ANALYSIS OF ENERGY STRATEGIES OF EU AND WORLD COUNTRIES AND ROLE OF RENEWABLES IN THEIR ENERGY SYSTEMS

UABio Position Paper N 13

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December 1, 2015

Publication at www.uabio.org: 01.12.2015
The publication is available at: www.uabio.org/activity/uabio-analytics
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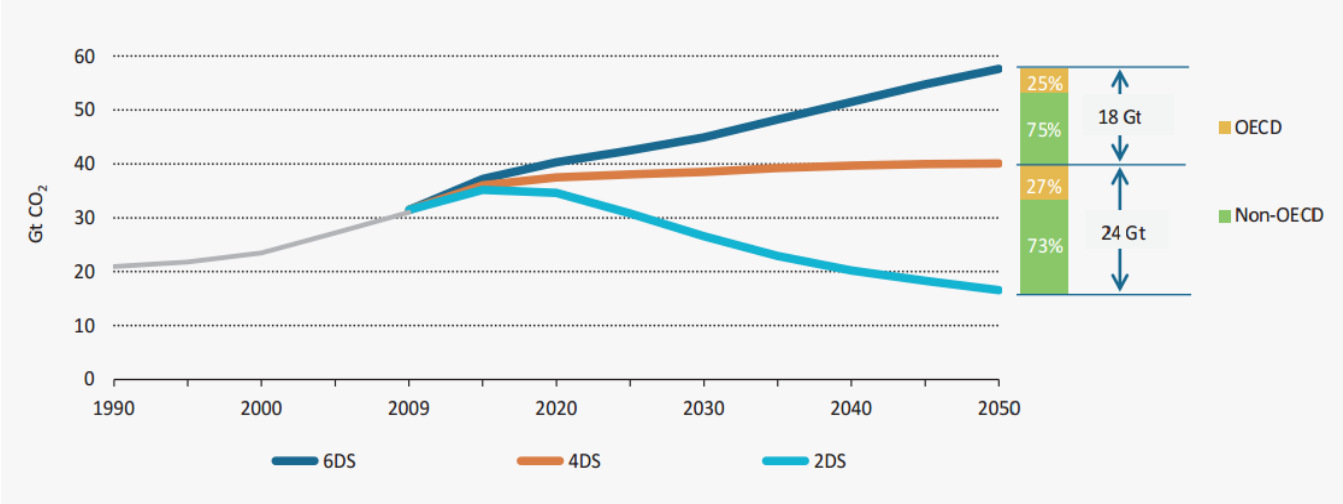
Introduction

UABio's Position Paper N 13 covers issues related to the state of the art and prospects for renewable energy development in the world, the European Union and Ukraine. It contains analysis of EU energy strategies as a whole and also individual energy strategies of some EU and world countries including Ukraine. The Paper considers the role of renewable energy sources in the strategies. Special attention is paid to the countries, which set target to reach 50% RES in their final energy consumption by 2050. It is shown that in order to achieve this object it is necessary not only to develop RES capacities but also reduce consumption of primary energy at the expense of introducing energy efficiency measures.

Threat of global warming

With the growth of industrial production in the world, emissions of greenhouse gases in the atmosphere have increased, which in turn led to global climate change. To prevent this, in 1997 the Kyoto Protocol was adopted, which (as of November 2009) joined the 192 countries responsible for 64% of greenhouse gas emissions in the world. Despite the efforts of many countries to implement the Kyoto Protocol, their implementation could not prevent global warming. In December 2015 at the meeting of the Conference of the UN Framework Convention on Climate Change in Paris planned to adopt a new global climate agreement that will replace the Kyoto Protocol.

The International Energy Agency in 2012 presented analysis, and 3 scenarios based on different energy priorities **(Fig. 1)**. The most attractive and safest of the reviewed scenarios for our planet is a *2DS (average temperature increase of 2 degrees by 2050).* To achieve this scenario, it is required huge changes in the world energy system and reduction of energy-related greenhouse gas emissions two times less than in 2009 by 2050. To perform 2DS energy scenario, the world economy must continually decline, and energy demand should decrease **(Fig. 2, 3)**. Without achieving this reduction, the 2DS scenario is very costly, if not impossible.



6DS, 4DS, 2DS – scenarios of increasing of the average temperature by 6 ºC, 4 ºC, 2 ºC, respectively

Fig. 1. Growth of GHG emissions in the world and climate change scenarios [1]

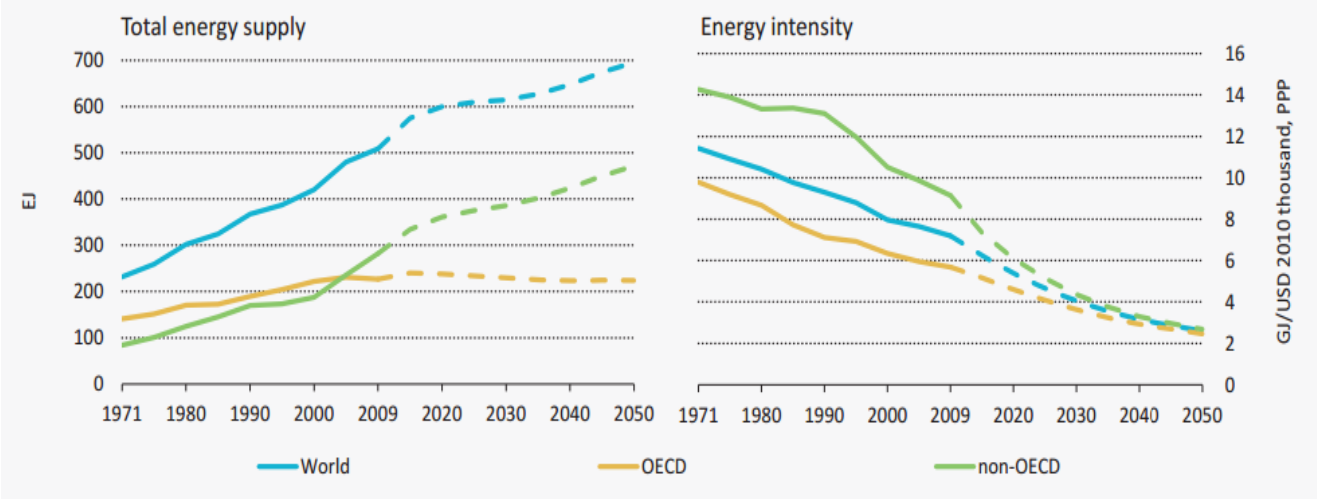


Fig. 2. Trends of the energy supply and energy intensity per unit of GDP under the 2DS scenario [1]

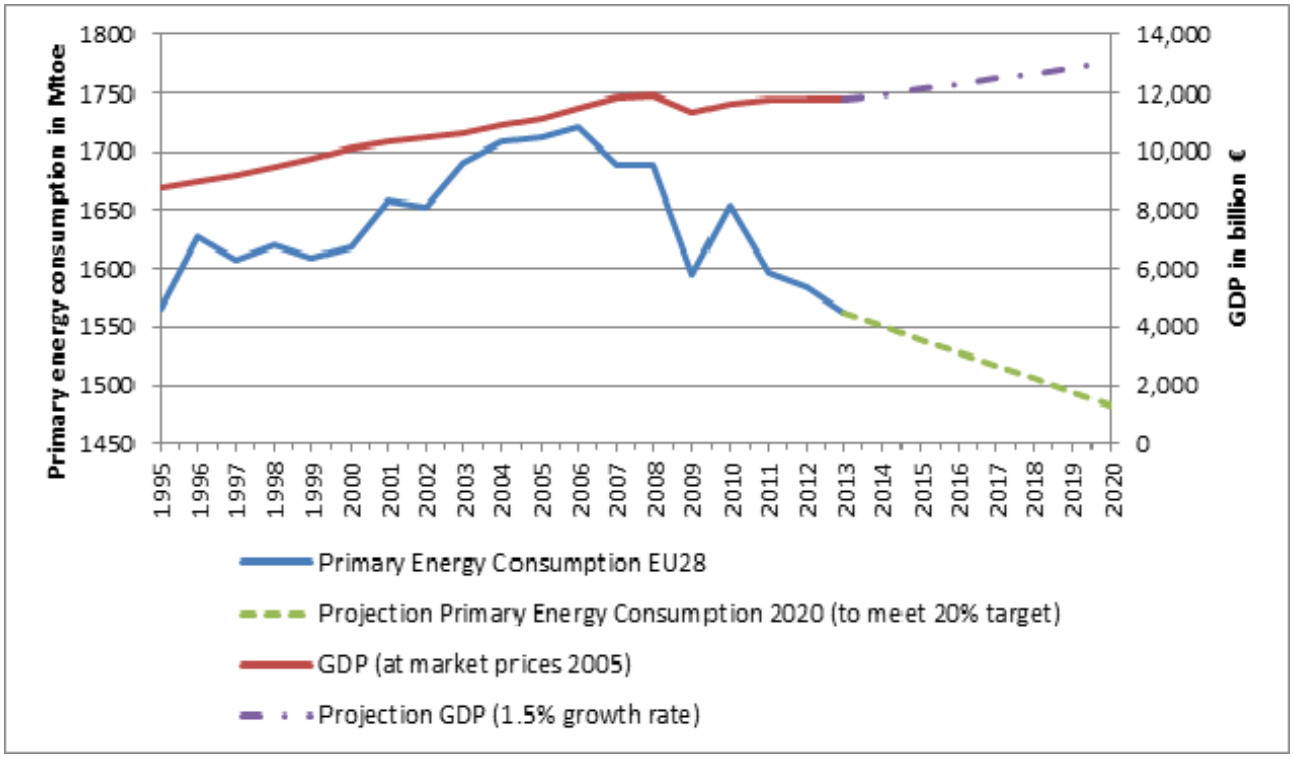


Fig. 3. Trends of the primary energy consumption and GDP in the EU-28 [2]

State of the art and prospects for renewable energy development in the world

At present renewable energy sources cover about **19%** of the world final energy consumption including traditional biomass **9%**, modern renewables over **10%** (production of heat and power, motor fuels) (**Fig. 4**). About **14%** of the final energy consumption is covered by biomass (traditional and modern).

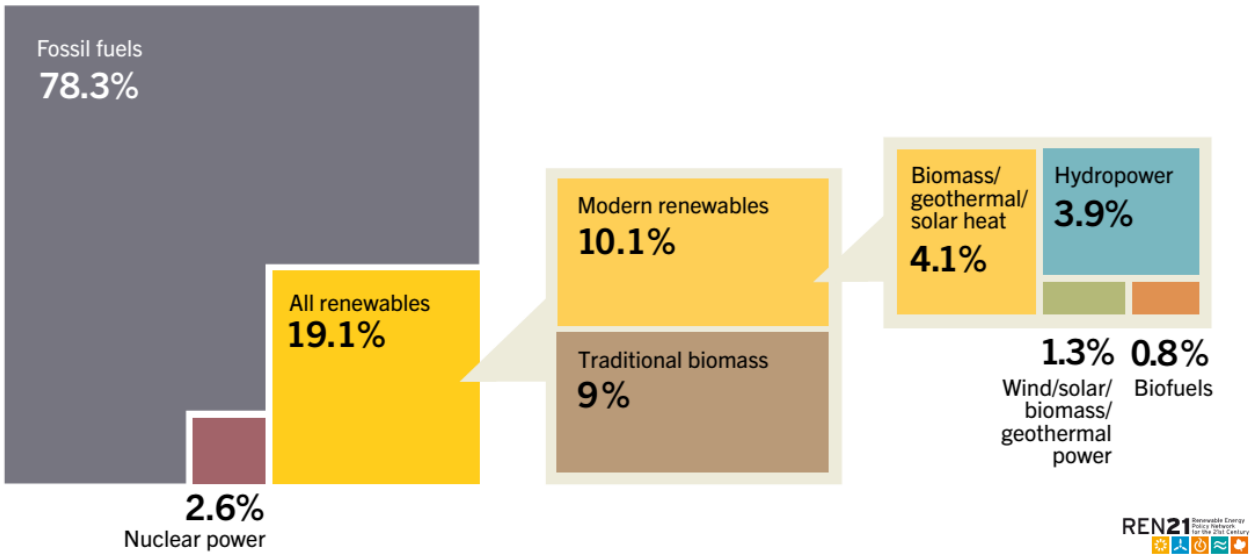


Fig. 4. Structure of the world final energy consumption, 2013 [5]

Renewable energy makes up almost **23%** of the global power production, at that hydro energy provides the lion share of **16.6%**. Of the rest, the biggest contribution is made by wind power (**3.1%)** which is followed by biomass (**1.8%)** (**Fig. 5**).

