A vision for Belarus based on INFORSE's Vision2050
- Background note.

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This background note gives an overview of the potentials for renewable energy and energy efficiency that is used in the sustainable energy vision developed by International Network for Sustainable Energy (INFORSE) – Europe and Minsk Division of International Academy of Ecology. The vision includes growth in most sectors.

The current version of this paper will be improved gradually as new and consolidated information is developed. All comments are welcome.

Renewable Energy Potentials

Windpower

A few wind turbines work well in Belarus at the moment and it has been shown that more than 2000 full load hours are possible. The turbines should, however, be designed for low wind conditions.

We find that there are reasonable sites for windpower, mainly in NW Belarus where the potential is no less than 2000 MW with average annual full load hours of 2000.

The installed capacity of windpower in Belarus was 3 MW in 2010. We expect in this vision that the development of windpower will grow to:
-300 MW (15%) by 2015
-1000 MW (50%) by 2020
-2000 MW (100%) by 2030 and then remain stable

Solar Energy

The energy in solar radiation in Belarus is about 1000 kWh/m^2 on a horizontal surface, with smaller regional variations.

The solar collector area is in this vision limited to 10 m^2/capita, e.g. 74 million m^2, but the full area might not be used in this vision.

The area used for solar energy is divided between:

- Solar collectors for hot water (directly used domestically for service sector, industrial heat demand or eventually district heating) with an annual yield of 400 kWh/year (about 40% efficiency) and
- Solar electric cells (PV-cells) with an annual yield of 100 kWh/year (about 10% efficiency).

The solar heating installations can be used for low to medium temperature heat demand (below 150'C) and district heating. Normal flat-plate solar collectors will be limited to supply heat below 90'C, while higher temperatures can be achieved with use of vacuum tube solar collectors that also have higher efficiencies.

The use of solar energy is limited to:
- 1/3 of buildings' space-heat demand (limited because of seasonal variation) for domestic and service sector heating
- 2/3 of low-temperature process heat (assuming equal demand throughout the year)
-15% of medium-temperature heat

To cover 1/3 of buildings demand for space heating and hot water, will require energy storages of 1-3 months. This is also necessary to cover 2/3 of low-temperature process heat. Because of the costs of such storages, they are only included from 2030. Until 2030 we have limited solar heating installations to cover 60% of domestic hot water demand, equal to about 12% of domestic total heat demand (assuming 20% of total heat demand is used for hot water and 80% for space heating), estimated.

There have been introductions of solar heating in Belarus, but a commercial sector does not exist yet. However, we expect solar heating to take off around 2010 and then follow a path like this:

-2010-2015: 5,000 m^2/year (total 25,000 m^2 (0.11%) installed by 2015)
-2015-2020: 10,000 m^2/year (total 75,000 m^2 (0.34%) installed by 2020)
-2020-2030: 90,000 m^2/year (total 975,000 m^2 (4.43%) installed by 2030), producing 1.4 PJ
-2030-2040: 500,000 m^2/year (total 5,975,000 m^2 (27.15%) installed by 2040)
-2040-2050: 1,602,500 m^2/year until 2050 when there would be 22 million m^2, equal to 3 m^2/person

The installed area for solar electric generation (PV) is expected to take off at the same pace as solar thermal from 2020; but to expand stronger than solar thermal after 2030, leading to the potential area of 36 million m^2 used in 2050.

With this development, 22 million m^2 (38% of total solar installations) will be used for solar heating and 36 million m^2 (62% of total solar installations) will be used for solar electric generation. In total, no less than 58 km^2! This is equal to about 8 m^2/person for solar energy use in 2050 in total. Most of this is expected to be on rooftops. This area is of course not a maximum; it leaves room for additional solar installations after 2050.

Biomass
The potential for solid biomass consists of wood and straw available for energy purposes. Bio-fuel for transportation, biogas and energy plantations are all treated separately below.

Wood is already used to a large extent today, mainly for heating in the domestic and service sectors and in district heating. From primary supply and use of 34 PJ (IEA statistics) in 2000 it has increased to 47 PJ in 2005 and 54 PJ in 2008 (incresing to 58 PJ in 2010 following the trend). The t The potential is 147 PJ according to Belarus experts (147 PJ = 3.5 Mtoe which is the lower level of the potential of 3.5 – 4.5 Mtoe[1]).

