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A Comparison of Electricity Generation Reference Costs for Different Technologies of Renewable Energy Sources

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1. Introduction

The target value for electricity production from renewable resources in Slovenia till 2020 has amounted to additional 3.146 GWh. The highest share of this additional electricity will be obtained in majority from hydro power plants: additional 1.299 GWh will be obtained from big hydro power plants (that requires 618,3 mio € for investment); wind power plants with additional 567 GWh (that requires 345,6 mio € investment); photovoltaic with 469 GWh (which requires 1.641,5 mio € additional investment); biomass with additional 267 GWh (that requires 11,3 mio € of investment); small hydro power plants with additional 194 GWh and the needed investment amount of 148,8 mio €; natural gas with additional 191 GWh (that requires the investment amount of 95,5 mio €); and geothermal power plants with 150 GWh (that required investment amount of 93,8 mio € investicij). (Kavkler, Festić, Repina 2009).

Considering the economy and the contribution of particular technologies of renewable energy sources (RES) to the national economy macro indicators an adequate system for state incentives and abatements of RES investments in energy industry had to be made. The key eligibility condition for support of investments in renewable energy sources is the electricity cost price of particular RES technologies. Financial aid for electric power generated from renewable energy sources is defined in "The decree regulating subsidies for electricity generated from renewable energy sources", published in the Official Gazette of the Republic of Slovenia", nr. 37/09. Among other things the decree also defines (see art. 1):

- types of RES production facilities eligible for subsidies;
- allocation of RES production facilities into size classes;
- a more detailed definition of subsidies;
- the method of reference costs determination for electricity generated from renewable energy sources;
- the method of subsidy rate fixing and the eligibility conditions for support.

Production facilities exploiting the following renewable energy sources meet the eligibility criteria for subsidies (art. 3):

i. energy potential of watercourses;
ii. wind energy exploited in land-based production facilities;
iii. solar energy exploited in production facilities using photovoltaics;
iv. geothermal energy;
v. energy generated from biomass;
vi. energy generated from biogas originating from the treatment of biomass and biologically degradable waste
vii. energy generated from landfill gas
viii. energy generated from biogas originating from sludges from the treatment of industrial waste water;
ix. energy generated from biologically degradable waste.

Size classes of RES production facilities defined in "The decree regulating subsidies for electricity generated from renewable energy sources" are listed in Table 1.

Size classes of RES production facilities	Potential
1. Micro	less than 50 kW
2. Small	less than 1.000 kW
3. Middle	from 1 to 10 MW
4. Big	over 10 to including 125 MW

Source: "Methodology of reference costs determination for electricity generated from renewable energy sources", IJS, p. 9, table 1.

Table 1. Size classes of RES production facilities.

Subsidies are defined as potentially eligible financial aid to the generation of electricity by particular RES technologies if their production costs of electricity top the market price. The fifth article of "The decree regulating subsidies for electricity generated from renewable energy sources" defines two types of subsidies for RES production facilities:

1. compulsory purchase of electricity;
   The subsidiary centre purchases all net generated electricity at prices defined by this decree.
2. financial aid for current operations;
   These subsidies are granted to the net generated electricity if production costs top the market price of electricity.

Since reference costs of electricity generation (RCEG) are the starting point for the calculation of subsidy amounts for RES production facilities in the continuation of the paper a short description of RCEG methodology and RCEG calculations for different RES technologies will be introduced. A sensitivity analysis taking into account the financial volume of the investment and the interest rate of the loan will also be displayed.

2. A short description of the employed methodology

Reference costs of electricity were calculated in accordance with the "Methodology for the reference costs calculation of RES generated electricity" instructions that had been prepared at the Institute Jozef Stefan Energy Efficiency Centre. Investment risk was accessed by means of sensitivity analysis.

2.1 Reference costs of electricity

In the "Methodology for the reference costs calculation of RES generated electricity" reference costs of electricity generation (RCEG) are defined on page 7 as follows:

RCEP represent the total annual operation costs of a typical RES production facility reduced for all revenues and benefits of operations (sale of heat, etc.) and can be formulated in Eur/MWhel by means of the following equation:

RSEG = (COSTS - REVENUES) / ELECTRICITY

COSTS	= annual investments (annual instalment) + operating expenses (Eur) + cost of fuel (Eur)
REVENUES	= sale of heat (Eur) + other benefits (Eur)
ELECTRICITY	= annually generated electricity (MWh)
	= installed power (MWel) * annual operating hours (h)

The method of RCEG calculation is based on an annuity method of investment cost evaluation that also takes into account the cost of capital and the required return on invested capital respectively.

