiency	
Coal IGCC CCS	Tech|Electricity|Coal|IGCCC|w/ CCS|Efficiency	Efficiency|Electricity|Coal|w/ CCS|1
Coal CHP	Tech|Electricity|Coal|CHP|w/o CCS|Efficiency	Efficiency|Electricity|Coal|w/o CCS|3
Coal CHP CCS		Efficiency|Electricity|Coal|w/ CCS|2
Gas OC	Tech|Electricity|Gas|GT|Efficiency	Efficiency|Electricity|Gas|w/o CCS|1
Gas CC	Tech|Electricity|Gas|CC|w/o CCS|Efficiency	Efficiency|Electricity|Gas|w/o CCS|2
Gas CHP	Tech|Electricity|Gas|CHP|w/o CCS|Efficiency	Efficiency|Electricity|Gas|w/o CCS|3
Gas CHP CCS		Efficiency|Electricity|Gas|w/ CCS|2
Gas CC CCS	Tech|Electricity|Gas|CCC|w/ CCS|Efficiency	Efficiency|Electricity|Gas|w/ CCS|1
Nuclear		Efficiency|Electricity|Nuclear
Oil ST	Tech|Electricity|Oil|DOT|Efficiency	Efficiency|Electricity|Oil|w/o CCS|1
Oil CC		Efficiency|Electricity|Oil|w/o CCS|2
Oil CC CCS		Efficiency|Electricity|Oil|w/ CCS|1
Oil CHP		Efficiency|Electricity|Oil|w/o CCS|3
Oil CHP CCS		Efficiency|Electricity|Oil|w/ CCS|2

The table below shows the correspondence between *premise*, REMIND, IMAGE, regarding efficiency variables for cement and steel producing technologies. For cement and steel, it is different, as *premise* derives efficiencies by dividing the the final energy demand by the production volume (to obtain GJ/t steel or cement). This is because efficiency variables for cement and steel is not always given as such. The mapping files are available in the library root folder: mappingCement and mappingSteel.

name in premise	name in REMIND	name in IMAGE
cement	Final Energy|Industry|Cement	FE|Industry|Cement
steel - primary	Final Energy|Industry|Steel	FE|Industry|Steel|Primary
steel - secondary	Final Energy|Industry|Steel|Electricity	FE|Industry|Steel|Secondary

The table below shows the correspondence between *premise*, REMIND, IMAGE, regarding efficiency variables for fuels producing technologies. The mapping file is available in the library root folder: mappingFuels.

name in premise	name in REMIND	name in IMAGE
biomethane	Tech|Gases|Biomass|w/o CCS|Efficiency	
diesel	Tech|Liquids|Oil|Efficiency	
gasoline	Tech|Liquids|Oil|Efficiency	
diesel, synthetic, wood		Efficiency|Liquids|Biomass|FT Diesel|Woody|w/o CCS
diesel, synthetic, wood, with CCS		Efficiency|Liquids|Biomass|FT Diesel|Woody|w/ CCS
diesel, synthetic, grass		Efficiency|Liquids|Biomass|FT Diesel|Woody|w/o CCS
diesel, synthetic, grass, with CCS		Efficiency|Liquids|Biomass|FT Diesel|Woody|w/ CCS
biodiesel, oil	Tech|Liquids|Biomass|Biofuel|Biodiesel|w/o CCS|Efficiency	Efficiency|Liquids|Biomass|Biodiesel|Oilcrops|w/o CCS
biodiesel, oil, with CCS		Efficiency|Liquids|Biomass|Biodiesel|Oilcrops|w/ CCS
bioethanol, wood	Tech|Liquids|Biomass|Biofuel|Ethanol|Cellu CCS|Efficiency	Efficiency|Liquids|Biomass|Ethanol|Woody|w/o CCS
bioethanol, wood, with CCS		Efficiency|Liquids|Biomass|Ethanol|Woody|w/ CCS
bioethanol, grass	Tech|Liquids|Biomass|Biofuel|Ethanol|Cellu CCS|Efficiency	Efficiency|Liquids|Biomass|Ethanol|Grassy|w/o CCS
bioethanol, grass, with CCS		Efficiency|Liquids|Biomass|Ethanol|Grassy|w/ CCS
bioethanol, grain	Tech|Liquids|Biomass|Biofuel|Ethanol|Conv CCS|Efficiency	Efficiency|Liquids|Biomass|Ethanol|Maize|w/o CCS
bioethanol, grain, with CCS		Efficiency|Liquids|Biomass|Ethanol|Maize|w/ CCS
bioethanol, sugar	Tech|Liquids|Biomass|Biofuel|Ethanol|Conv CCS|Efficiency	Efficiency|Liquids|Biomass|Ethanol|Sugar|w/o CCS
bioethanol, sugar, with CCS		Efficiency|Liquids|Biomass|Ethanol|Sugar|w/ CCS
methanol, wood		Efficiency|Liquids|Biomass|Methanol|Woody|w/o CCS
methanol, grass		Efficiency|Liquids|Biomass|Methanol|Grassy|w/o CCS
methanol, wood, with CCS		Efficiency|Liquids|Biomass|Methanol|Woody|w/ CCS
methanol, grass, with CCS		Efficiency|Liquids|Biomass|Methanol|Grassy|w/ CCS

premise stores the change in efficiency (called *scaling factor*) of a given technology relative to 2020. This is based on the fact that the efficiency of ecoinvent datasets are believed to reflect current (2020) efficiency.

Note: If a technology, in a given region, is given a *scaling factor* of 1.2 in 2030, this means that the corresponding ecoinvent dataset is adjusted so that its efficiency is improved by 20% (by multiplying the dataset inputs by 1/1.2). In other words, *premise* does not use the efficiency given by the IAM, but rather its change over time relative to 2020.

The *scaling factors* considered for a given scenario can be consulted, like so:

```
ndb.scenarios[0]["iam data"].efficiency
```

2.5.3 Land use and land use change

When building prospective databases using the IAM IMAGE model, the latter provides additional variables relating to average *land use* and *land use change* emissions, for each type of crop grown to be used in biofuel production. Upon the creation of biofuel supply chains in the *Fuels* transformation function, such information is used to adjust the inventories of crop farming datasets. The table below shows the IMAGE variables used to that effect. The mapping file is available in the library root folder: mappingCrops.

Crop family in premise	Crop type in premise	Land use variable in IMAGE [Ha/GJ-Prim]	Land use change variable in IMAGE [kg CO2/GJ-Prim]
sugar	sugarbeet, sugarcane	Land Use|Average|Biomass|Sugar	Emission Factor|CO2|Energy|Supply|Biomass|Average|Sugar
oil	rapeseed, palm oil	Land Use|Average|Biomass|OilCrc	Emission Factor|CO2|Energy|Supply|Biomass|Average|Oilcrops
wood	poplar, eucalyptus	Land Use|Average|Biomass|Wood	Emission Factor|CO2|Energy|Supply|Biomass|Average|Woody
grass	switchgrass, miscanthus	Land Use|Average|Biomass|Grassy	Emission Factor|CO2|Energy|Supply|Biomass|Average|Grassy
grain	corn	Land Use|Average|Biomass|Maize	Emission Factor|CO2|Energy|Supply|Biomass|Average|Maize

The *land use* and *land use change* emissions considered for a given scenario can be consulted, like so:

```
ndb.scenarios[0]["iam data"].land_use
ndb.scenarios[0]["iam data"].land_use_change
```

2.5.4 Carbon Capture and Storage

Some scenarios involve the capture and storage of CO2 emissions of certain sectors (e.g., cement and steel). The capture rate of a given sector is calculated from the IAM data file, as:

```
rate = amount of CO2 captured / (amount of CO2 captured + amount of CO2 not captured)
```

The table below lists the variables needed to calculate those rates.

name in premise	name in REMIND	name in IMAGE
cement - CO2 (not captured)	Emi|CO2|FFaI|Industry|Cement	Emissions|CO2|Industry|Cement|Gross
cement - CCO2 (captured)	Emi|CCO2|FFaI|Industry|Ceme	Emissions|CO2|Industry|Cement|Sequestered
steel - CO2 (not captured)	Emi|CO2|FFaI|Industry|Steel	Emissions|CO2|Industry|Steel|Gross
steel - CCO2 (captured)	Emi|CCO2|FFaI|Industry|Steel	Emissions|CO2|Industry|Steel|Sequestered

The *carbon capture rates* which are floating values comprised between 0 and 1, can be consulted like so:

```
ndb.scenarios[0]["iam data"].carbon_capture_rate
```

2.5.5 Data sources external to the IAM

premise tries to adhere to the IAM scenario data as much as possible. There are however a number of cases where external data sources are used. This is notably the case for non-CO2 pollutants emissions for different sectors (electricity, steel and cement), as well as expected efficiency gains for photovoltaic panels.

2.5.5.1 Air emissions

premise relies on projections from the air emissions models GAINS-EU and GAINS-IAM to adjust the emissions of pollutants for different sectors. As with efficiencies, *premise* stores the change in emissions (called *scaling factor*) of a given technology relative to 2020. This is based on the fact that the emissions of ecoinvent datasets are believed to reflect the current (2020) situation. Hence, if a technology, in a given region, has a *scaling factor* of 1.2 in 2030, this means that the corresponding ecoinvent dataset is adjusted so that its emissions of a given substance is improved by 20%. In other words, *premise* does not use the emissions level given by GAINS, but rather its change over time relative to 2020.

For more information about this step, refer to sub-section "GAINS emission factors" in the EXTRACT section.

2.5.5.2 Photovoltaic panels

Module efficiencies in 2010 for micro-Si and single-Si are from **IEA_** Task 12 report. For multi-Si, CIGS, CIS and CdTe, they are from IEA2 road map report on PV panels.

Current (2020) module efficiencies for all PV types are given by a 2021 report from the Fraunhofer Institute.

The efficiencies indicated for 2050 are what has been obtained in laboratory conditions by the Fraunhofer Institute. In other words, it is assumed that by 2050, solar PVs will reach production level efficiencies equal to those observed today in laboratories.

% module efficiency	micro-Si	single-Si	multi-Si	CIGS	CIS	CdTe
2010	10	15.1	14	11	11	10
2020	11.9	17.9	16.8	14	14	16.8
2050	12.5	26.7	24.4	23.4	23.4	21

CHAPTER

THREE

TRANSFORM

A series of transformations are applied to the Life Cycle Inventory (LCI) database to align process performance and technology market shares with the outputs from the Integrated Assessment Model (IAM) scenario.

3.1 Biomass

Run

```
from premise import *
import brightway2 as bw

bw.projects.set_current("my_project)

ndb = NewDatabase(
    scenarios=[
            {"model":"remind", "pathway":"SSP2-Base", "year":2028}
        ],
    source_db="ecoinvent 3.7 cutoff",
    source_version="3.7.1",
    key='xxxxxxxxxxxxxxxxxxxxxxxxx'
)
ndb.update("biomass")
```

3.1.1 Regional biomass markets

premise creates regional markets for biomass which is meant to be used as fuel in biomass-fired powerplants or heat generators. Originally in ecoinvent, the biomass being supplied to biomass-fired powerplants is "purpose grown" biomass that originate forestry activities (called "market for wood chips" in ecoinvent). While this type of biomass is suitable for such purpose, it is considered a co-product of the forestry activity, and bears a share of the environmental burden of the process it originates from (notably the land footprint, emissions, potential use of chemicals, etc.).

However, not all the biomass projected to be used in IAM scenarios is "purpose grown". In fact, significant shares are expected to originate from forestry residues. In such cases, the environmental burden of the forestry activity is entirely allocated to the determining product (e.g., timber), not to the residue, which comes "free of burden".

Hence, *premise* creates average regional markets for biomass, which represents the average shares of "purpose grown" and "residual" biomass being fed to biomass-fired powerplants.

The following market is created for each IAM region:

market name	location
market for biomass, used as fuel	all IAM regions

inside of which, the shares of "purpose grown" and "residual" biomass is represented by the following activities:

name in premise	name in REMIND	name in IMAGE	name in LCI database
biomass - purpose grown	SE|Electricity|Biomass|Energy Crops	Primary Energy|Biomass|Energy Crops	market for wood chips
biomass - residual	SE|Electricity|Biomass|Residues	Primary Energy|Biomass|Residues	supply of forest residue

The sum of those shares equal 1. The activity "supply of forest residue" includes the energy, embodied biogenic CO2, transport and associated emissions to chip the residual biomass and transport it to the powerplant, but no other forestry-related burden is included.

Note: You can check the share of residual biomass used for power generation assumed in your scenarios by generating a scenario summary report.

Note: When running *premise* with the consequential method, the biomass market is only composed of purpose-grown biomass. This is because the residual biomass cannot be considered a marginal supplier for an increase in demand for biomass.

```
ndb.generate_scenario_report()
```

3.2 Power generation

Run

```
from premise import *
import brightway2 as bw

bw.projects.set_current("my_project)

ndb = NewDatabase(
    scenarios=[
            {"model":"remind", "pathway":"SSP2-Base", "year":2028}
        ],
    source_db="ecoinvent 3.7 cutoff",
    source_version="3.7.1",
    key='xxxxxxxxxxxxxxxxxxxxxxxxx'
)
ndb.update("electricity")
```

The energy conversion efficiency of power plant datasets for specific technologies is adjusted to align with the efficiency changes indicated by the IAM scenario. Two approaches are posisble: * application of a scaling factor to the inputs of the dataset relative to the current efficiency * application of a scaling factor to the inputs of the dataset to match the absolute efficiency given by the IAM scenario

The first approach (default) preserves

3.2.1 Combustion-based powerplants

First, *premise* adjust the efficiency of coal- and lignite-fired power plants on the basis of the excellent work done by Oberschelp et al. (2019), to update some datasets in ecoinvent, which are, for some of them, several decades old. More specifically, the data provides plant-specific efficiency and emissions factors. We average them by country and fuel type to obtain volume-weighted factors. The efficiency of the following datasets is updated:

- electricity production, hard coal
- electricity production, lignite
- heat and power co-generation, hard coal
- heat and power co-generation, lignite

The data from Oberschelp et al. (2019) also allows us to update emissions of SO2, NOx, CH4, and PMs.

Second, *premise* iterates through coal, lignite, natural gas, biogas, and wood-fired power plant datasets in the LCI database to calculate their current efficiency (i.e., the ratio between the primary fuel energy entering the process and the output energy produced, which is often 1 kWh). If the IAM scenario anticipates a change in efficiency for these processes, the inputs of the datasets are scaled up or down by the scaling factor to effectively reflect a change in fuel input per kWh produced.

The origin of this scaling factor is the IAM scenario selected.

To calculate the old and new efficiency of the dataset, it is necessary to know the net calorific content of the fuel. The table below shows the Lower Heating Value for the different fuels used in combustion-based power plants.

name of fuel	LHV [MJ/kg, as received]
hard coal	26.7
lignite	11.2
petroleum coke	31.3
wood pellet	16.2
wood chips	18.9
natural gas	45
gas, natural, in ground	45
refinery gas	50.3
propane	46.46
heavy fuel oil	38.5
oil, crude, in ground	38.5
light fuel oil	42.6
biogas	22.73
biomethane	47.5
waste	14
methane, fossil	47.5
methane, biogenic	47.5
methane, synthetic	47.5
diesel	43
gasoline	42.6
petrol, 5% ethanol	41.7
petrol, synthetic, hydrogen	42.6

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Table 1 – continued from previous page

name of fuel	LHV [MJ/kg, as received]
petrol, synthetic, coal	42.6
diesel, synthetic, hydrogen	43
diesel, synthetic, coal	43
diesel, synthetic, wood	43
diesel, synthetic, wood, with CCS	43
diesel, synthetic, grass	43
diesel, synthetic, grass, with CCS	43
hydrogen, petroleum	120
hydrogen, electrolysis	120
hydrogen, biomass	120
hydrogen, biomass, with CCS	120
hydrogen, coal	120
hydrogen, from natural gas	120
hydrogen, from natural gas, with CCS	120
hydrogen, biogas	120
hydrogen, biogas, with CCS	120
hydrogen	120
biodiesel, oil	38
biodiesel, oil, with CCS	38
bioethanol, wood	26.5
bioethanol, wood, with CCS	26.5
bioethanol, grass	26.5
bioethanol, grass, with CCS	26.5
bioethanol, grain	26.5
bioethanol, grain, with CCS	26.5
bioethanol, sugar	26.5
bioethanol, sugar, with CCS	26.5
ethanol	26.5
methanol, wood	19.9
methanol, grass	19.9
methanol, wood, with CCS	19.9
methanol, grass, with CCS	19.9
liquified petroleum gas, natural	45.5
liquified petroleum gas, synthetic	45.5
uranium, enriched 3.8%, in fuel element for light water reactor	4199040
nuclear fuel element, for boiling water reactor, uo2 3.8%	4147200
nuclear fuel element, for boiling water reactor, uo2 4.0%	4147200
nuclear fuel element, for pressure water reactor, uo2 3.8%	4579200
nuclear fuel element, for pressure water reactor, uo2 4.0%	4579200
nuclear fuel element, for pressure water reactor, uo2 4.2%	4579200
uranium hexafluoride	709166
enriched uranium, 4.2%	4579200
mox fuel element	4579200
heat, from hard coal	1
heat, from lignite	1
heat, from petroleum coke	1
heat, from wood pellet	1
heat, from natural gas, high pressure	1
heat, from natural gas, low pressure	1
heat, from heavy fuel oil	1

continues on next page

Table 1 – continued from previous page

name of fuel	LHV [MJ/kg, as received]
heat, from light fuel oil	1
heat, from biogas	1
heat, from waste	1
heat, from methane, fossil	1
heat, from methane, biogenic	1
heat, from diesel	1
heat, from gasoline	1
heat, from bioethanol	1
heat, from biodiesel	1
heat, from liquified petroleum gas, natural	1
heat, from liquified petroleum gas, synthetic	1
bagasse, from sugarcane	15.4
bagasse, from sweet sorghum	13.8
sweet sorghum stem	4.45
cottonseed	21.97
flax husks	21.5
coconut husk	20
sugar beet pulp	5.11
cleft timber	14.46
rape meal	31.1
molasse, from sugar beet	16.65
sugar beet	4.1
barkey grain	19.49
rye grain	12
sugarcane	5.3
palm date	10.8
whey	1.28
straw	15.5
grass	17
manure, liquid	0.875
manure, solid	3.6
kerosene, from petroleum	43
kerosene, synthetic, from electrolysis, energy allocation	43
kerosene, synthetic, from electrolysis, economic allocation	43
kerosene, synthetic, from coal, energy allocation	43
kerosene, synthetic, from coal, economic allocation	43
kerosene, synthetic, from natural gas, energy allocation	43
kerosene, synthetic, from natural gas, economic allocation	43
kerosene, synthetic, from biomethane, energy allocation	43
kerosene, synthetic, from biomethane, economic allocation	43
kerosene, synthetic, from biomass, energy allocation	43
kerosene, synthetic, from biomass, economic allocation	43

Additionally, the biogenic and fossil CO2 emissions of the datasets are also scaled up or down by the same factor, as they are proportional to the amount of fuel used.

