MSc Program
Renewable Energy in Central and Eastern Europe

Assessment of the regulatory framework for wind power in Croatia

A Master's Thesis submitted for the degree of
"Master of Science"

supervised by
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Vienna, 24.08.2009

Affidavit

I, Dipl.-Ing. Ivana GODJEVAC, hereby declare

1. that I am the sole author of the present Master's Thesis, "ASSESSMENT OF THE REGULATORY FRAMEWORK FOR WIND POWER IN CROATIA", 86 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted this Master's Thesis as an examination paper in any form in Austria or abroad.

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Abstract

In this work with the title "Assessment of the regulatory framework for wind power (RES-E) in Croatia" the future of the wind power energy in Croatia until 2020 is the main object of the interest. Wind power is a renewable energy form, and because of this fact, it is an interesting possibility for generating "green" and "proper" energy on the territory of Croatia. Furthermore, the country Croatia is a member candidate for the European Union (EU), and therefore the political and regulatory framework for the energy market in Croatia has to be adjusted to the guidelines of the EU.

This work is separated into several parts: at the beginning, the economic and energy situation of the country Croatia is described. Then the current status of the wind energy plants is discussed; additionally, the planned projects "under construction" are mentioned, too. The main winds and the suitable sites for wind energy production in Croatia are taken under consideration, too; you can see, the onshore winds and sites are more suitable for energy production than the offshore winds/sites. For estimating the realisable wind energy potential of Croatia until 2020, the method of the so called dynamic cost-resource curves resp. dynamic cost-potential curves is discussed and introduced, which has been already used for calculating the energy potential of renewable energies in general (RES-E) in the EU, but not yet for Croatia. The best implementation of the dynamic cost-potential curve discussion is the so called Green-X model, which is described in the framework of this work, too. Also the Green X model has already been used for the calculation of the wind energy potential within the EU, but not for Croatia until now. So this work gives an impression of the Green X model applied on the situation of the EU. Furthermore, it depicts the "state of art" in the research of the realisable wind potential in Croatia until 2020, too. The result is that a potential of roundabout 1200 kW in the year 2020 can be expected for Croatia.

This work understands itself as a pre-study for the implementation of the Green X model for the realisable wind energy potential in Croatia, for which in future still more scientific research has to be done. At the end of this work, some conclusions and recommendations for a realistic wind energy policy in Croatia are made.

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1 Introduction

1.1 Motivation of this study

The motivation for this study can be summarized as such: it is important to explore the future of the wind energy sector in Croatia until the year 2020. In the renewable energy sector "scene" wind power plants have a growing influence. For the safety of the energy policy concerning renewable energy resources (especially wind power), it is necessary to develop statistical methods for forecasting the future of the renewable energy sector in comparison with the "traditional" ways of energy generation. So in this study a method is introduced which allows to describe this future: the so called *"dynamic cost resource curves"* method, developed for the RES-E sector (renewable energy sector). It can be used for developing the so called *"Green-X"* computer simulation model, which is described detailed in the chapters 3 and 4. Another reason for developing such a method is the harmonisation of the energy policy in the framework of the EU and the EU-associated states (Croatia is a member candidate for the EU within the next years, too). The Green-X model was not used for calculating the Croatian wind potential until now. This will be a task for future research; in this context, this work can be described as a kind of "pilot study" for reaching this goal in the nearer future.

1.2 Core question

The core question of this study is whether the above mentioned method is able to describe the future of the wind power sector in Croatia in a correct and reliable way. Another question of this study is an assessment of the regulatory framework for wind power in Croatia. For this reason, the realisable wind potential of Croatia until the year 2020 must be thematized; this will take place especially in chapter 4.4., as a necessary prestage for implementations of the Green-X model for calculating the *realisable* wind potential in Croatia in the nearer future – so can be hoped. In a second step, the regulatory framework must be taken under consideration concerning the question, whether all available and adequate measures and means have already been used by the government and the energy sector operators in Croatia for reaching this wind potential goal (see chapter 5).

1.3 Citation of main literature

The literature cited in this study is mainly about the energy production in Croatia and in the EU in general and about the wind power generation in particular. It contains – among other things – statistical material about the economy, the situation of the energy sector and the way how the future scenarios of the wind power can be described with the above mentioned dynamic and non-linear statistical method.

1.4 The structure of the work

The structure of this work has the following "golden thread":

At the beginning of this work, the economic and energy situation of the current Croatia is described. This is necessary for analysing the starting situation. After this, the Croatian wind power situation of nowadays and its wind energy potential in the future is in the focus of the interest. This is a necessary prestep for analysing future scenarios, for which the description of the dynamic cost-resource curve and the so called *"Green-X model"* is a necessary precondition, too. There have been future scenarios for the "Green energy" for the European Union already, *but still not for Croatia*. But there had been made other research with other methods for the *realisable* wind potential of Croatia, too. So in this study there is thematized *both:* the already realised Green-X model studies for the EU, and the results for the wind energy and RES-E potential in Croatia with the help of other scientific research, too. So this could be a prestep for employing the Green-X model on the situation of Croatia; the other studies show which results can perhaps be expected after implementing the Green-X calculation on Croatia. After this comparison, some conclusions and recommendations for the wind energy policy can be drawn, and also some hints for future scientific research concerning implementing the Green-X model on the situation in Croatia.

According to this "golden thread", the structure of the work can be described as such:

In chapter 2, there are given some information about the country Croatia, its economic situation and the current situation of the energy sector in general and of the renewable resources sector in particular.

In chapter 3, the current status of wind power in Croatia and its potential in the future is thematized. At first, the wind energy development in the framework of the general Croatian energy policy strategy is discussed. Then the subsidies for the Croatian wind power are mentioned. After that, the winds of Croatia and the suitable sites for wind energy production in Croatia are taken under consideration. Then the planned projects of wind farms in Croatia and the potential problems for investors are discussed. At last, the dynamic cost-resource curve is introduced and explained; this can be understood as a prestudy for future research by employing the dynamic cost-resource curve resp. cost potential curve on the *realisable* wind potential in Croatia which has not been taken place until now.

In chapter 4, the latest state of the art concerning future scenarios for the wind energy generation in Croatia until 2020 is discussed. The realisable wind energy potential for Croatia is here in the focus of the interest. The Green-X was not employed on the Croatian situation yet. This will be a challenge for future scientific work, for which this work is a preparation and "introduction".

In chapter 5, some conclusions and recommendations are drawn.

2 General information regarding the country Croatia

In the beginning, it is necessary to give some general information about the country Croatia, its economy and energy situation.

2.1 Fundamental facts of the country Croatia

The fundamental facts are:

- Area: 56.594 km^2
- Population (2008 census): 4,491,543 inhabitants
- Population density per km^2: 78,5
- Capital: Zagreb (779,145 inhabitants) (Ministry of Economy, Labor and Entrepreneurship 2008, p. 15).

2.2 Economic situation of Croatia

The real Gross Domestic Product (GDP) growth rate was 4,8 % in the year 2006; it increased in the year 2007 for 0,8 % to 5,6 %. There was a significant growth of personal consumption as a consequence of positive tendencies on the labor market, which strengthened the public and private investment spending (Ministry of Economy, Labor and Entrepreneurship 2008, p. 16).

After a strong acceleration in the first half and a slowdown in the third quarter, the real GDP growth in 2007 showed a significant acceleration of economic activities. In the 4^{th} quarter of 2007 the economic growth rate declines, but seen in general, the year 2007 had still a high standard of employment growth (Ministry of Economy, Labor and Entrepreneurship 2008, p. 16).

The inflation rate raised in the last quarter of 2007, caused by shocks on the supply side (generated externally) and inflationary tendencies on the demand side. The real

GDP growth in Croatia in 2007 achieved 5,6 %; the GDP deflator was 4,0 % in 2007. Nominal level of GDP reached 275.1 billion HRK (= the national currency of Croatia) in 2007, which corresponds to 8.500 € GDP per capita (compared with 7.700 € GDP per capita in 2006). Personal consumption raised in 2007 compared to 2006 for 6,2 %, which was the biggest growth since 2002. Import of goods and services increased for 5,8 % in 2007, the export for 5,7 %. Seen in a longer period, it can be assumed that the 2007 positive trend of Croatian economy can be continued; in the last years the GDP raised also per capita. (Ministry of Economy, Labor and Entrepreneurship 2008, p. 17).

The macroeconomic indicators of the Croatian economy between 2000 and 2007 are shown in this figure (Ministry of Economy, Labor and Entrepreneurship 2008, p. 25, table 1.2.1).

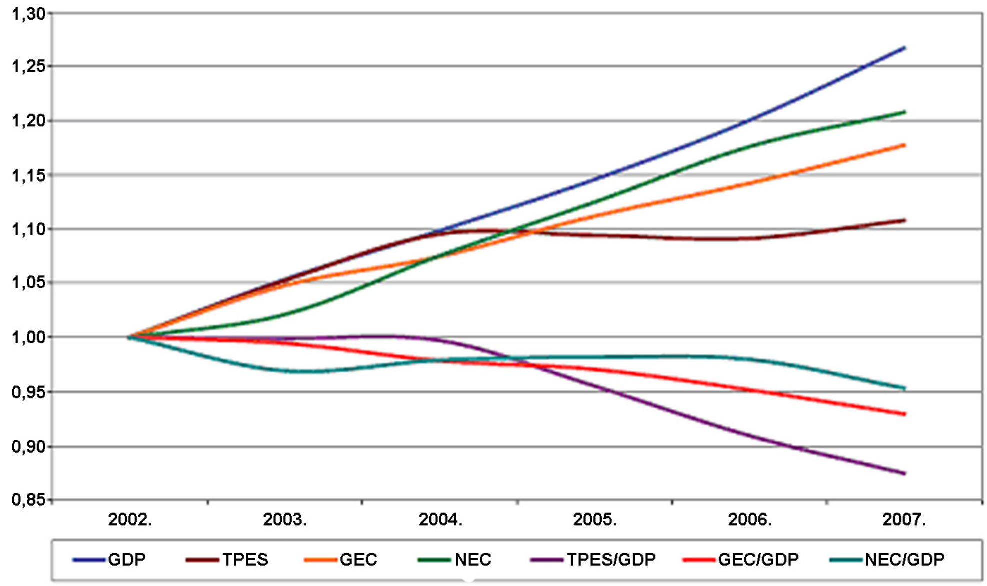
Table 1: Macroeconomic trends of the Croatian economy 2000-2007.

	2000.	2001.	2002.	2003.	2004.	2005.	2006.	2007.
GDP (million HRK)	152 519	165 639	181 231	198 422	212 827	231 349	250 590	275 078
GDP (million HRK, 1997 constant prices	129 438	135 189	142 730	150 351	156 758	163 491	171 277	255 819
Real GDP growth rate (%)	2,9	4,4	5,6	5,3	4,3	4,3	4,8	5,6
GDP (million USD 2000 constant price)	18 404	19 221	20 294	21 377	22 288	23 246	24 353	42 995
GDP (million USD 2000 constant price PPP)	41 365	43 203	45 613	48 048	50 096	52 248	54 736	65 006
GDP per capita (USD 2000 constant price)	4 201	4 332	4 568	4 813	5 021	5 233	5 485	9 684
GDP per capita (USD 2000 constant price PPP)	9 442	9 737	10 266	10 817	11 285	11 762	12 328	14 641
Year-on-year consumer price growth (%)	4,6	3,8	1,7	1,8	2,1	3,3	3,2	2,9
Current account balance (million €)	-477	-806	-2 091	-1 874	-1 457	-1 992	-2 671	-3 226
Current account balance (% of GDP)	-2,4	-3,6	-8,5	-71	-5,1	-6,4	-7,8	-8,6
Export of goods and services (% of GDP)	47,1	48,7	45,5	50,1	49,6	48,8	49,6	49,0
Import of goods and services (% of GDP)	52,3	54,6	56,4	57,9	56,5	55,9	57,3	57,3
External debt (million €, end of period)	12 264	13 609	15 143	19 884	22 933	25 748	29 199	32 929
External debt (% of GDP)	61,4	61,4	61,9	75,8	80,0	82,4	85,3	87,8
Unemployment rate (%, ILO)	16,1	15,8	14,8	14,3	13,8	12,7	11,2	9,6
Employment rate (% ILO, persons aged over 15)	42,6	41,8	43,3	43,1	43,5	43,3	43,6	44,2
Average exchange rate HRK:EUR)	7,6339	7,4710	7,4070	7,5642	7,4957	7,4000	7,3228	7,3360
Average exchange rate HRK:USD)	8,2874	8,3392	7,8725	6,7044	6,0312	5,9500	5,8392	5,3660
Average net monthly wage (HRK)	3 324	3 541	3 719	3 939	4 172	4 375	4 603	4 841
Tourism revenue, mil. USD	2 758	3 335	3 811,4	6 310,5	6 726,7	7 370,1	7 990,1	9 226,4
International reserves, mil. USD	3 524,8	4 704,2	5 885,8	8 191,3	8 759	8 801,1	11 488,6	13 675,3
Foreign direct investments in Croatia, mil. EUR	1 140,6	1 467,5	1 137,9	1 762,4	949,6	1 467,9	2 737,9	3 625,9
Total persons in employment	1340 957	1348 308	1359 015	1392 510	1409 634	1420 573	1467 876	1516 909

2.3 The current situation of the Croatian energy sector

As already mentioned, the GDP increased by 5,6 % in 2007 in Croatia. The total primary energy supply raised by 1,5 % in 2007, the total electricity consumption by 3,1 % and the total net electricity consumption by 2,7 % in the same year. But the net electricity consumption does not include transmission and distribution losses, which were 6,2 % higher in 2007 than in 2006. From 2002 to 2007, there was an average GDP growth rate of 4,8 % p. a.; the total primary energy supply increased at an average level of 2,1 % p. a. In the same years, the total electricity consumption raised at an average annual rate of 3,3 %, and net electricity consumption at an average rate of 3,8 % p. a. (Ministry of Economy, Labor and Entrepreneurship 2008, p. 36).

In 2007, the energy intensity of total primary energy supply declined by 3,8 % (Ministry of Economy, Labor and Entrepreneurship 2008, p. 36). As the following figure shows, in the period between 2002 and 2007 the tendency towards reducing of the energy intensity was going on (Ministry of Economy, Labor and Entrepreneurship 2008, p. 35, fig. 2.1.1).



GDP – Gross Domestic Product;
TPES – Total Primary Energy Supply;
GEC – Gross Electricity Consumption;
NEC – Net Electricity Consumption (losses excluded);
TPES/GDP – Total Primary Energy Supply/Gross Domestic Product – the ratio showing the energy intensity of the total primary energy supply, i.e. the total primary energy supply per unit of gross domestic product;
GEC/GDP – Gross Electricity Consumption/Gross Domestic Product - the ratio showing the energy intensity of gross electricity consumption, i.e. the average electricity consumption per unit of gross domestic product;
NEC/GDP – Net Electricity Consumption/Gross Domestic Product – the ratio showing the energy intensity of the net electricity consumption, i.e. the average loss-free electricity consumption per unit of gross domestic product.

Figure 1: The most important indicators of development

The trends concerning the total primary energy supply in the years 1988-2007 are illustrated in the following picture. Related to the year 2007, the total primary energy supply raised by 1,5 %. The reason for this was caused by higher consumption in the transportation sector, in the industry, energy's own usage and non-energy-consumption (Ministry of Economy, Labor and Entrepreneurship 2008, p. 36 and p. 37, fig. 2.1.2).

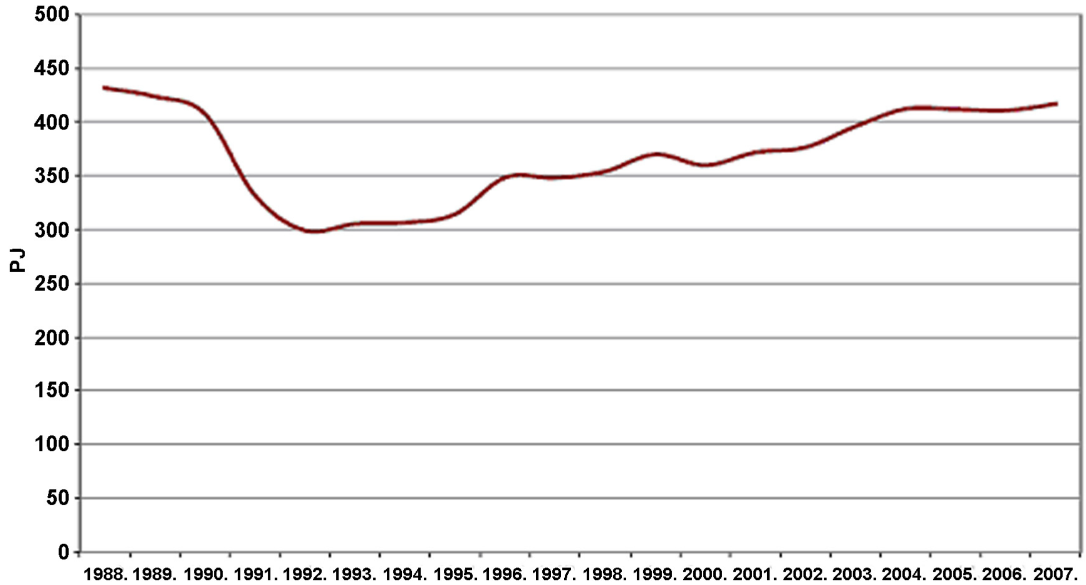


Figure 2: Total primary energy supply in Croatia between 1988 and 2007

The development of the electricity consumption in Croatia between 1988 and 2007 is shown in this figure (Ministry of Economy, Labor and Entrepreneurship 2008, p. 36 and p. 37, fig. 2.1.3).

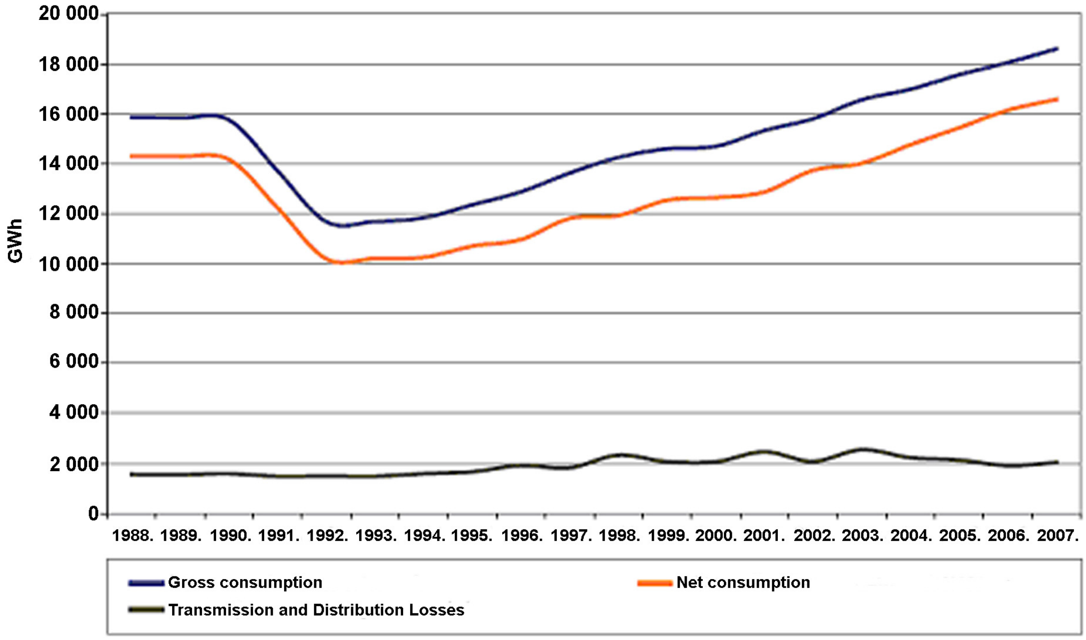


Figure 3: Electricity consumption in Croatia between 1988 and 2007.

2.4 Wind power and other renewable sources in Croatia – some statistical material

The following two figures give an impression of the incentive prices from the Tariff System to promote electricity generation from diverse renewable energy sources, *"having in mind that the values for incentive prices are obtained by multiplying the tariff item (C) with the correction factor that depends on the share of domestic component in the project. The correction factor takes values between 1 (from 60 % of domestic share and more) and 0,93 (for domestic share of 45 % and less)."* (Ministry of Economy, Labor and Entrepreneurship 2008, p. 207).

