NORDIC ENERGY STATISTICS DATABASE

Nordic Clean Energy Scenarios

Nordic Energy Research

About this publication

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List of contents

1 User guide for the Nordic Energy Statistics Database

The Nordic Energy Statistics Database aims for harmonising energy sector and related data across all the five Nordic countries. It will serve as a reference for research work as well as for the general public to see energy related data and selected progress indicators. The database will be published and maintained by Nordic Energy Research.

1.1 REQUIREMENTS FOR THE DATABASE

The main use cases for the database are

1. Data source for the visualisations of historical statistics (web application)
2. Data source for historical energy data for researchers and other advanced users (database queries)
3. Source of information for the general public on selected energy related data variables and progress indicators

To support easy access to the data (especially in use case #3), a web front-end to the data is required. To support transparency of the data, rich metadata should be stored along with the data itself.

1.2 DATABASE CONTENTS

Data variables

List of the data variables is in Table 1. Data will be aggregated to the national level in each country with annual total or end-of-year values (generation capacities). Other details depend on the variable and could be e.g. type of fuel, generation sector etc. In general, 'fuel' includes also generation types not using a fuel, e.g. wind power. Fuels are based on Standard International Energy Product Classification (SIEC)[1] top-level products.

[1] See https://unstats.un.org/unsd/classifications/Family/Detail/2007

Table 1. Data variables in the database. Variables mentioned in the project plan are highlighted with bold.

Variable	Units	Spatial	Temporal	Detail(s)
building area	m^2	country	year	–
CO_2 emissions	kt CO2	country	year	sector
district heat production	GWh	country	year	type of plant, fuel
electricity consumption	GWh	country	year	sector
electricity consumption	GWh	bidding area	year	–
electricity generation	GWh	bidding area	year	fuel
electricity production	**GWh**	**country**	**year**	**fuel**
exchanged power with 3rd countries	GWh	country	year	3rd country, direction
final energy consumption in industry	PJ	country	year	fuel
final energy consumption in residential sector	PJ	country	year	fuel
final energy consumption in services sector	PJ	country	year	fuel
final energy consumption in transport	PJ	country	year	fuel
generation capacity (district heating)	GW	country	end of year	type of plant
generation capacity (electricity)	**GW**	**country**	**end of year**	**fuel**
generation capacity (electricity)	GW	bidding area	end of year	fuel
gross energy consumption	PJ	country	year	fuel
number of new passenger car registrations	–	country	year	car model
number of passenger cars	–	country	year	car model
production of biomass fuels	PJ	country	year	fuel
total export of electricity	GWh	bidding area	year	–
total import of electricity	GWh	bidding area	year	–
total primary energy demand	PJ	country	year	–

For each data value, the following metadata is stored:

- Description: how the data was processed or otherwise aggregated
- Sources: what are the original sources of the data
- Licenses: what licenses apply to the data, can it be shared or redistributed

- Timestamp: when the value was updated
- Contributors: who contributed in gathering or uploading the data

More details for the data coverage of each variable and their data sources is given in Appendix A.

1.3 INDICATORS FOR TRACKING PROGRESS

Progress indicators are calculated from the data variables. Aggregation for each indicator is national annual values. The indicators are the following:

1. Share of RE in electricity
2. CO2 emissions (Mt CO2) from power and district heating
3. Share of bioenergy from gross RE consumption
4. Battery and plug-in hybrid electric vehicles share of total passenger vehicle stock
5. District heat generation (PJ) by fuel
6. CO2 emissions (Mt CO2) from the industrial sector
7. Final energy consumption by source (PJ) in industry
8. Energy intensity (kWh/m2) and CO2 emissions intensity (kgCO2/m2) in the buildings sector
9. CO2 emissions (Mt CO2) from road transport

Indicator values are computed and stored in the database for quick access. Each in indicator is stored in its own table.

The formulae to calculate the indicators are in Annex B.

1.4 FRONT-END

A web-based graphical front-end will be used for visualising the data and indicators. In the front-end, only selected data variables but all progress indicators are presented as graphs. The front-end web-based tool can be accessed through the Nordic Clean Energy Scenarios project page.[2]

