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Renewable energy in Croatia: a review of present state and future development

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Abstract

Renewable energy has recently experienced a rapid expansion in Croatia. The improved feed-in tariff system attracted substantial investments and boosted the electricity generated from renewable energy systems. The installed renewable energy capacity rose rapidly from 100 MW in 2011 to more than 500 MW in 2016. In 2014 alone, 200 MW of new wind power plants were added. The total installed capacity in renewable power plants is capable of generating around 1250 GWh of renewable electricity per year. Renewable electricity represents a share of around 7% in the annual electricity consumption of Croatia. Wind energy is by far the most significant renewable energy source in Croatia, generating more than 85% of the renewable electricity. By installed capacity, the 455 MW in wind power plants is followed by 25 MW in biomass and biogas power plants, 12 MW in cogeneration and 8 MW in solar PV power plants. In order to keep up with the running expenditures within the feed-in tariff system, the incentive fee for renewable electricity support was increased fivefold by the end of 2013. At present, end consumers support renewable electricity generation with 5% of the cost of electricity. This incentive fee is expected to rise with newly added renewable power plants, aiming to double the share of renewable electricity from the present 7% up 13.6% by 2020.
Keywords: *Renewable energy, Croatia, feed-in tariff system, solar PV, solar thermal, wind energy*

1. Introduction

This paper gives an overview of the present state and future development of renewable energy in Croatia. Wind and solar PV energy are the most rapidly expanding renewable energy markets in Croatia. On the other hand, solar thermal and hydropower have slower growth rates. The substantial renewable energy growth is fueled by increasing energy demand, fossil fuel price and energy supply insecurity. Furthermore, improved policies and incentive programs as well as enhanced renewable energy components and systems have also contributed the renewable energy growth both in Croatia and worldwide [1-3]. The improved Croatian feed-in tariff system made investing in renewable energy more attractive to entrepreneurs and boosted the installed capacities of wind power in the first place. However, the feed-in tariff system collecting incentive fees presents an increasing financial burden to electricity customers since the agreed renewable electricity share targets are still far away.

2. Global renewable energy overview

The solar PV global installed capacity rose from 16 GW in 2008 to 232 GW while the wind global installed capacity rose from 121 GW in 2008 to 433 GW at the end of 2015 [1], as shown in figs. 1 and 2. The leading countries for installed solar PV capacities are China (44 GW), Germany (40 GW), Japan (36 GW), USA (27 GW) and Italy (20 GW). The country with the largest newly added solar PV capacity in 2015 was China with 15 GW, overtaking long-time leader Germany. The solar water heating collector capacity is estimated at 435 GWth (621 million m^2) in 2015, with China at the first place reaching a share of 73%, and followed by USA, Germany, Turkey and Brazil, whose combined share is 12% [4-6]. The solar water heating sector

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slowed down in 2014 and 2015, mainly due to shrinking markets in Europe and China. The concentrating solar thermal power (CSP) market has a global installed capacity of 4.8 GW with Spain and USA holding about 90% of the world total capacity.

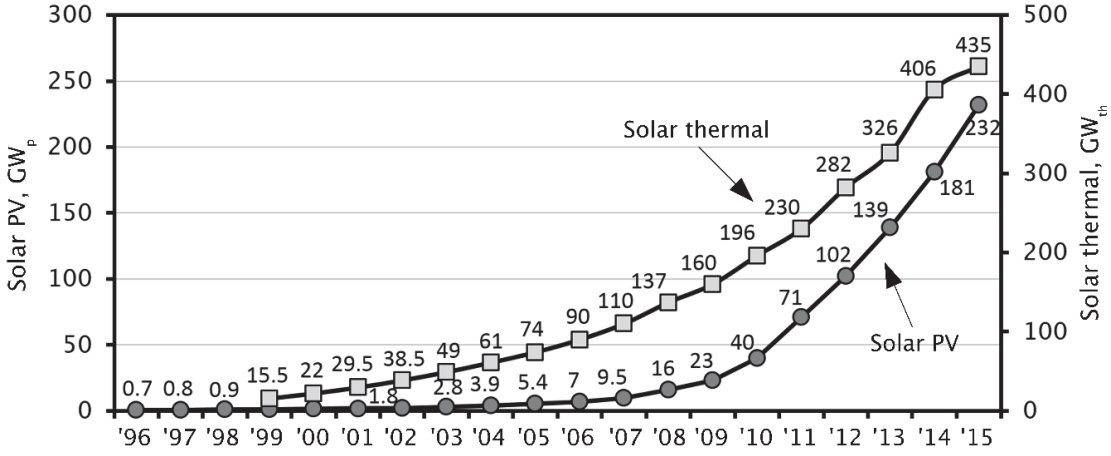

Fig. 1: Solar PV and solar thermal global installed capacity, 1996-2013, [1-6]