Here is the first figure (Ministry of Economy, Labor and Entrepreneurship 2008, p. 208, table 8. 2.1):

Table 2: Tariff system of Croatia 1 (renewable energy sources)

Plant type	C
a. Solar power plants	
a.1. Solar power plants with installed power up to and including 10 kW	3,40
a.2. Solar power plants with installed power exceeding 10 kW up to and including 30 kW	3,00
a.3. Solar power plants with installed power exceeding 30 kW	2,10
b. Hydro power plants	0,69
c. Wind power plants	0,64
d. Biomass power plants	
d.1. Solid biomass from forestry and agriculture (branches, straw, kernels….)	1,20
d.2. Solid biomass from wood – processing industry (bark, saw dust, chaff….)	0,95
e. Geothermal power plants	1,26
f. Biomass power plants from agricultural plants (corn silage…) and organic remains and waste from agriculture and food processing industry (corn silage, manure, slaughterhouse waste, waste from the production of biofuel….)	1,20
g. Liquid biofuel power plants	0,36
h. Landfill gas power plants and waste water treatment biogas power plants	0,36
i. Power plants on other renewable energy sources (sea waves, tidal….)	0,60

Now comes the second figure concerning the Croatian tariff system for the renewable energy sources (Ministry of Economy, Labor and Entrepreneurship 2008, p. 209, table 8. 2. 2):

Table 3: Tariff system of Croatia 2 (renewable energy sources)

Plant type	C
a. Hydro power plants with installed power up to and including 10 MW	
a.1. Power up to and including 5 000 MWh produced in the calendar year	0,69
a.2. Power exceeding 5 000 MWh up to and including 15 000 MWh produced in the calendar year	0,55
a.3. Power exceeding 15 000 MWh produced in the calendar year	0,42
b. Wind power plants	0,65
c. Biomass power plants	
c.1. Solid biomass from forestry and agriculture (branches, straw, kernels….)	1,04
c.2. Solid biomass from wood – processing industry (bark, saw dust, chaff….)	0,83
d. Geothermal power plants	1,26
e. Biomass power plants from agricultural plants (corn silage…) and organic remains and waste from agriculture and food processing industry (corn silage, manure, slaughterhouse waste, waste from the production of biofuel….)	1,04
f. Liquid biofuel power plants	0,36
g. Landfill gas power plants and waste water treatment biogas power plants	0,36
h. Power plants on other renewable energy sources (sea waves, tidal….)	0,50

The next figure expresses the heat and electricity production by renewable sources in Croatia in the year 2007 (Ministry of Economy, Labor and Entrepreneurship 2008, p. 210, table 8. 3. 1):

Table 4: Installed electricity power capacity in Croatia in 2007 (renewable sources)

Type of renewable energy source	Installed heat capacity (MW)	Installed electrical power capacity (MW)
Solar	45,50	0,04996
Wind	0	17,15
Biomass	512,00	2,00
Small hydro	0	32,76
Geothermal	36,66 113,90	0
Total	**594,16**	**51,96**
	671,40	

The situation of the wind power electricity generation is discussed elaborately in the following chapter 3.

3 Current status of wind power in Croatia and its wind energy potential in the future

3.1 Wind energy development in the framework of the general Croatian energy strategy

3.1.1 The energy strategy of the country Croatia

Based on the energy demand of Croatia shown already in chapter 2 (Pregled 2009), the Croatian "Ministry of Economy, Labor and Entrepreneurship" in Zagreb in cooperation with the "United Nations Development Programme" (UNDP) describes the purpose and goals of the updated Croatian energy strategy as such:

"Croatia is approaching times when it has to make difficult and far-reaching decisions regarding its energy sector development. These decisions shall have a long-term impact on the Croatian economy, environment and society as a whole. The Strategy is aimed at showing current situation in the Croatian energy system and consequences of possible development options, as well as at establishing a transparent, decisive; add comprehensive national energy policy on the basis of extensive public consultation process followed by a political decision.
The purpose of the Croatian Energy Strategy update and upgrade is to define the development of Croatian energy sector by 2020.
The goal of the Strategy is to build, under the conditions of uncertainty in the global energy market and scarce local energy resources, a sustainable energy system that makes a balanced contribution to security of energy supply, competitiveness, and environmental protection and provides for security and availability of energy supply to the Croatian citizens and business sector." (Ministry of Economy, Labor and Entrepreneurship and United Nations Development Programme (UNDP) 2008, p. 1)

According to Article 80 of the Constitution of the Republic of Croatia and Article 5, Section 3 of the Energy Act (Official Gazette 68/2001), the Parliament of Croatia adopted the Energy Strategy of the Republic of Croatia at is session held on March, 19th, 2002 (Official Gazette, 38/2002). This 2002 Strategy conceals the period until 2030 (Ministry of Economy, Labor and Entrepreneurship and United Nations Development Programme (UNDP) 2008, p. 1).

Since the 2002 Energy Strategy, there were several important changes on the national and international level. These transformations contain the following points:

- Croatia has become a membership candidate of the European Union (EU). This means that Croatia has to adapt to the framework of the energy policy of the EU. This fact has legal effects on the legislative framework of Croatia: Diverse sub laws for renewable energy systems (feed-in-tariffs, mandatory share in 2010 [5,8 %], privileged producer status, registration of all RES projects); grid code for wind farms resp. mills; spatial planning and construction law; regulation on environmental impact assessment; the energy strategy seeks 1200 MW wind by 2020; a revised energy law a. s. o. (Ognjan 2009, p. 4).
- The so called “Energy Community Treaty” has been signed and ratified.
- Croatia ratified the Kyoto Protocol together with the United Nations Framework Convention on Climate Change.
- Increase of the energy prices and instability of the global energy market (Ministry of Economy, Labor and Entrepreneurship and United Nations Development Programme (UNDP) 2008, p. 1).

The Croatian energy strategy has – considering the changes in the world economy and the world energy market – three main objectives:

1. Security of energy supply
2. Competitive energy system
3. Sustainable energy sector development (Ministry of Economy, Labor and Entrepreneurship and United Nations Development Programme (UNDP) 2008, p. 1 f.).

These main objectives are based on these fundamental principles:

Table 5: The fundamental principles of the Croatian energy strategy

- The energy strategy points out the role of the government, especially the responsibility in securing and exploitation of energy sources, for competitiveness and the protection of the environment.
- The Croatian energy system is an open system, integrated in the energy system of the European Union (EU) and the regional energy system of the Southeast of Europe.
- The energy sector of Croatia should be based on capitalist market principles. The government should only intervene when the stakeholders are in danger to be affected by disturbed supply security, environmental quality, and monopolization tendencies.
- The energy sector is an entrepreneurial, infrastructural and export-oriented activity.
- Croatian legislative, regulatory and institutional framework should be brought together with the *EU Acquis Communautaire.*
- The raising of the energy efficiency is another important goal of the Croatian energy policy.
- Croatia aims the biggest possible diversification in the field of the energy sector.
- The specific Croatian geographic position is particularly suitable concerning the potentials for the Croatian energy sector. Croatia is a transit country with excellent potential sites for installing of power generation plants.
- There must be a mix of several energy sources, especially natural gas, liquefied petroleum gas and of course renewable energy sources (f. e. wind energy).
- Energy strategy should integrate the environmental goals and measures with the national policies to mitigate climate change (Ministry of Economy, Labor and Entrepreneurship and United Nations Development Programme (UNDP) 2008, p. 2 f.; Integrated Energy and Climate Change Legislative Package 2008).

3.1.2 The Potential of Wind Power in Croatia and the current situation

The table below shows the energy production and capacity of renewable energy sources respect. systems (RES) in the year 2005 (Granić/Preberg 2007, p. 58, table 2):

Table 6: Energy production and capacity of RES in 2005

Resources	Installed heat capacity	Installed power capacity	Electricity production	Heat production
Solar	n. a.	48,84 kW	50.14 MWh	n. a.
Wind	***0***	***5.95 MW***	***9.5 GWh***	***0***
Biomass	512 MW	2 MW	10.9 GWh	14,767 PJ
SHPPs	0	26.7 MW	108.3 GWh	0
Geothermal	113.9 MW	0	0	547.33 TJ
Total	**625.9 MW**	**34.654 MW**	**128.7 GWh**	**15.314 PJ**

The research priorities in RES assessment are – among others - the following:

- An increased number of high-tower wind measurement stations, located in remote areas suitable for wind developments and a limited number of upper-air measurement stations.
- A development and application of advanced wind resource modelling approaches respect. tools.
- Investigation of alternative methods for using solar radiation components (e. g. multipyranometer array method).
- Development of solar radiation utilization chart for solar thermal systems (Granić/Preberg 2007, p. 58 f.).

Croatia commissioned its first wind farm for generating electricity in February 2005. It is the Ravna I project on the Pag Island.

The following table gives an overview of the Croatian wind projects in the years 2005 and 2006 (Granić/Preberg 2007, p. 63, table 5):

Table 7: Wind projects in Croatia 2005/06

Status	Project	Installed or planned power (MW)	Planned power production (estimated) in GWh
Commissioned	Ravna I Trtar-Krtolin	5.95 11.20	12-15 25-30
Site permit or more	Stupišce Orlice Jasenice I	5,95 6.00 10.00	n. a. n. a. n. a.
Environmental impact study and assessment	Four projects are currently in the phase of environmental impact assessment (EIA)		
Wind measurements	Wind measurements take place at additional 20 or more sites		

Ravna I is a wind farm with seven wind mills on the island of Pag and can be seen as a pioneer in the wind power market in Croatia; the investor of this project is Hypo Alpe Adria (Kopecek/Reis/Weinberger 2008, p. 31; see also: Adria Wind Power 2009). It consists of 7 Vestas wind turbines. Each of these wind turbines has a capacity of 850 kW, totalling in 5.95 MW.

The second wind farm was installed in Trtar-Krtolin in May 2006 (Granić/Preberg 2007, p. 63). Trtar Krtolin is suited near Sibenik and features 14 Enercon E-48 wind units with a combined capacity of 11,2 MW, single power with 800 kW; planned is a later capacity of annually 30 GWh. The German company Enersys invested € 12.5 million into this project. The construction lasted one year. The generated electricity of this second wind power project in Croatia will be bought by HEP in the next 15 years (Kopecek/Reis/Weinberger 2008, p. 33; Ognjan 2009, p. 6; Energetika-Net 2009).

The current market shares of the Croatian wind farms (2009) are shown in this figure (Karadza/Horváth/Knezevic 2009, p. 3, fig. 2.1)

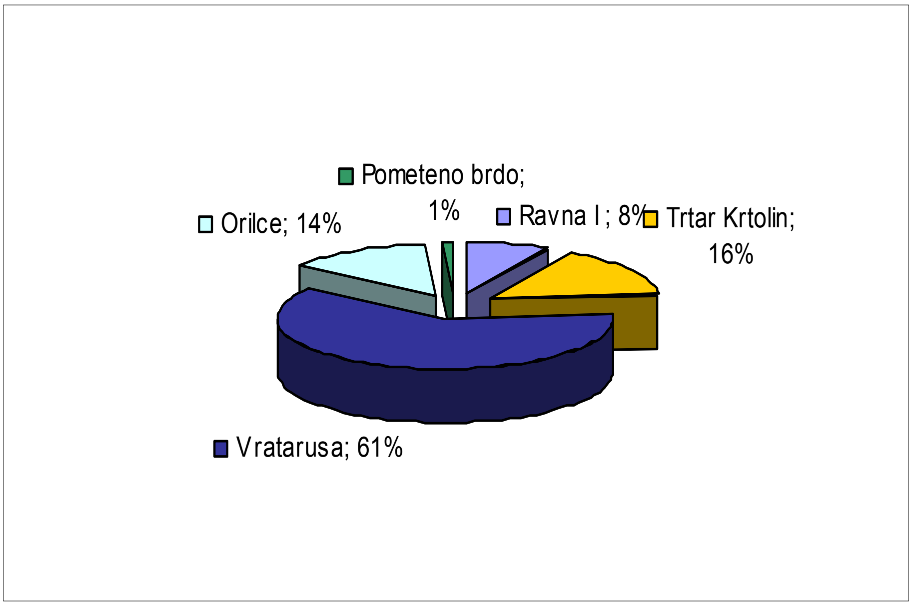


Figure 4: Market shares of the current Croatian wind farms (2009)

As you can see, the wind power plant of Vratarusa has the highest market share of all Croatian wind farms in the meantime (2009), more than all other wind farms together (61 % Vratarusa, 39 % the total market share of the others together).

Croatia has substantial wind resources, especially at the Adriatic coast, where at a lot of locations there are annual wind speeds of nearly 6 m/s. It can be expected that most of the Croatian wind farms will operate between 2000 and 2400 full load hours (Granić/Preberg 2007, p. 64).

"More specifically, Croatia has a promising wind potential, particularly in the coastal regions, but large regions are either completely unexplored or poorly evaluated. Locations of existing meteorological stations are more or less impropriate for wind resource assessment and existing data can only partially be used for regional/national wind resource estimates because of low density and low quality of the data. Because of rather complex terrain, available data is insufficient, which makes wind resource assessment and micro location analysis for future wind projects difficult and overall cost analysis uncertain." (Granić/Preberg 2007, p. 64).

The assumed onshore potential of wind parks is presumed with the energy consumption projections while *"the electricity-generating capacity of wind power is calculated dividing projected energy by an average of 2,200 operation hours per annum (WP load factor is equal to 0,25)."* (Ministry of Economy, Labor and Entrepreneurship and United Nations Development Programme (UNDP) 2008, p. 75, see also: Potočnik/Lay 2002)

Table 8: Estimated Onshore wind park potential in Croatia

- The natural potential of onshore Wind parks (WPS) in Croatia (56,542 km2) is appraised at 120 TWh electricity per year (per annum), which is equivalent to 54.5 GW installed electricity-generating capacity in wind power plants.
- Technically spoken, the onshore potential of wind parks in Croatia is assumed to nearly 10 TWh of generated electricity which is an equivalent to 4.54 GW of installed wind power electricity-generating capacity.
- The forecasted economic potential of onshore wind energy in southern and central Dalmatia is valued at 0,36–0,79 TWh/annum with producing units of 250-750 kW (ENWIND 2001). *"Unofficial estimates with larger units are around 1,5 to 4 TWh where the larger amount accounts for possible trading with electricity balanced out with surrounding power systems."* (Ministry of Economy, Labor and Entrepreneurship and United Nations Development Programme (UNDP) 2008, p. 75)

The expected sea potential of wind parks in Croatia looks like this:

Table 9: Estimated sea (Offshore) potential of Croatian WPS

- The natural offshore potential of WPS in Croatia (territorial waters of Adriatic Sea: 61,067 km2) is estimated at roundabout 150 TWh electricity per annum.
- Technically spoken, the offshore potential of wind parks in Croatia are estimated at almost 12 TWh of electricity per annum. Unfortunately, this is 12 times less the average of Italy (150 TWh/annum) but which has 4 to 6 times more sea territory than Croatia under relatively similar meteorological conditions.

- Economically seen, the offshore potential of Croatian wind power plants was calculated already in 1998 for two locations: Vis and Lastovo, at around 0,5 TWh/annum. Unofficially, it was assumed in 2001, that for a larger number of locations for modern wind turbines around 2 TWh/annum may be possible, including a valued electricity trade for balancing surrounding power systems up to 5 TWh per year (Ministry of Economy, Labor and Entrepreneurship and United Nations Development Programme (UNDP) 2008, p. 75).

At the moment, *there exists no wind energy resources atlas for Croatia.* At the end of July 2004, the first metering system was introduced to measure the wind potential; a metering campaign was started to collect data for creating a wind atlas for the Republic of Croatia. In the meantime, research at individual locations is made by potential investors themselves (Ministry of Economy, Labor and Entrepreneurship and United Nations Development Programme (UNDP) 2008, p. 75).

At the end of this sub-chapter, the following map shows the geographical scattering of wind power plants in several phases of planning:

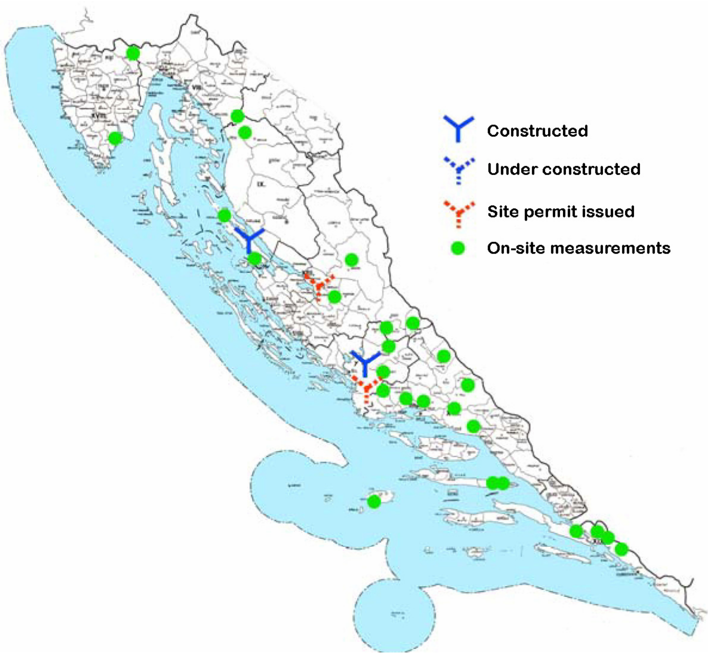


Figure 5: Geographical scattering of wind projects in various planning stages
(Source: Horváth 2006, p. 3, fig. 1)

3.1.3 Objectives of the wind energy strategy in Croatia

In 2020, Croatia should have assumed 1,200 MW of implemented electricity-generating capacity per installed electricity-generating capacity in WPS for each 1,000 population head. This will achieve Spain's current level of 348 kW per 1000 population head.

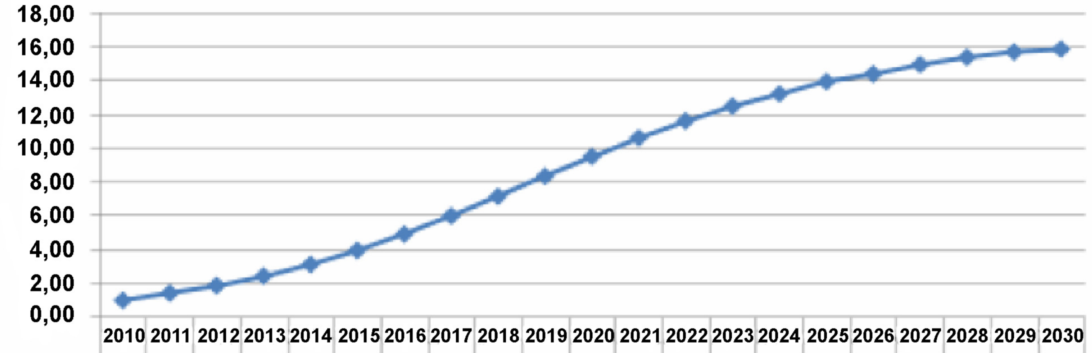
In 2030, Croatia should have 450 kW of working electricity-generating capacity in WPS per 1,000 population head which is – in total – 2,000 MW of installed electricity-generating capacity. It can be assumed that the energy balances will be reached by trading on the open market with the power systems of neighbourhood countries (Ministry of Economy, Labor and Entrepreneurship and United Nations Development Programme (UNDP) 2008, p. 76).

The growth dynamics of installed capacities for producing electricity in wind parks to 2020 and 2030 is shown in the following table (Ministry of Economy, Labor and Entrepreneurship and United Nations Development Programme (UNDP) 2008, p. 76, table 9-6):

Table 10: Growth dynamics of installed capacities for producing electricity in Croatian wind parks to 2020 resp. 2030

	2010	2020	2030
Installed power [MW]	129	1200	2000
Electricity production [TWh]	0.28	2.64	4.40
Electricity production [PJ]	1.02	9.50	15.84

The following figure shows the growth dynamics of electricity generated in Croatian WPS until 2020 (Ministry of Economy, Labor and Entrepreneurship and United Nations Development Programme (UNDP) 2008, p. 76, figure 9-3):



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Wind power [PJ]	1,02	1,45	1,89	2,45	3,14	3,97	4,93	6,00	7,15	8,34	9,50	10,6	11,6	12,4	13,2	13,9	14,3	14,9	15,3	15,6	15,8

Figure 6: Growth dynamics of electricity generated in Croatian WPS until 2020

3.1.4 Future activities concerning wind parks in Croatia and the question of energy efficiency

Wind parks can be seen as the most important renewable energy source/system (RES) for producing electricity in Croatia (not counting potential in already existing large hydropower plants). The interest of investors is great in investing into this energy field, as long the legislation implements the right framework and conditions and there are guaranteed sales prices (feed-in tariffs). But all these things do not automatically guarantee future activities in this energy field. Additional activities seem to be necessary, especially the following:

- Streamlining and accelerating administrative procedures to obtain the necessary permits for constructing and installing wind farms
- Updating physical plans, and – lust but not least –
- Creating a significant wind energy atlas for Croatia – but this is still “under construction” (Ministry of Economy, Labor and Entrepreneurship and United Nations Development Programme (UNDP) 2008, p. 76).

Concerning all these activities, it must be considered that the feasibility of RES projects is *very cost-sensitive*, especially wind power (energy) projects (Samardžić 2009, p. 2).