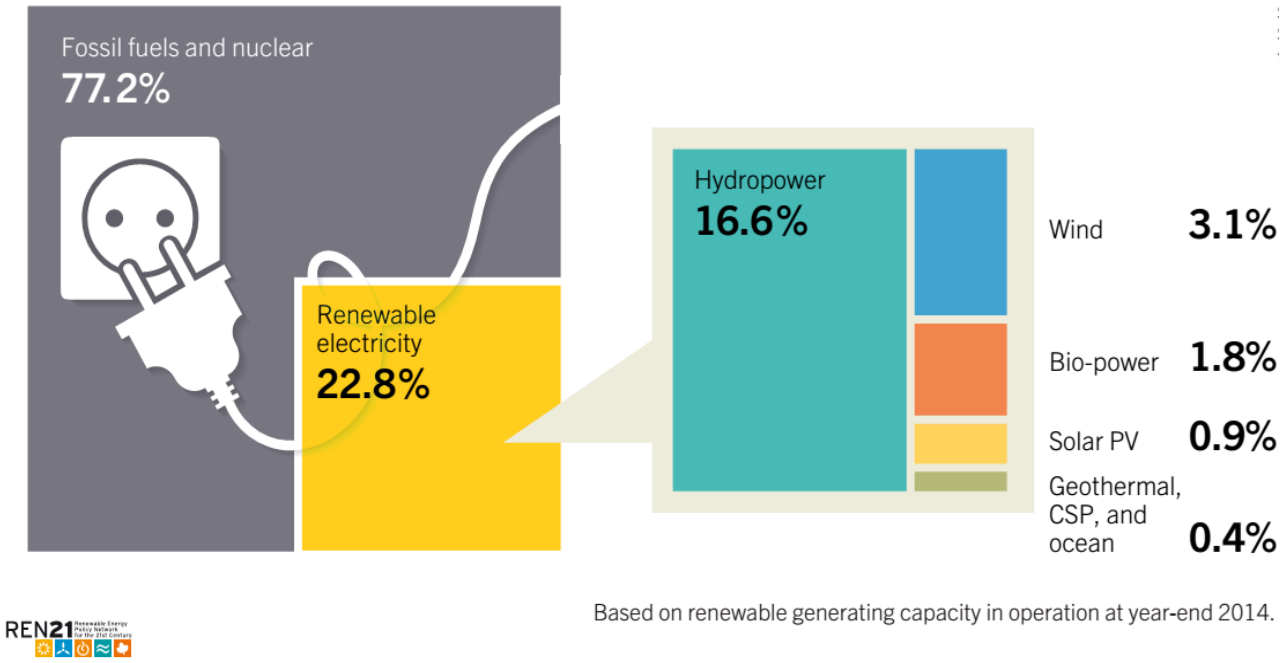


Рис. 5. Structure of the power production in the world, 2014 [5]

Seven countries are the largest generators of renewable electricity, their total renewable electric capacity makes up 71.5% of the global (470 GW excluding hydropower). These countries are China, USA, Germany, Italy, Spain, Japan, and India (**Fig. 6**).

Heat energy makes up about half the global energy consumption. Over **quarter** of the heat demand is covered by renewables including 17% by traditional biomass, 7% by modern biomass and only 1% by other modern RES.

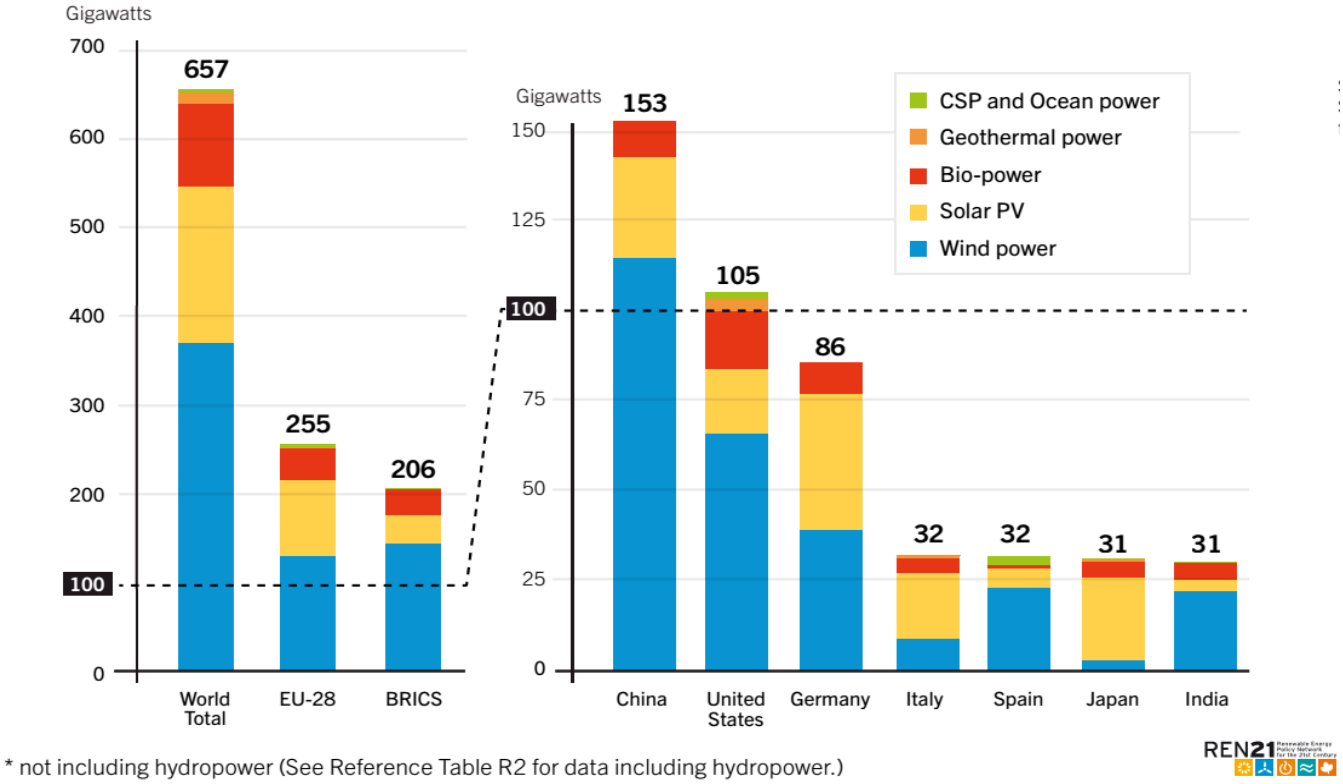


Fig. 6. Installed renewable electric capacity in the world[1], 2014 [5]

The International Renewable Energy Agency (IRENA) elaborated a Renewable Energy Roadmap for doubling the share of renewables in the global energy consumption by 2030 as compared with 2010 (***REmap 2030***): from **18%** RES in the total energy consumption (2010) to **36%** (2030). At that, modern renewables must gradually replace traditional biomass. Since in 2010 half of RES contribution was made by **traditional biomass,** the share of modern renewables in 2030 must be more than 3 times as higher (up to **30%**), and only **6%** will be left for traditional biomass (**Fig. 7**).

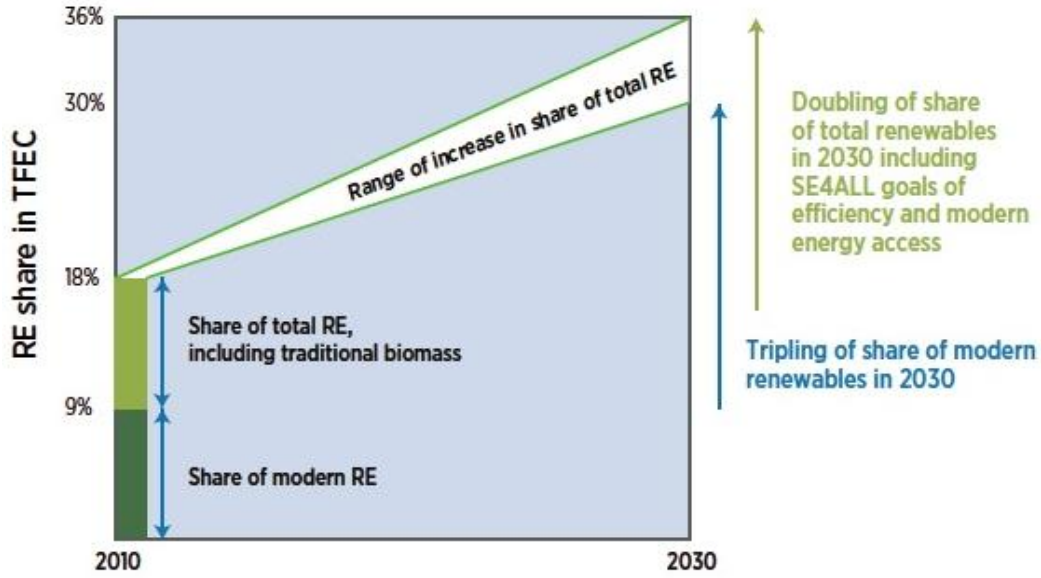


Fig. 7. Doubling the share of renewables by 2030 according to *a Renewable Energy Roadmap 2030* (IRENA) [6]

[1] Excluding hydropower.

It is interesting to compare IRENA's REmap 2030 with the forecast of the World Energy Council (WEC). WEC has elaborated ***two scenarios for development of the global energy until 2050*** – *Jazz and Symphony* [12]. *Jazz* envisages rather slow development of renewable energy – 20% of the total primary energy supply in 2050 p., and rather big rise of TPES as compared with 2010 – by 38% (from 546 EJ/yr in 2010 to 879 EJ/yr in 2050) (**Fig. 8**). The scenario seems not to be realistic as its target for RES is achieved already now. *Symphony* is more realistic. It projects priority development of renewable energy and increase of energy efficiency. Owing to this, in 2050 the share of RES is to reach about **30%** in TPES and **50%** in power production. At that, the total energy supply during 2010-2050 will increase only by 22%.

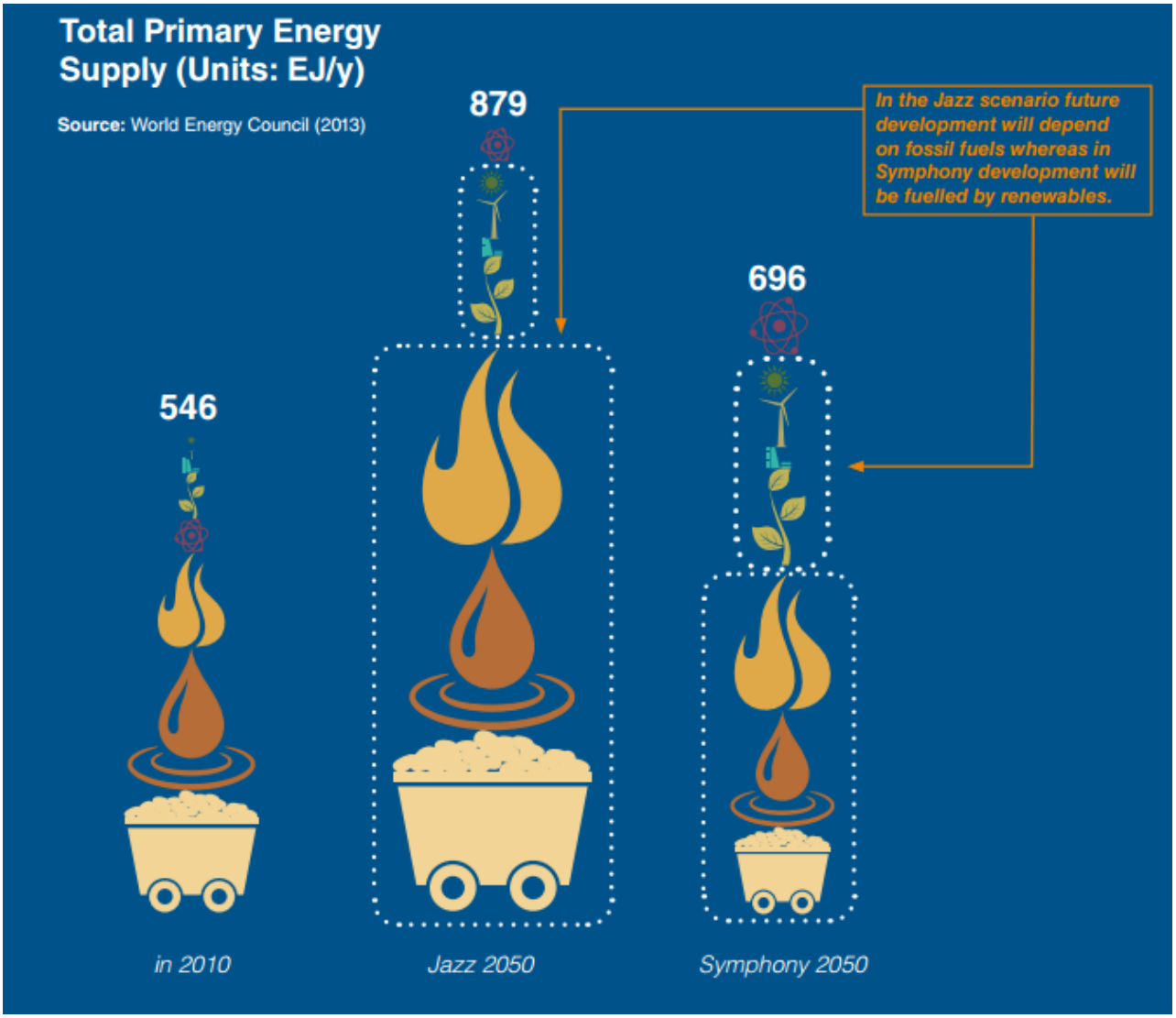


Fig. 8. Structure of energy resources in 2050 according to «Jazz» and «Symphony» *scenarios* developed by *the World Energy Council* [12]

Projects on 100% consumption of renewable energy

Nowadays in the world, there are about 148 planned and already implemented projects on substitution of fossil fuel use and complete switching to renewable energy. The projects are divided into several categories [7]:

- City;

• Regional;
• State;
• Residential;
• Business.