The leading countries for installed wind power capacities are China (145 GW), USA (74 GW), Germany (45 GW), India (25 GW) and Spain (23 GW), fig. 2. Again, China is the leading country for newly added wind power capacities with 32 GW in 2015 alone. The hydropower global capacity surpassed 1000 GW in 2013 and it was 1069 GW at the end of 2015. The leading countries for installed hydropower are China (296 GW), Brazil (92 GW), USA (80 GW), Canada (79 GW), Russia (48 GW) and India (47 GW). China added 16 GW of new hydropower plants in 2015 [1].

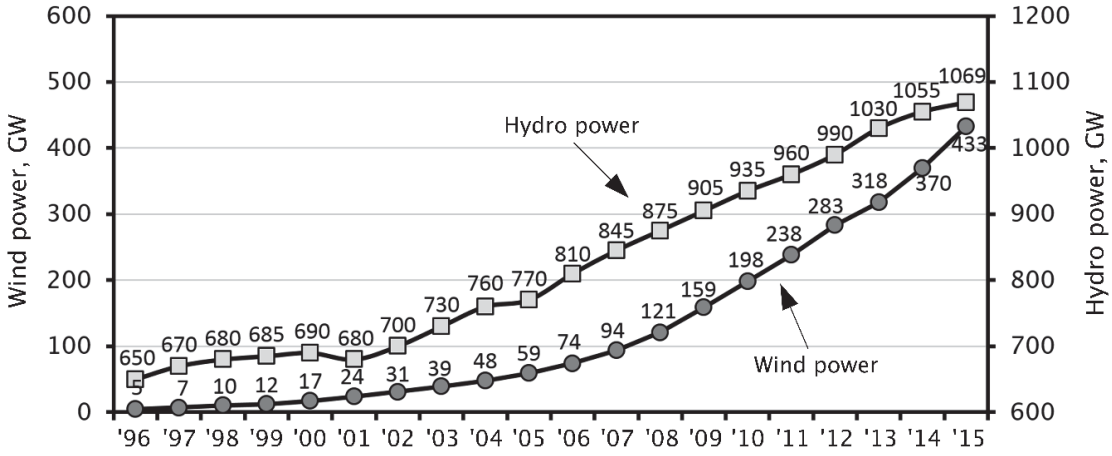

Fig. 2: Hydro and wind power global installed capacity, 1996-2013, [1-3]

Wind, hydro, biomass and geothermal energy are the most financially viable renewable energy sources on the market. The cost of electricity generation from hydro power plants is in the range of 0.02 to 0.09 €/kWh with a levelized cost (LCOE) of 0.045 €/kWh. Onshore wind power plants have costs of electricity generation in the range of 0.03 to 0.09 €/kWh with a LCOE of 0.054 €/kWh. Biomass energy, including solid, liquid and gaseous fuels, has a cost of electricity generation between 0.03 and 0.09 €/kWh with a LCOE of 0.06 €/kWh. The costs of electricity generation from geothermal sources is in the range of 0.05 to

0.11 €/kWh with a LCOE of 0.07 €/kWh. Nowadays, wind, hydro, biomass and geothermal energy provide electricity at a competitive cost, compared to the conventional fossil fuels. Electricity generation in fossil fuel power plants come at costs between 0.04 and 0.12 €/kWh and a LCOE of 0.055 €/kWh, all excluding health, environment and carbon emission costs.