To reduce these costs, it is necessary to heighten the *energy efficiency,* especially on the demand side. The possible energy efficiency has a direct connection to the demand reduction that will be generated (GWh) and to the implementation costs (€/MWh) (Labanca et al. 2009, p. 4). If an electricity price is predefined, you can *"therefore select cost efficient measures as those with a cost of conserved energy lower than the price of electricity."* (Labanca et al. 2009, p. 4)

The above mentioned issues can be illustrated with this figure (Labanca et al. 2009, p. 4):

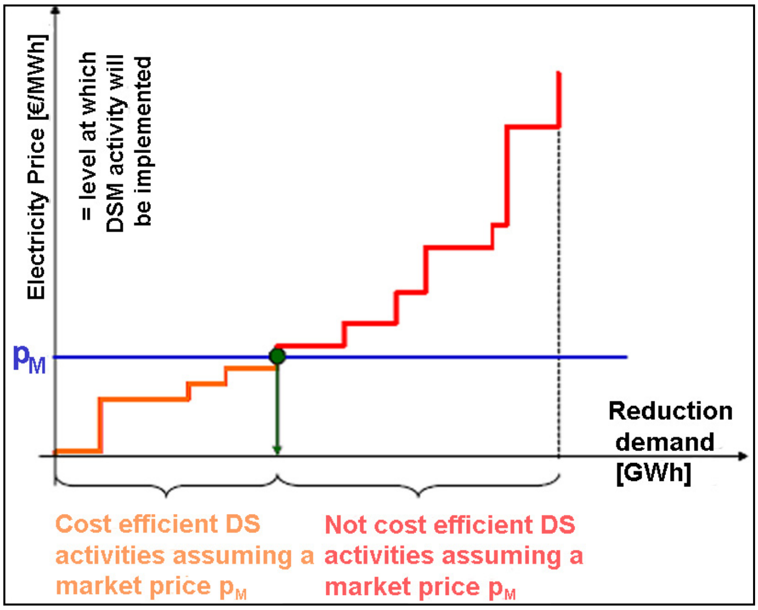


Figure 7: Energy Efficiency Measures on the Demand Side

3.2 Subsidies for Croatian Wind Power

Another important point concerning the costs of energy are the *subsidies.*

The tariff system for the electricity production in the framework of RES contains the producer's right to an incentive price payable by the market operator (called "feed-in-tariffs"). The most important tariff elements for cost calculation of RES electricity production are:

- The resource type
- The power and other elements of the supplied energy
- The means and conditions for the usage of these elements (Kopecek/Reis/Weinberger 2008, p. 17).

The tariffs are based on these elements:

- Justified operation costs
- Maintenance costs
- Replacement
- Construction or reconstruction of RES and other costs (Kopecek/Reis/Weinberger 2008, p. 17).

The application of the tariff systems of the energy prices is supervised by HERA (Kopecek/Reis/Weinberger 2008, p. 17).[1]

3.3 The Winds

The next point is which kinds of *winds* are blowing in Croatia, and which are suitable for generating energy by wind farms.

In Croatia, there are appearing the following, most known winds:

- *Bora:* This is a dry cold and squally catabatic wind. The air having cooled down on the high plateau of the Dinarish Mountains produces this wind. This wind hurls over the steep slopes down to the relatively warm Dalmatian coast and to the sea. The Bora causes a strong temperature reduction and is very stormy. Bora can produce a speed of nearly 100 km/h (Kopecek/Reis/Weinberger 2008, p. 20). *"In case those strong winds are further accelerated by down-gusts as this happens at the coast, extremely heavy gusts can reach up to 110 kn. Bald slopes of islands showing to the mainland mean that the Bora is extremely fierce in this area. The Bora can blow very short up to 5 days in the summer session. It is frequent in Golf of Triest, Golf of Rijeka and Kvarner Golf, Senj with Velebitski-channel, the region around Sibenik and Split, the north coast of the peninsula Peljesac and the region around Dubrovnik."* (Kopecek/Reis/Weinberger 2008, p. 20)

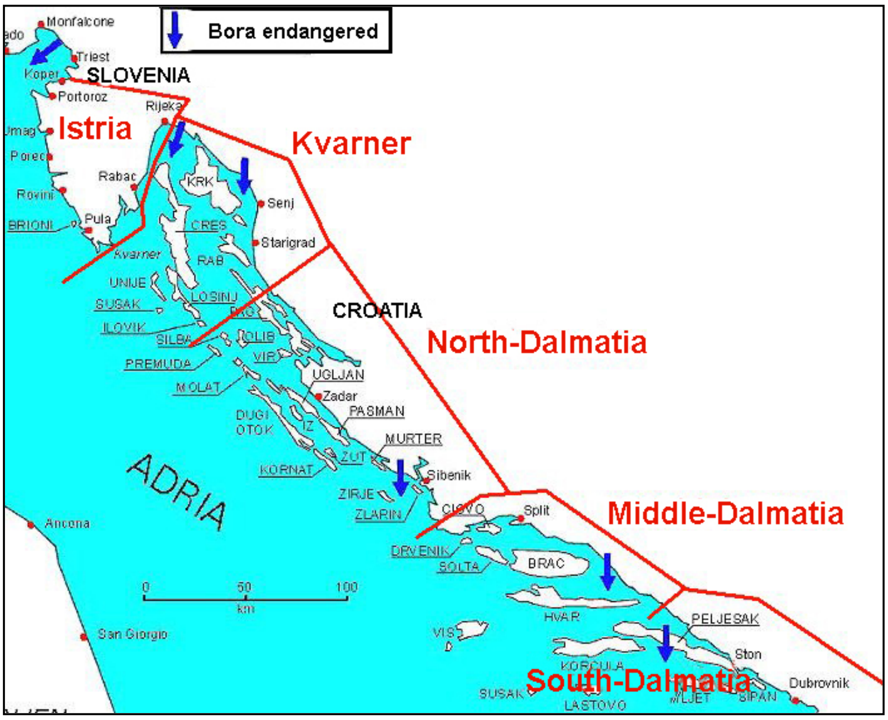


Figure 8: The Bora Wind Map
(source: http://www.esys.org/rev_info/croa-map.jpg)

- Concerning the Adria Wind Power ("Seewind") project, it can be said about "Bora" the following things:
  - Bora in the North is not a good wind, worst on Pag Island and in Senj, less a problem in the South. South has the *Scirocco* wind.
  - Bora is less bad in the Central region.

[1] Concerning the structure of the Croatian tariff system, see chapter 2.4.

  - Bora lasts only maximally 10 days, and it is better to switch off the plants then.
  - Predictability of wind needs improvement so that the wind mill operations could be more efficient; this measure would make the grid more stable (Kopocek/Reis/Weinberger 2008, p. 21).

- *Jugo:* The Jugo wind is warm and damp, coming from the South. “Jugo” occurs in the late summer, sets up in a slowly way und lasts several days until the rainy wind begins.
- *Maestral:* This is a local wind from the sea to the coast, which increases in the afternoon and cools the land tracts which are overheated by the sun.
- *Koshava:* The “Koshava” rises between the Carpathian and the Balkan mountains and is blowing from Romania to Serbia. It is caused by the differences in pressure and temperature of the bordering regions (Kopocek/Reis/Weinberger 2008, p. 22).

The Wind and Wave Atlas of the Mediterranean Sea looks like this (Cavaleri 2005, p. 257, figure 3):

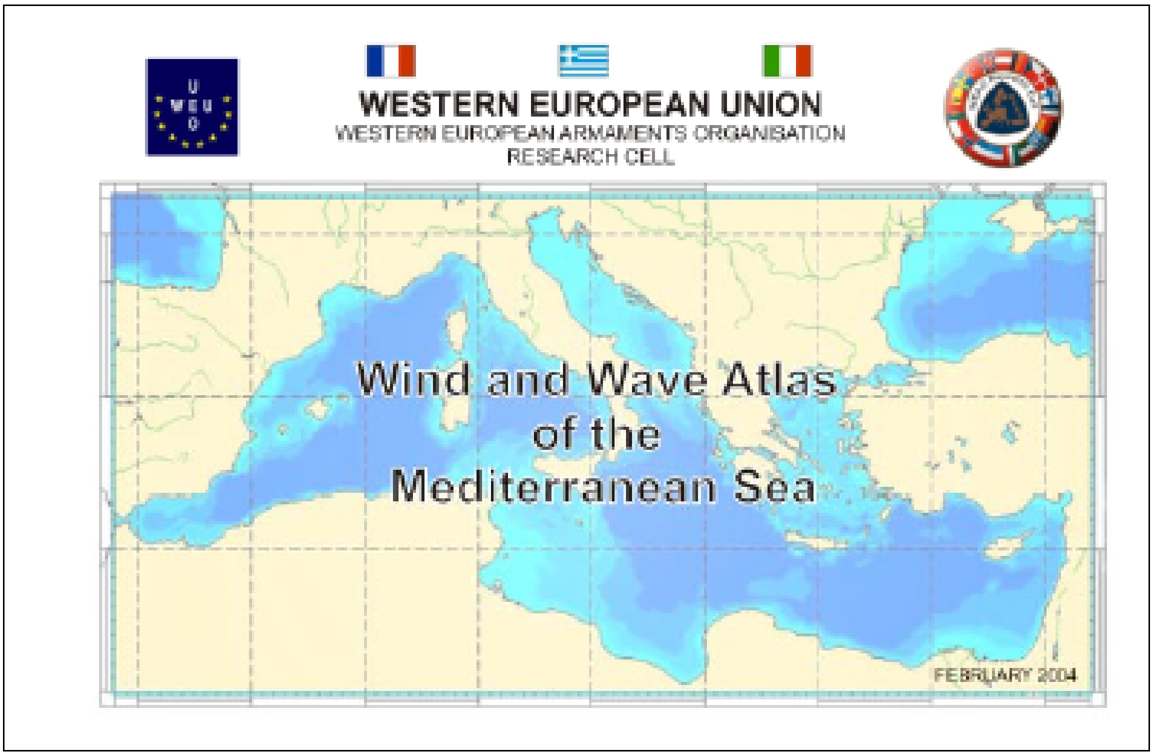


Figure 9: Wind and Wave Atlas of the Mediterranean Sea

3.4 Suitable sites for wind energy projects in Croatia

As next, the most suitable and promising sites for wind farm projects in Croatia must be thematized. The Croatian wind potential can be divided into four zones. The best sites are within 30 to 40 km from the shore and in the mountains, too. The most promising land is in state ownership and can only be rent. In the water, there is no offshore potential where the water becomes too deep further out. Furthermore, it is not allowed to build wind mills on islands and within 1.000 meters from the coastline as well in areas which are protected by the "Natura 2000" act[2] (Kopecek/Reis/Weinberger 2008, p. 24; see also: Goić/Lovrić 2005).

3.5 Planned projects and potential problems of the investors

The real existing wind-park projects have already been mentioned in chapter 3.1.2 (see table 3). Moreover, there are about 3.500 MW of developing projects, among them about 1.500 MW of high-developed projects (Kopecek/Reis/Weinberger 2008, p. 25; Ognjan 2009, p. 6).

Investors are considerably interested in wind-energy projects in Croatia, especially in the region of Dalmatia. Nearly 50 projects are in preparation or planned. The "Registry of Renewable Energy Resource and Cogeneration, Projects and Privileged Producers" lists the licensed projects. This prior authorization gives the developers of the wind energy projects the right for applying for all other licenses; this has the consequence that this is a crucial, important step in the development of WPS. The big national and

[2] *„Natura 2000 is an ecological network of protected areas in the territory of the European Union.. Croatia is in the process of establishing the Natura 2000 network. The country has a considerable wealth and diversity of flora and fauna. It has 65 diverse habitats, which are home to significant numbers of strictly protected and protected species: Protected areas cover a land area of a total of 5,379.41 km2 or ca. 9,5 %... The major part of this area is protected as nature and national parks and a* ***limiting factor to wind-park projects****."* (Kopecek/Reis/Weinberger 2008, p. 24; accentuation in the original text). Or see the self-description of "Natura 2000" on its homepage: *"NATURA 2000 is a basic program in EU nature protection policy. It includes a network of protected areas in all EU countries. These protected areas are important for conservation of endangered habitat types and species included in annexes of Council Directive 92/43/EEC (Habitats) and Council Directive 79/409/EEC (Birds). All member states contribute to establishing NATURA 2000 network by specifying Special Areas of Conservation, according to Article 4 of Habitat Directive."* (Natura 2000, 2007).

international players are registered. Big players like E.ON, RWE and EDF have already shown interest for developed projects (Kopecek/Reis/Weinberger 2008, p. 33).

The most important problems for investors which intend to invest into Croatian wind farms are:

- Spatial planning – not all locations are suitable or allowed.
- Environmental impact assessment – the consequences for the environment must be estimated before.
- Preliminary design vs. optimal positioning – not all designs fit to the chosen location.
- Grid capacity limit – there are limits of the absorption capacities of the available grids.
- Poor cooperation between authorities – this can cause time delays in the planning and implementation of projects.
- Frequent changes of legislation – this can cause additional costs or again time delays (Ognjan 2009, p. 7).

Here is not the place to describe all planned or/and projected wind energy mills within the territory of Croatia, but they can be mentioned here (Kopecek/Reis/Weinberger 2008, pp. 33-47):

- Adria Wind Power d.o.o. AWP will start up at least one plant in 2009.
- CEMP d.o.o. (CEMP = Cista Energija Mediterana I Panonije d.o.o.)
- CEMP d.o.o./KRS Padjane Project
- Dalekovod Eko
- Eko d.o.o.
- Eko-Energjja d.o.
- E. H. N. d.o.o. Split (Acciona Energia)
- Jura Energjja d.o.o.
- Jura Energija d.o.o./Project Wind-park Svilaja
- Kastel International, Zadar

- Koncar
- Koncar Tovarnik Project
- Potetnia Venti d.o.o.
- RP Global CSE d.o.o.
- GEP/Dovanj Project
- GEP/Bubrig and Crni Vrh Project
- GEP/Velika Glava Project
- SEM 1986 d.d. (Investment: 12 Mio. €)
- VALALTA d.o.o – Wallenborn/Vratarusa Project (Investment: 55 Mio. €)
- Wallenborn/Project Senj (Investment: 84 Mio. €)
- WPD AG (Enersys)/Project wind-park in Peljesac (Investment: 35 Mio. €).

3.6 One way to find more out: The Dynamic cost potential curve

There was only few research concerning the estimated and *realisable* wind potential in Croatia until now; the main results of this research will be thematized in sub-chapter 4.4. But one way for more successful and important research in this direction is the method of the so called *"dynamic cost potential curve"* resp. *"dynamic cost-reserve curve"* which will be discussed in the following.

3.6.1 Supply-demand equilibrium

The RES (Renewable Energy Sources) market follows the same regularities as other markets. For this reason, it seems necessary to consider the supply-and-demand aspects of markets in general at first; later the specifities of the RES-market are stated. For developing a dynamic cost potential curve for the RES-market and making its preconditions a subject of discussion, this sub-chapter follows in main points the description of Gustav Resch (2005).

The Equivalence Theory is derived from the economic theory, and you can describe it as such: *"A supply-demand equilibrium is reached when the sum of producer's and consumer's surpluses is maximized."* (Resch 2005, p. 14).
An equilibrium figure shows the case when one commodity is exchanged. The equilibrium point is represented by the letter "E". It occurs as the intersection of the supply and the demand curves (here: RES-E). Consumer supply is the difference between what a consumer is paying and the higher price that he/she would pay for smaller quantities. The producer surplus is the difference between the received price and the lower price accepted in the case of smaller quantities (Resch 2005, p. 14).

"Obviously, the area between the two curves is maximized at point E, representing the intersection of both curves. Producer and consumer surpluses in sum are often called the net social surplus, which is a proxy for welfare." (Resch 2005, p. 14).

The following figure shows the equilibrium between demand and supply for a very *competitive* market (Wikipedia 2009 a):

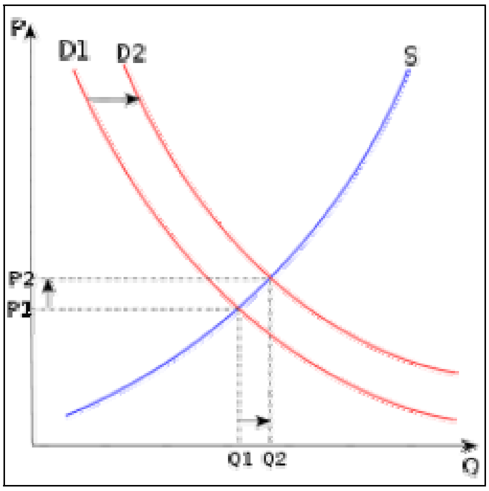


Figure 10: Illustration of a supply-demand equilibrium (S for Supply, D for Demand)

The figure can be described in the following way:

"The price P of a product is determined by a balance between production at each price (supply S) and the desires of those with purchasing power at each price (demand

D), along with a consequent increase in price and quantity Q sold of the product." (Wikipedia 2009 a; see also: Encyclonomic WEB-pedia 2009)
The Equivalence Theory implicates some simplifications, f. e. the linearization of demand by piecewise linear mathematical functions (Resch 2005, p. 14).

3.6.2 Supply and demand in the field of the electricity market for RES-E

The RES equilibrium point E for the electricity market can be described from a static point of view, which is only a simplified one. Given an initial demand before any promotional strategy (this amount can be described as the intersection between of the demand-curve D and the supply curve S'), this initial demand can be named q0 for the electricity generated by RES. Rabates f. e. shifts the supply curve downwards (S'). This has an increase of the total electricity generation from RES as a consequence (from q0 to q1 and q2). A strategy on the demand side (f. e. quota) moves the demand curve upwards (D''); this leads to the electric output q3. Under the precondition of a voluntary willingness to pay (D') the electricity output will raise up to q1 (Resch 2005, p. 15).

A similar situation is shown in the following figure: An out-ward or right-ward shift in demand increases both equilibrium price and quantity (Wikipedia 2009 a; see also: Gillis 2009):

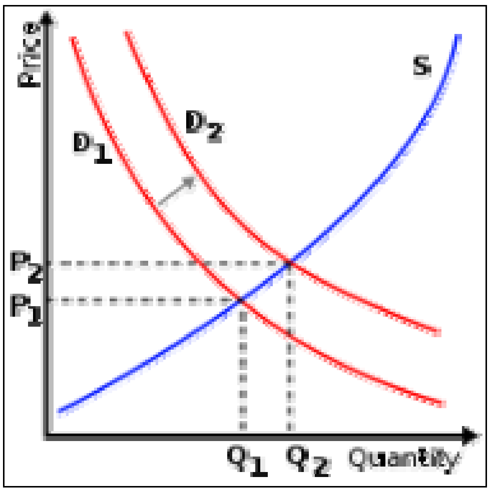


Figure 11: Supply and demand "behaviour" in the case of a right-ward shift, increasing both equilibrium price and quantity

Summarized, the basic principles of static-resource curves are (Weißen-steiner/Resch/Obersteiner 2008, p. 6):

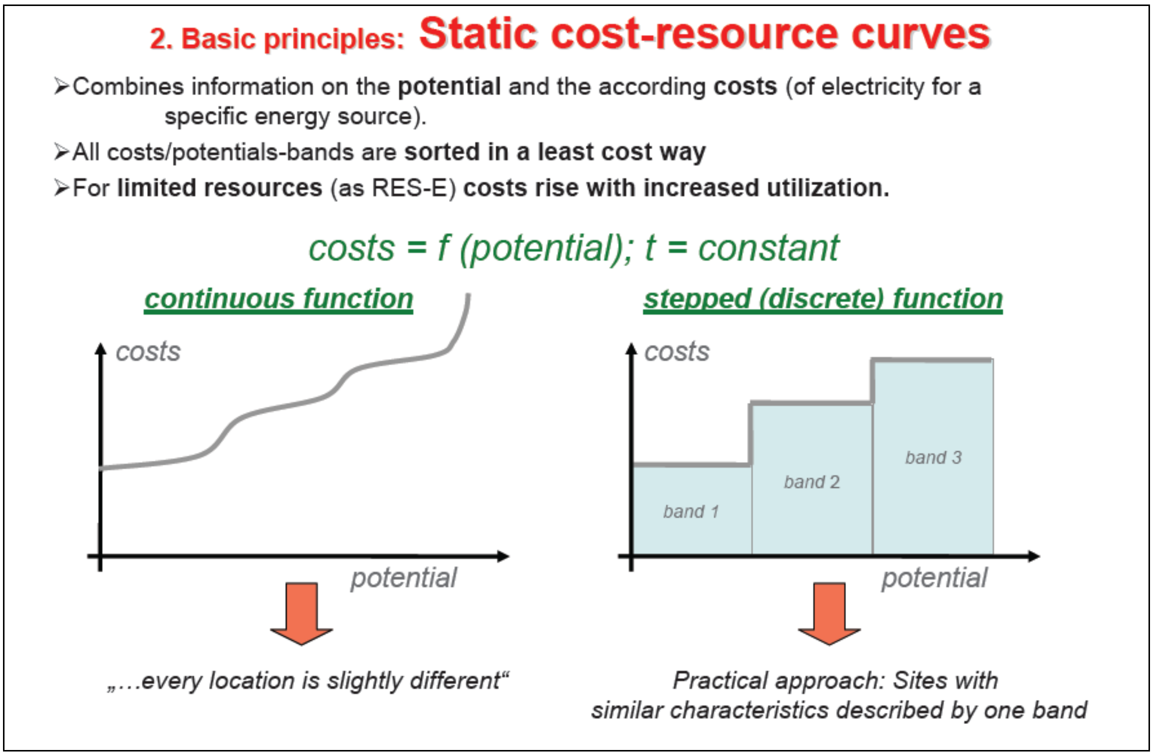


Figure 12: The basic principles of static cost-resource curves

3.6.3 Important influences on the supply-side

The most important factors on the supply-side are, in the case of RES-E:

Costs and potentials for RES-E

The unit costs of the electricity and the consequent potentials of them constitute the parameters of the supply-side. In a competitive and deregulated capitalist market, these costs have a huge influence on the energy source which is used for the production of electricity.

