Business As Usual Energy Scenario for Armenia

Gunnar Boye Olesen, INFORSE-Europe, 18/9 2017

This paper describes a business as usual scenario for Armenia, for comparison with the action scenario proposed for a transition to renewable energy[1]. It is based on available information in April 2017 from Armenian and international sources. The main elements are:

- scenario for development of energy service demands
- scenario for development of energy efficiency
- scenario for possible development of renewable energy
- Final energy use
- Energy System & change of energy carriers
- Primary energy use and CO_2 emissions

In this paper the description of each scenario is on the left page and assumption + sources on the right page. On chapter 5 this format was not possible, though.

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[1] Sustainable Energy Scenarios for Armenia, INFORSE-Europe, Gunnar Boye Olesen, 2017

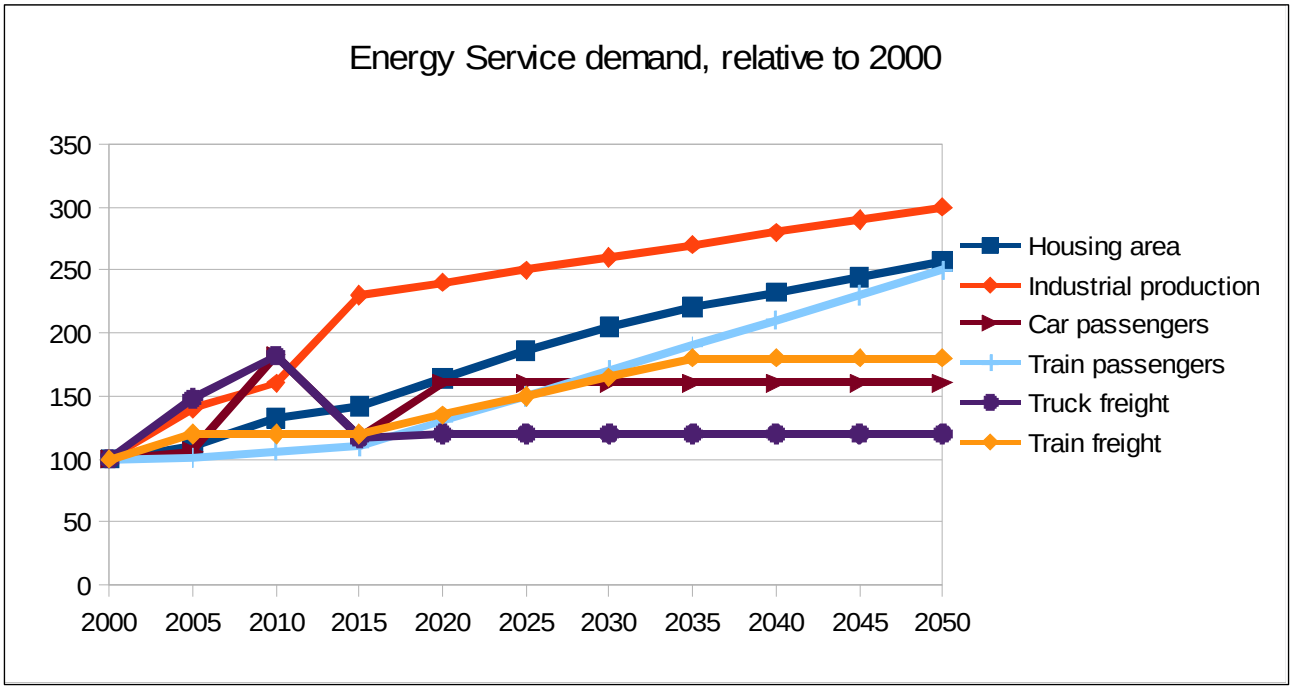
1. BAU Scenario for future developments of energy service demand

The Armenian economy has grown around 3%/year[2] of GDP in the past years, thus Armenia can be expected to have similar growth in the future.