Electricity generation in offshore wind power plants have significantly higher costs than those of the onshore wind power plants. The levelized cost of electricity generation (LCOE) in offshore wind power plants is almost three times the cost of electricity in onshore wind power plants: 0.15 €/kWh against 0.054 €/kWh. The cost of electricity generation from solar energy is still the highest among renewable energy sources. The cost of electricity is in the range of 0.07 to 0.20 €/kWh for utility PV power plants, 0.15 to 0.25 €/kWh for small-scale rooftop PV systems and 0.20 to 0.30 €/kWh for CSP thermal power plants. The levelized costs are 0.14 €/kWh for utility PV, 0.19 €/kWh for rooftop PV and 0.23 €/kWh for CSP. The efficiency of solar PV modules is still a major drawback, yet improvement is being made in this field as well. The efficiency of crystalline silicon PV modules is 10-20% while the efficiency of thin-film technology is only 5-12%. Nevertheless, the efficiency of concentrating PV modules (CPV) is 25% on average. The most-efficient existing PV module is a four-junction CPV which peaked a world record of 46% solar-to-grid efficiency. Hybrid photovoltaic thermal solar collectors (PVT) and concentrating PVT (CPVT) modules are capable of producing electricity and heat at efficiencies significantly higher than those of electricity-only CPV modules, with manufacturers claiming efficiencies of up to 75%. Solar thermal water heating systems reach 30-50% efficiency at an average cost between 0.05 and 0.15 €/kWh. Large-scale solar thermal systems, for multi-family houses and district heating have costs of energy generation between 0.03 and 0.10 €/kWh.

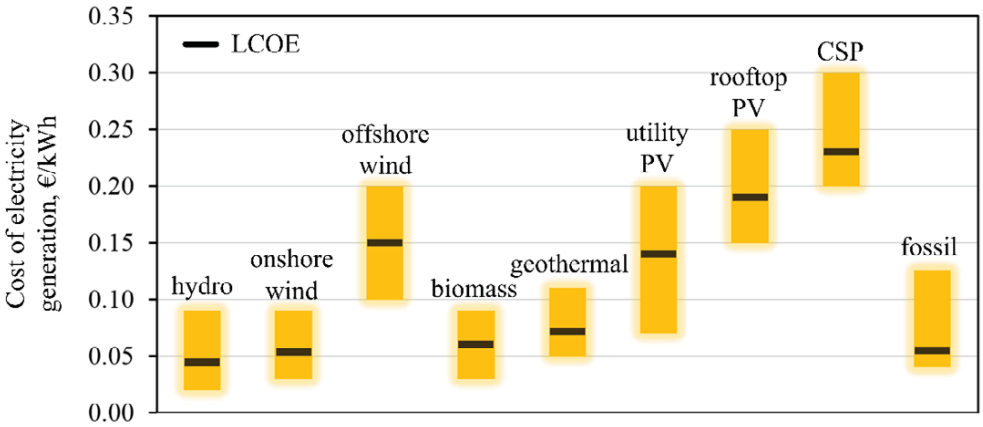

Fig. 3: Range of cost and levelized cost (LCOE) for electricity generation from renewable energy sources [1-3]

3. Renewable energy in Croatia

3.1. Present state

Under the Croatian feed-in tariff system, the currently installed renewable energy capacity of around 530 MW is capable of producing around 1250 GWh of electricity per year [7]. Ranked by installed capacity, wind energy dominates overwhelmingly with 455 MW and is followed by biomass and biogas installations, each having a total capacity of 25 MW, cogeneration with 12 MW, solar PV with 8 MW, small hydro with 3 MW and waste energy with 2 MW. Ranked by the number of operating power plants, the leading is solar PV with 155 power plants and is followed by 21 biogas installations, 17 wind power plants, 10 biomass installations, 7 small hydro power plants, 4 cogenerations and 1 waste energy power plant.

The nature of wind energy in Croatia is highly intermittent, whereas frequent and abrupt oscillations in the electricity output are expected over short periods of time, usually between morning and evening hours. In 2015, during 10% of the time the wind electricity output was negligible, usually less than 1% of the nominal capacity. On the other hand, the maximum instantaneous wind electricity output was 370 MW, which

corresponds to a maximum capacity factor of 84%. The average capacity factor for Croatian wind power plants is 25%, which corresponds to 2200 working hours at nominal capacity over a period of one year. For comparison, Danish wind power plant are able to achieve annual capacity factors between 50 and 60%.