"As long as an overcapacity of power plants exists to meet electricity demand, no new power plant is necessary to meet the demand. Accordingly, competition between the different generators is only determined by the variable costs of a plant. With future demand growth and plant replacement, new capacity has to be constructed. Competi-

tion between different >new< generators is influenced by the total costs of electricity generation." (Resch 2005, p. 15).

The advantages of using more wind power energy in Croatia when the demand will grow in the future are:

- A lower increase in the price of electric energy
- Croatia is getting more independent from other countries. Until now 25 % of electricity has to be imported.
- Wind power creates local employment
- Wind energy offers a secure supply from domestic sources (Godjevac/ Sharbafian/Tsoukanas 2008, p. 32).

In the cases of an overcapacity and a future demand growth, combined with a plant replacement, the costs are depending on these factors:

- An applied conversion technology and
- An applied energy source (Resch 2005, p. 15).

But there is still another correlation which must be regarded: the correlation between the costs of generating electricity and the availability of capacities. Every energy resource (fossil fuel, gas, nuclear power, RES or whatever) for generating electricity has its own limitations (for the usage of wind energy in Croatia see: Godjevac/Sharbafian/Tsoukanas 2008, p. 32 ff.); this has the consequence that the costs are depending on the previous exploitation and the established and available capacity. As an example you can take the wind energy: if the best sites for generating wind power are already in use, the costs of electricity generation produced by wind increase (Resch 2005, p. 16).

A stronger promoted penetration of the Croatian electricity market by RES-E as a future strategy must be planned very carefully on the basis of a detailed analysis of costs and potentials for generating electricity by different kinds of RES (Resch 2005, p. 16).

Strategies for RES-E driven by the price on the demand-side

In the past, there were used several measures and instruments for reducing the high costs of electricity generation. Some of these incentives on the supply side are called the *price-driven instruments* (Resch et al. 2005).

The *demand side* depends on the following factors:

The viewpoint of the industrial economy

The price for conventional electricity depends on the demand and supply for electricity in general. There are different price levels in the electricity market in every country and in every region. The further deregulation of the electricity market and the efforts of "liberalization" on a global level will urge these differentiations of the prices.
Under these conditions, the price of conventional electricity/energy production will influence the market penetration of RES-E, too. Only if the quantity of "eco" or "green" electricity is raised, this could lower the costs and the price of "green" energy and could be competitive with the already existing price level of conventionally produced electricity (Resch 2005, p. 16).

The attendance of paying for electricity produced by RES

Promoting RES-E *("green tariffs")* is depending on the willingness of the consumers to pay voluntarily *more* for "green" electricity/energy compared with its "grey competitors". Especially in the Northern parts of Europe, the consumers are willing to pay a higher price for "green" energy, as surveys show, most notably in these countries:

- Denmark
- Luxembourg
- Netherlands
- Finland
- Sweden (The European Opinion Research Group 2002).

But there are still bigger divergences between the real demand and the aspiration which is expressed in such surveys (Resch 2005, p. 16).

There are connections between regulatory and voluntary approaches; the regulatory approaches influence the voluntary ones, as f. e. Menges (2003) could point out. *"This interaction relates to the existing asymmetrical relationship between both approaches, which explains the... relatively poor >readiness< of German consumers, facing a high regulatory demand for RES-E, to pay more for green electricity, despite their well-known environment awareness."* (Resch 2005, p. 16).

Strategies for RES-E on the demand-side, driven by quantity

An additional demand for RES "green" electricity/energy could be generated by the governments of the diverse countries. If a quota for RES-E is established, a mandatory (inelastic) demand for "green" electricity would be the result. This inelastic demand is generated because obliged actors *"are required to pay a higher price for electricity from RES in order to fulfil the quota qQ."* (Resch 2005, p. 17). If green electricity is produced more than the quota level prescribes, no one will demand an additional quantity (Resch 2005, p. 17).

Summarized, the *potentials* of static cost-resource curves can be shown in this figure (Weißensteiner/Resch/Obersteiner 2008, p. 7):

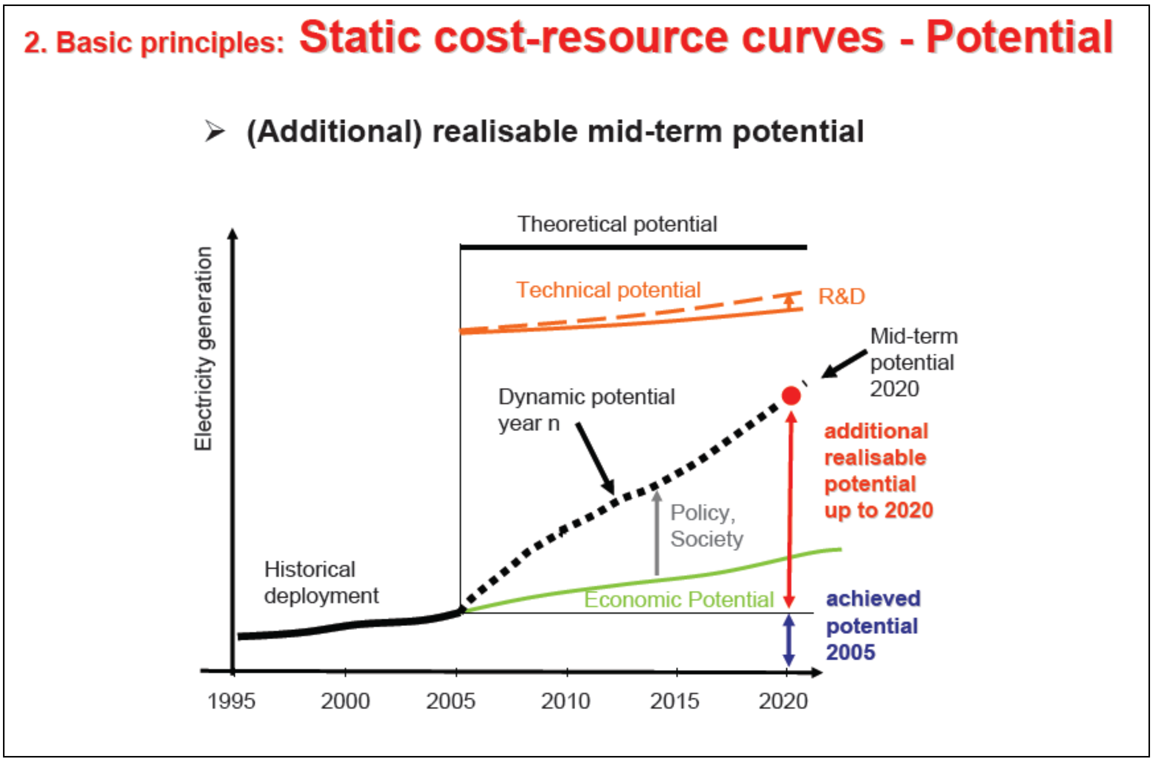


Figure 13: The potentials of the static cost-resource curves (basic principles)

3.6.4 The concept of dynamic cost resource curves for RES-E – the overcoming of the static point of view

The concepts of *dynamic cost-resource curves* concerning electricity generation resp. production which can go further than the static ones, are based on the following three principles explained next.

<u>Static curves concerning cost-resource</u>

Renewable energy sources are limited, with the consequence that the costs are rising with increasing usage. If wind power sites are exploited first, these sites are gone, the following wind power sites will create increasing costs for the generation of electricity. This can be represented with the static cost-resource curve which describes both costs and potential (Resch 2005, p. 18).

Seen generally, the static cost-resource curve is describing the relation between technical available potentials (f. e. wind energy, biogas, hydropower a. s. o.) and the correlative costs of using this potential at the particular date (the static cost-resource curve cannot express learning effects and technological progress) (Resch 2005, p. 18).

Curves driven by experience

In the long run, the ongoing technological development is an important factor for a raising market of green electricity production/generation. Energy models have the intention to consider the technological development factor for their modelling. The conventional method of modelling exclusively is based on exogenous forecasts by expert judgements (efficiency studies) of the technological developments and the economic performance (investment, O & M costs a. s. o.). In the meantime, descriptions of cost dynamics generated by technological developments allow endogenous outlooks on the technological change in future energy models. *"This approach of so-called technological learning or experience/learning curves takes into account that a decline of costs depends on accumulation of actual experience and not simply on the passage of time."* (Resch 2005, p. 19).

Experience curves picture the relationship between declining costs and the cumulative production (of technological progress). The latter involves the accumulated experience of inventing and using a particular technology. The empirical experience shows that the costs decline by a constant percentage with each doubling of the units which are produced or implemented (Resch 2005, p. 19).

The formula for the experience curve can be described in such a way (Resch 2005, p. 19):

CCUM = C0 * CUMb

Explanation:

CCUM = Costs per unit as a function of output

C0 = Costs of the first unit produced or implemented/installed

CUM = Cumulative production over time

b = Experience index

Figure 14: Formula of the experience curve and its elements

The experience index (b) is used for the description of the relative cost reduction for each doubling of the cumulative production. The value (2b) can be described as the *progress ratio (PR)* of the cost reduction. Progress ratios and their pendants, called *learning rates (LR)* (i. e. LR = 1-PR), can express the progress of cost reductions for different types of technologies. An example can explain this: A progress ratio of 85 % means *"that costs per unit are reduced by 15 % for each time cumulative production is doubled."* (Resch 2005, p. 19)

Grübler et al. (1998) makes the following constraint for the "experience formula": *"... such straight-line plots should not be misunderstood to imply that >linear< progress can be maintained indefinitely. The potential for reduction becomes increasingly exhausted as the technology matures."* (Grübler et al. 1998)

The experience curve can be illustrated in a figure in such a way (Wikipedia 2009 b; see also: National Aeronautics and Space Adiministration 2007):

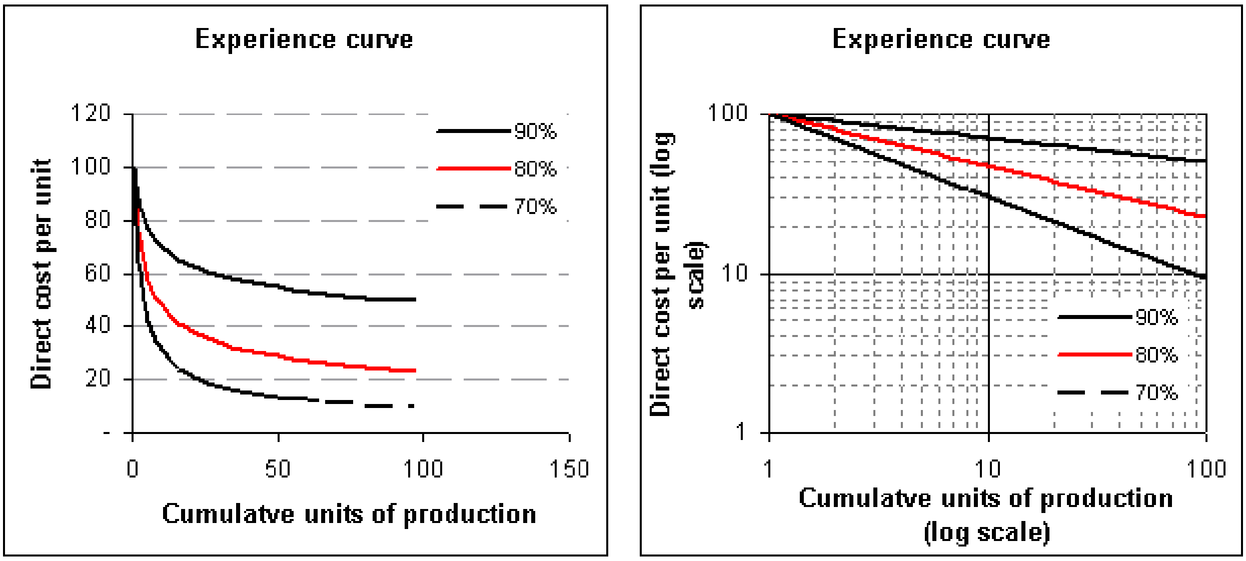


Figure 15: Experience curve

The experience is made on different levels, f. e.:

- Individuals in performing routine tasks
- Organisations on a logistic level
- Plant management a. s. o. (Resch 2005, p. 20; Grübler et al. 1998, pp. 247-280).

Diffusion of technology

For technology dynamics, there is another factor of main importance: the way technologies diffuse through competitive markets (Grübler et al. 1998). The general diffusion theory shows that the penetration of market by a new commodity can be described by an "S curve" (Resch 2005, p. 20). The S curve concept can be illustrated by this figure (Christensen 2004, p. 1):

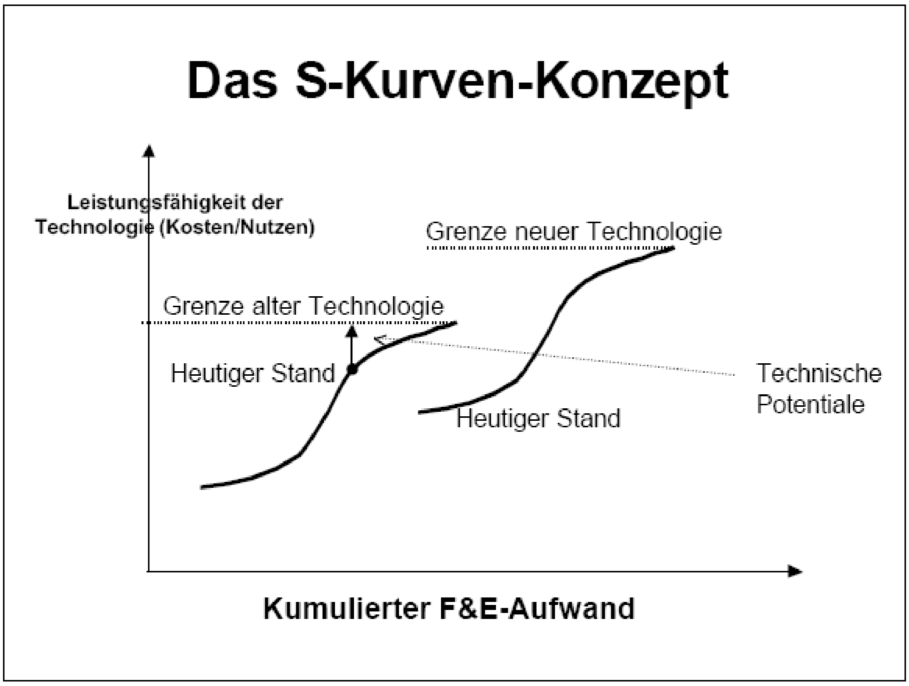


Figure 16: The S curve concept (text in the figure in German)

The S curve concept *"points to relatively modest growth in the early stage of deployment, whilst the costs of technologies are gradually reduced to an economically competitive level. As this is achieved for more competitive technological concepts, there* *will be accelerating growth in deployment over the medium term. This will finally be followed by a slowing down in deployment, corresponding to nearly full penetration of the market."* (Resch 2005, p. 20)

At last, the principles of the experience curves are shown in this figure (Weißen-steiner/Resch/Obersteiner 2008, p. 10):

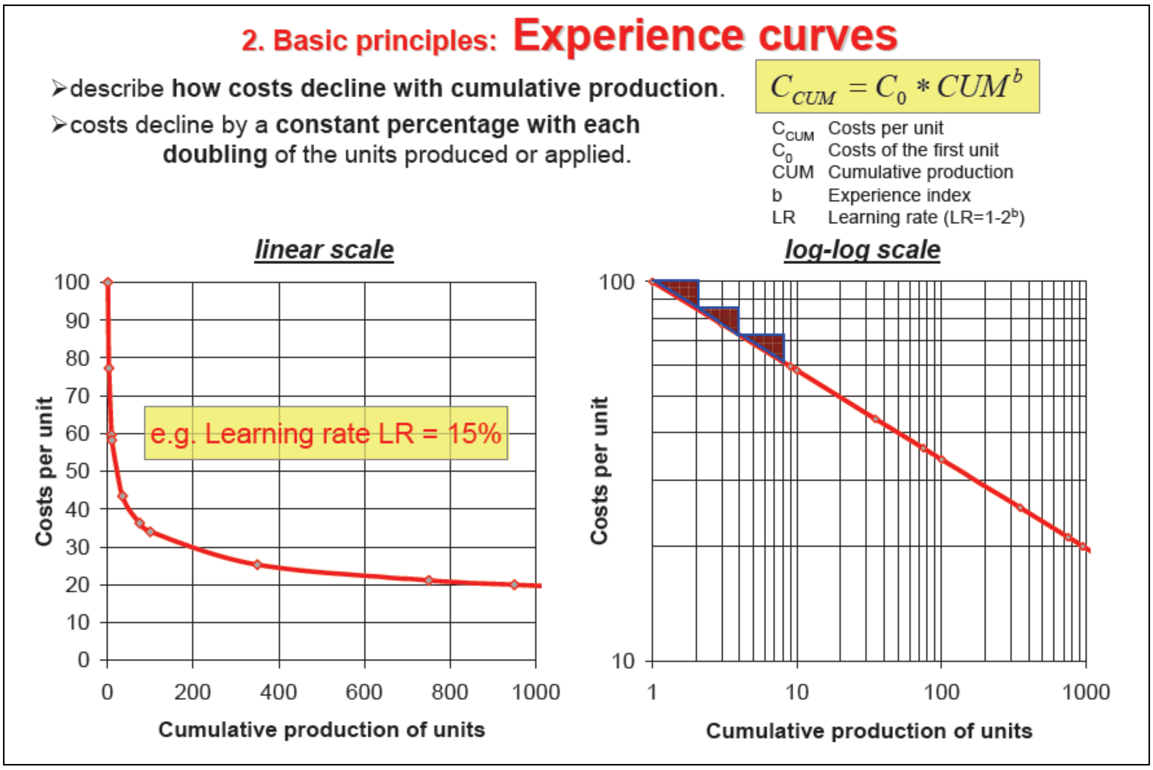


Figure 17: The basic principles of experience curves

3.6.5 The dynamic cost-resource curves for RES-E

A *dynamic cost-resource curve* is a tool to combine the three methods which were described in chapter 3.6.4. These approaches/methods were (to remember it):

- The formal description of costs resp. potentials by means of static cost-resource curves;
- The dynamic cost assessment by using experience curves;

- Implications of dynamic restrictions in combination with technology diffusion (S curve concept) (Resch 2005, p. 21).

The dynamic cost-resource curves are suitable for developing the *"Green-X model"* (Resch 2005, p. 21). This model is a method to combine the following parts:

- *Developing a static cost-resource curve for each RES-E category for diverse investigated countries:* As already mentioned, these curves describe potentials which are available, and also the connected costs. In this context, the Green-X model has to make a sharp distinction between already existing plants (f. e. wind energy plants) (achieved potential), and new planned plants for generating electricity (this is the additional mid-term potential). The economic conditions for new energy-producing plants can be described by *long-term marginal costs*; for the already existing plants the *short-term marginal costs* are more relevant (inclusive fuel and O & M costs). For new options concerning the potentials the *additional realisable mid-term potentials* can be analysed for each RES-E category on country-level. So the maximal additional achievable potential for the year 2020 can be estimated (under the assumption that all barriers can be hurdled and all driving forces could be activated).
- *The dynamic valuation, including a dynamic assessment of costs and potential restrictions (constraints):* The Green-X model can be analysed and described on an annual basis. The goal is to derive dynamic cost-resource curves for each particular year, whereby the already mentioned static cost-resource curves are considered. There are two in the Green-X model: the dynamic cost assessment and the application of dynamic constraints (Resch 2005, p. 22).