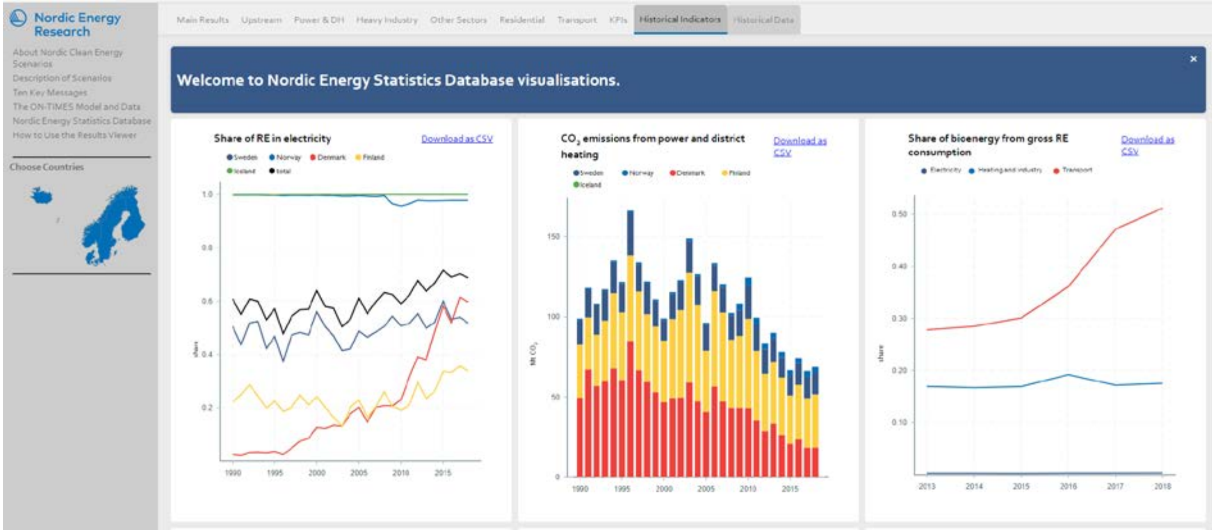

Figure 1. Example of the web interface for the data.

The web interface also allows downloading underlying data of each graph as a CSV[3] file. There are two tabs of historical data: one with the indicators and the other with graphs of raw data variables (as in Table 1). Selecting and deselecting countries in the left panel map affects the data displayed in the graphs.

1.5 BACK-END

Data back-end is implemented as a relational database. Each data variable has its own table with required columns specified by the spatial, temporal, and other details. A relational database suits well in this situation, as it is known very well what data is to be stored in the database and the table structure is easily understandable. Relational integrity can also be enforced with ease. Downside of a database management system is the required overhead in running and administering it. It is still preferred over a set of files or other, non-relational database systems.

Advanced users can make queries directly to the database back-end. Access levels to the back-end will be the following:

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[2] https://www.nordicenergy.org/project/nordic-clean-energy-scenarios-solutions-for-carbon-neutrality/

[3] Comma Separated Values, see RFC 4180 - Common Format and MIME Type for Comma-Separated Values (CSV) Files (https://tools.ietf.org/html/rfc4180)

- Public read access, also used by the front end
- Restricted contributor access: insert, update and delete rows
- Very limited admin access, including modifying the structure of the database

Regular backups of the data need to be made in order to prevent loss of data and work effort.

1.6 TECHNICAL DESCRIPTION

The pg-nces2020 is a PostgrSQL database hosted on Heroku, a cloud platform with virtual servers. The database can be managed with any data management system which can connect to PostgreSQL databases. The two systems used in the development phase are Hasura and pgAdmin4. It is possible to migrate the database to another Heroku user or to migrate the database to any other PostgreSQL server, physical or virtual.

1.7 MAKING QUERIES TO THE DATABASE

The database GraphQL endpoint can be accessed for example using GraphQL Playground web application (https://www.graphqlbin.com/). The endpoint url to use is https://nces2020-gql-pg.herokuapp.com/v1/graphql (see Figure 2).

Figure 2. GraphQL Playground entry view.

Figure 3 shows the GraphQL Playground with the query editor in the left-hand side panel and the results views on the right-hand side.