All of these projects aimed to achieve 100% of energy from renewable sources, but they have different end dates of implementation. Among these projects for individual countries, cities and companies are the following.

Fig. 9. Designation of official projects switching to 100% RES [7]

Countries:

- Denmark: **100%** of electricity and heat from renewable sources after 2035 and **100%** in all sectors after 2050.
- Iceland has reached **99%** of electricity and **70%** of the final consumption of all energy from RES
- Scotland: **100%** of electricity from RES by 2020 and **30%** of the total energy needs.
- Maldives: **100%** of energy from RES by 2020.

Cities:

Today in the USA, three cities have completely switched to renewable energy (Aspen, Burlington, Vermont). Other cities may be noted:

- Vancouver (Canada): in 2015, obligations were assumed to transfer the city for **100%** energy from RES.
- Frankfurt (Germany): decarbonization of the city due to renewables and alternative automotive fuel by 2050.
- Copenhagen (Denmark): **100%** of electricity and heat from RES by 2030 and **100%** in all sectors by 2050.
- Munich (Germany): **100%** of electricity from RES for homeowners by 2015 and for all consumers by 2025.
- Malmö (Sweden): **100%** of renewable electricity by 2020.
- Sydney (Australia): **100%** of electricity, heat and cold from RES by 2030.

American cities such as San Francisco, Palo Alto, San Diego, Ithaca, Greensburg, Georgetown, San Jose took a goal to switch to renewable energy and already have adopted programs. Every year the number of cities increases.

It should be also noted that Asian and African countries follow the global trend and implement their projects, especially in the regions where it is difficult or impossible to provide a centralized power supply. As for Australia, it also started a program to promote renewable energy among the population, the aim of which is the country's switch to 100% renewable energy in the future.

Businesses

The following world famous brands as IKEA, Johnson & Johnson, Nike, Procter & Gamble, Starbucks, Voya Financial and Walmart, Google, Apple, RWE, E.ON and others joined the action of switching to renewable energy. For this purpose, they want to provide themselves with electricity only from renewable sources in all their sectors of activity.

Energy strategies of some EU and world countries

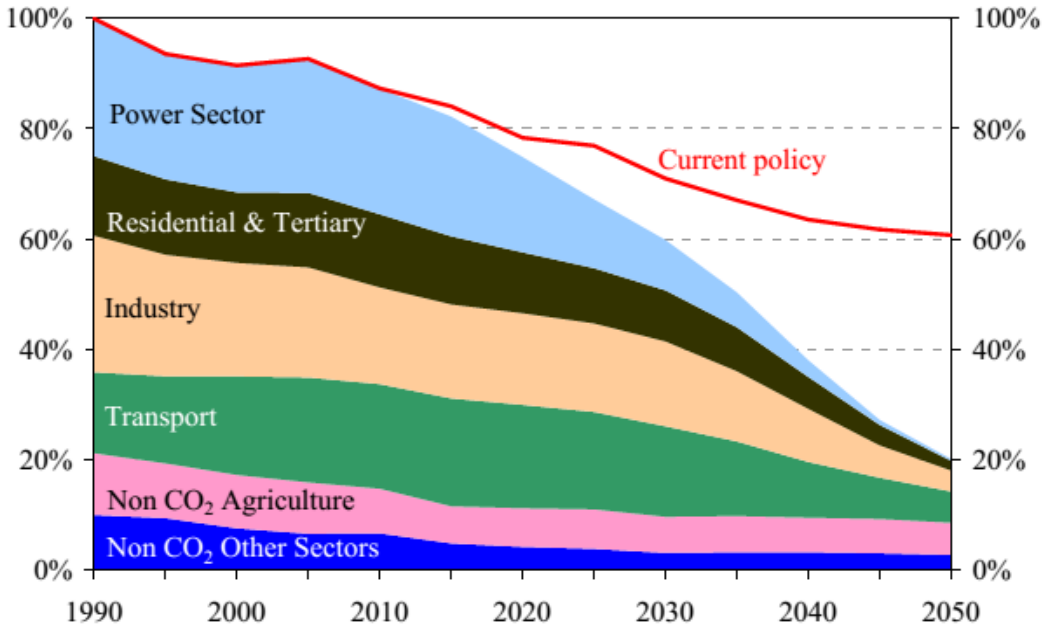
In the European Union, the state of renewable energy development on the whole is close to that in the world. Contribution of RES to the final energy consumption is **15%** (2013, **Table 1**) including biomass about **9%**. RES share in the power production is **25.4%** including about **5%** covered by biomass. Over **19%** of the total heat production in the EU comes from renewables, mostly from biomass.

Table 1. Current and planned figures on RES shares in the gross final energy consumption in the European Union (**%**) [40]

	2013	**2020**		**2013**	**2020**
EU	15.0	20	Lithuania	23.0	23
Belgium	7.9	13	Luxemburg	3.6	11
Bulgaria	19.0	16	Hungary	9.8	13
Czech Republic	12.4	13	Malta	3.8	10
Denmark	27.2	30	Netherlands	4.5	14
Germany	12.4	18	Austria	32.6	34
Estonia	25.6	25	Poland	11.3	15
Ireland	7.8	16	Portugal	25.7	31
Greece	15.0	18	Romania	23.9	24
Spain	15.4	20	Slovenia	21.5	25
France	14.2	23	Slovakia	9.8	14
Croatia	18.0	20	Finland	36.8	38
Italy	16.7	17	Sweden	52.1	49
Cyprus	8.1	13	Great Britain	5.1	15
Latvia	37.1	40			

To follow 2DS climate change scenario, in 2011 the European Union once more confirmed its official target on the reduction of GHG emission (decarbonization) by 2050 by **80-95%** in comparison with 1990 (**Fig. 10**) [8]. As the energy sector is one of the major sources of GHG emission caused by human activity, the main reduction of the emission should be realized in it. Based on this the European

Commission elaborated ***Energy Roadmap 2050*** [9] that includes analysis of ways for achieving the targets on decarbonization and ensuring reliability competitiveness of energy supply.

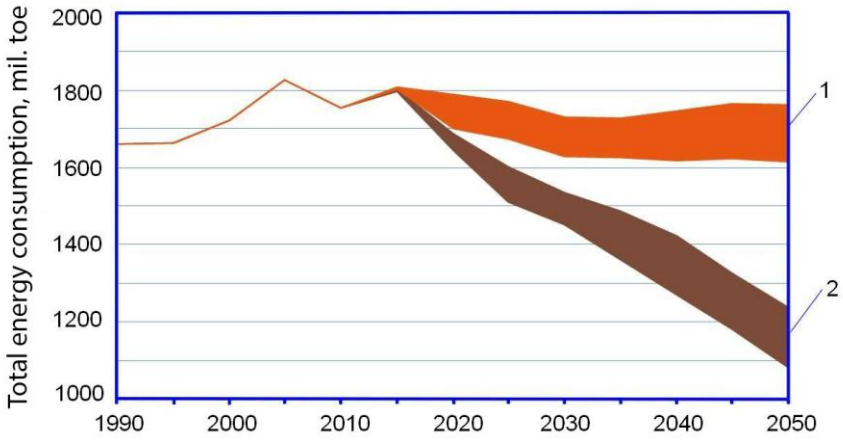


Note: GHG emission in 1990 is considered 100%

Fig. 10. Strategy for GHG emission reduction in the EU by 80% by 2050 as compared with 1990 according to official obligations [8]

Energy Roadmap 2050 covers *five* possible scenarios for energy development (so called decarbonization scenarios). Each of them is based on one of the following assumptions as for a prevailing tendency in the future of EU energy sector[2]:

1. Considerable increase of energy efficiency and energy saving ("energy efficiency" scenario). Owing to this, EU's energy demand by 2050 is to decrease by 40% as compared with peaks in 2005-2006 (**Fig. 11**).



1 – basic scenarios, 2 – decarbonization scenarios

Fig. 11. Development of total energy consumption of the EU over time according to *Energy Roadmap 2050* by the European Commission [9]

[2] More detailed analysis of the five decarbonization scenarios is presented in [10].

2. Considerable increase in the share of renewables in the energy balance *("RES" scenario*). As a result, RES contribution to the final energy consumption is to reach **75%** and the contribution to power consumption **97%** in 2050.

3. Diversification of energy supply sources. The scenario does not give priority to any energy source and they all compete with each other in the market. In this case, decarbonization will be achieved by implementing relevant tax policy regarding carbon emission.

In addition, two variants of this scenario were considered:

4. Diversification of energy sources with postponed implementation of carbon capture and storage technologies.

5. Diversification of energy sources, if new nuclear units will not be built, except those which are under construction now. It is noteworthy that "RES scenario" is in good agreement with the forecast of the EU energy development prospects, carried out by the European Renewable Energy Council (EREC) – ***"RE-Thinking 2050"*** [11]. EREC analysis shows a real opportunity to cover the needs of the EU energy demand in 2050 by **almost 100%** from renewable sources (**Fig. 12**).

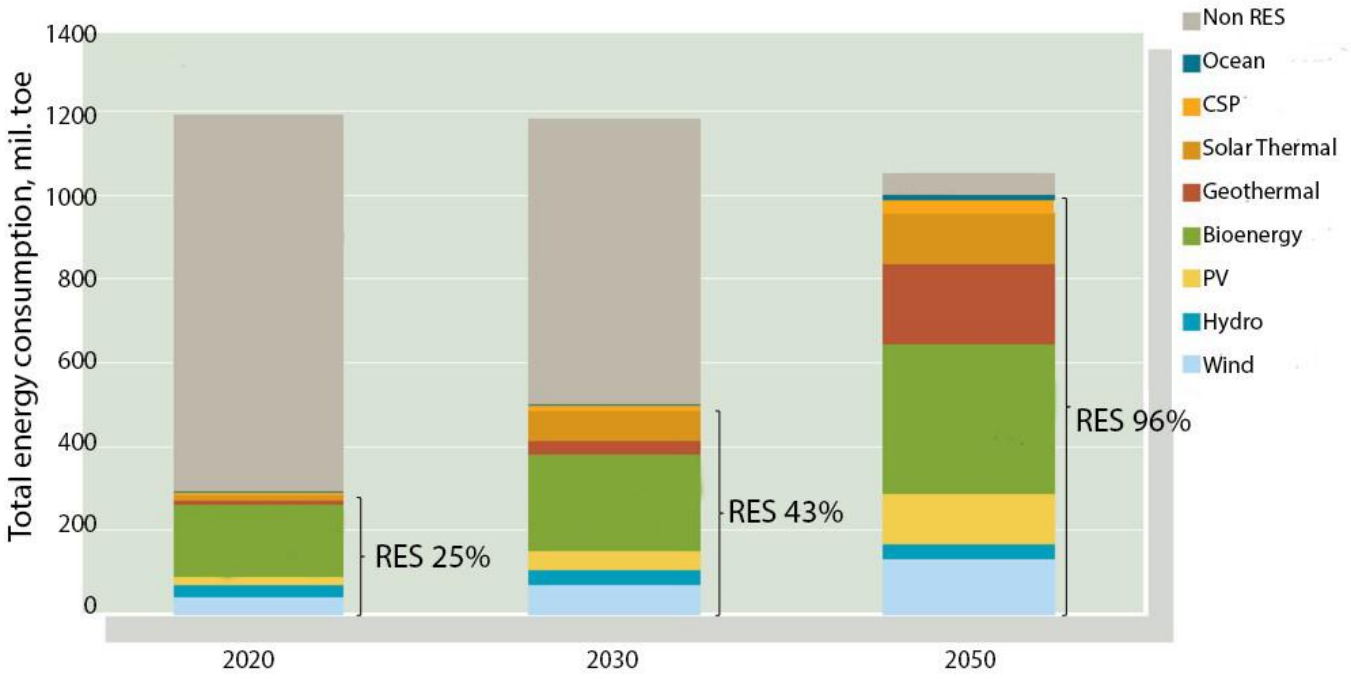


Fig. 12. RES contribution in final energy consumption in the EU in accordance with the forecast *"RE-Thinking 2050"* (EREC) [11]

Denmark

In 2011, the Government of Denmark ratified the ***Energy Strategy 2050*** (Strategy) [15], which presented proposals to achieve a long-term objective – national independence from coal, oil and gas. This ambitious and promising strategy, which is based on the findings of the commission on climate change and the results of previous policies and energy deals, establishes laws on energy policy as leverage necessary to achieve long-term energy goals of Denmark and defines a clear medium-term actions for the government.