For the most RES-E technologies (wind power, biogas, hydro-power, sun energy a. s. o.), the basis is always the ability to learn (technological learning in the sense of technological progress for reducing the costs of energy production). Technology-based learning rates can be estimated for each decade separately, with regard to the global development in cultivating new "green" energy technologies (Resch 2005, p. 21, Wene 2000)

The dynamic cost-resource curves for RES-E and their basic principles can be summarized in this figure (Weißensteiner/Resch/Obersteiner 2008, p. 11; see also: Barth/Weber/Swider 2008):

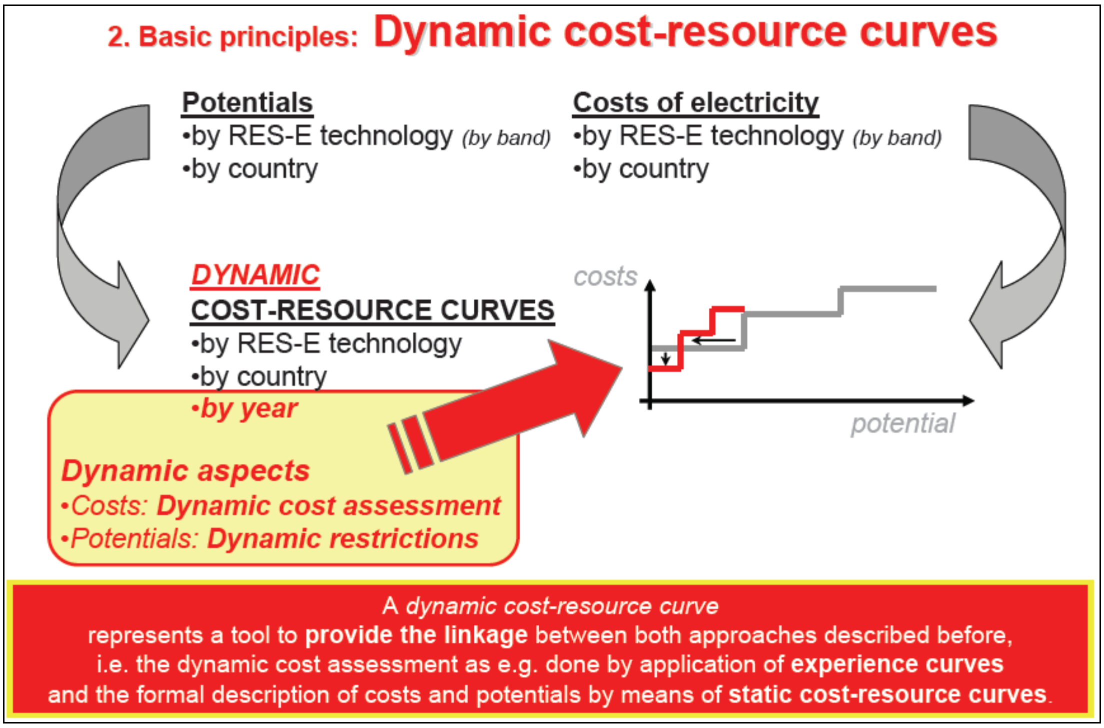


Figure 18: The basic principles of the dynamic cost-resource curves

But also the dynamic *restrictions* resp. *limitations* of the potentials must be considered; these constraints are shown in this figure (Weißensteiner/ Resch/Obersteiner 2008, p. 8):

2. Basic principles: Dynamic restrictions - Potentials

➢Dynamic **limitation of annual realisable potential…**

Dynamic restricitons & their characterization		Techn.-specific	Country-specific	Band-specific	Linkage to policy	Impact on Costs	Impact on Potentials	Methodology to implement
Industrial constraints	Growth rate of industry	X					X	EU-wide limitation of annual installations…
	…							
Technical constraints	Grid constraints (i.e. extension necessary)	X	X	X		(X)	X	Band-specific limitation of annual installations, additional costs for grid extension…
	…							
Market & administr. constraints	Market transparency	X	X				X	…
	„bureaucracy“	X	X		X	(X)	X	…
	…							
Societal constraints	'Willingness to accept'	X	X	X	X		X	(Band-specific) limitation of annual realisable potential

Figure 19: The dynamic restrictions of the potentials (basic principles)

3.6.6 Criteria and options for the Croatian energy policy

The basic principles of cost-resource curves from a static point of view for the *marginal costs* (costs for electricity) are illustrated in the following picture; this must be mentioned first before we can go forward to the dynamic standpoint (Weißensteiner/Resch/Obersteiner 2008, p. 9):

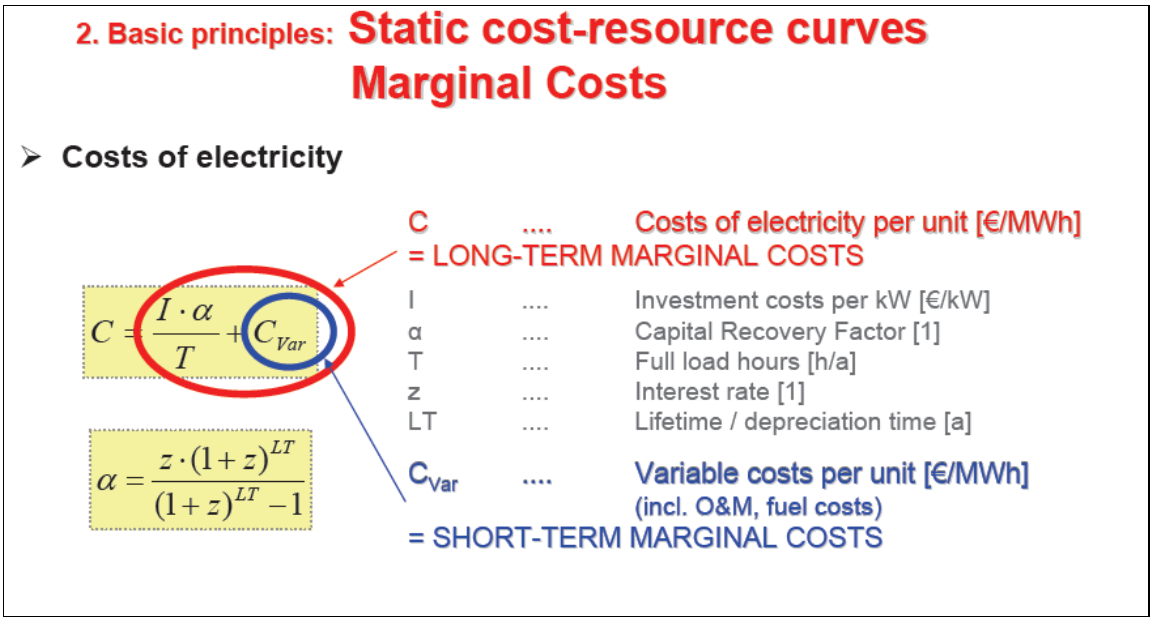


Figure 20: Static cost-resource curves for the marginal costs (basic principles)

The development of instruments and methods for a "mixed" energy policy for RES-E must take the dynamic cost-resource curves under consideration[3] which are advancements of the static-resource curves for the production of electricity.[4] An evaluation of these instruments for a "green" energy policy especially in Croatia has to find out criteria which are convenient for and adjusted to this policy (Resch 2005, p. 23). Energy policy instruments for RES-E must be

- *effective* for raising the penetration of RES-E and
- *efficient* with regard to minimizing/reducing the resulting public costs (which are the transfer costs for consumers and the society in general[5]) in the long run (Resch 2005, p. 23).

For fulfilling these challenges, the following conditions for a "green" energy policy in Croatia must be taken into account:

[3] See also chapter 3.6.4 und 3.6.5.
[4] See for this chapter 3.6.1 to 3.6.3.
[5] „***Transfer costs for consumer/society*** *(sometimes also called additional/premium costs for consumer/society) are defined as direct premium financial transfer costs from the consumer to the producer due ro the RES-E policy compared to the case that consumers would purchase conventional electricity form the power market. This means that these costs do not consider any indirect costs or*

- *Minimizing energy costs:* This goal can be achieved when the total RES-E generation costs (GC) can be reduced to an achievable minimum level. For this reason, the system should offer incentives so that the investors can select technologies, sizes and sites which can reduce the generation costs effectively.
- *Lower producer profits:* In a second step, the minimizing/reduction of the transfer costs for consumer/society must be attempted. For this, the feed-in tariffs, the subsidies or the trading systems should be designed in a way that these transfer costs can also be minimized. This point also means that the producer surplus (PS)[6] must be limited (Resch 2005, p. 23 f.).

The following figure shows the basic definitions of the cost elements (Huber et al. 2004, p. 12, fig. 3.1):

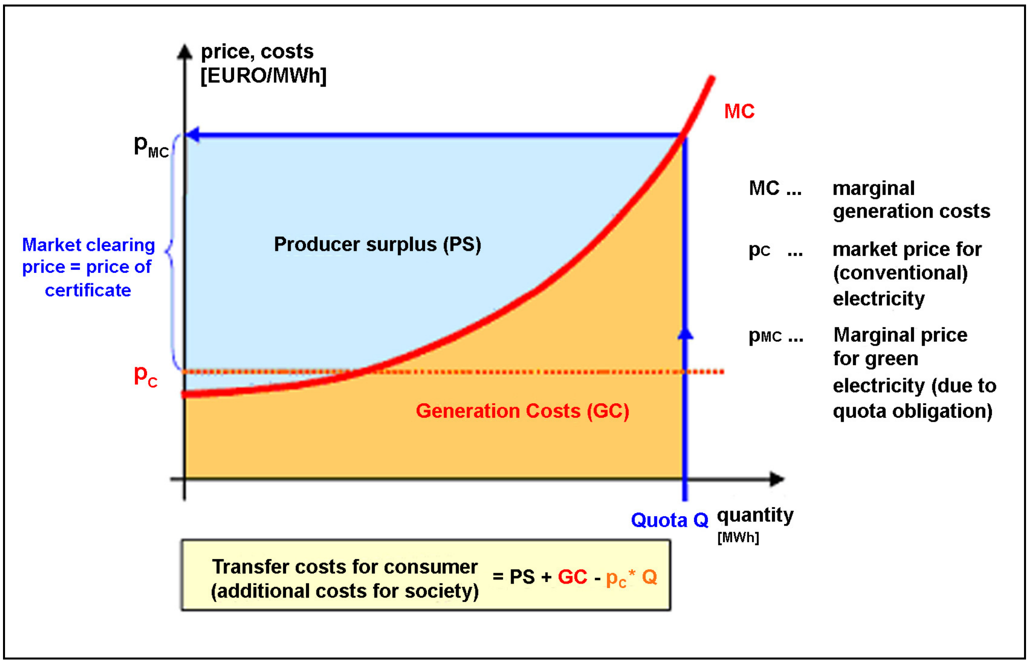


Figure 21: Basic definitions of the cost elements

externalities (environmental benefits, change of employment, etc.)." (Resch 2008, p. 23, footnote 43; accentuation in the original text).

[6] *„The producer surplus is defined as the profit of the green electricity generators. If for example, a green producer receives a feed-in tariff of 60 € for each MWh of electricity he sells and his generation costs are 40 €/MWh, the resulting profit would be 20 € for each MWh. The sum of the profits of all green generators defines the producer surplus."* (Resch 2005, p. 24, footnote 44)

A strategy for renewable resources in the framework of a green energy policy concerning f. e. the legislation, has to consider the following principles with the goal of minimizing the costs and avoiding possible barriers for the implementation of RES technologies:

- *Simplicity:* Defined quota for RES in combination with a guaranteed feed-in-price;
- *Fairness:* The incremental costs of support mechanisms have to be carried by *all* customers/consumers f. e. with the help of a specialized fee which must be added to the electricity price;
- *Practicality:* All existing institutions should be involved through spreading the obligations and arranging the authorization procedures;
- *Transparency:* All cash-flows for the promotion of RES should be clear and really transparent;
- *Flexible approach to implementation and possibility of extension:* This includes – among others – the possibility of dividing the energy price into the market price on the one hand and green components on the other a. s. o. (Horváth 2006, p. 3).

The regulation of the RES market in the framework of the general electricity market was started with the following ideas, which were enlarged on the Croatian electricity market by political means in the last years and are still under construction in the sense of establishing a well-working green electricity sector in Croatia:

- The minimum share of RES-E of the whole energy production of Croatia should be determined by the Croatian Government.
- Renewable producers should get incentives for a total quantity of RES electricity until the quota determined by the Croatian government is achieved.
- The system operator should be responsible for the take-off of the electricity production generated by RES.
- The preferential support system should be based on fixed and guaranteed feed-in-tariffs.

- Mechanisms for incremental cost distribution should be stimulated inter alia by a newly established market operator (in cooperation with LoEM), which should be responsible for the management of these mechanisms, too.
- Money for the incentives should come from a special fee which should be part of the electricity price.
- The market operator should contract with renewable producers on the one hand, and the electricity suppliers on the other hand (Horváth 2006, p. 3 f.).

"Due to generally high production costs the legislator envisaged the introduction of financial support to wind and other RES. At the same time, supply companies are obliged by law to use a certain portion of RES in the energy mix they are selling... the law obliges the Government of Croatia to define this share by the ***Decree on minimum share of RES and cogeneration****. The role of an intermediary between renewable producers and supply companies is given to the recently established independent market operator. According to the LoEM, the market operator is responsible for contracting with renewable generators on one side, and remunerating them at a price determined by the* ***Tariff system for electricity production from RES and cogeneration****, and with suppliers on the other, ensuring that they fulfil their legal obligations."* (Horváth 2006, p. 4; accentuations in the original text)

The following figure shows the already achieved and additional RES-E mid-term resource potentials for "green" electricity for the EU 27, specialized for every country level; these are the frameworks for the energy policy in which it has to act actually and in the future (Weißensteiner/Resch/Obersteiner 2008, p. 13):

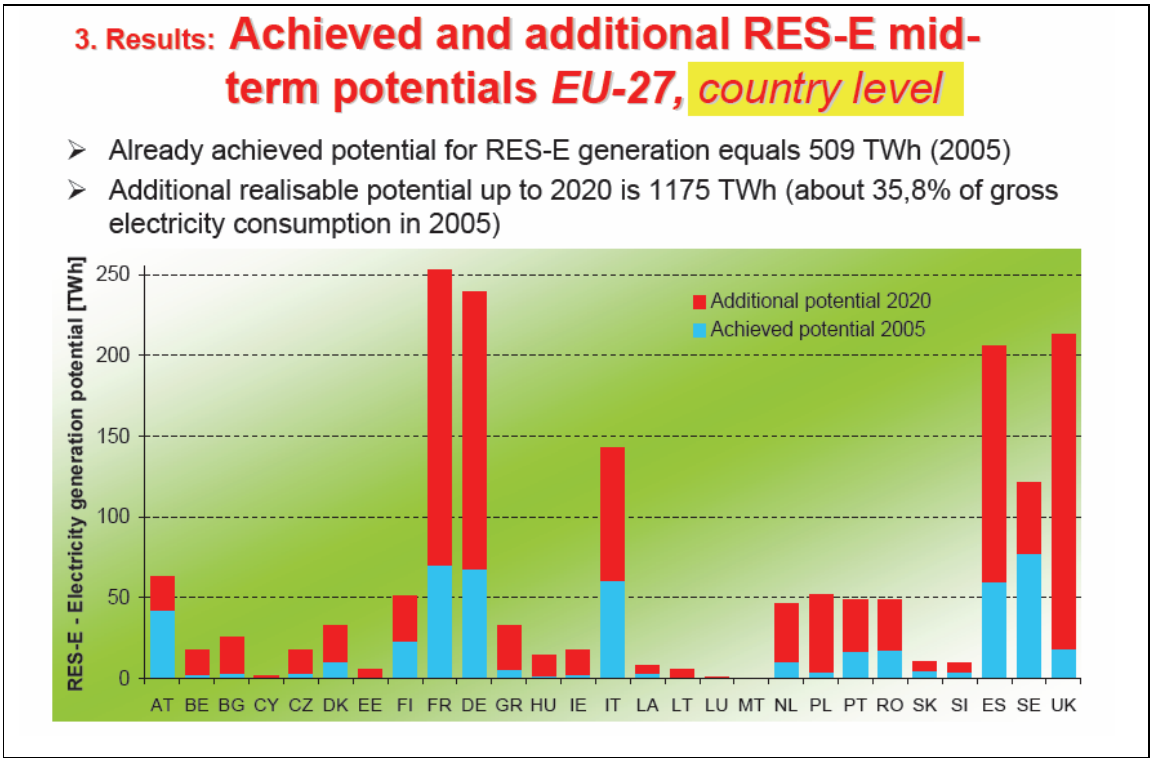


Figure 22: Achieved and additional RES-E mid-term potentials EU-27, specialized for every country level (2005/achieved and 2020/intended)

3.7 Calculation

3.7.1 The model Green-X computer simulation: an introduction

The *Green-X computer model* was developed by the Energy Economics Group (EEG) and the Vienna University of Technology which allows a comparative and quantitative analysis of the interactions and the relationships between RES-E, CHP, DSM activities and GHG-reduction within the liberalized and de-regulated energy sector for the EU-27 and the countries Switzerland, Norway and Croatia (Resch 2005, p. 25; Huber et al. 2004 a, Faber et al. 2004). But also several Balkan countries are included as a database for Green-X resp. Green*Net*, as the following figure shows (Weißensteiner/ Resch/Obersteiner 2008, p. 3):

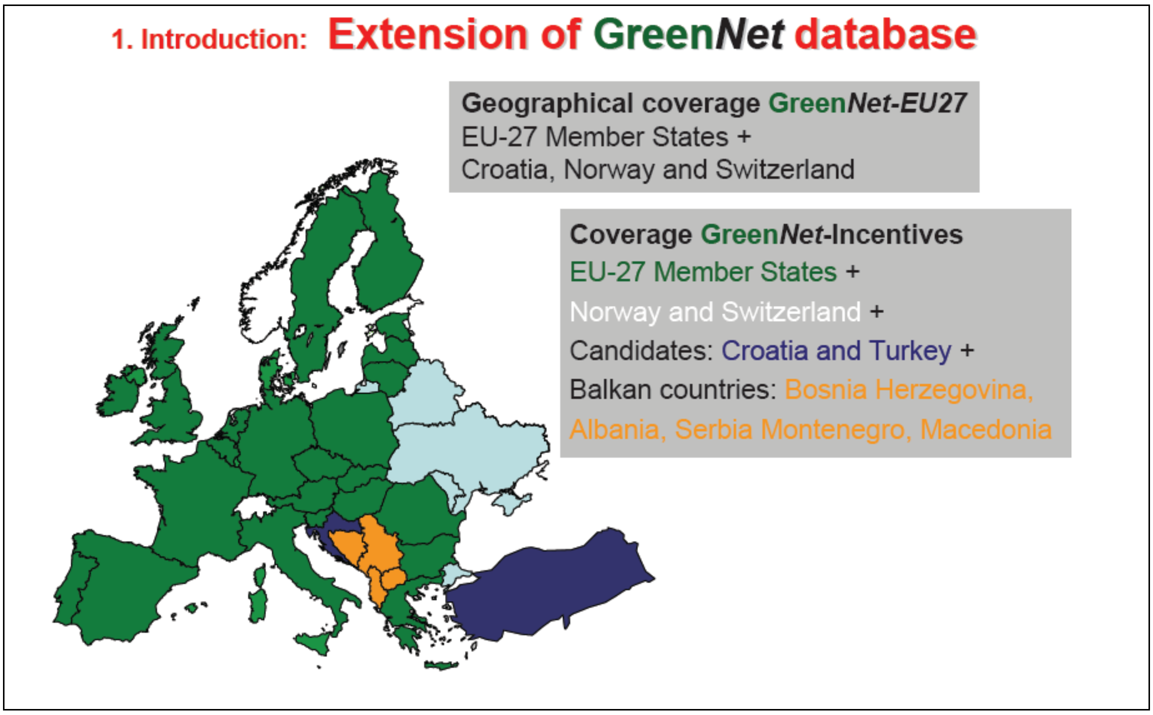


Figure 23: Extension of Green-X resp. Green*Net* database

The following figure gives an overview of the most important elements of the Green-X computer model (Huber et al. 2004 b, p. IX, fig. 0.1):

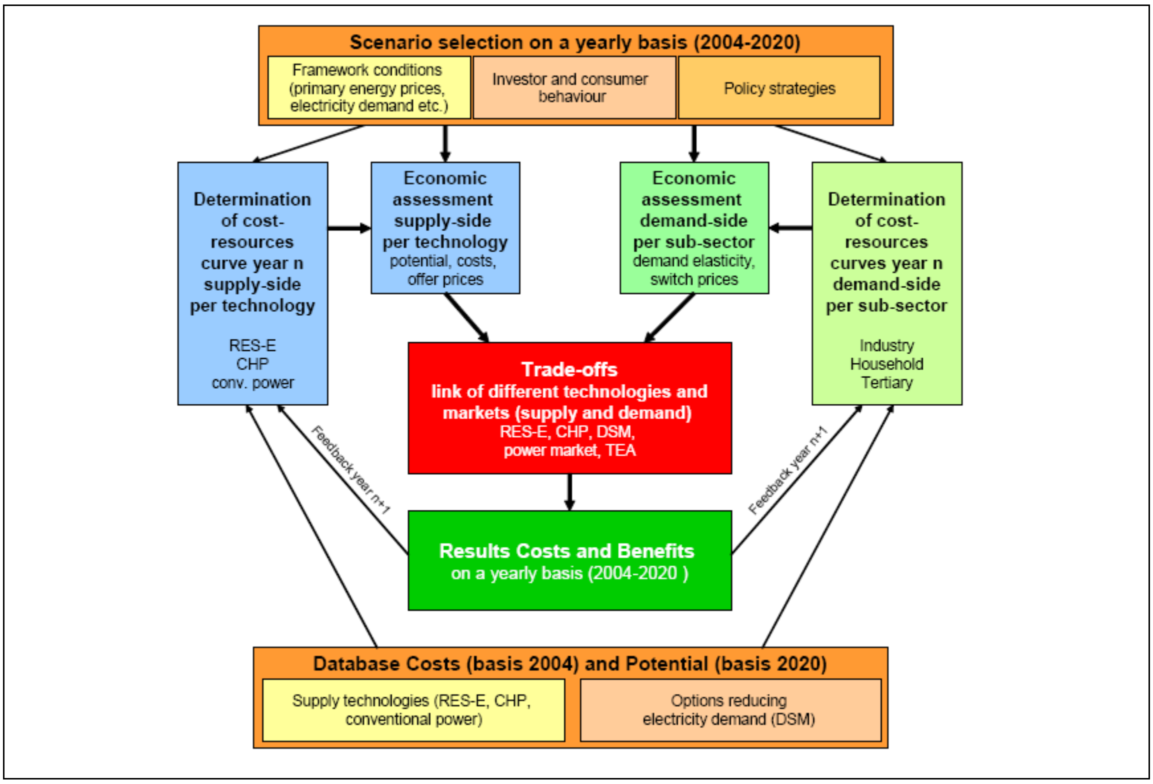


Figure 24: Overview on the computer model Green-X

"The general modelling approach to describe both supply side electricity generation technologies and electricity demand reduction options is to derive dynamic cost-resource curves for each generation and reduction option in the investigated region. Dynamic cost curves are characterised by the fact that the costs as well as the potential for electricity generation/demand reduction can change year by year. The magnitude of these changes is given endogenously in the model, i. e. the difference in the values compared to the previous year depends on the outcome of this year and the (policy) framework conditions set for the simulation year." (Resch 2005, p. 25).

