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Energy Sector

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Note

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Croatia – Energy Sector Policy Note

Croatia joined the EU in 2013 and has been implementing energy sector reforms in accordance with EU commitments relating to energy efficiency, integration of renewables and reduction of greenhouse gas emissions[1] and Croatia's energy strategy, which includes establishing a power market and unbundling the transmission and distribution sub-sectors from power generation and supply.

The state-owned electric and gas utility HEP Group has undergone vertical unbundling, resulting in establishment of separated entities for generation, transmission, distribution and supply. New companies have entered the electricity and gas supply business, and electricity and gas prices have been gradually deregulated, starting with non-residential customers. The electricity exchange CROPEX commenced operations in 2016, and two years later, in July 2018, it coupled with the Slovenian exchange. Market coupling was extremely successful and resulted in exponentially higher volumes of electricity trades, 449,305 MWh in October 2018, which exceed the amounts traded by CROPEX in its entire first two years of existence. Regional electricity trade and a liquid, transparent and competitive market results in customers having access to more economic sources of generation. In addition, competitive regional electricity trade allows generators to be more efficient and to produce electricity when and where it is most economic. Competition among energy providers results in a reduced number of operational hours for inefficient thermal power plants, thereby also contributing to reduced emissions. This created prerequisites for Croatia to improve system flexibility needed to reduce price volatility and to absorb excess renewable energy when the system is over-generating electricity, to quickly ramp up production when the sun stops shining or the wind stops blowing and to import electricity to cover its winter and summer peak demand, at times when it is more economic than running expensive thermal units.

Croatia's energy intensity, driven by energy efficiency improvements, has been decreasing, but this has not occurred as rapidly as for some of its European Union neighbors. This is largely due to inefficient use of energy in the building and transport sectors, as well as due to growing demand for cooling in the Adriatic region of the country, where summer tourism is booming. Croatia has prepared the Low Carbon Strategy and is updating its Energy Strategy. Together, these will lead to the formulation of the National Energy and Climate Change Action Plan (NECCAP). As an EU member country, Croatia is obliged to complete NECCAP by the end of 2019. In addition, the National Development Strategy is being prepared, which cuts across energy sector issues such as the tourism-dominated energy demand and supply solutions, eco-friendly renewable energy, electric vehicles and smart electricity grid applications.

Croatia is a net importer of energy, with energy imports valued at around 5 percent of GDP (in 2016). Croatia imports nearly 40 percent of its electricity needs, 40 percent of its gas and 80 percent of oil. In 2016, almost half of net primary energy supply (PES) was imported, led by oil and gas (76 percent of imported primary energy). Imported coal accounted for almost 8 percent of PES. Biomass, including fire wood, remained substantial in Croatia, at 15 percent of PES, and has grown by more than 1.7 percent

[1] The EU 2020 commitments on energy are summarized in three overarching targets: (i) 20 percent cut in greenhouse gas emissions (from 1990 levels); (ii) 20 percent of EU energy from renewables; and 20 percent improvement in energy efficiency which are further elaborated in EU directives (such as EPBD (2010/31/EU , EED 201/27/EU) and transposed into Croatia's national legislation and action plans (such as 4th National Energy Efficiency Action Plan). The targets for 2030 are becoming more demanding (such as 40% cut in greenhouse gas emissions compared to 1990 levels, at least a 27% share of renewable energy consumption, and indicative target for an improvement in energy efficiency at EU level of at least 27%). For more details on EU legislation see https://eur-lex.europa.eu/summary/chapter/energy.html?root_default=SUM_1_CODED=18

each year, due to close to half of Croatian households heating their homes with biomass. Natural gas production declined at an average annual rate of 7.5 percent. Hydropower accounted for 7 percent of PES, with no new major capacity under construction. Although solar and wind energy in Croatia has increased considerably in recent years, with an annual growth rate of 34.8 percent, their contribution to the overall PES remains small, at less than 2 percent (largely due to continued reliance on fossil fuels in the transport sector). Altogether, PES in Croatia had decreased on average 0.6 percent per year during 2011–2016.

The objective of this Policy Note is to provide an assessment of the energy sector in Croatia as background information contributing to the elaboration of Croatia's National Development Strategy, managed by the Ministry of Regional Development and EU Fund. The targeted audiences for this Policy Note are government officials, non-governmental organizations, and energy-sector practitioners. This Policy Note follows a background analysis[2] and is comprised of seven sections, namely:

I) Overview of the global trends and societal challenges;
II) Overview of developments in Croatia (in the energy sector);
III) Assessment of the main developmental challenges and opportunities for Croatia;
IV) Prioritized policy recommendations;
V) Cross-cutting issues and their implications for policy;
VI) Proposed implementation roadmap; and
VII) Proposals for strategic ("Flagship") projects.

The first two sections provide qualitative and quantitative assessments of trends and challenges globally and in Croatia. The remaining sections are a synthesis of the findings obtain from such assessment and from consultation with stakeholders in Croatia. The authors endeavor to present these remaining sections in a non-technical manner per the objective of this Policy Note.

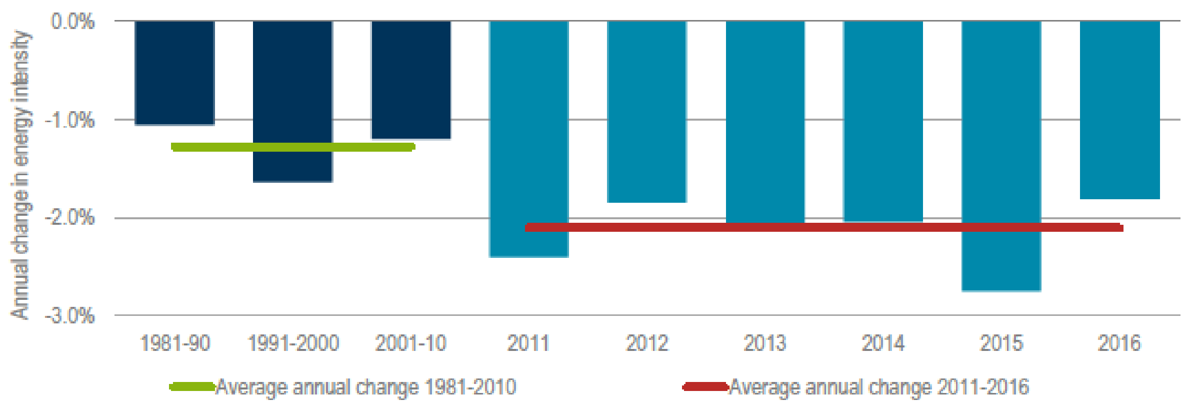
Additional details on biomass applications and opportunities appear in the Annex of this Policy Note.

[2] The background analysis appears in the report: Croatia Energy Sector Note, September 2018, World Bank.

1 Overview of the global trends and societal challenges (including best practices)

(a) Energy Intensity and Efficiency[3]. Croatia's energy intensity, driven by energy efficiency improvements, has been decreasing, but not as rapidly as some of Croatia's European Union neighbors. To better understand this, it is helpful to examine global trends. According to the International Energy Agency's (IEA) Energy Efficiency 2017 report, the global economy's energy intensity continues to fall, with an average annual improvement of approximately 2 percent in recent years (as can be seen in Figure 1.1 below). Both advanced and developing economies saw steady declines in energy intensity in the last few decades, signifying that more units of GDP are produced for each unit of energy demand. Globally, energy intensity dropped 13% between 2000 and 2016. Among the advanced economies, the largest declines were seen in the United Kingdom (23%), Japan (21%) and the United States (15%).[4] Among the 28 EU countries, the average annual energy intensity decline (between 2005 and 2016) was 2.1%. Contrastingly, in Croatia it was 1.6% in the same period (a more detailed analysis of Croatia's energy intensity trends is provided in the next section).[5]

Figure 1.1: Annual changes in global primary energy intensity, 1981–2016 (IEA)



Note: Energy intensity is calculated as primary energy demand per USD 1 000 of GDP in 2016 prices at purchasing power parity.
Sources: Adapted from IEA (2016a), *World Energy Outlook 2016*; and IEA (2017a), *World Energy Statistics and Balances 2017* (database), www.iea.org/statistics.

Improvements in energy efficiency and intensity also contribute to a reduction in greenhouse gas emissions. Energy intensity decreases were responsible for 77 percent of the reduction in global emissions from GDP growth since 2014, while changing fuel mix (more natural gas and renewables) offset the remaining 23 percent, as can be seen in Figure 1.2 below.

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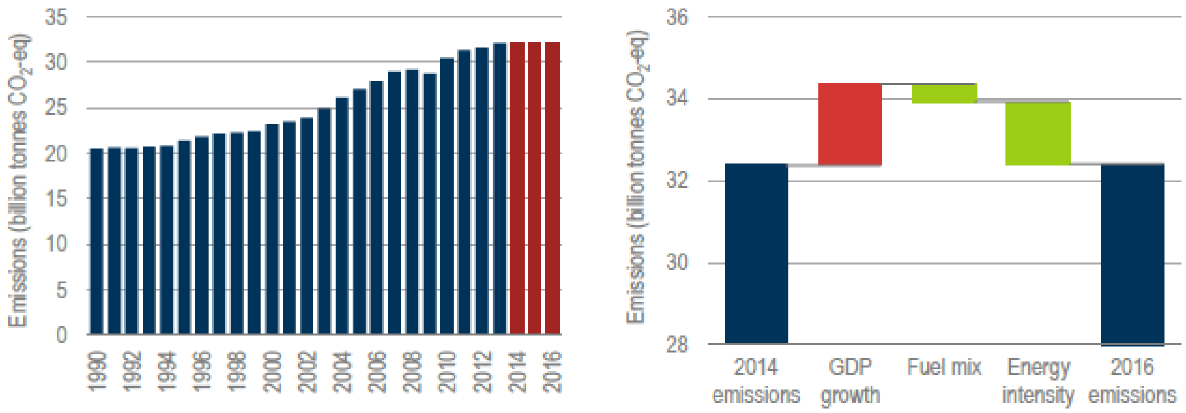
[3] Energy intensity (EI) is a measure of energy use per unit of GDP generated. Energy use could be measured at different stages, such as at the primary energy demand/supply stage or at the final energy consumption stage. GDP is measured relative to a given base year. EI could be measured at the overall economy level or at the energy consuming sector level, depending on data availability.

[4] See https://www.iea.org/publications/freepublications/publication/Energy_Efficiency_2017.pdf

[5] See https://www.eea.europa.eu/data-and-maps/indicators/total-primary-energy-intensity-3/assessment-2

Figure 1.2: Global energy-related GHGs since 1990 (left) and an analysis of the factors that influence GHGs, 2014–2016 (right) (IEA)



Note: Energy intensity is calculated as TPES per thousand USD of GDP in 2016 prices and PPP.

Sources: Adapted from IEA (2017a), *World Energy Statistics and Balances 2017* (database), www.iea.org/statistics; IEA (2017b), *CO_2 Emissions from Fuel Combustion* (database), www.iea.org/statistics.

Changes in global primary energy intensity are influenced by improvements in energy efficiency on both the demand side, such as through the reduction of energy use in buildings or improvement in fuel efficiency standards in transport, and the supply side, such as through improvements to the efficiency of the power generation and heating/cooling sectors. Importantly, energy intensity is also affected by changes in the economic structure, such as the shifting of economic activity away from energy intensive industries, towards less intensive service sectors.

On the demand side, the effect of energy efficiency gains has been most evident in the residential sector, where improvements in heating intensity (energy use per floor area), more efficient lighting (use of CFL and LED bulbs) and minimum energy performance levels for appliances resulted in a steady decline in energy use. Worldwide, thanks to policy actions focused primarily on the building envelope, energy efficiency in buildings continues to improve. For example, the IEA reports that Denmark and Germany have seen dramatic improvements in the energy efficiency of buildings following significant investments to upgrade building envelopes. Highly efficient building envelopes enable the use of higher-efficiency equipment and energy sources, such as low temperature waste heat, heat pumps and renewable energy. However, more progress is needed to improve equipment policies that would update heating, ventilation and air conditioning (HVAC) equipment. Worldwide, with the exception of Japan and Korea, fossil-fuel based and conventional electric equipment continue to dominate the global buildings market, accounting for more than 80% of buildings' heating equipment stock. Even though solar thermal heat capacity has increased by 250% over the last decade and heat pump sales are increasing in many markets, more work is needed. District heating systems continue to play a large role in meeting heating demand (especially space heating) in many parts of Europe, Russia and China. But significant effort is still needed to reduce the carbon intensity of district heating. This is especially true in countries like Croatia, where one half of all households use biomass for heating.

Space cooling is another area where investments are needed. Overall, space cooling accounts for just 2% of global energy use, but higher standards of living and migration toward warmer regions are causing rapid increases in demand, where efficiency standards are weakest. The IEA predicts that over the next three decades, the use of air conditioning for cooling homes and offices is set to soar, becoming one of the top drivers of global electricity demand. As incomes rise and populations grow, especially in the world's hotter regions, the use of air conditioners is becoming increasingly common. The International Panel on Climate Change (IPCC) estimates that about 75% of the increased demand is due to increasing income in emerging market countries and 25% is due to climate change. The EU Heating and

Cooling Strategy foresees a strong increase in residential cooling consumption, i.e. from about 35 TWh in 2015 to 137 TWh in 2050 for the reference scenario, and 78 TWh for the energy efficiency scenario in 2050. Space cooling can account for a large share of peak demand, placing further stress on the power system, especially during periods of extreme heat.[6]

As we further elaborate on in section 2, Croatia's energy intensity has been decreasing driven by energy efficiency improvements, but not as rapidly as some of its European Union neighbors. Croatian demand for cooling is growing, especially in the Adriatic region where tourists often expect air conditioning in the vacation properties they rent.[7]

(b) Competition in the Global Energy Systems

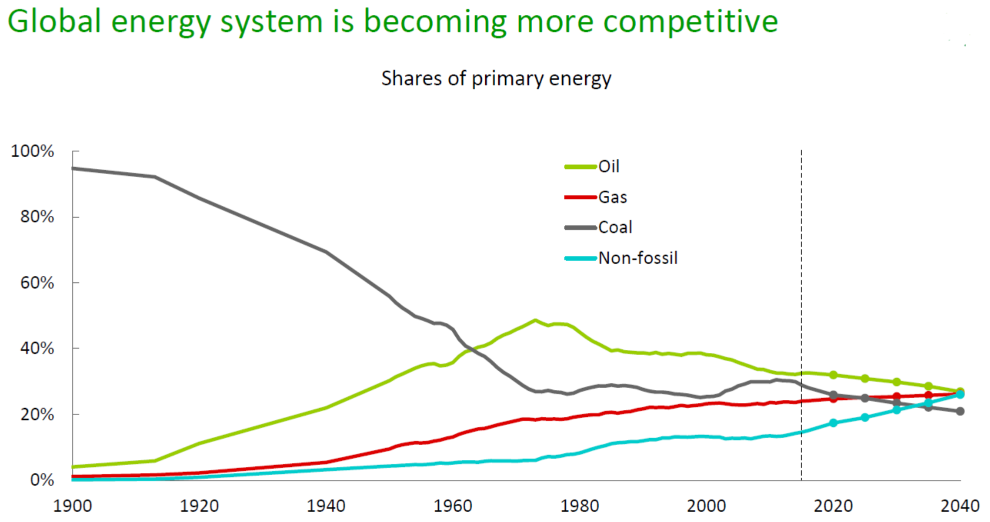
Considering Croatia's location close to the heart of Europe and its dependence on imports of primary fuels like natural gas and coal, as well as on imports of electricity it is critical to consider global energy trends. Competition is the driving force for innovation and more efficient use of resources on the supply side. Today's global energy systems are more integrated and competitive than ever before, due to the increased trade in primary energy sources, regional coordination of electricity markets, rapid spread of disruptive technologies (from rooftop solar to electric vehicles). Competition and the pressing need to de-carbonize world's energy systems in order to reduce the effects of global warming further drive innovation and more efficient use of resources For example, the mobility of LNG cargoes and their ability to be diverted in response to price signals means that, much like the prices for oil and other global commodities, movements in global gas prices are becoming more synchronized.

Falling prices for onshore and offshore wind, batteries and solar power around the world have an effect on the energy fuel mix in both the developed and developing countries around the world. Clean renewable energy is more competitive than ever before and is forecast to grow faster than any other energy source, accounting for over half of the increase in global power generation. The chart below depicts the predicted rate of growth of renewable energy in the coming decades, suggesting that the world is becoming less dependent on fossil fuels and has more choices of fuels than ever before.