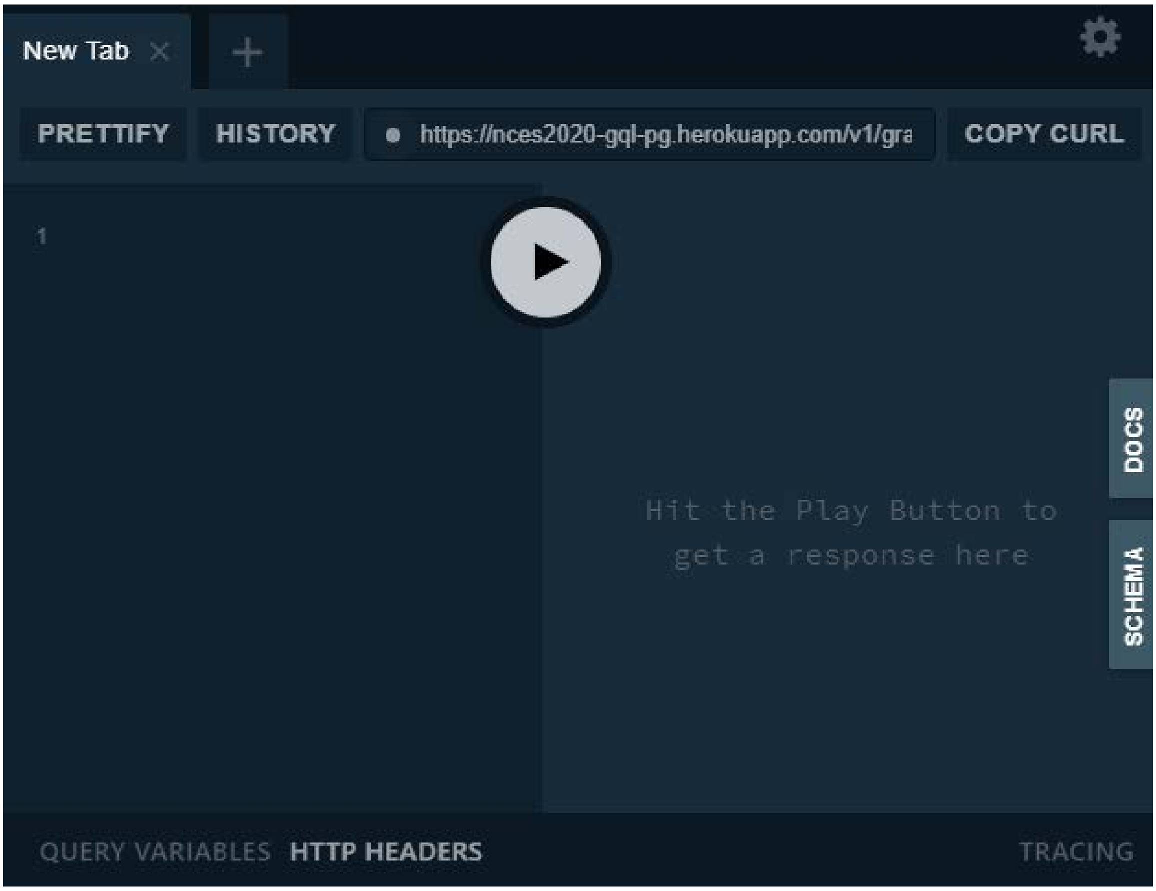


Figure 3. GraphQL Playground query editor

Entering the following query into the left-hand side box gives the annual electricity production in each country by fuel or generation type sorted by country, year, and fuel:

```
{
  nces_eleproduction(  # Name of table
    order_by: {  # Ordering
      country: asc,
      year: asc,
      fuel: asc}
  ) {
    # Get name of country from linked table
    nces_country {
      name
    }
    year
    # Get name of fuel from linked table
    nces_fuel_type {
      fuel_type
    }
    value
    updated_at

  }
}
```

The results appear on the right-hand panel in JSON format:


```
{
  "data": {
    "nces_eleproduction": [
      {
        "nces_country": {
          "name": "Denmark"
        },
        "year": 1990,
        "nces_fuel_type": {
          "fuel_type": "Wind electricity"
        },
        "value": 610,
        "updated_at": "2020-10-13T08:43:52.192228"
      },
      {
        "nces_country": {
          "name": "Denmark"
        },
        "year": 1990,
        "nces_fuel_type": {
          "fuel_type": "Renewable waste"
        },
        "value": 39,
        "updated_at": "2020-10-13T08:43:52.192228"
      },
      ...
    ]
  }
}
```


For example, JSON Formatter (https://jsonformatter.org/) can be used to convert the output into CSV. Paste the JSON result into the left-hand box and choose Convert JSON to CSV from the controls in the middle. The CSV for the previous example looks like this:


```
nces_country,year,nces_fuel_type,value,updated_at
Denmark,1990,Wind electricity,610,2020-10-13T08:43:52.192228
Denmark,1990,Renewable waste,39,2020-10-13T08:43:52.192228
Denmark,1990,Solar photovoltaic,0,2020-10-13T08:43:52.192228
Denmark,1990,Hydroelectricity,28,2020-10-13T08:43:52.192228
...
```