The calculation of RCEG for RES production facilities based on cogeneration of heat and electricity (CHE) and those that use different fuels is also affected by the following two parameters ("Methodology for the reference costs calculation of RES generated electricity", p. 10):

1. electricity efficiency (EffEl),

i.e. the ratio between the CHE production facility potential and fuel input potential;

2. thermal efficiency (EffT),

i.e. the ratio between the output calorific power (useful heat) of the RES production facility and fuel input potential.

Fuel consumption and the generation of useful heat can be calculated by means of the following equations (p. 10):

Fuel consumption (MWh) = Electricity potential (MWEl) * Operating hours (h)

Useful heat (MWh) = Electricity potential (MWEl) * EffT/ EffEl * Operating hours (h)

= Generated electricity (MWh) * EffT/ EffEl

2.2 Sensitivity analysis

We do not know the exact net cash flows of the investment since they are exposed to numerous risks and can only be estimated. By means of sensitivity analysis we get to know

how the changes of certain variables influence the volume of cash flows and consecutively the investment effectiveness indicators. Each time only one of the variables is varied assuming that the values of all other variables remain unchanged. It is of crucial importance that critical variables whose changes have a substantial influence on electricity reference costs are chosen (Brigham and Houston, 2001).

3. Assumptions and data

Assumptions are recapitulated from the "Methodology for the reference costs calculation of RES generated electricity":

- Depreciation period: 15 years

Datum corresponds to an average depreciation period for RES production facilities with regard to the existing practice.

- Share of own resources: 40 %
- Loan: 60 % of the investment.
- Required yield on own invested resources: 20 %

The required yield on own invested resources in Slovenia is relatively high because of the possible production transfer abroad.

- Cost of loan: 6.5 %

Calculation of loan costs is made on the basis of EURIBOR for 2008 (4.7 %) with an extra payment of 1.8 %.

- Discount rate: 12 %

Discount rate is defined as a weighed average of capital costs (WACC). For solar power stations (in accordance with the guidelines from abroad) because of the most expensive technology a lower discount rate (8 %) was used.

- Annual cost of labour: 25.000 Eur/person.
- Basic price of wooden biomass in 2008: 23 Eur/MWh
- Average price of substrata mixture for biogas plants in 2009: 14,98 Eur/MWh
- Value of useful heat for all sizes of RES production facilities in 2009: 26,74 Eur/MWh

Tables containing basic data for different types of power plants are taken from the "Methodology for the reference costs calculation of RES generated electricity". For waste incinerators unfortunately there are no available data. Data used include the potential of power plants (MW), number of annual operating hours, amount of investment (Eur/kW), costs of maintenance, operation and insurance (as a % of investment) and the cost of labour (number of persons employed) and are stated in Tables 2 to 7.

Electrical efficiency for a small production facility using biomass that exceeds the 90 % share of fuel energy is 12 % while for a middle sized it is 17 %; a minimum 70 % operating efficiency is required.

Size class	Size	Operating hours	Spec. investment	Maintenance	Operation	Insurance	Labour
	MWe	h/year	Eur/kWel	% inv.	% inv.	% inv.	nr. of persons
up to 50kW	0,05	4.000	2.300	0,9 %	0,6 %	1,5 %	0,03
up to 1MW	1	3.500	1.700	1,5 %	0,6 %	1,7 %	0,4
up to 10MW	5	3.500	1.500	1,5 %	0,6 %	1,8 %	1,8
up to 125MW	30	3.500	1.400	1,5 %	0,6 %	1,8 %	9

Source: "Methodology for the reference costs calculation of RES generated electricity", IJS, p. 20, table 5

Table 2. Hydroelectric power plants - basic data.

Size class	Size	Operating hours	Spec. investment	Maintenance	Operation	Insurance	Labour
	MWe	h/year	Eur/kWel	% inv.	% inv.	% inv.	nr. of persons
up to 50kW up to 1MW up to 10MW	5	2.100	1.200	0,3 %	0,2 %	1,3 %	0,5
up to 125MW	50	2.100	1.100	0,3 %	0,2 %	1,3 %	5

Source: "Methodology for the reference costs calculation of RES generated electricity", IJS, p. 21, table 6.

