PROJECT

STRENGTHENING CIVIL SOCIETY TO ADVOCATE FOR SUSTAINABLE ENERGY TRANSITION

SUSTAINABLE ENERGY SCENARIOS FOR ARMENIA

2017

Sustainable Energy Scenarios for Armenia

Draft by Gunnar Boye Olesen, INFORSE-Europe, 24/4 2017

This paper describes scenarios for the possible development of Armenian energy supply and use until 2050. 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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This publication is prepared by «EcoTeam Energy and Environmental consulting» NGO within «Strengthening civil society to advocate for sustainable energy transition» project under the grant agreement with NGO OVE (Denmark). The project is funded by CISU Foundation (Denmark). The Project is an NGO Cooperation across the INFORSE-Europe network in 5 Eastern European countries: Armenia, Belarus, Macedonia, Serbia, Ukraine and Denmark.

The overall development objective of the Project is the transition of the 5 project countries, and ultimately the region to sustainable energy in a way that eliminates energy poverty and reduces poverty in general via creation of local jobs in energy efficiency and renewable energy.

The electronic version of the publication can be found on the following web-sites:
http://users.freenet.am/~ecoteam/; http://www.inforse.org/europe/ASET.htm

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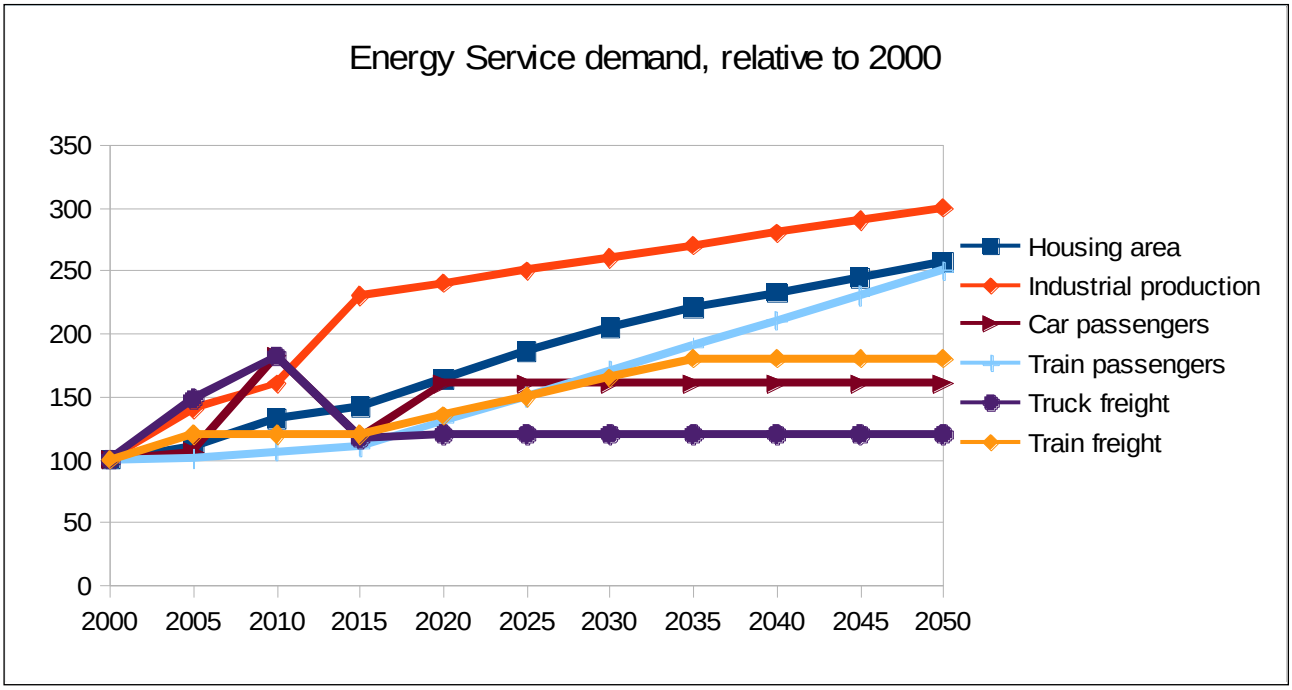
1. Scenario for future developments of energy service demand