[6] Heatwaves can push up electricity demand dramatically. For instance, the heatwave in France in August 2003, when temperatures rose to around 40°C across most of the country, increased power needs by about 4,000 MW, circa 10% more than the normal peak summer electricity demand. Such dramatic increases in electricity demand usually result in price spikes, which are often between two to four times the cost per kWh of baseload electricity supply. This is because in times of scarcity only the most expensive peaking generators, that are not used the rest of the year (due to high cost of fuel like natural gas or oil) are required to run. Relying on new peaking generators is often very expensive as, because although they only run a few hours a year, they need compensation to be available throughout the years. Therefore, many countries, n the integrated EU common electricity market, choose to rely on imports to cover their peak capacity needs, especially if the neighboring region is usually not experiencing scarcity conditions at the same time.

[7] https://www.eea.europa.eu/publications/trends-and-projections-in-europe-2018-climate-and-energy/at_download/file

Figure 1.3



Source: BP Energy Outlook, 2018

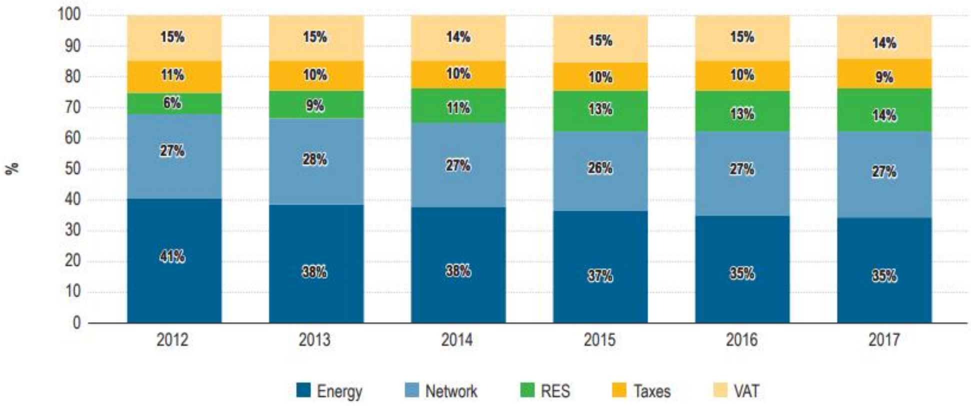
Consumers around the world are driving innovation on the demand side, as smart grid technologies and advanced metering enable a more *transactive* market with many new stakeholders, - notably "prosumers" and aggregators - at countless new feed-in and take-out points. Energy consumers in Croatia are as affected by the rapid technological changes and trends as consumers in many of the other EU countries who are demanding more control over how, when and at what price they consume energy. Sophisticated digital, computational, and operational tools, which allow a more granular pricing in terms of location and time, are creating the conditions for harnessing distributed energy resources (such as solar PV, demand response, batteries, EV charging load, mini-grid load, and other). Blockchain (and blockchain-enabled sensors) will also play a key in role in securing data and enabling real-time transactions between customers and utilities, and between distributed producers themselves. Distributed energy markets are also expected to interact with networks of intelligent electric charging stations for transportation, that are to be well-integrated with rest of the power system.

European countries have undertaken an ambitious path towards de-carbonization by deploying increasingly large quantities of renewables, improving energy efficiency and electrifying the transport sector. By 2040, European countries aim to cover up to 80 percent of demand with renewables, and to reduce carbon emissions by 80-90 percent compared to 1990 levels.[8] To minimize the amount of curtailed energy, European markets are optimizing the geographical spreading of renewable energy resources and looking into complementary solutions like storage and improved import/export network connections among EU countries. This is especially important due to the intermittent nature of wind and solar generation. The systems have to be flexible enough to handle large variations in net demand for electricity. This also implies greater price volatility, with higher peak prices due to higher variable batteries or gas turbines lifting prices; and lower off-peak prices due to low variable cost wind and solar pulling down prices. Increased penetration of renewables does not come without a cost. As shown in the figure below, European renewable energy charges have increased from an average of 6 percent in 2012 to 14 percent in 2017.

[8] https://tyndp.entsoe.eu/tyndp2018/

Figure 1.4[9]

Weighted average breakdown of incumbents' standard electricity offers for households in capital cities – 2012–2017 (%)



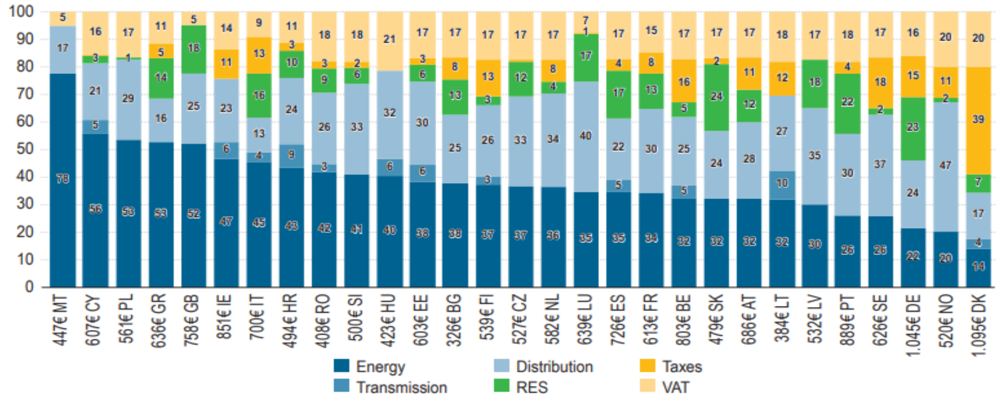
Source: Source: ACER calculations based on data from price comparison tools, incumbent suppliers' websites, NRAs, collected via ACER Retail Database (2018).

Note: For the purpose of this analysis, the average electricity price for household consumers in the EU is based on the standard incumbent offers for an annual pan-European average consumption of 3,500 kWh/year, weighted by total household consumption in each MSs, which is provided by CEER.

The relative share of the energy component (that reflects mainly the cost of purchasing electricity and gas on the wholesale market, but also suppliers' operating costs of running the business, and profit margin) in the final price has declined from 41 percent in 2012 to 35 percent in 2017. In Croatia, it stands at around 43%.

Figure 1.5[10]

Breakdown of incumbents' standard electricity offers for households in capital cities – November/December 2017 (%)

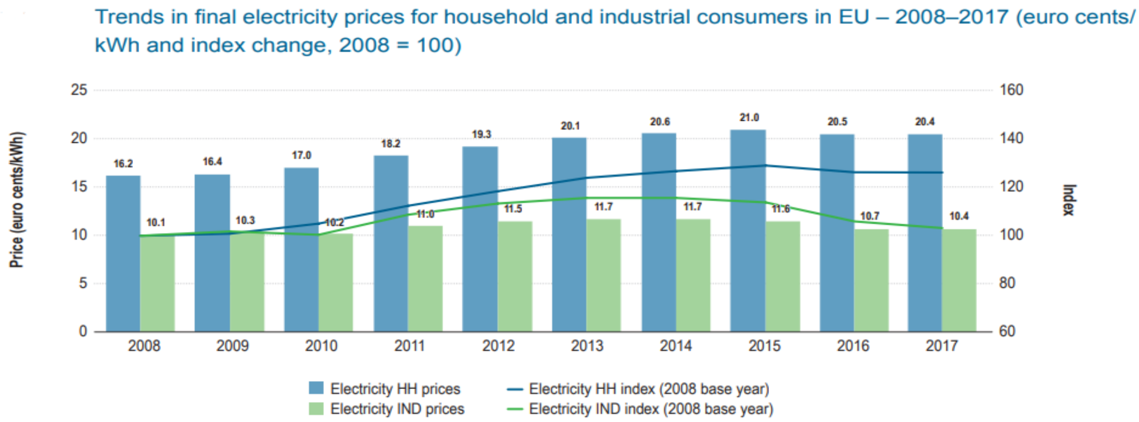


Source: Agency for the Cooperation of Energy Regulators and the Council of European Energy Regulators

[9] Source: Agency for the Cooperation of Energy Regulators and the Council of European Energy Regulators.
https://www.acer.europa.eu/Official_documents/Acts_of_the_Agency/Publication/MMR%202017%20-%20RETAIL.pdf
[10]. https://www.acer.europa.eu/Official_documents/Acts_of_the_Agency/Publication/MMR%202017%20-%20RETAIL.pdf

As shown in the chart below, average household electricity prices grew over 25 percent, while prices for industrial customers (who are often exempt from paying for renewable energy charges) increased by 3.7 percent in the last decade.

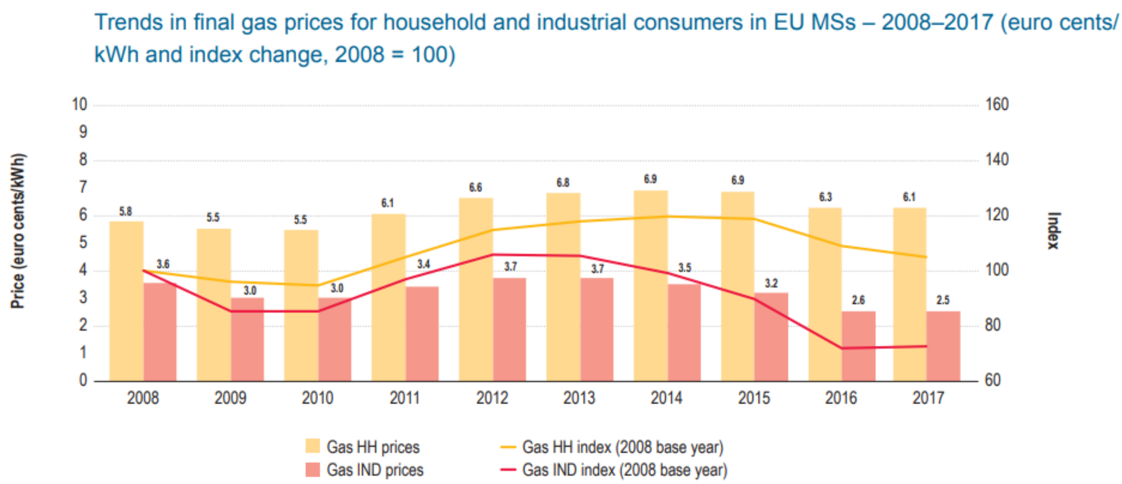
Figure 1.6



Source: Agency for the Cooperation of Energy Regulators and the Council of European Energy Regulators

In the same period, household prices for gas have remained relatively stable, as shown below, while prices for industrial consumers have seen a significant decrease of 28 percent.

Figure 1.7



Source: ACER calculations based on Eurostat, Band D2: 20–200 GJ (household gas consumption) and Band I5: 1,000,000–4,000,000 GJ (industrial gas consumption) - (29 May 2018).

(c) Energy Poverty

Energy poverty broadly entails the inability for energy consumers to adequately access energy sources for basic needs such as lighting, cooking, heating and cooling. There is no common definition for energy poverty. In the EU, a number of proxy indicators are used to indicate energy poverty, such as; the share of population that are in arrears on utility bills (arrears), the share of energy expenditure in household income, and the inability to keep a home adequately warm[11]. In December 2016, The European Commission created the EU Energy Poverty Observatory (EPOV) project[12] to assist members in measuring and addressing energy poverty. EPOV 2016 statistics indicate that on average in the EU 10.5 percent of the population is late on utility bills payments and 11.2 percent report an inability to keep their home adequately warm[13].

In South East Europe (SEE), common energy poverty issues are inadequate heating, poor insulation of homes, indoor air pollution from biomass cooking and heating, the unaffordability of commercial energy (as households shift from firewood to natural gas, district heating), and potential energy price increases and volatility following energy market liberalization. According to the 2016 report "Energy Poverty in South East Europe: Surviving the Cold", while energy use per capita in SEE countries is about half that of the European Union (EU), the inefficiency of building stock, household appliances and heating systems means that the energy required to provide the same comfort levels is much higher than in the EU.

[11] The World Health Organization defines adequate heating as 21 degrees Celsius in the living room and 18 degrees Celsius in other rooms.
[12] https://www.energypoverty.eu/about/role-and-mission
[13] The same statistics for Croatia indicate 21.5 percent of the population is late on utility bills payment and 12.3 percent of the population reports an inability to keep their home adequately warm.

2 Overview of developments in Croatia

a) Energy Intensity and Efficiency

Demand Side Efficiency

Available data shows Croatia's energy intensity is higher than the EU28 average. Furthermore, Croatia's primary energy intensity, in the period between 2005-2015, decreased at a slower rate than the EU28 average, in part due to inefficient heating in the residential sector and a lack of structural changes in the energy intensive transport, and building and construction sectors. Compared to other Central and Eastern Europe Countries, Croatia is doing better however, there is still room for Croatia to further improve its energy intensity.

Figure 2.1: Energy Intensity EU28 and Selected Countries[14]

Countries	Relative energy intensity 2014 (GDP 2010, EU28 =100)	Gross inland consumption per capita (TOE) 2014
EU 28	100	3.2
Croatia	155	1.9
Austria	87	3.8
Czech Republic	212	3.9
Slovenia	151	3.2
Hungary	176	2.3

Source: European Environment Agency

Due to advancements in energy efficiency initiatives, improvements are being made across the EU to reducte energy intensity. "Between 2005 and 2014, gross inland energy consumption in EU-28 decreased by 1.4 percent per year, while GDP increased by 0.8 percent per year. As a consequence, energy intensity in the EU-28 decreased by an average of 2.2 percent per year during this period" (Energy Intensity, 2016).

Energy consuming sectors in Croatia ranked from the largest to smallest share of consumption, are: households, construction, services (mainly tourism), transport sector, and the industrial sector.

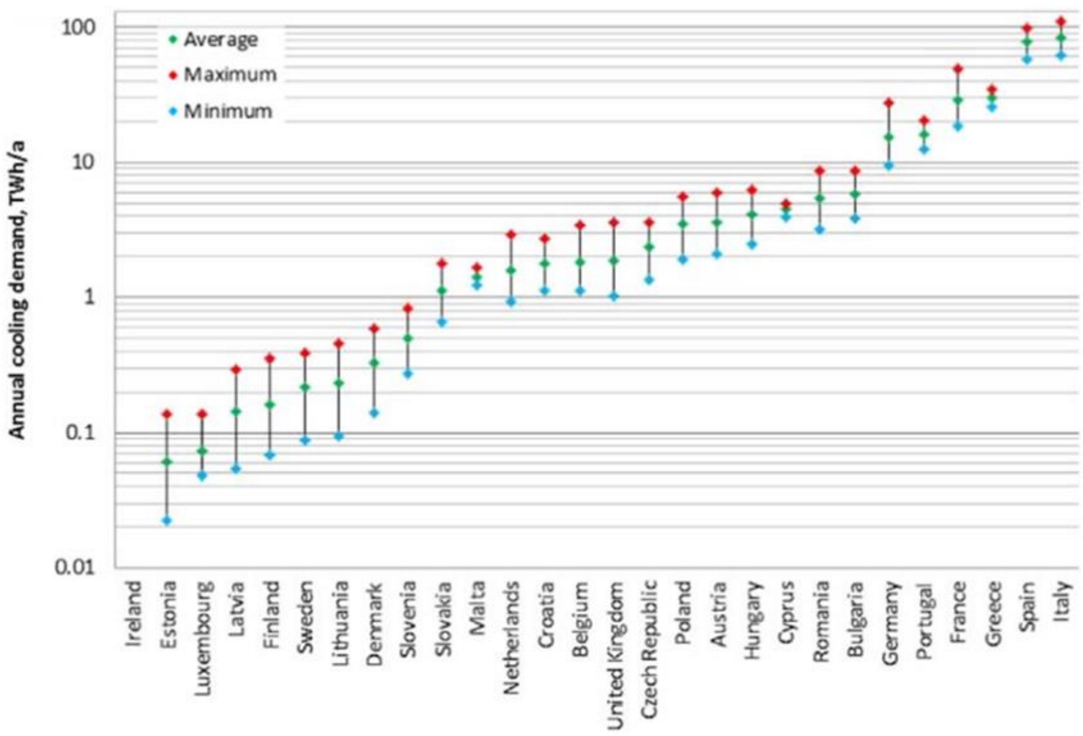
Increased cooling demands

In 2016, for the second time in the country's history, Croatia saw its electricity consumption peak in the summer months, when tourists visiting the coastal areas increasingly rely on air conditioning. Croatia's

[14] In 2018, the European Environment Agency started to publish energy intensity data calculated on the basis of purchasing power parity GDP (instead of nominal GDP). The value for Croatia's relative energy intensity in 2014, based on PPP GDP, would be 104.

summer tourism is booming, attracting many visitors from other EU member states, where air conditioning use is more common. [15] Demand driven by the tourism sector combined with Croatia's own domestic demand for cooling, is changing the dynamics of electricity consumption in the country. It is estimated that Croatia's current demand for cooling stands at 1 TWh, but may double, resulting in a need for an additional 260 MW of installed capacity (or imports). [16] The chart below shows that Croatia's estimated average cooling demand potential may approach that of the United Kingdom (a much larger, but more northern country) and neighboring South East European countries like Bulgaria and Romania.