Table 3. Wind farms - basic data.

Size class	Size	Operating hours	Spec. investment	Maintenance	Operation	Insurance	Labour
	MWe	h/annum	Eur/kWel	% inv.	% inv.	% inv.	nr. of persons
up to 50kW	0,05	1.050	3.620	0,1 %	0,05 %	0,4 %	0,015
up to 1MW	0,5	1.050	3.330	0,1 %	0,05 %	0,4 %	0,15
up to 10MW	2	1.050	2.685	0,1 %	0,04 %	0,4 %	0,5
up to 125MW	10	1.050	2.455	0,1 %	0,04 %	0,4 %	4

Source: "Methodology for the reference costs calculation of RES generated electricity", IJS, p. 24, table 8.

Table 4. Solar power plants (as independent objects) - basic data.

Size class	Size	Operating hours	Spec. investment	Maintenance	Operation	Insurance	Labour
	MWe	h/annum	Eur/kWel	% inv.	% inv.	% inv.	nr. of persons
up to 50kW up to 1MW up to 10MW	5	6.000	4.600	2,0 %	0,7 %	1,2%	12
up to 125MW	(1)	(1)	(1)	(1)	(1)	(1)	(1)

(1) Individual treatment of production facilities.

Source: "Methodology for the reference costs calculation of RES generated electricity", IJS, p. 25, table 10.

Table 5. Geothermal power plants - basic data.

Size class	Size	Operating hours	Spec. investment	Maintenance	Operation	Insurance	Labour
	MWe	h/annum	Eur/kWel	% inv.	% inv.	% inv.	nr. of persons
up to 50kW							
up to 1MW	0,5	5.500	4.500	2,0 %	0,8 %	1,2%	1
up to 10MW	2	5.500	3.200	2,0 %	0,8 %	1,2 %	3
up to 125MW							

Source: "Methodology for the reference costs calculation of RES generated electricity", IJS, p. 28, table 11.

Table 6. Production facilities using biomass that exceeds the 90 % share of fuel energy.

Size class	Size	Operating hours	Spec. investment	Maintenance	Operation	Insurance	Labour
	MWe	h/annum	Eur/kWel	% inv.	% inv.	% inv.	nr. of persons
up to 50kW	0,05	6.800	4.000	2,0 %	0,8 %	1,2 %	0,12
up to 1MW	0,5	6.800	3.800	2,0 %	0,8 %	1,2%	1
up to 10MW	2	6.800	3.300	2,0 %	0,8 %	1,2 %	3
up to 125MW	(1)	(1)	(1)	(1)	(1)	(1)	(1)

(1) RCEG are not defined.

Source: "Methodology for the reference costs calculation of RES generated electricity", IJS, p. 31, table 13. For biogas plants electrical efficiency of 34 % was used.

Table 7. Biogas plants operating on biogas produced from biomass - basic data.

4. Results

4.1 Reference costs of electricity

Reference costs of electricity generation (RCEG) for 5 types of power plants were calculated on the basis of methodology developed at the Institute Jozef Stefan Energy Efficiency Centre. Calculations for small and middle sized hydro power plants were done separately while for other types of RES production facilities the greatest power for which relevant data existed was used. For waste incinerators unfortunately there were no data available. Results stated in Table 8 are in accordance with the RCEG from "The decree regulating subsidies for electricity generated from renewable energy sources", Official Gazette of the Republic of Slovenia", nr. 37/09 and from the "Methodology for the reference costs calculation of RES generated electricity".

Type of power plant	Power (MW)	Investment Spec. (Eur/kW)	RCEG (Eur/MWh)
Hydro power plant (small)	1	1.700	92,16
Hydro power plant (big)	30	1.400	76,57
Wind	50	1.100	86,74
Solar	10	2.455	269,22
Geothermal	5	4.600	152,47
Biomass	2	3.200	167,43
Biogas	2	3.300	140,77

Table 8.

As already mentioned solar power stations have the highest while hydroelectric power plants and wind farms have the lowest reference costs. Results are displayed graphically in Picture 1.