The generated renewable electricity of 1250 GWh represents around 7% of the gross electricity generation which amounts to 17500 GWh in Croatia [7-10]. If large hydro power plants (> 10 MW) are accounted for in the renewable electricity mix of Croatia, the renewable electricity share varies significantly, depending on the quantity and distribution of rainfall throughout the year. For example, the share of renewable electricity was only 28% in 2012 but reached 58% in 2014. Likewise, the renewable energy share in the total primary energy consumption of Croatia is also variable: from 14% in 2012 up to 28% in 2014.

Under the European energy and climate plan, Croatia agreed that the share of renewable energy in the final energy consumption should reach 20% by the end of 2020. Furthermore, Croatia decided for two sub-targets: increase the renewable electricity share to 13.6% and increase the cogeneration electricity share to 4%, both with respect to the final electricity consumption. Unlike renewable electricity, the Croatian solar thermal sector is having a slower progress, because of smaller subsidies. The total installed solar thermal surface was around 200.000 m^2 by the end of 2015 in Croatia. This gives a specific solar thermal surface of only 47 m^2 per 1000 inhabitants in Croatia, whereas the EU-28 average is 85 m^2 per 1000 inhabitants [4-6].

3.2. Future development

Renewable energy has seen a fivefold increase of installed capacities in the last four years: from 100 MW in 2011 to more than 500 MW as of September 2016, as shown in Fig. 4. Wind power plants are usually installed along the coastal region of the Adriatic Sea, because of favourable wind conditions. On the contrary, solar PV systems are more frequently installed in West and North Croatia, despite lower annual solar irradiation but more attractive support schemes.

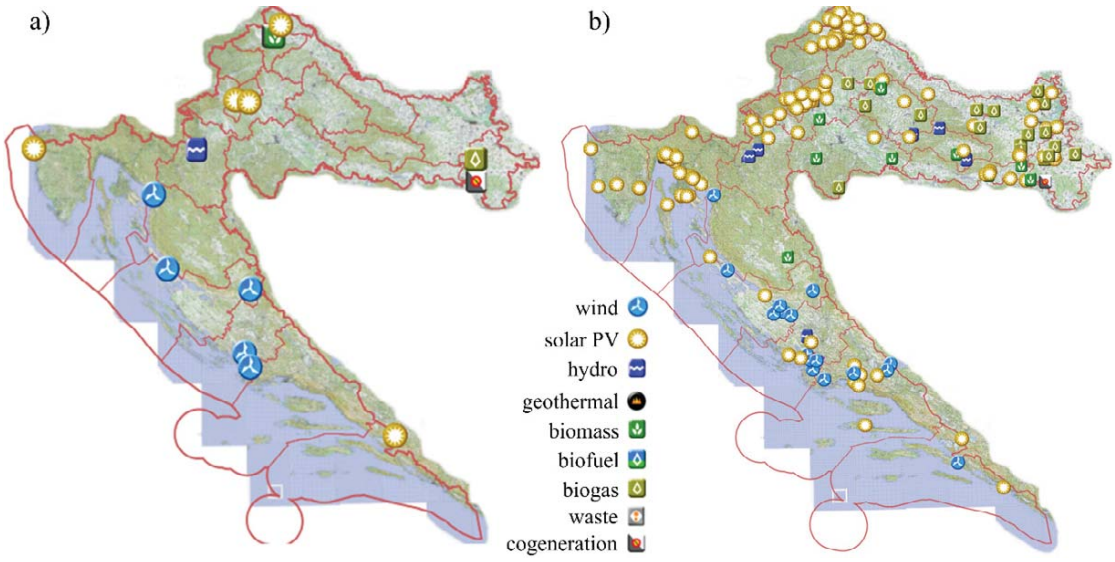

Fig. 4: Renewable energy installations in Croatia: a) 100 MW in 17 power plants in 2011; b) 530 MW in 215 power plants as of September 2016 [6]

At present, the 530 MW of installed renewable energy capacities supply around 7% of the electricity demand in Croatia. On the other hand the share of electricity from cogeneration systems is still negligible, less than 1% in the annual electricity consumption. In order to meet the agreed targets of 13.6% in renewable electricity share and 4% in cogeneration electricity share, a substantial increase in total capacity and number of installations in renewable electricity and cogeneration is necessary. It is estimated that an additional 500 MW in renewable electricity and 140 MW in cogeneration are required to meet the agreed share targets.