Below is an example of a natural gas power plant with a current (2020) conversion efficiency of 77%. If the IAM scenario indicates a scaling factor of 1.03 in 2030, this suggests that the efficiency increases by 3% relative to the current level. As shown in the table below, this would result in a new efficiency of 79%, where all inputs, as well as CO2 emissions outputs, are re-scaled by 1/1.03 (=0.97).

While non-CO2 emissions (e.g., CO) are reduced because of the reduction in fuel consumption, the emission factor per energy unit remains the same (i.e., gCO/MJ natural gas)). It can be re-scaled using the *.update("emissions")* function, which updates emission factors according to GAINS projections.

electricity production, natura gas, conventional	before	after	unit
electricity production	1	1	kWh
natural gas	0.1040	0.1010	m3
water	0.0200	0.0194	m3
powerplant construction	1.00E-08	9.71E-09	unit
CO2, fossil	0.0059	0.0057	kg
CO, fossil	5.87E-06	5.42E-03	kg
fuel-to-electricity efficiency	77%	79%	%

premise has a couple of rules regarding projected *scaling factors*:

- *scaling factors* inferior to 1 beyond 2020 are not accepted and are treated as 1.
- *scaling factors* superior to 1 before 2020 are not accepted and are treated as 1.
- efficiency can only improve over time.

This is to prevent degrading the performance of a technology in the future, or improving its performance in the past, relative to today.

Note: You can check the efficiencies assumed in your scenarios by generating a scenario summary report, or a report of changes. They are automatically generated after each database export, but you can also generate them manually:

```
ndb.generate_scenario_report()
ndb.generate_change_report()
```

3.2.2 Photovoltaics panels

Photovoltaic panels are expected to improve over time. The following module efficiencies are considered for the different types of PV panels:

% module efficiency	micro-Si	single-Si	multi-Si	CIGS	CIS	CdTe
2010	10	15.1	14	11	11	10
2020	11.9	17.9	16.8	14	14	16.8
2050	12.5	26.7	24.4	23.4	23.4	21

The sources for these efficiencies are given in the inventory file LCI_PV:

Given a scenario year, *premise* iterates through the different PV panel installation datasets to update their efficiency accordingly. To do so, the required surface of panel (in m2) per kW of capacity is adjusted down (or up, if the efficiency is lower than current).

To calculate the current efficiency of a PV installation, *premise* assumes a solar irradiation of 1000 W/m2. Hence, the current efficiency is calculated as:

```
current_eff [%] = installation_power [W]  / (panel_surface [m2] * 1000 [W/m2])
```

The *scaling factor* is calculated as:

```
scaling_factor = current_eff / new_eff
```

The required surface of PV panel in the dataset is then adjusted like so:

```
new_surface = current_surface * (1 / scaling_factor)
```

For scenario years beyond 2050, 2050 efficiency values are used.

The table below provides such an example where a 450 kWp flat-roof installation sees its current (2020) module efficiency improving from 20% to 26% by 2050. THe are of PV panel (and mounting system) has been multiplied by 1 / (0.26/0.20), all other inputs remaining unchanged.

450kWp flat roof installation	before	after	unit
photovoltaic flat-roof installation, 450 kWp, single-SI, on roof	1	1	unit
inverter production, 500 kW	1.5	1.5	unit
photovoltaic mounting system, …	2300	1731	m2
photovoltaic panel, single-SI	2500	1881	m2
treatment, single-SI PV module	30000	30000	kg
electricity, low voltage	25	25	kWh
module efficiency	20%	26%	%

3.2.2.1 Markets

premise creates additional datasets that represent the average supply and production pathway for a given commodity for a given scenario, year and region.

Such datasets are called *regional markets*. Hence, a regional market for high voltage electricity contains the different technologies that supply electricity at high voltage in a given IAM region, in proportion to their respective production volumes.

3.2.3 Regional electricity markets

premise creates high, medium and low-voltage electricity markets for each IAM region. It starts by creating high-voltage markets and define the share of each supplying technology by their respective production volumes in respect to the total volume produced.

High voltage supplying technologies are all technologies besides:

- residential (<=3kWp) photovoltaic power (low voltage)
- waste incineration co-generating powerplants (medium voltage)

Several datasets can qualify for a given technology, in a given IAM region. To define to which extent a given dataset should be supplying in the market, *premise* uses the current production volume of the dataset.

For example, if coal-fired powerplants are to supply 25% of the high voltage electricity in the IAM region "Europe", *premise* fetches the production volumes of all coal-fired powerplants which ecoinvent location is *included* in the IAM region "Europe" (e.g., DE, PL, LT, etc.), and allocates to each of those a supply share based on their respective production volume in respect to the total production volume of coal-fired powerplants.

For example, the table below shows the contribution of biomass-fired CHP powerplants in the regional high voltage electricity market for IMAGE's "WEU" region (Western Europe). The biomass CHP technology represents 2.46% of the supply mix. Biomass CHP datasets included in the region "WEU" are given a supply share corresponding to their respective current production volumes.

energy type	Supplier name	Supplier location	Contribution within energy type	Final contribution
Biomass CHP	heat and power co-generation, wood chips	FR	3.80%	0.09%
Biomass CHP	heat and power co-generation, wood chips	AT	2.87%	0.07%
Biomass CHP	heat and power co-generation, wood chips	NO	0.06%	0.00%
Biomass CHP	heat and power co-generation, wood chips	FI	7.65%	0.19%
Biomass CHP	heat and power co-generation, wood chips	SE	9.04%	0.22%
Biomass CHP	heat and power co-generation, wood chips	IT	8.27%	0.20%
Biomass CHP	heat and power co-generation, wood chips	BE	4.59%	0.11%
Biomass CHP	heat and power co-generation, wood chips	DE	12.53%	0.31%
Biomass CHP	heat and power co-generation, wood chips	LU	0.05%	0.00%
Biomass CHP	heat and power co-generation, wood chips	DK	6.60%	0.16%
Biomass CHP	heat and power co-generation, wood chips	GR	0.01%	0.00%
Biomass CHP	heat and power co-generation, wood chips	CH	1.81%	0.04%
Biomass CHP	heat and power co-generation, wood chips	ES	5.10%	0.13%
Biomass CHP	heat and power co-generation, wood chips	PT	1.34%	0.03%
Biomass CHP	heat and power co-generation, wood chips	IE	0.77%	0.02%
Biomass CHP	heat and power co-generation, wood chips	NL	2.32%	0.06%
Biomass CHP	heat and power co-generation, wood chips	GB	33.18%	0.81%
_	_	Sum	100.00%	2.46%

Transformation losses are added to the high-voltage market datasets. Transformation losses are the result of weighting country-specific high voltage losses (provided by ecoinvent) of countries included in the IAM region with their respective current production volumes (also provided by ecoinvent). This is not ideal as it supposes that future country-specific production volumes will remain the same in respect to one another.

3.2.4 Storage

If the IAM scenario requires the use of storage, *premise* adds a storage dataset to the high voltage market. *premise* can add two types of storage:

- storage via a large-scale flow battery (electricity supply, high voltage, from vanadium-redox flow battery system)
- storage via the conversion of electricity to hydrogen and subsequent use in a gas turbine (electricity production, from hydrogen-fired one gigawatt gas turbine)

The electricity storage via battery incurs a 33% loss. It is operated by a 8.3 MWh vanadium redox-based flow battery, with a lifetime of 20 years or 8176 cycle-lifes (i.e., 49,000 MWh).

The storage of electricity via hydrogen is done in two steps: first, the electricity is converted to hydrogen via a 1MW PEM electrolyser, with an efficiency of 62%. The hydrogen is then stored in a geological cavity and used in a gas turbine, with an efficiency of 51%. Accounting for leakages and losses, the overall efficiency of the process is about 37% (i.e., 2.7 kWh necessary to deliver 1 kWh to the grid).

The efficiency of the H2-fed gas turbine is based on the parameters of Ozawa et al. (2019).

The workflow is not too different from that of high voltage markets. There are however only two possible providers of electricity in medium voltage markets: the high voltage market, as well as waste incineration powerplants.

High-to-medium transformation losses are added as an input of the medium voltage market to itself. Distribution losses are modelled the same way as for high voltage markets and are added to the input from high voltage market.

Low voltage regional markets receive an input from the medium voltage market, as well as from residential photovoltaic power.

Medium-to-low transformation losses are added as an input from the low voltage market to itself. Distribution losses are modelled the same way as for high and medium voltage markets, and are added to the input from the medium voltage market.

The table below shows the example of a low voltage market for the IAM IMAGE regional “WEU”.

supplier	amount	unit	location	description
market group for electricity, medium voltage	1.0238804	kilowatt hour	WEU	input from medium voltage + distribution losses
market group for electricity, low voltage	0.0255382	kilowatt hour	WEU	transformation losses (2.55%)
electricity production, photovoltaic, residential	0.0003569	kilowatt hour	DE	
electricity production, photovoltaic, residential	0.0001438	kilowatt hour	IT	
electricity production, photovoltaic, residential	9.38E-05	kilowatt hour	ES	
electricity production, photovoltaic, residential	9.03E-05	kilowatt hour	GB	
electricity production, photovoltaic, residential	7.82E-05	kilowatt hour	FR	
electricity production, photovoltaic, residential	6.80E-05	kilowatt hour	NL	
electricity production, photovoltaic, residential	3.76E-05	kilowatt hour	BE	
electricity production, photovoltaic, residential	2.16E-05	kilowatt hour	GR	
electricity production, photovoltaic, residential	2.08E-05	kilowatt hour	CH	
electricity production, photovoltaic, residential	1.48E-05	kilowatt hour	AT	
electricity production, photovoltaic, residential	9.44E-06	kilowatt hour	SE	
electricity production, photovoltaic, residential	8.66E-06	kilowatt hour	DK	
electricity production, photovoltaic, residential	6.83E-06	kilowatt hour	PT	
electricity production, photovoltaic, residential	2.60E-06	kilowatt hour	FI	
electricity production, photovoltaic, residential	1.30E-06	kilowatt hour	LU	
electricity production, photovoltaic, residential	1.01E-06	kilowatt hour	NO	
electricity production, photovoltaic, residential	2.40E-07	kilowatt hour	IE	
distribution network construction, electricity, low voltage	8.74E-08	kilometer	RoW	
market for sulfur hexafluoride, liquid	2.99E-09	kilogram	RoW	
sulfur hexafluoride	2.99E-09	kilogram		transformer emissions

Note: You can check the electricity supply mixes assumed in your scenarios by generating a scenario summary report.

```
ndb.generate_scenario_report()
```

3.2.5 Long-term regional electricity markets

Long-term (i.e., 20, 40 and 60 years) regional markets are created for modelling the lifetime-weighted burden associated to electricity supply for systems that have a long lifetime (e.g., battery electric vehicles, buildings).

These long-term markets contain a period-weighted electricity supply mix. For example, if the scenario year is 2030 and the period considered is 20 years, the supply mix represents the supply mixes between 2030 and 2050, with an equal weight given to each year.

The rest of the modelling is similar to that of regular regional electricity markets described above.

Market datasets originally present in the ecoinvent LCI database are cleared from any inputs. Instead, an input from the newly created regional market is added, depending on the location of the dataset.

The table below shows the example of the low voltage electricity market for Great Britain, which now only includes an input from the "WEU" regional market, which "includes" it in terms of geography.

Output	_	_	_
producer	*amount*	*unit*	*location*
market for electricity, low voltage	1.00E+00	kilowatt hour	**GB**
Input	_	_	_
supplier	*amount*	*unit*	*location*
market group for electricity, low voltage	1.00E+00	kilowatt hour	**WEU**

Once the new markets are created, *premise* re-links all electricity-consuming activities to the new regional markets. The regional market it re-links to depends on the location of the consumer.

3.3 Cement production

The modelling of future improvements in the cement sector is relatively simple at the moment, and does not involve the emergence of new technologies (e.g., electric kilns).

Run

```
from premise import *
import brightway2 as bw

bw.projects.set_current("my_project)

ndb = NewDatabase(
    scenarios=[
            {"model":"remind", "pathway":"SSP2-Base", "year":2028}
        ],
    source_db="ecoinvent 3.7 cutoff",
    source_version="3.7.1",
    key='xxxxxxxxxxxxxxxxxxxxxxxxx'
)
ndb.update("cement")
```

premise duplicates clinker production datasets in ecoinvent (called "clinker production") so as to create a proxy dataset for each IAM region. The location of the proxy datasets used for a given IAM region is a location included in the IAM region. If no valid dataset is found, *premise* resorts to using a rest-of-the-world (RoW) dataset to represent the IAM region.

premise changes the location of these duplicated datasets and fill in different fields, such as that of *production volume*.

premise then adjusts the thermal efficiency of the process. It does so by calculating the technology-weighted energy requirements per ton of clinker. Based on GNR/IEA roadmap data, *premise* uses:

- **the share of kiln technology for a given region today (2020):**
  - wet,
  - dry,
  - dry with pre-heater,
  - and dry with pre-heater and pre-calciner
- the energy requirement for each of these technologies today (2020).

Once the energy required per ton clinker today (2020) is known, it is multiplied by a *scaling factor* that represents a change in efficiency between today and the scenario year.

Note: You can check the efficiency gains assumed relative to 2020 in your scenarios by generating a scenario summary report.

```
ndb.generate_scenario_report()
```

Note: *premise* enforces a lower limit on the fuel consumption per ton of clinker. This limit is set to 2.8 GJ/t clinker and corresponds to the minimum theoretical fuel consumption with an moisture content of the raw materials, as considered in the 2018 IEA cement roadmap report. Hence, regardless of the scaling factor, the fuel consumption per ton of clinker will never be less than 2.8 GJ/t.

Once the new energy input is determined, *premise* scales down the fuel, and the fossil and biogenic CO2 emissions accordingly, based on the Lower Heating Value and CO2 emission factors for these fuels.

Note that the change in CO2 emissions only concerns the share that originates from the combustion of fuels. It does not concern the calcination emissions due to the production of calcium oxide (CaO) from calcium carbonate (CaCO3), which is set at a fix emission rate of 525 kg CO2/t clinker.

If the IAM scenario indicates that a share of the CO2 emissions for the cement sector in a given region and year is sequestered and stored, *premise* adds CCS to the corresponding clinker production dataset.

The CCS dataset used to that effect is from Meunier et al., 2020. The dataset described the capture of CO2 from a cement plant. To that dataset, *premise* adds another dataset that models the storage of the CO2 underground, from Volkart et al, 2013.

Besides electricity, the CCS process requires heat, water and others inputs to regenerate the amine-based sorbent. We use two data points to approximate the heat requirement: 3.66 MJ/kg CO2 captured in 2020, and 2.6 MJ/kg in 2050. The first number is from Meunier et al., 2020, while the second number is described as the best-performing pilot project today, according to the 2022 review of pilot projects by the Global CCS Institute. It is further assumed that the heat requirement is fulfilled to an extent of 15% by the recovery of excess heat, as mentioned in the 2018 IEA cement roadmap report.

Note: You can check the the carbon capture rate for cement production assumed in your scenarios by generating a scenario summary report.

```
ndb.generate_scenario_report()
```

Run

```
from premise import *
import brightway2 as bw

bw.projects.set_current("my_project)

ndb = NewDatabase(
    scenarios=[
            {"model":"remind", "pathway":"SSP2-Base", "year":2028}
        ],
    source_db="ecoinvent 3.7 cutoff",
    source_version="3.7.1",
    key='xxxxxxxxxxxxxxxxxxxxxxxxx'
)
ndb.update("cement")
```

When clinker production datasets are created for each IAM region, *premise* duplicates cement production datasets for each IAM region as well. These cement production datasets link the newly created clinker production dataset, corresponding to their IAM region.

premise used to modify the composition of cement markets to reflect a lower clinker content over time, based on external projections. This is no longer performed, as it is not an assumption stemming from the IAM model, but rather a projection of the cement industry.

Market datasets originally present in the ecoinvent LCI database are cleared from any inputs. Instead, an input from the newly created regional market is added, depending on the location of the dataset.

The table below shows the example of the clinker market for South Africa, which now only includes an input from the "SAF" regional market, which "includes" it in terms of geography.

Output	_	_	_
producer	amount	unit	location
market for clinker	1.00E+00	kilogram	**ZA**
Input	_	_	_
supplier	amount	unit	location
market for clinker	1.00E+00	kilogram	***SAF**

Once cement production and market datasets are created, *premise* re-links cement-consuming activities to the new regional markets for cement. The regional market it re-links to depends on the location of the consumer.

3.4 Steel production

Run

```
from premise import *
import brightway2 as bw

bw.projects.set_current("my_project)

ndb = NewDatabase(
    scenarios=[
            {"model":"remind", "pathway":"SSP2-Base", "year":2028}
        ],
    source_db="ecoinvent 3.7 cutoff",
    source_version="3.7.1",
    key='xxxxxxxxxxxxxxxxxxxxxxxxx'
)
ndb.update("steel")"
```

The modelling of future improvements in the steel sector is relatively simple at the moment, and does not involve the emergence of new technologies (e.g., hydrogen-based DRI, electro-winning).

premise duplicates steel production datasets in ecoinvent for the production of primary and secondary steel (called respectively "steel production, converter" and "steel production, electric") so as to create a proxy dataset for each IAM region.

The location of the proxy datasets used for a given IAM region is a location included in the IAM region. If no valid dataset is found, *premise* resorts to using a rest-of-the-world (RoW) dataset to represent the IAM region.

premise changes the location of these duplicated datasets and fill in different fields, such as that of *production volume*.

Regarding primary steel production (using BO-BOF), *premise* adjusts the inputs of fuels found in:

- the pig iron production datasets,
- the steel production datasets,

assuming an integrated steel mill unit, by multiplying these fuel inputs by a *scaling factor* provided by the IAM scenario.

Typical fuel inputs for these process are natural gas, coal, coal-based coke. Emissions of (fossil) CO2 are scaled accordingly.

Regarding the production of secondary steel (using EAF), *premise* adjusts the input of electricity based on the scaling factor provided by the IAM scenario.

Note: You can check the efficiency gains assumed relative to 2020 for steel production in your scenarios by generating a scenario summary report.

```
ndb.generate_scenario_report()
```

Warning: If your system of interest relies heavily on the provision of steel, you should probably consider modelling steel production based on primary data. ecoinvent datasets for steel production rely on a few data points, which are then further process transformed by *premise*. Therefore, there is a large modelling uncertainty.

If the IAM scenario indicates that a share of the CO2 emissions from the steel sector in a given region and year is sequestered and stored, *premise* adds a corresponding input from a CCS dataset. The datatset used to that effect is from Meunier et al., 2020. The dataset described the capture of CO2 from a cement plant, not a steel mill, but it is assumed to be an acceptable approximation since the CO2 concentration in the flue gases should not be significantly different.

To that dataset, *premise* adds another dataset that models the storage of the CO2 underground, from Volkart et al, 2013.