The Armenian economy has grown around 3%/year 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



In this scenario industrial production and housing area are expected to continue to grow, as well as industry, while truck transport is expected to stay close to the 2015 level and 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 is made, the following estimated increases in energy services for 2000 – 2015 are 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

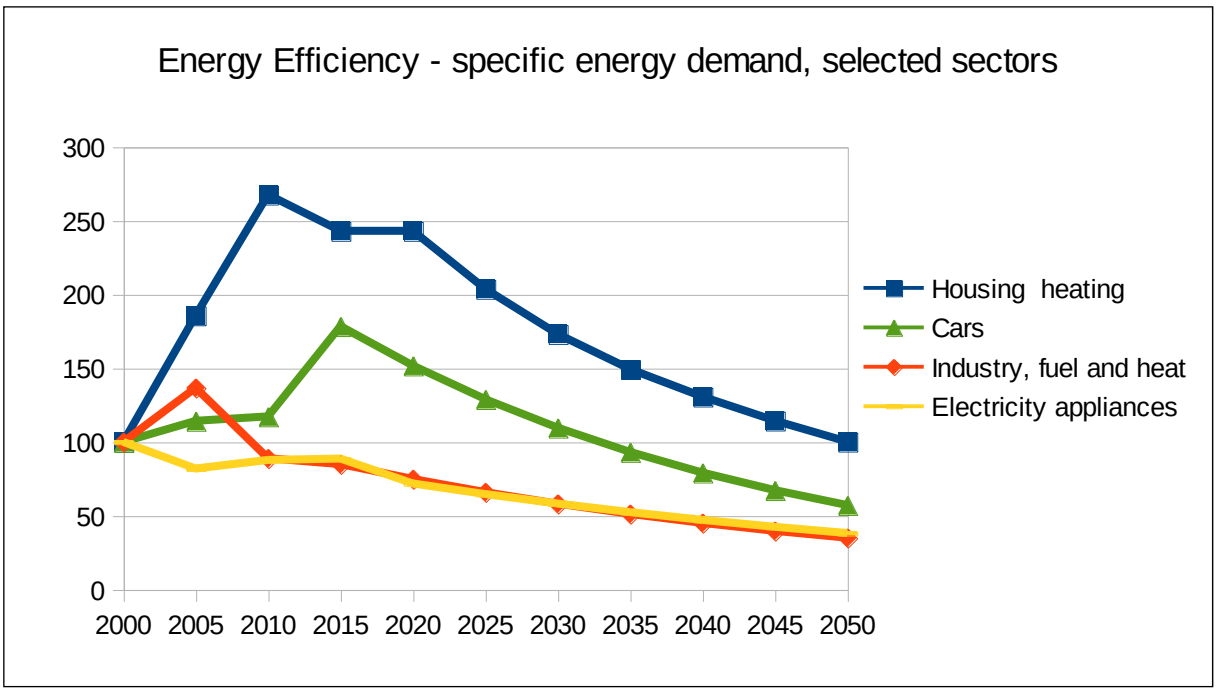
For future energy service demands are used the following growth estimates 2015 - 2050:

- Housing and service area and electricity demanding services: 81%
- Industry: 180% growth in fuel and heat using services, 33% growth in electricity demanding service
- Agriculture: No change
- Passenger cars: 37% growth
- Buses: 7% growth
- Passenger trains: 127% growth
- Road freight (trucks): 3% growth
- Rail freight (trains): 50% growth

2. Scenario for development of energy efficiency

Energy efficiency is expected to improve in all sectors. There are large potentials for improvement: houses can be near zero energy for heating, many electricity uses can be 2-4 times as efficient, cars can be 4 times as efficient with change from petrol and diesel cars to electric cars. Energy use in industry and agriculture can be 2-4 times as efficient.

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, 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 follows:

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, maybe 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: 59% reduction (increase in energy efficiency) for heat and fuel use, and 55% reduction for electricity use
- Housing: 59% reduction for heat and fuel use, 57% reduction for electricity use
- Industry: 59% reduction for heat and fuel use, 65% for electricity use
- Agriculture: 33% reduction for heat and fuel use, 33% reduction for electricity use
- Passenger car use: 68% reduction with change to mainly electric cars
- Buses: 52% reduction with change to many electric buses
- Passenger train use: 30% reduction
- Road freight (trucks): 52% reduction with change to many electric trucks (for shorter distances and hydrogen-fuel cell trucks
- Rail freight (trains): 30% reduction.

