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International Institute
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and Strategy

Development of the Primary Energy Factor of Electricity Generation in the EU-28 from 2010-2013

prepared for the European Heat Pump Association (EHPA)

prepared by

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Acronyms

CC	combined-cycle
CSP	concentrating solar power
CZ	Czech Republic
DE	Germany
EC	European Commission
EHPA	European Heat Pump Association
el	electricity
ES	Spain
EU	European Union
EUROSTAT	Statistical Office of the European Union
GEMIS	Global Emissions Model for integrated Systems
ICE	internal combustion engine
IINAS	International Institute for Sustainability Analysis and Strategy
IT	Italy
kWh	kiloWatt-hours
MS	EU Member States
NL	The Netherlands
PEF	Primary Energy Factor
PL	Poland
PV	photovoltaics
th	thermal
UK	United Kingdom

Introduction

The European Heat Pump Association (EHPA) commissioned a brief study on the development of the Primary Energy Factor (PEF) of the electricity generation mix in the EU-28 for the years 2010-2013. IINAS prepared this summary report to present the key findings.

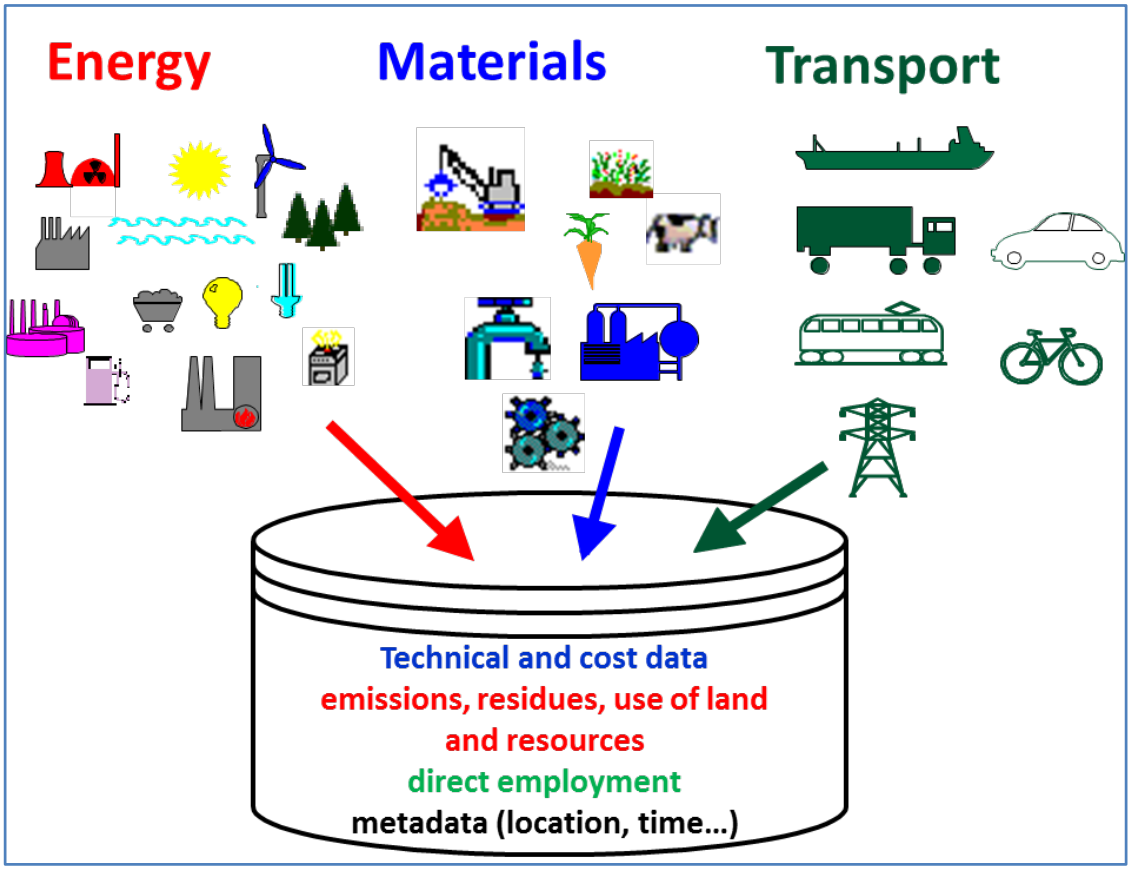
1 Background: The GEMIS Model

GEMIS is a model and database for life-cycle analysis (IINAS 2014a). It evaluates environmental impacts of energy, material and transport systems, i. e. air emissions, greenhouse gases, wastes, and resource use (primary energy, raw materials, land, water). It also determines costs and employment balances.