The long-term goal of the Danish government is independence from coal, oil and gas in 2050. The second aim of the strategy is to ensure Danish energy sector position as a world leader in the energy sector, prevent climate change and protect the environment. The strategy of Denmark will also reach other goals and commitments such as climate and energy package of objectives of the EU and the Energy Agreement 2008. The government also wants to be among the top three countries in terms of progress of the RES projects implementation by 2020 and become one of the most energy efficient OECD countries by 2020.

The strategy outlines a number of new short and medium-term policy initiatives. Their implementation will reduce the consumption of fossil fuels in the energy sector (excluding transport and related to the North Sea activities) in 2020 by **33%** compared to 2009 while during the same period the contribution of renewables to final energy consumption will increase to **33% (Table 2)**. New initiatives, aimed to improve energy efficiency, will reduce energy consumption according to forecasts by **6%** in 2020 compared to 2006 **(Fig. 13).**

Table 2. The main objectives of the Energy Strategy of Denmark in 2050 and government's actions to achieve them [15]

Objectives	Actions on Energy Strategy2050 implementation
Independence from fossil fuels by 2050.	Initiatives to increase the use of renewable energy and energy efficiency will reduce the use of fossil fuels in the energy sector by 33% in 2020 compared to 2009.
The share of renewables in final energy consumption should increase up to 30% in 2020 as part of the overall EU objective – 20% of renewables in 2020	Government initiatives to expand the use of biomass, biogas and wind energy will provide the share of renewable energy of 33% by 2020, and thus the EU fixed target will be exceeded.
The share of renewables in the transport sector should reach 10% in 2020	Government initiative on 10% of transport biofuel by 2020 as well as the initiative to promote electric vehicles will ensure that the objectives of the EU in 2020 will be met.
In 2020, primary energy consumption should be 6% lower than in 2006.	Government initiatives to improve energy efficiency in private homes, businesses, public and municipal buildings will reduce energy consumption by 6% in 2020 compared to 2009, which corresponds more the national strategy.
Greenhouse gas emissions in sectors not related to the emissions trading market should be reduced over the period 2013-2020 and achieve a 20% reduction to 2020 compared to 2005 as part of the EU common goal to reduce greenhouse gas emissions by 20% to 2020 compared to 1990	Government initiatives to reduce fossil fuels also reduce emissions in sectors not related to the emissions trading market by 4.5 mln. t of CO_2 over the period 2013-2020. The government will regularly monitor the efforts to ensure observing the obligations to Committee on Climate Change in 2020 and start new initiatives as required.

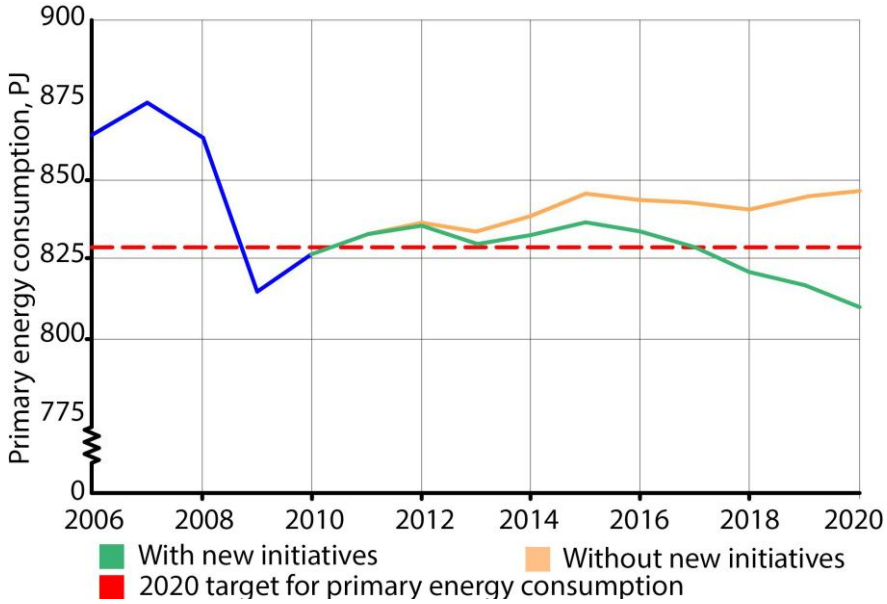


Fig. 13. Changes in primary energy consumption of Denmark according the official *Energy Strategy 2050* [15]

Significant expansion of renewable energy use will mean that Denmark will get the largest share of renewables in its energy system among other world countries. By 2020, the consumption of biomass, wind, biogas and biofuels will grow due to existing and new technologies. With a significant increase of the use of solid biomass, biogas and biofuels, bioenergy will continue to have a large part of the total consumption of renewable energy in 2020.

It is expected that the share of renewables will continue growing after 2020 depending on the dynamics of prices, new initiatives, etc. Due to new initiatives to expand the use of wind energy and biomass, it can be said that Denmark is on track for a successful implementation of the Energy Strategy 2050, as shown in **Fig. 14**.

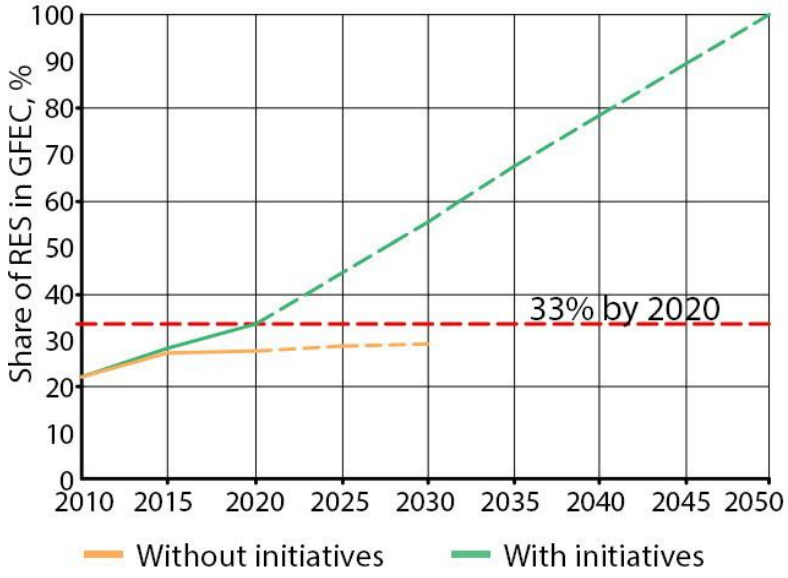


Fig. 14. RES share in the gross final energy consumption of Denmark according to the official *Energy Strategy 2050* [15]

Austria

At present, renewable energy sources rank second in the structure of energy consumption of Austria (30%) after oil products (36%). Biomass and organic waste make up 58% of all RES [30].

Austrian Energy Strategy until 2020 is aimed to increase RES share in the gross final energy consumption up to **34%** in 2020. At that an important part will be played by energy efficiency measures as owing to them it is planned to keep GFEC at the level of 2005 by 2020 (about 1150 PJ/yr) (**Fig. 15**). Without implementation of the energy efficiency measures the gross final energy consumption of the country may increase by 200 PJ/yr by 2020.

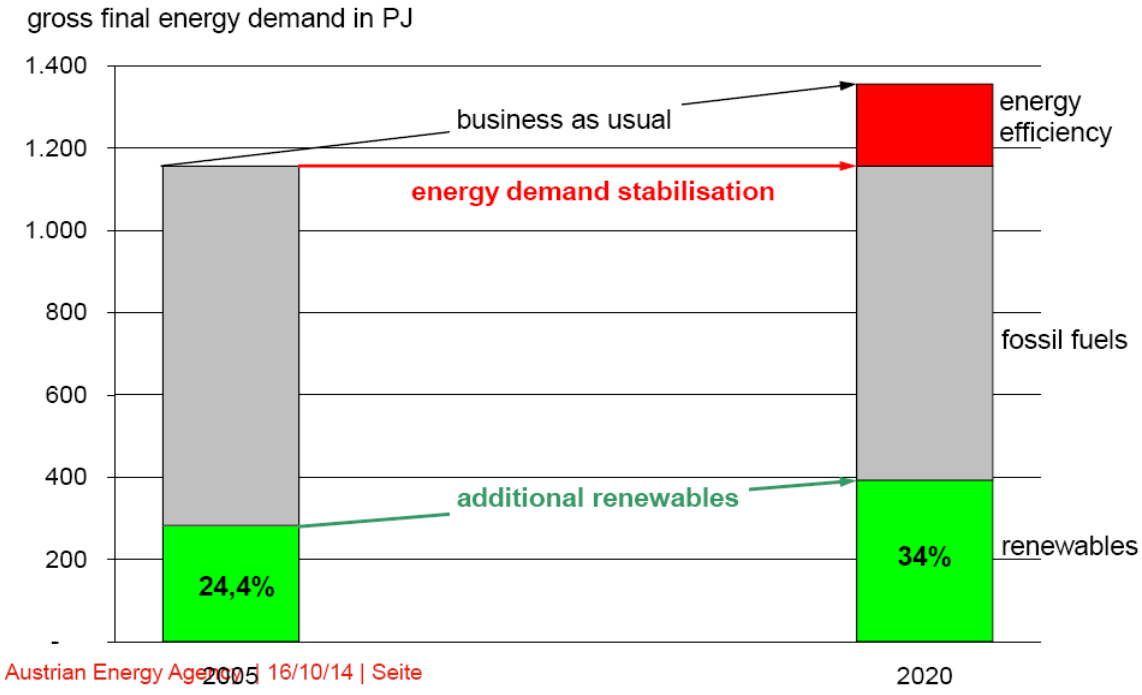


Fig. 15. The rise of renewables share in the gross final energy consumption of Austria according to the official *Energy Strategy until 2020* [30]

Now Austria has its official Energy Strategy until 2020 but there take place some debates in the society and on top level as for necessity to adopt a new energy strategy for a longer period and with targets that are more ambitious. Austrian Renewable Energy Association suggests adopting a new energy strategy at least until 2030 with the following key targets: reduction of final consumption by 940 PJ as compared with 1990, rise of renewables share up to 60% and reduction of greenhouse gases emission by 60% by 2030 [34].

There are also forecasts made by other core organizations. According to Austrian Energy Agency, in 2050 the country can cover its final energy consumption (about 650 PJ/yr) fully by RES. At that energy consumption is to decrease by 500 PJ/yr as compared with 2020 at the expense of implementation of energy efficiency technologies and measures (1150-500=650 PJ/yr) (**Fig. 16**). It is planned to reduce GFEC by 1.5% per year until 2050 and to increase RES share by 3% per year by 2030.

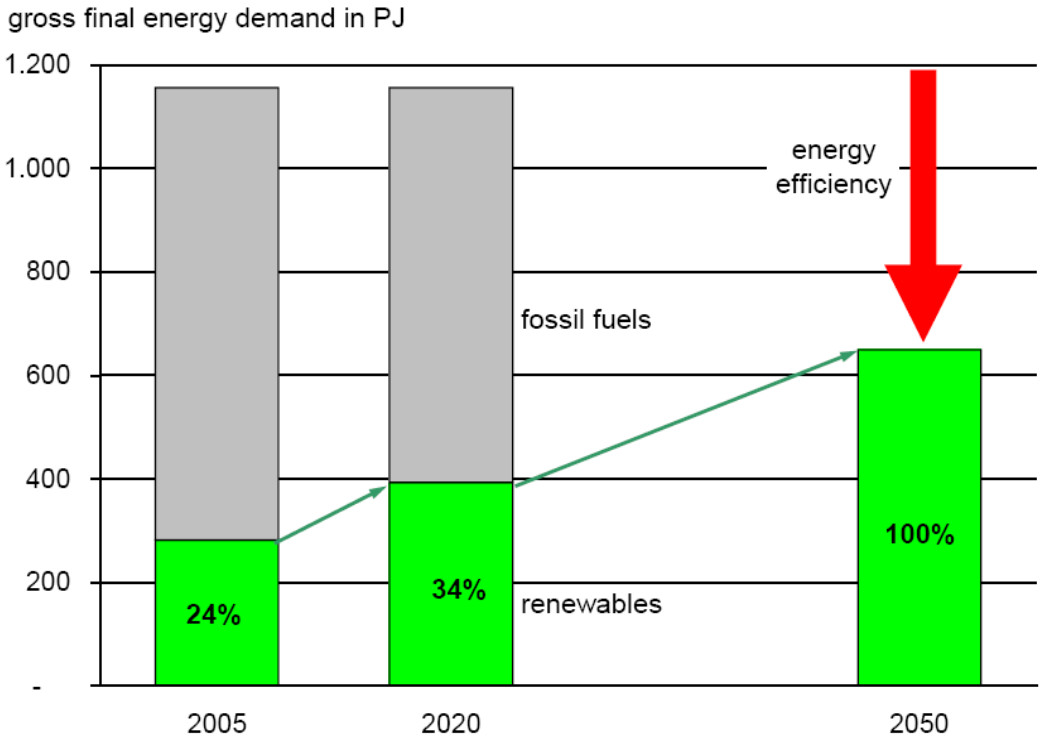


Fig. 16. Strategy to reach 100% of RES in the gross final energy consumption of Austria in 2050 according to the *forecast by Austrian Energy Agency* [30].