Wind energy will continue to dominate the renewable electricity mix in Croatia. According to the Croatian action [11] plan for renewable energy, the present wind energy capacity of 455 MW will reach 750 MW by 2020, as shown in fig. 5. Solar PV, from the present 8 MW is expected to reach 55 MW by 2020. Hydro energy (including large hydro) will be upgraded from the present 2100 MW up to 2500 MW by 2020, of which small hydro power plants will represent 100 MW. Biomass and biogas power plants have a combined total capacity of 50 MW, which is expected to increase up to 125 MW by 2020. Geothermal installations for electricity generation are at test phase at the moment and will reach 10 MW by 2020. The annual generated electricity can be estimated from the number of working hours at nominal capacity: 3000 hours for hydro, 2200 hours or wind, 1150 hours for solar PV, 6500 hours for biomass and biogas, 7200 hours for geothermal energy. Thus, the generated renewable electricity (excluding large hydro) will increase to 3200 GWh by 2020, from the present 1250 GWh. This returns a predicted renewable electricity share of around 18%, which is even more than the agreed target share of 13.6%. At present, wind power plants generate more than 85% of the renewable electricity in Croatia. However, this wind share is expected to decline to around 50% as new hydro, biomass and cogeneration capacities enter the renewable electricity mix of Croatia.

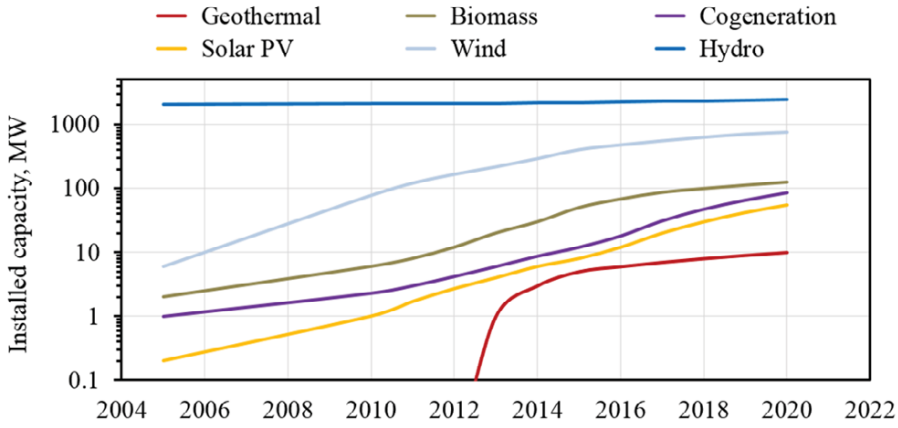

Fig. 5: Predicted renewable energy capacities in Croatia till 2020

The Croatian action plan [11] for renewable energy is a roadmap for increasing the use of renewable energy in the three major sectors of energy consumption: electricity, heating & cooling and transport, as shown in fig. 6. The overall combined share of renewable energy in the final energy consumption should be 20% or more by the end of 2020 in Croatia. The target share for renewable energy in electricity consumption of 39% by 2020, including large hydro power plants, will be achieved by upgrading hydro and wind capacities as well as installing new capacities of solar PV, biomass and cogeneration power plants.

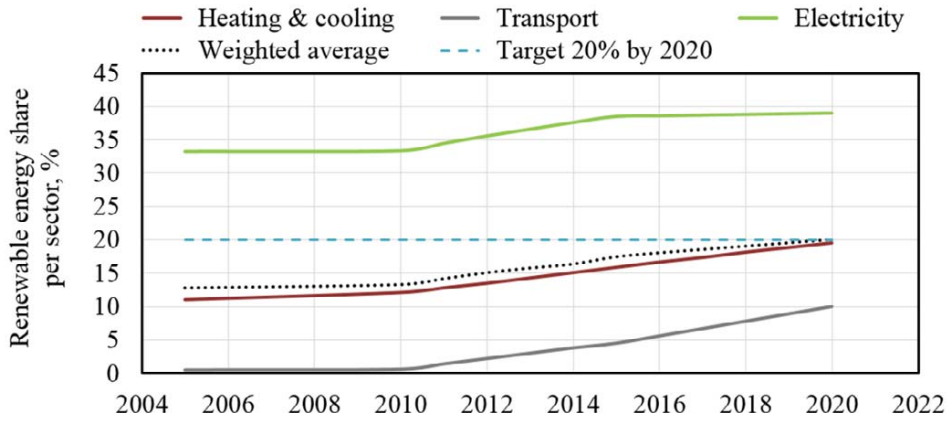

Fig. 6: Planned renewable energy share by consumption sector till 2020 in Croatia