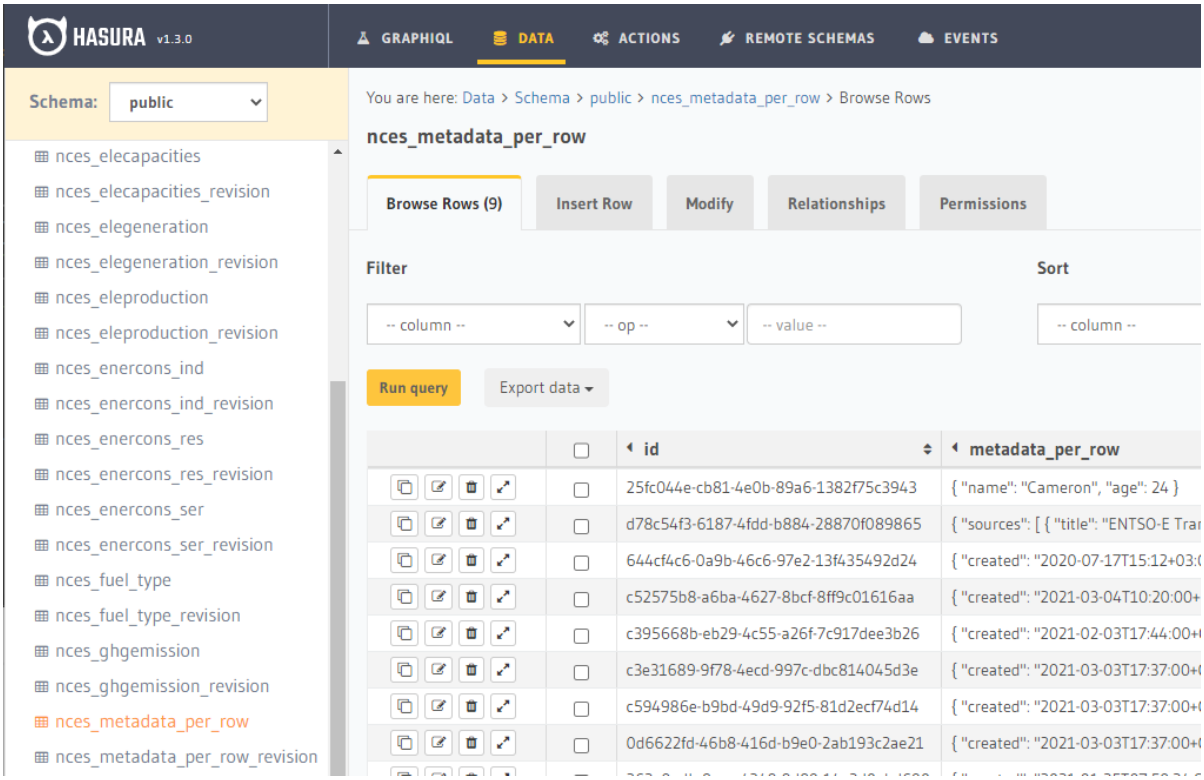

1.8 UPDATING DATA

Updating a table is done by accessing the Hasura endpoint: https://nces2020-gql-pg.herokuapp.com/console using a secret key (admin-secret). The key can be requested from NER.

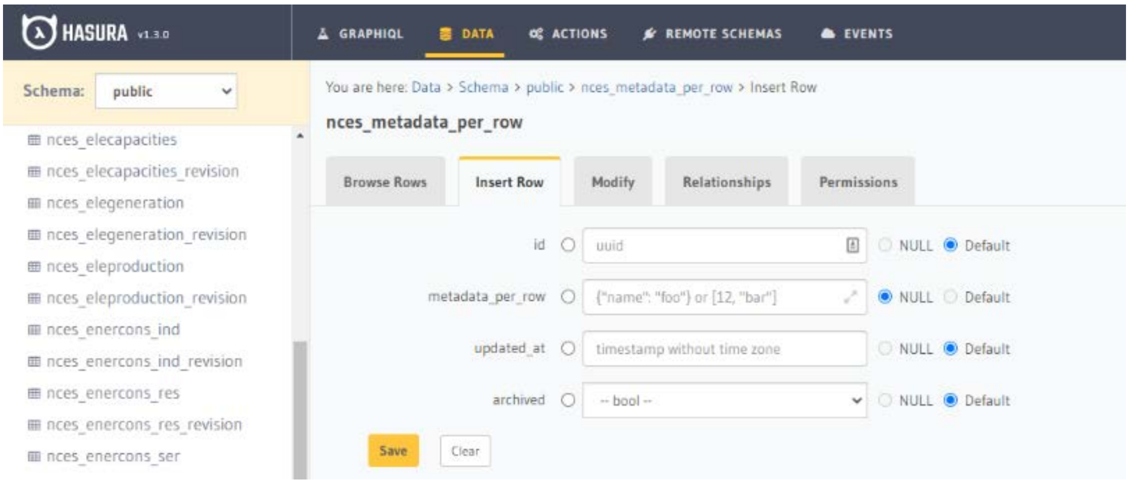
Step 1: Add metadata for the new entry

First, the metadata for the new entry must be added to the metadata table. To do this go to the **Data** tab in the header:

To the left scroll down and choose the table <u>nces_metadata_per_row</u> as seen in the screenshot below. Make sure it is not a revision table.



Then you will choose the **Insert Row** tab.



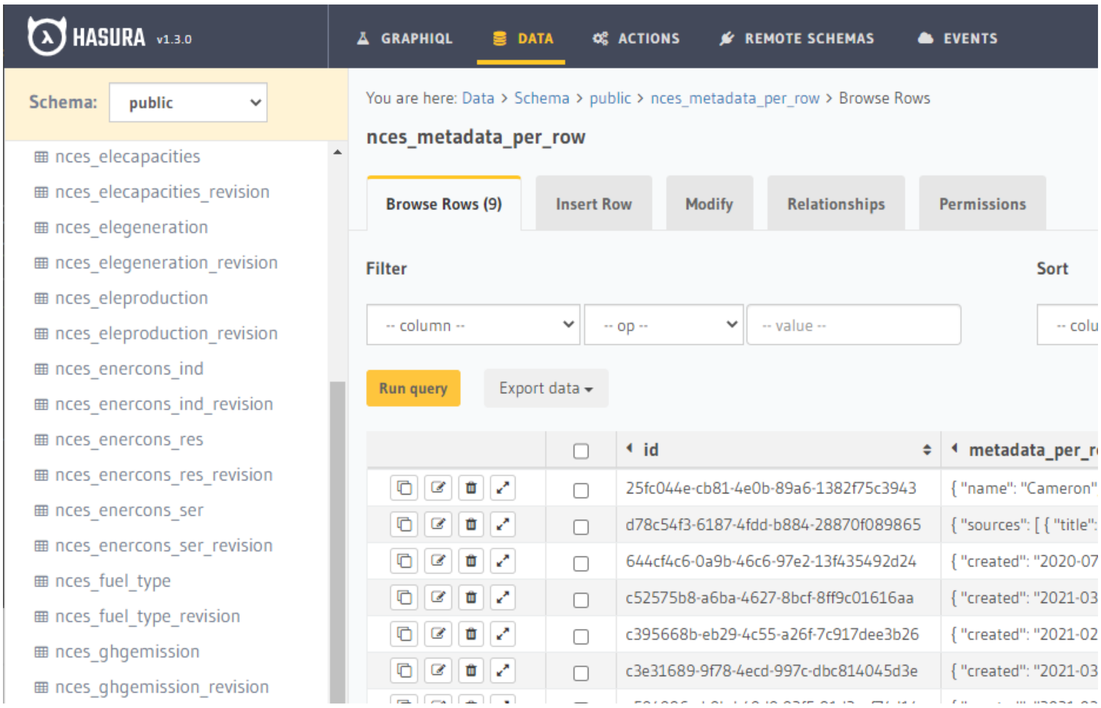
Here you can fill in a JSON text string with the metadata (see example below) to the field `metadata_per_row`. Fields `id`, `updated_at` and `archived` should be left at default and not be filled in with any new information.