It should be noted that 100% of the electricity used in Austria's largest state is now generated using renewable sources of energy. Lower Austria now gets 63% of its electricity from hydroelectric power, 26 % from wind energy, 9% from biomass and 2% from solar. In Austria as a whole 75% comes from renewables and the rest from fossil fuels [37].

Sweden

Swedish energy policy is ruled by two laws[3], which were adopted by the Parliament of Sweden in 2009. The law on "Integration of climate and energy policy" ("En integrerad energi- och klimatpolitik") sets ambitious targets for the introduction of common EU 20/20/20 goals and introduces standards and national laws that are stricter than European government offers. Switching to a policy of sustainable development and environmental protection, competitiveness and long-term stability bring the country to a new level in the EU, where Sweden is planning to be a leader.

Short- and medium-term goals for Sweden in 2020:

- **40%** reduction of greenhouse gas emissions (or about 20 mln. tons of CO_2) compared to 1990, to be achieved outside the EU emissions trading market (EU-ETS). **2/3** of emissions should be reduced directly in Sweden and 1/3 – by investing in other EU countries or the use of flexible trading mechanisms;
- at least **50%** is the share of RES in the gross final consumption of energy;
- at least **10%** is the share of renewables in the transport sector;
- **20%** more energy efficiency compared to 2008.

[3] 162 and 163 2008/09

Long-term priorities:

- by 2020, Sweden aims the gradual substitution of fossil fuels in heating systems;
- by 2030, Sweden should have a fleet of motor vehicles that won't dependent on fossil fuels;
- Sweden seeks to develop an additional component in power supplying with hydro and nuclear power industries. With an increase of cogeneration, wind energy and other renewables, vulnerability will decrease and security of supply of electricity will increase;
- by 2050, Sweden will have a sustainable and efficient use of energy resources with achieved decarbonization goals.

Sweden sees the role of natural gas as a transitional fuel in industry and cogeneration.

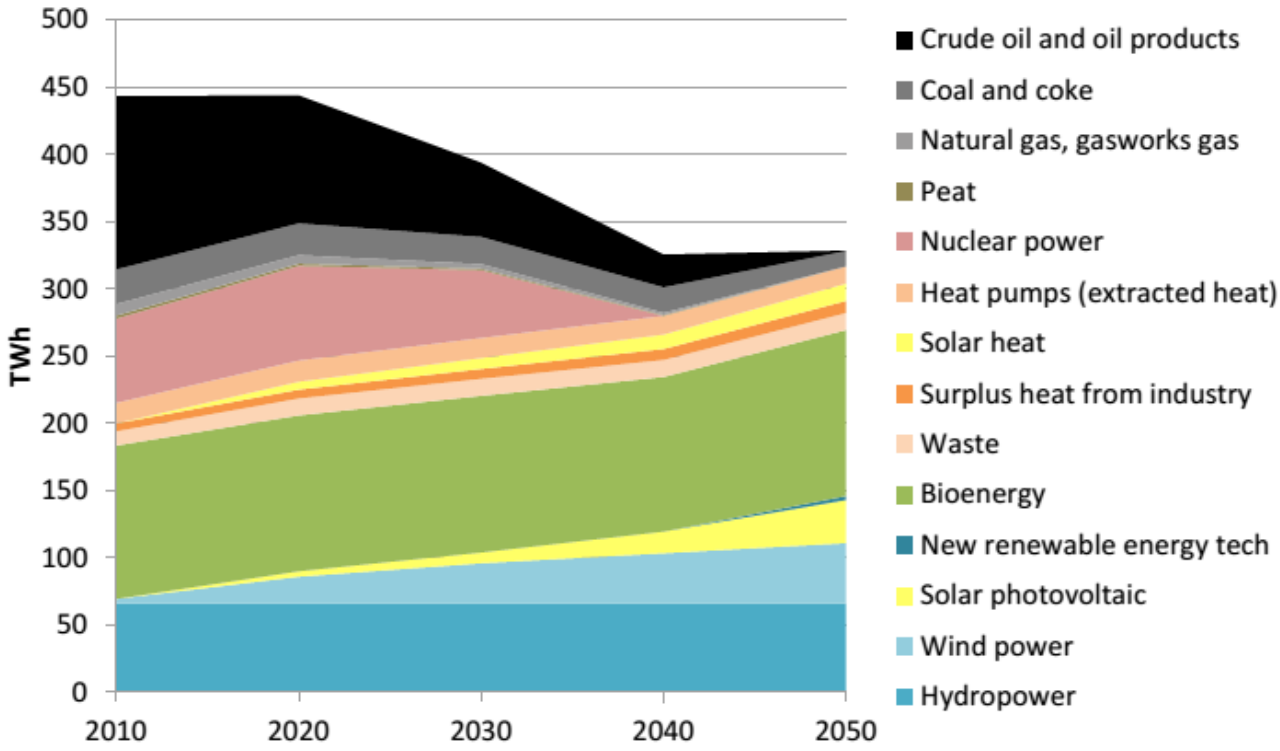


Fig. 17. Structure of the total energy supply in Sweden 2010-2050 according to the forecast of *IVL (Swedish Environmental Research Institute)* [22]

To implement the government's plan for energy independence from fossil fuels, a committee was established. Its purpose was to present concrete proposals to achieve the goal of Sweden decarbonization in 2030. These proposals are based on three concepts [31]:

- *Action Plan for Renewable Energy*

As a part of an integrated climate and energy policy, Sweden has implemented the action plan on renewable energy. It includes more ambitious goals for the system of green certificates – increase of production by 25 TWh by 2020 compared to 2002 when the system was introduced. Sweden also set national targets for the production of electricity at wind farms – 30 TWh by 2020 (20 TWh – land, 10 TWh – offshore) to facilitate the planning of production on sites.

- *Action Plan for Energy Efficiency*

Together with the law on climate and energy policy, Sweden adopted a comprehensive five-year energy efficiency program for 2010-2014 in amount of 1.35 bill. SEK (156.2 mln. Euros) or 270 mln.

SEK (31.2 mln. Euros) per year. Activities under this program were aimed to strength regional and local climate and energy initiatives, "green" implementations in the public sector, the promotion of small and medium enterprises to control and verify their energy consumption, energy efficiency technologies. In addition, Sweden continued the program on energy efficiency in energy-intensive industries. Total funding from the state budget in the energy efficiency sector was about 530 mln. SEK (61.4 mln. Euros) per year.

Also in 2015, the Government of Sweden made a decision to **become the first country that refuses fossil fuels**[4]. In particular, the allocation was made [41]:

- 390 mln. SEK per year for the period 2017-2019 on solar power generation with plans to invest 1.4 bln. SEK in total;
- 50 mln. SEK on electricity storage research;
- 10 mln. SEK on Smart grids;
- 1 bln. SEK on modernization of residential buildings and improving their energy efficiency;
- Grants and investments to support the development of "green" vehicles;
- Increasing funding for projects related to the climate change in developing countries (up to 500 mln. SEK).

- *Reform of nuclear power*

Nuclear power in Sweden remains controversial, and the policy development of the industry is changing with time. As part of the agreement of 2009, Sweden extended the transitional period during which nuclear power will be used, allowing the construction of new reactors on existing sites within the existing ten reactors.

In 2010, the Swedish parliament abolished a law on phased refusal of nuclear energy and banned new construction by the law on the activities in the nuclear energy field. Replacement of old reactors will be possible if the old reactor is not working and new reactor located in the same place. The law came into force on 1 January 2011. The government provides no direct or indirect subsidies for new nuclear power plants. Control and supervision over nuclear power plants were strengthened.

Germany

Energy Strategy of Germany until 2050 (adopted in 2010) envisages complete rejection of nuclear power by 2022[5]. Implementation of the plan started from the shutdown of 8 oldest NPPs. The Strategy determines that future energy supply will be provided mainly by renewable energy sources. There were also developed 7 legal measures to support the development of RES and energy efficiency. The measures are described in the program of «Energy transition» (*Energiewende*) [2, 27].

Key targets of the Energy Strategy of Germany until 2050 are presented in **Table 3**. RES Act 2012 (*EEG 2012*) pronounced the targets binding. In 2050, renewables will contribute to the total final energy consumption with **60%** and to power consumption with **80%**. At that, the consumption of primary energy will decrease by 20% in 2020 and by 50% in 2050 as compared with 2008.

[4] But remains the use of nuclear energy

[5] The period (shorter than the previously adopted one) was fixed after the accident at Fukushima Daiichi NPP that occurred in March 2011.

Table 3. Key figures of Energy Strategy of Germany until 2050 [32].

Indexes	2012	2020	2030	2040	2050
RES in the total final energy consumption	10%	18%	30%	45%	60%
RES in power consumption	20%	35%	50%	65%	80%
Reduction in primary energy consumption (as compared with 2008)	-5%	-20%	-30%	-40%	-50%
Reduction in power consumption (as compared with 2008)	-1%	-10%	n.d.	n.d.	-25%
Reduction in final energy consumption on transport (as compared with 2008)	n.d.	-10%	n.d.	n.d.	-40%
Reduction in GHG emission (as compared with 1990)	-27%	-40%	-55%	-70%	-80%

n.d. – no data.

The stated targets seem to be very ambitious and in order to meet them it is necessary, among other things, to increase energy efficiency. Germany is among the world leaders in terms of energy-efficient buildings. Conception of energy-efficient buildings stated in the Energy Strategy until 2050 includes several aims to be achieved [32]:

- reduction of the heat demand by 20% by 2020;
- around 80% reduction of the primary energy demand in the housing sector by 2050, which will require doubling the renovation rate of buildings from less than 1% of the total building stock per year at present to a new target of 2%;
- from 2020, all new buildings should be "climate-neutral" in compliance with primary energy-specific values.

By now, one can see certain progress in meeting targets of the Energy strategy of Germany until 2050: the share of RES in the final consumption has increased to 12% and in power consumption to 28% (**Fig. 18**).

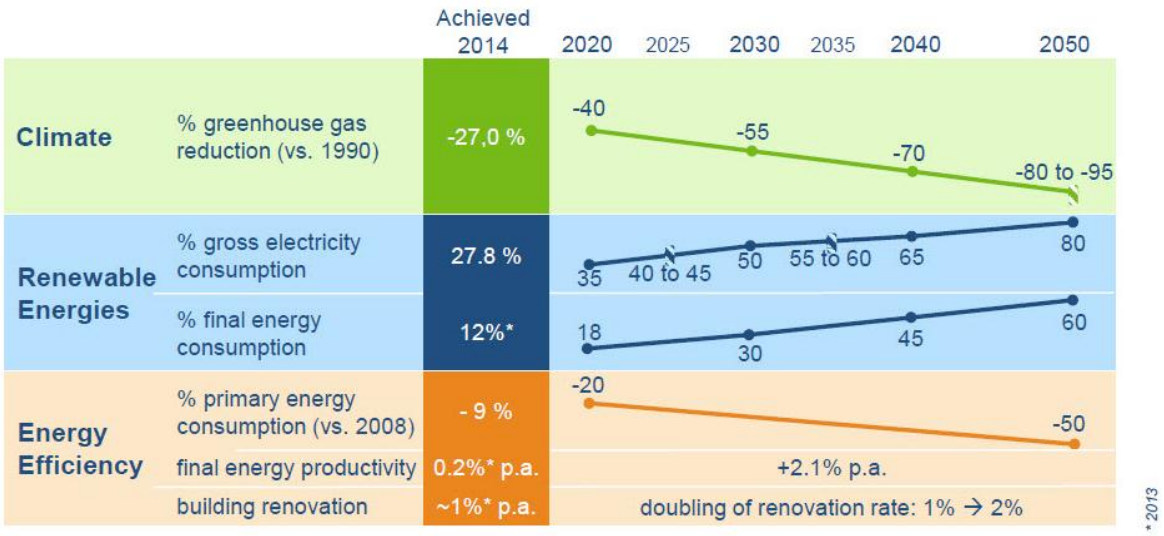


Fig. 18. Key figures of the official *Energy Strategy of Germany until 2050* and current state of achieving the targets [4]

USA

In 2014, President Barack Obama proposed the so-called ***"Comprehensive Energy Strategy"*** (The All-of-the-Above Energy Strategy) [19]. One of its key elements is the development of renewable energy, primarily electricity generation. In particular, it is planned to nearly triple the amount of electricity from RES up to **20%** in 2030 (excluding hydropower). At the same time, greenhouse gas emissions by US power plants must decrease by **32%** to 2030. It should be noted that some states, such as California, are moving steadily towards achieving of **100%** renewable energy.

California

Despite of the existing official state program only up to 2018, most states have their own visions of their future development. As noted earlier, at present in America, three cities have switched to 100% renewable energy, and other seven cities are going to do the same. It should be noted that the most of these cities are located in the western US, particularly in California.

An authoritative American scientists[6] in the field of energy efficiency carried out a study and analysis of the future energy development of the state. The main idea was to refuse fossil fuels and nuclear energy in favor of renewable energy sources. By increasing new capacities of renewable energy, implementing of energy efficiency measures and switching from technologies of power generation using combustion processes to the WWS[7] energy, the state may switch to **100%** renewable energy and completely refuse fossil fuels already in 2050 **(Fig. 19)**. An interesting fact of this study is that the area of land used for WWS energy to meet the needs of all the state will cover just **4.77%** of the total area of California (Fig. 20).