The share of renewable energy in heating & cooling energy consumption is expected to grow from the present 15% up to 20% by 2020. This goal will be achieved with nationwide support programs for the energy retrofit of existing buildings, installation of solar collectors for space and water heating and replacement of fuel oil boilers with biomass and biogas boilers. The share of renewable energy in transport is expected to reach 10% by 2020. At the moment this goal seems hardly achievable, and attractive support programs will be necessary for the introduction of biofuel, hybrid and electric vehicles.

3.3. Economic aspects

To keep up with the running expenditures within the Croatian feed-in tariff system, domestic consumers had their taxes for renewable electricity generation increased in 2013. This increase was driven by the discrepancy between collected and distributed funds, which occurred in 2012 and 2013 [12], as shown in Fig. 7. Taking into account that the present renewable electricity tax is 5.8 €/MWh and that the price of electricity is 120 €/MWh for domestic consumers, nearly 5% of the price of electricity goes to renewable electricity support in Croatia. The renewable electricity taxes are going to rise since new renewable energy capacities are planned. The share of renewable electricity will be doubled by 2020, from the present 7% up to 13.6%. Recently, the Ministry of Economy of Croatia announced that the renewable electricity tax for domestic consumers will be raised to 20 €/MWh in 2017, and further to 23.3 €/MWh in 2018 and 25 €/MWh in 2019.

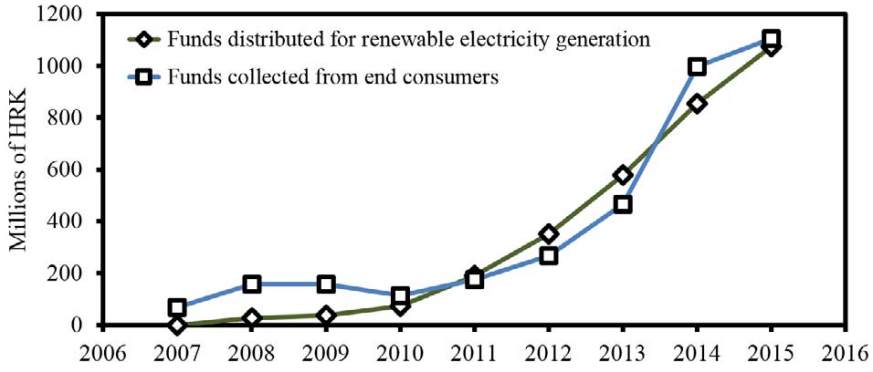

Fig. 7: Distributed and collected funds within the Croatian feed-in tariff system (1 EUR = 7.5 HRK)

The financial support for renewable electricity generation inside the Croatian feed-in tariff system was around 150€ million, or 1125 million HRK, in 2015. For a total amount of generated renewable electricity of 1250 GWh under the feed-in tariff system, the specific support for renewable electricity generation was equal to 120 €/MWh. For comparison, the European weighted average support for renewable electricity generation was 110 €/MWh in 2013 [13], as shown in figure 8.