The increasing trend from 2005 to 2010 is expected to continue, and 80% of the potential is expected to be used in 2020. We expect the following development of wood for energy:
- 58 PJ (37% of total wood biomass potential) in 2010

[1]**Возможности использования альтернативных источников энергии в Республике Беларусь, 2004, p.46**

- 118 PJ (80% of total wood biomass potential) in 2020
- 147 PJ (100% of total wood biomass potential) in 2030

Straw is to a large extent burned in the fields. An estimation of the potential that could be used is 6-9 million tons/year. In this vision we include a potential of 5 million tons of straw per year. With an average energy content of straw of 4 MWh/ton, 5 million tons per year of straw has an energy content of 20 TWh, equal to 72 PJ.
Straw is hardly used today for energy in Belarus. This is not expected to change before 2010, while half of the potential (36) PJ is expected to be used in 2020 in this vision and the full potential in 2030.
In total the solid biomass potential is then 219 PJ, combining the 147 PJ of wood and 72 PJ of straw.
This results in the following development of total solid biomass for energy:
2010: 58 PJ – 26%
2015: 80 PJ – 36%
2020: 154 PJ – 70%
2025: 198 PJ – 90%
2030: 219 PJ – 100%

Liquid Bio-fuel
Please note: So far no reliable data on the liquid biofuels potential for Belarus has been found. This does not mean that no liquid biofuel is currently being produced in Belarus nor that it will not be a part of the energy mix going forward.
In 2008 the biodiesel production was 7,000 toe, equal to 0.29 PJ. There is a potential to increase this, and in this vision we have included a modest increase to 4 PJ. This will require 110,000 tons of rapeseed oil.

Biogas
For the potential for biogas (from waste water, agriculture etc.) we use the figure from Belarus experts[2] of 24 PJ (6.7 TWh). This is primarily from agriculture.
When waste incineration is not used, as in Belarus, the organic fraction of the waste should preferably be treated separately to avoid methane generation in landfills. This separated waste can give an additional biogas potential.
The potential of landfill gas is included in the above potential, but is only a small part of the total.

Biogas for energy is not developed in Belarus at the moment, which we do not expect to change before 2010. Then we expect a large development of biogas, resulting in the full potential utilised by 2030.

Energy Crops
The potential for energy crops is dependent on the excess land of agriculture. There is substantial unused land in Belarus, including areas too humid for profitable normal agriculture. It is estimated that 400,000 ha (4000 km^2) is abandoned but fertile agricultural land that can be used for energy crops such as energy forests.

[2] From Возможности использования альтернативных источников энергии в Республике Беларусь, 2004

With a yield on the land of 7 tons dry matter/ha and an energy content of 4.9 MWh/ton[3] of dry matter, the corresponding energy potential is 13.7 TWh = 49 PJ. This figure equals 70-80% of the average yield of willow-plantations in Southern Scandinavia, where the yield is about 10 tons of dry matter/year. Similar yields can be achieved with other fast-growing trees, such as poplar.

We expect the development of energy plantations to take off after 2020 and that the area then will be increased with 100 km^2/year until 2040 (50% of the total potential) and then increasing until the full potential is used in 2050
This results in the following development pattern:

2025: 6.2 PJ – 13%
2030: 12.3 PJ – 25%
2035: 37 PJ – 75%
2040: 49.4 PJ – 100%
2045: 49.4 PJ – 100%
2050: 0.7 PJ – 2%

In 2050 the model sees a sharp drop to 2%, due to overall reduced energy usage as a result of vastly improved energy efficiencies.

Geothermal energy
There are some geothermal reserves in Belarus, but the temperature is not sufficiently high for it to really matter, so we have not included the use of geothermal energy in this study.

Hydropower
The hydropower production was 80 TJ in 2000 (IEA statistics), which increased to 130 TJ in 2005 and 140 TJ in 2008. According to Belarus experts the potential is 10 PJ (2,8 TWh), and we therefore expect an expansion of hydropower to use 2% of the potential in 2010 and 15% in 2020 and after. Environmental costs may be prohibitive to further development.