The Green-X scenario considers the following specific conditions for developing a dynamic cost-resource curve:

- The chosen policy strategies
- Investor behaviour
- Consumer behaviour
- Primary energy and demand forecasts (Resch 2005, p. 25).

The selected policies are the most important factor for the price-driven strategies (feed-in-tariffs, investment subsidies, tax incentives, subsidies on fuel input a. s. o.) and the demand-driven strategies (quota obligations on the basis of tradable green certificates, tendering schemes). All these instruments can be used for RES and conventional options, including a combination of heat power and power production. The general taxes including the energy taxes, environmental taxes on CO2-emissions, policies supporting the demand-side as well as climate policy options can be adjusted as required, the effects can be simulated. Green-X makes it possible to change and modify the policy and parameter settings in a simulation run (f. e. by year). Each country can be analysed individually (Resch 2005, p. 25).

The results of every year can be derived by fixing the equilibrium level of demand and supply within each investigated market segment, f. e. the tradable green certificate market, electricity power market, tradable emissions permit market a. s. o. So the different technologies can be collected in the framework of each market; the equilibrium point fluctuates with the calculated demand (Resch 2005, p. 25).

For each state, the Green-X simulation model can appropriate the following outputs on a yearly basis up to the year 2020; also this can be done for each technology concerning the electricity generation/production (Huber et al. 2004 b, p. IX). So the mentioned outputs are:

General results

- Installed capacity (MW)
- Total fuel input electricity generation (TJ, MW)
- Total electricity production (GWh)
- National electricity consumption (GWh)
- Import/export electricity balance sheet (GWh, % of generation)
- Total CO2-emissions produced by electricity generation in comparison with the selected scenario baseline (%)
- Electricity market price (annual average price) (€/MWh)
- The market price of the tradable green certificates (€/MWh)

Impacts on producers

- Total electricity generation costs (M€, €/MWh)
- Marginal generation costs per technology for the generation of electricity (€/MWh)

Impacts on consumers

- Additional costs due to the promotion of RES-E (M€, €/MWh)
- Additional costs due to DSM strategy (M€, €/MWh)
- Additional costs compliant with the CO2-strategy in total (M€, €/MWh)
- Total (transfer) costs compliant with the selected support schemes and policy decisions/options (Huber et al. 2004 b, p. IX f.)

3.7.2 Methodology of the Green-X simulation model

3.7.2.1 Supply-side cost-resource curves for RES-E

The *supply side* of RES-E is described in the Green-X model by generation/production costs and related potentials on an annual basis. The development of these cost-resource curves is explained in three steps:

1. Calculation of electricity generation costs from RES
2. Analysis of the potential
3. Specification of cost-resource curves (methodology) (Resch 2005, p. 31).

Starting point is the input-database supply for the first year which is investigated. The database includes information about existing power plants (end of 2001) and of possible new plants. Furthermore, the core information of the already existing plants contains investment costs, operation and maintenance costs (O & M costs) and the magnitude of the electricity production of every plant within a year (Resch 2005, p. 31 f.). The most relevant points for the planned new plants or for those under construction are:

- Investment costs
- O & M costs
- Efficiency
- Additional potential of electricity generation in the end year 2020 (mid-term potential) (Resch 2005, p. 32).

Most of the data do not need any change or modification as output variables; but there are some exceptions – these parameters have to be adjusted. *"These parameters are, e. g. the primary energy (fuel) prices, interest rate... and potential for electricity generation which is available for this year. The breakdown of the available additional potential 2020 for the subsequent year will be conducted with the help of dynamic assessment, by considering the existing industrial, technical, market and societal barriers and obstacles."* (Resch 2005, p. 32)

The analysis of different promotion schemes and diverse market conditions makes it necessary to adjust the dynamic cost-resource curve. The result are offer prices and *not* costs, in other words, a transition takes places: not generation costs, but bids and offers are in the focus of this analysis step (Resch 2005, p. 32).

At the end of this simulation run (year n-1), the database for the following year adapts the input database for the year n. In this context, modifications are necessary for the following factors:

- Investment costs
- O & M costs
- Efficiency rates and related parameters
- Database of existing plants – new ones must be added, old and not longer used ones must be removed
- Database on new plants (options) (the remaining mid-term potential has to be reduced if parts of this potential have been already exploited in the examined year (Resch 2005, p. 33).

"This adapted input database serves as a starting point for the dynamic cost-resource curve development for the next subsequent year." (Resch 2005, p. 33)

3.7.2.2 Data "designing" and needs

The Green-X model needs three sorts of data inputs:

1. County level
2. Technology level
3. Band level (Resch 2005, p. 33).

The *country level* requires the following parameters:

- Population, land size, GDP per capita
- Fuel prices for renewable primary energy carriers
- Conventional electricity prices for each sector
- Specific GHG-emissions by energy carrier
- Grid extension limitations
- Market transparency
- Investor behaviour/interest rate
- Willingness of the consumers to accept new plants (Resch 2005, p. 33, table 4.1)

Concerning the *technology level*, these data/parameters are required:

- Lifespan of the particular technology
- Payback time
- Dynamic cost development of technologies (including the fact of technological learning [experience curve[7]])
- Growth rate of the industry
- Grid extension restrictions
- Market transparency
- Investor behaviour/interest rate
- Willingness of the customers to accept new plants (Resch 2005, p. 34, table 4.2).

The *band level* considers that the parameters are not always the same, but varies from region to region, from technology to technology etc. For this reason, it is necessary to introduce several bands within every RES-E category. Bands reflect the particular economic, technological, social and geographical conditions (Resch 2005, p. 34; Huber et al. 2004, pp. 16 ff.).

The supply-side database is built of the two sub-bases: a) existing plants and b) new plants. The input-database "excising plants" has the goal to give information about the generation costs for electricity as well as of the potential of the electricity production. New generation options of the year n are discussed with the help of the input-database "new plants". The parameters can fluctuate from year to year, equivalent to the other levels mentioned above (Resch 2005, p. 34).

[7] See chapter 3.6.4.

4 Future scenarios: Europe and Croatia

4.1 Summary of important signs for policy assessment in the framework of a green policy energy concept

In the following, it is discussed whether the computer simulation model of Green-X (dynamic cost reserve curves) is adaptable on specialized energy policy models for a future policy concept on the field of Croatian wind energy. Moreover, the practicability for predictions of RES-E deployment on the basis of special policy inputs will be demonstrated. *This discussion is only a preparation for future scientific work, because the Green-X model was not adapted to the special conditions of Croatia until now. This work can be understood as a necessary step for additional research in this direction in the nearer future.*

For the assessment of indicators of special energy policy strategies, the following list is performed and described in the framework of an economic evaluation only (Resch 2005, p. 106).

- *Average financial support for new RES-E power plants:* the unit here is: €/MWh-RES. This indicator describes the dynamic development of indispensable financial support for new RES-E power plants (on an average basis). The values are connected with the corresponding year. *"The amount represents from an investors point-of-view the average additional premium on top of the power price guaranteed (for a period of 15 years) for a new RES-E installation in a certain year, whilst from a consumer perspective it indicates the required additional expenditure per MWh-RES-E for a new RES-E plant compared to a conventional option (characterised by the power price)."* (Resch 2005, p. 106). With "conventional option" the choice of traditional energy resources is meant.
- *Transfer costs for customers (due to the development of RES-E generation):* the unit is represented by: M€/year or €/MWh-Demand. Transfer costs for consumers or/and society (sometimes called additional premium costs for customers/society) can be described as direct premium financial transfer costs from

the consumer to the producer/manufacturer due to the RES-E policy in comparison with the case that customers would prefer conventional electricity from the electricity market. These costs do not consider any indirect costs/externalities (f. e. change of employment, environmental benefits/advantages a. s. o.). The consumer's transfer costs are either expressed in Mio € per year or can be related to the total consumption of electricity energy. In the second case, the premiums costs are referred to each MWh of electricity which is consumed (Resch 2005, p. 106).

- *Total transfer costs for customers (due to the development/promotion of RES-E):* the units are here defined as: M€ or % (compared with the reference costs). The cumulated transfer costs for consumers in the year 2020 are the combination of the total consumer burden within the contemplable period of 2005 to 2020 and the residual costs for the years after 2020. *"The required yearly consumer expenditure in the period of 2005 to 2020 as well as the estimated residual expenditures for the following years after 2020 are translated into their present value in 2020*[8]*... More precisely, cumulated cost burden within the investigated period is calculated by summing up present values of... yearly transfer costs. Residual costs refer to RES-E plant installed up to 2020, and accordingly their guaranteed support...*[9]*"* (Resch 2005, p. 107).

These are the three most important indicators in the policy assessment from an economic point-of-view.

4.2 Definitions and assumptions of the Green-X scenario

Several simulations can be made for analysing the effects of RES-E policy on Res-E portfolio, deployment and costs. But for simplifying it, the following scenario characteristics were selected:

[8] A yearly inflation rate of 2,5 % is assumed (Resch 2005, p. 107, footnote 122).

[9] *„Assume e. g. a wind power plant is installed in 2015 and a support is guaranteed by a feed-in tariff scheme for 10 years. Accordingly, residual costs describe the required net-transfer costs for the years 2021 to 2024."* (Resch 2005, p. 107, footnote 123).

- A "business as usual" (BAU) policy is forecasted resp. estimated.
- After a certain time of transition, a harmonisation of the support schemes within the EU and associated states will take place. It is assumed that the same RES-E target as under BAU conditions will be achieved until 2020. Furthermore, the policies of the following points are estimated to be harmonised until 2020: feed-in tariff, international and national TGC systems.
- The RES-E target influences the efficiency of support schemes. So it can be assumed that a second more ambitious RES-E target should be reached in 2020. This means that a continuation of the BAU policy is made until 2012, and after that there should be reached a harmonised system within the EU and Southeast Europe until 2020. For this reason, the feed-in tariff system and the international TGC system should be applied as support mechanisms.
- In the year 2010, an "interim target" should be achieved (Huber et al. 2004 b, p. X).

The Green-X model is based on the following estimations, too:

- The Gross electricity consumption is based on the forecasts by the "European Energy and Transport Trends until 2030"
- Primary energy prices are based on the project "World Energy, Technology and Climate Policy Outlook" (WETO 2003)
- The definition of the necessary rate of return is rested upon the weighted average cost of capital methodology (WACC). There are two options, either 6,5 % (default case) and the higher risk case of 8,6 %.
- Concerning the technologies, the future investment costs are based on endogenous technological learning processes. Learning rates are estimated for each decade separately referring the global development of the particular technology. For the less mature technologies, the standard costs are used (f. e. wave technology) (Huber et al. 2004 b, p. X f.).

The investigated strategies can be described by the following features:

- Stable horizon of planning;
- Continuing a reliable RES-E policy with long-term goals;
- A well-defined and clear tariff structure;
- Minimized investment and O & M costs, raising the energy efficiency over the time;
- Reduction of barriers and a high acceptance in the public in the long run (Huber et al. 2004 b, p. XI).

With the exception of the BAU option, for all other scenarios is estimated:

- Financial support is only given for new capacities;
- The duration in which investors can receive additional financial support is restricted to 15 years (Huber et al. 2004 b, p. XI and p. XI, footnote 22).

Concerning the policy instrument "quota obligation combined with tradable green certificates", the following trends are estimated:

- Tradable green certificates are standardised and harmonized on an international level.
- Full competition which means a) market transparency; b) an appropriate level of trading and c) investors are seeking the most efficient/effective RES-E resources.
- Further support for less mature RES-E technologies does not longer exist.
- Reliable and constant annual interim targets.
- Penalties for not fulfilling the quota obligations (up to 150 €/EWh) (Huber et al. 2004 b, p. XI).

The policy instrument "feed-in-tariff" has the following assumed design:

- The guaranteed tariffs are specific for certain technologies;
- Tariffs are as low as reasonable by not causing a lower deployment rate over the RES-E portfolio;

- The guaranteed tariffs are decreasing or keep constant at least for particular RES-E technologies;
- Tariffs for wind power are constructed as a stepped feed-in-tariff (Huber et al. 2004 b, p. XI).

4.3 The most important results of the Green-X simulation model

On basis of the EU-15, the model shows that the electricity production raised from 2004 to 2010 by 19 % and to 2020 by 24,3 % (under the assumption: no changes in the support scheme) (Huber et al. 2004 b, p. XII).

The following figure illustrates the dynamic "evolution" of RES-E generation for the "business-as-usual" scenario (scale on left hand) and the scenario under the assumption of a harmonised and unitary feed-in-tariff scheme which started in 2005 for the TWh target (scale on right hand) (Huber et al. 2004 b, p. XIII, fig. 0.2):

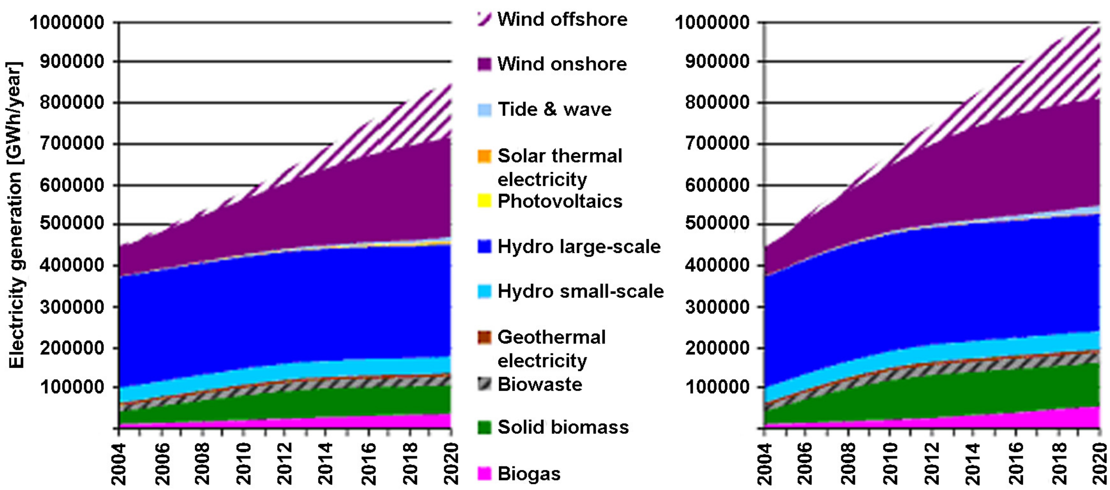


Figure 25: Development of RES-E production in the years 2004 to 2020 within EU-15 under the assumption of the BAU scenario (left hand) and under a harmonised feed-in-tariff system achieving a RES-E generation of 1000 TWh in the year 2020 (right hand).

The authors of the scenario especially right hand are pointing out that high investments would be necessary to be able for building up new capacities (Huber et al. 2004 b, p. XIII). The following figure illustrates the necessary investments in total into wind onshore and biogas power plants and other RES-E technologies estimating the BAU scenario (2005-2020) (Huber et al. 2004 b, p. XIII, fig. 0.3):

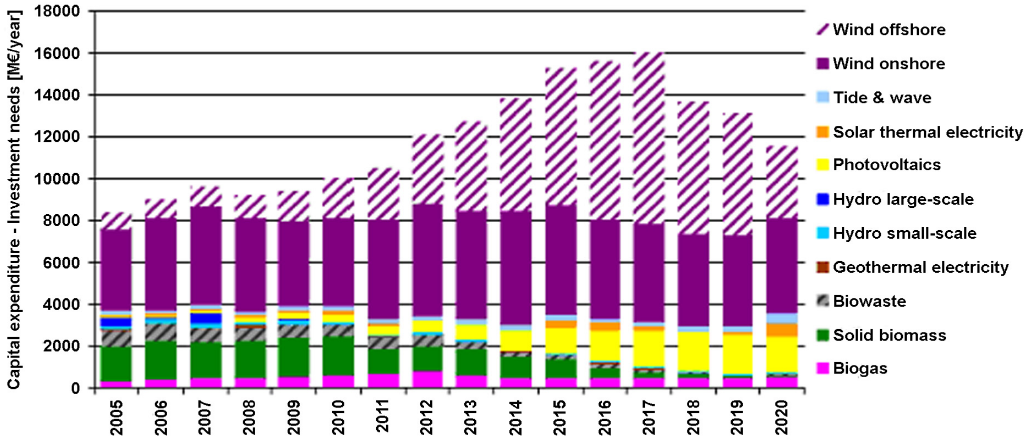


Figure 26: Assumable total investment costs between 2005 and 2020 within the EU-15, BAU scenario.

Investments into wind offshore and photovoltaic technology will occur mainly after the year 2010. These investments will stimulate technology learning which means dropping production/generation costs in the future (Huber et al. 2004 b, p. XIII).

The efficiency of the diverse support mechanisms depends on the necessary public financial support. The annual necessary transfer costs for customers on EU-15 level on the basis of the BAU goal are shown for four investigated cases in the following figure (Huber et al. 2004 b, p. XIV, fig. 0.4):

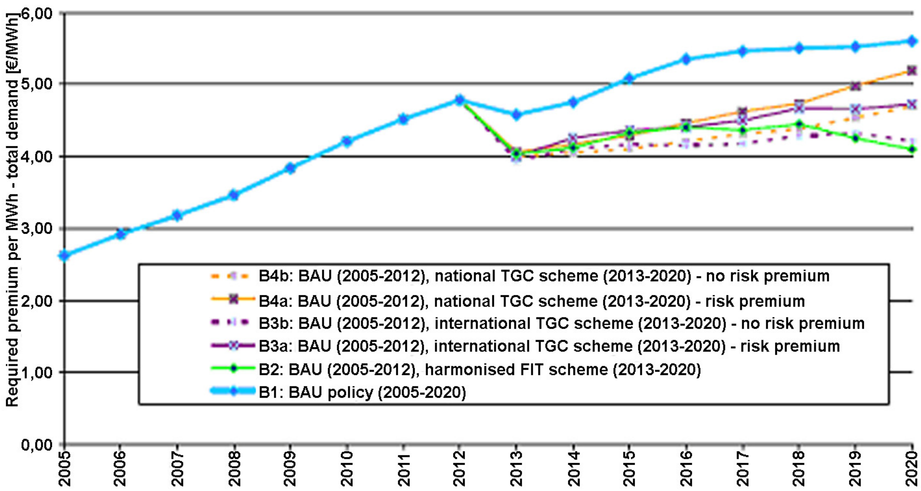


Figure 27: Necessary transfer costs for consumers, achieving the BAU goal 2020 (848 TWh in 2020) – comparison of four cases resp. scenarios

The figure shows that the annual burden for the costumers is the highest under the assumption that the current policy schemes are maintained. In this case, the transfer costs for the society are increasing continuously over time. The costs will be relatively stable when a technology specific feed-in-tariff will be introduced in 2013. Assumed, the TGC scheme burden in the first years is dropping in comparison with the 2012 level, it will increase over time (Huber et al. 2004 b, p. XIV).