GEMIS is used in EU and OECD countries, some developing countries (e.g., China, India, South Africa), and Central/Eastern Europe. The software is *public domain* (i.e., free of charge), and updated regularly.

The most prominent part of GEMIS is the database (see following figure).

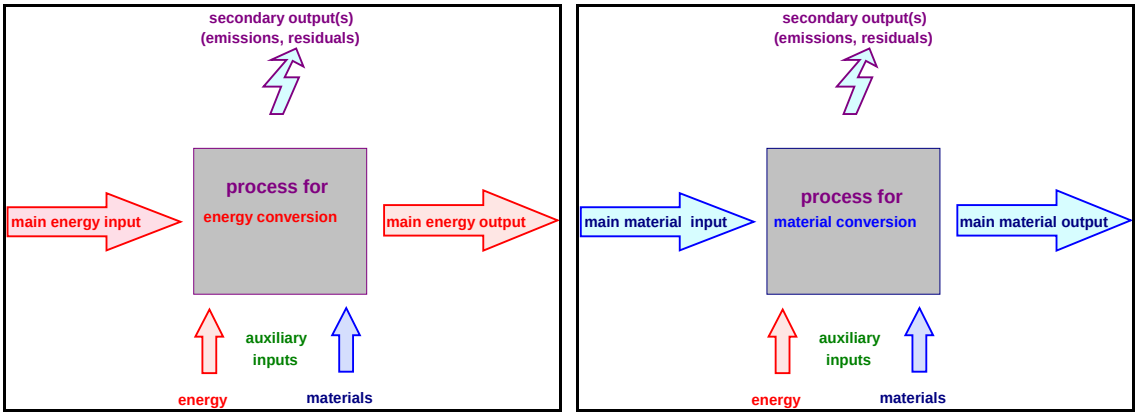
Figure 1 The GEMS Database



The database stores information on "unit" processes reflecting activities for which efficiency, emissions etc. can be measured, calculated, or derived from other sources (e.g. standards).

No formal distinction is made between energy and material flows - all are interlinked, and have the same structure (see following figure).

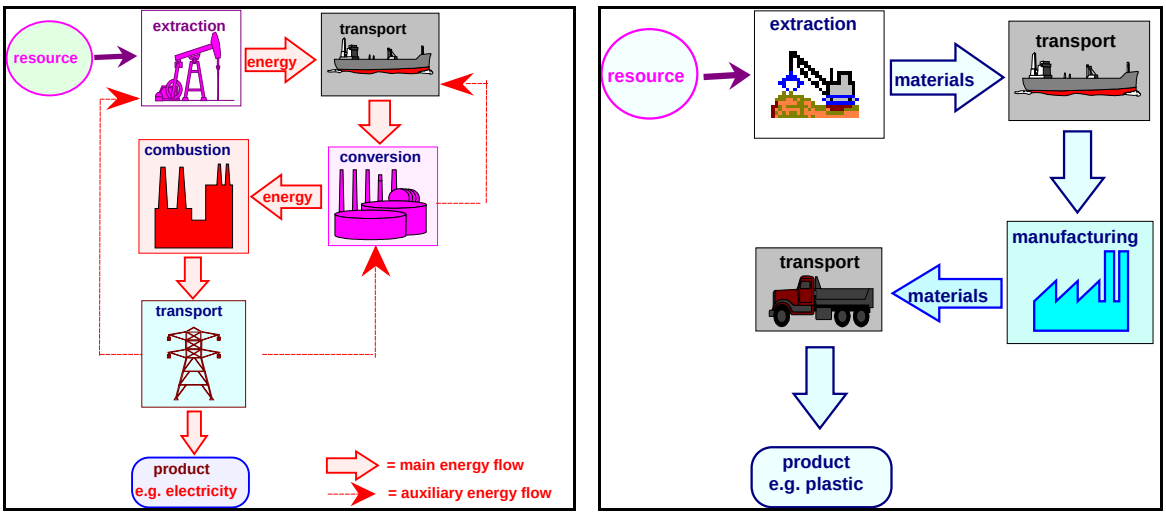
Figure 2 Unit Processes for Energy and Materials Conversion