While GDP can be expected to grow until 2050, the growth of "energy services", the drivers of energy demand will not necessarily grow with the same pace. We have for this scenario made estimations of the growth relative to year 2000 for the following energy services:

- Area of heated floorspace for living (housing)
- Area of heated floorspace for service sector, public + private services'
- Electric equipment use in housing
- Electric equipment use for service sector
- Industrial production, heat and fuel use
- Industrial production, electricity use
- Agriculture, heat and fuel use
- Agriculture, electricity use
- Use of passenger cars
- Use of buses
- Use of passenger trains
- Volume of road freight (trucks)
- Use of rail freight (trains)

Development of energy services is shown for selected sectors in the graph below



The developments are the same as in the action scenario. Industrial production and housing area are expected to continue to grow, truck transport is expected to stay close to the 2015, thereby deviating

[2] While Armenia had a high growth of over 7% pa until 2007, the growth 2009 – 2016 have been 3.3% pa and the forecast for 2017-2019 is 3% pa, according to World Bank, see https://data.worldbank.org/country/armenia. Based on this we use the assumption of future growth of 3% pa.

from the 2010-2015 trends of falling truck freight. Passenger car use is expected to grow to 60% above the 2015 level until 2050. The development 2000 – 2015 is based on available statistical. Unfortunately the statistical data available are limited, as explained on the following page.

Assumptions for development of energy service demand

All energy services are given relative to their 2000 level, and therefore it is not in principle necessary to know the actual levels, but only the relative levels to the year 2000 level. As year 2000 is the basis, the value is always 100% for this year.

For the years 2005, 2010, and 2015 is used statistics. For 2015 is used 2014 statistics, as 2015 statistics is still not fully available. For some sectors, actual statistics is available: housing, passengers in passenger cars, freight. These data are from Armenian statistics. For other sectors only consumption of energy (fuel, heat and electricity) is available. Energy consumption is taken from International Energy Agency (IEA) online statistics. For the sectors where only energy statistic is available, is used estimate of energy efficiency development, to estimate energy service demands in 2005, 2010, and 2015.
Because of very large growth in energy consumption in some sectors, with the highest growth in service sector from 0.3 PJ in 2000 to 7.3 PJ in 2015, the assumed growth of energy service demands is very high. Most likely this big change is due to statistical errors. With this method, the values for 2014 (included as 2015 in the graphs) are the basis for the estimations of the future energy service demands. This is done with the assumption that there are least errors in the latest statistics.

Energy service demands from Armenian statistics is given in the table below:

Year	2000	2005	2010	2014/ 2015
Total area of total housing stock in 1000m2	67111	74359	88634	95024
Passengers turnover, mln. passenger-km	2062.6	3199.4	3937.8	2 525.0
CARGO TURNOVER, (mln. T-km)	2309.6	2300.7	3126.3	3 746.0

For the sectors with only energy statistics, the following estimated increases in energy services 2000 – 2015 is used:

- Service sector: 850% for heated area (see comment above) and 425 % for electricity use
- Industry: 85% in heat and fuel using services and 213% for electricity use
- Agriculture: 150% in heat and fuel using services and 70% for electricity use

For future energy service demands are used the following growth estimates 2015 – 2050 :

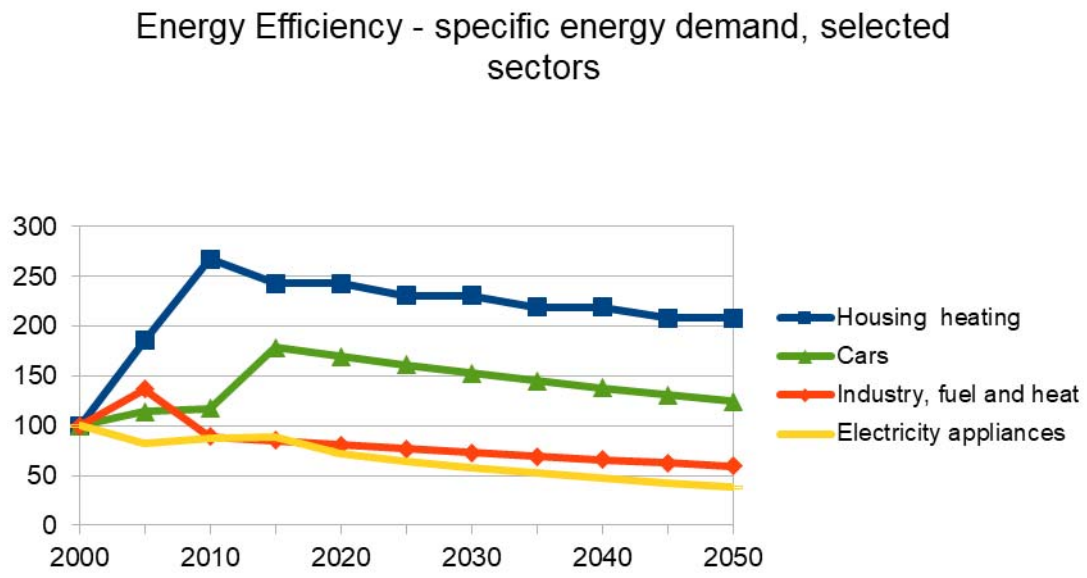
- Housing and service area and electricity demanding services: 81% growth, realising a growth of 1.7% pa, just above the growth 2010-2015 of 1.4% pa
- Industry: 180% growth in fuel and heat using services, equal to 3% pa growth as GDP, 40% growth in electricity service in industry,
- Agriculture: No change, assuming that agriculture will stay with same output in the future as today
- Passenger cars: 37% growth, assuming a moderate growth because of priority of trains.