The harmonisation of the schemes in the different EU member states (one unit of new RES-E for each technology) does not automatically lead to a uniformed burden for the consumers per MWh electricity consumption (Huber et al. 2004 b, p. XIV).

- In the case a tender or feed-in-tariff scheme is introduced, the transfer resp. premium costs for the society are depending on the current national RES-E deployment. This has the consequence that the burden for the consumers/the society is relatively high in countries with a high potential when a high total electricity production from renewable energies occur. If the international TGC scheme is introduced, the most relevant point is that the burden is depending on the agreed national RES-E target (which means that the costs do not depend on the actual national RES-E generation). The difference to the quota level can be purchased from the international TGC market.
- The annual transfer costs for customers are depending on the historical level of promotion of renewable energies, too. These costs do not depend on the current RES-E policy when estimating that the existing capacities remain in their traditional promotion scheme, which means that the new schemes are transferred only to new capacities (Huber et al. 2004 b, p. XIV).

The annual transfer costs for the consumers/society for all simulated 1000 TWh cases are illustrated in the following figure (Huber et al. 2004 b, p. XV, figure 0.5):

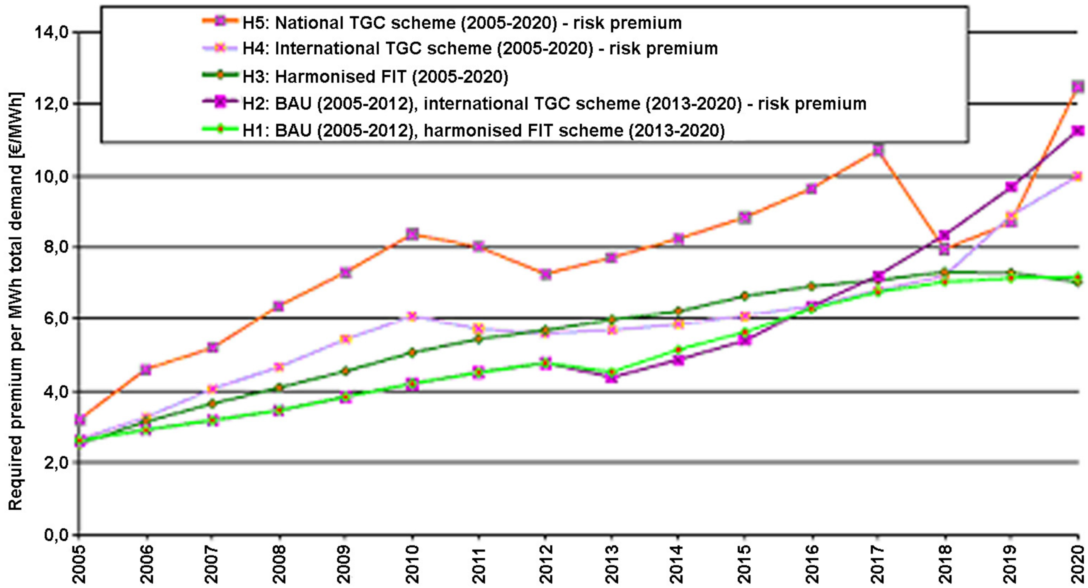


Figure 28: Necessary transfer costs for consumers/society achieving the 1000 TWh target in 2020, starting in 2005 with a harmonised approach from 2013 on (H1 – H6) – a comparison.

"For the case that harmonisation should be taken place after a transition period of 7 years the following main effects can be observed: Yearly transfer costs are higher in the early phase applying a feed-in-tariff scheme compared to an international TGC scheme as, firstly, the tariff is designed in a way that it drops over time and, secondly, a higher deployment occur in this (early) period. Assuming a full harmonisation already in 2005 the following conclusion can be drawn: Transfer costs within a TGC scheme are... higher if the target (quota) is very ambitious (high interim target 2010) and with advanced RES-E deployment, i. e. from 2018 onwards." (Huber et al. 2004 b, p. XV)

The annual burden can be changed by the guaranteed duration of the support scheme. Assuming, the yearly amount raises by guaranteeing a tariff for 10 years instead of 15 years, then the transfer costs must be paid only for 10 years; so the total burden can be more or less constant over the years (Huber et al. 2004 b, p. XV).

The figure below shows the full transfer costs for consumers/society in comparison (Huber et al. 2004 b, p. XVI, fig. 0.6):

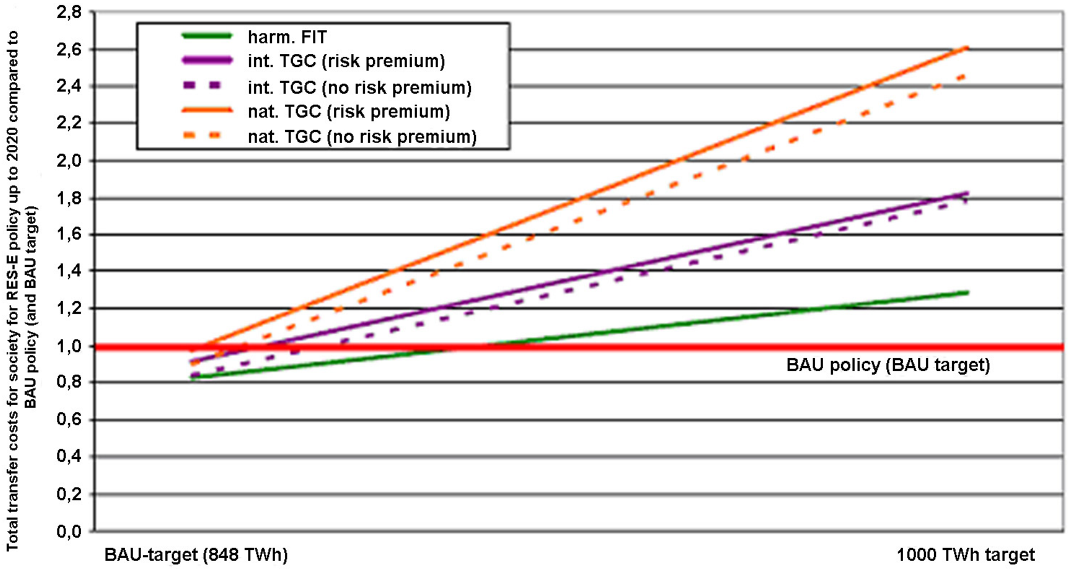


Figure 29: Comparison of total premium (transfer) costs for customers/society achieving a moderate target (BAU = left) and an ambitious goal (1000 TWh = right).

In all cases, the usage of a technology specific support scheme is leading to the lowest premium costs for the whole society. If a moderate RES-E target (BAU) is estimated, then the differences are more or less low. The total premium costs for society are the lowest ones when technology specific support is applied, followed by an international resp. national TGC scheme with the impact the current policy is highest retained up to the year 2020 (Huber et al. 2004 b, p. XVI).

If an ambitious RES-E deployment is assumed, technology specific support systems are preferred by the consumers in comparison to schemes which do not involve a technology specific support for fulfilling the ambitious RES-E goal in the future (Huber et al. 2004 b, p. XVI). *"In all investigated cases the necessary average financial support is lower applying a well designed technology specific feed-in-tariff system compared to a non technology specific TGC scheme."* (Huber et al. 2004 b, p. XVI).

4.4 The wind potential: a forecasting for Croatia

As already mentioned[10], the Green-X model was not employed on the Croatian wind potential yet. But similar research has been made in the meantime. In this sub-chapter, the main results of this research are described in on overview.

The starting point for calculating the dynamic *realisable* potential is *"the determination of the additional mid-term potential for electricity generation for a specific technology in a specific country. The additional mid-term potential is the maximal additional achievable potential assuming that all existing barriers can be overcome and all driving forces are active."* (Energy Economics Group [EEG] 2009, p. 3). The "dynamic potential" is defined as the maximal achievable realisable potential for the year n under the assumption *that the word "realisable" can be understood as the consideration of the real existing barriers which constitutes the difference between the realisable potential and the theoretical potential.* These barriers are:

- Social barriers
- Technical barriers
- Market and administrative constraints (EEG 2009, p. 6 f.).

The additional mid-term potential for electricity generation especially of wind power plants is referring to the year 2020 (EEG 2009, p. 3).

Under these conditions, the following picture of the realisable wind potential in Croatia can be drawn:

The following figure shows the total electricity demand in 2003 (a), the population density (people/km^2) (b), the nominal GDP per capita ($US) (c), and the total number of rural resp. agricultural dwellings (d) in Croatia (Schneider/Duić/Bogdan 2007, p. 1733, figure 1):

[10] See chapter 4.1.

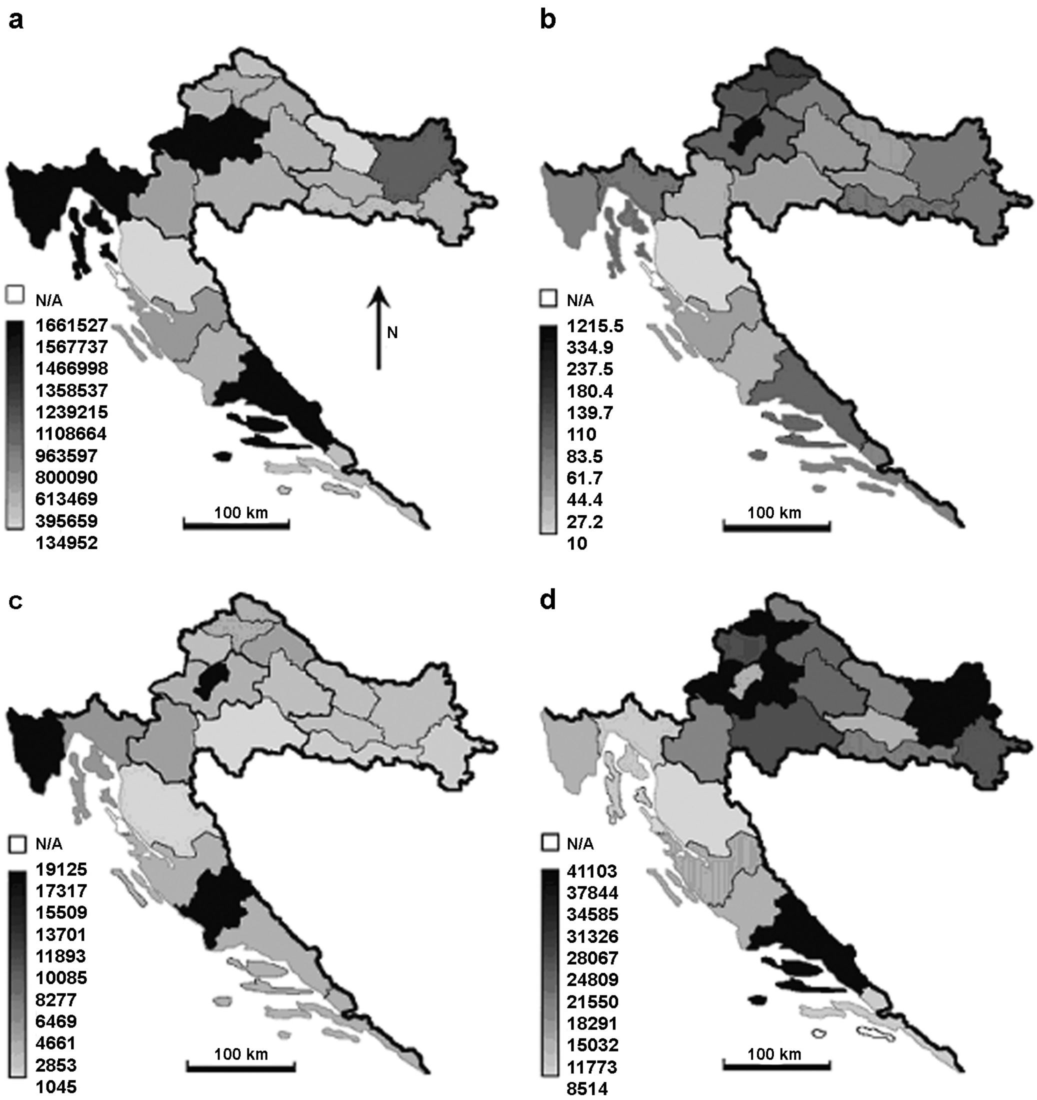


Figure 30: (a) Total electricity demand (MWh), (b) population density (people/km2), (c) nominal GDP per capita ($US), (d) total number of rural dwellings in the year 2003 (Croatia).

The following figure shows the average yearly wind velocity (m/s) and the maximum load capacity of planned wind facilities (MW) (Schneider/Duić/Bogdan 2007, p. 1735, figures 3 a and b) for the country Croatia:

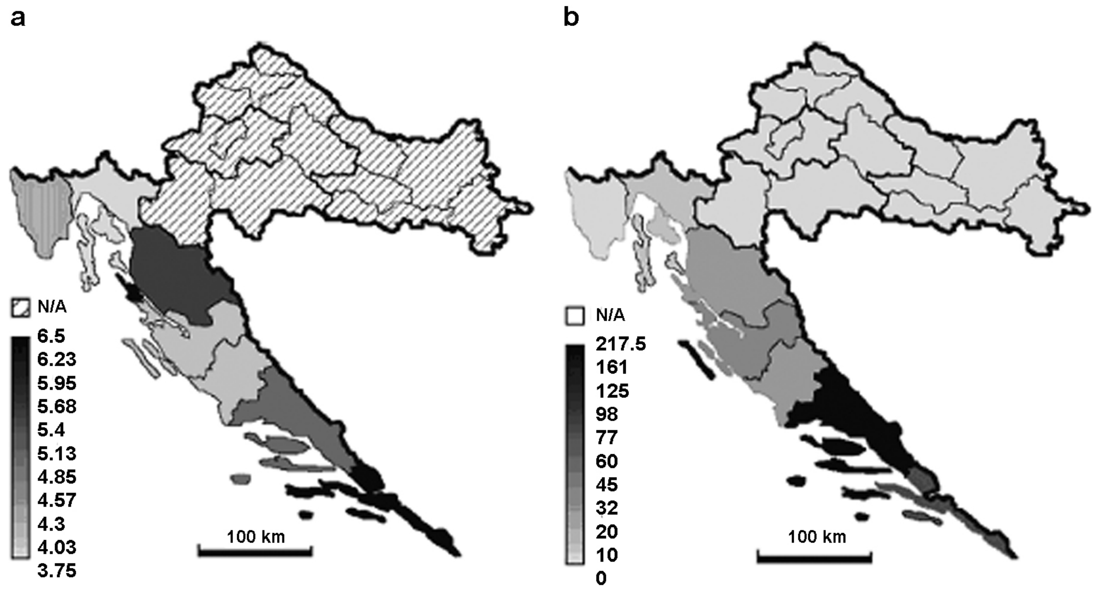


Figure 31: (a) Average yearly wind velocity (m/s) and (b) maximum load capacity of planned wind power plants (MW).

The RES electricity production costs for the diverse energy forms are differing from each other. As you can see in the following figure, the biomass cogeneration facilities have nearly the same low energy production costs as wind energy plants (Schneider/Duić/Bogdan 2007, p. 1737 and p. 1736, table 1):

Type of RES	Region (NUTS 2)	Capital cost (€/kW)	Fuel cost (€/kWh/year)	O&M (€kW/year)	Insurance €/kW/year	Energy supply costs (c€/kWh)
Large hydro	Central Croatia	1827	—	13.15	10.96	5.73
	Zagreb region	2268	—	16.33	13.61	4.87
	Eastern Croatia	—	—	—	—	—
	Adriatic Croatia	1866	—	13.44	11.20	7.73
Small hydro	Central Croatia	11718	—	84.37	70.30	28.80
	Zagreb region	7141	—	51.41	42.84	16.51
	Eastern Croatia	4038	—	29.07	24.23	10.80
	Adriatic Croatia	2051	—	14.77	12.31	5.82
Wind power	Central Croatia	—	—	—	—	—
	Zagreb region	—	—	—	—	—
	Eastern Croatia	—	—	—	—	—
	Adriatic Croatia	994	—	24.84	7.95	7.86
Small PV	Central Croatia	—	—	—	—	—
	Zagreb region	—	—	—	—	—
	Eastern Croatia	4202	—	14.71	21.01	53.26
	Adriatic Croatia	—	—	—	—	—
Biomass	Central Croatia	1931	0.02	15.60	19.31	8.40
	Zagreb region	1907	0.02	11.46	19.07	8.06
	Eastern Croatia	1943	0.01	15.14	19.43	7.04
	Adriatic Croatia	1722	0.01	13.22	17.22	6.95
Geothermal	Central Croatia	2925	—	102.37	23.40	7.24
	Zagreb region	—	—	—	—	—
	Eastern Croatia	2084	—	72.93	16.67	5.15
	Adriatic Croatia	—	—	—	—	—

Figure 32: Average energy production costs for several RES technologies

In comparison with wind energy, biomass has the advantage of higher social benefits in the shape of raising employment of the local workforce and additional activities for the farmers that produce raw material (Schneider/Duić/Bogdan 2007, p. 1737).
The resources that are available and the plant cost projections are shown in the following figures for the years 2006 and 2010. For finding out the basis for this calculation, the existing electricity costs, the technological "state of art", existing commitments on RES development and bearable costs for fuel were considered for calculating the resource availability (Schneider/Duić/Bogdan 2007, p. 1740 and p. 1741, figures 8 and 9):

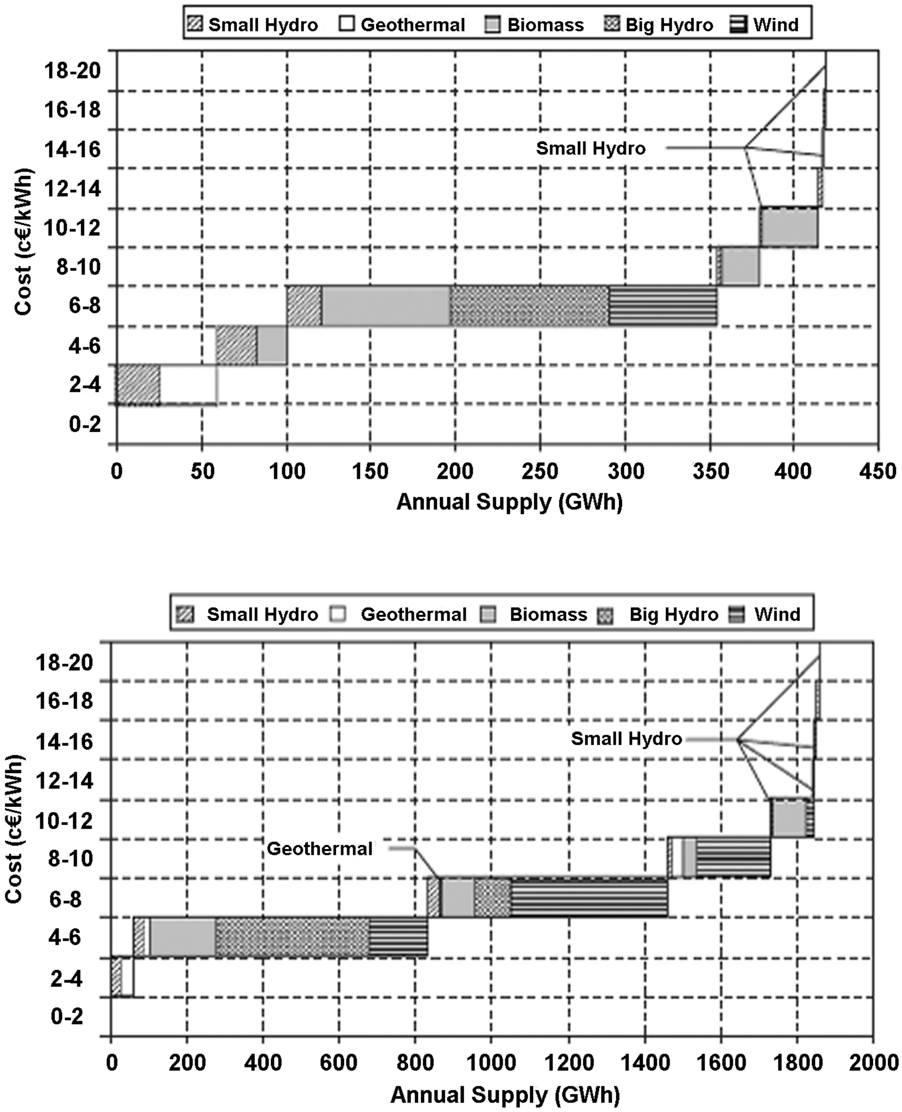


Figure 33: RES cost-supply curves for 2006 and 2010 (Croatia).

The figure 32 shows that more wind resource will be available in the year 2010 in the cost band of 6-8 c€/kWh. The costs are progressively decreasing, but will be still higher than the costs of other RES energy forms which will be available in the cost band of 4-6 c€/kWh (Schneider/Duić/Bogdan 2007, p. 1740).