Example metadata:

```
{
    "created": "2021-03-03T17:37:00+000",
    "sources": [
        {
            "path": "https://ec.europa.eu/eurostat/data",
            "title": "Eurostat (2021), 'Complete energy balances [NRG_BAL_C]'"
        }
    ],
    "licenses": [
        {
            "path": "https://ec.europa.eu/eurostat/about/policies/copyright",
            "name": "other-at",
            "title": "Copyright notice and free re-use of data"
        }
    ],
    "contributors": [
        {
            "email": "firstname.lastname@email.com",
            "role": "author",
            "title": "Firstname Lastname"
        }
    ]
}
```

Then you can save the entry by clicking the save button.

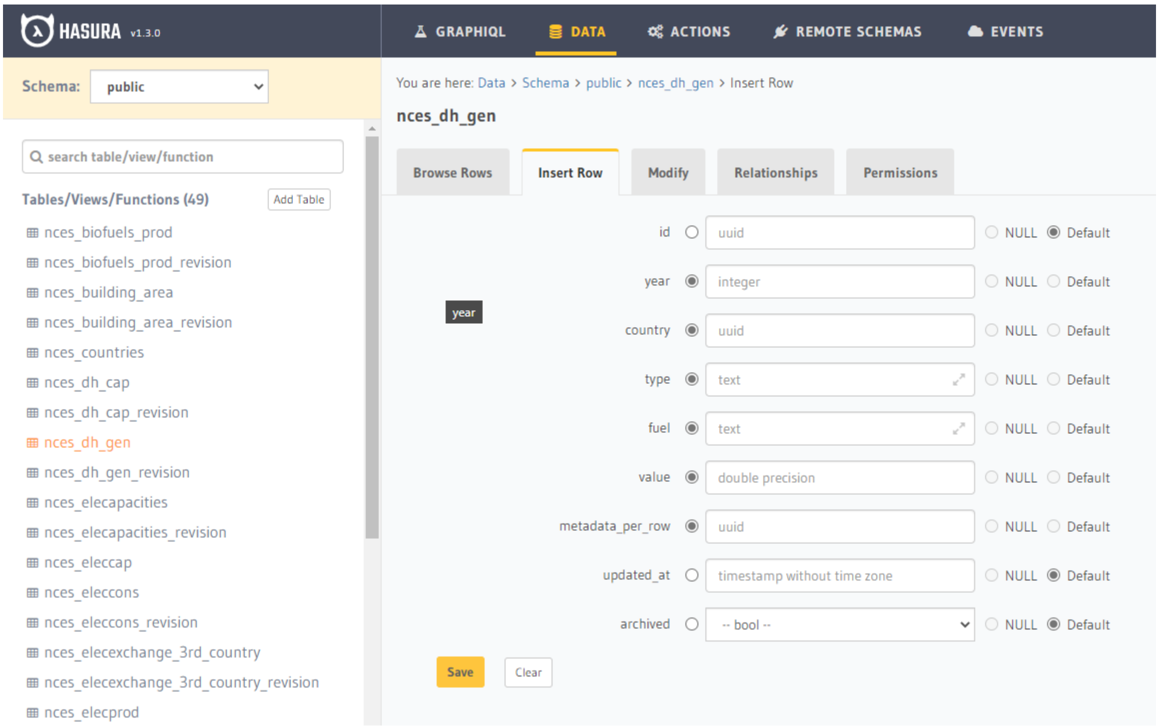
Go back to the tab Browse Rows:



You will now find that the metadata entry has been added to the list and you will find it at the bottom of the list. To proceed you will need to copy the id of the new entry.