Besides electricity, the CCS process requires heat, water and others inputs to regenerate the amine-based sorbent. We use two data points to approximate the heat requirement: 3.66 MJ/kg CO2 captured in 2020, and 2.6 MJ/kg in 2050. The first number is from Meunier et al., 2020, while the second number is described as the best-performing pilot project today, according to the 2022 review of pilot projects by the Global CCS Institute. It is further assumed that the heat requirement is fulfilled to an extent of 15% by the recovery of excess heat, as mentioned in the 2018 IEA cement roadmap report, which is assumed to be also valid in the case of a steel mill.

premise create a dataset "market for steel, low-alloyed" for each IAM region. Within each dataset, the supply shares of primary and secondary steel are adjusted to reflect the projections from the IAM scenario, for a given region and year, based on the variables below.

name in premise	name in REMIND	name in IMAGE	name in LCI database
steel - primary	Production|Industry|Steel|Primary	Production|Steel|Primary	steel production, converter
steel - secondary	Production|Industry|Steel|Secondary	Production|Steel|Secondary	steel production, electric

The table below shows an example of the market for India, where 66% of the steel comes from an oxygen converter process (primary steel), while 34% comes from an electric arc furnace process (secondary steel).

Output	_	_	_
producer	amount	unit	location
market for steel, low-alloyed	1	kilogram	IND
Input			
supplier	amount	unit	location
market group for transport, freight, inland waterways, barge	0.5	ton kilometer	GLO
market group for transport, freight train	0.35	ton kilometer	GLO
market for transport, freight, sea, bulk carrier for dry goods	0.38	ton kilometer	GLO
transport, freight, lorry, unspecified, regional delivery	0.12	ton kilometer	IND
steel production, **converter**, low-alloyed	0.66	kilogram	IND
steel production, **electric**, low-alloyed	0.34	kilogram	IND

Market datasets originally present in the ecoinvent LCI database are cleared from any inputs. Instead, an input from the newly created regional market is added, depending on the location of the dataset.

The table below shows the example of the clinker market for South Africa, which now only includes an input from the "SAF" regional market, which "includes" it in terms of geography.

Output	_	_	_
producer	amount	unit	location
market for clinker	1.00E+00	kilogram	**ZA**
Input	_	_	_
supplier	amount	unit	location
market for clinker	1.00E+00	kilogram	**SAF**

Once steel production and market datasets are created, *premise* re-links steel-consuming activities to the new regional markets for steel. The regional market it re-links to depends on the location of the consumer.

3.5 Transport

Run

```
from premise import *
import brightway2 as bw

bw.projects.set_current("my_project)

ndb = NewDatabase(
    scenarios=[
            {"model":"remind", "pathway":"SSP2-Base", "year":2028}
        ],
    source_db="ecoinvent 3.7 cutoff",
    source_version="3.7.1",
    key='xxxxxxxxxxxxxxxxxxxxxxxxx'
)
ndb.update("two_wheelers")
ndb.update("cars")
ndb.update("trucks")
ndb.update("buses")
```

premise imports inventories for transport activity operated by:

- two-wheelers
- passenger cars
- medium and heavy duty trucks
- buses

These inventories are available for the construction year of 2000 to 2050, by steps of 5 years, but *premise* only imports vehicles with a construction year inferior or equal to the scenario year (vehicle from 2050 will not be imported in a database for the scenario year of 2030, but vehicles from 2020 will, as they are necessary to build the fleet average vehicles).

The following size classes of medium and heavy duty trucks are imported:

- 3.5t
- 7.5t
- 18t
- 26t

- 40t

These weights refer to the vehicle gross mass (the maximum weight the vehicle is allowed to reach, fully loaded).

Each truck is available for a variety of powertrain types:

- fuel cell electric
- battery electric
- diesel hybrid
- plugin diesel hybrid
- diesel
- compressed gas

but also for different driving cycles, to which a range autonomy of the vehicle is associated:

- urban delivery (required range autonomy of 150 km)
- regional delivery (required range autonomy of 400 km)
- long haul (required range autonomy of 800 km)

Those are driving cycles developed for the software VECTO, which have become standard in measuring the CO2 emissions of trucks.

The truck vehicle model is from Sacchi et al, 2021.

Note: Not all powertrain types are available for regional and long haul driving cycles. This is specifically the case for battery electric trucks, for which the mass and size prevent them from completing the cycle, or surpasses the vehicle gross weight.

Warning: A consequence of replacing original truck datasets with those provided by *premise* may be a steep increase in CO2-eq. emissions, especially if the urban driving cycle is chosen. Overall, considering and size classes, diesel truck datasets from ecoinvent have lower fuel consumption and exhaust emissions.

3.5.1 Fleet average trucks

REMIND and IMAGE provide fleet composition data, per scenario, region and year.

The fleet data is expressed in “vehicle-kilometer” performed by each type of vehicle, in a given region and year.

premise uses the following loads to translate the transport demand from “vehicle-kilometers” to “ton-kilometers”, derived from TRACCS:

load [tons]	urban delivery	regional delivery	long haul
3.5t	0.26	0.26	0.8
7.5t	0.52	0.52	1.6
18t	1.35	1.35	4.1
26t	2.05	2.05	6.2
32t	6.1	6.1	9.1
40t	6.1	6.1	9.1

Note: Loads from the TRACCS survey data are representative for EU-28 conditions. *premise* applies these loads to all IAM regions. Hence, there might be some inconsistency at this level. Also, these loads are much lower than those assumed in original ecoinvent truck datasets.

premise uses the fleet data to produce fleet average trucks for each IAM region, and more specifically:

- a fleet average truck, all powertrains and size classes considered
- a fleet average truck, all powertrains considered, for a given size class

They appear in the LCI database as the following:

truck transport dataset name	description
transport, freight, lorry, 3.5t gross weight, unspecified powertrain, long haul	fleet average, for 3.5t size class, long haul cycle
transport, freight, lorry, 3.5t gross weight, unspecified powertrain, regional delivery	fleet average, for 3.5t size class, regional delivery cycle
transport, freight, lorry, 3.5t gross weight, unspecified powertrain, urban delivery	fleet average, for 3.5t size class, urban delivery cycle
transport, freight, lorry, 7.5t gross weight, unspecified powertrain, long haul	fleet average, for 7.5t size class, long haul cycle
transport, freight, lorry, 7.5t gross weight, unspecified powertrain, regional delivery	fleet average, for 7.5t size class, regional delivery cycle
transport, freight, lorry, 7.5t gross weight, unspecified powertrain, urban delivery	fleet average, for 7.5t size class, urban delivery cycle
transport, freight, lorry, 18t gross weight, unspecified powertrain, long haul	fleet average, for 18t size class, long haul cycle
transport, freight, lorry, 18t gross weight, unspecified powertrain, regional delivery	fleet average, for 18t size class, regional delivery cycle
transport, freight, lorry, 18t gross weight, unspecified powertrain, urban delivery	fleet average, for 18t size class, urban delivery cycle
transport, freight, lorry, 26t gross weight, unspecified powertrain, long haul	fleet average, for 26t size class, long haul cycle
transport, freight, lorry, 26t gross weight, unspecified powertrain, regional delivery	fleet average, for 26t size class, regional delivery cycle
transport, freight, lorry, 26t gross weight, unspecified powertrain, urban delivery	fleet average, for 26t size class, urban delivery cycle
transport, freight, lorry, 40t gross weight, unspecified powertrain, long haul	fleet average, for 26t size class, long haul cycle
transport, freight, lorry, 40t gross weight, unspecified powertrain, regional delivery	fleet average, for 26t size class, regional delivery cycle
transport, freight, lorry, 40t gross weight, unspecified powertrain, urban delivery	fleet average, for 26t size class, urban delivery cycle
transport, freight, lorry, unspecified, long haul	fleet average, all powertrain types, all size classes
transport, freight, lorry, unspecified, regional delivery	fleet average, all powertrain types, all size classes
transport, freight, lorry, unspecified, urban delivery	fleet average, all powertrain types, all size classes

3.5.2 Relinking

Regarding trucks, *premise* re-links truck transport-consuming activities to the newly created fleet average truck datasets.

The following table shows the correspondence between the original truck transport datasets and the new ones replacing them:

Original dataset	Replaced by (REMIND)	Replaced by (IMAGE)
transport, freight, lorry, unspecified	transport, freight, lorry, unspecified	transport, freight, lorry, unspecified
transport, freight, lorry 16-32 metric ton	transport, freight, lorry, 26t gross weight, unspecified powertrain	transport, freight, lorry, 26t gross weight, unspecified powertrain
transport, freight, lorry 28 metric ton, fatty acid methyl ester 100%	transport, freight, lorry, 26t gross weight, unspecified powertrain	transport, freight, lorry, 26t gross weight, unspecified powertrain
transport, freight, lorry 3.5-7.5 metric ton	transport, freight, lorry, 3.5t gross weight, unspecified powertrain	transport, freight, lorry, 26t gross weight, unspecified powertrain
transport, freight, lorry 7.5-16 metric ton	transport, freight, lorry, 7.5t gross weight, unspecified powertrain	transport, freight, lorry, 26t gross weight, unspecified powertrain
transport, freight, lorry >32 metric ton	transport, freight, lorry, 40t gross weight, unspecified powertrain	transport, freight, lorry, 40t gross weight, unspecified powertrain
transport, freight, lorry with reefer, cooling	transport, freight, lorry, unspecified	transport, freight, lorry, unspecified
transport, freight, lorry with reefer, freezing	transport, freight, lorry, unspecified	transport, freight, lorry, unspecified
transport, freight, lorry with refrigeration machine, 3.5-7.5 ton	transport, freight, lorry, 3.5t gross weight, unspecified powertrain	transport, freight, lorry, 26t gross weight, unspecified powertrain
transport, freight, lorry with refrigeration machine, 7.5-16 ton	transport, freight, lorry, 7.5t gross weight, unspecified powertrain	transport, freight, lorry, 26t gross weight, unspecified powertrain
transport, freight, lorry with refrigeration machine, cooling	transport, freight, lorry, unspecified	transport, freight, lorry, unspecified
transport, freight, lorry with refrigeration machine, freezing	transport, freight, lorry, unspecified	transport, freight, lorry, unspecified

Note that IMAGE fleet data only uses 26t and 40t trucks.

Additionally, *premise* iterates through each truck transport-consuming activities to calculate the driving distance required. When the reference unit of the dataset is 1 kilogram, the distance driven by truck can easily be inferred. Indeed, for example, 0.56 tkm of truck transport for 1 kg of flour indicates that the flour has been transported over 560 km.

On this basis, *premise* chooses one of the following driving cycles:

- *regional delivery*, if the distance is inferior or equal to 450 km
- *long haul*, if the distance is superior to 450 km

Hence, in the following dataset for "market for steel, low-alloyed" for the IAM region of India, *premise* chose the *regional delivery* driving cycle since the kilogram of steel has been transported on average over 120 km by truck. The truck used to transport that kilogram of steel is a fleet average vehicle built upon the REMIND fleet data for the region of India.

Output	_	_	_
producer	amount	unit	location
market for steel, low-alloyed	1	kilogram	IND
Input			
supplier	amount	unit	location
market group for transport, freight, inland waterways, barge	0.5	ton kilometer	GLO
market group for transport, freight train	0.35	ton kilometer	GLO
market for transport, freight, sea, bulk carrier for dry goods	0.38	ton kilometer	GLO
transport, freight, lorry, unspecified, **regional delivery**	0.12	ton kilometer	IND
steel production, converter, low-alloyed	0.66	kilogram	IND
steel production, electric, low-alloyed	0.34	kilogram	IND

3.6 Direct Air Capture

Run

```
from premise import *
import brightway2 as bw

bw.projects.set_current("my_project)

ndb = NewDatabase(
    scenarios=[
            {"model":"remind", "pathway":"SSP2-Base", "year":2028}
        ],
    source_db="ecoinvent 3.7 cutoff",
    source_version="3.7.1",
    key='xxxxxxxxxxxxxxxxxxxxxxxxx'
)
ndb.update("dac")
```

premise creates different region-specific Direct Air Capture (DAC) datasets, based on the inventories from Qiu et al., 2022.

If provided by the IAM scenario, *premise* scales the inputs of electricity and heat of the DAC datasets to reflect changes in efficiency.

3.7 Fuels

Run

```
from premise import *
import brightway2 as bw

bw.projects.set_current("my_project)
```

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(continued from previous page)

```
ndb = NewDatabase(
    scenarios=[
            {"model":"remind", "pathway":"SSP2-Base", "year":2028}
        ],
    source_db="ecoinvent 3.7 cutoff",
    source_version="3.7.1",
    key='xxxxxxxxxxxxxxxxxxxxxxxxx'
)
ndb.update("fuels")
```

premise create different region-specific fuel supply chains and fuel markets, based on data from the IAM scenario.

The biomass-to-fuel efficiency ratio of bioethanol and biodiesel production datasets is adjusted according to the IAM scenario projections.

Inputs to the biofuel production datasets are multiplied by a *scaling factor* that represents the change in efficiency relative to today (2020).

Several pathways for hydrogen production are modeled in *premise*:

- electrolysis
- steam methane reforming of natural gas
- steam methane reforming of biomethane
- gasification of coal
- gasification of woody biomass

The last four pathways are modeled with and without CCS.

Inventories for these pathways are available under:

- premise/data/additional_inventories/lci-hydrogen-electrolysis.xlsx
- premise/data/additional_inventories/lci-smr-atr-natgas.xlsx
- premise/data/additional_inventories/lci-smr-atr-biogas.xlsx
- premise/data/additional_inventories/lci-hydrogen-coal-gasification.xlsx
- premise/data/additional_inventories/lci-hydrogen-wood-gasification.xlsx

In case the IAM variable that relates to a given hydrogen pathway's efficiency is not available, the process' efficiency is not modified, with the exception of electrolysis, which is modified regardless.

A scaling factor is calculated for each pathway, which is the ratio between the IAM variable value for the year in question and the current efficiency value (i.e., in 2020). *premise* uses this scaling factor to adjust the amount of feedstock input to produce 1 kg of hydrogen (e.g., m3 of natural gas per kg hydrogen).

If the IAM variable that relates to the efficiency of the electrolysis hydrogen process is not available, *premise* adjusts the amount of electricity needed to produce 1 kg of hydrogen by electrolysis, on the basis of the following requirements, which are sourced from Bauer et al, 2022:

kWh/kg H2, 25 bar	2010	2020	2050
electricity	58	55	44

When building a database using IMAGE, land use and land use change emissions are available. Upon the import of crops farming datasets, *premise* adjusts the land occupation as well as CO2 emissions associated to land use and land use change, respectively.

Output	_	_	_
producer	amount	unit	location
Farming and supply of corn	1	kilogram	CEU
Input			
supplier	amount	unit	location
market for diesel, burned in agricultural machinery	0.142	megajoule	GLO
petrol, unleaded, burned in machinery	0.042	megajoule	GLO
market for natural gas, burned in gas motor, for storage	0.091	megajoule	GLO
market group for electricity, low voltage	0.004	kilowatt hour	CEU
Energy, gross calorific value, in biomass	15.910	megajoule	_
Occupation, annual crop	1.584	square meter-year	_
Carbon dioxide, in air	1.476	kilogram	_
Carbon dioxide, from soil or biomass stock	1.140	kilogram	_

The land use value is given from the IAM scenario in Ha/GJ of primary crop energy. Hence, the land occupation per kg of crop farmed is calculated as:

```
land_use = land_use [Ha/GJ] * 10000 [m2/Ha] / 1000 [MJ/GJ] * LHV [MJ/kg]
```

Regarding land use change CO2 emissions, the principle is similar. The variable is expressed in kg CO2/GJ of primary crop energy. Hence, the land use change CO2 emissions per kg of crop farmed are calculated as:

```
land_use_co2 = land_use_co2 [kg CO2/GJ] / 1000 [MJ/GJ] * LHV [MJ/kg]
```

premise builds several supply chains for synthetic fuels, for each IAM region. THe reason for this is that synthetic fuels can be produced from a variety of hydrogen and CO2 sources. Additionally, hydrogen can be supplied by different means of transport, and in different states.

premise starts by building different supply chains for hydrogen by varying:

- the transport mode: truck, hydrogen pipeline, re-assigned CNG pipeline, ship,
- the distance: 500 km, 2000 km
- the state of the hydrogen: gaseous, liquid, liquid organic compound,
- the hydrogen production route: electrolysis, SMR, biomass gasifier (coal, woody biomass)

Hence, for each IAM region, the following supply chains for hydrogen are built:

- hydrogen supply, from electrolysis, by ship, as liquid, over 2000 km
- hydrogen supply, from gasification of biomass by heatpipe reformer, by H2 pipeline, as gaseous, over 500 km
- hydrogen supply, from ATR of from natural gas, by truck, as gaseous, over 500 km
- hydrogen supply, from gasification of biomass by heatpipe reformer, by truck, as liquid organic compound, over 500 km
- hydrogen supply, from SMR of from natural gas, with CCS, by truck, as liquid organic compound, over 500 km
- hydrogen supply, from SMR of from natural gas, with CCS, by ship, as liquid, over 2000 km
- hydrogen supply, from coal gasification, by CNG pipeline, as gaseous, over 500 km
- hydrogen supply, from SMR of from natural gas, by ship, as liquid, over 2000 km

- hydrogen supply, from coal gasification, by truck, as liquid, over 500 km
- hydrogen supply, from gasification of biomass by heatpipe reformer, by truck, as liquid, over 500 km
- hydrogen supply, from ATR of from natural gas, with CCS, by truck, as liquid organic compound, over 500 km
- hydrogen supply, from SMR of from natural gas, with CCS, by truck, as liquid, over 500 km
- hydrogen supply, from electrolysis, by truck, as liquid organic compound, over 500 km
- hydrogen supply, from gasification of biomass, by truck, as liquid organic compound, over 500 km
- hydrogen supply, from SMR of from natural gas, with CCS, by truck, as gaseous, over 500 km
- hydrogen supply, from SMR of biogas, with CCS, by CNG pipeline, as gaseous, over 500 km
- hydrogen supply, from SMR of from natural gas, by truck, as gaseous, over 500 km
- hydrogen supply, from SMR of from natural gas, by H2 pipeline, as gaseous, over 500 km
- hydrogen supply, from gasification of biomass, with CCS, by truck, as liquid organic compound, over 500 km
- hydrogen supply, from gasification of biomass, by ship, as liquid, over 2000 km

Each supply route is associated with specific losses. Losses for the transport of H2 by truck and hydrogen pipelines, and losses at the regional storage storage (salt cavern) are from Wulf et al, 2018. Boil-off loss values during shipping are from Hank et al, 2020. Losses when transporting H2 via re-assigned CNG pipelines are from Cerniauskas et al, 2020. Losses along the pipeline are from Schori et al, 2012., but to be considered conservative, as those are initially for natural gas (and hydrogen has a higher potential for leaking).