Figure 2.2: Annual Cooling Demand



Source: Jakubcionis and Carlsson, Estimation of European Union Residential Sector Space Cooling Potential, Energy Policy (2017)

E-mobility to Further Add to Growing Demand for Electricity

Today, one-third of Croatia's total energy usage results from transportation and around 90 percent of vehicles on the road are either diesel or petrol.[17] In order to reduce energy intensity in the transport

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[15] While a direct link between tourism and increases in electricity consumption is difficult to establish, HERA, Croatia's electricity regulator, states in its last annual report that according to HOPS, the transmission system operator, "the reason for this is an exceptionally mild winter and a good tourist season (increased use of air conditioning units)."
https://www.hera.hr/en/docs/HERA_Annual_Report_2016.pdf

[16] https://ac.els-cdn.com/S030142151630653X/1-s2.0-S030142151630653X-main.pdf?_tid=d7b999cf-796a-4d09-bf91-fc004e5f4e9e&acdnat=1528315033_2b9f9bd56c2d3ce34d6fbd68bea2e2ec

[17] https://glashrvatske.hrt.hr/en/news/economy/state-providing-subsidies-for-electric-vehicles/

sector, Croatia has offered new incentives to its citizens and companies for the purchase of electric vehicles (EV). Over EUR 3.3 million has been allocated for this purpose – EUR 1.62 million for citizens and EUR 1.75 million for companies. Individuals can receive up to 40% of the car's value from the Environmental Protection and Energy Efficiency Fund. The incentives go up to EUR 10,700 (HRK 80,000) for electric cars.[18] The Fund has already provided about EUR 6.75 million in subsidies, which helped buyers purchase about 1,420 electric and hybrid vehicles. However, the goals and expected long-term impact of these subsidies still need to be elaborated. In Croatia, there are currently about 200 charging stations. Estimates predict that by 2030, as many as 35 percent of new vehicles will be electric.[19] Some non-standard estimates are being used to quantify how the addition of EVs would affect the total demand for electricity in Croatia in the coming decades, global forecasts suggest that it may represent an increase in electricity load in the range of 10-20 percent. Croatia's energy sector should explore how to integrate EV charging stations into its strategies, as most car owners would require a convenient location for their cars to charge overnight. Additionally, expanding the network of charging stations along the major highways, could further increase Croatia's connections with the rest of Europe. Innovation in the sector could facilitate cross-industry collaboration and the development of the services segment of the market.

Supply Side Efficiency

Electricity. Until 2016, the average efficiency of thermal power plants in Croatia was 32.5 percent with substantial room for further improvement. In particular, the new/planned combined-cycle gas turbines (CCGT) power/heat plants (e.g. 150 MW EL-TO Zagreb, 446 MW Osijek plant) have the potential to raise efficiency towards 50 percent together with the benefit of lower CO_2 emission relative to oil and coal power generation.

District heating. Most heat plants operate on natural gas. The first level of heat losses—from heat generators transmitted to different types of consumers—was around 6 percent in recent years. There are additional losses within each DH system: for instance, a World Bank 2010 report[20] indicates a heat loss of 9.45 percent for Zagreb DH and 6.8 percent for Osijek DH. A 2015 report commissioned by IFC indicates 22 percent heat loss for Karlovac and 26 percent in Rijeka. There are opportunities to utilize biomass (including wood chips or straw), waste heat from industry, waste-to-energy incineration, and geothermal in DH.

Transmission and distribution. Croatia has succeeded in reducing electricity distribution and transmission losses from 14.4 percent in 2000 to around 10 percent in 2016 (1,807 million kWh)[21], however, since 2010, improvements have been less than 1 percent. Going forward, Croatia will need to implement measures to both reduce technical losses, that might require capital investment (for which cost and benefit tradeoff should be considered), and to address non-technical losses (theft).

[18] https://balkangreenenergynews.com/croatia-gives-new-incentives-to-citizens-companies-for-ev-purchases/

[19] https://www.total-croatia-news.com/business/21952-major-subsidies-coming-for-electric-vehicles-and-infrastructure

[20] Implementation Completion and Results Report, Croatia District Heating Project, December 2010.

[21] Transmission losses ~ 2.2 % (data for 2015 and 2016, 1,9 in 2017), distribution losses ~ 8.1 %. Sources: HOPS, Enerdata, Energy in Croatia 2016.

Figure 2.3: Electricity Supply and Losses

	2011	2012	2013	2014	2015	2016
Electricity supplied to grid (mil. kWh)	18,528	18,186	17,922	17,507	18,190	18,350
T&D losses (mil. kWh)	1,831	1,887	1,944	1,764	1,802	1,807
T&D losses, %	9.9%	10.4%	10.8%	10.1%	9.9%	9.8%

Source: Energy in Croatia 2016

Natural gas losses in the transmission and distribution system are related to the concepts of "Lost and Unaccounted for Gas (LAUF)". LAUF includes all components of loss, such as gas used by the transmission and distribution operators, adjusted for meter errors, billing cycle issues, and other considerations as well as leakage, venting, theft, etc. Overall, natural gas losses in Croatia are low and in line with the industry norms.

Financing for Energy Efficiency

There is a mature energy services market in Croatia. However, although there are energy efficiency financing fundamentals in place, there is still large untapped potential. Energy service companies develop, implement and sometimes finance, energy efficiency projects, which are then compensated through energy savings. Croatia has over a decade of experience with the ESCO model. The first ESCO, HEP ESCO, was established in Croatia under the aegis of the national utility company HEP in 2003[22] to provide financing support to improve energy efficiency in public buildings (schools, hospitals, offices), public lighting, the residential sector, and the commercial and industrial sectors. The use of financial instruments, of about EUR 70 million in total (of which roughly half would be from European structural and investment funds, and the other half from commercial banks participating in the instrument) are being considered[23].

Between 2003 and 2009, HEP was the sole market provider of ESCO. Since HEP was fully state-owned and subject to public debt ceiling limit, this limited HEP ESCO's ability to increase one of its main services -- energy performance contracts (EPC)[24] -- because EPC were treated as debt liabilities to be repaid/reduced over time (Budget Act in 2008). It was not until 2014 that the Energy Efficiency Act (Official Gazette 127/14) transposed the EU energy efficiency directive (Directive 2012/27/ EU), which provided impetus for EPC expansion. This directive requires member states to encourage public bodies to use, where appropriate, ESCO and EPC to finance renovations. Further, when tendering service contracts with significant energy content, public bodies should asses the possibility of concluding long-term EPC that provide long-term energy savings. While this directive was supposed to boost EPC services in Croatia, in the few years following this directive, the number of implemented EPC projects was still below ten. The implementation of the Energy Efficiency Program for Public Buildings in 2014-2015 led to the renovation of 69 buildings and savings of 60 GWh/year. Some underlying causes for limited EPC

[22] Supported by the World Bank-funded Energy Efficiency Project, approved in 2008
[23] Public consultations of financial instrument were finalised in December 2018
[24] EPCs are agreements underwritten by ESCO that guarantee a minimum performance by energy efficiency improvement measures (e.g. lighting, heating and cooling, manufacturing processes).

projects include; mistrust due to the lingering effects of negative experiences from past projects, procurement constraints (especially for public sector clients), relatively low energy prices in Croatia, projects being too small, and a lack of capacity to aggregate projects[25], the lack of commercial banks' appetite to finance EPC, and a perceived high risk of ESCO's business resulting in high borrowing cost.

There are presently about ten active ESCOs operating in Croatia. Despite the presence of ESCOs, surveys and perceptions continue to indicate limited available financing for EE, mainly as a result of high interest rates. Mainstream financial institutions are generally not active in EE financing.

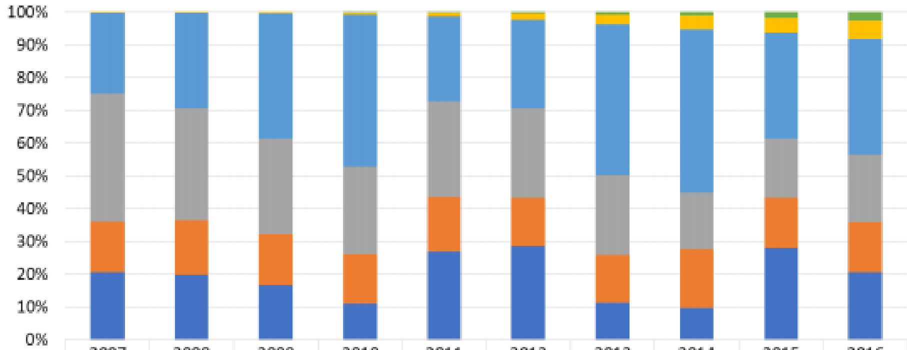
(b) Energy Security and Energy Markets (including renewables and natural gas)

b-1 Croatia's size and location make connectivity with the neighboring countries a priority. Croatia is one of Europe's smallest countries, located near the geographic center of Europe. In 2016, Croatia's domestic electricity consumption was 17.7 terawatt hours (TWh).[26] This was about 10 percent less than it was before the crisis of 2008-2009 and only half a percentage point higher than in 2015. Croatia's moderate electricity consumption growth trends are influenced by the changes in its overall economy, as it moves away from energy-intensive cement, and chemical and metals industries (usually supplied at high voltages) to tourism, paper, printing and food industries (supplied at medium and low voltages).

Croatia gets over half of its electricity from domestic hydropower, which accounts for close to half of its installed capacity (2,112 MW of 4,762 MW). Imported fuel powers five gas and fuel oil plants, one fuel oil and one coal-fired power/heat generation plants. In addition to domestic hydro, coal and gas-fired power stations, HEP Generation owns a 50% stake in the 696 MW Krško nuclear power plant in Slovenia, near the Croatian border. The shares of individual sources of electricity from 2007 to 2016 are shown below.

[25] Complex procurement increases transaction costs and decrease returns on investment, which can be prohibitive for small projects. On the other hand, large projects have bigger risks and access to finance can be challenging.
[26] In comparison, Italy's consumption in the same year was around 285 GWh.

Figure 2.4: Shares of individual sources of electricity (in GWh)



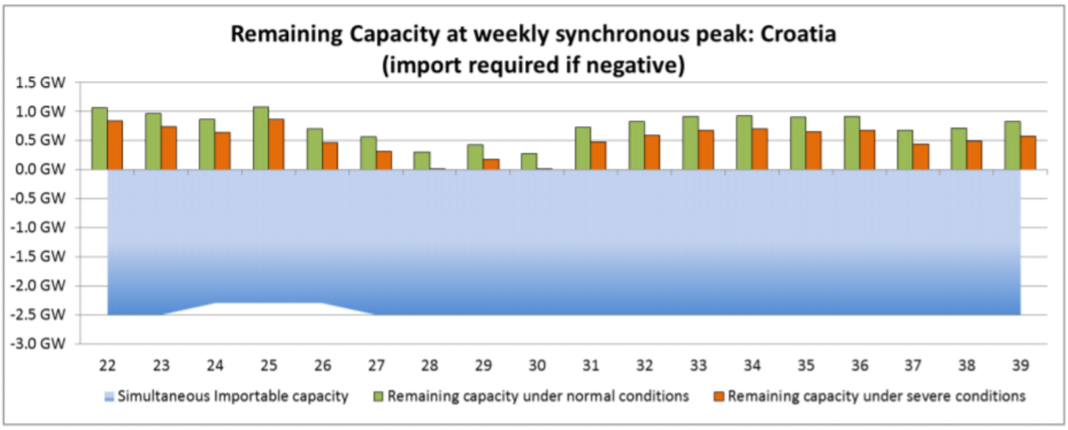
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Other RES	0	0	5	16	33	85	132	194	298	454
Wind	35	40	45	138	201	329	517	730	794	1,002
Water	4,357	5,277	6,765	8,305	4,578	4,772	8,054	8,356	5,715	6,250
Fossil fuels	6,877	6,101	5,207	4,825	5,184	4,791	4,228	2,912	3,192	3,625
Krško NPP	2,714	2,986	2,730	2,690	2,953	2,622	2,518	3,030	2,685	2,715
Net import (without Krško NPP)	3,647	3,591	2,952	1,986	4,752	5,002	1,973	1,642	4,948	3,628

Source: HERA Annual Report, 2016[27]

Croatia is a net importer of electricity. In 2016, imports reached 12 TWh and came from Bosnia Herzegovina (38%), Hungary (30%), Slovenia (21%) and Serbia (11%), while power exports (6 TWh) went mainly to Slovenia (74%) and Bosnia Herzegovina (19%). Imports are often more economically efficient compared to the dispatch of expensive thermal units.[28]

During peak demand, Croatia imports up to 40 percent of its electricity. Figures 2.5 and 2.6 below demonstrate Croatia's ability to meet summer and winter peak demand and import dependency.

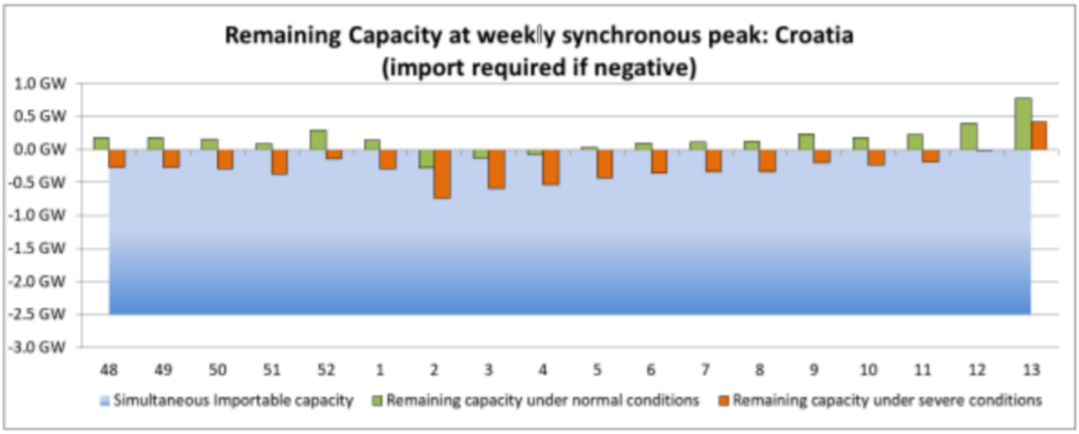
Figure 2.5: Croatia's Ability to Meet Summer Peak Demand



Source: ENTSO-E Summer Outlook 2017

[27] https://www.hera.hr/en/docs/HERA_Annual_Report_2016.pdf
[28] https://docstore.entsoe.eu/Documents/SDC%20documents/Winter%20Outlook%202018-2019_Report(final).pdf?deliveryName=DM6962

Figure 2.6: Croatia's Ability to Meet Winter Peak Demand



Source: ENTSO-E Winter Outlook 2017-18

As we explain below, growing electricity demand during the summer months is largely driven by the growing tourism sector along the Adriatic coast.

In 2016, Croatia made significant progress in its efforts to open its electricity sector to competition. Since joining the European Union (EU) in 2013, Croatia has implemented a number of EU directives aimed at opening its electricity sector to competition and integrating it into a single EU electricity market.

Competition in Croatia's electricity market is still very limited. **Market reforms are needed to improve the investment climate and create incentives for new entrants**. HEP Generation is the largest electricity generation company, with an 85 percent market share. [29] At the wholesale level, the market is largely based on bilateral contracts, in which producers (power generators) and customers (retail electricity supply companies and large customers) directly negotiate and agree on the price of electricity. Since opening in February 2016, CROPEX registered 17 members, including Germany's RWE, which commands 7 percent of the Croatian market.[30]

In July 2018, CROPEX coupled with the Slovenian exchange. Market coupling was extremely successful. The number of buyers and sellers increased from 6 in 2017 to 16, Volumes of electricity trades ,449,305 MWh in October 2018, exceeds the amount traded on CROPEX in the entire first two years of its existence, and is close to reaching the volume of electricity traded on the Slovenian power exchange, BSP South Pool (699,040 MWh in October 2018). A liquid market, with more buyers and sellers provides better economic signals for existing and new generators, as well as prosumers., and allows traders to take advantage of the differences in the hydro inflow regimes across the market, divergence in weather conditions, and non-coincidence of load patterns. A liquid, transparent and competitive market results in customers having access to more economic sources of generation. Similarly, a liquid market provides

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[29] Croatian Transmission System Operator Ltd. Annual Report for 2016. Page 38. http://www.hep.hr/UserDocsImages//dokumenti/Godisnje_izvjesce_EN//2016Annual.pdf

[30] German energy group RWE seeks bigger market share in Croatia. Reuters, February 23, 2018, https://uk.reuters.com/article/uk-croatia-energy-rwe/german-energy-group-rwe-seeks-bigger-market-share-in-croatia-idUKKCN1G71NR

signals for more efficient generation - producing electricity at the time or in the location that it is most economic.