- Buses: 7% growth, assuming priority of buses will reverse the reductions seen since 2010
- Passenger trains: 127% growth, assuming priority of trains
- Road freight (trucks): 3% growth, reverse reductions since 2010
- Rail freight (trains): 50% growth, assuming priority of freight on trains

2. Scenario for development of energy efficiency

Energy efficiency is expected to improve in all sectors.

We express energy efficiency with its inverse: the specific energy demand relative to 2000. In this way specific energy demand "100" means the same energy efficiency as in the year 2000 while "50" means twice as efficient as in the year 2000. The estimated development of energy efficiency is illustrated in the graph below for selected sectors' development of specific energy demands.



In this scenario all energy uses are expected to have increase of energy efficiency 2015 - 2050. The large growth in specific energy demands 2000 – 2015 can be statistical errors, as explained above, but it can also be due to special developments for Armenia, such as increased heating use in houses with the end of the crisis in the 1990's.

The final energy demand for a given year can then be calculated from final energy demand in the base year, relative energy service level, where 100% is the level the base year, and specific energy demand, where 100% is for the base year. The formula for the final energy demand is:

Final energy (FE) demand = FE demand yr 2000 * relative energy service * specific energy demand

Assumptions for development of energy efficiency

All specific energy demands are given relative to their 2000 level, and therefore it is not in principle necessary to know the actual levels, but only the relative levels to the year 2000 level. As year 2000 is the basis, the value is always 100% for this year.

For the years 2005, 2010, and 2015 is used statistics. For 2015 is used 2014 statistics, as 2015 statistics is still not fully available. For some sectors statistics is available for energy services: housing, passengers in passenger cars, freight. For other sectors only consumption of energy (fuel, heat and electricity) is available, from IEA. For the sectors where only energy statistic is available, is used estimate of energy efficiency development and energy service demands in 2005, 2010, and 2015.

The following development of specific energy demands 2000 – 2015 are used:

- Service sector: 213% increase, probably due to statistical errors
- Housing area: 143% increase
- Industry: 15% reduction (improved energy efficiency) in heat and fuel, no change for electricity use
- Agriculture: 39% increase for heat and fuel use, 48% reduction for electricity use
- Passenger car use: 79% increase, maybe due to statistical errors
- Buses: 39% increase
- Passenger train use: 15% decrease (increased efficiency)
- Road freight (trucks): 79% increase, mayb due to statistical errors
- Rail freight (trains): 85%, estimated as passenger trains

For development 2015 – 2050 is expected the following reductions in specific energy use:

- Service sector: 15% reduction (increase in energy efficiency) for heat and fuel use, and 55% reduction for electricity use
- Housing: 15% reduction for heat and fuel use, 57% reduction for electricity use
- Industry: 30% reduction for heat and fuel use, 65% for electricity use
- Agriculture: 30% reduction for heat and fuel use, 33% reduction for electricity use
- Passenger car use: 30% reduction of fuel use/km
- Buses: 30% reduction of fuel use/km
- Passenger train use: 30% reduction of energy use/km
- Road freight (trucks): 30% reduction of fuel use/ton-km
- Rail freight (trains): 30% reduction of fuel and electricity use/km

The reductions in specific energy use is in line with expected developments without new policies. For electricity use is expected gradual replacement with equipment that follow EU Ecodesign requirements, as the technical standards of energy efficiency in Armenia are expected to approach EU Ecodesign regulations. This will give large savings with minimal costs and without other policies.

3. Scenario for renewable energy

Armenia has large potentials for increasing the use of renewable energy, but without policies, only some of them are expected to expand substantially.