_	_	truck	ship	H2 pipeline	CNG pipeline	reference flow
gaseous	compression	0.5%		0.5%	0.5%	per kg H2
_	storage buffer			2.3%	2.3%	per kg H2
_	storage leak			1.0%	1.0%	per kg H2
_	pipeline leak			0.004%	0.004%	per kg H2, per km
_	purification				7.0%	per kg H2
liquid	liquefaction	1.3%	1.3%			per kg H2
_	vaporization	2.0%	2.0%			per kg H2
_	boil-off	0.2%	0.2%			per kg H2, per day
liquid organic compound	hydrogenation	0.5%				per kg H2

Losses are cumulative along the supply chain and range anywhere between 5 and 20%. The table below shows the example of 1 kg of hydrogen transport via re-assigned CNG pipelines, as a gas, over 500 km. A total of 0.13 kg of hydrogen is lost along the supply chain (13% loss):

Output	_	_	_
producer	amount	unit	location
hydrogen supply, from electrolysis, by CNG pipeline, as gaseous, over 500 km	1	kilogram	OCE
Input			
supplier	amount	unit	location
hydrogen production, gaseous, 25 bar, from electrolysis	1.133	kilogram	OCE
market group for electricity, low voltage	3.091	kilowatt hour	OCE
market group for electricity, low voltage	0.516	kilowatt hour	OCE
hydrogen embrittlement inhibition	1	kilogram	OCE
geological hydrogen storage	1	kilogram	OCE
Hydrogen refuelling station	1.14E-07	unit	OCE
distribution pipeline for hydrogen, reassigned CNG pipeline	1.56E-08	kilometer	RER
transmission pipeline for hydrogen, reassigned CNG pipeline	1.56E-08	kilometer	RER

- 7% during the purification of hydrogen: when using CNG pipelines, the hydrogen has to be mixed with another gas to prevent the embrittlement of the pipelines. The separation process at the other end leads to significant losses
- 2% lost along the 500 km of pipeline
- 3% at the regional storage (salt cavern)

Also, in this same case, electricity is used:

- 1.9 kWh to compress the H2 from 25 bar to 100 bar to inject it into the pipeline
- 1.2 kWh to recompress the H2 along the pipeline every 250 km
- 0.34 kWh for injecting and pumping H2 into a salt cavern
- 2.46 kWh to blend the H2 with oxygen on one end, and purify on the other
- 0.5 kWh to pre-cool the H2 at the fuelling station (necessary if used in fuel cells, for example)

premise builds markets for the following fuels:

- market for petrol, unleaded
- market for petrol, low-sulfur
- market for diesel, low-sulfur
- market for diesel
- market for natural gas, high pressure
- market for hydrogen, gaseous

based on the IAM scenario data regarding the composition of liquid and gaseous secondary energy carriers:

Warning: Some fuel types are not properly represented in the LCI database. Available inventories for biomass-based methanol production do not differentiate between wood and grass as the feedstock.

Note: **Modelling choice**: *premise* builds several potential supply chains for hydrogen. Because the logistics to supply hydrogen in the future is not known or indicated by the IAM, the choice is made to supply it by truck over 500 km, in a gaseous state.

Because not all competing fuels of a same type have similar calorific values, some adjustments are made. The table below shows the example of the market for gasoline, for the IMAGE region of Western Europe in 2050. The sum of fuel inputs is superior to 1 (i.e., 1.4 kg). This is because the market dataset as "1 kg" as reference unit, and methanol and bioethanol have low calorific values comparatively to petrol (i.e., 19.9 and 26.5 MJ/kg respectively, vs. 42.6 MJ/kg for gasoline). Hence, their inputs are scaled up to reach an average calorific value of 42.6 MJ/kg of fuel supplied by the market.

This is necessary as gasoline-consuming activities in the lCI database are modelled with the calorific value of conventional gasoline.

Output	_	_	_
producer	amount	unit	location
market for petrol, low-sulfur	1	kilogram	WEU
Input			
supplier	amount	unit	location
petrol production, low-sulfur	0.550	kilogram	CH
market for methanol, from biomass	0.169	kilogram	CH
market for methanol, from biomass	0.148	kilogram	CH
market for methanol, from biomass	0.122	kilogram	CH
market for methanol, from biomass	0.122	kilogram	CH
Ethanol production, via fermentation, from switchgrass	0.060	kilogram	WEU
Ethanol production, via fermentation, from switchgrass, with CCS	0.053	kilogram	WEU
Ethanol production, via fermentation, from sugarbeet	0.051	kilogram	WEU
Ethanol production, via fermentation, from sugarbeet, with CCS	0.051	kilogram	WEU
Ethanol production, via fermentation, from poplar, with CCS	0.041	kilogram	WEU
Ethanol production, via fermentation, from poplar	0.041	kilogram	WEU

Run

```
from premise import *
import brightway2 as bw

bw.projects.set_current("my_project)

ndb = NewDatabase(
    scenarios=[
            {"model":"remind", "pathway":"SSP2-Base", "year":2028}
        ],
    source_db="ecoinvent 3.7 cutoff",
    source_version="3.7.1",
    key='xxxxxxxxxxxxxxxxxxxxxxxxx'
)
ndb.update("heat")
```

Datasets that supply heat and steam via the combustion of natural gas and diesel are regionalized (made available for each region of the IAM model) and relinked to regional fuel markets. If the fuel market contains a share of non-fossil fuels, the CO2 emissions of the heat and steam production are split between fossil and non-fossil emissions. Once regionalized, the heat and steam production datasets relink to activities that require heat within the same region.

Here is a list of the heat and steam production datasets that are regionalized:

- diesel, burned in …
- steam production, as energy carrier, in chemical industry
- heat production, natural gas, …
- heat and power co-generation, natural gas, …
- heat production, light fuel oil, …
- heat production, softwood chips from forest, …
- heat production, hardwood chips from forest, …

These datasets are relinked to the corresponding regionalized fuel market only if *.update("fuels")* has been run. Also, heat production datasets that use biomass as fuel input (e.g., softwood and hardwood chips) relink to the dataset *market for biomass, used as fuel* if *update("biomass")* has been run previously.

premise iterates through activities that consume any of the newly created fuel markets to update the way CO2 emissions are modelled. Based on the fuel market composition, CO2 emissions within the fuel-consuming activity are split between fossil and non-fossil emissions.

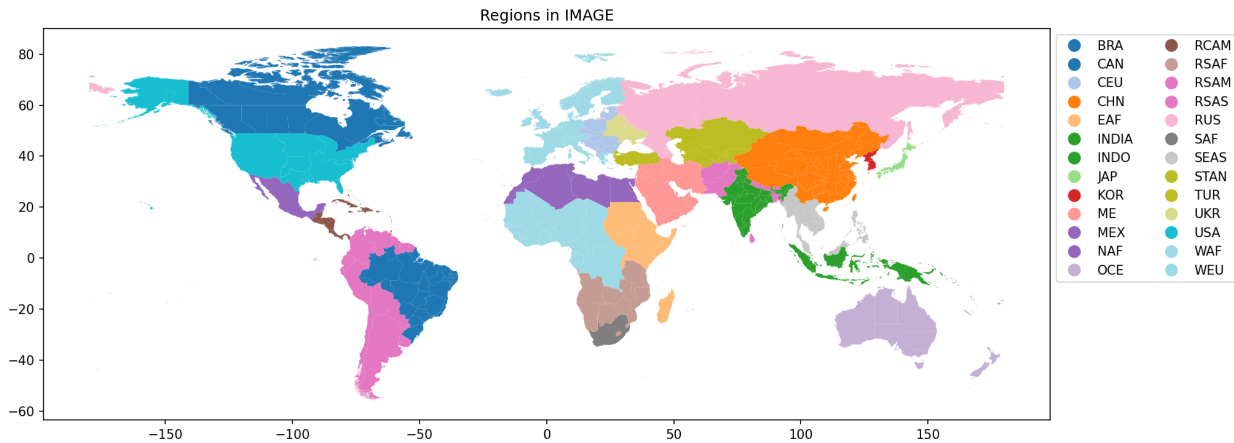
The table below shows the example where the CO2 emissions of a 3.5t truck have been split into biogenic and fossil fractions after re-link to the new diesel market of the REMIND region for India.

Output	before	after	_	_
producer	amount	amount	unit	location
transport, freight, lorry, diesel, 3.5t	1	1	ton-kilometer	IND
Input				
supplier	amount	amount	unit	location
treatment of tyre wear emissions, lorry	-0.0009	-0.0009	kilogram	RER
market for road maintenance	0.0049	0.0049	meter-year	RER
market for road	0.0041	0.0041	meter-year	GLO
treatment of road wear emissions, lorry	-0.0008	-0.0008	kilogram	RER
market for refrigerant R134a	2.84E-05	2.84E-05	kilogram	GLO
treatment of brake wear emissions, lorry	-0.0005	-0.0005	kilogram	RER
Light duty truck, diesel, 3.5t	1.39E-05	1.39E-05	unit	RER
market for diesel, low-sulfur	0.1854	0.1854	kilogram	IND
Carbon dioxide, fossil	0.5840	0.5667	kilogram	_
Carbon dioxide, non-fossil	0.0000	0.0173	kilogram	_
Nitrogen oxides	0.0008	0.0008	kilogram	_
Nitrogen oxides	0.0003	0.0003	kilogram	_

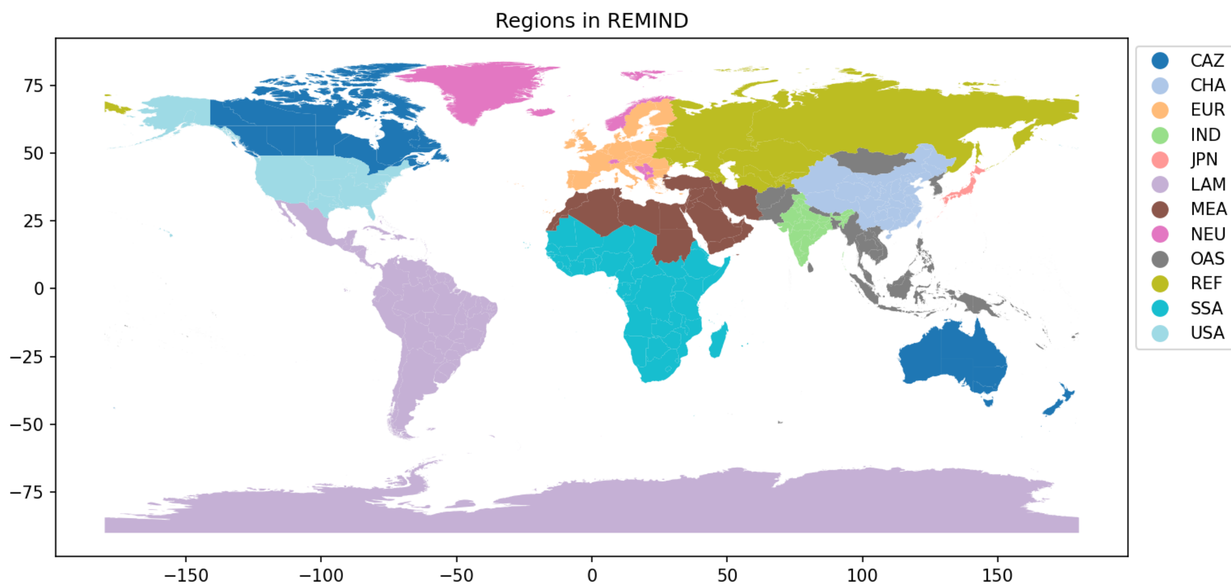
3.8 Geographical mapping

IAM models have slightly different geographical resolutions and definitions.

Map of IMAGE regions



Map of REMIND regions



premise uses the following correspondence between ecoinvent locations and IAM regions. This mapping is performed by the constructive_geometries implementation in the wurst library.

ecoinvent location	REMIND region	IMAGE region
AE	MEA	ME
AL	NEU	CEU
AM	REF	RUS
AO	SSA	RSAF
APAC	OAS	SEAS
AR	LAM	RSAM

continues on next page

Table 2 – continued from previous page

ecoinvent location	REMIND region	IMAGE region
AT	EUR	WEU
AU	CAZ	OCE
AZ	REF	RUS
BA	NEU	CEU
BD	OAS	RSAS
BE	EUR	WEU
BG	EUR	CEU
BH	MEA	ME
BJ	SSA	WAF
BN	OAS	SEAS
BO	LAM	RSAM
BR	LAM	BRA
BR-AC	LAM	BRA
BR-AL	LAM	BRA
BR-AM	LAM	BRA
BR-AP	LAM	BRA
BR-BA	LAM	BRA
BR-CE	LAM	BRA
BR-DF	LAM	BRA
BR-ES	LAM	BRA
BR-GO	LAM	BRA
BR-MA	LAM	BRA
BR-MG	LAM	BRA
BR-Mid-western grid	LAM	BRA
BR-MS	LAM	BRA
BR-MT	LAM	BRA
BR-North-eastern grid	LAM	BRA
BR-Northern grid	LAM	BRA
BR-PA	LAM	BRA
BR-PB	LAM	BRA
BR-PE	LAM	BRA
BR-PI	LAM	BRA
BR-PR	LAM	BRA
BR-RJ	LAM	BRA
BR-RN	LAM	BRA
BR-RO	LAM	BRA
BR-RR	LAM	BRA
BR-RS	LAM	BRA
BR-SC	LAM	BRA
BR-SE	LAM	BRA
BR-South-eastern grid	LAM	BRA
BR-Southern grid	LAM	BRA
BR-SP	LAM	BRA
BR-TO	LAM	BRA
BW	SSA	RSAF
BY	REF	UKR
CA	CAZ	CAN
CA-AB	CAZ	CAN
CA-BC	CAZ	CAN
CA-MB	CAZ	CAN

continues on next page

Table 2 – continued from previous page

ecoinvent location	REMIND region	IMAGE region
Canada without Quebec	CAZ	CAN
CA-NB	CAZ	CAN
CA-NF	CAZ	CAN
CA-NS	CAZ	CAN
CA-NT	CAZ	CAN
CA-NU	CAZ	CAN
CA-ON	CAZ	CAN
CA-PE	CAZ	CAN
CA-QC	CAZ	CAN
CA-SK	CAZ	CAN
CA-YK	CAZ	CAN
CD	SSA	WAF
CENTREL	EUR	CEU
CG	SSA	WAF
CH	NEU	WEU
CI	SSA	WAF
CL	LAM	RSAM
CM	SSA	WAF
CN	CHA	CHN
CN-AH	CHA	CHN
CN-BJ	CHA	CHN
CN-CQ	CHA	CHN
CN-CSG	CHA	CHN
CN-FJ	CHA	CHN
CN-GD	CHA	CHN
CN-GS	CHA	CHN
CN-GX	CHA	CHN
CN-GZ	CHA	CHN
CN-HA	CHA	CHN
CN-HB	CHA	CHN
CN-HE	CHA	CHN
CN-HL	CHA	CHN
CN-HN	CHA	CHN
CN-HU	CHA	CHN
CN-JL	CHA	CHN
CN-JS	CHA	CHN
CN-JX	CHA	CHN
CN-LN	CHA	CHN
CN-NM	CHA	CHN
CN-NX	CHA	CHN
CN-QH	CHA	CHN
CN-SA	CHA	CHN
CN-SC	CHA	CHN
CN-SD	CHA	CHN
CN-SGCC	CHA	CHN
CN-SH	CHA	CHN
CN-SX	CHA	CHN
CN-TJ	CHA	CHN
CN-XJ	CHA	CHN
CN-XZ	CHA	CHN

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Table 2 – continued from previous page

ecoinvent location	REMIND region	IMAGE region
CN-YN	CHA	CHN
CN-ZJ	CHA	CHN
CO	LAM	RSAM
CR	LAM	RCAM
CU	LAM	RCAM
CW	LAM	RCAM
CY	EUR	CEU
CZ	EUR	CEU
DE	EUR	WEU
DK	EUR	WEU
DO	LAM	RCAM
DZ	MEA	NAF
EC	LAM	RSAM
EE	EUR	CEU
EG	MEA	NAF
ENTSO-E	EUR	WEU
ER	SSA	EAF
ES	EUR	WEU
ET	SSA	EAF
Europe without Austria	EUR	WEU
Europe without Switzerland	EUR	WEU
Europe without Switzerland and Austria	EUR	WEU
Europe, without Russia and Turkey	EUR	WEU
FI	EUR	WEU
FR	EUR	WEU
GA	SSA	WAF
GB	EUR	WEU
GE	REF	RUS
GH	SSA	WAF
GI	EUR	WEU
GLO	World	World
GR	EUR	WEU
GT	LAM	RCAM
HK	CHA	CHN
HN	LAM	RCAM
HR	EUR	CEU
HT	LAM	RCAM
HU	EUR	CEU
IAI Area, Africa	SSA	RSAF
IAI Area, Asia, without China and GCC	OAS	SEAS
IAI Area, EU27 & EFTA	EUR	WEU
IAI Area, Gulf Cooperation Council	MEA	ME
IAI Area, North America	USA	USA
IAI Area, Russia & RER w/o EU27 & EFTA	REF	RUS
IAI Area, South America	LAM	RSAM
ID	OAS	INDO
IE	EUR	WEU
IL	MEA	ME
IN	IND	INDIA
IN-AP	IND	INDIA

continues on next page

Table 2 – continued from previous page

ecoinvent location	REMIND region	IMAGE region
IN-AR	IND	INDIA
IN-AS	IND	INDIA
IN-BR	IND	INDIA
IN-CT	IND	INDIA
IN-DL	IND	INDIA
IN-Eastern grid	IND	INDIA
IN-GA	IND	INDIA
IN-GJ	IND	INDIA
IN-HP	IND	INDIA
IN-HR	IND	INDIA
IN-JH	IND	INDIA
IN-JK	IND	INDIA
IN-KA	IND	INDIA
IN-KL	IND	INDIA
IN-MH	IND	INDIA
IN-ML	IND	INDIA
IN-MN	IND	INDIA
IN-MP	IND	INDIA
IN-NL	IND	INDIA
IN-North-eastern grid	IND	INDIA
IN-Northern grid	IND	INDIA
IN-OR	IND	INDIA
IN-PB	IND	INDIA
IN-PY	IND	INDIA
IN-RJ	IND	INDIA
IN-SK	IND	INDIA
IN-Southern grid	IND	INDIA
IN-TN	IND	INDIA
IN-TR	IND	INDIA
IN-UP	IND	INDIA
IN-UT	IND	INDIA
IN-WB	IND	INDIA
IN-Western grid	IND	INDIA
IQ	MEA	ME
IR	MEA	ME
IS	NEU	WEU
IT	EUR	WEU
JM	LAM	RCAM
JO	MEA	ME
JP	JPN	JAP
KE	SSA	EAF
KG	REF	STAN
KH	OAS	SEAS
KP	OAS	KOR
KR	OAS	KOR
KW	MEA	ME
KZ	REF	STAN
LB	MEA	ME
LK	OAS	RSAS
LT	EUR	CEU

continues on next page

Table 2 – continued from previous page

ecoinvent location	REMIND region	IMAGE region
LU	EUR	WEU
LV	EUR	CEU
LY	MEA	NAF
MA	MEA	NAF
MD	REF	UKR
ME	NEU	ME
MG	SSA	EAF
MK	NEU	CEU
MM	OAS	SEAS
MN	OAS	CHN
MT	EUR	WEU
MU	SSA	EAF
MX	LAM	MEX
MY	OAS	SEAS
MZ	SSA	RSAF
NA	SSA	RSAF
NE	SSA	WAF
NG	SSA	WAF
NI	LAM	RCAM
NL	EUR	WEU
NO	NEU	WEU
NORDEL	NEU	WEU
North America without Quebec	USA	USA
NP	OAS	RSAS
NZ	CAZ	OCE
OCE	CAZ	OCE
OM	MEA	ME
PA	LAM	RCAM
PE	LAM	RSAM
PG	OAS	INDO
PH	OAS	SEAS
PK	OAS	RSAS
PL	EUR	CEU
PT	EUR	WEU
PY	LAM	RSAM
QA	MEA	ME
RAF	SSA	RSAF
RAS	CHA	CHN
RER	EUR	WEU
RER w/o CH+DE	EUR	WEU
RER w/o DE+NL+RU	EUR	WEU
RER w/o RU	EUR	WEU
RLA	LAM	RSAM
RME	MEA	ME
RNA	USA	USA
RO	EUR	CEU
RoW	World	World
RS	NEU	CEU
RU	REF	RUS
RW	SSA	EAF

continues on next page

Table 2 – continued from previous page

ecoinvent location	REMIND region	IMAGE region
SA	MEA	ME
SAS	IND	INDIA
SD	MEA	EAF
SE	EUR	WEU
SG	OAS	SEAS
SI	EUR	CEU
SK	EUR	CEU
SN	SSA	WAF
SS	SSA	EAF
SV	LAM	RCAM
SY	MEA	ME
TG	SSA	WAF
TH	OAS	SEAS
TJ	REF	STAN
TM	REF	STAN
TN	MEA	NAF
TR	MEA	TUR
TT	LAM	RCAM
TW	CHA	CHN
TZ	SSA	RSAF
UA	REF	UKR
UCTE	EUR	WEU
UCTE without Germany	EUR	WEU
UN-OCEANIA	CAZ	OCE
UN-SEASIA	OAS	SEAS
US	USA	USA
US-ASCC	USA	USA
US-HICC	USA	USA
US-MRO	USA	USA
US-NPCC	USA	USA
US-PR	USA	USA
US-RFC	USA	USA
US-SERC	USA	USA
US-TRE	USA	USA
US-WECC	USA	USA
UY	LAM	RSAM
UZ	REF	STAN
VE	LAM	RSAM
VN	OAS	SEAS
WECC	USA	USA
WEU	EUR	WEU
XK	EUR	CEU
YE	MEA	ME
ZA	SSA	SAF
ZM	SSA	RSAF
ZW	SSA	RSAF

3.9 Regionalization

Several of the integration steps described above involve the regionalization of datasets. It is the case, for example, when introducing datasets representing a process for each of the IAM regions. In such case, the datasets are regionalized by selecting the most representative suppliers of inputs for each region. If a dataset in a specific IAM region requires tap water, for example, the regionalization process will select the most representative water suppliers in that region.