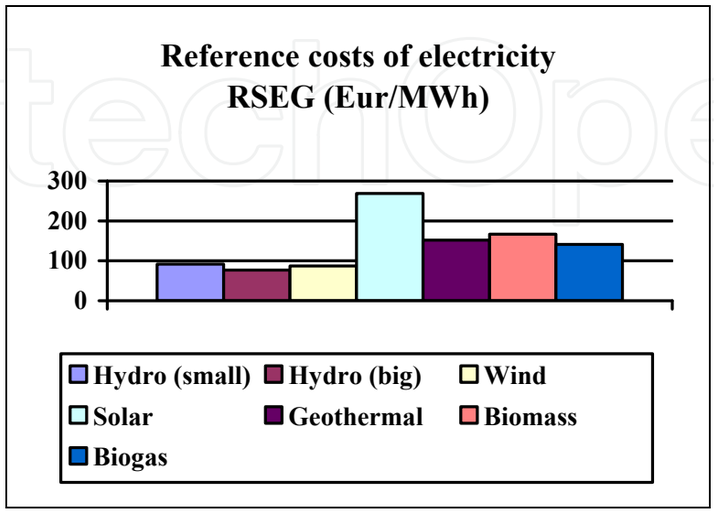

Fig. 1. Graphical display of electricity reference costs.

4.2 Sensitivity analysis

Taking into account the available data it was reasonable to perform a sensitivity analysis in view of the amount of investment and the interest rate of the loan. With investment costs a reduction of 10% and 20 % and an increase of 10% and 20 % was taken into account. Interest rate of the loan was varied as follows: 4,5 %, 5,5 %, 7,5 % and 9,5 %. The results are displayed in Tables 9 to 15. Investments are more sensitive to the investment input modification.

RATE OF INVESTMENT					
	- 20 %	- 10 %		+10 %	+ 20 %
RCEG(Eur/MWh)	78,19	85,17	92,16	99,14	106,13
INTEREST RATE OF THE LOAN					
	4,5 %	5,5 %		7,5 %	8,5 %
RCEG(Eur/MWh	88,30	90,20	92,16	94,18	96,26

Table 9. Results of the RCEG sensitivity analysis for small hydroelectric power plants.

RATE OF INVESTMENT					
	- 20 %	- 10 %		+10 %	+ 20 %
RCEG(Eur/MWh)	65,06	70,82	76,57	82,32	88,07
INTEREST RATE OF THE LOAN					
	4,5 %	5,5 %		7,5 %	8,5 %
RCEG(Eur/MWh	73,39	74,95	76,57	76,23	79,94

Table 10. Results of the RCEG sensitivity analysis for big hydroelectric power plants.

RATE OF INVESTMENT					
	- 20 %	- 10 %		+10 %	+ 20 %
RCEG(Eur/MWh)	71,67	79,21	86,74	94,27	101,8
INTEREST RATE OF THE LOAN					
	4,5 %	5,5 %		7,5 %	8,5 %
RCEG(Eur/MWh	82,58	84,62	86,74	88,92	91,16

Table 11. Results of the RCEG sensitivity analysis for wind farms.

RATE OF INVESTMENT					
	- 20 %	- 10 %		+10 %	+ 20 %
RCEG(Eur/MWh)	319,93	244,58	269,22	293,67	318,51
INTEREST RATE OF THE LOAN					
	4,5 %	5,5 %		7,5 %	8,5 %
RCEG(Eur/MWh	264,29	266,76	269,22	271,69	274,15

Table 12. Results of the RCEG sensitivity analysis for solar power plants.

RATE OF INVESTMENT					
	- 20 %	- 10 %		+10 %	+ 20 %
RCEG(Eur/MWh)	130,41	141,44	152,47	163,49	174,52
INTEREST RATE OF THE LOAN					
	4,5 %	5,5 %		7,5 %	8,5 %
RCEG(Eur/MWh	146,38	149,37	152,47	155,66	158,94

Table 13. Results of the RCEG sensitivity analysis for geothermal power plants.

RATE OF INVESTMENT					
	- 20 %	- 10 %		+10 %	+20 %
RCEG(Eur/MWh)	150,69	159,06	167,43	175,79	184,16
INTEREST RATE OF THE LOAN					
	4,5 %	5,5 %		7,5 %	8,5 %
RCEG(Eur/MWh	162,81	165,08	167,43	169,85	172,34

Table 14. Results of the RCEG sensitivity analysis for production facilities using biomass that exceeds the 90 % share of fuel energy.

RATE OF INVESTMENT					
	- 20 %	- 10 %		+10 %	+20 %
RCEG(Eur/MWh)	126,81	133,79	140,77	147,75	154,72
INTEREST RATE OF THE LOAN					
	4,5 %	5,5 %		7,5 %	8,5 %
RCEG(Eur/MWh	136,91	138,81	140,77	142,79	144,86

Table 15. Results of the RCEG sensitivity analysis for biogas plants operating on biogas produced from biomass.