Hydro-power is the most developed form of renewable energy in Armenia. There is still some potential for increase of hydro-power, and an increase of 10% is included in this scenario.

There are in certain parts of Armenia very good wind conditions, in high mountain areas. Only a few wind turbines are installed and there is no ongoing windpower development, but it is expected that after 2020 will be a development even without specific policies, gradually leading to 1100 MW windpower in 2050.

Armenia has large solar energy potentials with up to twice the solar energy per m^2 compared to most Western European countries. In spite of this, solar energy is not much developed today, but in the scenario is expected development of solar heating to capture 3,9 PJ in 2050 with 1.6 million m^2 of solar heaters, while solar electricity is expected to capture 3.3 PJ in 2050 with 6 million m^2 of solar PV.

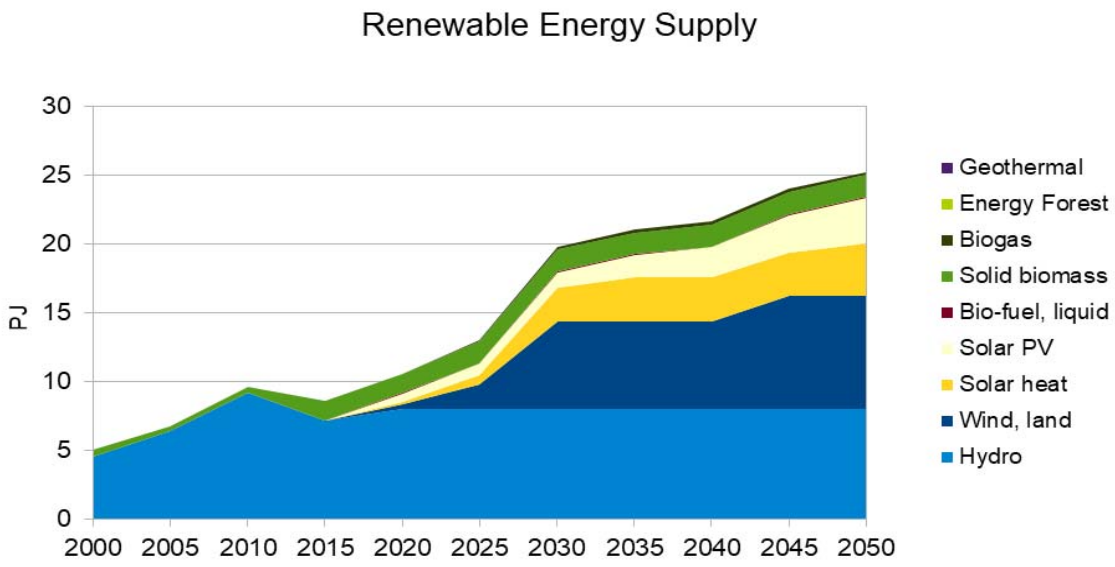
There are potentials for geothermal energy in many parts Armenia, but this is not expected to be used in this scenario.

Solid biomass is a traditional energy source in Armenia and is used extensively today for space heating. There is a potential to expand the use, and 12% increase is expected after 2020, to be used for power production.

Energy forest development is not included in this scenario.

Biogas is included with a small development to reach 0.2 PJ of gas production by 2050
Biofuel is not expected to be developed in this scenario,

The scenario's development of renewable energy use illustrated in the graph below (next page).