The reductions in specific energy use is in line with what is expected in many Western European countries. For service sector, housing and industry is included that efficiency of these sectors in Armenia will approach the levels in Western Europe, thus having higher increases in efficiency in the period than in Western Europe.

3. Scenario for renewable energy

Armenia has large potentials for increasing the use of renewable energy. This is documented in the report "Assessment of Renewable Energy Potential in Armenia"[1].

Hydro-power is the most developed form of renewable energy in Armenia. There is still some potential for increase of hydro-power, but it is also important to take environmental concerns into account. In the scenario is continued development of hydropower.

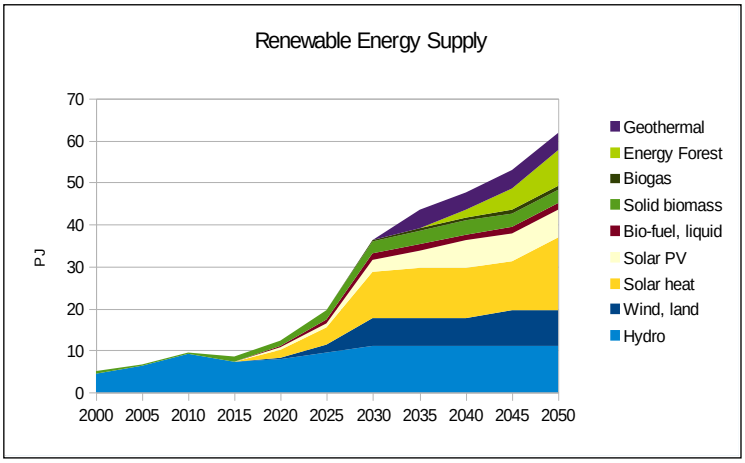
There are in certain parts of Armenia very good wind conditions, in high mountain areas. Only a few wind turbines are installed and there is no ongoing wind power development. With the scenario is expected that wind power is installed in the best locations until 2040[2], and after 2040 also a few of the next best locations will be used (less accessible, with lower wind speed).

Armenia has large solar energy potentials with up to twice the solar energy per m^2 compared with the most Western European countries. In spite of this, solar energy is not much developed today. In the scenario is included substantial development of solar power, up to the limit given by the demand for electricity during sunny days. A larger development of solar heating is included, as solar heat easily can be stored as hot water until the heat is needed.

There are potentials for geothermal energy in many parts Armenia, including potentials for combined heat and power (CHP). In the scenario is included substantial development of geothermal CHP, up to the potentials reported in (1).

Biomass is a traditional energy source in Armenia and is used extensively today for space heating. There is a potential to expand the use with a small biomass CHP and also to plant energy forest, which could be part of the forest expansion plans of Armenia. For energy forest is included in the scenario that 2.5% of Armenian land is used. This must be combined with actions to make the biomass use sustainable. There is an ongoing problem with illegal logging today.

Biogas and liquid biofuel development are also included in the scenario with their relative small potentials, reported in (1).The scenario's development of renewable energy use illustrated in the graph below.



1 Assessment of Renewable Energy Potential in Armenia, EcoTeam, Armenia, April 2017, available from http://users.freenet.am/~ecoteam/

2 Locations with wind speed above 8 m/s at 50 m height is estimated to have a potential of 1050 MW, of which we expect around 80% is accessible, see "1". This is the potential expected to be used until 2040

Assumptions for development of renewable energy

In the scenario the potentials specified in (1) is expected to be used for hydro-power, wind power, geothermal energy, biomass excluding energy forests, biogas, liquid biofuels. For the other renewable energy sources is expected the following development:

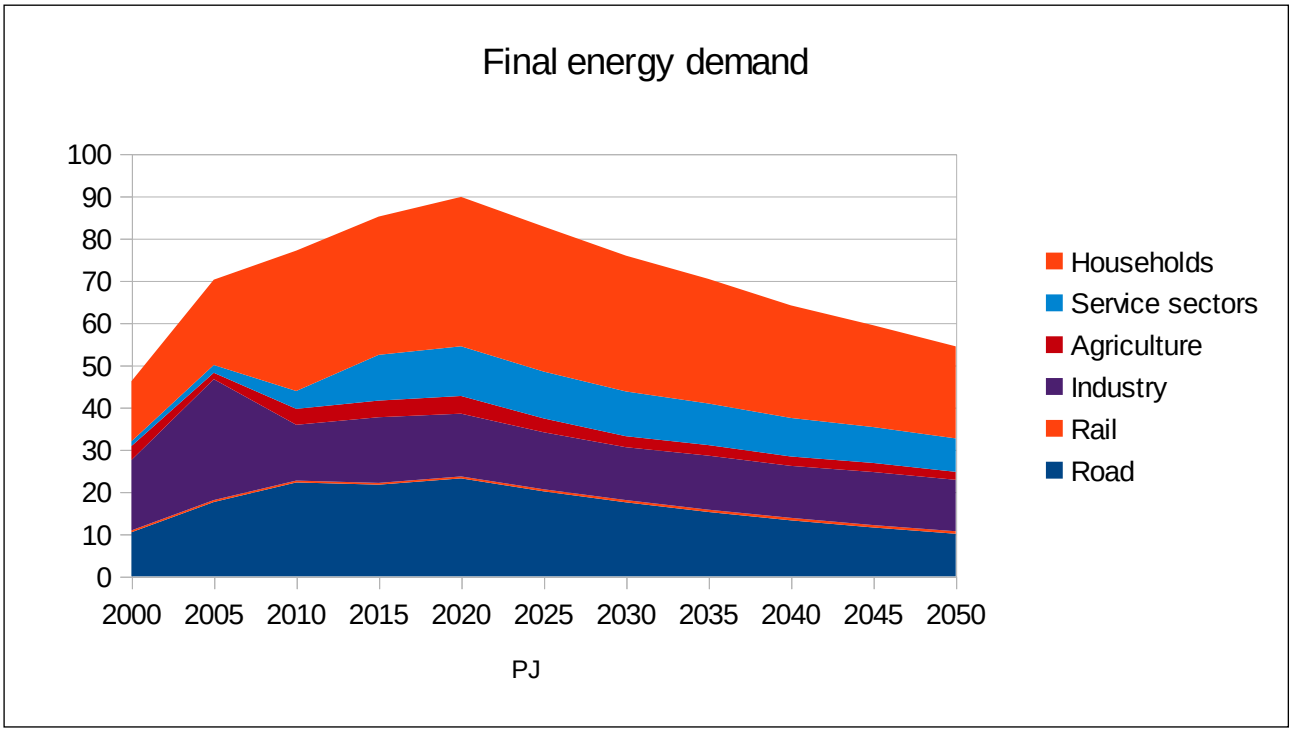
- solar power: installation of 1200 MW, which would be possible with increased power demand, in which case the peak demand will also increase
- solar heating: installation of solar heating to capture 17 PJ of solar heat covering 60% of district heating demand, 30% of household heat demand and 15% of industrial heat demand. To cover such large share of district heat demand will require seasonal heat storages as are developed in Western Europe today
- Energy forest: planting of trees and other vegetation that can give 3 PJ in 2040 increasing to 14 PJ in 2050.

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		17
Solar PV	1200	6.6
Bio-fuel, liquid		1.5
Solid biomass		3.2
Biogas		0.8
Energy Forest		8.4
Geothermal		4.3
Hydro	1500	11
Total		61

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.



While the energy demand is expected to grow in the near future following existing trends, the energy consumption in the longer term is expected to decrease. This is because expected increases in efficiency are higher than the expected growth in energy services.