The World Bank's 2018 "Doing Business" report shows that it is still expensive to get electricity in Croatia for a new business and that electricity is not as reliable as it could be, with high indicators for interruptions. Croatia ranked 75th among more than 190 countries, indicating that structural changes are needed.[31]

Figure 2.7: Doing Business in Croatia, 2018

✔ Reform making it easier to do business ✘ Change making it more difficult to do business

CROATIA		Europe & Central Asia		GNI per capita (US$)	12,110
Ease of doing business rank (1–190)	**51**	**Overall distance to frontier (DTF) score (0–100)**	**71.70**	**Population**	**4,170,600**

Starting a business (rank)	87
DTF score for starting a business (0–100)	86.39
Procedures (number)	8
Time (days)	7
Cost (% of income per capita)	7.2
Minimum capital (% of income per capita)	12.5
✘ **Dealing with construction permits** (rank)	126
DTF score for dealing with construction permits (0–100)	63.00
Procedures (number)	18
Time (days)	126
Cost (% of warehouse value)	9.4
Building quality control index (0–15)	12.0
Getting electricity (rank)	75
DTF score for getting electricity (0–100)	76.26
Procedures (number)	5
Time (days)	65
Cost (% of income per capita)	298.5
Reliability of supply and transparency of tariffs index (0–8)	5
✔ **Registering property** (rank)	59
DTF score for registering property (0–100)	71.44
Procedures (number)	5
Time (days)	62
Cost (% of property value)	4.0
Quality of land administration index (0–30)	22.5

Getting credit (rank)	77
DTF score for getting credit (0–100)	55.00
Strength of legal rights index (0–12)	5
Depth of credit information index (0–8)	6
Credit bureau coverage (% of adults)	100.0
Credit registry coverage (% of adults)	0.0
Protecting minority investors (rank)	29
DTF score for protecting minority investors (0–100)	68.33
Extent of disclosure index (0–10)	5
Extent of director liability index (0–10)	6
Ease of shareholder suits index (0–10)	6
Extent of shareholder rights index (0–10)	8
Extent of ownership and control index (0–10)	9
Extent of corporate transparency index (0–10)	7
Paying taxes (rank)	95
DTF score for paying taxes (0–100)	70.90
Payments (number per year)	35
Time (hours per year)	206
Total tax and contribution rate (% of profit)	20.6
Postfiling index (0–100)	61.20

Trading across borders (rank)	1
DTF score for trading across borders (0–100)	100.00
Time to export	
Documentary compliance (hours)	1
Border compliance (hours)	0
Cost to export	
Documentary compliance (US$)	0
Border compliance (US$)	0
Time to import	
Documentary compliance (hours)	1
Border compliance (hours)	0
Cost to import	
Documentary compliance (US$)	0
Border compliance (US$)	0
Enforcing contracts (rank)	23
DTF score for enforcing contracts (0–100)	70.60
Time (days)	650
Cost (% of claim)	15.2
Quality of judicial processes index (0–18)	13.0
Resolving insolvency (rank)	60
DTF score for resolving insolvency (0–100)	55.11
Time (years)	3.1
Cost (% of estate)	14.5
Recovery rate (cents on the dollar)	32.7
Strength of insolvency framework index (0–16)	12.0

Source: World Bank

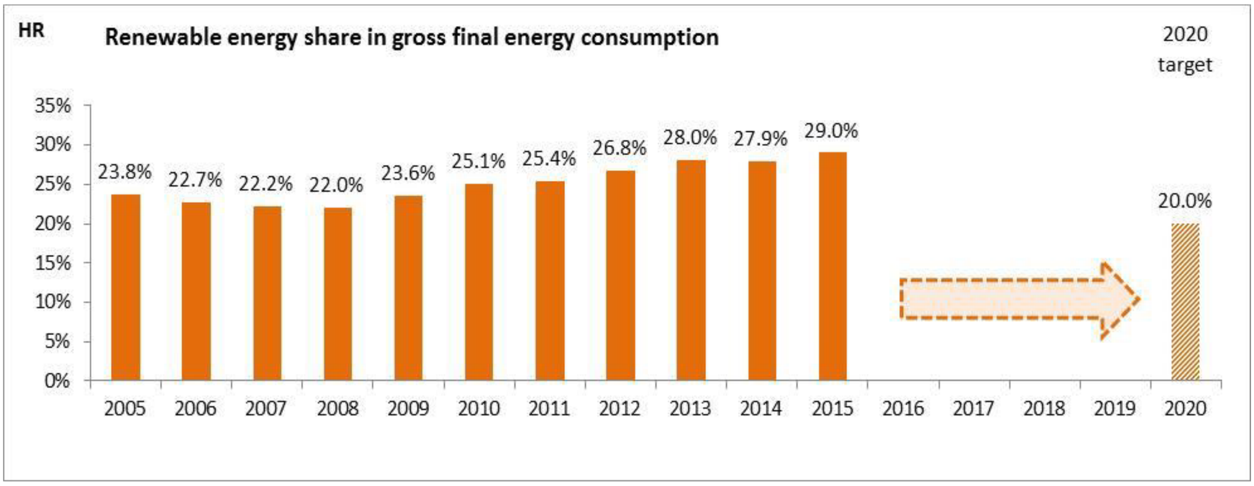
b-2 Electricity from Renewables in Croatia

Croatia has committed to decarbonizing its energy sector through the expansion of renewable energy and reduction of the carbon emission of fossil fuels. Furthermore, adding more renewables to the system could help decarbonize Croatia's energy sector by replacing fossil such as coal and natural gas. Thanks to existing hydropower[32] plants and the recent addition of wind and solar power generators, Croatia has exceeded the 2020 EU renewable energy target of 20 percent final energy consumption (39% in power production and 20% in heating and cooling). In 2016, hydroelectric power plants accounted for the largest share of installed plant capacity (at 45.37%), followed by thermal (42.10%), wind (10.05%), biomass (1.32%) and solar (1.16%) power plants. Intermittent wind and solar capacity accounted for 11 percent (539 MW) of installed grid-connected power generation capacity in Croatia (2016).

[31] http://www.doingbusiness.org/content/dam/doingBusiness/media/Annual-Reports/English/DB2018-Full-Report.pdf

[32] New hydropower in Croatia would be relatively expensive compared to other South East European countries, as many rivers are already used for power generation. http://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/IRENA_Cost-competitive_power_potential_SEE_2017.pdf

Figure 2.8: Croatia Renewable Energy Share in Final Energy Consumption



Energy Union Factsheet Croatia, 2017

The table below shows the mix of renewable power generation capacities in Croatia.

Figure 2.9: Croatia Installed Capacity of Renewable Power Plants

Type of Plant	Installed capacity (MW)
Hydropower plants	2,198.7
Wind power plants	483.1
Solar power plants	55.8
Thermal Power plants (biomass)	26.0
Thermal Power Plants (biogas)	35.9
Small Hydro power plants	6.6
Total	**2,806.1**

Energy in Croatia 2016

An enabling framework for further deployment of renewables is needed.

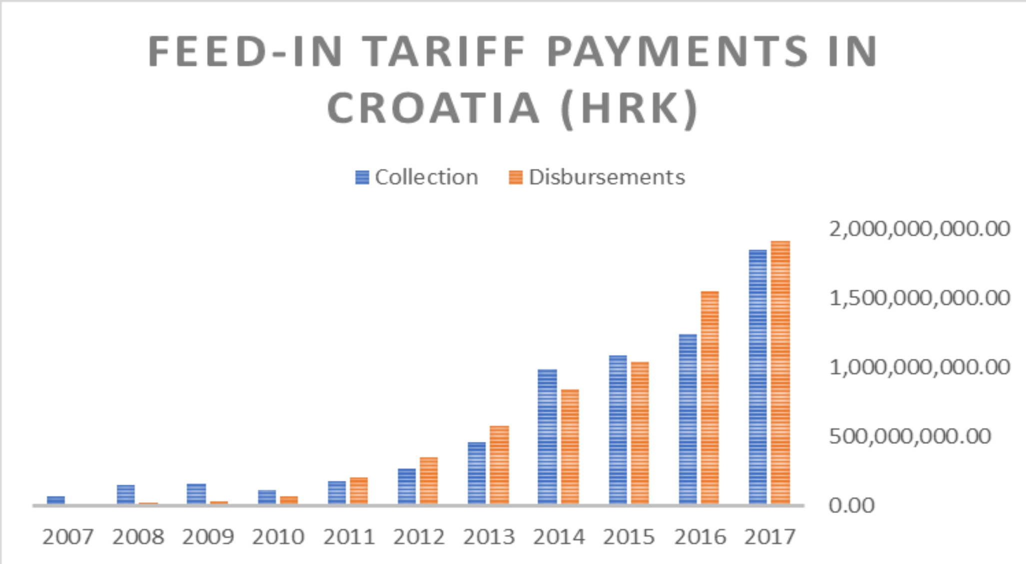
Reaching 2030 goals will be more challenging, as: (i) Croatia is lagging behind the planned schedule for phasing out the existing support system and introducing new market principles; (ii) technical (smart metering), legislative, and regulatory, barriers (including a market design impedes the efficient integration of electricity produced from renewable sources into the market); (iii) role of end-users in electricity market is limited and (iv) methodology for allocating the costs of balancing energy to renewable generators is lacking and (v) there is no market for ancillary services.

The existing feed-in tariff system supports electricity production from renewables and co-generation since 2007. It guarantees a regulated revenue stream to the producers of wind, solar, hydro, biomass, and geothermal biogas power for a period of up to 14 years. The level of the feed-in tariff is differentiated for technology and installation size and is adjusted based on inflation. For large plants, the tariff is determined according to a reference price, which is calculated on a daily basis. In addition, developers are granted priority dispatch (mandatory offtake) and tendering procedures for new capacities on state-owned land. The existing large hydropower plants that are owned by the HEP group are not eligible for feed-in tariffs. As an additional support measure, the Croatian Bank for Reconstruction and

Development (HBOR) provides financing options for renewable energy projects through loans covering up to 75% of project costs. Furthermore, the Fund for Environmental Protection and Energy Efficiency supports small renewable energy projects, such as solar, thermal, and heating pumps.

The feed-in system represents a significant burden for the final customers and suppliers and has negative impact on the development of supply market. HROTE, the state-owned Croatian market operator, collects funds to pay feed-in tariffs from the end consumers and suppliers in Croatia. Generally, electricity tariffs in Croatia are cost reflective.[33]

Figure 2.10: Feed in Tariff Payments in Croatia



- Total electricity generated by power plants under the incentive system: 1.7 TWh, or 9.7% of total electricity consumption (2016).
- Total payments to eligible renewable producers: HRK 1.9 billion (2017, € 260 million).
- Average price under the incentive system: HRK 0.84/kWh for electricity generated in plants, which is more than twice the annual average price of electricity on the Croatian, Hungarian, and Slovenian electricity exchanges (2017).

Source: HROTE

End consumers pay a fee, which is included in their electricity bill. Suppliers are obliged to purchase electricity generated in the incentive system, in the amount that is proportional to their market share (in terms of total electricity delivered to consumers). Final customers pay either HRK 0.007/kWh (for those obliged to obtain a permit for greenhouse gas emission) or HRK 0.105/kWh (which is applied to all other customers). Prior to September 2017, these fees were, respectively, HRK 0,005/ kWh and HRK 0.035/kWh. Suppliers are obliged to purchase electricity generated in the incentives system at the regulated price of HRK 0.42/kWh (prior to 2016 - HRK 0.53/kWh).

[33] There are very limited direct government budgetary subsidies for energy products; electricity and natural gas tariffs help provide cross-subsidies for district heating tariffs.

In 2017, HROTE paid more than HRK 1.9 billion in incentives, and only collected HRK 1.8 billion, as shown in the figure above. This number is growing as the number of generators covered by the FiT has grown, despite no new resources being eligible since 2015. That is because the generators admitted into the system from 2007 through 2015 are cumulatively producing a greater amount of power under the guaranteed off-take contracts. The entry into operation of facilities that have signed contracts with HROTE will further increase the costs of the incentive system. HROTE's payment obligations for generators with contract are due to end around 2030.[34] Revenues collected by HROTE will not be sufficient to fully cover the costs of the system. It is not defined how HROTE will collect the funds to meet its obligations. In addition, generators up to 500 kW are still eligible for feed in tariff. Thus, payment obligations will continue beyond 2030.

Delay in the implementation of a competitive element to the allocation of state support being offered to renewable energy producers is dampening investment. To promote renewable energy in line with the new EU guidelines, Croatia adopted the *2015 Law on Renewables and Highly Efficient Cogeneration (2015)*, to enable competitive auctions, which tend to be more cost-effective to mobilize private sector financing for renewable energy in the power sector. Two different auctions were presented in the Law – the first offers a sliding premium for plants with a capacity greater than 30 kW, and the second offers a guaranteed purchase price for plants smaller than 30 kW. Before these provisions became operational, amendments to the law (adopted in December 2018) were made, inceasing the threshold to 500 kW . The Law prescribes a multi-technology scheme in which all types of power generation based on renewable energy sources as well as high-efficiency cogeneration can participate. It describes the option of introducing quotas for specific technologies and/or installation sizes. However, progress with the implementation of the new system, which aimed to the gradually phase out the support mechanism and introduce market-based pricing, has stalled. The Government did not adopt the necessary implementing regulations. Instead, two regulations were adopted by the Government, delaying the introduction of the premium model and the implementation of balancing responsibilities –first until January 1st, 2018 and then again until January 1st, 2019.

The delay in the establishment of the eco-balancing group has had a negative impact on the volume of intra-day trading, since other market participants had to cover the imbalances, resulting in additional financial burdens on HOPS. Imposing balancing responsibility will encourage renewable generators to install better wind/solar forecasting software or electric storage, resulting in smaller deviations from planned schedules, and thus minimizing balancing costs. This would also improve the reliability of the system, especially during periods of intense inflows into storage hydro which coincide with strong wind levels (in March 2018 this caused some downward regulation problems).[35]

Since the existing feed-in system only applies to pre-existing eligible producers that signed power purchase agreements prior to 2016 and the new incentive mechanism is not yet in place, no new renewable generation development is taking place, and hundreds of megawatts of projects have been cancelled. There is subsidy scheme for solar PV for self-consumption in the industry, providing an investment subsidy. These installations cannot be included in the feed-in scheme.

A transition to auctions that are well-structured and transparent will be a positive development for Croatia, as it will enable the country to grow its domestic supply of renewable energy resources and reduce import dependence at least cost. In December 2018, amendments to the law

[34] Payments start as generators become operational and may last up to 14 years. Generators that signed contracts up until 2015 should become operatational couple of years later (i.e. generators that started producing in 2017 will phase out from the system in 2030).
[35] https://docstore.entsoe.eu/Documents/SDC%20documents/Winter%20Outlook%202018-2019_Report(final).pdf?deliveryName=DM6962

were adopted in Parliament. The amendments address the obligation to buy-off share of energy produced by eligible producers (defined by a quota), functioning of eco-balancing. By moving away from the feed-in tariffs, Croatia will reduce the burdens placed on end-users. A long-term power purchase agreement and a feed-in premium (the obligatory purchase of all generated renewable electricity at the price of the day-ahead market plus a compensation to the renewable generator if the day-ahead market price is below the auction price) – if well-designed and properly implemented – could provide a transparent and predictable environment for investors and financiers, thus reducing the cost of capital and auction prices. Special quotas for state support (by location, type of generation, etc.), can, in principle, enable the government to encourage such renewable generation that would have most value for the overall power system.

FiT policies have played an important role in improving the economic attractiveness of renewables, driving their initial deployment, as well as continued technological innovation and cost reductions in Croatia and around the world. However, FiT by their nature try to capture faster-than-expected cost reductions for technology, which results in relatively costly deployment. While utility scale onshore wind and solar PVs no longer need direct financial incentives to attract new investment, they still require a market framework that ensures long-term revenue certainty. Many countries, like Germany, Denmark, Brazil are therefore switching to renewable energy auctions. The figure below shows their advantages and disadvantages.

Figure 2.11: Feed in Tariffs and Auctions

	FITs	AUCTIONS
Advantages	• Limit the risks for investors (including in emerging technologies) • Facilitate the entry of new players in the market • Can be funded by consumers and not expose public budget • Long term security drives deployment and brings lower costs	• Flexibility of design according to objectives and based on local policies • Allow true price discovery in the given country/market • Provide greater control over quantities and possibly also location of plants • Enable transparency and enforceable commitments to build power plants
Disadvantages	• Costly with high deployment rates and tariff adjustment process is complex • No exposure to competition and electricity market prices	• Relatively high transaction costs for both developers and auctioneer • Risk of underbuilding of the system, delays, etc.