Efficiency Potentials
Official estimates from the Belarus Ministry of Energy are that energy savings of 4.6 Mtoe is possible until 2010 equal to 19% of the primary energy consumption.

For this vision we use the finding that the efficiency can be increased a factor 4-10 with known technologies. This has been shown to be possible for Western European energy consuming sectors, see e.g. "Factor 10 Club" (www.factor10.de). Even though the increase of efficiency is cost effective, it will not happen by itself, as the decision-makers, e.g. the designers and manufacturers of equipment are not dedicated to supply and install energy-efficient products for a number of reasons. The increase in efficiency can be measured as decrease in the specific amount of energy

[3] Biomass includes humidity and the calorific value depends on this. As an example coniferous wood with 40% humidity has a lower calorific value of 2.9 MWh/ton, but relative to the dry matter content (60%) the lower calorific value is 4.8 MWh/ton. For beech wood with 20% humidity the lower calorific value is 4.1 MWh/ton and relative to the dry matter the lower calorific value is 5.1 MWh/ton. For straw with 15% humidity the lower calorific value is 4.0-4.2 for different types of straw and relative to its dry matter content the lower calorific value is 4.7 – 4.9 MWh/ton. As an average the (lower) calorific value is set to 4.9 MWh (17.6 GJ) / tons of dry matter.

used to provide a certain energy service (heated floor space, transported persons or amount of goods, amount of industrial production, use of electric appliances etc.)

For transport, electric appliances, and industrial production, energy consuming vehicles and equipment will be changed several times during the more than 40 years that the vision covers. Thus, there are no technical limitations to raise the efficiency a factor of 4 or more. The following increase in efficiency is included in the vision for industrial appliances (heat, fuels and electricity), electricity use and road transport (cars, buses, freight) to reach a factor 4 efficiency increase 2000 – 2050:

- 2000-2010: 5% in total
- 2010-2020: 2%/year
- 2020-2030: 3%/year
- 2030-2040: 4%/year
- 2040-2050: 4%/year

In the transport sector the realisation of the efficiency will require a technological shift from the presently dominating internal combustion engines with 15-20% efficiency to hydrogen fuel cells with >60% efficiency and electric vehicles with about 80% efficiency, including battery charging cycle losses. In addition we expect implementation of technologies able to regain brake-energy from vehicles.

In the industry sector, the efficiency increase is not expected before 2010 neither for heat and fuel nor for electricity use. This is in line with the increase of consumption 2000-2005 and the expectation of stable production.

For agriculture, construction and rail transport the following efficiency increases are included until 2050: 50% for agriculture and 50% for construction, 65% for rail transport (partly achieved with electrification from currently 25%).

Efficiency of heating

In Belarus total heat consumption (fuel and district heating) of dwellings was 276 PJ in 2000 of which 49% was district heating. This demand has declined until 2005 to 223 PJ (19%) with district heating declining in share to 46%. At the same time, 4 million m^2 of dwellings a year are built, of which we assume 90% will increase dwelling area and the rest replace demolition.
About 180 million m^2 of dwellings were expected to be built in 2000-2010 (which would equal an increase in dwelling area of 20%), but data from the National Statistics Committee of the Republic of Belarus, only shows an increase in total housing stock of 8% , and an increase of 16% in privately owned housing.
Increase in efficiency of heating for households in the decade of 2000-2010, has been 4% - which is hardly impressive, and certainly *much* less than expected.
From 2015, we assume continued efforts for increasing energy efficiency with further implementation of building regulations and rising energy prices, leading to an improvement in building efficiency of 3%/year. This is above the assumptions for visions for Western Europe, but as the starting point is lower, we expect such rapid increase in efficiency to be possible.
If this holds true, the efficiency increase around 2020-2025 will be about 34% or in other words what had previously been expected already in 2010 – except ten to fifteen years later! Small deviations from a projected path can add up to very significant amounts over time.

This gives the following specific heat demand and heating system efficiencies of dwellings, compared with 2000:

	Specific heat demand
2000	100%
2005	101% (observed)
2010	96% (observed)
2015	82%
2020	71%
2025	61%
2030	52%
2035	45%
2040	38%
2045	33%
2050	28%

Belarus heat consumption in the service sector (fuel and district heating) increased from 50 PJ in 2000, to 52 PJ in 2005, but then fell rather dramatically to 40 PJ in 2008, according to IEA statistics.