If more than one supplier is available, the regionalization process will allocated a supply share to each candidate supplier based on their respective production volume. If no adequate supplier is found for a given region, the regionalization process will select all the existing suppliers and allocate a supply share to each supplier based on their respective production volume.

Here is the decision tree followed:

Decision Tree for Processing Datasets

The process begins with a dataset that requires processing.

3.9.1 Decision: Is the Exchange in Cache?

- **Yes**
  - Use `process_cached_exchange()`.
    - Retrieve cached data.
    - Update `new_exchanges` with cached data.
- **No**
  - Use `process_uncached_exchange()`.
    - **None**
      - Print a warning and return.
    - **One**
      - Use `handle_single_possible_dataset()`.
      - Use the single matched dataset.
      - Update `new_exchanges` with this dataset information.
    - **Multiple**
      - Use `handle_multiple_possible_datasets()`.
      - **Yes**
      - Use the matched dataset location.
      - **No**
      - Use `process_complex_matching_and_allocation()`.
      - **IAM Region**
      - Use `handle_iam_region()`.

- Match IAM region to ecoinvent locations.
- Update `new_exchanges` with IAM region-specific data.
- Cache the new entry.
- **Global ('GLO', 'RoW', 'World')**
- Use `handle_global_and_row_scenarios()`.
- Allocate inputs for global datasets.
- Update `new_exchanges` with global data.
- Cache the new entry.
- **Others**
- Perform GIS matching.
- Determine intersecting locations with GIS.
- Allocate inputs based on GIS matches.
- Update `new_exchanges` with GIS-specific data.
- Cache the new entry.

3.9.2 Final Steps

- If no match is found, use `handle_default_option()`.
  - Integrate new exchanges into the dataset.

3.10 GAINS emission factors

Run

```
from premise import *
import brightway2 as bw

bw.projects.set_current("my_project)

ndb = NewDatabase(
    scenarios=[
            {"model":"remind", "pathway":"SSP2-Base", "year":2028}
        ],
    source_db="ecoinvent 3.7 cutoff",
    source_version="3.7.1",
    key='xxxxxxxxxxxxxxxxxxxxxxxxx'
)
ndb.update("emissions")
```

When using *update("emissions")*, emission factors from the GAINS-EU and GAINS-IAM models are used to scale non-CO2 emissions in various datasets.

The emission factors are available under https://github.com/polca/premise/tree/master/premise/data/GAINS_emission_factors

Emission factors from GAINS-EU are applied to activities in European countries. Emission factors from GAINS-IAM are applied to activities in non-European countries, or to European activities if an emission facor from GAINS-EU has not been applied first.

Emission factors are specific to:

- an activity type,
- a year,
- a country (for GAINS-EU, otherwise a region),
- a fuel type,
- a technology type,
- and a scenario.

The mapping between GAINS and ecoinvent activities is available under the following file: https://github.com/polca/premise/blob/master/premise/data/GAINS_emission_factors/gains_ecoinvent_sectoral_mapping.yaml

The table below shows the mapping between ecoinvent and GAINS emission flows.

ecoinvent species	GAINS species
Sulfur dioxide	SO2
Sulfur oxides	SO2
Carbon monoxide, fossil	CO
Carbon monoxide, non-fossil	CO
Carbon monoxide, from soil or biomass stock	CO
Nitrogen oxides	NOx
Ammonia	NH3
NMVOC, non-methane volatile organic compounds, unspecified origin	VOC
VOC, volatile organic compounds, unspecified origin	VOC
Methane	CH4
Methane, fossil	CH4
Methane, non-fossil	CH4
Methane, from soil or biomass stock	CH4
Dinitrogen monoxide	N2O
Particulates, > 10 um	PM10
Particulates, > 2.5 um, and < 10um	PM25
Particulates, < 2.5 um	PM1

We consider emission factors in ecoinvent as representative of the current situation. Hence, we calculate a *scaling factor* from the GAINS emission factors for the year of the scenario relative to the year 2020. note that premise prevents scaling factors to be inferior to 1 if the year is inferior to 2020. Inversely, scaling factors cannot be superior to 1 if the year is superior to 2020.

Two GAINS-IAM scenarios are available:

- **CLE**: **C**urrent **LE**gislation scenario
- **MFR**: **M**aximum **F**easible **R**eduction scenario

By default, the CLE scenario is used. To use the MFR scenario:

```
ndb = NewDatabase(
    ...
    gains_scenario="MFR",
)
```

Finally, unlike GAINS-EU, GAINS-IAM uses IAM-like regions, not countries. The mapping between IAM regions and GAINS-IAM regions is available under the following file:

https://github.com/polca/premise/blob/master/premise/iam_variables_mapping/gains_regions_mapping.yaml

For questions related to GAINS modelling, please contact the respective GAINS team:

- GAINS-EU: https://gains.iiasa.ac.at/gains/EUN/index.login
- GAINS-IAM: https://gains.iiasa.ac.at/gains/IAM/index.login

3.11 Logs

premise generates a spreadsheet report detailing changes made to the database for each scenario. The report is saved in the current working directory and is automatically generated after database export.

The report lists the datasets added, updated and emptied. It also gives a number of indicators relating to efficiency, emissions, etc. for each scenario.

Finally, it also contains a "Validation" tab that lists datasets which potentially present erroneous values. These datasets are to be checked by the user.

This report can also be generated manually using the *generate_change_report()* method.

CHAPTER

FOUR

LOAD

4.1 Back to a brightway2 project

4.1.1 Regular brightway2 database

premise uses *bw2io* to load the LCI database back into a *brightway2* project. This is done as follows:

```
ndb.write_db_to_brightway()
```

If several databases have been built, the user can give them specific names, like so:

```
ndb.write_db_to_brightway(name=["db_1", "db_2"])
```

4.1.2 Superstructure database

If several scenario databases are built, *premise* can generate a superstructure database, as explained in Steubing et al, 2021. This allows to explore several scenarios while writing only one database in a brightway2 project. Besides writing the database to disk, this also creates a *scenario difference file* that will be read by Activity-Browser.

This is done as follows:

```
ndb.write_superstructure_db_to_brightway()
```

You can also specify a file path for the export of the scenario difference file:

```
ndb.write_superstructure_db_to_brightway(filepath="some_file_path")
```

Finally, you can also give a name to the superstructure database:

```
ndb.write_superstructure_db_to_brightway(filepath="some_file_path", name="my_db")
```

Note: Superstructure databases can only be used by Activity-Browser at the moment.

4.2 As sparse matrices

premise can generate a sparse matrix representation of the database(s). This is useful when no LCA software can be used, or when connections to SQL databases should be avoided.

This is done as follows:

```
ndb.write_db_to_matrices()
```

This creates a set of CSV files:

- a CSV file that represents product exchanges between activities, under the form [a, b, x]
- a CSV file that represent natural flow exchanges between activities and the biosphere, under the form [a, c, x]
- and another two CSV files contains the mapping between the activity names are the indices in the matrices

with a being the row index of an activity, b being the column index of an activity, c being a natural flow, and x being the value exchanged.

For example, the following piece of script calculates the GWP score of all activities in the database:

```
""" COLLECT DATA """
# creates dict of activities <--> indices in A matrix
A_inds = dict()
with open("A_matrix_index.csv", 'r') as read_obj:
    csv_reader = reader(read_obj, delimiter=";")
    for row in csv_reader:
        A_inds[(row[0], row[1], row[2], row[3])] = row[4]
A_inds_rev = {int(v):k for k, v in A_inds.items()}

# creates dict of bio flow <--> indices in B matrix
B_inds = dict()
with open("B_matrix_index.csv", 'r') as read_obj:
    csv_reader = reader(read_obj, delimiter=";")
    for row in csv_reader:
        B_inds[(row[0], row[1], row[2], row[3])] = row[4]
B_inds_rev = {int(v):k for k, v in B_inds.items()}

# create a sparse A matrix
A_coords = np.genfromtxt("A_matrix.csv", delimiter=";", skip_header=1)
I = A_coords[:, 0].astype(int)
J = A_coords[:, 1].astype(int)
A = sparse.csr_matrix((A_coords[:,2], (J, I)))

# create a sparse B matrix
B_coords = np.genfromtxt("B_matrix.csv", delimiter=";", skip_header=1)
I = B_coords[:, 0].astype(int)
J = B_coords[:, 1].astype(int)
B = sparse.csr_matrix((B_coords[:,2] *- 1, (I, J)), shape=(A.shape[0], len(B_inds)))

# a vector with a few GWP CFs
gwp = np.zeros(B.shape[1])

gwp[[int(B_inds[x]) for x in B_inds if x[0]=="Carbon dioxide, non-fossil, resource␣
↪correction"]] = -1
```

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```
gwp[[int(B_inds[x]) for x in B_inds if x[0]=="Hydrogen"]] = 5
gwp[[int(B_inds[x]) for x in B_inds if x[0]=="Carbon dioxide, in air"]] = -1
gwp[[int(B_inds[x]) for x in B_inds if x[0]=="Carbon dioxide, non-fossil"]] = 1
gwp[[int(B_inds[x]) for x in B_inds if x[0]=="Carbon dioxide, fossil"]] = 1
gwp[[int(B_inds[x]) for x in B_inds if x[0]=="Carbon dioxide, from soil or biomass stock
↪"]] = 1
gwp[[int(B_inds[x]) for x in B_inds if x[0]=="Carbon dioxide, to soil or biomass stock
↪"]] = -1

l_res = []
for v in range(0, A.shape[0]):
    f = np.float64(np.zeros(A.shape[0]))
    f[v] = 1
    A_inv = spsolve(A, f)
    C = A_inv * B
    l_res.append((C * gwp).sum())
```

4.3 As Simapro CSV files

premise can export the databases as Simapro-CSV files.

This is done as follows:

```
ndb.write_db_to_simapro()
```

Note: The categorization of activities in the Simapro activity tree looks different from that of the original ecoinvent database accessed from Simapro. That is because *premise* relies on ISIC v.4 and CCP classifications to categorize activities. Also, a number of activities do not have a category and are found under *Meterials/Others*.

4.4 As Simapro CSV files for OpenLCA

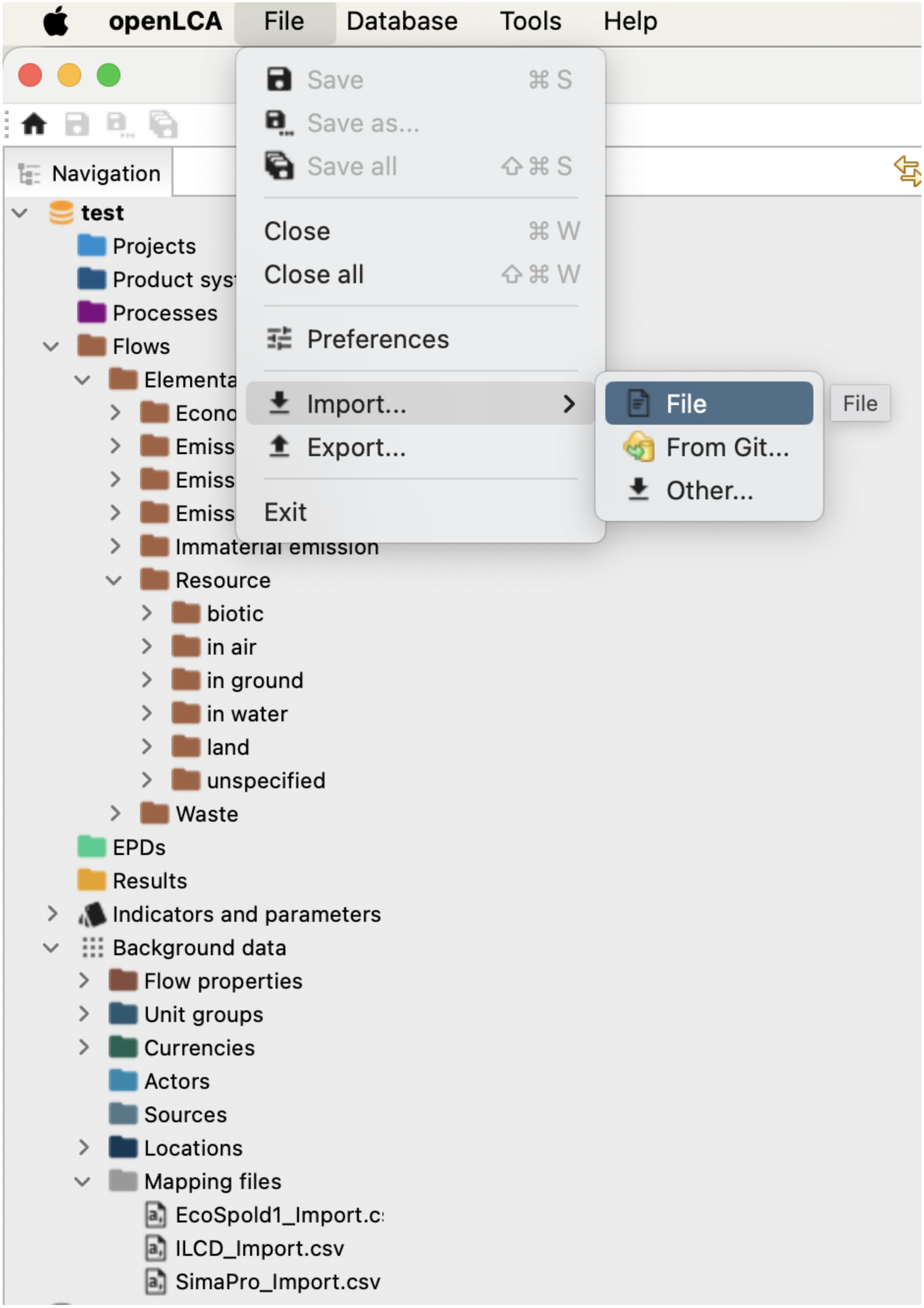
premise can export the databases as a modified version of Simapro-CSV files compatible with OpenLCA.

This is done as follows:

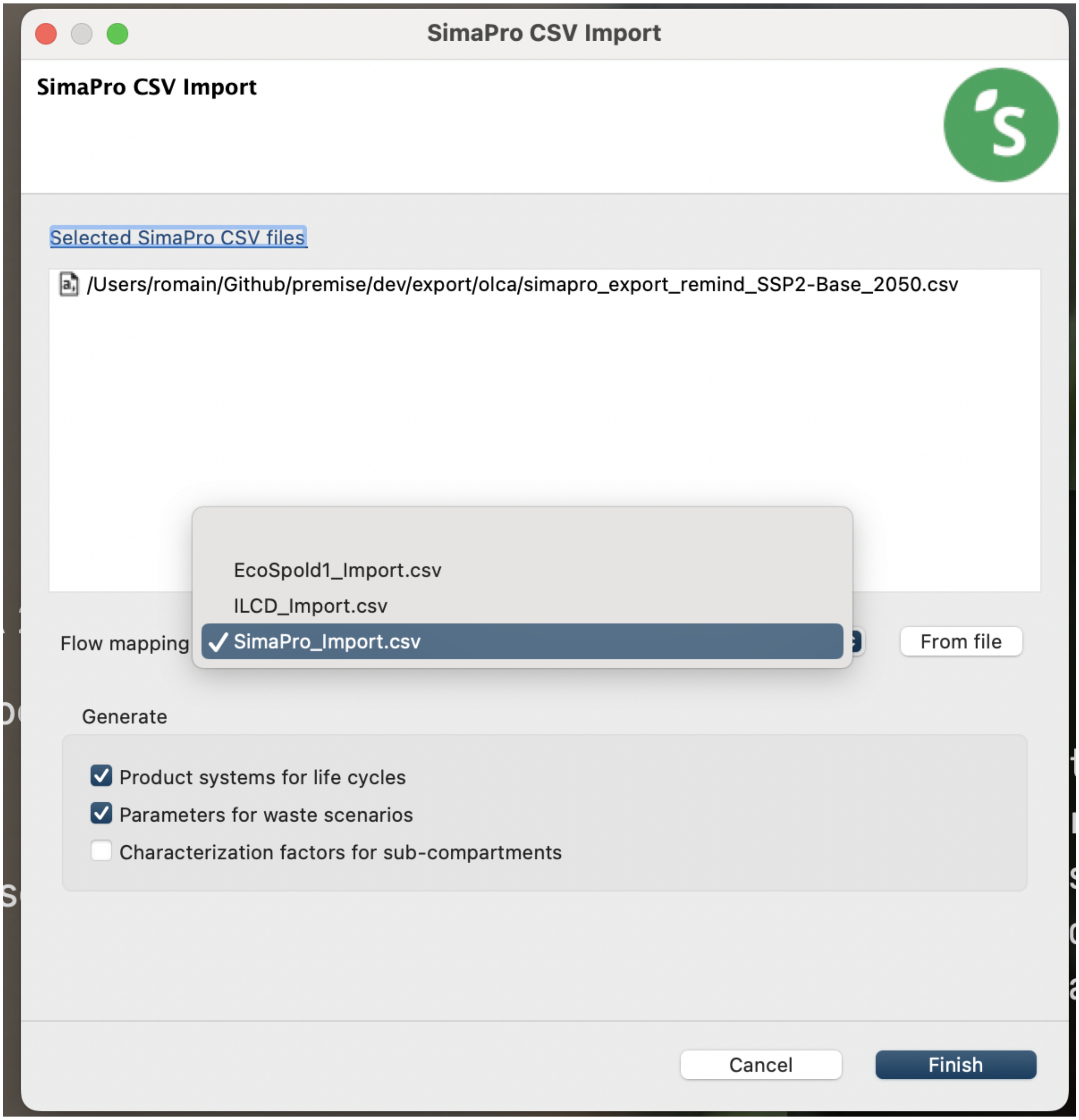
```
ndb.write_db_to_olca()
```

Note: The categorization of imported activities may differ from OpenLCA's original classification.

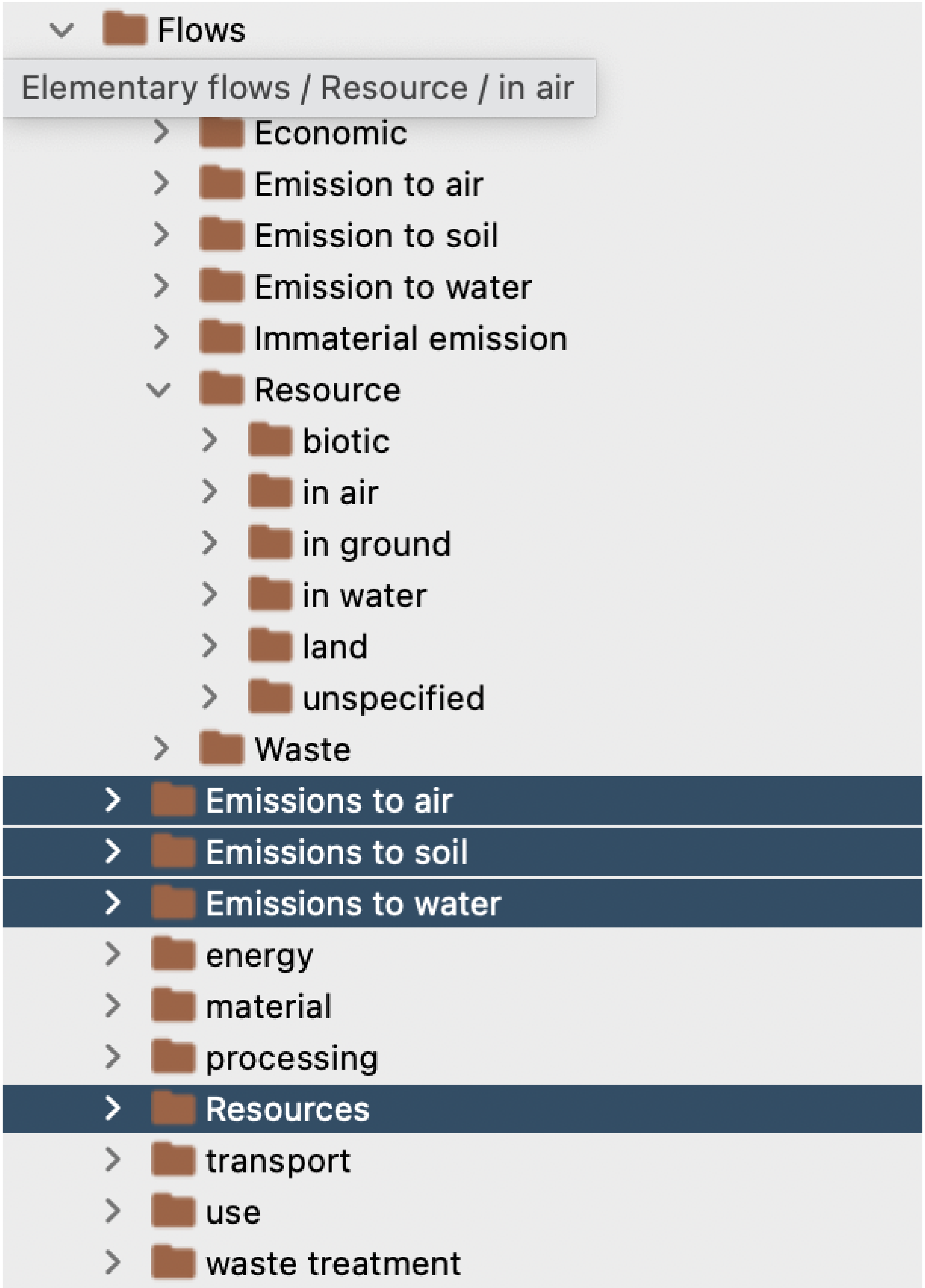
The Simapro CSV files can be imported in OpenLCA in a new database like so:


openLCA
File
Database
Tools
Help
Save ⌘ S
Save as...
Save all ⇧ ⌘ S
Close ⌘ W
Close all ⇧ ⌘ W
Preferences
Import...
Export...
Exit
File
From Git...
Other...
File
Navigation
test
Projects
Product sys
Processes
Flows
Elementa
Econo
Emiss
Emiss
Emiss
Immaterial emission
Resource
biotic
in air
in ground
in water
land
unspecified
Waste
EPDs
Results
Indicators and parameters
Background data
Flow properties
Unit groups
Currencies
Actors
Sources
Locations
Mapping files
EcoSpold1_Import.c
ILCD_Import.csv
SimaPro_Import.csv

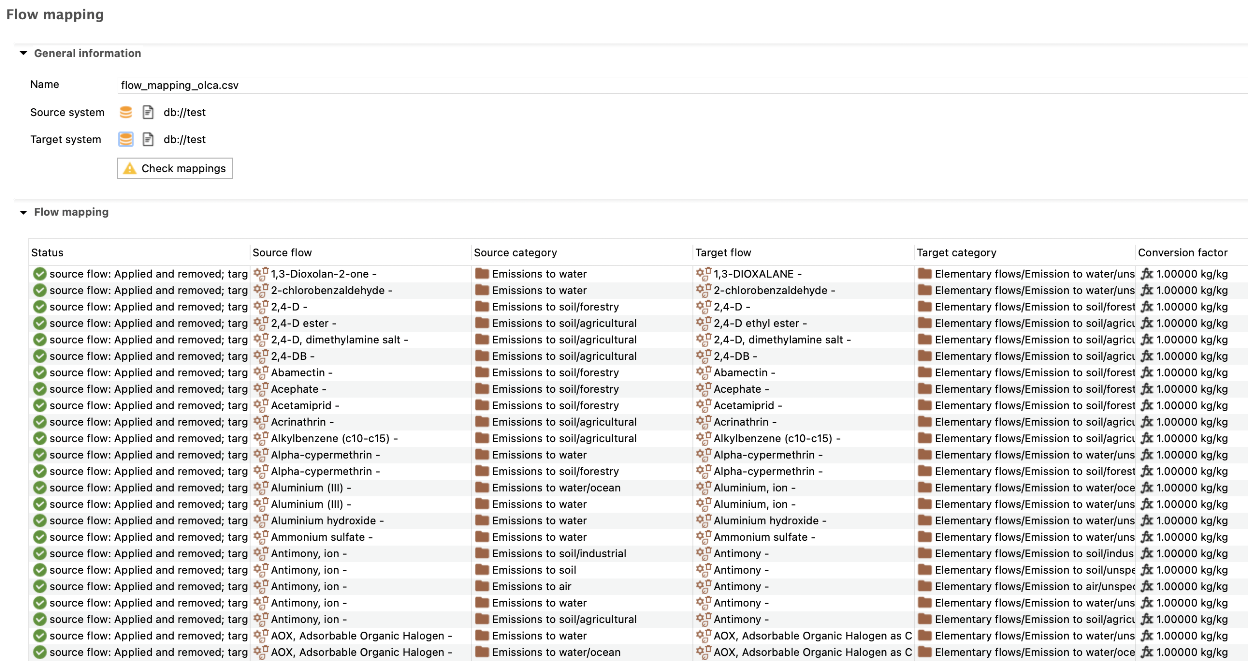
You will need to select "SimaproCSV_Import.csv" as mapping file to use.



Finally, once imported, unlinked flows remain. They can be found under these highlighted folders:


Flows
Elementary flows / Resource / in air
Economic
Emission to air
Emission to soil
Emission to water
Immaterial emission
Resource
biotic
in air
in ground
in water
land
unspecified
Waste
Emissions to air
Emissions to soil
Emissions to water
energy
material
processing
Resources
transport
use
waste treatment

To link them, you need to import an additional mapping flow that you can find here (“Tools” > “Flow mapping” > “Open file”).



Flow mapping

General information

Name flow_mapping_olca.csv

Source system db://test

Target system db://test

Check mappings

Flow mapping

Status	Source flow	Source category	Target flow	Target category	Conversion factor
source flow: Applied and removed; targ	1,3-Dioxolan-2-one -	Emissions to water	1,3-DIOXALANE -	Elementary flows/Emission to water/uns	1.00000 kg/kg
source flow: Applied and removed; targ	2-chlorobenzaldehyde -	Emissions to water	2-chlorobenzaldehyde -	Elementary flows/Emission to water/uns	1.00000 kg/kg
source flow: Applied and removed; targ	2,4-D -	Emissions to soil/forestry	2,4-D -	Elementary flows/Emission to soil/forest	1.00000 kg/kg
source flow: Applied and removed; targ	2,4-D ester -	Emissions to soil/agricultural	2,4-D ethyl ester -	Elementary flows/Emission to soil/agricu	1.00000 kg/kg
source flow: Applied and removed; targ	2,4-D, dimethylamine salt -	Emissions to soil/agricultural	2,4-D, dimethylamine salt -	Elementary flows/Emission to soil/agricu	1.00000 kg/kg
source flow: Applied and removed; targ	2,4-DB -	Emissions to soil/agricultural	2,4-DB -	Elementary flows/Emission to soil/agricu	1.00000 kg/kg
source flow: Applied and removed; targ	Abamectin -	Emissions to soil/forestry	Abamectin -	Elementary flows/Emission to soil/forest	1.00000 kg/kg
source flow: Applied and removed; targ	Acephate -	Emissions to soil/forestry	Acephate -	Elementary flows/Emission to soil/forest	1.00000 kg/kg
source flow: Applied and removed; targ	Acetamiprid -	Emissions to soil/forestry	Acetamiprid -	Elementary flows/Emission to soil/forest	1.00000 kg/kg
source flow: Applied and removed; targ	Acrinathrin -	Emissions to soil/agricultural	Acrinathrin -	Elementary flows/Emission to soil/agricu	1.00000 kg/kg
source flow: Applied and removed; targ	Alkylbenzene (c10-c15) -	Emissions to soil/agricultural	Alkylbenzene (c10-c15) -	Elementary flows/Emission to soil/agricu	1.00000 kg/kg
source flow: Applied and removed; targ	Alpha-cypermethrin -	Emissions to water	Alpha-cypermethrin -	Elementary flows/Emission to water/uns	1.00000 kg/kg
source flow: Applied and removed; targ	Alpha-cypermethrin -	Emissions to soil/forestry	Alpha-cypermethrin -	Elementary flows/Emission to soil/forest	1.00000 kg/kg
source flow: Applied and removed; targ	Aluminium (III) -	Emissions to water/ocean	Aluminium, ion -	Elementary flows/Emission to water/oce	1.00000 kg/kg
source flow: Applied and removed; targ	Aluminium (III) -	Emissions to water	Aluminium, ion -	Elementary flows/Emission to water/uns	1.00000 kg/kg
source flow: Applied and removed; targ	Aluminium hydroxide -	Emissions to water	Aluminium hydroxide -	Elementary flows/Emission to water/uns	1.00000 kg/kg
source flow: Applied and removed; targ	Ammonium sulfate -	Emissions to water	Ammonium sulfate -	Elementary flows/Emission to water/uns	1.00000 kg/kg
source flow: Applied and removed; targ	Antimony, ion -	Emissions to soil/industrial	Antimony -	Elementary flows/Emission to soil/indus	1.00000 kg/kg
source flow: Applied and removed; targ	Antimony, ion -	Emissions to soil	Antimony -	Elementary flows/Emission to soil/unspe	1.00000 kg/kg
source flow: Applied and removed; targ	Antimony, ion -	Emissions to air	Antimony -	Elementary flows/Emission to air/unspec	1.00000 kg/kg
source flow: Applied and removed; targ	Antimony, ion -	Emissions to water	Antimony -	Elementary flows/Emission to water/uns	1.00000 kg/kg
source flow: Applied and removed; targ	Antimony, ion -	Emissions to soil/agricultural	Antimony -	Elementary flows/Emission to soil/agricu	1.00000 kg/kg
source flow: Applied and removed; targ	AOX, Adsorbable Organic Halogen -	Emissions to water	AOX, Adsorbable Organic Halogen as C	Elementary flows/Emission to water/uns	1.00000 kg/kg
source flow: Applied and removed; targ	AOX, Adsorbable Organic Halogen -	Emissions to water/ocean	AOX, Adsorbable Organic Halogen as C	Elementary flows/Emission to water/oce	1.00000 kg/kg

And then go to “Flow mapping” > “Apply on database”. A few dozens of unlinked flows will remain. You may fix that by manually mapping them.

4.5 As a data package

premise can export the databases as a data package, which is a standardized way of packaging data. This is useful when you want to share your databases with others, without sharing the source database (i.e., ecoinvent), which is under restrictive license.

This is done as follows:

```
ndb.write_db_to_datapackage()
```

This creates a zip file that contains the all the data necessary for other users to replicate the databases, provided they have access to the source database locally.

See the library <`unfold` https://github.com/polca/unfold/tree/main>_ for more information on data packages for sharing LCA databases. `unfold` can read these data packages and create brightway2 databases (or superstructure databases) from them. `unfold` can also fold premise databases registered in your brightway2 project into data packages, to be shared with and recreated by others.

CHAPTER

FIVE

MAPPING

5.1 Link to a new IAM model

Although *premise* comes with a set of scenarios from the REMIND and IMAGE IAM models, it is possible to link it to a new IAM model. To do so, you need to populate the .yaml mapping files under the folder https://github.com/polca/premise/tree/master/premise/iam_variables_mapping.

For each variable in each of the .yaml files, specify the corresponding IAM variable name as follows:

```
Biomass CHP:
  iam_aliases:
    remind: SE|Electricity|Biomass|++|Combined Heat and Power w/o CC
    image: Secondary Energy|Electricity|Biomass|w/o CCS|3

    new_IAM: new_IAM_variable_name <--- this is the new IAM variable name

  eff_aliases:
    remind: Tech|Electricity|Biomass|Combined Heat and Power w/o CC|Efficiency
    image: Efficiency|Electricity|Biomass|w/o CCS|3

    new_IAM: new_IAM_efficiency_variable_name <--- this is the new IAM variable name

  ecoinvent_aliases:
    fltr:
      - heat and power co-generation, wood chips
    mask:
      reference product: heat
  ecoinvent_fuel_aliases:
    fltr:
      - market for wood chips, wet, measured as dry mass
```

If efficiency-related variables are not available, the corresponding technologies will simply not have their efficiency adjusted.

Additionally, add your model name to the models list as well as the list of geographical regions as LIST_xxx_REGIONS, with xxx being the IAM model name, in the file iam_variables_mapping/constants.yaml.

Lastly, inform premise about the geographical definitions of the IAM model you are using. Create a .json file listing ISO 3166-1 alpha-2 country codes and their corresponding IAM regions, as shown below, and store it under premise/iam_variables_mapping/topologies, under the name: iamname-topology.json.

Note that the IAM region names must be identical to the ones used in the IAM scenario files.

5.2 IAM scenario file

The scenario file should be a comma-separated text file (i.e., csv) with data presented in a tabular format, such as:

Model	Scenario	Region	Variable	Unit	2005	2010	2015	2020	2025
REMIND	SSP2EU-Base	CAZ	Emi|CO2|+|En	Mt CO2/yr	1011.3407	976.72028	993.85251	957.31991	945.014101
REMIND	SSP2EU-Base	CHA	Emi|CO2|+|En	Mt CO2/yr	6720.3134	8601.5756	10086.371	11281.469	10996.79931
REMIND	SSP2EU-Base	EUR	Emi|CO2|+|En	Mt CO2/yr	4235.6489	3730.5328	3392.4211	3114.2840	2860.549231
REMIND	SSP2EU-Base	IND	Emi|CO2|+|En	Mt CO2/yr	1215.4664	1664.1851	2146.9406	2477.4599	2946.357462
REMIND	SSP2EU-Base	JPN	Emi|CO2|+|En	Mt CO2/yr	1457.2522	1415.6663	1345.2780	1181.6792	1060.684659
REMIND	SSP2EU-Base	LAM	Emi|CO2|+|En	Mt CO2/yr	1410.6092	1575.5584	1682.9300	1613.4512	1739.260156
REMIND	SSP2EU-Base	MEA	Emi|CO2|+|En	Mt CO2/yr	1782.4082	2254.0501	2607.9525	2793.9723	3064.426497
REMIND	SSP2EU-Base	NEU	Emi|CO2|+|En	Mt CO2/yr	378.17100	421.22772	477.62410	498.46521	500.4845903
REMIND	SSP2EU-Base	OAS	Emi|CO2|+|En	Mt CO2/yr	1787.0718	2073.8638	2442.5237	2780.8808	3264.746917
REMIND	SSP2EU-Base	REF	Emi|CO2|+|En	Mt CO2/yr	2551.1107	2472.6372	2544.6904	2607.2863	2681.647657

The following columns must be present:

- Region
- Variable
- Unit

as well as the time steps (e..g, 2005 to 2100). Other columns can be present, but they will be ignored.

You need to point to that file when initiating *NewDatabase*, like so:

```
ndb = NewDatabase(
    scenarios = [{"model":"remind", "pathway":"my_special_scenario", "year":2028,
                  "filepath":r"C:\filepath\to\your\scenario\folder"}],
    source_db="ecoinvent 3.6 cutoff", # <-- name of the database
    source_version="3.6", # <-- version of ecoinvent
)
```

There are essentially two types of variables needed from the IAM scenario files:

- variables that relate to the production volumes of technologies. These variables are used to scale the production volumes of the corresponding activities in the ecoinvent database. For example, if the IAM scenario file contains a variable named `Electricity|Production|Wind` for the region `EUR`, it will help premise calculate the share of wind power in the electricity consumption mix of the said region. Hence, the unit of such variables should refer to a production volume over time (e.g., `GWh/year`, `EJ/year`, etc.).
- variables that relate to the efficiency of technologies over time. These variables are used to calculate scaling factors (which are relative by default to 2020), to adjust the energy or material efficiency of the correspond-

ing activities in the ecoinvent database. For example, if the IAM scenario file contains a variable named `Electricity|Efficiency|Coal` for the region `EUR`, it will help premise adjust the amount of coal and related emissions per unit of kWh produced in the said region. Hence, the unit of such variables can be unitless, or relate to an efficiency ratio or percentage.

CHAPTER SIX

USER-DEFINED SCENARIOS

6.1 Purpose

premise enables users to seamlessly integrate custom scenarios, in addition to (or as an alternative to) existing IAM scenarios. This feature is particularly useful when users wish to incorporate projections for a sector, product, or technology that may not be adequately addressed by standard IAM scenarios.

6.2 Available user-defined scenarios

Link to public repository of user-defined scenarios:

https://github.com/premise-community-scenarios

6.3 Using user-generated scenarios

To put it simply, users must first obtain the URL of the datapackage.json file corresponding to the desired scenario. By utilizing the datapackage library, users can load the scenario package, which includes a scenario file, inventories, and a configuration file. This package can then be added as an argument to the *premise* instance. Users have the flexibility to include any number of custom scenarios in this list. However, compatibility between user-defined scenarios is not guaranteed.

Example

```
from premise import *
import brightway2 as bw
from datapackage import Package
bw.projects.set_current("ei_38")

fp = r"https://raw.githubusercontent.com/premise-community-scenarios/cobalt-perspective-
↪2050/main/datapackage.json"
cobalt = Package(fp)

ndb = NewDatabase(
scenarios = [
    {"model":"image", "pathway":"SSP2-Base", "year":2025},
    {"model":"image", "pathway":"SSP2-Base", "year":2030},
],
source_db="ecoinvent cutoff 3.8",
```

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```
source_version="3.8",
key='xxxxxxx',
external_scenarios=[
    cobalt,
]
```

The function **ndb.update("external")** can be called after that to implement the user-defined scenario in the database.

```
ndb.update("external")
```

Of course, if you wish your database to also integrate the projections of the global IAM model, you can run the function **ndb.update()**.

```
ndb.update()
```

Or if you just want the IAM projections relating to, for example, electricity and steel:

```
ndb.update([
    "electricity",
    "steel",
    "external"
])
```

Once the integrations are complete, you can export your databases to Brightway2, within the activated project:

```
ndb.write_db_to_brightway(name="my_custom_db_2025", "my_custom_db_2030")
```

Or as a SuperStructure database, which allows you to export only one database to Brightway2, regardless of the number of scenarios:

```
ndb.write_superstructure_db_to_brightway()
```

Note: SuperStructure databases can only be used from the Activity-Browser.