The principle of life-cycles is to logically link “unit” processes to each other, so that from the individual process data, the overall flow per unit of output (“service”) can be calculated.

The energy and material flows (and the associated transport needs) can then be used to calculate the emissions which occur along the life-cycles. For this, the turnover in each process “box” is multiplied with emission data, and the sum of all processes involved is then calculated by GEMIS.

Figure 3 Linked Unit Processes for Energy and Materials Life-Cycles



To fully embrace the cradle-to-grave logic, not just the operation ("life") of energy, material, and transport systems must be considered, but also their "births" and "deaths":

It takes materials to construct an energy facility, and similarly, transport systems must be built before they can deliver fuels or other freight.

Thus, there are three levels of possible environmental impacts in **life-cycles**:

- direct impacts from operation,
- indirect impacts from auxiliaries (energy, transport, etc.), and
- indirect impacts from materials needed to built the process(es).

Typical life-cycles also cross national borders: Energy carriers and materials are imported from other countries, and products manufactured domestically are exported to other nations (e.g. hardware, food).

Therefore, the GEMIS database traces the origins of energy and materials from more than 30 countries, using various transport systems, and extraction technologies.

To determine the Primary Energy Factors (PEF), GEMIS calculates all primary energy inputs of the respective life-cycles, taking into account resource extraction, transport and conversion of energy carriers, the use of fuels in e.g. powerplants and heating systems, and the auxiliary energy use as well as materials needed for the construction of all systems involved in the life-cycles.

The PEF results are presented as totals, and disaggregated into the non-renewable (i.e. fossil and nuclear), renewable and "other" (e.g. waste heat) shares.

2 Primary Energy Factors of EU-28 Electricity Generation

2.1 Data Sources

To determine the PEF developments, the existing GEMIS database was updated to reflect the EU-28 electricity generation mix in the years 2010-2013, based on EUROSTAT (2015).

The respective data are shown in the following table.

Table 1 Electricity Generation Mix in the EU-28, 2010-2013

Energy source	2010	2011	2012	2013
Coal	494	497	545	528
Lignite	326	344	347	333
Oil	98	86	85	73
Gas	795	731	612	538
Nuclear	917	907	882	877
Wastes (non-renewable)	19	20	20	21
Hydro, tidal	377	312	336	371
Geothermal	6	6	6	6
Solar-PV	23	45	67	81
Solar-thermal	1	2	4	4
Wind	149	180	206	235
Biogas	32	38	46	53
Bioliquids	5	3	4	4
Solid biomass	70	74	80	82
Wastes (renewable)	17	18	19	19
Other	38	35	38	38
Total	**3364**	**3297**	**3298**	**3261**

Source: Computation by IINAS based on EUROSTAT (2015); data given in TWh (gross production)

As the “real” electricity generation in the EU-28 is comprised of a variety of different powerplants using different fuel qualities, and the fuel inputs come from both domestic sources and imports (e.g. coal, natural gas, oil), this aggregated data is not sufficient to describe electricity life-cycles.

Thus, the existing GEMIS database for electricity generation in EU Member States was used to disaggregate the overall generation mix into key components. This allows to make use of all existing “upstream” data for e.g. fuel mixes, import sources etc.

A description of this approach is given for the case of Germany in earlier reports (IINAS 2012, 2013, 2014b).

2.2 Results for the Primary Energy Factors in the EU-28

Using the refined GEMIS database, the results for the Primary Energy Factor (PEF) were calculated and are given in the following table.