We assume that the IEA-2005 figures are more reliable than the 2000 figures, so we include the reported increase in the activity of the sector, while we include that the efficiency has not changed. After 2010 we expect an increase in efficiency of 2% p.a.. This gives the following specific heat demand and heating system efficiencies of service sector buildings:

	Specific heat demand
2000	100%
2005	103% (observed)
2010	83% (observed)
2015	75%
2020	68%
2025	61%
2030	55%
2035	50%
2040	45%
2045	41%
2050	37%

Efficiency in Energy Supply

In an official estimation from Belarus Ministry of Energy, efficiency in the energy supply, in particular in CHP plants can save 0.9 Mtoe (38 PJ) until 2010.

For energy supply we expect an increase in the conversion efficiency in the electricity and heat sector, leading to a decrease in the average loss in power and CHP plants.

From the electricity efficiency in the CHP plants of 15% in 2000, we expect increases in 2010 with renovation of power plants, in line with official estimates and statistics for 2008 (20% electric efficiency according to 2008 statistics for 2008).

We use the following efficiencies for power plants in the vision:

Power plant efficiencies	2000	2010	2020	2030	2040 and later
Electric	15,30%/39,4%*	20,00%/39,4%*	45%/45%*	46%/46%	47%/55%*
Heat	53,60%	53,00%	40,00%	39,00%	39,00%
Total	68,90%	73,00%	85,00%	85,00%	86,00%

* Second value for power only plants.

The electric efficiencies after 2010 are based on power plant efficiency data used for Danish energy planning for new plants (Danish Energy Authority, "Technology Data for Electricity and Heat Generating Plants" from www.ens.dk), with reductions due to only partial replacement of power plants. The Danish energy efficiencies data are:

Power plant efficiencies, new plants*		2010	2020 and later
Gas-fired combine-cycle, 100 – 400 MW	Electric (at 100% load)	58-62% (no heat prod.) 53-58% (full heat) 6% lower at 50% load	59-64% (no heat prod.) 54-60% (full heat) 6% lower at 50% load
	Total (at full heat)	90%	91%
Gas-fired combine-cycle, 10 – 100 MW	Electric (at full heat)	47-55% (100% load)	48-56% (100% load)
	Total (at full heat)	90%	91%
Gas engine 1-5 MW	Electric	41-44% (100% load)	as 2010
	Total	88-96%	as 2010
Large biomass-fired steam turbine plant, 400 MW	Electric	46.5% (100% load) 2.5% lower at 50% load	48.5% (100% load) 2.5% lower at 50% load
	Total	90%	as 2010
Straw-fired steam turbine, 5-15 MW**	Electric	29-30%(>75%load)	as 2010
	Total	90%	as 2010
Wood gasification, 1-20 MW	Electric	35-40% 5% lower at 50% load	37-45% 0-5% lower at 50% load
	Total	103%***	103%***

*Net efficiencies, adjusted for own consumption
** Larger installations have larger electric efficiencies
*** With flue gas condensation

The electric efficiency of the plants in 2030 (46%) can be achieved with 20% of production on combined-cycle gas-fired power plants with 60% electric efficiency, 55% on large biomass plants with 48% efficiency and 25% on smaller biomass plants with 31% efficiency.

The heat efficiencies of the CHP plants are below the plant specifications, as the plants will not run with full heat production during the whole year.

Also the efficiency of the electric grid is expected to increase. We expect that the electric grid losses that was 14% of production in 2000, gradually will be reduced from 2020, reaching 10% in 2040.

The loss in the heat grid was 7% of production in 2000 according to IEA statistics. We do not expect this loss to change, as more efficient grid will be combined with expansion of heat network.

Demand for energy services
In this model we do not include an automatic link of economic development (GDP growth) and energy consumption. Instead we include expected growth of energy consuming factors, such as heated floor area, transport and production to increase in *volume*, not in *value*. These drivers are referred to as energy service demands.