Step 2: Add new data entry

After copying the id of the new metadata entry, you can proceed to add a new data entry. Again, browse to the data tab in the header and choose the table to add data to from the left-hand side column. Make sure it is not a revision table. Refer to the variable names in Appendix A to find the right table. After selecting the table, choose the **Insert Row** tab. Add the data. Fields `id`, `updated_at` and `archived` should be left untouched. To the field `meta_data_per_row` must be the id copied from above. Finally, press the **Save** button. The example below shows adding data to the district heating production table (*nces_dh_gen*):



1.9 UPDATING

Annual updates need to be made to keep the database up-to-date. Estimated 1 PM of effort is needed. The updating person should be familiar with energy technologies and statistical sources as well as have basic understanding on programming and automated data processing using scripting languages (Python).

The update work consists of the following tasks

1. Finding and getting the original data, including getting rights to re-publish the data
2. Aggregate and save data as a CSV file with right column headers
3. Enter metadata to create a Data Package[4]
4. Import the package into the data back-end using provided scripts
5. Update the values of the progress indicators using most recent data

[4] See Data Package | Frictionless Data Specs (https://specs.frictionlessdata.io/data-package/)

CSV files are used for their wide support and easy. The Data Package format is good for storing the intermediate files before importing to the database as the metadata can be stored there as well.

Each package has a descriptor file called *datapackage.json* that describes its contents and required metadata. The file is written in JSON format, an example is given in Appendix C.

1.10 USES OF THE DATASET AND SOURCES

Keeping the dataset up-to-date requires regular effort. The fact that this dataset is limited to the Nordic countries makes its use cases somewhat limited. If comparisons to other countries (e.g. EU, OECD) are to be made, wider area data needs to be acquired from other sources. In this regard, the data sources listed in this document might actually be the most valuable result of this work package.

Appendix A: Data variable details

id	variable	units	spatial	temporal	details	sources	notes	coverage	start	end
biofuelprod	production of biomass fuels	PJ	country	year	fuel	Eurostat	National energy balances	All Nordic countries	1990	2019
building-area	building area	m^2	country	year	–	Statistics Finland, Statistics Denmark, Statistics Norway, Statistics Sweden,	No national stats for Iceland; e.g. in StatFin, 'Building and dwelling production' contains the area info but it seems to be the constructed of the year.	Denmark, Finland, Norway, Sweden	2013	2019
dh_cap	generation capacity (district heating)	GW	country	end of year	type of plant	Finnish Energy		Finland	2019	2019
dh_gen	district heat production	GWh	country	year	type of plant, fuel	Statistics of Finland		Finland	2019	2019
eleccap	generation capacity (electricity)	GW	country	end of year	fuel	IEA: OECD - Net electrical capacity	Permission from IEA to republish	Denmark, Finland, Norway, Sweden	1990	2018
eleccap-bzones	generation capacity (electricity)	GW	bidding area	end of year	fuel	ENTSO-E Transparency Platform	no records for Iceland, lack info on bidding area details for Sweden	Denmark, Finland, Norway, Sweden	2015	2020

id	variable	units	spatial	temporal	details	sources	notes	coverage	start	end
eleccons	electricity consumption	GWh	country	year	sector	Eurostat	Eurostat does not report values for each bidding area, only national aggregates. ENTSO-E reports values per bidding area, but not by use type. The two sources could be combined, yet this level of detail cannot be obtained	All Nordic countries	1990	2018
elecexchange-3rd_country	exchanged power with 3rd countries	GWh	country	year	3rd country, direction	ENTSO-E Transparency Platform	Not directly available, requires a little elaboration, commercial exchange	All Nordic countries; Estonia, Germany, Netherlands, Lithuania, Poland	2015	2020
elecexport-bzones	total export of electricity	GWh	bidding area	year	–	ENTSO-E Transparency Platform	scheduled commercial exchange	All Nordic countries	2015	2020
elecgen-bzones	electricity generation	GWh	bidding area	year	fuel	ENTSO-E Transparency Platform	No right to re-use without agreement from data owners	Denmark, Finland, Norway, Sweden	2017	2018
elecimport-bzones	total import of electricity	GWh	bidding area	year	–	ENTSO-E Transparency Platform	scheduled commercial exchange	All Nordic countries	2015	2020
elecload-bzones	electricity consumption	GWh	bidding area	year	–	ENTSO-E Transparency Platform	Eurostat does not report values for each bidding area, only national aggregates. ENTSO-E reports values per bidding area, but not by use type. The two sources could be combined, yet this level of detail cannot be obtained	All Nordic countries	2015	2019
elecprod	electricity production	GWh	country	year	fuel	Eurostat	Free to publish	All Nordic countries	1990	2018