Table 2 PEF of the Electricity Generation Mix in the EU-28, 2010-2013

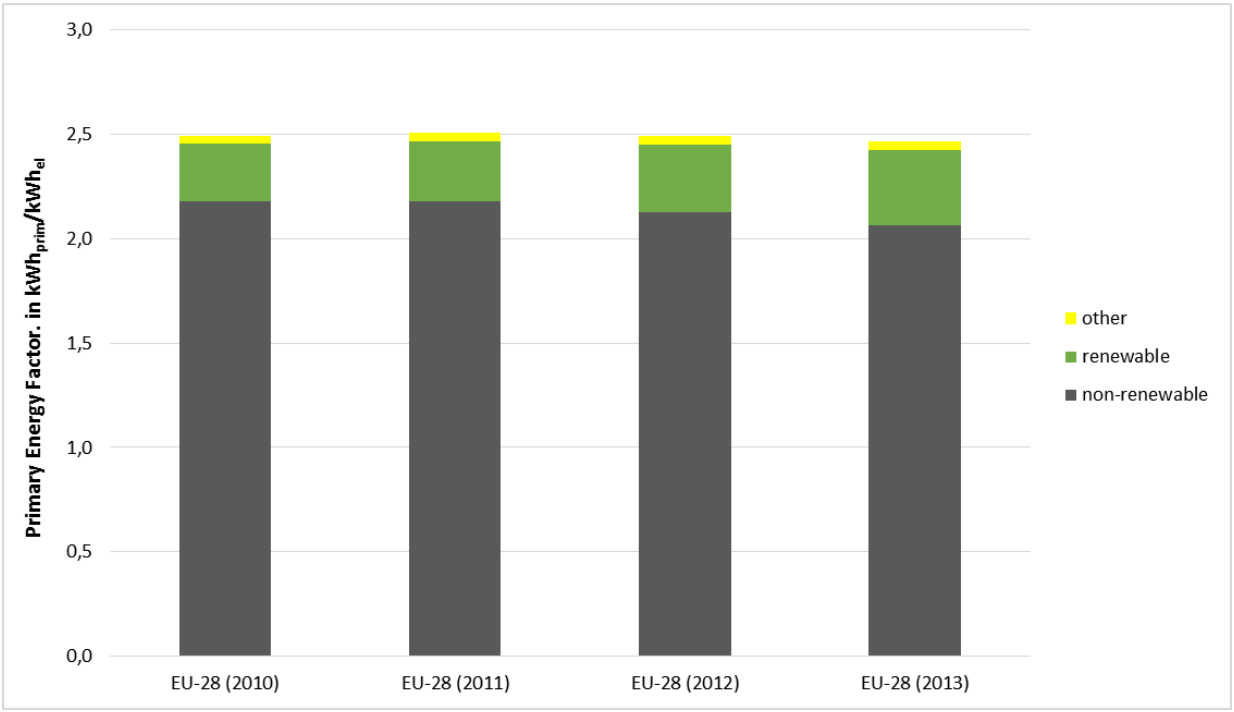
PEF [kWh_{prim}/kWh_{el}]	PEF-total	PEF non-renewable	PEF renewable	PEF other*
2010	2,49	2,18	0,28	0,04
2011	2,51	2,18	0,29	0,04
2012	2,49	2,12	0,32	0,04
2013	2,46	2,06	0,36	0,04

*Source: IINAS computation with GEMIS 4.9; *= includes waste heat, and non-renewable wastes*

As can be seen, the total PEF in terms of primary energy per unit of electricity generated slightly increased from 2010 to 2011, but is reduced again below the 2010 level in the following years. This is mainly an effect of the increase in renewable electricity generation which has a comparatively low PEF.

The following figure shows the composition of the PEF in graphical form.

Figure 4 PEF of the Electricity Generation Mix in the EU-28, 2010-2013



Source: IINAS computation with GEMIS 4.9

The EU-28 electricity PEF is dominated by the non-renewable primary energy use, and rather stable over the last years.

The breakdown into the different forms of primary energies used for electricity generation is shown in the following table.