The demand for energy services (heated floor space, transport etc.) is expected to increase as follows:

Heating (district heating + fuels):
Dwelling area is increasing with construction of 4 million m^2 of new dwellings every year. We assume that 90% of this is actual increase in dwelling area and the rest replaces demolition. There are official plans to increase construction of dwellings to 10 million m^2/year, but given the economic crisis we do not expect it to happen soon, and given the need to replace panel houses, we find that an increase of dwellings will replace more demolition rather than leading to a faster increase of dwellings. The dwelling area is low in Belarus compared with many other countries, so we expect an increase until at least 2050. The development is expected to follow this path compared with 2000, when there were about 180 million m^2 of dwellings:
2000: 100%
2005: 109% (observed)
2010: 116% (observed)
2015: 128%
2020: 134%
2025: 139%
2030: 144%
2035: 149%
2040: 154%
2045: 159%
2050: 164%

For the service sector we have not been able to find the relevant data on the National Statistics Committee's website, and we therefore assume that 1) the physical size of the public and private service sector is pretty much equal and 2) no significant growth or shrinkage in the total floor space that this sector occupies, has taken place between 2000 and 2009.
We expect growth at a very modest 1% p.a. until 2020, then 2% p.a. until 2050. The following development in service sector area can be observed:
2000: 100%
2005: 100%
2010: 100%
2015: 105%
2020: 116%
2025: 128%
2030: 141%
2035: 156%
2040: 172%

2045: 190%
2050: 210%
There has been a large increase in private service sector turnover and in the number of employees, as well as a significant decrease in public service during the decade, most likely due to continued privatization. While the heat and fuel demand has decreased 2000-2008, we expect this is due to increased efficiency and not a decrease in total floor space. Effectively, we expect the heated floor space for public and private service to have been largely stable throughout the decade.

Heat demand had risen in 2010 in both industry and agriculture, by 12% and 21% respectively, compared to 2000, using IEA 2008-data as proxy for 2010 by taking total energy consumption for the respective sectors and subtracting electricity consumption. We expect the level of activity to remain constant throughout the period, measured in product volume that drives energy consumption. The actual consumption will go down with increased efficiency

Heat and fuel demand in the construction sector rose by 32% from 2000 to 2010. It is then expected that the activity will remain constant on the current higher level.

Electricity:
Household Sector: we expect household use of electric appliances to increase 20% more than the increase in floor space. Half of this additional increase is expected to be achieved in 2010. This will lead to an energy service level in 2050 of 1.97 times the 2000 level.

Service sector: The sector increased its electricity consumption by 18% from 2000 to 2010, because of increase in energy services (more electricity using equipment). We expect it to increase in lockstep with floor area (from heating), leading to a level in 2050 of 247% of the 2000 level.

Industry and agriculture: Industry electricity demand rose by 12% in 2010 compared to 2000 (using IEA 2008-data as proxy). Agricultural electricity demand fell rather sharply by 23%. We assume electricity service demand for both these sectors to remain stable throughout the period (but the actual consumption will decrease with efficiency as for other sectors).

Construction: A doubling of electricity demand in the construction sector was expected, due to increased activity. However in 2010 (using IEA 2008-data as proxy), demand was only 28% higher than in 2000. We expect the activity level to remain constant at this level throughout the period.

Transport:
For cars, we use data from the National Statistics Committee(NSC); total million passenger-km minus rail, bus, air and inland water transport. Assuming the resulting data is reasonably accurate, we can observe a decline in activity in private car usage by 22% in 2010 compared to 2000. We assume the decline will stagnate and that growth will resume at a very modest pace, so that by 2030 there will be 1.5 times the cars in 2000, and we expect it to remain constant at this level.
Public transport was expected in our 2008 report to increase slowly at 5% for trains 10% for buses from 2000 to 2010. However, data from the National Statistics Committee of Belarus show a sharp *decline* in million passenger-km for both bus and rail transport. Personal transport by bus fell by 22% and rail transport no less than 58%, a *huge* deviation from what was expected.
We do however expect the activity in bus and rail transport to pick up again, though not to the extent expected in our 2008 report. For rail transport, we assume the decline will halt, and that growth will resume at 3% p.a. from 2015 onwards. As rail transport was expected to grow more

vigorously than bus transport, we expect the decline in bus transport will stagnate and that growth will resume at 2.5% p.a. from 2015 onwards.
While air transport is not explicitly included in this study, it has, in marked contrast to road and rail transport, increased by no less than **209%** in 2010 (using NSC 2009-data as proxy) compared to 2000! This huge increase might explain, at least in part, the downturn in road and rail transport.
This gives the following development of personal transport relative to 2000:

	Cars	Train	Buses etc.
2000	100%	100%	100%
2005	82%	58%	100%
2010	78%	42%	78%
2015	96%	48%	89%
2020	114%	56%	100%
2025	132%	65%	114%
2030	150%	75%	129%
2035	150%	87%	145%
2040	150%	101%	165%
2045	150%	118%	186%
2050	150%	136%	211%

Air transport is not included in this vision.