Summarized, the most profitable RES energy systems are the wind power systems. The wind farms with new feed-in-tariffs are becoming more and more profitable in Croatia. The second-most profitable RES energy plants are using biomass (Schneider/Duić/Bogdan 2007, p. 1742 f. see also: Lončar/Duić/Bogdan 2009, pp. 134-144).

HEP, still the biggest player on the electricity market in Croatia and state-owned, says that the minimum share of RES electricity in general in total electricity consumption will be 5,8 % in 2010; the share in 2007 was only 0,7 % (not including large scale hydro) (HEP 2008, p. 9). Each consumer pays extra RES fee for every spent kWh:

- 2007: 0,0089 kn/kWh (0,12 c€)
- 2008: 0,0198 kn/kWh (0,27 c€)
- 2009: 0,0271 kn/kWh (0,37 c€) (HEP 2008, p. 10).

The monthly increase in bill for electricity for an average household is 0,27 to 0,55 € (HEP 2008, p. 10).

The tariff system in Croatia for the electricity production of RES resources and co-generation is built up in such a way (HEP 2008, p. 11):

Table 34: Tariff system for electricity production by RES resources and cogeneration in Croatia 2008.

RES	Tariff (kn)*	
	Installed Capacity **below 1 MW**	Installed Capacity **above 1 MW**
PV	2,10 – 3,40	-
Small Hydro	0,69	0,42 – 0,69
Wind	0,64	0,65
Biomass	0,95 – 1,2	0,83 – 1,04
Geothermal	1,26	1,26
Other	0,60	0,50

* 1 kn ~ 0,13 €

Since 2007, the RES technologies/resources are subsidized in Croatia. The already installed wind energy performance in Croatia was 18 MW at the end of the year 2008 (Glahr 2009, p. 14). The wind potential in Croatia is better than f. e. in Germany or generally in Central Europe. The strongest winds are “Bora”, “Jugo” and “Maestral”. Though there is still no existing wind atlas in Croatia, the technical potential on the country-side is valued at 4,54 GW; this corresponds to the estimations made on the basis of the Green-X model (Glahr 2009, p. 17).

After becoming member of the European Union (EU), Croatia will have a share of 20 % of RES technologies on the total electricity supply in the year 2020; already in 2010, Croatia will achieve an energy saving of 22 % with the help of growing using of the RES resources and technologies (Glahr 2009, p. 19 and p. 24). Croatia will double its energy production out of renewable energies in the year 2020 in comparison to 2006 (Glahr 2009, p. 30). The produced energy resp. the *realisable potential* out of wind energy will be 1.200 MW in 2020 in Croatia (Glahr 2009, p. 31). Other scenarios are estimating the realisable wind potential in Croatia at 1.300 MW in 2020 (GTZ/Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung 2004, p. 13).

The *natural,* the *technical* and the *economical* potential on the *mainland* and on the *ocean* side in Croatia can be summarized as such (Kracar 2009):

- Natural potential (270 TWh/year): ocean 56 %, mainland 44 %.
- Technical potential (22 TWh/year: ocean 55 %, mainland 45 %.
- Economical potential (use of higher units and market-surrounded systems to 9 TWh/year): Ocean 56 %, mainland 44 %.

So you can say that the potential on the ocean side is a little higher than on the mainland side.

5 Conclusions and recommendations

The following conclusions can be drawn, derived from the Green-X simulation model described above[11] (Huber et al. 2004 b, pp. XVI ff.; Godjevac/Sharfabian/Tsoukanas 2008, pp. 43 ff; Ministry of Economy, Labor and Entrepreneurship 2008, pp. 210 ff.):

- The penetration of RES-E technology in the field of the energy market is depending on two obstacles: a) economic barriers – they are considered by the net production costs, inclusive policy strategies; b) non-economic barriers like social, administrative, market and technical obstacles – these obstacles imitate the available potential of electricity production for the current year(s).
- No support mechanism can be preferred, each one has its advantages and disadvantages. The preferable instrument is depending on the particular policy objective (Huber et al. 2004 b, pp. XVI).

The optimal RES-E policy is dependent on the core issue, as the figure below shows (Huber et al. 2004 b, pp. XVII, table 0.2).

Summarized, you can say it in the words of Huber et al.: *"... a coordination and harmonisation of the support between the Member States can be recommended."* (Huber et al. 2004 b, pp. XVIII) You can add: This is not only right for the Member States of the EU, but the EU-associated states, too.

[11] See chapter 4.

Table 11: Optimal RES-E policy in dependency of the policy issue

Policy issue	Feed- in tariff [A]	National TGC system [B]	International TGC system [B]	Tender procedure [C]
Ensure a brad RES-E technology portfolio	++	-	- -	++
Allow an ambitious RES-E target for a short period	++	- -	- / +	+
Minimise generation system costs	- / +	+ / -	+ / -	+
Minimise transfer costs for consumers	++	-	- / +	+
Encourage competition among generators	- -	+	++	++
Leads to a homogeneous burden among consumers over time	++	- -	+	+
Can contribute to a fair international burden sharing for consumers	-	-	+	-

Note: The discussed effects refer to the most common design option of the instrument, i.e. by changing the most effects can be changed too.

[A] Feed-in tariffs are technology specific and decreases with technological progress

[B] Quota obligations are uniform, i.e. there are neither technology specific quotas nor additional support for less cost efficient instruments (e.g. tax relief or investment subsidies)

[C] Tender schemes are technology specific, but to maintain competition less specific than under a feed-in tariff system

- The consideration of the dynamics is the most important point; at the same time, the instruments vary from a static point-of-view. In this context, there are the following things of importance: a) technological diffusion due to changes of real existing barriers over time; b) decreasing generation costs and lower financial incentives; c) non-linear dynamic target (quota setting).
- The effective strategy is an important success criteria, too. It has effects on the RES-E deployment, the investor stability etc.
- For ensuring a significant RES-E deployment in the long run, it is necessary for designing a broad portfolio of different RES-E technologies (new technologies).
- The maximum RES-E deployment rate is depending on the technology differentiation of the individual renewable energies technology.

- The effects of diverse RES-E instruments on RES-E deployment are depending on the designing of these instruments and methods. Similar instruments are producing similar effects.
- The development of a national RES-E policy demands a continuous and reliable RES-E policy.
- Different ambitious national policies concerning the renewable energy resources are problematic in a deregulated power market.
- The future development of societal costs for promoting RES-E depends on the development of the electricity prices on the conventional market, too. A higher societal burden for electricity prices can be compensated by lower societal costs for promoting RES-E.
- The electricity demand has also an important influence on the development of acceptable societal costs for achieving the policy targets for RES-E. Setting supply-side incentives for RES-E, it is also necessary to initiate demand-side measures for minimising the overall societal burden.
- Strategies for promoting RES-E are less successful if they are implemented in an uncoordinated manner (on national level) within the framework of an international power market, because the power price only reacts marginally on such policies, compared with an isolated national energy market and an internationally coordinated policy (Huber et al. 2004 b, pp. XVII f.)

What does this mean for the future of the Croatian wind energy market? Until next year (2010), Croatia is able to dispose of further six wind farms with the capacity of 171.65 MW. There is also the possibility to install 600 MW wind energy plants with a generation of about 1900 GWh in the long run (Godjevac/Sharfabian/Tsoukanas 2008, p. 43).

Large potential regions for wind energy production are still poorly explored; for this reason, the Croatian government tries to find new investors for various projects and projects the drawing-up of a wind atlas (including financial support for the latter project). Global Environment Facility programmes of the World Bank offer development funds of 5,5 million $ for Croatia until 2010. Additionally, it is planned to use wind power to supply water on islands. Furthermore, it is planned to combine wind power and photovoltaic technology in the nearer future (Godjevac/Sharfabian/Tsoukanas 2008, p. 43).

The estimated and *realisable* wind potential of Croatia until 2020 will reach 1.200 to 1.300 MW[12]; in the year 2030, it will reach nearly 2000 MW. This can be shown in this figure (Krajcar 2009):

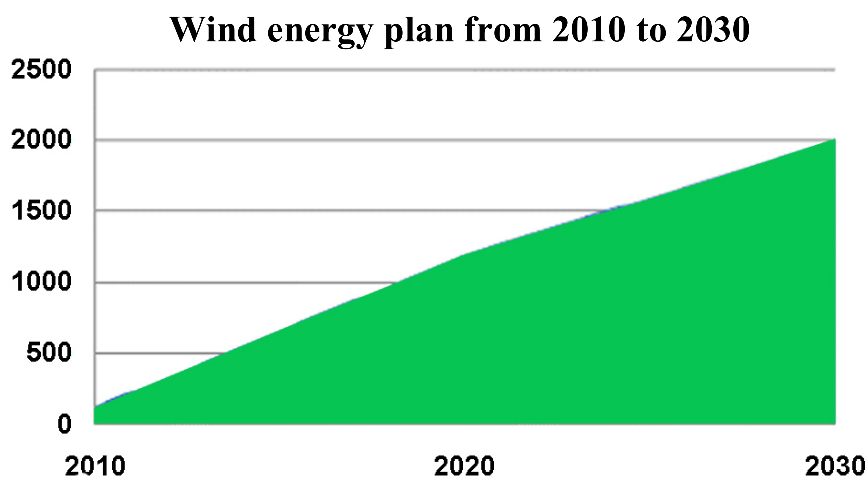


Figure 35: Installed power from wind energy (MW) in a projection until the year 2030 (Krajcar 2009).

The assumed electricity production from wind energy in TWh until the years 2020 resp. 2030 is illustrated in this picture (Krajcar 2009):

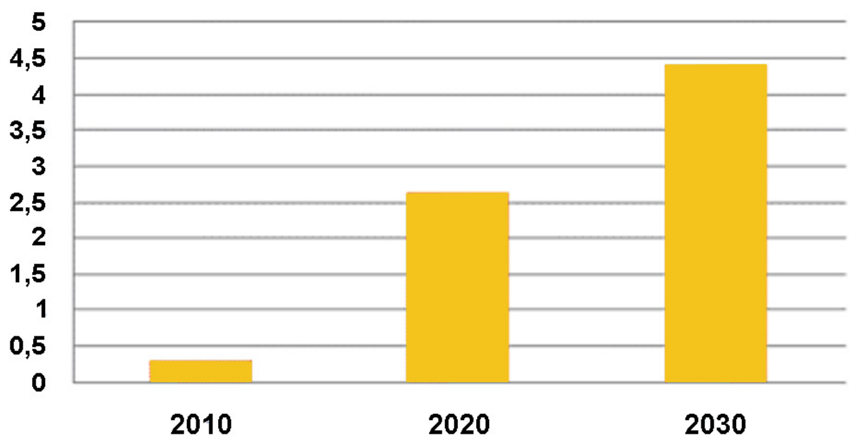


Figure 36: Electricity production from wind energy (TWh) in Croatia until the year 2030

[12] See chapter 4.4.

The *aims* for the electricity production from wind energy will be until to the year 2030:

- 2020: 345kW/1000 inhabitants about – 1200 MW
- 2030: to reach 450kW/1000 inhabitants about – 2000 MW (Krajcar 2ß09).

The *appropriate activities* for reaching these aims must be:

- Simplification of administration
- Update of Spatial Data Infrastructure
- Construction of the Croatian wind atlas (Krajcar 2ß09).

The realisable share of RES technologies/resources in general in the total energy supply will reach 20 % in 2020 in Croatia. Under these assumptions, the wind energy will be the most profitable RES technology, followed by biomass.[13] Additionally, three further conditions must also be considered: that the electricity market will be still more liberalized and private investors will be enticed in the nearer future, and, thirdly, the country Croatia will be member of the European Union in a foreseeable time. For the latter reason, a further adjustment to the rules and principles of the EU energy market and its political framework must take place in Croatia.

For making the wind energy policy of Croatia still more successful, some further requirements are necessary to consider:

- Proposed draft regulation has to be used
- The state must guarantee surety for the market operators
- HEP should be entitled for fixing the prices for renewable fee
- Suppliers should be compelled to resell total RES-E generation to the final customers (Godjevac/Sharfabian/Tsoukanas 2008, p. 44).

[13] See chapter 4.4.

By all means, it is right to use natural resources, especially wind energy, to go forward in protecting the environment and to implement a new approach to energy production (Godjevac/Sharfabian/Tsoukanas 2008, p. 44).

As said several times[14], the implementation of the Green-X model for calculating the *realisable* wind potential in Croatia has not been taken place yet. But the already realised research concerning this question can give some worthful hints which results can be expected when the implementation will have happened.

[14] See chapters 1 and 4.

Literature

Adria Wind Power, Homepage, 2009, URL: http://www.adriawindpower.hr/VE_Ravna_1/ (Download: 6/22/2009).

Barth, R./Weber, C./Swider, D. J., Distribution of costs induced by the integration of RES-E power, Stuttgart/Duisburg-Essen (Germany) 2008, URL: http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6V2W-4SPSHJW-2&_user=10&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=c14d76784028b2c499754eb5ce4fe3dd (Download: 6/10/2009).

Cavaleri, L., The wind and wave atlas of the Mediterranean Sea – the calibration phase. In: Advances in Geoscience, 2, 2005, pp. 255-257, URL: http://hal.archives-ouvertes.fr/docs/00/29/68/93/PDF/adgeo-2-255-2005.pdf (Download: 5/10/2009).

Christensen, C., Technologiestrategie III, Vorlesung vom 12. Mai 2004, University of Regensburg (Germany), 5/12/2004, URL: http://www.wiwi.uni-regensburg.de/dowling/files/tech_man/Tm04/TM12-05-04.PDF (Download: 6/2/2009).

Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ)/Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung, Energiepolitische Rahmenbedingungen für Strommärkte und erneuerbare Energien, 21 Länderanalysen: Kroatien, Eschborn, Juni 2004, URL http://www.gtz.de/de/dokumente/de-windenergie-kroatien-studie-2004.pdf (Download: 7/14/2009).

Encyclonomic WEB-pedia, Marginal utility and demand, 2009, URL: http://www.amosweb.com/cgi-bin/awb_nav.pl?s=wpd&c=dsp&k=marginal+utility+and+demand (Download: 6/2/2009).

Energetika-Net, Postavljena VE Trtar-Krtolin, 2009, URL: http://energetika-net.hr/oie/vijesti/1231 (Download: 6/22/2009).

Energy Economics Group (EEG), Dynamic cost-reserve curves – Methodology for model implementation in Grren-X, Vienna 2009, URL: http://www.green-x.at/GX%20viewer%20-%20data/GXviewer_framework.htm (Download: 7/14/2009).

Faber, T./Huber C./Resch, G., Handbook for the toolbox Green-X. Report of work package 2 within the European rearch project Green-X - funded by the European Commission, DG Research, Energy Economics Group (EEG) and Vienna University of Technology, Vienna 2004.

Gillis, M. Basic Supply and Demand, 2009, URL: http://demonstrations.wolfram.com/BasicSupplyAndDemand/ (Download: 6/2/2009).

Glahr, J. H., Aktueller Stand der Windenergienutzung in Kroatien, Rahmenbedingungen, Seminarreihe „GO EAST“ Kroatien, Berlin, 14th May 2009, URL: http://www.offshoretage.de/Kroatien%201000%20Jan%20Hinrich%20Glahr.pdf. (Download: 7/14/2009).

Goić, R./Lovrić, M., Vjetroelektrane u Hrvatskoj: stanje i perspektive, Mostar 2005, URL: http://www.fesb.hr/~rgoic/referati/Prezentacija_Mostar.pdf (Download: 6/22/2009).

Godjevac, I./N. Sharbafian/K. Tsoukanas, Comparison of wind energy potential and development in Australia, Croatia and Iran, 2nd Homework, MSc Program Renewable Energy in Central and Eastern Europe, November 2008.

Granić, G./F. Preberg, Renewable Energy Projects in Croatia: Present Situation and Future Activities. In: Thermal Science, Vol 11, 2007, No. 3, pp. 55-74.

Grübler, A./N. Nakićenović/D. G. Victor, Dynamics of energy technologies and global change. In: Energy Policy 27, 1999, pp. 247-280.

HEP, Harmonisation and coordination of European RES-E support mechanisms, Ljubljana, 11th April 2008.

Horváth, L., Will new energy regulation help wind industry to emerge to Croatia?, Zagreb 2006.

Huber, C./Haas, R./Resch, G. et al., Action plan for a dynamic RES-E policy. Report of the European research project Green-X – funded by the European Commission, DG Research, Energy Economics Group (EEG) and Vienna University of Technology, Vienna 2004 a.

Huber, C./Faber, T./Haas, R. et al., Green-X – Deriving optimal promotion strategies for increasing the share of RES-E in a dynamic European electricity market. Final report of the project Green-X – a research project within the fifth framework programme of the European Commission, supported by DG Research, Vienna 2004 b, URL: http://www.green-x.at/downloads/Final%20report%20of%20the%20project%20Green-X.pdf (Download: 6/10/2009).

Integrated Energy and Climate Change Legislative Package, EC, January 2008.

Karadza, N./L. Horváth/S. Knezevic, Status and prospects of Croatian Wind Market, Legal Framework and Permitting Procedures, Zagreb 2009.

Kopecek, Chr./Th. Reis./A. Weinberger, Wind-power in Croatia with a comparison to other SEE countries – Second Homework, MSc Program Renewable Energy in Central and Eastern Europe, w. l. (without location), November 2008.

Krajcar, S., Obnovljivi izvor energije u strategiji i razvoja energetike RH, Zagreb 2009.

Labanca, N./Pagliano, L./Inzoli, F. et al., Potentials and Cost of Energy Efficiency Measures in the Western Balkan Countries and Turkey, 2009, URL: http://www.greennet-europe.org (Download: 5/23/2009).

Lončar, D./N.Duić/Z. Bogdan, An analysis of the legal and market framework for the cogeneration sector in Croatia, Zagreb, 13 January 2009, pp. 134-144 (received 13 November 2007).

Menges, R., Supporting renewable energy on liberalised markets: green electricity between additionality and consumer sovereignty. In: Energy Policy 31, No. 7, 2003, pp. 583-596.

Ministry of Economy, Labor and Entrepreneurship, Energy in Croatia 2007, Zagreb, December 2008.

Ministry of Economy, Labor and Entrepreneurship and United Nations Development Programme (UNDP), Update/Upgrade of the energy strategy and of the implementation programme of the Republic of Croatia, Green Paper Draft, Zagreb, October 2008.

Nacionalni energetski programi – ENWIND – Nove spoznaje i provedba, Energetski institut Hrovoje Požar, Zagreb 2001.

National Aeronautics and Space Administration (NASA), Learning Curve Calculator, 25 May 2007, URL: http://cost.jsc.nasa.gov/learn.html (Download: 6/2/2009).

Natura 2000, Homepage, last update: 3/15/2007, URL: http://www.cro-nen.hr/content.php?id=38 (Download: 6/22/2009).

Ognjan, D., Connecting wind farms to electrical system – developer's view -, GreenNet Conference on RES integration, Zagreb, 15th April 2009.

Parliament of Croatia, Energy Strategy of the Republic of Croatia, Official Gazette 38/2002.

Potočnik, L./V. Lay, Obnovljivi izvori energije i zaštita okoliša u Hrvatskoj, Ministry of Environmental Protection and Physical Planning, Zagreb 2002.

Pregled, K., Energy in Croatia 2007, Zagreb 2009.

Republic of Croatia, Energy Act, Official Gazette 68/2001.

Resch, G., Dynamic cost-resource curves for electricity from renewable energy sources and their application in energy policy assessment, Vienna, April 2005.

Resch, G./M. A. Lopez-Polo/H. Auer et al., Electricity from renewable energy sources in EU-15 countries – a review of promotion strategies. Report within work phase 1 of the European research project EXPANSION – funded by the European Commission, DG TREN; Energy Economics Group (EEG), Vienna University of Technology, Vienna 2005.

Samardžić, Ž, Techno-economic aspects of wind plant grid connection. Final dissemination Conference on RES Grid Integration, FER – Zagreb, April, 14th, 2009.

Schneider, D. R./N. Duić/Z. Bogdan, Mapping the potential for decentralized energy generation based on renewable energy sources in the Republic of Croatia. In: Energy 32, 2007, pp. 1731-1744.

The European Research Group, Energy: Issues, Options and Technologies – Science and Society (Eurobarometer), 2002.

Weißensteiner, L./Resch, G./Obersteiner, C., Potentials and Costs of RES-E in the EU27+ Region, Green-*Net* Incentives, Energy Economics Group (EEG)/Vienna University of Technology, Vienna 2008.

Wene, C. O., Experience curves for energy technology policy, International Energy Agency, Paris 2000.

Wikipedia, Experience curve effects, last modified: 29 April 2009, URL http://en.wikipedia.org/wiki/Experience_curve_effects (Download: 6/2/2009).

Wikipedia, Supply and demand, last modified: 2 June 2009, URL: http://en.wikipedia.org/wiki/Supply_and_demand (Download: 6/2/2009).