You can also export the databases to a csv file, which can be used by Simapro, or as a set of sparse matrices.

6.4 Producing your own scenario

The user can produce his/her own scenario by following the steps below:

1. Clone an existing scenario repository from the public repository.
2. Modify the scenario file (**scenario_data/scenario_data.csv**).
3. Add any inventories needed, under **inventories/lci-xxx.csv**.
4. Modify the configuration file (**configuration_file/config.yaml**), to instruct **premise** what to do.
5. Ensure that the file names and paths above are consistent with what is indicated in **datapackage.json**.
6. Once definitive, you can contact the admin of the public repository to add your scenario to the repository.

6.5 Example with Ammonia scenarios

Using ammonia as an example, this guide demonstrates how to create prospective databases from custom scenarios and other background scenarios using premise.

First, clone the Ammonia scenario repository:

```
git clone https://github.com/premise-community-scenarios/ammonia-prospective-scenarios.
↪git
```

This command downloads a copy of the repository to your local machine. You can then rename and modify it as desired.

A datapackage requires four files (referred to as resources) to define a scenario:

1. datapackage.json: A datapackage descriptor file that specifies the scenario author, name, description, version, and the file names and paths of the scenario file, configuration file, and inventories.
2. scenario_data.csv: A scenario file that outlines various variables (e.g., production volumes, efficiencies) across time, space, and scenarios.
3. config.yaml: A configuration file that instructs premise on the required actions. It provides information on the technologies considered in the scenario, their names in the scenario data file and inventories, and the inventories to use for each technology. Additionally, it indicates the markets to be created and their corresponding regions.
4. lci-xxx.csv: Optional; a CSV file containing the inventories of the scenario, which is necessary if the LCA database lacks the required inventories.

6.5.1 datapackage.json

The datapackage.json file is a descriptor file that indicates the scenario author, scenario name, scenario description, scenario version, and the file names and paths of the scenario file, configuration file, and inventories.

Example:

```
{
    "profile": "data-package",
    "name": "ammonia-prospective-scenarios",
    "title": "Ammonia decarbonisation pathways and their effects on life cycle␣
↪assessments: Integrating future ammonia scenarios into background data for prospective␣
↪LCAs",
    "description": "Implementation of the scenarios on future ammonia supply from the␣
↪Master thesis of J. Boyce, 2022.",
    "source":"Boyce, J. C. (2022). Ammonia decarbonisation pathways and their effects on␣
↪life cycle assessments: Integrating future ammonia scenarios into background data for␣
↪prospective LCAs [Master's Thesis, Leiden University and TU Delft].",
    "version": "0.0.1",
    "contributors":[
        {
        "title": "Johanna C. Boyce",
        "email": "xxxx@umail.leidenuniv.nl"
}
```

The mapping between IAM scenarios and user-defined scenarios is established within the datapackage.json file. For instance, the SSP2-Base scenario from IAM models IMAGE and REMIND is mapped to the user-defined scenario Business As Usual. This implies that when users opt for the SSP2-Base scenario from IMAGE and REMIND, the user-defined scenario Business As Usual will be selected. Although your custom scenario may not be intended for use alongside an IAM scenario, it must still be mapped to one (this aspect could be improved in the future).

```
"scenarios": {
    "Business As Usual": [
        {
            "model": "image",
            "pathway": "SSP2-Base"
        },
        {
            "model": "remind",
            "pathway": "SSP2-Base"
        }
    ],
```

The resources section of the datapackage.json file indicates the file names, location of the scenario file, configuration file, and inventories, as well as how their data should present.

For example, here the scenario file is called **scenario_data.csv**, and is located in the **scenario_data** folder. The data in the file is in the **long** format, with the columns **region**, **year**, **scenario**, **variable**, etc. A scenario is, along with a configuration file, a mandatory resource of a scenario package – inventories are optional.

```
"resources": [
    {
        "path": "scenario_data/scenario_data.csv",
        "profile": "tabular-data-resource",
        "name": "scenario_data",
        "format": "csv",
        "mediatype": "text/csv",
        "encoding": "utf-8-sig",
        "schema": {
            "fields": [
                {
                    "name": "model",
                    "type": "string",
                    "format": "default"
                },
```

6.5.2 Scenario data

The **scenario_data.csv** file contains the scenario data. Having this file as a csv is mandatory, as it allows to track changes between scenario versions. Below are shown some variables that indicate the efficiency of the production of hydrogen from alkaline-based electrolysers, from 2020 to 2050, for the **Sustainable development** scenario, for several regions. The actual meaning of this variable is not important here, as it is defined in the configuration file.

mode	path-way	scenario	re-gion	variables	unit	2020	2025	2030	2035	2040	2045	2050	2100
im-age	SSP2-RCP19	Sus-tainable develop-ment	CHN	Effi-ciency|Hydrogen|Alka Electrolysis (elec-tricity)	%	66	67.5	69	71	73	74.5	76	76
im-age	SSP2-RCP19	Sus-tainable develop-ment	IN-DIA	Effi-ciency|Hydrogen|Alka Electrolysis (elec-tricity)	%	66	67.5	69	71	73	74.5	76	76
im-age	SSP2-RCP19	Sus-tainable develop-ment	CAN	Effi-ciency|Hydrogen|Alka Electrolysis (elec-tricity)	%	66	67.5	69	71	73	74.5	76	76
im-age	SSP2-RCP19	Sus-tainable develop-ment	USA	Effi-ciency|Hydrogen|Alka Electrolysis (elec-tricity)	%	66	67.5	69	71	73	74.5	76	76
im-age	SSP2-RCP19	Sus-tainable develop-ment	MEX	Effi-ciency|Hydrogen|Alka Electrolysis (elec-tricity)	%	66	67.5	69	71	73	74.5	76	76

The first column is the **model** column, which indicates the IAM model that the scenario maps with. The second column is the **pathway** column, which indicates the IAM scenario that the user-defined scenario should map with. The third column is the name of the user-defined scenario. The fourth column is the region, which can be either a country or a region. The fifth column is the **variable** column, which indicates the variable that the scenario data is about. The sixth column is the **unit** column, which indicates the unit of that variable. The columns after that are the values of the variable across time.

Variables can be production volumes (used to build markets), efficiencies, or other variables that are needed to modify/adjust inventories.

6.5.3 Inventories

Inventories are stored in csv files (for version control). The name of the csv file should be similar to what is indicated in the *datapackage.json* file. For example, if the *datapackage.json* file indicates that the inventory file is **inventories/lci-xxx.csv**, then the inventory file should be named **lci-xxx.csv** under the folder **inventories** in the root folder.

6.5.4 config.yaml

The config.yaml file is a configuration file that indicates the mapping between the variables in the scenario data and the variables in the LCA inventories.

It is composed of two main parts: **production pathways** and **markets**. The **production pathways** part indicates the mapping between the variables representing a production route and listed in the scenario data file, with the names of the LCI datasets. It is where one can indicate the efficiency of a production route, the amount of electricity used, the amount of hydrogen used, etc.

Consider the following example:

```yaml
# `production pathways` lists the different technologies
production pathways:
  # name given to a technology: this name is internal to premise
  MP:
    # variables to look for in the scenario data file to fetch production volumes
    # values fetched from the scenario data file as production volumes are used to␣
↪calculate
    # the supply share if markets are to be built
    production volume:
      # `variable` in `production volume` refers to the variable name in the scenario␣
↪data file
      variable: Production|Ammonia|Methane Pyrolysis
    # dataset in the imported inventories that represents the technology
    ecoinvent alias:
      # name of the original dataset
      name: ammonia production, hydrogen from methane pyrolysis
      # reference product of the original dataset
      reference product: ammonia, anhydrous, liquid
      # indicate some string that should not be contained in the dataset name
      mask: solid
      # indicate whether the dataset exists in the original database
      # or if it should be sourced from the inventories folder
      exists in original database: False
      # indicate whether a region-specific version of the dataset should be created
      regionalize: True
      # indicate if the production volume from the scenario data should be multiplied by␣
↪a factor
      # to account, for exmaple, for a difference in units relative to the other inputs␣
↪(e.g., here, cubic meter instead of kilogram)
      ratio: 0.78
```

This excerpt from the config.yaml file indicates that the variable **Production|Ammonia|Methane Pyrolysis** in the scenario data file should be mapped with the dataset **ammonia production, hydrogen from methane pyrolysis** in the LCA inventories. The **reference product** of the dataset is **ammonia, anhydrous, liquid**. The **regionalize** parameter indicates that a region-specific version of the dataset should be created for each region listed in the scenario data file in the *region* column. The **exists in original database** parameter indicates that the dataset does not exist in the original database, but is sourced from the inventories folder.

Also, consider this other example from the *config.yaml* file:

```yaml
#adding PEM and AE separately to make a sub-market
# and allow for efficiency improvements to the
# electrolysis processes
AE:
  production volume:
    variable: Production|Hydrogen|Alkaline Electrolysis
  ecoinvent alias:
    name: hydrogen production, alkaline electrolysis
    reference product: hydrogen, alkaline electrolysis
    exists in original database: False
    regionalize: True
  efficiency:
    - variable: Efficiency|Hydrogen|Alkaline Electrolysis (electricity)
```

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```yaml
    reference year: 2020
    includes:
      # efficiency gains will only apply to technosphere flows whose name
      # contains `electricity`
      technosphere:
        - electricity
    excludes:
        # but not to flows whose name contains `renewable` and `hydro`
        technosphere:
            - renewable
            - hydro
```

This is essentially the same as above, but it indicates that the variable **Efficiency|Hydrogen|Alkaline Electrolysis (electricity)** in the scenario data file should be mapped with the **efficiency** of the dataset **hydrogen production, alkaline electrolysis** in the LCA inventories.

The **includes** parameter indicates that the efficiency gains will only apply to flows of type *technosphere* whose name contains **electricity**. In practice, this will reduce the input of electricity over time for that dataset. If you do not specify **includes**, then the efficiency gains will apply to all flows (of type *technosphere* and *biosphere*).

The field **reference year** indicates the baseline year **premise** should use to calculate the factor by which the flows should be scaled by. For example, if the electrolyzer has an efficiency of 60% in 2020, and 70% in 2030, the input of electricity will be reduced by 14.3% (1 / (70%/60%)) if the database is created for 2030.

The **markets** part indicates which markets to build, which production routes these markets should be composed of, which inputs should they provide, and if they substitute a prior market in the database.

Consider the following example from the *config.yaml* file:

```yaml
# name of the market dataset
- name: market for ammonia (APS)
  reference product: ammonia, anhydrous, liquid
  # unit of the market dataset
  unit: kilogram
  # names of datasets that should compose the market
  includes:
    - MP
    - SMR
    - SMR_w_CCS
    - ELE
    - OIL
    - CG
    - CGC
  # 'market for ammonia` will replace the existing markets.
  replaces:
    - name: market for ammonia, anhydrous, liquid
      reference product: ammonia, anhydrous, liquid
  # but only in German datasets
  replaces in:
    - location: DE

  # indicates that the market is a fuel market and emissions of activities
  # using this market as a supplier should be adjusted
  is fuel:
```

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```
    petrol:
      Carbon dioxide, fossil: 3.15
      Carbon dioxide, non-fossil: 0.0
    bioethanol:
      Carbon dioxide, fossil: 0.0
      Carbon dioxide, non-fossil: 3.15

  # we also want to manually add some emissions to the market
  add:
    - name: market for electricity, low voltage
      reference product: electricity, low voltage
      amount: 0.0067

  # If true, flip signs
  waste market: False
```

This tells **premise** to build a market dataset named **market for ammonia (APS)** with the reference product **ammonia, anhydrous, liquid** and the unit **kilogram**. The market should be composed of the production routes **MP**, **SMR**, **SMR_w_CCS**, **ELE**, **OIL**, **CG**, and **CGC**, which have been defined in the **production pathways** part of the *config.yaml* file. The market will replace the existing market dataset **market for ammonia, anhydrous, liquid**.

The **replaces** parameter is optional. If it is not provided, the market will be added to the database without replacing any existing supplier.

The **replaces in** parameter is also optional. If it is not provided, the market will be replaced in all regions. In this case, the market will only be replaced in the regions indicated in the **replaces in** parameter. But **replaces in** is flexible. For example, instead of a region, you can indicate a string that should be contain in the *name* or *reference product* of activities to update.

The **is fuel** parameter is optional. It indicates that the market is a fuel market. The **petrol** and **bioethanol** parameters indicate the emissions associated with the production of petrol and bioethanol, respectively. The emissions are in kg CO2 per kg of fuel. Indicating this will adjust the indicated flows in any activity that uses the market as a supplier.

```
# name of the market dataset
- name: market for ammonia (APS)
  reference product: ammonia, anhydrous, liquid
  # unit of the market dataset
  unit: kilogram
  # names of datasets that should compose the market
  includes:
    - MP
    - SMR
    - SMR_w_CCS
    - ELE
    - OIL
    - CG
    - CGC
  # 'market for ammonia` will replace the existing markets.
  replaces:
    - name: market for ammonia, anhydrous, liquid
      reference product: ammonia, anhydrous, liquid
  replaces in:
    - reference product: urea
    - location: DE
```

Hence, in this example, the ammonia supplier will be replaced in all activities whose reference product contains the string **urea** and location in **DE**.

6.6 Main contributors

- Romain Sacchi

CHAPTER

SEVEN

CONSEQUENTIAL MODELLING

The premise module allows users to import and adjust the consequential system model of the ecoinvent database v3.8 and 3.9, with a focus on electricity and fuel markets. This work is based on a publication with available at https://doi.org/10.1016/j.rser.2023.113830

If you use this module, please cite the publication:

Ben Maes, Romain Sacchi, Bernhard Steubing, Massimo Pizzol, Amaryllis Audenaert, Bart Craeye, Matthias Buyle, **Prospective consequential life cycle assessment: Identifying the future marginal suppliers using integrated assessment models,** Renewable and Sustainable Energy Reviews, Volume 188, 2023, doi: 10.1016/j.rser.2023.113830

Currently, the identification of marginal supplying technologies is limited to the electricity and fuel sectors.

Some technologies are excluded from the marginal markets due to constraints on their feedstock availability. This typically applies to waste-to-energy (e.g., waste-based CHP) or waste-to-fuel (e.g., residue-based biofuel) plants. For steel markets, only the BF-BOF route is considered.

Some imported inventories cannot be directly linked to the ecoinvent consequential database. To address this, a mapping file is provided under https://github.com/polca/premise/blob/master/premise/data/consequential/blacklist.yaml which proposes alternative candidates to link to the ecoinvent consequential database.

7.1 How does it work?

From the user viewpoint, the process is as follows:

- prepare a set of parameters that condition the identification of the marginal electricity suppliers
- supply the parameters to *NewDatabase()*
- point to the your local ecoinvent consequential database

The parameters used to identify marginal suppliers that make up a market are:

- range time (years, default = 2)
- duration (years, default = 0)
- foresight (True or False, default = False)
- lead time (True or False, default = False)
- capital replacement rate (True or False, default = False)
- measurement (0 to 4, default = 0)
- weighted slope start (default = 0.75)
- weighted slope end (default = 1.00)

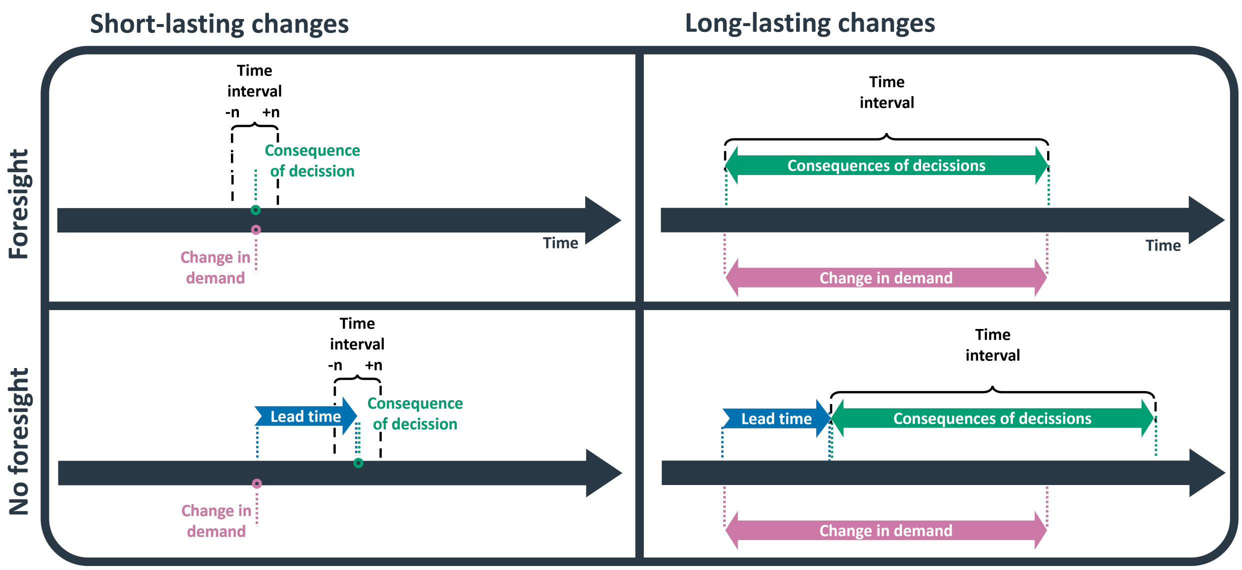

Fig. 1: Techniques to determine the time interval of a study considering the supplier's foresight and the duration of the change.