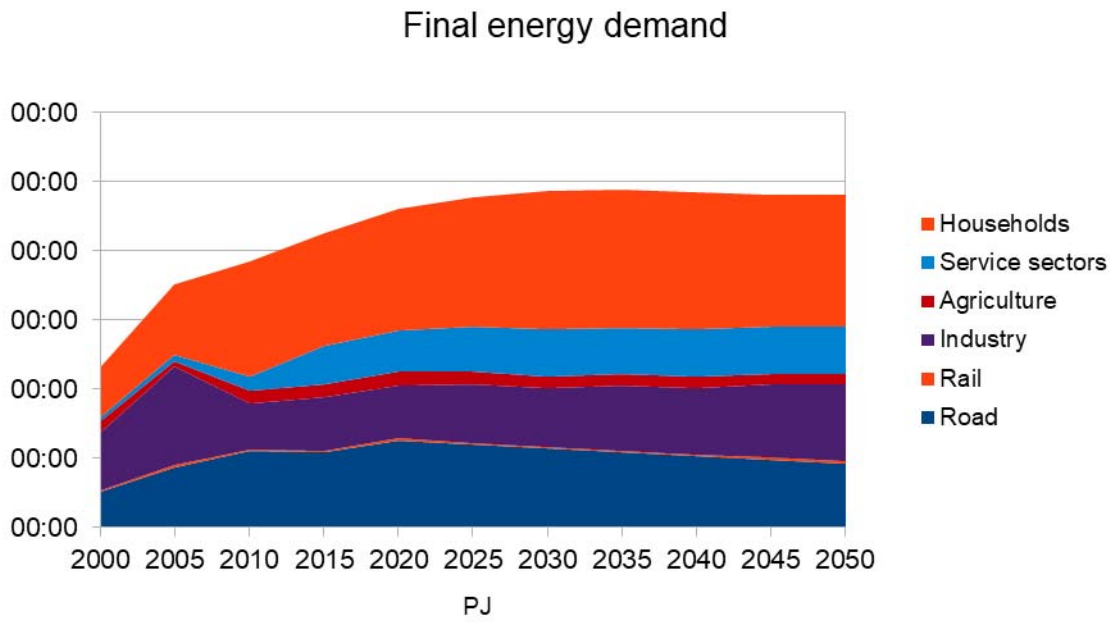


The energy supply and, where relevant, capacities of the renewable energy use in 2050 in the scenario is given in the table below:

Renewable energy use 2050 (scenario)	Capacity (MW)	Energy (PJ)
Windpower	1100	8.2
Solar heat		3,9
Solar PV	600	3.3
Bio-fuel, liquid		0
Solid biomass		1.6
Biogas		0.2
Energy Forest		0
Geothermal		0
Hydro		8
Total		25.2

4. Final energy use

Combining the energy service demand and the development of energy efficiency we get the final energy demand of the scenario. It is illustrated in the graph below.