Table 3 Breakdown of the PEF for the EU-28 Electricity Generation Mix, 2010-2013

Contribution to total PEF [kWh_{prim}/kWh_{el}]	**2010**	**2011**	**2012**	**2013**
Coal	0,35	0,36	0,39	0,39
Lignite	0,24	0,26	0,26	0,26
Oil	0,10	0,09	0,09	0,08
Natural gas	0,47	0,44	0,37	0,34
Nuclear	1,02	1,03	1,00	1,01
Wastes (non-renewable)	0,04	0,04	0,04	0,04
Biomass	0,02	0,02	0,02	0,02
Wastes (renewable)	0,09	0,10	0,11	0,11
Geothermal	0,00	0,00	0,00	0,00
Hydro	0,12	0,10	0,11	0,12
Solar	0,01	0,01	0,02	0,03
Wind	0,05	0,06	0,06	0,07
Total	**2,49**	**2,51**	**2,49**	**2,47**

Source: IINAS computation with GEMIS 4.9

3 Additional PEF Data

The background of the EU-28 PEF data is the variety of individual power generation systems in the EU Member States. To allow for a comparison, the following tables gives the specific PEF data per unit of electricity generated by each system.

Table 4 PEF Data for Electricity Generation Systems in the EU in 2010

PEF [kWh_{prim}/kWh_{el}]	Total	non-renewable	renewable	other
lignite-DE-Lausitz	2,37	2,37	0,00	0,00
lignite-DE-rhine	2,40	2,40	0,00	0,00
lignite-CZ	2,30	2,31	0,00	-0,01
lignite-PL	2,69	2,69	0,00	0,00
coal-DE	2,31	2,30	0,00	0,00
coal-DE-import	2,50	2,48	0,01	0,00
coal-EU	2,45	2,44	0,01	0,00
gas-CC-DE	1,93	1,93	0,00	0,00
gas-CC-ES	1,96	1,96	0,00	0,00
gas-CC-IT	1,98	1,98	0,00	0,00
gas-CC-NL	1,79	1,79	0,00	0,00
gas-CC-UK	1,81	1,81	0,00	0,00
oil-heavy-DE	2,75	2,74	0,01	0,00
oil-heavy-ES	2,76	2,75	0,01	0,00
oil-heavy-IT	2,78	2,77	0,01	0,01
nuclear-DE	3,29	3,27	0,02	0,01
nuclear-FR	4,05	4,01	0,02	0,02
nuclear-UK	3,15	3,14	0,00	0,01
wastes-EU	5,50	0,00	0,00	5,50
hydro-ROR	1,01	0,01	1,00	0,00
geothermal-IT	1,02	0,02	1,00	0,00
solar-CSP-ES	1,03	0,03	1,00	0,00
solar-PV- DE	1,25	0,23	1,02	0,01
wind-park-DE	1,03	0,03	1,00	0,00
biogas-manure-ICE-EU	2,71	0,09	2,60	0,02
biogas-maize-ICE-EU	2,83	0,22	2,60	0,02
rapeseedoil-ICE-DE	2,03	0,43	1,60	0,00
wood-cogen-EU	2,99	0,09	2,90	0,00
biowaste-cogen-DE	2,96	0,00	2,95	0,00

Source: IINAS computation with GEMIS 4.9; CC = combined-cycle; CSP = concentrating solar power; PV = photovoltaics; ICE = internal combustion engine;

PEF data are also required for heating buildings, especially with natural gas and oil. The following table provides specific PEF data per unit of heat supplied by these systems.

Table 5 PEF Data for Selected Heat Supply Systems in the EU in 2010

PEF [kWh_{prim}/kWh_{th}]	**Total**	**non-renewable**	**renewable**	**Other**
Coal	1,79	1,77	0,01	0,00
Natural gas	1,34	1,33	0,00	0,00
Oil	1,35	1,34	0,01	0,00
Wood pellets	1,30	0,11	1,19	0,00
Electricity	2,67	2,33	0,30	0,04

Source: IINAS computation with GEMIS 4.9

4 Perspectives

It can be expected that the PEF will further decline in the future due to the continuing increase of renewable electricity (EC 2013), and the parallel reduction of nuclear generation which will be a consequence of the German nuclear phase-out (see IINAS 2014b).

It is beyond this brief study to determine the future PEF of EU electricity generation in concrete numbers, though.

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