Freight transport was growing in Belarus in the period 2000 – 2010 as it did in many other Central European countries. Road freight transport increased no less than 269% in the period 2000-2010, according to data from the National Statistics Committee.[4]
We regard such strong growth as unsustainable, and expect road freight transport to fall back to 1.5 the 2000 level by 2050.
Rail freight transport increased by 39% by 2005, and fell back a little by 2010. We expect rail freight transport to grow to around 1.5 the 2000 level by 2050. This gives the following development with regards to rail and road freight transport:

Freight transport	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Road	100	186	269	250	233	216	201	187	174	162	150
Rail	100	139	136	139	142	143	144	146	147	149	150

Pipeline transport is expected to be fully electrified until 2040, but at the same time decrease in importance with gradual decline from 2020 to 2050, where it will just 14% of the 2000 level, with the remaining capacity used to transport renewable gases.

Fuel shift
Fuel shift is in general limited to max 3%/year increase or decrease for a specific energy source in a specific sector, but the total can be more as more fuel shifts can happen simultaneously.

[4] http://belstat.gov.by/homep/en/indicators/transport.php

Fuel shift in transport is starting with introduction of biofuels in transport, initially using the full potential for road transport in 2020, covering 6.4% of road transport fuels.
In 2030 we expect that railways will be more electrified, covering 40% of rail transport (from 27% until 2020) while we also expect that electricity will cover 15% of energy demand on roads, via the use of electric vehicles.

In 2040 we expect that the use of electricity in rail and road transport will increase to respectively 80% and 35%. We don't expect hydrogen to play any major role, if any at all.
In 2050 we expect that the railways will be fully electrified while road transport will be covered by 85% electricity, and the rest by biofuels and a tiny bit of fossil fuels.

Fossil fuels and Imports
The production of gas and oil is expected to continue until 2030 and then phase out with declining resources until 2040. The peat production of 21 PJ in 2000 increased to 23 PJ in 2005 and 24 PJ in 2008 but is expected to begin declining until 2020-2025 and gradually be phased out as demand is taken over by renewable energy.
Fossil fuels that are not produced in the country will be imported; but with the conversion to renewable energy, the import of fossil fuel will be reduced gradually to virtually nothing in 2050.
The electricity import will be reduced, in the current version of the vision from 26 PJ in 2000 to 13 PJ in 2010, 8 PJ in 2025 and finally nothing from 2030 onwards.

Energy storages and Heat Pumps
Higher reliance on intermittent renewable energy – wind and solar- will require efficient energy storage and flexible energy use. The total fraction of intermittent electricity production in 2020 is 7% rising to 13% in 2030 and further to 28% in 2050.
To cope with this, regulating the capacity of the other power plants and adopting a more flexible energy consumption can be used.

In the electricity sector we also introduce some flexible consumption:

- Hydrogen production for transport.
- Electric cars with batteries that can be charged at different times at night
- Heat pumps in the district heating systems that can produce heat when there is high electricity production compared with supply. In this vision we include heat pumps from 2040 and in 2050 they are expected to cover 50% of the district heating supply.

For the CHP plants, daily/weekly heat storage (water tanks) is needed to de-couple electricity and heat deliveries. The heat pumps mentioned above should also be coupled with these storages that are integrated in the district heating systems.

There might be need for a few seasonal storages for solar heating after 2040 as the limits for use of solar heating without these storages is reached.

About this note
This note was developed by Gunnar Boye Olesen, INFORSE-Europe in cooperation with Evgenij Shirokov, MD-IAE for the Vision2050 for Belarus. Read more about the vision for Belarus and for other countries at www.inforse.org/europe. Please send comments to ove@inforse.org.