id	variable	units	spatial	temporal	details	sources	notes	coverage	start	end
enercons-gross	gross energy consumption	PJ	country	year	fuel	Eurostat	Data code: nrg_bal_c, Final energy consumption - total	All Nordic countries	1990	2019
enercons-ind	final energy consumption in industry	PJ	country	year	fuel	Eurostat	Data code: nrg_bal_c	All Nordic countries	1990	2019
enercons-res	final energy consumption in residential sector	PJ	country	year	fuel	Eurostat	Data code: nrg_bal_c	All Nordic countries	1990	2019
enercons-ser	final energy consumption in services sector	PJ	country	year	fuel	Eurostat	Data code: nrg_bal_c	All Nordic countries	1990	2019
enercons-trans	final energy consumption in transport	PJ	country	year	fuel	Eurostat	Data code: nrg_bal_c	All Nordic countries	1990	2019
ghgems	CO_2 emissions	kt CO_2	country	year	sector	Eurostat, European Environment Agency (EEA)		All Nordic countries	1990	2018
primencons	total primary energy demand	PJ	country	year	–	Eurostat		All Nordic countries	1990	2019
vehiclenumber-new	number of new passenger car registrations	–	country	year	car model (BEV, PHEV, total)	Eurostat, Icelandic Transport Authority, Statistics Denmark	Data code: road_eqr_carpda. Not directly available as share, but easily obtainable. Permission for free re-use and publishing is confirmed via email contact.	All Nordic countries	2013	2019
vehiclenumber-stock	number of passenger cars	–	country	year	car model (BEV, PHEV, total)	Eurostat, Icelandic Transport Authority		All Nordic countries	2013	2019

Appendix B: Indicator formulae

1. Share of RE in electricity

- Relevant data variables: elecprod

$$Indicator_{year} = \frac{\sum_{country \in countries} \sum_{fuel \in RE} elecprod_{country,fuel,year}}{\sum_{country \in countries} \sum_{fuel} elecprod_{country,fuel,year}}, \qquad \forall\ year$$

$RE = \{\text{Biofuels, Geothermal, Hydroelectricity, Solar photovoltaic,}$

$\text{Solar thermal, 'Tide, wave, ocean', Wind electricity}\}$

2. CO_2 emissions (Mt CO_2) from power and district heating

- Relevant data variable: ghgems

$$Indicator_{country,\ year} = \sum_{i \in SRC\_CRF, j \in AIRPOL} ghgems_{country,i,j,year},$$

$$\forall country, \forall year$$

$where$

$SRC\_CRF = \{\text{Fuel combustion in public electricity and heat production}\}$

$AIRPOL = \{\text{Greenhouse gases, Carbon dioxide}\}$

$$Indicator_{year} = \sum_{country \in countries} Indicator_{country,\ year}, \qquad \forall year$$

3. Share of bioenergy from gross RE consumption

This should be calculated for three sectors: 1) electricity, 2) heating and industry as well as 3) transport.

In electricity share of bioenergy is the share of biofuels (etc.) from total RE sources.

$$Indicator_{country,year} = \frac{elecprod_{year,country,biofuel}}{elecprod_{year,country,fuel}} \qquad \forall\ country, \forall\ year$$

$biofuel\ \in \{Biofuels\},$

$fuel\ \in \{Biofuels, Geothermal, Hydroelectricity, Solar\ photovoltaic,$

$Solar\ thermal, 'Tide, wave, ocean', Wind\ electricity, Renewable\ waste\}$

In industry and heating share of biofuels from other renewable sources (excluding electricity).

Note: *enercons.ind* = `enercons-ind` variable in the database (formulas do not allow dashes in variable names).

$$Indicator_{country,year} = \frac{enercons.ind_{year,country,bf} + enercons.res_{year,country,bf} + enercons.ser_{year,country,bf}}{enercons.ind_{year,country,fuel} + enercons.res_{year,country,fuel} + enercons.ser_{year,country,fuel})} \quad \forall\ country, \forall\ year$$

$bf\ \in \{Biofuels\},$

$fuel\ \in \{Biofuels, Geothermal, Solar\ thermal, Renewable\ waste, Ambient\ heat\ (heat\ pumps)\}$

In transport share of biofuels from other renewable fuels (if any?) direct CO2 emissions?

$$Indicator_{country,year} = \frac{enercons.ind_{year,country}}{enercons.ind_{year,country,fuel}} \quad \forall\ country, \forall\ year$$

$biofuel\ \in \{Biofuels\},$

$fuel\ \in \{Biofuels, Geothermal, Solar\ thermal, ty, Renewable\ waste\}$

4. Battery and plug-in hybrid electric vehicles share of new passenger vehicle sales (Electrification of transport)
   - Relevant data variable: vehiclenumber-stock

$$EV\ share_{country,\ year} = \frac{\sum_{car\ model \in EV} value_{car\ model,country,year}}{value_{car\ model=total,country,year}}, \qquad \forall country, \forall year$$

$where$

$$EV = \{BEV, PHEV\}$$

5. District heat generation (PJ) by fuel (Electrification of heat supply)
   - Relevant data variable: dh_gen

Note: below FUEL = FUEL_CATEGORY

$$Indicator_{FUEL,\ \ year} = \sum_{country \in countries} \sum_{i \in FUEL} value_{country,i,year},$$

$$\forall FUEL \in FUEL\_CATEGORY, \forall year$$

$where$

$FUEL\_CATEGORY = \{$

$Fossil\ fuels, Waste, Surplus\ heat, Electric\ boilers\ and\ heat\ pumps,$

$\text{Geothermal, Bio fuels, Other generation}$

$\}$

$Fossil\ fuels = \{Coal, Natural\ gas, Oil, Oil\ shale$

$/oil\ sand, Peat\ and\ peat\ products\}$

$Waste = \{Non-renewable\ waste, Renewable\ waste\}$

$Surplus\ heat = \{Heat\}$

$Electric\ boilers\ and\ heat\ pumps =$

$\{Ambient\ heat, Electricity, (Hydroelectricity, Solar\ photovoltaic, Wind\ electricity)\}$