The results of the sensitivity analysis of electricity reference costs for small sized hydro power plants are displayed graphically in Picture 2. A comparison of sensitivity analysis based on the modifications of observed input parameters for the remaining types of RES technologies leads to similar conclusions.

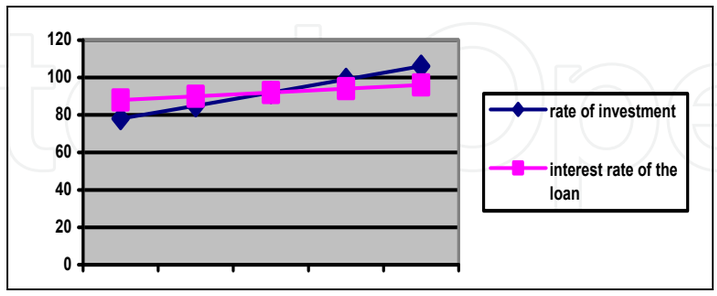

Fig. 2. Graphical display of sensitivity analysis for small sized hydro power plants.

The inclination of the pink line indicates that reference costs are more sensitive to the modification of the investment rate than to the interest rate of the loan. The cross-section point of both lines represents the starting value of electricity reference costs for small-sized hydro power plants (92,16 Eur) reached in accordance with basic assumptions regarding the rate of investment and interest rate of the loan that are 1.700 Eur/kW (Table 8) and 6,5 %.

Modification of the loan interest rate obviously does not represent a significant economic risk because an increase of the effective interest rate for 1 percentage point leads to an increase of electricity reference costs from approximately 1,5 Eur for big hydro power plants to approximately 3 Eur for geothermal hydro power plants. If the investment input is increased for 10 % electricity reference costs will increase from 5 to 9 %. A 5 % increase is noticed with biogas plants and production facilities operating on the basis of wooden biomass while a 9 % increase of RCEG is noticed with solar power plants. Results depend on the share of investment costs in total costs. When comparing changes of RCEG it is also necessary to take into account the cost of fuel for biogas plants and production facilities operating on the basis of wooden biomass while for the remaining five types of RES technology this is not the case.

5. Conclusions

In accordance with the proposal of the European Parliament directive Slovenia should by 2020 reach a 20 % share of RES energy in the total energy consumption. The results of our analysis display that reference costs for RES generated electricity are substantial and for most technologies even higher than the market price of electricity. In the years to come energy policy will play a crucial role as it will have to see to the decrease of capital costs and at the same time establish market conditions and incentive schemes which meet the technically conditioned effectiveness and the service life of RES production facilities.

At present in Slovenia a "Plan of action to reach target shares of RES generated electricity final consumption by 2020" is in the process of preparation. The latter will also form the basis for the adoption of the Slovenian national action plan. The target of the national action plan is to generate additional 3.000 GWh of RES generated electricity in 2020 in comparison with the currently generated volume. This plan of action makes several proposals for different possibilities and scenarios in order to reach this target.

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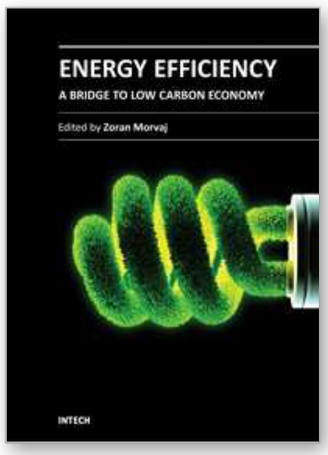

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Energy efficiency is finally a common sense term. Nowadays almost everyone knows that using energy more efficiently saves money, reduces the emissions of greenhouse gasses and lowers dependence on imported fossil fuels. We are living in a fossil age at the peak of its strength. Competition for securing resources for fuelling economic development is increasing, price of fuels will increase while availability of would gradually decline. Small nations will be first to suffer if caught unprepared in the midst of the struggle for resources among the large players. Here it is where energy efficiency has a potential to lead toward the natural next step - transition away from imported fossil fuels! Someone said that the only thing more harmful then fossil fuel is fossilized thinking. It is our sincere hope that some of chapters in this book will influence you to take a fresh look at the transition to low carbon economy and the role that energy efficiency can play in that process.

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