Source: Authors

Croatia should consider evaluating the international best practices for conducting renewable energy auctions. For instance, Croatia should consider avoiding a scenario in which the quotas are set without conducting a sufficiently robust analysis of whether the system integration of renewable generations is technically and economically feasible. Another issue to consider is the level of the feed-in premium. Some countries, like the United Kingdom, decided to reduce the burden on ratepayers by ensuring that the generators are fully exposed to both the up-side and down-side of the wholesale electricity market. In instances where the wholesale power price is higher than the renewable auction price, the contract requires that the generator makes payments to the contract counterparty. Croatia may want to consider the use of such mechanisms. It is also important to consider whether to have an auction for each technology type or one auction for all technologies. One auction for all technologies will encourage greater competition and result in the lowest overall cost. However, technologically neutral auctions will likely promote the adoption of only the most mature technologies. Some EU countries, like the Netherlands, organized technology-neutral auctions. Other EU countries opted for specific auctions, like France and Germany (solar PV), as well as Denmark (off-shore wind). Non-EU countries, like South Africa and Brazil, have also run technology-specific tenders. Further, Croatia might consider the opportunity for a regional auction, limited to a specific geographical location where transmission capacity is available. In such cases, it is also critical that the responsible authorities indicate to the auction participants all the transmission nodes where there is space to interconnect. If the bidder is not able to secure a transmission node because of the MW constraint or because of price, then he/she should have the option to pick another node (if that node has space and the offered price makes it). Last but not least, Croatia may want to consider curtailment order based on plant economics or ability to alleviate local congestion.

In addition to utility scale renewable generation, Croatia must consider the need to improve the framework for facilitating decentralized or distributed renewable generation solutions. The amendments to the Renewable Energy Law provide for keeping feed-in tariffs for small-scale installations that have a total capacity below 500 kW. This would enable Croatia to develop distributed generation and to diversify renewable investments, contributing to local economic development groups, and alignment of the system with the EU rules on state aid. Such investments should not be limited to rooftop solar installations, but should rather also apply to heat pumps, electric storage, minigrids and other emerging technologies. As of today, Croatia's net metering incentive systems only applies to residential and industrial rooftop solar installations, up to 500 kW. Even though these resources are allowed to sell excess generation back into the grid, the typical payback period is more than 10 years for the industrial customers and 20 years for the residential customers, due to a large (around 50%) share of grid usage (non-energy) costs. These include grid costs and fees in the electricity price that are not netted and must be fully paid for every kilowatt-hour taken from the grid. In addition, excess energy produced and dispatched to the grid is not fully taken into account but is instead reduced by a factor of 90%. In addition, the billing period is one month, which further reduces the economic viability of the scheme, because seasonal balancing is not allowed. The National Environmental Protection and Energy Efficiency Fund, which already supports industrial and commercial sectors, is expected to grant individuals subsidies for equipment purchase. However, even if this subsidy is equally available for households, it is not sufficient to make household installations economically viable. Croatia, with its remote island regions, could benefit from developing renewables-based energy generation systems. The development of the mini-grids in Croatia is in the piloting phase in several islands (e.g. Unije, Lastovo).

b-3 Natural gas in Croatia

Croatia has a long history of gas exploration and utilization. The construction of the first main gas pipeline from Janja Lipa[36] to Zagreb started in 1954, and the gas network has since expanded country-wide

[36] 100 km south-east of Zagreb.

to encompass the east and the south[37]. The gas network is connected with Hungary (north east) and Slovenia (north), which enables international gas transport.

In Croatia, natural gas is the second largest primary energy source following oil[38]. Natural gas is used mostly for electricity and heat generation, and for household heating and cooking. Gas use in industry and transport is relatively small (with the exception of the fertilizer-production company Petrokemija, that used 0.6bcm of gas per year). While the share of renewables has been increasing, in the coming decade, as the use of coal gradually declines and more customers shift to cleaner energy sources, the demand for natural gas is also estimated to increase.

By 2016, the proven reserve of gas totaled 13.2 billion cubic meters (bcm) and its production totaled 1.65 bcm. The only existing gas storage facility in Croatia is located in the Sisak-Moslavina County, with a designed capacity to store 0.55 bcm of gas. Meanwhile, domestic crude oil production covers about 20 percent of demand.[39]

Figure 2.12: Croatia Gas Supply and Demand 2011 vs 2016

	2011	2016
Production in Croatia	2.47 bcm	1.65 bcm
Import	0.88 bcm	1.26 bcm
Export	(0.26) bcm	(0.39) bcm
Gas-to-electricity/heat/energy	1.21 bcm *(38% of supply)*	0.99 bcm *(38% of supply)*
Household	0.67 bcm *(21%)*	0.56 bcm *(21%)*
Industry	0.33 bcm *(11%)*	0.20 bcm *(8%)*
Services	0.17 bcm *(5%)*	0.22 bcm *(8%)*
Agriculture	0.02 bcm *(1%)*	0.03 bcm *(1%)*
Transport	0.8 million cm	4.4 million cm

Source: Energy in Croatia

With no foreseen increase in gas reserves, Croatia's gas production is expected to dip toward 0.6 bcm per year in the next few years. Therefore, Croatia is planning to increase gas imports to meet domestic demand and expand international gas transit. The Krk Island LNG project is a candidate project to replace declining domestic production and enable increased international gas transit. Another international gas supply candidate is the Ionian Adriatic Pipeline (IAP), which would bring Caspian Sea gas to Croatia via the Trans Adriatic Pipeline in Albani, passing through Montenegro. Natural gas will help Croatia transition away from importing coal and cut Croatia's greenhouse gas emission faster.

[37] The technical capacity of Croatia's gas transmission system is around 9 bcm/year (269 million kWh/day). Source: Plinacro.
[38] Primary energy supply totaled 8.4 million tons of oil equivalent (2015), led by oil (40%), gas (27%), biomass/fuel (17%), coal (8%), hydro (7%), geothermal/wind/solar (1%). Source: IEA.
[39] In 2016 crude oil production was 31,47PJ and import 107.32 PJ

(c) Energy Poverty

The deregulation of Croatia's energy markets raised concerns about energy affordability. With the passing of the new Energy Act and the Act on Regulation of Energy Activities, Croatia deregulated its energy market in line with the European Union's Third Energy Package.[40] This deregulation of energy markets raised concerns on energy affordability and evidenced the lack of well-designed measures to offer protection for the vulnerable. The 2016 World Bank report[41] highlighted that poor households in Croatia, like in other EU countries, tend to devote a higher share of their budgets to securing their energy needs. Consequently, the report highlighted a need for policies to alleviate the burden on the poor, along with interventions focusing on energy efficiency.

The interventions available to support vulnerable households are not straightforward, due to Croatian households' reliance on a broad array of energy sources, such as biomass, electricity, natural gas, and district heating. Moreover, the energy sources used vary considerably based on both geographical location and income groups. Additionally, there are access problems; for example, district heating is not available throughout the country, and wood is extensively used in rural and urban areas.

An additional concern is households' inability to pay bills on time. According to the EU-SILC,[42] in 2013 (the last year for which data is available), close to 30 percent of households reported being in arrears in their utility bills. According to the latest data available, by 2016 the percentage of households who report being in arrears on their utility bills has dropped to 25 percent. The development, although commendable, still leaves many in a precarious situation since households commonly state that they would like to avoid the risk of their utilities being disconnected. This is particularly salient during the winter season, when households report giving priority to paying their utility over many of their other needs.

Energy efficiency upgrades are also a potential source to improve energy savings and affordability. However, despite such upgrades being subsidized for up to 60 percent of the total cost, the cost of upgrades such as insulation could be prohibitive to both energy poor and economically poorer households. Economically poor households tend to lack access to financing, and even if they happen to be aware of the necessity of energy efficiency upgrades, they have no option but to opt out of implementing such projects.

Additionally, households that rely on time-of-use meters, where different rates are applied to electricity use during different times of the day, try to switch their use of electricity to non-peak hour tariffs to satisfy their needs. Non-peak hours are at night, (after 10pm in winter time, 9 PM in the summer), and this can have negative effects on the quality of life for members who stay at home during the day, which are usually women who oversee household chores.

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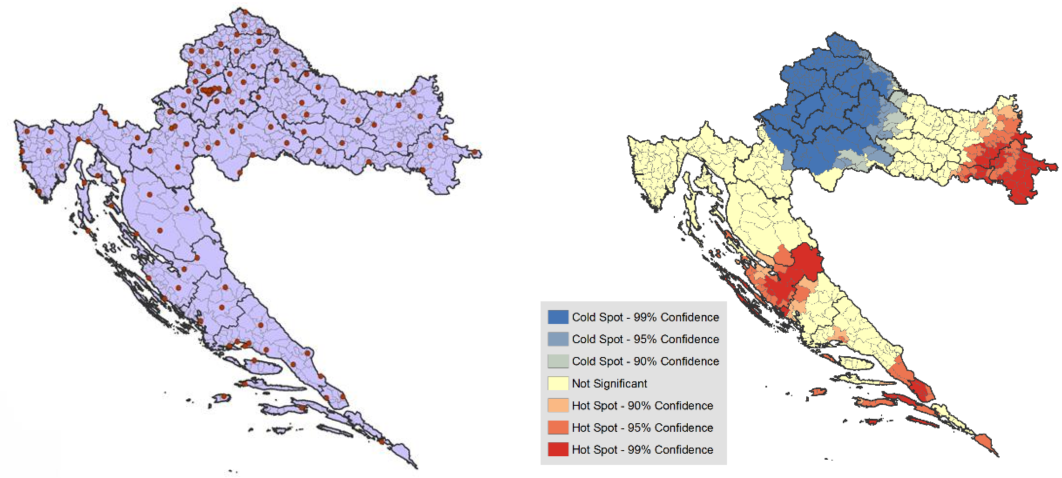
[40] The Third Energy Package aims to make the EU energy market more effective and to create a single EU gas and electricity market, with the aim to keep prices as low as possible and increase the standards of service and the security of supply.
[41] World Bank (2016), Ensuring Energy Affordability in Croatia.
[42] The nationally representative SILC survey has been run in Croatia since 2010, and provides all the information to calculate the relative income poverty, material deprivation and labor market attachment indicators needed to measure the share of population at-risk-of poverty and social exclusion (AROPE), which is the headline poverty figure at the European level and for individual EU Member States.

Addressing Energy Affordability in Croatia

Since the publication of the World Banks's Croatia Policy Note on Energy Affordability in 2016, energy affordability concerns have been addressed in Croatia. Two major policy interventions have taken effect since 2015. The first is the introduction of an energy allowance, tied to the Guaranteed Minimum Benefit[43] for households who qualify by satisfying the program's requirements. The second directly addresses price concerns through a reduction in value added taxes on electricity.

The Guaranteed Minimum Benefit (GMB) which is administrated by the Ministry of Demography, Family, Youth and Social Policy (MDFYSP), is a program which is explicitly intended for the poorest in Croatia, in the form of a subsistence benefit. The GMB is a means tested program intended for households with an income below the household's basic needs threshold and is dependent upon the household's characteristics and composition. Potential beneficiaries are expected to apply through social welfare centers in their place of residence. There are centers across the country, and thus the travel burden on most individuals is not high (Figure 2.13., left).[44] Hotspot analysis (Figure 2.13., right), reveals that the travel distance for individuals is lowest around Zagreb, while in some of the poorest areas of the country (see Figure 2.14.) there are social welfare center blind zones.[45]

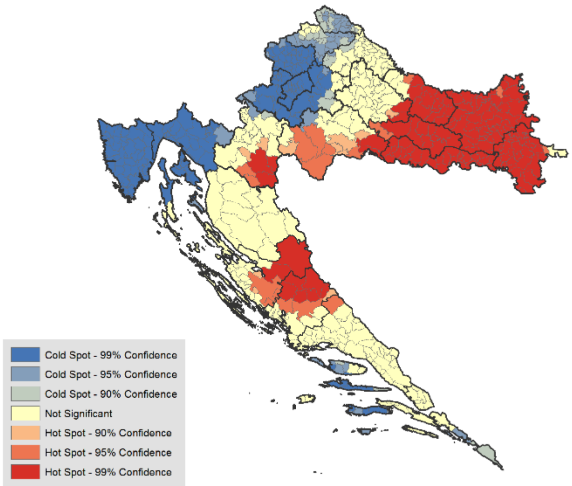
Figure 2.13 Location of Social Welfare Centers and travel distance Hotspots



Source: WB & MDFYSP (2017)

[43] The potential beneficiary's income needs to be below a certain threshold to qualify for the benefit.
[44] WB and MDFYSP (2017), Assessment of Social Benefit Effectiveness.
[45] These are neighbourhoods where travel distance to a social welfare center is significantly higher than the national average.

Figure 2.14.: Income poverty Hot-spots



Source: CBS (2016)

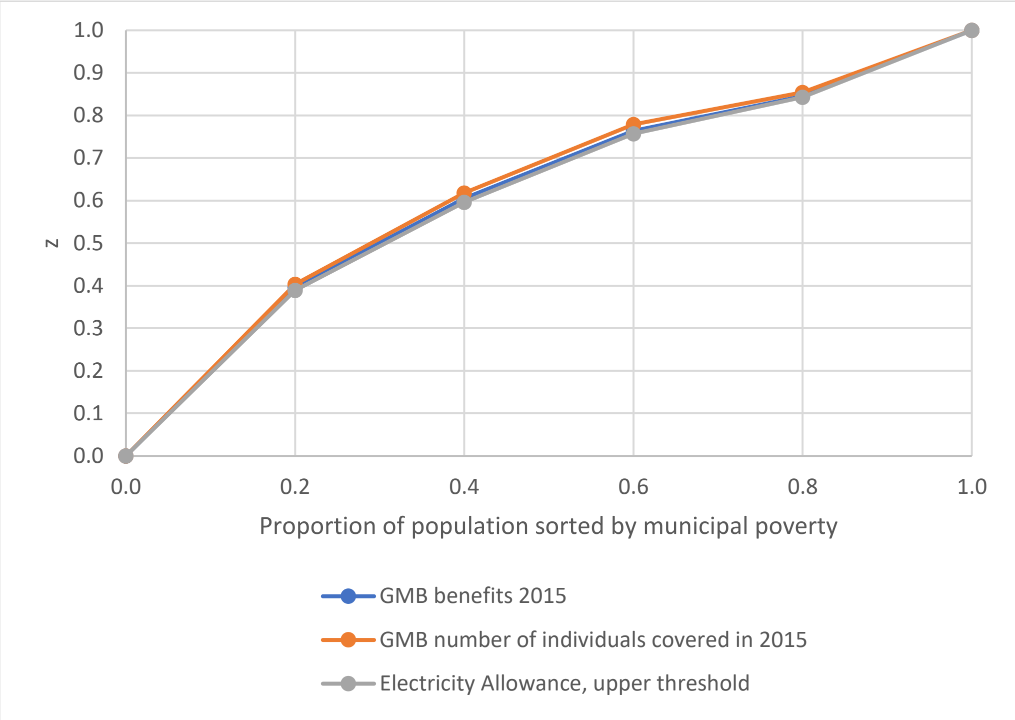
All beneficiaries of the Guaranteed Minimum Benefit[46] are also entitled to the benefit for energy buyers at risk introduced in October 2015, which may cover at most 200 HRK (or about 200 kWh of electricity in May 2018) of the beneficiary's energy bill. The bill is paid directly to the electricity provider with no money being transferred to beneficiaries, and any excess is transferred to the following month. An additional in-cash or in-kind allowance exists to supply firewood for beneficiaries of the GMB. This assistance is intended for those who use wood as a source of heating, and consists in a once-a-year payment of 3 m^3 of firewood, or in a cash payment to cover its cost.

While the GMB benefits address the energy needs of the economically poor, there is nothing in place for the energy poor. The energy poor could be exemplified by a one-income household on minimum wage that is technically above the poverty line, but has difficulty paying its bills (of which energy payments constitute a significant amount). A one-off payment of HRK 2,500 that can be raised to HRK 10,000 is available to the vulnerable to cover the purchase of appliances and pay medical bills or roof repairs. For the purchase of appliances, the beneficiaries are free to acquire any brand of their choosing, and not necessarily the most energy efficient option.

While a household level analysis of the guaranteed minimum benefit is not readily available,47 a municipal level analysis suggests that the guaranteed minimum benefit is spatially progressive, implying that the funds go to the population residing in the poorest areas of the country (Figure 2.15). Roughly 60 percent of the funds got to the 40 percent of the population who resides in the poorest municipalities of the country. Data on actual energy allowance distributed is not readily available,[48] but since the allowance is available to all GMB recipient households it is safe to assume that the program will also be spatially progressive.

[46] Beneficiaries of the Personal Disability Allowance are also by default beneficiaries of the Energy Allowance.
[47] Given the program's size, roughly 49 thousand recipient households in 2016, it is not accurately captured in household surveys.
[48] Households who are recipients of the Guaranteed Minimum Benefit or the Personal Disability Allowance receive a voucher of 200 HRK per month, the money is paid directly without the money being received by the beneficiary. Therefore, the actual value of the transfer may be considerably less than 200 HRK.