$Geothermal = \{Geothermal\}$

$Bio\ fuels = \{Biofuels\}$

$Other\ generation$

$= \{Other, (Nuclear\ fuels, Solar\ thermal, \text{'Tide, wave, ocean'})\}$

Stacked bar chart, one piece for each fuel category, total for all selected countries

6. CO_2 emissions (Mt CO_2) from the industrial sector (Decarbonisation of industry)

- Relevant data variable: ghgems

$$Indicator_{country,\ \ year} = \sum_{i \in SRC\_CRF, j \in AIRPOL} value_{country,i,j,year}, \qquad \forall country, \forall year$$

$where$

$$SRC\_CRF = \left\{ \begin{array}{c} Industrial\ processes\ and\ product\ use, \\ Other\ product\ manufacture\ and\ use, \\ Other\ industrial\ process\ and\ product\ use \end{array} \right\}$$

$AIRPOL = \{Greenhouse\ gases, Carbon\ dioxide\}$

$$Indicator_{year} = \sum_{country \in countries} Indicator_{country,\ year}, \qquad \forall year$$

Stacked bar chart, one piece for each (selected) country

7. **Final energy consumption by source (PJ) in industry** (Decarbonisation of industry)
   See in the data variable "enercons-ind".

   Sources

   Fossil fuels: Coal, Natural gas, Oil, Oil shale/oil sand, Peat and peat products

   Renewables: Biofuels, Geothermal, Solar thermal, 'Tide, wave, ocean',

   Derived heat: Ambient heat (heat pumps), Heat

   Power: Electricity, Hydroelectricity, Solar photovoltaic, Wind electricity, Nuclear fuels

   Waste: Non-renewable waste, Renewable waste

8. Energy intensity (kWh/m^2) and CO_2 emissions intensity ($kgCO_2/m^2$) in the buildings sector (Energy efficient and smart buildings)
   - Relevant data variable: building-area, enercons-res, enercons-ser, ghgems

$$energy\ intensity_{year} = \frac{\sum_{country \in countries} \sum_{variable \in relevant\_sectors} value_{variable,country,year}}{\sum_{country \in countries} value_{variable=building-area,country,year}}, \qquad \forall year$$

$where$

$$relevant\_sectors = \{enercons - res, enercons - ser\}$$

$$emissions\ intensity_{year} = \frac{\sum_{country \in countries} \sum_{i \in SRC\_CRF, j \in AIRPOL} value_{variable=ghgems,country,i,j,year}}{\sum_{country \in countries} value_{variable=building-area,country,year}}, \qquad \forall year$$

$where$

$$SRC\_CRF = \{Fuel\ combustion\ in\ public\ electricity\ and\ heat\ production\}$$

$$AIRPOL = \{Greenhouse\ gases, Carbon\ dioxide\}$$

Note: countries exclude Iceland

Line graphs, energy intensity and emissions intensity, total for all selected countries

9. CO_2 emissions (Mt CO_2) from road transport (Green mobility)

- Relevant data variable: ghgems

$$Indicator_{country,\ year} = \sum_{i \in SRC\_CRF, j \in AIRPOL} value_{country,i,j,year}, \quad \forall country, \forall year$$

where

$$SRC\_CRF = \{Fuel\ combustion\ in\ road\ transport\}$$

$$AIRPOL = \{Greenhouse\ gases, Carbon\ dioxide\}$$

$$Indicator_{year} = \sum_{country \in countries} Indicator_{country,\ year}, \qquad \forall year$$

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Nordic Clean Energy Scenarios

The project Nordic Clean Energy Scenarios aims to identify and help prioritise – through scenario modelling – the necessary actions up to 2030 and map potential long-term pathways to carbon neutrality. This report guides you through the Nordic energy system and illustrates how the Nordic countries can achieve the **Nordic Vision 2030**, to become the most sustainable and integrated region in the world, and make the green transition towards carbon neutrality a reality.

The Nordic Clean Energy Scenario analyses resulted in five solution tracks that capture the most significant options for successfully meeting the Nordics carbon neutrality targets: direct electrification; power-to-X (PtX fuels); bioenergy; carbon capture technologies (CCS) including in combination with bioenergy (BECCS); and behavioural change. A decarbonisation pathway that balances elements of all five solution tracks will likely be easier to realise and be the most resilient.

The differences between the Nordic countries' energy systems are a strength to realising our climate goals, while the development of necessary infrastructure, between and within countries, emerges as a major challenge. Making concerted planning, citizen involvement, and new cost distribution mechanisms instrumental, for a cost-effective and socially acceptable transition of the Nordic energy sector and for ensuring its contribution to Europe as a whole.