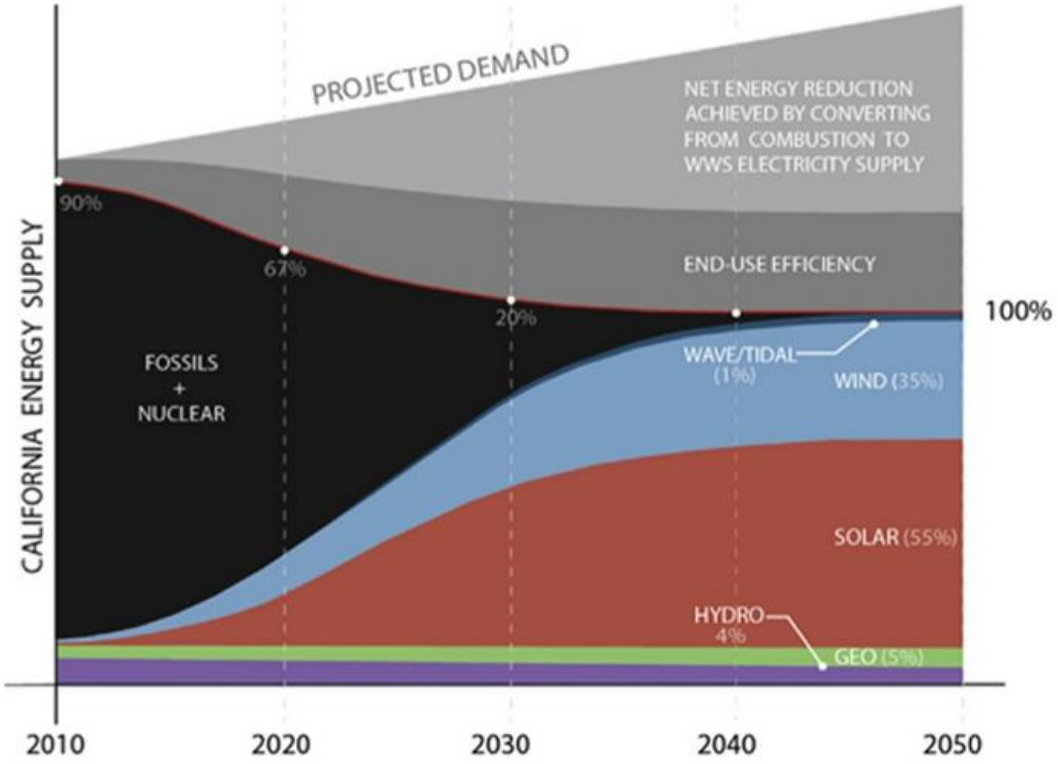


Fig. 19. Replacement of fossil fuels by renewable sources of energy in California according to the *forecast of the authoritative expert in the energy efficiency field Mark Jacobson*

[6] Mark Z. Jacobson, Professor at Stanford University.
[7] WWS – Wind, Water, Solar energy

Taking into account the statistics on the energy development of the state in recent years and the period of the study[8], it can be definitely said that even if the strategy of development in the energy sector will not be formally adopted, California is moving in the forecasted in the study direction. It is also confirmed by the official statements of international companies, whose headquarters are in the region, to switch to renewable energy in the nearest future.

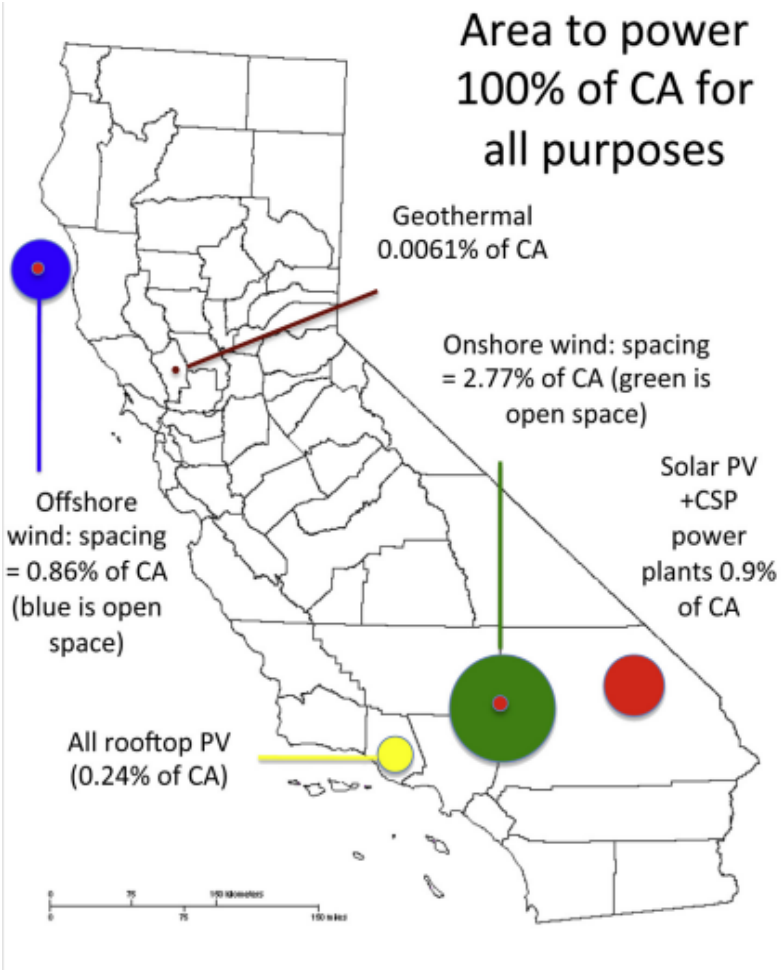


Fig. 20. Total areas of land for the needs of the renewable energy in California according to the *forecast of the authoritative expert in the energy efficiency field Mark Jacobson* [23]

Hawaii

In summer of 2015, President Barack Obama said on his twitter that Hawaii was the first state, which had officially presented his own program of switching to renewable energy. Taking into consideration the fact that Hawaii is the most dependent state on fossil fuels throughout America, this is a very big step toward "green" energy future.

The main goal of the state is the switching from fossil fuels to renewables in electricity production. Based on the fact that the islands of the state locate in the ocean and have a warm climate, the focus was on the use of wind and sun energy. In addition, a few active volcanoes may be considered as sources of geothermal energy.

[8] Study period is 2010 – 2050

Despite the official declaration of the state leadership to use **100%** of "green" electricity in 2045 **(Fig. 21)**, the representative of Blue Planet Foundation (BPF) believe that Hawaii have all chances to achieve this goal already in 2030.

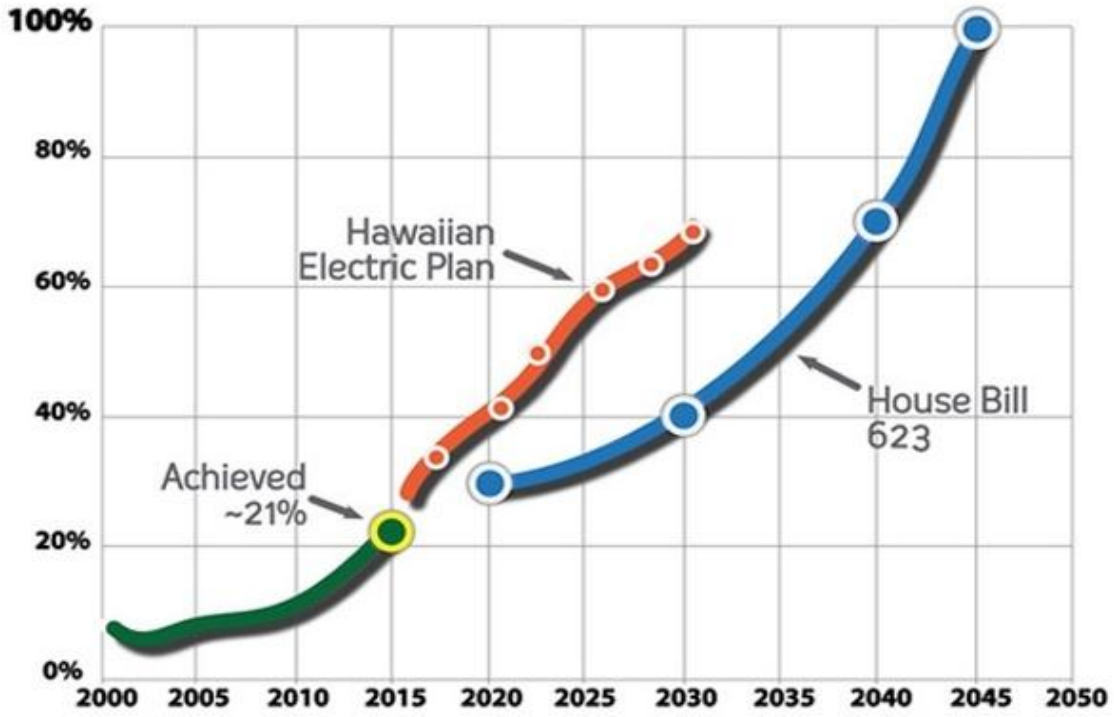


Fig. 21. *Official programs of Hawaii* (House Bill 623[9], 2015, blue line) and *official obligations of three state power companies* (Hawaiian Electric Plan, 2008[10]) [24]

China

In 2013 in China, new renewables capacities commissioning for electricity generation for the first time exceeded the new fossil fuels capacities commissioning because of the introduction of **13 GW$_e$** of solar photovoltaic cells. In 2014, the International Energy Agency made a forecast on the global energy development taking into account existing policies and measures in the world energy sector, which had been officially adopted by mid-2014. This forecast shows that China may have more than **960 GW$_e$** from renewables by 2040. The main expanding capacities **(55%)** will be due to wind power, solar photovoltaic cells and HPP. Their total capacity will be a quarter of new power generating capacities in the world.

China will remain the world's leader in nuclear power capacities expanding during the forecast period "New Strategies Scenario" (on average, almost **5 GW$_e$** per year). Electricity production from coal in China will grow more than in any other part of the world, but the share of coal in total electricity generation will decline considerably from **76%** in 2012 to **52%** in 2040 **(Fig. 22)**. The country consistently promotes electricity generation from "no hydro" renewables (predicted growth of **3%** in 2012 to **16%** in 2040), nuclear power (from 2% to 10%) and gas (from 2% to 8%). The share of hydropower in total electricity generation will decline by **4%** as the result of possible decrease of large dams building. At the same time, the amount of electricity production at hydropower plants will

[9] [28]

[10] Key indicator of obligations assumed power generation companies in 2008: 21% of electricity from RES in 2015, 65% in 2030, 100% in 2050 [29]

increase by **70%** by 2040, which will be almost a quarter of the amount of electricity production growth in the world.

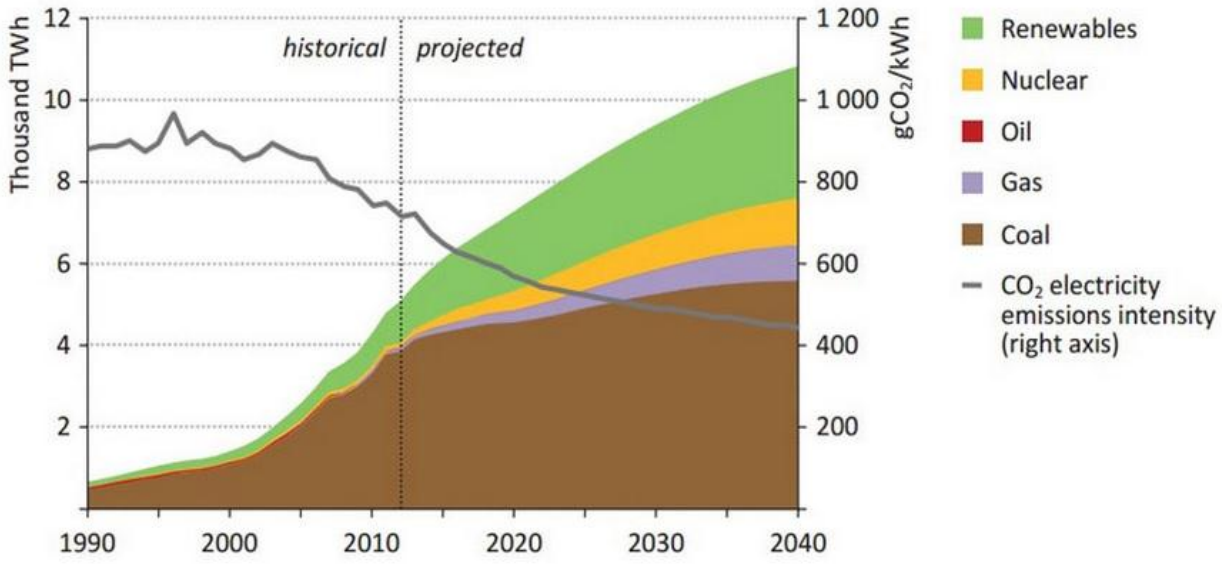


Fig. 22. Development of electricity generation and CO_2 emission reduction in the process of electricity production in China by 2040 according to the *forecast of the International Energy Agency (2014)* [25]

Changes in the structure of electricity generation in China will lead to a reduction of CO_2 specific emissions (g/kWh) by more than a third.