Figure 2.15: Spatial Concentration of GMB and Energy Allowance



Source: WB & MDFYSP (2017)

Non-targeted support, such as value added tax reductions for electricity, should be reconsidered. As of 2017, Croatia introduced a value added tax (VAT) reduction on electricity; where common goods carry a VAT of 25 percent, electricity now carries a VAT of 13 percent. The average price per Kilowatt-hour in Croatia in the second half of 2016 was close to 1 HRK, and by the first semester of 2017 the average price had fallen to 0.89 HRK.[49] The share of taxes and levies paid by household consumers in Croatia, after the decrease in VAT, is 15.5 percent. The decrease in VAT is expected to be a life-line to poorer households, since these tend to devote a higher share of their expenditures towards electricity than those who are better off. However, the poor are not the sole beneficiaries of this; since everyone is eligible, (both households with big families and the better off tend to consume more electricity), most of the foregone revenue is likely not going to the poor.

The VAT reduction on electricity is expected to lessen the burden of energy expenditures on Croatian households. According to figures presented by the Croatian Bureau of statistics,[50] roughly 5 percent of total household expenditures in Croatia during 2014 were devoted to electricity[51]. In households with no employed individuals, roughly 13.6 percent of household expenditures is devoted to energy. As a result, counterbalancing the increase of renewables fee with the reduced VAT rate kept the electricity bills at the same level as before the change.

[49] Eurostat http://ec.europa.eu/eurostat/web/energy/data/database. Defined as medium-size consumers with an annual consumption within the range of 2 500 kWh and 5 000 kWh
[50] Results of Household Budget Survey, 2014 – Croatian Bureau of Statistics
[51] The latest household budget survey for Croatia is from 2014. The Survey of Income and Living Conditions (SILC), is conducted on an annual basis, however the survey does not collect information on household expenditures and consequently more recent data for budget shares is not readily available.

Despite the introduction of an energy allowance and VAT reduction, many households are still expected to suffer from energy poverty. Looking forward, many areas of improvement remain, particularly on energy efficient interventions, and low-income households will require considerable assistance in order to improve their energy efficiency. However, funds for this are available; in Croatia, between 2014 and 2020, 50 million Euros have been made available for energy efficient interventions. Nevertheless, this amount is unlikely to be sufficient, and thus other measures are likely needed.

A measure which is expected to considerably improve energy efficiency is one that will facilitate improving energy efficiency among energy vulnerable households through the improvement of household conditions. The measure is outlined in the Fourth National Energy Efficiency Action Plan of the Republic of Croatia,[52] and entails the replacement of old household appliances and windows, as well as the improvement of heating systems and increases in insulation. To some extent this also requires interventions addressing building owners, some of whom are vulnerable customers themselves, particularly for low-income households. The program shall rely on timely monitoring indicators from the Croatian Bureau of Statistics that will allow for the identification of energy poverty at the national level. The program expects to reach close to 330 households in Croatia per year between 2017 and 2026.Additional energy efficiency interventions expected to lessen the burden of energy costs among consumers is targeted at multifamily homes constructed before 1987. The focus is on renovating these buildings so as to comply with efficient energy standards. The plan will be co-financed through European Funds for Regional Development.

[52] https://ec.europa.eu/energy/sites/ener/files/hr_neeap_2017_en.pdf

3 Assessment of the main developmental challenges and opportunities for Croatia

Main challenges and opportunities:

(i) Croatia's energy intensity (EI) is high and could be substantially improved.

Croatia has more than a decade of experience in energy efficiency (EE) actions and financing. However, Croatia's EI remains 55 percent higher than the EU average, mainly due to inefficiencies in the building and transport sectors. Building on its EE experience and institutions, Croatia can leap forward and achieve a more ambitious EE and EI targets by scrutinizing sub-sectoral EE and EI targets as envisaged under Croatia's 4th EE Action Plan (households, construction, service and industrial sectors), submitted to the European Commission. The growing inter-dependence of the sub-sectors should be taken into account, along with the evolving dynamics of electricity use. Croatia must also focus on improving energy efficiency in the transport sector, as well as addressing poor households' inefficient energy usage. On the supply side, moving ahead with adding state of the art combined-cycle gas turbines and increasing efficiency of district heating will advance Croatia's EE and EI goals.

(ii) The next phase of renewable energy projects needs support.

Croatia has committed to decarbonizing its energy sector through expanding renewable energy and reducing the carbon emissions of fossil fuels. The key question is "how can the deployment of renewables be driven forward in Croatia"? Adding more renewables, the potential of which is still largely unused, could help reduce Croatia's carbon intensity by displacing fossil fuels such as coal and natural gas. There is still substantial room to grow intermittent wind and solar capacity, as it accounts for 11 percent (539 MW) of installed grid-connected power generation capacity in Croatia (2016). Potential hydropower projects are faced with environmental and social concerns[53]. Although the total costs of wind and solar power have declined, they are still higher than wholesale electricity prices in Croatia. The feed-in-tariff system to promote renewables was discontinued in 2015. The implementation of the renewable energy law only partially occurred, which halted the development of a new generation of renewable power projects. Amendments to the law adopted in December 2018 are expected to help foster the development of new projects. Croatian power exchange could stimulate more renewable energy participation by allowing for more granular, 15-minute bids, favored by intermittent generators such as wind or solar, which may be unable to deliver energy for a full hour. Finally, more traction could be had in Croatia by energy generation systems utilizing renewable sources such as distributed generation and mini-grid systems. Croatia, with its remote island regions, could benefit from developing such renewables-based energy generation systems.

[53] Currently there are approximately 2200 MW of installed hydro capacity in big HPP, and there are 56 small HPP (45,14 MW). There is roughly 6,2TWh of unused hydro potential. About 10% of technically available capacity is potential of small watercourses. Technical potential for big HPP is estimated at 1694 MW (4,74 TWh a year), for pumped hydropower plant 2276 MW (4612 GWh/year) and 149 MW (412,92 GWH/year) for small hydro power plants (up to to 5 MW).

(iii) Improving health benefits through clean energy.

Air pollution is a major environmental health risk in Croatia, contributing to premature deaths. Among EU member states, Croatia has the sixth highest death rate attributable to air pollution. The number of deaths per year attributable to household air pollution from solid fuels in Croatia is substantial[54]. A significant fraction of the Croatian population in urban areas continues to be exposed to particulate matter ($PM_{2.5}$) concentration levels higher than levels considered safe for human health. Use of biofuels by households, particularly in rural areas contributes to ambient air pollution. As much as three quarters of $PM_{2.5}$ emissions in Croatia originate from combustion in non-industrial furnaces. It is therefore essential to improve the combustion of fuels used in these operations by providing improved biomass stoves with and without chimneys and/or replacing solid fuels (wood and coal) with more environmentally friendly fuels or cleaner fuels. Household heating systems (particularly in rural areas) and district heating systems should be the prime targets for this action. A detailed assessment on the health benefits of clean energy appears in the Policy Note on Environment.

(iv) Ensuring energy security under a competitive and open energy market.

Since joining the European Union (EU) in 2013, Croatia has implemented a number of EU directives aimed at opening its electricity sector to competition with, and integration into, the EU electricity market. However, despite the recent coupling with Slovenia, competition in Croatia's electricity market is still very limited. Market reforms are needed to remove barriers to entry for new electricity generation, which would improve the investment climate and create incentives for new entrants. Enhancing electric connectivity with neighbors and increasing the liquidity of the Croatian Power Exchange would be key to enabling this strategy. Diversifying the energy mix with advancements in energy efficiency, renewable energy, and natural gas imports will help Croatia to further enhance its energy security. Increasing competition in the Croatian energy market for both gas and electricity will promote the development of new (clean) energy sources, reduce prices, and benefit consumers.

(v) The existing social support mechanisms for energy consumption could be improved.

To address concerns on energy affordability, the Croatian authorities have put in place an energy allowance to lessen the burden of energy consumption for households that fall under the poverty line. Although energy-poor households above the poverty line have no dedicated support, some measures have been implemented to prevent price increases. While these measures are crucial, further refinement to better target the support for the economically poor will help improve their effectiveness and minimize the fiscal cost. For instance, a blanket VAT reduction for all electricity consumption, while lessening the burden of electricity bills for the poor, should be reconsidered as it tends to overwhelmingly benefit the non- poor, who often consume more power. In addition, measures to improve energy efficiency and access to clean energy in both poor and energy poor households are still needed. This entails—to some extent—working with building owners who are often also vulnerable consumers, to ensure that efficiency is improved. A pilot study on how to identify the energy poor and develop targeted support measures could be useful in providing more insight into potentially viable options to improve energy affordability.

[54] An estimated 680 people per year.

(vi) Energy efficiency financing through traditional financial institutions remains limited.

Croatia has more than a decade of experience in the Energy Services Company (ESCO) model, with a good range of services on offers. ESCO, in this context refers to the integration of all energy services in all project phases through a single contract, with guarantees on energy savings and effective multi-faceted risk management. However, the gap in Croatia's ESCO model continues to be scaling up through traditional financial institutions. Confirming and addressing the constraints of ESCOs at a micro-level could help to substantially expand EE financing options and optimize their performance.

4 Prioritized policy recommendations

- **Energy Efficiency**:
  - Croatia has prepared the Low Carbon Strategy and is updating the Energy Strategy. Together these will lead to the formulation of the National Energy and Climate Change Action Plan (NECCAP) and the new Long-term Renovation Strategy (LRS) for buildings until 2050. As an EU member country, Croatia is obliged to adopt NECCAP by the end of 2019 and the LRS in 2020. In addition, the National Development Strategy should be leveraged to tackle issues which cut across the energy sector, such as the tourism-dominated energy demand and supply solutions, eco-friendly renewable energy, electric vehicles and smart electricity grid applications.
  - [Short & medium term] There is a clear and urgent need for the rehabilitation of buildings. Croatia should prioritize categories of buildings to be rehabilitated, which could be facilitated by conducting a cost-benefit study. For instance, Croatia might consider whether to prioritize the renovation of buildings constructed before 1990, publicly owned buildings, or privately-owned hotels located mainly on the Adriatic coast. These categories of buildings have significant impacts on electricity consumption and heating and cooling demand in the country. Although some types of renovations may only reduce seasonal demand for energy (such as renovation of hotels on the Adriatic coast) this limitation may be offset by their potential to reduce Croatia's dependency on imports during the summer months or a need to build peak capacity to meet summer peak demand.
  - [Short & medium term] In addition, Croatia must focus on EE/EI in transport, including by preparing for the expected increase in the electrification of road transport and by expanding rail and water transport alternatives.
  - [Short & medium term] Measures to promote energy efficiency in poor households are still needed, particularly through improving residential building insulation, and by replacing electric appliances and heating/cooking biomass stoves (with the added benefits of improving indoor air quality). This entails working with vulnerable homeowners to ensure that efficiency is improved.
  - [Short & medium term] On the supply side, Croatia must move ahead with adding state of the art combined-cycle gas turbines and increasing the efficiency of district heating.
- **Energy Market and Energy Security:**
  - Since joining the European Union (EU) in 2013, Croatia has implemented a number of EU directives aimed at opening its electricity sector to competition and integration into the single EU electricity market. However, competition in Croatia’s electricity market is still very limited. Market reforms are needed to improve the investment climate and create incentives for new entrants. Croatia, like the rest of the world, is seeing a growing demand for cooling and air conditioning in the summer months, especially in the south along its Adriatic coast. This places heavy strain on the power system to meet this peaking demand, especially since most of the new and planned generation capacity is coming from wind, which is located in the north of country and often not capable of producing energy at full capacity during the hot summers.
  - [Short term] Croatia must implement a system to replace the feed-in-tariffs for renewable energy.

- [Short and medium term] More traction could be had in Croatia by energy generation systems utilizing renewable sources such as distributed generation and mini-grid systems.
- [Short and medium term] Currently, Croatia is importing electricity to cover its peak winter and summer demand. Croatia should consider conducting additional specific studies assessing the needs to upgrade its transmission capacity from the north to the south, as well as its ability to address cross-border congestion. Experience with upgrading the interface with Slovenia (SyncroGrid) could inform this effort.
- [Short and medium term]. Croatia should start implementing active demand-side management, including demand-response to curb peak power demand. Differentiated pricing involving higher prices of electricity during peak periods can also incentivize changes in behavior and purchases of more efficient equipment.
- [Short term] Enhancing electric connectivity with neighbors and increasing the liquidity of the Croatian Power Exchange is key to ensuring the system flexibility needed to reduce price volatility and to absorb excess renewable energy when the system is over-generating electricity, or to quickly ramp up production when the sun goes down or the wind stops blowing.
- [Short, medium and long term] On the supply side, actions should be taken to reduce coal imports, expand renewable energy generation, and the need to inform and consult the public about technological, environmental and social aspects of LNG import.
- [Long term] Croatia should consider integrating into its grid emerging technologies such as solar cooling (either thermal or photovoltaic), battery, and thermal storage, as well as integrated solutions such as district cooling networks and new cooling solutions for buildings (e.g. heat pumps), which can also have a major impact on the needs for grid-based electricity capacity.

- **Affordability:**
  - [Short and medium term] To address concerns on energy affordability, the Croatian authorities have put in place social support mechanisms and an energy allowance to lessen the burden of energy consumption on low-income households. While these mechanisms are crucial, further refinement to better target the support for the poor will help improve the mechanism’s effectiveness and minimize the fiscal cost. There is also a need to establish mechanisms to support the energy poor, who are often hovering above the poverty line but are not entitled to any social support.

5 Cross-cutting issues and their implications for policy

There are cross-cutting issues that need to be driven by horizontal and vertical interactions across ministerial and regional levels, and between public and private actors. The strategic development of Croatia, in relation to energy, is elaborated through a series of multi-sectorial and sectorial strategies, plans and programs[55]. It is important for these multi-sectorial development documents to be aligned. Such complex operations require significant coordination efforts and multi-level governance. There is a need for a combination of formal and informal coordination mechanisms among institutions, including feedback loops from stakeholders. Therefore, the competent ministries, such as the Ministry of Energy and Environment, the Ministry of Construction and Spatial Planning, the regional governments, and utilities and private sector stakeholders, would benefit from closer collaboration and communication. From the lens of the energy sector, the following cross-cutting issues are notable:

a) Energy efficiency in the building sector.

The building sector, including residential buildings, is the largest energy consumer in Croatia, accounting for 44 percent of final energy consumption in 2016. The building sector in this context refers to commercial, public sector and residential buildings, as well as the specific activities in building management systems that support high energy efficiency such as insulation, temperature control, water management systems, ventilation systems, etc.

Since energy efficiency in the building sector is a cross-cutting issue, it has the highest potential for impactful energy savings. In order to attain these savings' potential, policy adjustments tackling cross-cutting constraints such as long and inefficient procurement, lack of skilled workforce, project irregularities, productivity related price increases, and cross-sector data management and dissemination should be incorporated in future plans.

b) Energy efficiency in the transport sector.

The transport sector is the second largest final energy consumer in Croatia, accounting for 29 percent of final energy consumption in 2016, and second only to the residential sector (at 34 percent). Road transport is the leading subsector, accounting for 95 percent of energy use in transport, and is the main source of demand for oil products. Energy efficiency in transport is a cross-cutting issue that can substantially improve Croatia's overall energy intensity. More energy saving in the transport sector should be emphasized, compared with the scenario in the 4th National Energy Efficiency Action Plan that envisages only 0.95 PJ[56] energy saving in the transport sector out of a total of 30.9 PJ until year 2020. Plans to push for the additional electrification of Croatia's transport sector, and the expansion of rail and water transport[57] should be part of the transport sector strategy.

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[55] Notable among them are: (i) the Low-Carbon Development Strategy until 2030 with an outlook on 2050; (ii) the Energy Strategy (under revision); (iii) the 4th National Energy Efficiency Action Plan for the Period of 2017-2019; (iv) the Action Plan for the Implementation of the Low-Carbon Development Strategy; (v) the Program for Energy Efficiency in Heating and Cooling; (vi) the Program for the Energy Efficiency in Public Lighting until 2025; and (vii) the Integrated Energy and Climate Change Plan for the Period of 2021-2030 (being finalized).

[56] Petajoule = 10^{15} of a joule (thousand million joules)

[57] The World Bank is identifying a Sava and Drina River Corridors Integrated Development Program to help improve water transport in Croatia and neighbouring countries, among other water management objectives.

c) Natural gas as a bridging fossil fuel while reducing coal and ramping up (and managing) renewable energy.

Croatia is on a path to reduce its reliance on fossil fuels. No new coal power and heat plants are under construction and the utilization of the existing coal cogeneration plant at Plomin is expected to decrease in the coming decades. In parallel, Croatia is planning to add more renewable energy in the energy mix. During the coming decades of energy transition, Croatia will need natural gas as a bridging fossil fuel—particularly for power/heat generation, residential use, industrial and commercial use—supplemented by imported electricity. As such, Croatia needs a medium-term natural gas strategy that provides energy security and operational/financial flexibility. This gas strategy will need to be aligned with gas demand in Croatia[58]. This points to Croatia's increasingly importing natural gas and/or LNG in the coming decade as domestic gas supply declines[59]. Any introduction of LNG will be new to Croatia and the required LNG infrastructure should provide operational/financial flexibility. This points to the flexible floating and storage regasification unit (FSRU) alternative, which Croatia would utilize when there is an economic demand for LNG in Croatia and/or for re-export of gas and could subsequently be divested when it is no longer needed.

d) Government investment in state-owned enterprises, including energy SOEs.