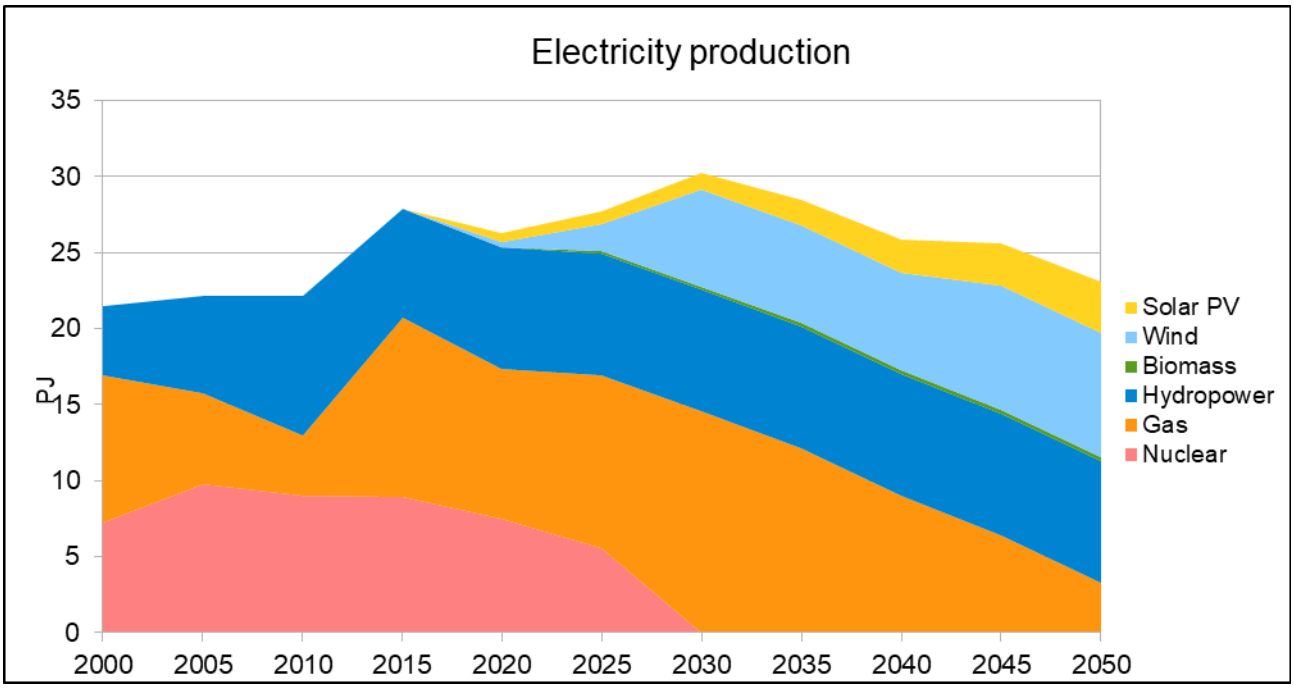


Assumptions for final energy use
Final energy use for 2000, 2005, 2010 and 2015 are from IEA statistics. For 2015 is used data for 2014 as the 2015-figures are not yet available.

Final energy use 2020 – 2050 is calculated for each sector using the assumptions for development of energy services and specific energy use described above.

5. Energy System & change of energy carriers

In the following graphs are shown the expected development of energy use for electricity.



Assumptions for energy system & change of energy carriers

In the scenario the changes of energy system is based on the above-described developments of final energy demand and of renewable energy production, as well as a series of assumptions of how the energy carriers for each sector is developing.
In the tables below are shown simplified energy balances for 2014 and 2050, to enable comparison of this scenario with present energy system and with end-year of scenario with 100% renewable energy (action scenario).

Energy Balance 2014	Oil	Gas	Nuclear	Biomass	RE electric.	RE heat	Electricity	Heating	H2	Total
Primary Production	0	0.0	26.9	1.4	7.2	0.0	0.0	0.0	0.0	35.5
Import/export	14.5	78.8	0.0	0.0	0.0	0.0	-4.0	0.0	0.0	89.3
Primary energy	15.0	77.0	26.9	1.4	7.2	0.0	-4.0	0.0	0.0	123.5
District heating	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Heat pump	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Condensing power	0.0	0.0	26.9	0.0	0.0	0.0	-8.9	0.0	0.0	18.0
Cogeneration	0.0	27.7	0.0	0.0	0.0	0.0	-11.8	0.0	0.0	15.8
RE	0.0	0.0	0.0	0.0	7.2	0.0	-7.2	0.0	0.0	0.0
Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Grid losses	0.0	0.0	0.0	0.0	0.0	0.0	3.3	0.0	0.0	3.3
Final energy	15.0	49.3	0	1.4	0	0.0	19.3	0.0	0.0	85.3
Roadt	9.8	11.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.7
Rail transport	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.4
Industry	1.6	8.7	0.0	0.0	0.0	0.0	5.3	0.0	0.0	15.6
Agriculture	3.3	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	3.9
Service sector	0.2	7.1	0.0	0.0	0.0	0.0	3.6	0.0	0.0	10.9
Housing	0.2	21.8	0.0	1.4	0.0	0.0	9.3	0.0	0.0	32.7

Energy balance 2050	Oil	Gas	Nuclear	Biomass	RE electric.	RE heat	Electricity	Heating	H2	Total
Primary Production	'	0.0	0.0	1.9	19.5	3.9	0.0	0.0	0.0	25.5
Import/expot	14.7	64.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	79.1
Primary energy	14.7	64.4	0.0	1.9	19.5	3.9	0.0	0.0	0.0	104.6
District heating	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Heat pump	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Condensing power	0.0	7.9	0.0	0.6	0.0	0.0	-3.5	0.0	0.0	4.9
Cogeneration	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RE	0.0	0.0	0.0	0.0	19.5	0.0	-19.5	0.0	0.0	0.0
Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Grid losses	0.0	0.0	0.0	0.0	0.0	0.0	2.8	0.0	0.0	2.8
Final energy	14.7	56.6	0.0	1.3	0.0	3.9	19.9	0.0	0.	97.3
Road	9.4	6.4	0.0	0.0	0.0	0.0	2.8	0.0	0.0	18.6
Rail	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.6
Industry	3.0	16.5	0.0	0.0	0.0	0.0	2.9	0.0	0.0	22.4
Agriculture	2.1	0.0	0.0	0.1	0.0	0.0	0.4	0.0	0.0	2.7
Service sector	0.0	10.9	0.0	0.0	0.0	0.0	3.0	0.0	0.0	14.0
Housing	0.2	22.7	0.0	1.2	0.0	3.9	10.0	0.0	0.0	38.0

6. Results including primary energy use and CO_2 emissions

The resulting development of primary energy use and CO_2 emissions are shown in the graphs below.