Assumptions for final energy use

Final energy use for 2000, 2005, 2010 and 2015 are from IEA statistics. For 2015 data for 2014 are used 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

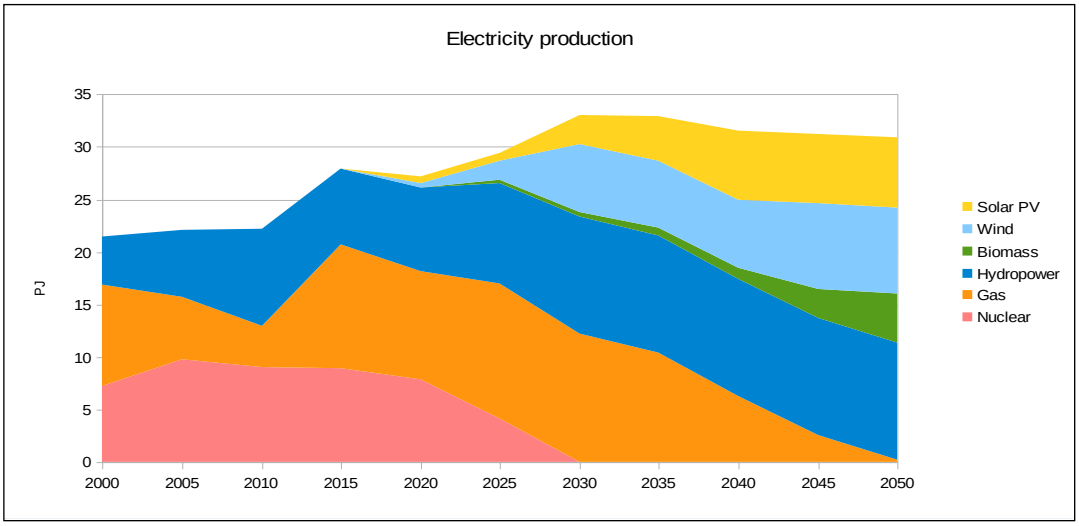
In the scenario the energy system is expected to have a gradual change from fossil fuels to renewable energy.

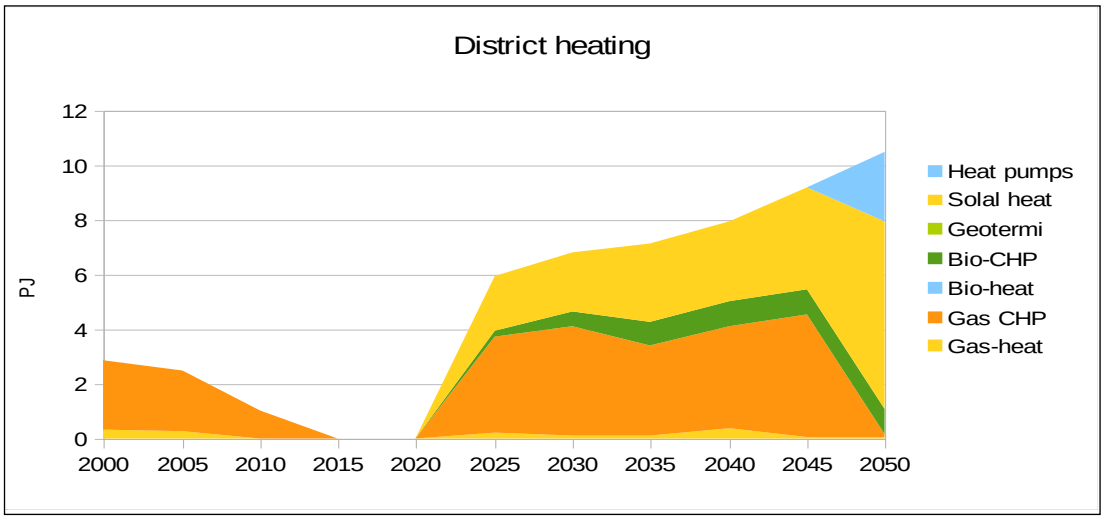
For the power sector, production will gradually be transferred to solar power, wind power, CHP from geothermal and biomass, while hydropower is expanded.

For the heat demand, it is proposed to reintroduce district heating that was phased out shortly after 2000, using heat from large solar heating fields, geothermal and biomass CHP, and heat pumps. In many European countries with high heat demand, district heating is constantly expanding.
Other heat sources will be direct solar heating, biomass, and heat pumps.

For the transport demand, it is proposed gradually to change energy carrier to biofuels, electricity and hydrogen, where the hydrogen is to be produced with electricity. Electric vehicles are introduced after 2020, while hydrogen is only introduced after 2030, as it presently a less commercialised and more expensive technology.