India

Government of India is planning to announce their energy strategy at the climate change conference in Paris at the end of 2015. Main aim of the strategy will be to have **40%** power generation capacity based on renewable energy technologies by 2030. It means almost 350 GW_e on renewables of the total 850 GW_e [35]. Other important targets of the strategy are [36]:

- Reduction in GHG emission by 33-35% in 2030 as compared with 2005.
- To create an additional carbon sink of 2.5 to 3 billion tons of CO_{2eq} through increasing forest and tree cover by 2030.
- Climate adaptation strategy of enhancing investments in development programs in sectors vulnerable to climate change, particularly agriculture, water resources, Himalayan region, coastal regions, health and disaster management.

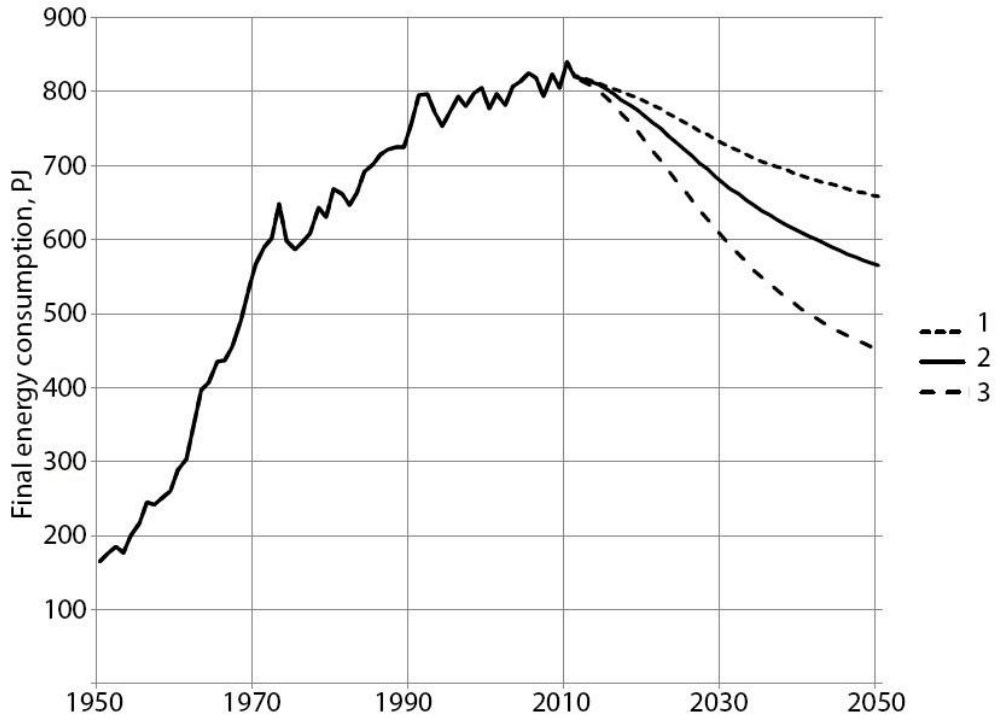
By now, the installed electrical capacity in India has come to 275 GW, of which 36 GW (about 13%) run on renewables.

The huge boost in the country's renewable energy target will mostly comprise of solar (250 GW) and wind power (100 GW). Announced installed capacity targets for 2022 are 100 GW solar power and 60 GW wind energy capacity. In the solar power market, the government is planning to have several auctions, including those for 25 ultra-mega solar power projects. In the wind energy sector, the government has announced policy to open the offshore wind energy market, and may consider competitive auctions.

Switzerland

After the accident at the Fukushima nuclear power station in Japan, governments around the world initiated energy strategies consideration in their countries. The Swiss government is no exception. According to the ***Energy Strategy 2050*** (November 2013), it is planned to refuse completely the use of nuclear power plants. To do this, the government accepted the terms of decommissioning of the state nuclear reactors when their age reach 60 years. With regard to private stations, even before the announcement of the official program they declared that modernization and further operation of nuclear reactors would not make economic sense.

To support this goal, the government adopted a program that provides energy tariffs increase to encourage the reduction of final energy consumption by **16%** in 2020 and **45%** in 2035 compared to 2010. Due to the increased tariffs and refusal of nuclear power, the Government plans to stimulate renewable energy development by funds obtained from the difference in tariffs. In addition, it is planned to increase its own energy production in the country. By 2020, it is planned to increase electricity generation up to 4,400 GWh and up to 14,500 GWh in 2035. The official energy strategy considered three scenarios: Business as usual, Government Program, and New Energy Policy **(Fig. 23)**.



Scenarios: 1 – Business as usual, 2 – Government Program, 3 – New Energy Policy

Fig. 23. Reduction of final energy consumption in Switzerland according to the *"Energy Strategy 2050"* under three scenarios [26]

Saudi Arabia

In 2040, the Kingdom of Saudi Arabia decided to completely refuse the use of fossil fuels. Traditional oil and coal will be replaced by renewable sources – solar and wind energy. To achieve this goal, the government is planning to invest 109 bln. US dollars in the infrastructure development of solar power plants over the next 20 years. The installed capacity of these plants is expected to reach **41 GW** in 2040.

Summarizing table with key figures of energy strategies of some countries

Information on key indicators of long-term energy strategies of some countries is presented in **Table 4.**

Table 4. Share of RES in the gross final energy consumption of some of the world's countries according to the official data of their energy strategies

Country	2014	2020	2030	2040	2050
Austria	30%	34% 16%[4] (1990) 17%[5] (2005)			
Denmark	25% 20%[5] (2005)	33%	55%	68%	100%
Germany	12.4% (in 2013) 27%[4] (1990) 9%[5] (2008)	18% 40%[4] (1990) 20%[5] (2008)	30% 55%[4] (1990) 30%[5] (2008)	45% 70%[4] (1990) 40%[5] (2008)	60% 80%[4] (1990) 50%[5] (2008)
Sweden	52.1% (in 2013)	50% 40%[4] (1990) 20%[5] (2008)	100%[3]		100%[4]
Switzerland	17.5% (in 2010)	45% 16%[5]		56% (in 2035) 45%[5] (in 2035)	60%
India	13%[1] (in 2015)		40%[2] 33-35%[4]		
China	13% (in 2010)			55%[1]	
USA (Hawaii)	20%	30%	40%	70%	100% (in 2045)
Costa Rica	95-99% 100%[1] (in 2015)	100%[4] (in 2021)			
Iceland	99%				
Saudi Arabia	1% (in 2015)			100%	

Note: year or the comparison or year of the achievement of indicators is given in brackets.

1) In electricity production.

2) Share of electricity generating capacities on RES.

3) In transport sector.

4) Reducing of greenhouse gases emissions.

5) Increasing of energy efficiency level.

Conception for the development of energy system of Europe until 2050

Over the past century population in the world has dramatically increased and, in particular, on the European continent. Growth in the number of population in Europe predetermined by different factors, but above all, by a stable political situation and high standard of living, which encourage people from less developed countries to move there. Constant population growth determines the constant increase of this or that country's needs, and the energy sector is no exception. Without enough space for the construction of new power plants and supporting sustainable development

policies and decarbonization, a number of countries require to buy energy surplus from its neighbors to meet the needs of its population. It is the complexity of the situation and the steady growth of energy consumption in the energy sector needs push politicians to find new solutions. One of these solutions, which are widespread in the EU, is ***the idea of an interconnected power system***. The purpose of this system is load leveling, smoothing the peaks and the optimal use of various renewable energy sources for electricity production. In winter, more electricity is produced by wind power plants located in the northern EU countries, in summer – by solar power plants that operate in the southern countries. By 2050, it is planned to develop the network so that RES will cover 80% of the total electricity production. At that, the main "flow" is expected between Spain-France (installed capacity of 47 GW_e) and France-Germany **(Fig. 24, 25)**.

Such concept of the united energy system can be fully implemented, taking into account the experience of already existing local association, such as the northern electricity market Nord pool that joints together the countries of Scandinavia, the Baltic countries and generating companies from Germany and the UK. Such cooperation between countries helps to use their installed capacities more efficiently and redirect electricity surplus to neighbors at a time when it is needed.

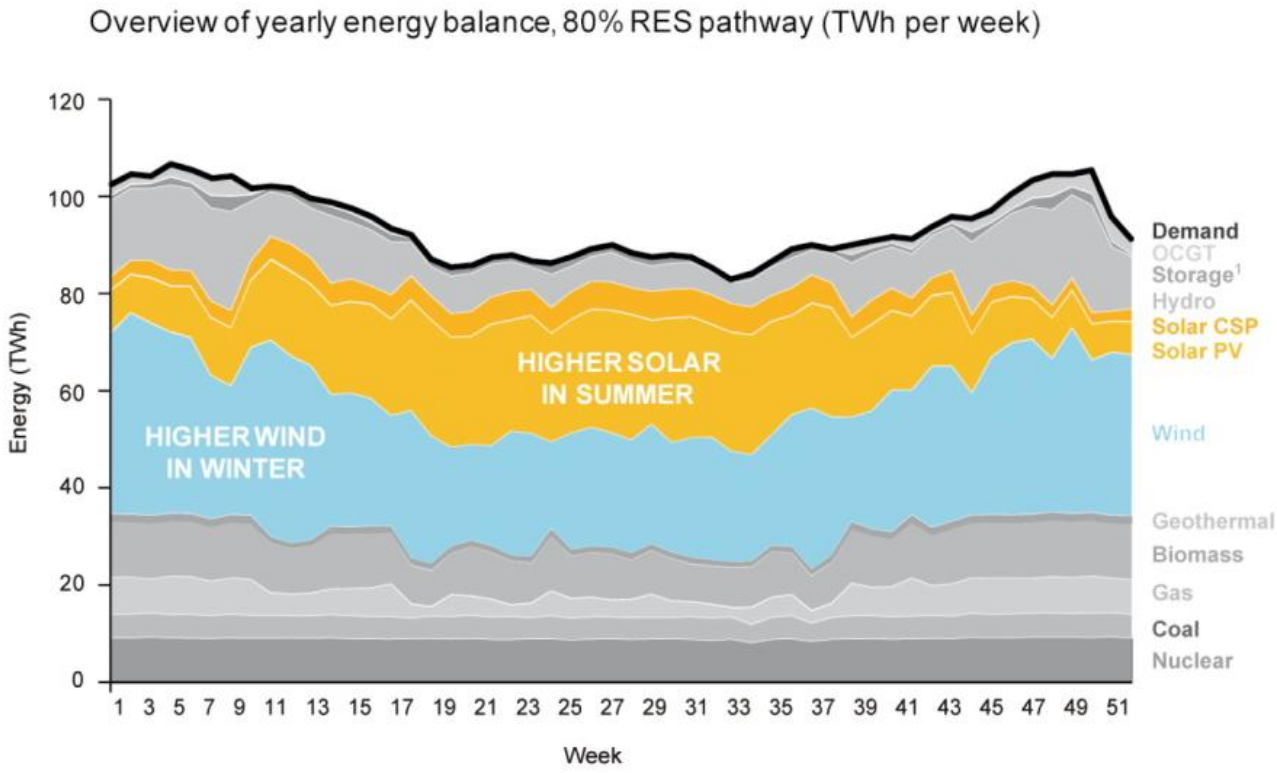


Fig. 24. Annual energy balance, the share of renewables is 80% [33]