How to best use Croatia government's budgetary resources is an overarching question. In the energy sector, fully state-owned SOEs such as HEP Group and Plinacro are financially self-funding, including through methods such as borrowing and bond issuance, and do not require direct government budgetary allocation. However, they gain either directly or indirectly from their parastatal status, which benefits their credit standing or ratings.

The government's investments in SOEs is a cross-cutting issue that warrants careful analysis and decision-making. Questions surrounding this issue include; going forward, should fully state-owned SOEs continue to reinvest a majority of their internally generated funding surplus into their businesses? Would it be more economically beneficial for the country if these SOEs remit more dividends back to the government for other needs? These SOEs could perhaps tap more private capital for their future. Or the government could divest its equity stakes in financially viable SOEs and use the proceed for other needs.

Based on recent data, HEP Group's capital expenditures amounted to about 0.7 percent of Croatia's GDP in 2015, 2016 and 2017 alike, while dividend payments were about 0.2 percent of GDP in 2016 and 2017[60]. Capital expenditures include transmission investments, in accordance with Croatia's ten-year development plan for the transmission network (2017 - 2026), which has been functionally harmonised with the ten-year development plan for the European transmission network.

[58] Demand for power/heat generation accounted for 38 percent and the residential sector accounted for 21 percent of gas supply in Croatia in 2016.
[59] Domestic gas supply is estimated to reduce toward 0.6 billion cubic meters per year in a few years, while gas demand is estimated at around 2 billion cubic meters per year in the coming decade.
[60] Dividend payout ratio of 29 percent (2016) and 61 percent (2017) of net profit, respectively.

Figure 5.1 Croatia's planned transmission investments, 2017-2026

Investments	Amount [Thousands HRK]
Own investments in the transmission network	5,944,490
Investments for the connection of end consumer buildings	154,477
Investments for the connection of new conventional power plants	416,191
Investments for connection of wind power plants	105,000
Investments for European Union projects of common interest[2]	99,825
Total	**6,719,983**

Source: HOPS

Capital expenditures also include investments in the distribution network, in accordance with the Ten-Year Development Plan for the HEP-ODS Distribution Network from 2017 to 2026.

Figure 5.2 Croatia's planned distribution investments, 2017-2026

Investment category	Amount [Thousands HRK]
Transformation 110/x kV and SN network 35 kV	1,712,884
Mid-voltage network 10(20) kV	2,031,811
Low-voltage network	797,700
SDV, automation of SN network, metering devices and new technologies	1,531,300
Business infrastructure	590,450
Electric power conditions and connections	3,500,000
Total	**10,164,145**

Source: HEP-ODS

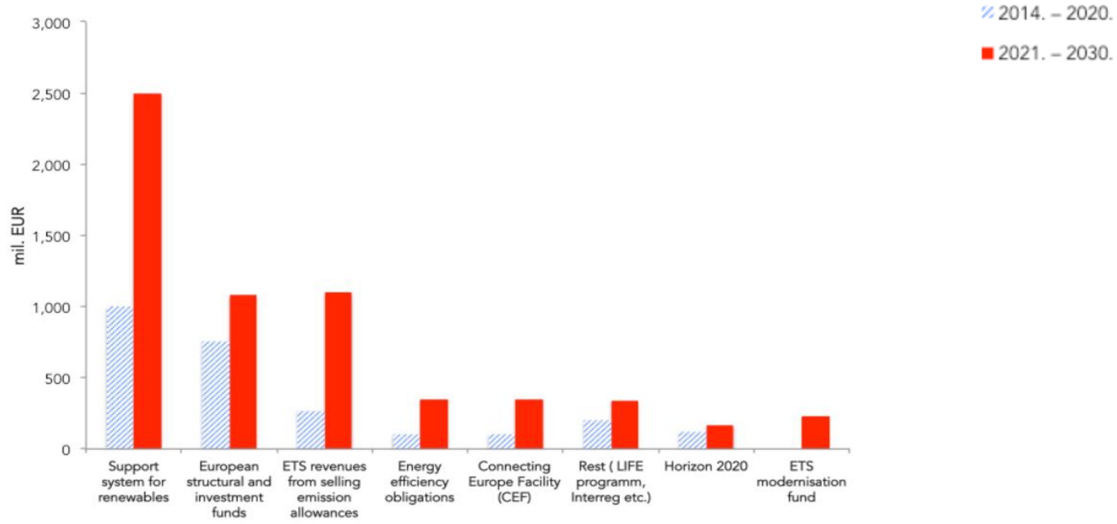
e) Accessing and absorbing EU funds in the energy sector.

The Croatian energy sector has been able to access EU funds for its diverse portfolio of projects and activities. These include a range of energy efficiency initiatives, improvement in the district heating network, the planned Krk Island LNG project and other natural gas infrastructure projects. However, there remain funding gaps that could benefit from more EU funds. For instance, funds to support low-income households to improve household insulation, to replace heating and cooking stoves with cleaner and more efficient biomass stoves, or to switch to district heating or gas boilers.

EU funds absorption is a cross-cutting issue that should be addressed in very close coordination with traditional financial institutions, line sector authorities, specialized financial institutions (such as ESCO in the energy sector), and suppliers of the goods, work or equipment that need to be eventually procured. Minimally, the eligibility criteria would need to be adjusted to increase access and absorption rates of various EU funds.

An illustration of various EU funds potentially available to the Croatian energy sector are outlined below:

Figure 5.3 Availability of EU funds to the Croatian energy sector



Source: Financing the Croatian low carbon development strategy, 2017

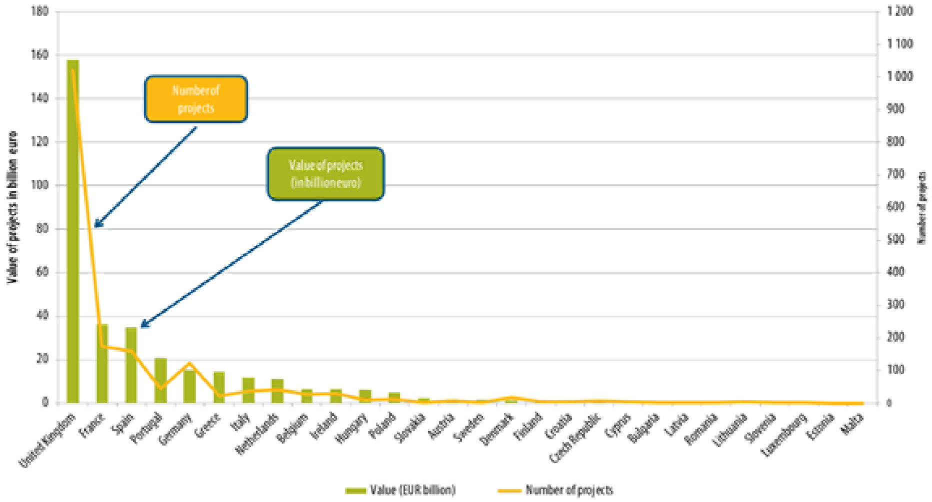
f) PPP in the energy sector

The Croatian law clearly defines PPP; it has all supporting regulations, acts and ordinances, as well as an unambiguous assessment/approval procedure. The oversight roles of the Ministry of Finance and the Agency for Competitiveness and Investment (AIK) lay out a solid foundation for carrying out large cross-cutting, predominantly infrastructure projects. The Croatian legislative framework for the preparation, evaluation, implementation and supervision of PPP projects is highly regarded.[61] Despite the strong legal framework in Croatia, specific bottlenecks would need to be dealt with for the PPP process to move forward. There are, among others, implementation issues due to weak administrative capacity, project delays and cost overruns.

Examples of energy sector PPP projects include the announced street lighting reconstruction in the cities of Pazin and Vrgorac,[62] while an example of blended PPP (the combination of EU funds with private sources) is the BEECO Biomass project, which is based on converting lignocellulosic perennial crops to biofuels, fiber, biochemical products or energy.[63] The PPP model can also be combined with ESCOs for energy efficiency projects. The European Commission regards PPPs as one of the financing tools at the disposal of Member States and project promoters, and a potential instrument of policy implementation. The extent to which the model is to be used remains at the discretion of Member States.[64] An illustration of the size of PPP market per EU member state can be seen below:

[61] https://www.researchgate.net/publication/321075821_Value_for_Money_in_Croatian_PPP_Projects_1
[62] http://www.aik-invest.hr/en/ppp/ppp-projects/
[63] https://ec.europa.eu/eipp/desktop/en/projects/project-8871.html
[64] http://publications.europa.eu/webpub/eca/special-reports/ppp-9-2018/en/

Figure 5.4 Size of the EU PPP market



Source: European court of Auditors Special Report, 2018.

The decision of whether to increase the use of PPP or blended PPP activities should depend on value-for-money, as well as on their alignment with overall strategies and investment policies.

6 Proposed implementation roadmap

As public consultation on the new National Energy Strategy (NES) was initiated in late May 2019, the following proposed roadmaps are prepared for a number of proposed policy recommendations and strategic projects that are not part of existing long-term plans (e.g. 10-year power and gas transmission plans). The proposed roadmaps indicate major milestones and the approximate time duration for their implementation. The World Bank team stands ready to support the Ministry of Regional Development and EU Funds, Ministry of Environment and Energy and other relevant ministries and agencies throughout 2019 to ensure a good alignment of the proposed roadmaps and the new NES.

a) Roadmap for Improving Household Air Quality

Timeframe	Activities	Leading Entities
T_0 + 9 months	• Collect and compile household data to identify the number and location of households for support • Prepare eligibility criteria for the provision of financial support • Quantify the amount of required financial support • Identify implementation stakeholders such as government ministries, local authorities (municipalities), stove suppliers, transportation providers, financial institutions, etc.	Central Bureau of Statistics/ contractor MoEE, Mininstry of Construction EPEEF Ministry of Finance
Next 9 months	• Identify and apply for government and other financing support (e.g. government budget, grant, supplier credit, consumer credit) • Prepare an "Implementation Plan" for support. This could be divided by geography or other criteria	MoEE Ministry of Construction EPEEF Ministry of Finance
Next 12 months	• 1st stage launch of the Implementation Plan (smaller scale) • Full launch of the Implementation Plan	LGUs/RGUs, EPEEF
Afterward	• Evaluation of Implementation Plan output and outcomes	Governemt/contractor

b) Roadmap for District Heating Improvement/Expansion Projects

Timeframe	Activities	Leading Entities
T_0 + 4 months	• Scoping of candidate projects with DH companies • Identify the availability of EU funds for DH for the next programming period [after 2020]	DH companies MRDEUF
Next 12 months	• Prepare "Investment Prospectus" for candidate projects. The IP may include feasibility assessment (technical, economic & finance, environmental & social aspects), cost estimates (construction and operation phases), and indicative financing requirements • Identify Government of Croatia's financial support (e.g. grant, guarantee, taxation) for candidate projects	DH companies Ministry of Environment and Energy Ministry of Finance Local authorities (municipalities)
Next 12 months	• Invite investors/financiers to appraise the candidate projects • "Final Investment Decision" made	DH companies
Next 12-24 months	• Project procurement and construction • Commence commercial operation	DH companies

c) Roadmap for Energy Efficiency Improvement in Buildings

Timeframe	Activities	Leading Entities
T_0 + 9 months	• Per EU Directive 2018/844 (covering energy performance of buildings and energy efficiency), prepare a New Long-term Renovation Strategy for buildings in Croatia. • Consult the European Commission on challenges in implementing the current round of the regional operational program and ways to enhance the effectiveness of EU funds for the next round. • Reconfirm and expand Croatian stakeholders for the New Strategy	Ministry of Construction & Physical planning MRDEUF
Next 12 months	• Carry out consultation with Croatian stakeholders of the draft Strategy • Government of Croatia's approval process • Enactment of law and regulations • Commence implementation	Ministry of Construction & Physical Plannig MRDEUF

d) Roadmap for Legal and Regulatory Setup for New Renewable Energy Projects

Timeframe	Activities	Leading Entities
T_0 + 12 months	• implement current legislation (speed up the work on the replacement of the feed-in tariff, implement the feed-in market premium mechanism for RES) • Finalize and adopt National Climate and Energy Plan • Define the energy transition scenario for new Energy Strategy, adopt new Energy Strategy	The Government, Ministry of Environment and Energy, HROTE
Next 12 months	• Prepare and adopt legislation for implementing new Energy Strategy and NCEP • Implement the prosumer bylaws to optimize the process of decentralized micro-production of energy	MoEE

e) Roadmap for Improving Social Support Mechanisms for Energy Consumptions

Timeframe	Activities	Leading Entities
T_0 + 12 months	• Collect and compile household data to identify the number and location of households requiring support • Review options of mechanisms to support the "energy poor" • Prepare eligibility criteria for the provision of financial support • Quantify the amount of required financial support • Consultation on mechanisms and eligibility criteria	Central Bureau of statistics/ contractor Ministry of Environment and Energy Ministry of Construction Ministry of Finance EPEEF
Next 4 months	• Final design of the selected mechanisms • Prepare legal documents required for the implementation of the selected mechanisms	MoEE EPEEF
Next 12 months	• Government of Croatia's approval process • Enactment of law and regulations • Commence implementation	The Government MoEE EPEEF,

f) Roadmap for Natural Gas Demand and Supply in Croatia

Timeframe	Activities	Leading Entities

T_0 + 9 months	• In parallel with analyzing the energy transition scenario for New Energy Strategy and finalizing the Croatia Energy and Climate Plan (by December 2019), carry out a detailed review of natural gas demand and supply for the next 10 years or longer.
	• For gas demand:
	  ○ Emphasize the need for an analysis of potential demand for heating (individual systems and district heating systems), cooking.
	  ○ Emphasize the need for an analysis on the impact on gas demand due to coal reductions, increased use of renewable energy, improved energy efficiency, and electricity imports.
	• For gas supply:
	  ○ Carry out an analysis of potential additional sources of domestic supply, supply through pipelines (Slovenia, Hungary, Bosnia) and LNG.
	  ○ Carry out an analysis of the impact of changes in gas demand in Croatia on gas transmission and distribution fees.
		Ministry of Environment and Energy
		Ministry of Transport
		Local authorities (municipalities)
		Plinacro
		Gas DSOs
		HEP
		LNG Croatia
		District heating companies

Next 12 months	• Incorporate a natural gas strategy in the New Energy Strategy and the Croatia Energy and Climate Plan	Ministry of Environment and Energy

7 Proposals for strategic (“Flagship”) projects

The following projects and activities could be considered strategic for Croatia. They are presented here in order of their significance to the overall energy sector improvement of Croatia. It is also from the lens of urgency for Croatia, as a number of activities/issues are not highlighted in the available Croatia’s strategic documents and have limited actions to address them so far.

A number of projects and activities are part of various plans developed by the leading energy organizations. For example, the 10-year plan developed by HOPS for power transmission, the 10-year plan developed by HEP ODS for power distribution, the 10-year plan developed by Plinacro for gas transmission. However, as the National Energy Strategy is being updated, this is the time to review and reprioritize projects and activities to fit the National Energy Strategy and the upcoming National Energy and Climate Change Action Plan.

(i) Improving household air quality, decarbonisation and expanding renewable energy options for households

- To improve indoor air quality, health benefits and energy efficiency for households—since almost half of final energy use is in the form of biomass (particularly firewood)—through the improvement of ventilation and biomass stoves.
- Expand and promote renewable energy options for households, particularly solar, geothermal and biogas energy.
- Benefits would also include improvement in Croatia’s energy intensity and wood utilization, as well as reduction of GHG emissions and dust emissions.

(ii) Efficiency improvement and expansion in district heating systems and efficiency gained in gas-fired power and heat generation

- HEP Toplinarstvo. Capital expenditures in district heating have been relatively small in recent years (less than 5 percent of HEP Group’s overall capex) and should be more emphasized in the coming years.
- Other district heating systems. The revised district heating tariff methodology should allow additional capital expenditures to be made in a financially viable manner, and should support the expansion of services to more customers.
- Further use of geothermal energy and biomass fuel in district heating, building on initiatives from Vukovar, Sisak, and Osijek. This option may include switching from electric heating to efficient biomass stoves in stand-alone buildings and heat-only-boilers in multistory buildings[65].
- Implementation of combined-cycle gas-turbine power and heat generation to replace old and inefficient gas power generators (e.g. EL-TO Zagreb CCGT).

[65] Technically feasible alternatives to increase biomass use include biomass-fueled district heating (DH) systems with heat-only-boilers (HOBs) or combined heat and power plants (CHPs) that can use both agricultural and woody biomass fuels. At the building-level, feasible technologies include stoves and small boilers fueled by wood logs, wood chips, briquettes, or pellets. Source: Biomass-Based Heating in the Western Balkans, World Bank, 2017.