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





Assumptions for energy system & change of energy carriers

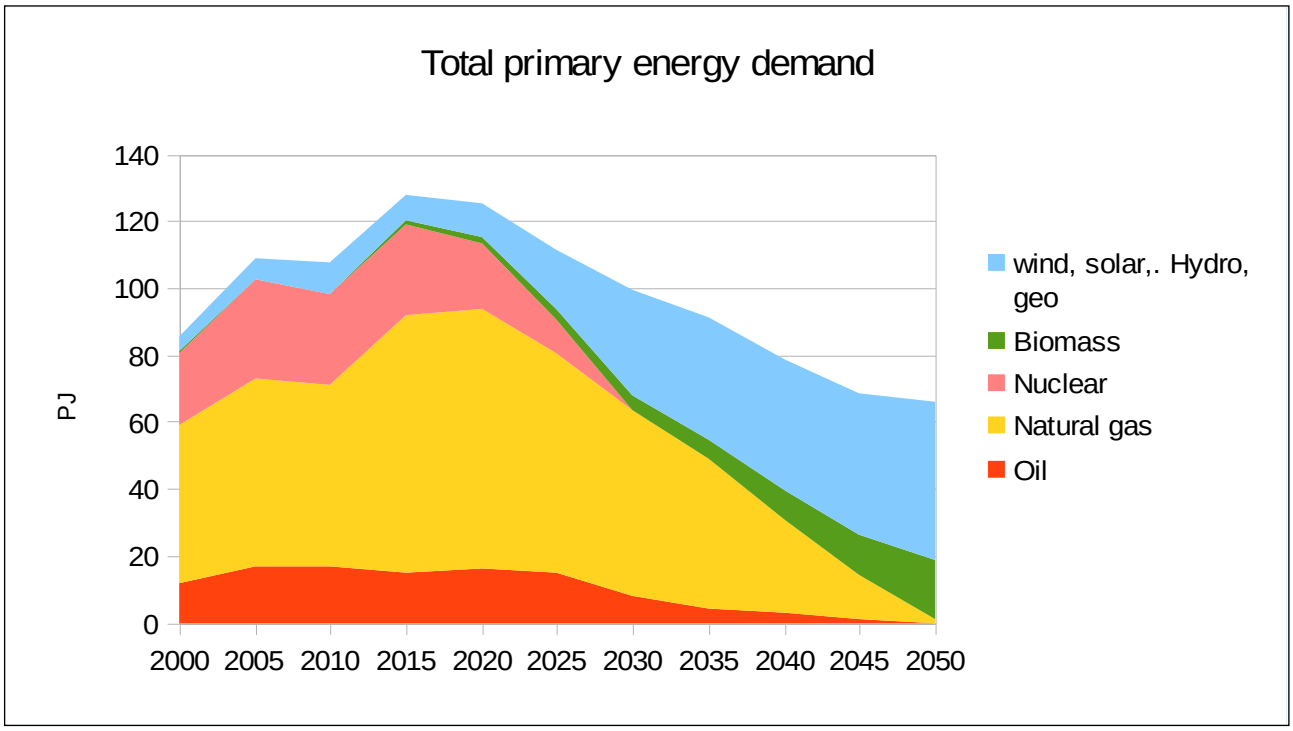
In the scenario the changes of energy system is based on the above-described developments of final energy demand and of renewable energy production, as well as a series of assumptions of how the energy carriers for each sector is developing.
In the tables below are shown simplified energy balances for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