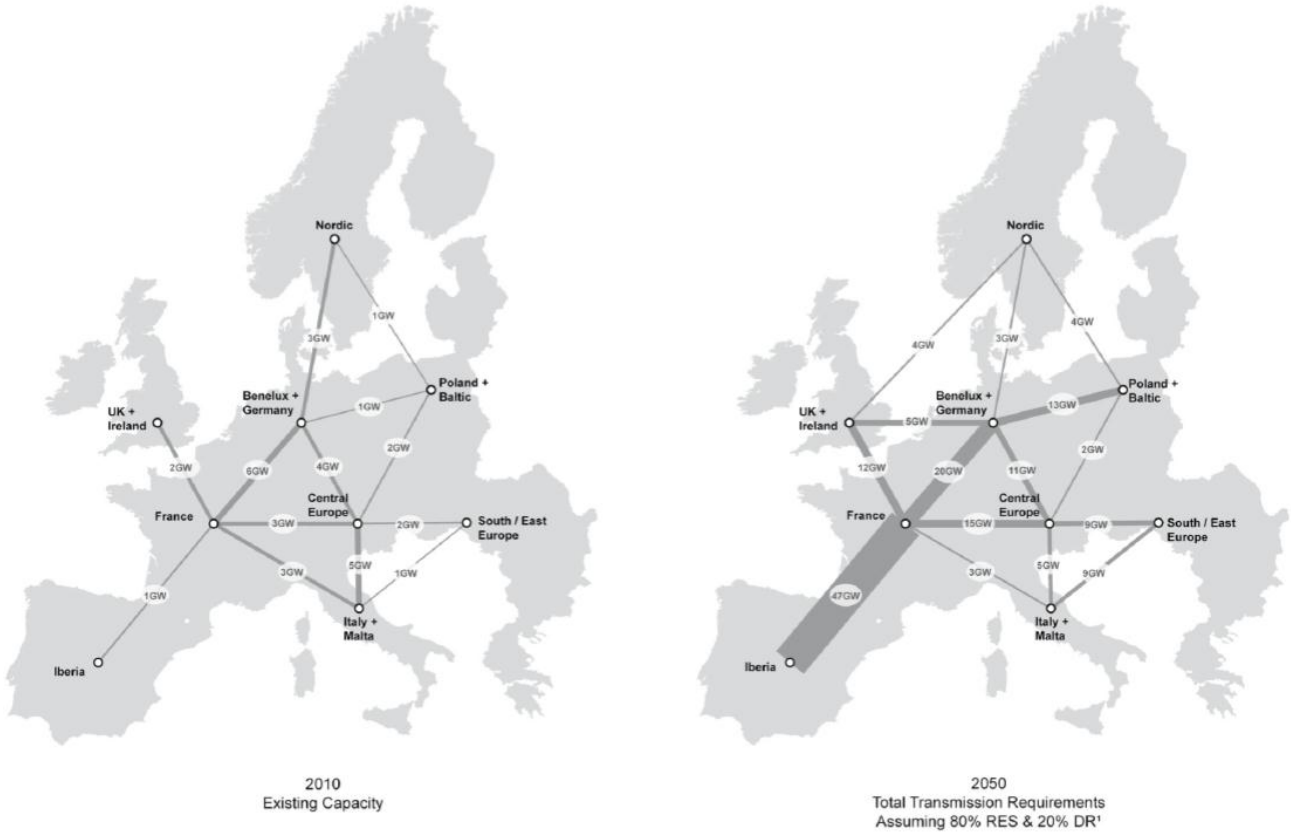


Fig. 25. Interconnected power system [33]

Analysis of situation in Ukraine

According to Ukraine's energy balance for 2013[11] [13], the share of RES in the gross final energy consumption was **3.62%**, including biomass 2.28% (**1.61** Mtoe). ***National Renewable Energy Action Plan of Ukraine until 2020*** [14] sets the target to achieve **11%** RES in the gross final energy consumption by 2020 that meets obligations of Ukraine as a member of Energy Community.

At present Ukraine has its current ***Energy Strategy until 2030*** [17] that was adopted by the Cabinet of Ministers on 24.07.2013 and at once was soundly criticized. Key figures of the document are not coordinated with NREAP. The Strategy (basic scenario) envisages rise in energy consumption by 25% in 2030 (238.1 Mtce) as compared with the basic 2010. It is also planned to increase power consumption considerably, by 55% by 2030 p. as compared with 2010. These prognoses seem to be incorrect as they are not aimed to save fuel and energy resources and raise energy efficiency. In addition, the existing Energy Strategy practically does not contain any concrete targets for RES development. In particular, there is no share of renewables in the gross final energy consumption planned by 2020. The stated figures for RES seem to be unreasonably low.

To improve the situation, two versions of a new document, ***Energy Strategy of Ukraine until 2035***, have been developed.

First version of the Strategy was elaborated by the National Institute for Strategic Research [16]. It is planned by the document to achieve **11%** RES in the gross final energy consumption in 2020 and **20%** in 2035. At that, the contribution of renewables to the total power production will be **13%** by

[11] Energy balance of Ukraine for 2014 will be issued by the State Statistics Service of Ukraine in **December 2015**.

2020 and **18%** by 2035. (**Table 4**). The figures are coordinated with NREAP that is a positive feature of the document.

Table 4. Key figures of the draft Energy Strategy of Ukraine until 2035 року (version developed by the National Institute for Strategic Research) [16]

Indexes	2013	2020	2025	2030	2035
Consumption of fuel and energy (for energy purposes), Mtoe	110.62	114.4	117.6	121.4	126.1
- including RES	3.13	9.6	13.3	17.3	19.5
RES in consumption of primary energy	*2.7%*	*8.4%*	*11.4%*	*14.2%*	*15.5%*
Final consumption, Mtoe[1)]	69.6	77.9	80.8	85.1	88.9
RES in the gross final energy consumption	*4.5%*	*12.3%*	*16.5%*	*20.3%*	*21.9%*
Final consumption, Mtoe[2)]	86.6	86.9	89.1	93.5	97.5
RES in the gross final energy consumption	***3.6%***	***11.0%***	***15.0%***	***18.5%***	***20.0%***
Production of power, TWh	194.4	209.46	232.97	258.24	276.62
- including RES	~15.7	28.12	38.44	47.60	50.1
RES in power production	*~8.1%*	*13.4%*	*16.5%*	*18.4%*	*18.1%*

1) According to energy balances.

2) According to requirements of Directive 2009/28/EC

However, this draft Energy Strategy envisages the rise in Ukraine's gross final energy consumption by 12.6% by 2035 as compared with 2013. This is not in line with the general trend of the EU aimed at reduction of energy consumption and rise of energy efficiency. Though the document contains some concrete targets to increase efficiency of the use of fuel and energy resources, they seem not to be enough to keep energy consumption at least at the current level. To be fair, it should be noted that NREAP also envisages increase in GFEC in 2020 as compared with 2014. The increase is 15.5% according to the basic scenario and 9% according to scenario of energy efficiency.

Second version of the draft Energy Strategy until 2035 called ***New Energy Strategy of Ukraine (NES***) was elaborated by Razumkov Centre along with the National Institute for Strategic Research attached to President of Ukraine and other key NGOs and research institutions of Ukraine.

Unlike the first version of the draft energy strategy of Ukraine until 2035 and the current energy strategy of Ukraine until 2030, draft NES projects reduction in the consumption of primary energy from 115.2 Mtoe in 2013 to 102.6 Mtoe in 2035. It gives right trend for the development of energy saving and energy-efficient technologies and surely it is a positive feature of this document.

However, the stated targets for RES development by 2020 do not meet obligations assumed by Ukraine as a member of the Energy Community, namely 11% RES in the gross final energy consumption. The same target (11%) is included in the National Renewable Energy Action Plan (Resolution of CMU N 902-p of 01.10.14). At that draft NES plans to achieve "over 7%" RES in the final energy consumption (page 10), and on page 86 one can see the figure of 8% RES in the gross final consumption of energy in 2020.

NES targets 20% RES in the total primary energy supply in 2035 (page 85) and at the same time 20% RES in the gross final energy consumption (page 86). The targets contradict each other.
It is stated that "increase in the renewable energy production will be reached at the expense of development of alternative energy in Ukraine (over 60% at the expense of biofuels)" (page 29). The statement is right and in line with the trends and available statistics of RES development in the EU and in the world. However, on page 85 one can see that the share of bioenergy is 39% of all

renewables that contradicts the previous statements and shows unreasonably low contribution of bioenergy in comparison with other renewables.

Energy efficiency

On 25 November 2015, the draft Resolution ***"On National Energy Efficiency Action Plan until 2020"*** was approved at a session of the CMU. According to the Plan, it is provided the achievement of the national indicative energy savings target of **9%** of the average final domestic energy consumption during 2005-2009 that equals 6.5 Mtoe. In addition, the National Action Plan defines an intermediate goal to reduce the energy consumption **by 5%** in 2017. To achieve these figures, it is planned to implement measures in the four major sectors of the final energy consumption. The first one is the domestic household, which is expected to have the greatest effect. Next is service sector, which includes the energy consumption by state-funded organisations, the others are industry and transport [20].

Reduction of GHG emission

Being a party of United Nations Framework Convention on Climate Change and Kyoto Protocol, Ukraine has an obligation to reduce GHG emission by 60% as compared with 1990 that is to **566** Mt CO_{2eq}/yr [21]. Actually, it means that at UN climate conference in Paris Ukraine is going to suggest increase of the emission instead of reduction. That is because as far back as in 2012 the emission of GHG was **402** Mt CO_{2eq} in the country. A number of NGOs and experts expressed their disagreement with the official position and suggested the Government to consider another scenario that does not project actual increase in GHG emission in Ukraine.

Conclusions

Now more and more world countries are aiming to reach **50%** and more of renewables in energy. Each of the countries has developed its own way to achieve the target, and these ways differ one from another by implementation time, scope and target area. It is connected with the need to strengthen energy security as well as prevent global climate change by reduction of carbon emission into the atmosphere. Another trend is awareness that it is necessary to widely implement energy-efficiency measures and include them in energy strategies. Thus, independence from fossil fuels can be achieved by two ways – introduction of renewable energy sources and reduction of total energy consumption. Analysis of main world energy strategies shows that the countries passed on to a new area of competitiveness where the main point is to become the most environment-friendly country of the world and achieve energy independence not slowing down at that its industrial development.

To speed up the development of renewable energy in Ukraine and increase energy efficiency *we consider it necessary*:

- To improve Energy Strategy of Ukraine until 2035 taking into account the above remarks and adopt it.
- To approve reasonable targets for GHG emission reduction and fulfill them regularly.
- In the long-term perspective (until 2050), try to follow examples of European and world countries which set high goals for the use of RES (50% and more), for reduction of GHG emission and increase of energy efficiency.
- On the national level, to contribute to the development of climate according to 2DS scenario (increase of the average annual temperature by 2 degrees by 2050).
- Take steps for implementing «environmental» Directives 2009/125/EC, 2010/30/EU[12] to increase competitiveness of the country on the international environmental scene.

[12] Ecodesign Directive 2009/125/EC; Directive 2010/30/EU On the indication by labelling and standard product information of the consumption of energy and other resources by energy-related products

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38. Directive on ecodesign requirements for energy-related products 2009/125/EC
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:285:0010:0035:en:PDF
39. Directive on the indication by labelling and standard product information on the consumption of energy and other resources by energy-related product 2010/30/EU
http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32010L0030&from=EN
40. Eurostat news release 43/2015 of 10.03.2015
http://ec.europa.eu/eurostat/documents/2995521/6734513/8-10032015-AP-EN.pdf/3a8c018d-3d9f-4f1d-95ad-832ed3a20a6b
41. Sweden to become one of world's first fossil fuel-free nations
http://ecowatch.com/2015/09/25/%E2%80%8Bsweden-fossil-fuel-free/

Abbreviations

BRICS – Brazil, Russia, India, China, South Africa
CA – California
CMU – Cabinet of Ministers of Ukraine
CSP – concentrated solar power
GDP – gross domestic product
EREC – European Renewable Energy Council
EU – European Union
GFEC – gross final energy consumption
GHG – greenhouse gases
HPP – hydro power plant
IEA – International Energy Agency
IRENA – International Renewable Energy Agency
NES – New Energy Strategy
NGO – Non-governmental organization
NPP – nuclear power plant
NREAP – National Renewable Energy Action Plan
OECD – Organisation for Economic co-operation and Development
PV – photovoltaic
RES – renewable energy sources
SEK – Swedish Krona
TPES – total primary energy supply
UK – the United Kingdom
UN – United Nations
WEC – World Energy Council
WWS – Wind, Water, Solar energy
2DS – 2 °C Scenario
4DS – 4 °C Scenario
6DS – 6 °C Scenario
tce – tons of coal equivalent
toe – tons of oil equivalent

Indexes

e – electricity
eq – equivalent

Previous publications by UABio

http://www.uabio.org/activity/uabio-analytics

1. *Position Paper N 1* (2012) "Position of bioenergy in the draft updated energy strategy of Ukraine till 2030".
2. *Position Paper N 2* (2013) "Analysis of the Law of Ukraine "On amending the Law of Ukraine «On Electricity" No5485-VI of 20.11.2012".
3. *Position Paper N 3* (2013) "Barriers to the development of bioenergy in Ukraine".
4. *Position Paper N 4* (2013) "Prospects of biogas production and use in Ukraine".
5. *Position Paper N 5* (2013) "Prospects for the electricity generation from biomass in Ukraine"
6. *Position Paper N 6* (2013) "Prospects for heat production from biomass in Ukraine"
7. *Position Paper N 7* (2014) "Prospects for the use of agricultural residues for energy production in Ukraine".
8. *Position Paper N 8* (2014) "Energy and environmental analysis of bioenergy technologies"
9. *Position paper N 9* (2014) "State of the art and prospects for bioenergy development in Ukraine"
10. *Position paper N 10* (2014) "Prospects for the growing and use of energy crops in Ukraine"
11. *Position paper N 11* (2014) "Prospects of biomethane production and use in Ukraine"
12. *Position paper N 12* (2015) "Prospects for the development of bioenergy as an instrument for natural gas replacement in Ukraine"

Civic union "Bioenergy Association of Ukraine" (UABio) was established to create a common platform for cooperation on bioenergy market in Ukraine, as well as to provide the most favorable business environment, accelerated and sustainable development of bioenergy. General constituent assembly of UABio was held on September, 25, 2012 in Kyiv. The Association was officially registered on 8 April 2013. Among UABio members there are over 10 leading companies and over 20 recognized experts working in the field of bioenergy.
http://uabio.org

Bioenergy Association of Ukraine