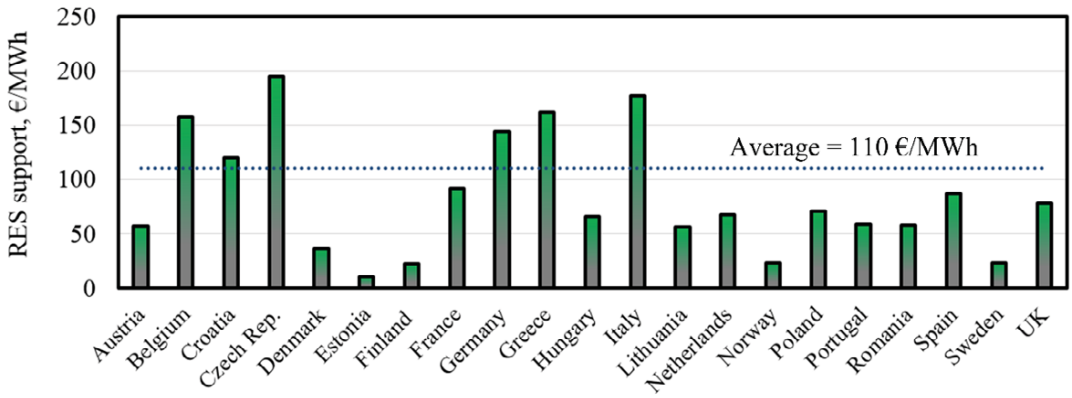

Fig. 8: Renewable energy support under the feed-in tariff system per unit of generated renewable electricity

The support for renewable electricity generation per unit of generated renewable electricity ranged between 11 €/MWh (Estonia) and 195 €/MWh (Czech Republic) in 2013. In Croatia, the specific support for renewable electricity generation was 120 €/MWh in 2015. However, this value does not take into account the penetration of renewable energy into the grid. Since the share of renewable electricity in the generated gross (renewable and conventional) electricity is 7% at the moment, the specific renewable electricity support per unit of generated gross electricity is 8.4 €/MWh in Croatia. The support for renewable electricity generation is collected from renewable electricity taxes for domestic and industrial consumers, carbon and environment taxes, grid fees, and other. At the moment, domestic consumers in Croatia have a renewable electricity tax of 5.8 €/MWh, which will be raised to 20 €/MWh in 2017 and further to 25 €/MWh in 2019. The annual electricity consumption of the average household in Croatia is 3500 kWh. Therefore, per year the average Croatian household supports renewable electricity generation with an amount of 20.3 €, which will become 87.5 € in the close future. In Europe, the specific support with respect to the gross electricity generation is up to 32 €/MWh (Italy), whereas the weighted average support is 13.7 €/MWh [13], as shown in fig. 9. Generally, countries with higher RES support in gross generated electricity have also higher shares of renewable electricity in their electricity markets.

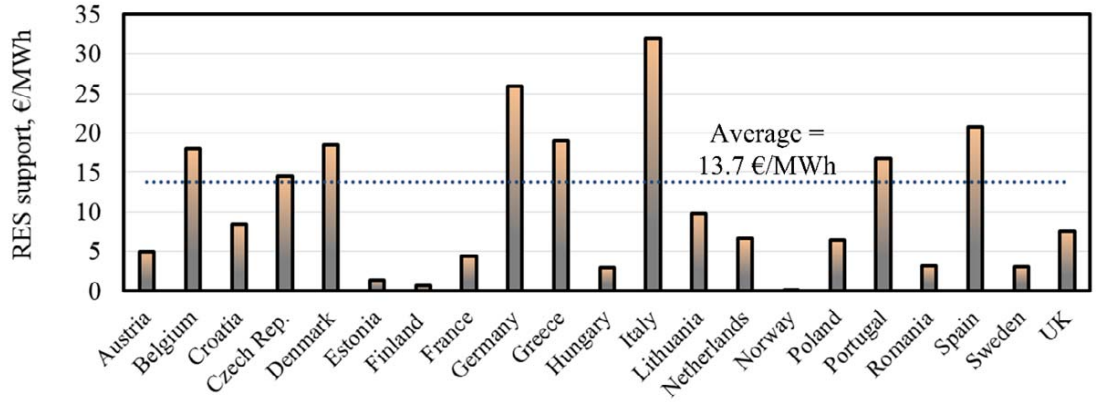

Fig. 9: Renewable energy support under the feed-in tariff system per unit of generated gross electricity

The renewable electricity support is somewhat correlated to a country's energy import dependency, as shown in fig. 10. Generally, countries with high dependency on imported energy tend to support more renewable electricity generation. For example, countries having high energy import dependency and large RES supports are: Italy with 79% and 32 €/MWh, Belgium with 77% and 18 €/MWh, Portugal with 75% and 17 €/MWh, Spain with 74% and 20 €/MWh, Greece with 66% and 19 €/MWh and Germany with 62% and 26 €/MWh. On the other hand, several countries have high energy import dependency, near or above 50%, but support renewable electricity generation to a lesser extent, such as Lithuania, Hungary, Finland, France and Croatia.