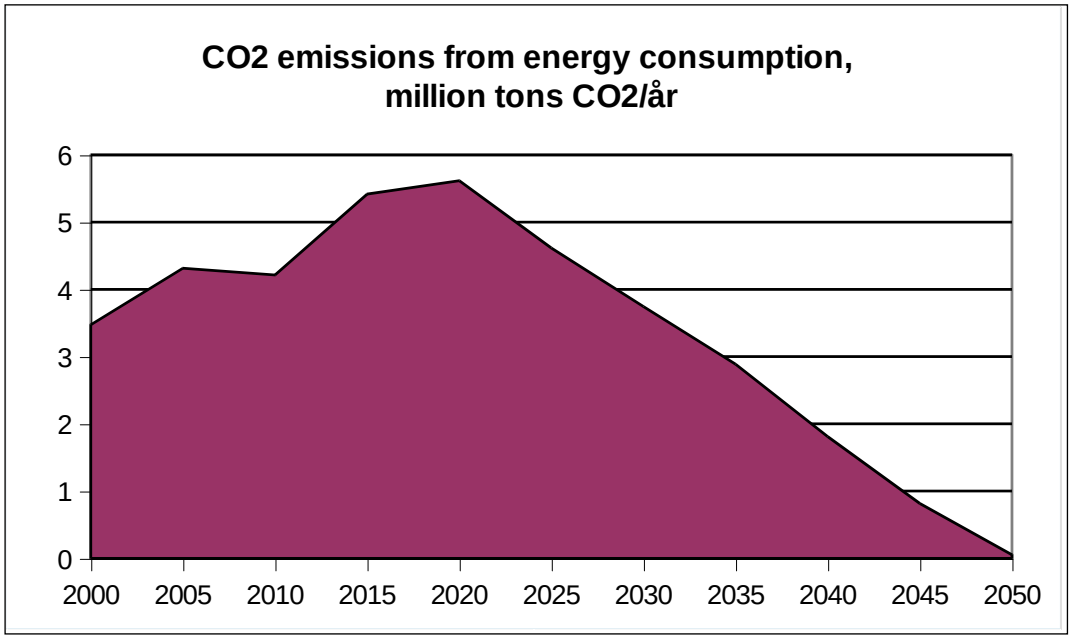
Energy Balance 2014	Oil	Gas	Nuclear	Biomass	RE electric.	RE heat	Electricity	Heating	H2	Total
Primary Production	0	0.0	26.9	1.4	7.2	0.0	0.0	0.0	0.0	35.5
Import/export	14.5	78.8	0.0	0.0	0.0	0.0	-4.0	0.0	0.0	89.3
Primary energy	15.0	77.0	26.9	1.4	7.2	0.0	-4.0	0.0	0.0	123.5
District heating	0.0	0.0	0.0	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	17.6	26.0	21.4	0.0	0.0	0.0	65.0
Import/expot	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Primary energy	0.0	0.1	0.0	17.6	26.0	21.4	0.0	0.0	0.0	64.7
District heating	0.0	0.1	0.0	0.0	0.0	8.6	0.0	-7.0	0.0	1.7
Heat pump	0.0	0.0	0.0	0.0	0.0	0.0	0.8	-2.5	0.0	-1.7
Condensing power	0.0	0	0.0	9.0	0.0	0.0	-3.6	0.0	0.0	5.0
Cogeneration	0.0	0.1	0.0	2.1	0.0	4.3	-2.6	-2.9	0.0	1.1
RE	0.0	0.0	0.0	0.0	26.0	0.0	-26.0	0.0	0.0	0.0
Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0	4.9	-0.7	-3.5	0.7
Grid losses	0.0	0.0	0.0	0.0	0.0	0.0	3.2	0.0	0.0	3.2
Final energy	0.0	0.1	0.0	6.5	0	8.5	22.8	12.6	3.5	52
Road	0.0	0.0	0.0	1.5	0.0	0.0	5.5	0.0	3.0	10.0
Rail	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.6
Industry	0.0	0.1	0.0	2.4	0.0	2.0	4.0	3.6	0.0	12.0
Agriculture	0.0	0.0	0.0	0.1	0.0	0.3	0.8	0.1	0.4	1.7
Service sector	0.0	0.0	0.0	0.0	0.0	2.2	3.2	2.5	0.0	7.9
Housing	0.0	0.1	0.0	2.5	0.0	4.0	8.7	6.5	0.0	21.8

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.





While this shows a positive effect for climate mitigation, for Armenia the scenario has a number of other important benefits:

- Solar and wind produces today cheaper power than nuclear, coal and gas
- Energy efficiency is cheapest, when done together with building renovations etc.
- Solar can provide large-scale, affordable heating
- The proposals will improve rural economy and national balance of payments
- The scenario will create more work places and will improve employment