7.1.1 Range time

Integer. Years. Used for single occurrences or short-lasting changes in demand (less than 3 years). Since the duration of the change is too short to measure a trend, the trend is instead measured around the point where the additional capital will be installed. A range of n years before and after the point is taken as the time interval. Note that if set to a value other than 0, the duration argument must be set to 0. A default range of 2 years is chosen. This value closely mirrors the recommended time interval in ecoinvent's consequential database, which is 3-4 years.

7.1.2 Duration

Integer. Years. Used for long-lasting changes in demand (3 years or more). Duration over which the change in demand occurs should be measured. Note that if set to a value other than 0, the range time argument must be set to 0.

7.1.3 Foresight

True or False. In the myopic approach (False), also called a recursive dynamic approach, the agents have no foresight on relevant parameters (e.g., energy demand, policy changes and prices) and will only act based on the information they can observe. In this case, the suppliers can answer to a change in demand only after it has occurred. In the perfect foresight approach, the future (within the studied time period) is fully known to all agents. In this case, the decision to invest can be made ahead of the change in demand. For suppliers with no foresight, capital will show up a lead time later.

7.1.4 Lead time

True or False. If False, the market average lead time is taken for all technologies. If True, technology-specific lead times are used. If Range and Duration are both set to False, then the lead time is taken as the time interval (just as with ecoinvent v.3.4).

If you wish to modify the default lead time values used for the different technologies, you can do so by modifying the file:

https://github.com/polca/premise/blob/master/premise/data/consequential/leadtimes.yaml

7.1.5 Capital replacement rate

True or False. If False, a horizontal baseline is used. If True, the capital replacement rate is used as baseline. The capital replacement rate is equal to -1 divided by the lifetime (in years) of the technology. It represents the rate at which the capital stock depreciates and must be replaced. Hence, it will be subtracted from the "growth" rate of the technology, to distinguish between the growth rate due to the change in demand and the growth rate due to the replacement of capital stock.

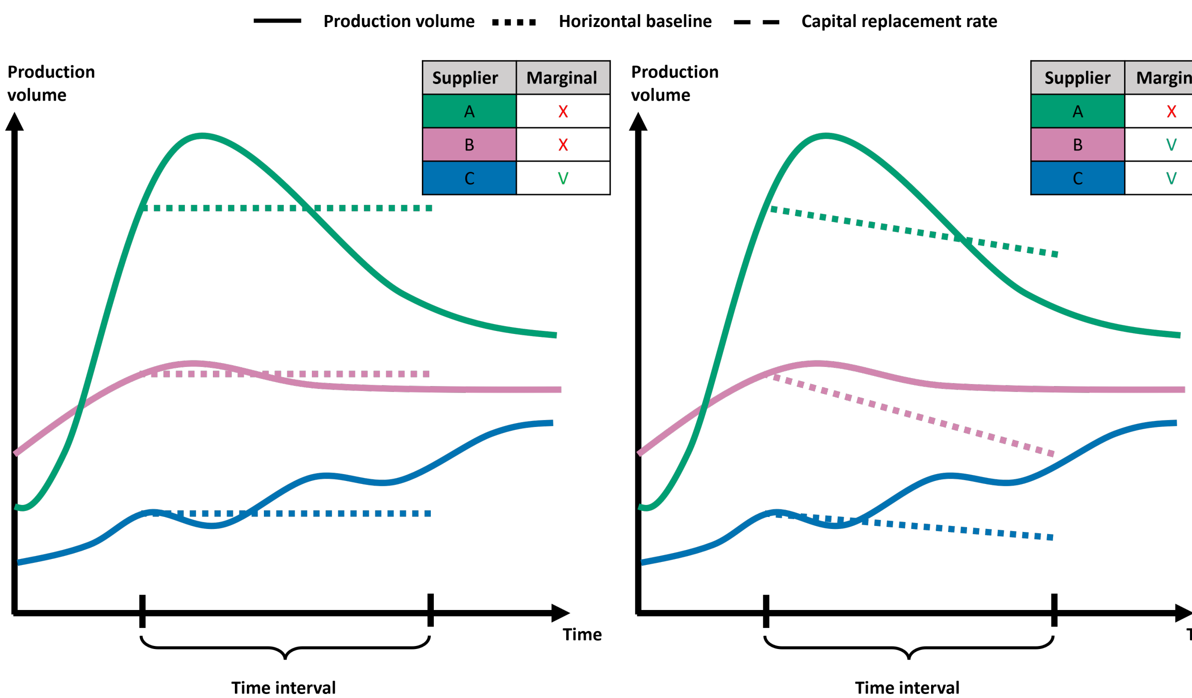

Fig. 2: (left). The capital replacement rate is not considered. (right) The capital replacement rate is subtracted from the growth rate to distinguish between the growth rate due to the change in demand and the growth rate due to the replacement of capital stock.

If you wish to modify the default lifetime values used for the different technologies, you can do so by modifying the file:

https://github.com/polca/premise/blob/master/premise/data/consequential/lifetimes.yaml

7.1.6 Measurement method

Methods 0 and 1 are used if the production volume follows an almost linear pattern. Methods 2, 3 and 4 are used if the production volume follows a non-linear pattern. Short-lasting changes tend to follow a linear pattern, whereas long-lasting changes often do not.

- 0 = slope: Default method, also used by ecoinvent.
- 1 = linear regression: Outliers have less of an effect on the results than with Method 0.
- 2 = area under the curve: Used if there is an emphasis on the consequences in the short term, e.g., if knowing "when" to best introduce the change is important.
- 3 = weighted slope: Curvature is determined using two slopes. First, the same slope as used in Method 0. Second, a shorter slope, which by default is placed at the end of the time interval. The ratio of the short and long slope is used to adjust the calculated values of Method 0. By placing the shorter slope at the end, exponential growth curves are favored. Used if there is an emphasis on the consequences in the long term, e.g., if the focus of the study is on reaching net zero emissions by 2050.
- 4 = time interval is split in individual years and measured: The more balanced approach out of the three non-linear methods (i.e., 2, 3, and 4). Short-, mid- and long-term developments are equally important.

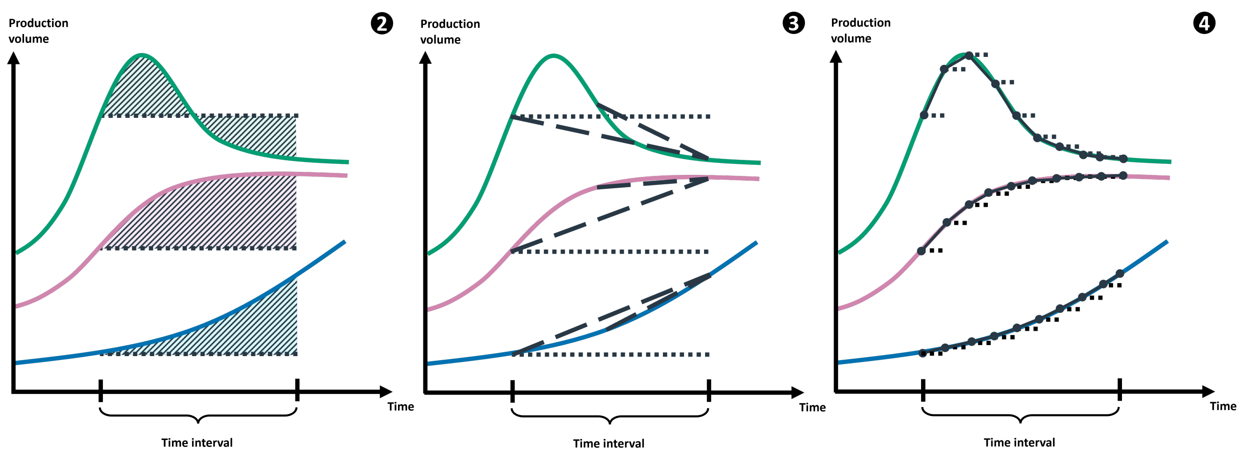

Fig. 3: Non-linear methods (2, 3 and 4) are used if the production volume follows a non-linear pattern. Short-lasting changes tend to follow a linear pattern, whereas long-lasting changes often do not.

7.1.7 Weighted slope start

Weighted slope start is needed for measurement method 3. The number indicates where the short slope starts and is given as the fraction of the total time interval.

7.1.8 Weighted slope end

Weighted slope end is needed for measurement method 3. The number indicates where the short slope ends and is given as the fraction of the total time interval.

7.1.9 Database creation

The user needs to specify the arguments presented above. If not, the following default arguments value are used:

```
args = {
    "range time":2,
    "duration":0,
    "foresight":False,
    "lead time":False,
    "capital replacement rate":False,
    "measurement": 0,
    "weighted slope start": 0.75,
    "weighted slope end": 1.00
}
```

```
ndb = NewDatabase(
    scenarios = scenarios,
    source_db="ecoinvent 3.8 consequential",
    source_version="3.8",
    key='xxxxxxxxx',
    system_model="consequential",
    system_args=args
)

ndb.update("electricity")

ndb.write_db_to_brightway()
```

CHAPTER

EIGHT

FREQUENTLY ASKED QUESTIONS

Here are some frequently asked questions about `premise`. If you have a question that is not answered here, please contact us.

8.1 Ecoinvent

8.1.1 What is ecoinvent?

Ecoinvent is a database of life cycle inventory data, which is used to calculate the environmental impacts of products and services. It is the most widely used LCI database in the world, and is maintained by the ecoinvent association, in Zurich, Switzerland.

8.1.2 What is the ecoinvent version used in `premise`?

`premise` can use the following system models:

- cut-off
- consequential

from version 3.6 to 3.9.1.

8.1.3 How does `premise` use ecoinvent?

`premise` adds and modifies inventories of the ecoinvent database, to represent the future state of the world, as projected by an Integrated Assessment Model (IAM). It does so by duplicating existing inventories and modifying them to represent the future state of the world. It also adds new inventories, when necessary.

8.1.4 Can I share the modified ecoinvent database?

No. The modified ecoinvent database is a derivative work of the ecoinvent database, and cannot be shared. However, you can share the IAM scenario and the code used to modify the ecoinvent database.

8.1.5 Can I share results obtained with the modified ecoinvent database?

Yes. You can share the results obtained with the modified ecoinvent database.

8.1.6 Can I use the modified ecoinvent database for commercial purposes?

While premise's license allows its use for commercial purposes, you need to check the ecoinvent license to see if it allows the use of the modified ecoinvent database for commercial purposes.

8.1.7 How can I share modified ecoinvent databases?

premise allows producing "datapackages" that contains the required multiplication factors to be applied to the ecoinvent database, for other users to reproduce the modified ecoinvent database. These datapackages can be shared freely, as they do not contain any ecoinvent data.

8.2 IAM models

8.2.1 I use a different IAM than REMIND or IMAGE ... Can I still use `premise`?

There is a MAPPING section in the documentation that explains how to link to a new IAM. The YAML files under ``` ``premise ```/iam_variables_mapping`` are the main body of files that needs to be changed, to properly establish a correspondence between your IAM variables and the variables used in `premise`. It is also necessary to provide `premise` with the geographical definitions of the regions used in your IAM. This is done by providing a .json file with the regions and their corresponding ecoinvent regions. The rest of the code is generic and should work with any IAM.

8.2.2 What columns are necessary in the IAM files?

The code has been refactored since. Any column other than:

- Region
- Variable
- Unit
- and the variable values for each time step

is ignored.

8.2.3 How big an effort would it be to link to a new IAM? As simple as an extension of the mapping files? What difficulties can be anticipated?

In principle, it is easy. Linking to a new IAM model is a matter of:

- providing the IAM variable for each `premise` variable listed in the .yaml mapping files
- and the geographical definitions of the regions used in the IAM.

In practice, it may not always be that simple. The IAM variables are not always available in the IAM output files (e.g., efficiency or land use-related variables). In that case, they need to be calculated from other variables or skipped. Also, some IAM models may represent a technology not yet considered in `premise` (e.g., nuclear fusion). In some cases, `premise`'s code needs to be extended.

8.3 IAM data collection

8.3.1 How was the list of variables in the mapping files established?

The list of IAM variables and mapping with `premise` variables has been established through collaboration with developers of IAM models, to ensure that the meaning between each IAM variable corresponds with that of `premise`.

8.3.2 Is it possible to expand this list? (e.g. agriculture crops for energy)

It is certainly possible to extend this list. You would however need to extend `premise`'s code to tell it what to do with these additional variables. For example, if you want to use the IAM output for integrating projections that relate to agriculture crops for energy, you would need to write a module in `premise` (e.g., energy_crops.py) that would perform a series of modifications on the LCA datasets, just like other modules do.

8.3.3 Is the unit and the description of these parameters documented? Or are they necessarily the same as the ones of the ecoinvent datasets they refer to?

They are now documented, under the MAPPING section. There are essentially two types of variables:

- variables that relate to production volumes of technologies, which units must represent a production volume over time (e.g., GWh/year)
- variables that relate to the efficiency of technologies, which is unitless, or represented by an efficiency ratio (e.g., %)

8.3.4 What if a variable in `premise` corresponds to several variables in the IAM?

We have not really seen that case yet. In any case, mapping one IAM variable to two `premise` variables is possible (whether it is methodologically correct is a question left to your appreciation).

8.4 Regionalization

8.4.1 Are datasets regionalized on the basis of the IAM scenario only, or does it come from other sources?

`premise` tries to limit the use of external sources of data. At the moment, the only sources of data, other than those from the IAM scenario, used for projections are:

- efficiency values for different photovoltaic panels (taken from the Fraunhofer ISE database)
- emissions factors for local air pollution (taken from the GAINS-EU and GAINS-IAM databases)

Hence, the regionalization of datasets is based on the IAM scenario only.

8.4.2 Does `premise` generate more regionalised datasets than in original EI3.x database?

Yes. `premise` generates regionalized datasets for all regions in the IAM model, for each technology for which a IAM-to-`premise` correspondence is provided, if not already existing in the Ecoinvent database. For example, if the IAM model considers technology A over 10 regions, `premise` collects datasets in the ecoinvent database (or imported inventories) that represent technology A and duplicates it for each region. Sometimes, only one dataset is available in the ecoinvent database, in which case `premise` duplicates it 10 times. Other times, several datasets are available (ie.g., in FR, CN and RoW), in which case `premise` uses the French dataset for the European region, the Chinese dataset for the Chinese region, and the RoW dataset for the other IAM regions. Then, `premise` proceeds to regionalize these datasets by finding the most appropriate inputs suppliers for each duplicated dataset.

8.4.3 How does `premise` handle the different granularities between the IAM regions and the Ecoinvent regions?

`premise` simply uses the correspondence between IAM regions and Ecoinvent regions (which are, most of the time defined by ISO alpha-2 country codes), often provided by the IAM developers.

For example, the REMIND `REF` region is associated with the following ecoinvent regions:

- AM
- AZ
- BY
- GE
- KZ
- KG
- MD
- RU
- TJ
- TM
- UA
- UZ

If a technology needs to be included within a market for that region (e.g., coal-based electricity), `premise` looks for datasets for that technology (e.g., `electricity production, hard coal`) in the ecoinvent database that are located in any of these above-listed locations, and calculates supply shares based on the production volumes information provided in each of these datasets (i.e., under the `production volumes` field). Hence, coal-based electricity in the `REF` electricity market is supplied by several coal-based electricity datasets, each of which is located in a different country (see list above) according to their current production volumes. This approach highlights a limitation, where current production volumes are used to calculate supply mix for a given technology within a given IAM region.

8.5 Consistency with climate targets

8.5.1 How do we ensure consistency between IAM scenario and pLCA results (in terms of global warming / temperature increase)?

In theory, there is consistency between the IAM scenario and pLCA database when 100% of the IAM variables and related projections are integrated into the pLCA database.

This is not the case today, as `premise` only integrates a subset of IAM variables, notably those that relate to:

- power production
- steel production
- cement production
- fuel production
- transport

Hence, important sectors are still left out, such as:

- agriculture
- heat
- chemicals
- paper

Also, sectors that are considered by `premise` are not fully or perfectly integrated, as:

- some IAM variables are sometimes not available (e.g., efficiency).
- some IAM variables are sometimes not considered by `premise` (e.g., fuel mix for cement production)

Hence, `premise`-generated databases are not fully consistent with the IAM scenario, including its climate target. If an ambitious climate target is considered, the use of `premise`-generated databases probably leads to an overestimate of GHG emissions, since sectors that are expected to under mitigation measures are left unchanged. It will however mostly depend on the product system you analyze.

8.6 Additional inventories

8.6.1 Can additional inventories be modelled with parameters? If so, how are they used?

Additional inventories (imported as such or via data packages) can be modelled with (brightway2) parameters, but those will not be considered by `premise`.

8.6.2 Can some parameters of the additional inventories be made scenario- and time-dependant?

Yes, via the use of data packages. Data packages allow to package additional scenarios to be considered in addition to the global IAM scenario. With data packages, it is possible to map the efficiency of processes to a variable. That variable can vary over time and across scenarios. Besides efficiency, it is also possible to change a market mix, distribution losses or any other aspects, of a product's supply chain, via the use of variables in data packages.

8.6.3 Can `premise` manage an efficiency evolution for the additional inventories?

Yes, via the use of data packages (see User-defined scenarios section). It is possible to map the efficiency of processes to a variable. That variable can vary over time and across scenarios.

8.7 Efficiency adjustments

8.7.1 Is the calculated scaling factor (ratio of efficiencies in year 20XX vs 2020) applied to all inputs of the transformed dataset, or only to the energy feedstock input?

It depends on the nature of the process. For energy conversion processes (e.g., power generation), all inputs are scaled up or down. For processes that convert energy and material (e.g., cement or steel production), only the inputs that relate to energy (e.g., fuel, electricity) inputs are scaled up or down, the input of material remaining unchanged.

8.7.2 What happens if the IAM does not provide efficiencies for certain processes?

They will be ignored and the efficiency of said process wil not be adjusted.

8.7.3 Why use external data sources for PV efficiency, rather than the output of IAM?

Efficiency values for photovoltaic panels are not always provided by IAM scenarios. When they are, they are often constant (i.e., the efficiency does not increase over time). This can become an issue when they represent a significant share of the electricity mix. Hence, at the moment, we use external sources to document the projected efficiency of photovoltaic modules. A venue of improvement may be to use IAM efficiency variables for photovoltaic panels when available, and fall back on external sources if not.