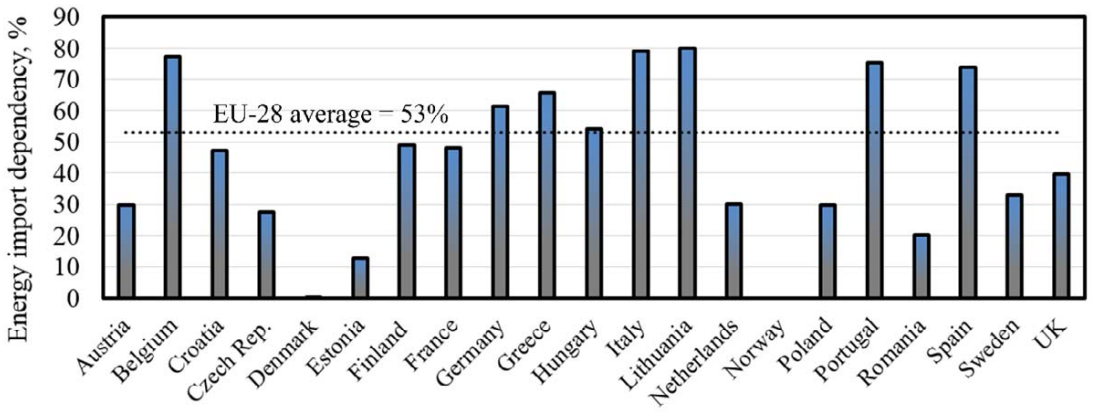

Fig. 10: Energy import dependency by country. Note: Norway is a net exporter, its energy dependency is set to 0.

4. Conclusion

Under the European energy and climate plan, Croatia agreed that the share of renewable energy in the final energy consumption should reach 20% by the end of 2020. Specific target shares have been decided for the three major energy consuming sectors: electricity, heating & cooling and transport. The target shares for renewable energy in electricity generation is 13.6% excluding large hydro or 39% including large hydro power plants. Today, excluding large hydro power plants, renewable electricity supplies 7% of the electricity consumption. If large hydro is included, the renewable electricity share is between 30 and 50%, depending on the available water resources during the year. The target shares for heating & cooling energy consumption and transport are set to 20% and 10%, respectively. At present, renewable energy represents 15% of the heating & cooling consumption and the 20% target will be most likely achieved. However, the renewable energy share in the transport sector is still negligible and the 10% target seem unreachable at the moment.

Renewable electricity is a fast growing market in Croatia. The support for renewable electricity generation will most likely continue to grow in the next 10 - 15 years. Today, the installed renewable electricity capacity is capable of supplying 7% of the electricity consumption in Croatia. The target share for renewable electricity has been set to 13.6% and the achievement of this target will require improved policy and stronger financial supports. The drawback of the fast growing renewable energy market are the increasing electricity prices in Croatia. The price of electricity is being pushed by the growing taxes for renewable electricity generation, which end consumers pay at a present rate of 5.8 €/MWh and will be paying at a rate of 20 €/MWh in 2017 and 25 €/MWh further in 2019. Inevitably, the price of electricity, which is 120 €/MWh at the moment, will grow alike. The collected funds from renewable electricity taxes are being converted into financial supports aiming to pull in new investments in the renewable sector. This renewable energy financial support, expressed in units of generated gross electricity, will grow from the present value of 8 €/MWh to around 20 or even 30 €/MWh in the next few years, whereas the EU average is 13.7 €/MWh. New renewable energy installations, especially wind farms, will need even more land to be converted to this purpose. However, the present expansion in the tourism sector opposes the expansion of renewable energy into islands and offshore areas, near seaside resorts and touristic centers.

On the other hand the solar thermal is having a slower progress. The total installed solar collector surface for water and space heating purposes was around 200.000 m^2 (140 MW_{th}) in Croatia by the end of 2015. It can be calculated that the per capita solar collector surface is 47 m^2 per 1000 inhabitants in Croatia which is only half of the EU-28 average with 85 m^2 per 1000 inhabitants. The slower progress of the solar thermal market in Croatia is mainly caused by less financial supports.

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