- Implementation of natural gas and/or the LNG import project to supplement declining domestic gas supply, reducing coal import while ramping up the next phase of renewable energy sources.

(iii) Energy efficiency in the building sector, covering residential and non-residential heating and cooling, as well as improving insulation.

- Prioritization of building categories for renovation, including the deep renovation concept and utilizing renewable energy in buildings, supported by cost-benefit analyses.
- Aggregating buildings for renovation, which enables the bulk procurement of contractors, goods and equipment.
- Further developing long-term financing instruments and models, alongside the traditional financing, grants and other support schemes. An upgraded ESCO model to deepen and expand ESCO services should be considered. Additionally, depending on the category of building occupants and building types, the percentage of grant given for renovation should be reviewed to ensure adequate funding and affordability for building renovation.

(iv) Energy efficiency in the transport sector, including electrification in transport and the expansion of multi-mode transport (particularly rail and water transport).

(v) Propelling the next phase of renewable energy projects, including off-grid, mini-grid, prosumers, aggregation, and the management of intermittent renewable sources. An enabling framework for further deployment of renewables.

- A transition to well-structured transparent auctions will be a positive development for Croatia because it will enable the country to grow its domestic supply of renewable energy resources and reduce import dependence at Least Cost.
- In addition to utility scale renewable generation, Croatia must consider improving the framework for facilitating decentralized or distributed renewable generation solutions.

(vi) Improvement in power and gas transmission and distribution

- HOPS (10-year plan)
- HEP ODS (10-year plan) power distribution improvement to decrease distribution losses to below 8.1 percent (2015) and to improve reliability indicators (e.g. SAIFI, SAIDI)
- Plinacro (10-year plan)
- Gas distribution DSO

Annex 1: Biomass applications and opportunities for Croatia

Global Trends in Biomass Utilization for Heating

Demands for modern biomass boiler

During the last two decades, demand for more efficient, safe and environmentally cleaner biomass-fired boilers for heating has increased. This demand from consumers, as well as new European regulations requiring increases in the share of renewable energy sources in the energy balance, have resulted in remarkable developments and innovations by the boiler manufacturing industry. In most European countries there are local manufacturers for small and medium size heating boilers utilizing various kinds of biomass.

There are European standards and directives applicable to all member states, laying out the requirements for biomass boilers and helping clients to purchase boilers suitable for their needs. The requirements for boiler efficiency and emission thresholds are specified in Standard EN 303-5:2012 for biomass heating boilers below 500 kW. EU Directive 2015/1187 of April 27th, 2015 specifies the requirements for energy labelling of solid fuel boilers considering boiler efficiency and emission levels.

According to the above-mentioned directive, a solid fuel boiler should come with an energy label indicating its energy efficiency on a scale from A++ (most efficient) to G (least efficient), applicable from April 1st, 2017. The range of this energy scale will be amended to A+++ to D, from September 26th, 2019. Packages of a solid fuel boiler, supplementary heaters, temperature controls and solar devices should come with an energy label indicating its energy efficiency on a scale from A+++ (most efficient) to G (least efficient), applicable from April 1st, 2017.

Individual boilers fueled by dry wood logs

The traditional way of using biomass is to utilize dry wood logs in an old-type of low-efficiency solid fuel boiler predominantly under-fire air, designed for natural up-draught combustion. This typically leads to low efficiency and the high emission of unburned particles and gasses, especially during initial periods of a boiler operation after loading of new wood batch.

Modern biomass boilers utilize a two-stage combustion process to combust fuel as fully as possible, thereby achieving high efficiencies and low emissions. In the primary combustion zone, which is located on the grate, drying and solid combustion take place. In the secondary combustion zone, the volatile gases are burned with air that is introduced in a controlled manner. Other advanced features include an electronic combustion control, a controlled fuel feed into the combustion chamber, a sophisticated burner with electronic ignition, and automatic ash removal, combustion chamber cleaning, and reduced heat losses.

The complete combustion of the fuel in an optimized, two-stage combustion design results in very low emissions of particulate matter because of the absence of unburned hydrocarbons in the flue gas. The particulate matter (dust) from the modern boilers is primarily inorganic, while emissions from lower-technology stoves and boilers are mostly unburned organics.

Wood boilers are usually connected to heat storage tanks (a water tank for the storage of heat). This is an advantage in terms of combustion efficiency and emissions, because the boiler can then be run at a regular heat output instead of being intermittently operated to directly follow the heat load of the house. This allows the biomass boiler to achieve optimal combustion conditions, leading to lower emissions and higher efficiencies.

Replacement of old-type boilers with modern wood boilers leads to increases in average combustion efficiency, from 60%-70% to over 90%, and the reduction of particles, volatile organic compounds, and gasses by 70-95%.

Croatia has a long history of using biomass for energy purposes

The country joined the IEA Bioenergy in 1998 when biomass utilization was at its earliest stages and limited mainly to the usage of firewood and wood residue in rural areas. Bioenergy production in Croatia is predominantly from forest derived fuels (wood-chips and pellets), used in combined heat and power household stoves, small boilers, etc. Efforts are being made to incorporate agricultural residues such as straw or olive pomace and the production of liquid biofuels into the energy market. The trends in primary energy production and the share of biomass are illustrated in the table below.

Table A1. Trends in primary energy production and the share of biomass

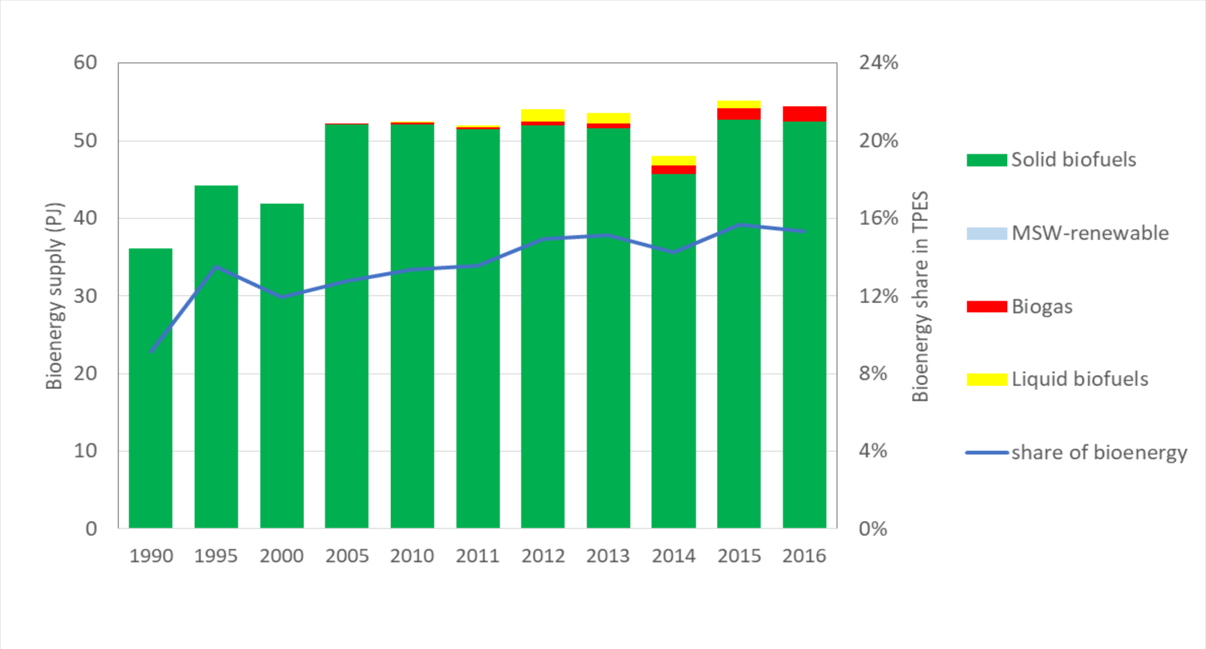
	2011.	2012.	2013.	2014.	2015.	2016.	2016./15.	2011.-16.
	PJ						%	
Ogrjevno drvo i biomasa Fuel Wood and Biomass	59,01	60,39	61,45	57,97	64,19	64,15	-0,1	1,7
Sirova nafta Crude Oil	28,37	25,62	25,71	25,38	28,62	31,47	10,0	2,1
Prirodni plin Natural Gas	85,02	69,19	63,11	60,52	61,61	57,52	-6,6	-7,5
Vodne snage Hydro Power	47,58	47,32	84,92	88,99	61,63	65,63	6,5	6,6
Toplinska energija Heat	0,60	0,61	0,63	0,52	0,62	0,66	6,0	2,1
Obnovljivi izvori Renewables	2,85	5,52	7,55	10,40	10,79	12,68	17,5	34,8
UKUPNO TOTAL	223,44	208,65	243,37	243,78	227,46	232,11	2,0	0,8

The production of fuel wood and other solid biomass had an average annual growth of 1.7 percent in the observed period.

(Source: EIHP, Energy in Croatia 2016)

Analysis of the total primary energy supply from bioenergy in Croatia from 1990 – 2016 shows an increase in both the overall share and in the utilization of other bioenergy sources such as biogas

Figure A1. Bioenergy in Croatia 1990-2016



(Source: IEA Bioenergy country report, 2018 via World Energy Balances © OECD/IEA 2018)

The equipment used in the industry is partially produced in Croatia, with the component parts deriving mainly from imports. Efforts are being made via government initiatives to revitalize the manufacturing industry in Croatia, including energy technology firms, as many are located in areas of special development interest in the northern and eastern regions of the country.

Wooded pellet-fired fully automated boilers

In the modern wooden pellet-based heating systems, the pellet-fuel is transported from storage to the combustion chamber, where it is ignited and combusted. The heat transfer and air supply are improved by a fan for optimal combustion. The flue gas from the combustion process passes through a heat exchanger and transfers its energy to the water. A pump circulates the heated water through the hydronic heat distribution system. The boiler has sufficient thermal insulation covered with a metal skin to reduce heat losses to the boiler room.

Modern biomass systems utilize a **two-stage combustion process** to combust fuel as completely as possible, thereby achieving high efficiencies and low emissions. Other advanced features of pellet-fired boilers include an electronic combustion control, a controlled fuel feed into the combustion chamber, a sophisticated burner with electronic ignition, automatic ash removal, and combustion chamber cleaning.

There are three main types of burners for pellet-fired boilers, that vary according to the orientation of their fuel feeds:

- **underfeed burners** (underfeed stoker or underfeed retort burners): the fuel is fed into the bottom of the combustion chamber or combustion retort.
- **horizontal feed burners** the combustion chamber is either fitted with a grate or a burner plate. The fuel is introduced horizontally into the combustion chamber. During combustion, the fuel is moved or pushed horizontally from the feeding zone to the burner plate or the grate.

- **top feed burners:** developed for pellet combustion in small-scale units. The pellets fall through a shaft onto a fire bed consisting of either a grate or a retort. The separation of the feeding system and the fire bed ensures the effective protection against burn-back into the fuel storage. This feeding system allows for a very accurate feeding of pellets according to the current heat demands.

Pellet-fired boilers are typically used in single family houses and small public buildings with a boiler capacity of up to 50 kW. They are characterized by the following features:

- convenient, fully automatic operation (automatic ignition and shutdown, fuel supply, ash removal, heat exchanger cleaning);
- high fuel efficiency (80-90%);
- ultra-low emissions;
- very high operation and fire safety standards;
- low fuel costs;
- the potential to combine with solar thermal systems, using an accumulator tank (storage tank);

Investment costs of pellet-fired boilers are remarkably higher than traditional wood-log fired boilers, which can be a barrier to their potential wider use in many countries. There are various kinds of investment support programs used in Europe to encourage home owners to change fuels or modernize their existing biomass-based heating systems to modern pellet-fired boilers.

Wood chip- fired boilers for district heating or large buildings

Wood chip boilers are typically used in biomass district heating systems, but they are also used to heat large buildings or a group of buildings. Boiler capacities 100 kW and above are suitable for wood chip-based boilers. Wood chip heating systems are often sited in free-standing heating containers (that combine boiler and storage) or - for larger systems – in their own separate buildings with a separate storage for wood chips. Fuel is typically delivered by tractors or trucks to the boiler site. The wood chips are then transported to the boiler, using a moving floor and screw feed systems.

Boiler technologies vary depending on the size of the boiler and other requirements of boiler user. Typical boiler types are the moving grate firing type, where the wood chips feeding system brings the fuel to a moving grate where combustion takes place in stages and the combustion air is blown partially below the grate and partially above it in order to optimize combustion. Arrangements depend on each manufacturers' design.

Wood chip boilers can be fully automated without needing a boiler operator to be on-site, typically an operator or maintenance staff has a remote alarm for cases requiring human intervention in the operation. Wood chip boilers require professional operators, who regularly visit the boiler house to monitor the operation.

Most efficient wood chip boilers are equipped with economizers which reduce the outgoing flue gas temperature by transferring remaining heat from the flue gases to DH water. The final flue gas temperatures can be below condensing point. In this way the total boiler efficiency can be above 95%.

Table A2. Characteristics of wooden biomass boilers

Criteria	Firewood	Wood pellets	Woodchips
Capacity [kW]	< 30	< 100	> 100 HOBs and CHP
Use	Farms, individual houses	Individual houses	District heating
Operation	Own work	Automatic operation	Operational staff
Investment costs	Low	High	Average
Fuel cost	Low	High	Average

Cost examples for biomass-fired boilers

Below are some examples of investment cost estimates for biomass boilers, which fulfil requirements of Standard EN 303-5:2012, class 5, which is the highest quality class under this standard. The costs are at European price level, which could be similar on most EU countries for the high-quality boilers. The cost estimates include only the boiler and, separately, an estimate for the complete installation including the boiler and all other accessory equipment, water storage tank, and chimney. The examples are:

I) Biomass boilers using wood logs, that are the highest-quality boilers on the market, with two stage combustion, and have a capacity of 32kW suitable for a single-family house;
II) Biomass pellet-fired fully automated boiler with two stage combustion with a capacity of 25 kW, suitable for a single-family house;
III) Biomass pellet fired fully automated boiler with two stage combustion with a capacity of 150 kW, suitable for a public building or for a multi-apartment building of about 10 apartments.

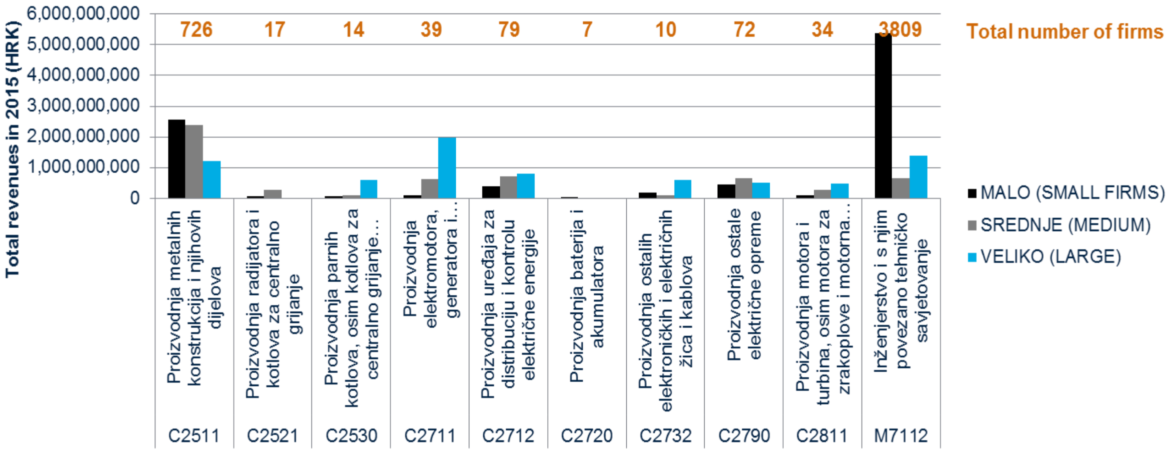
Table A3. Cost estimates of biomass-fired boilers

Boilers - 5th Class Standard EN 303-5:2012	Capacity [kW]	Estimated Costs [EURO]
Firewood quality boiler; storage tank 1000 liters	25	4,000
Pellet boiler, pellet container 1400 liters	32	3,600
Pellet boiler, pellet container 3000 liters	150	23,250
Complete plants		
Firewood quality boiler; storage tank 1000 liters, equipment, chimney, works	25	6,500
Pellet boiler, pellet container 1400 liters, pellet storage 3 m^3, equipment, chimney, works	32	7,600
Pellet boiler, pellet container 3000 liters, pellet storage 10 m^3, equipment, chimney, works	150	31,000

Boiler manufacturing industry in Croatia

Croatia has a strong legacy in energy technology, systems and equipment manufacturing. The number and size of the companies in the industry are illustrated in the graph below.

Figure A2. Number of producers in Croatia



Source: CIRAZ and World Bank analysis of FINA data – Assessment of the Global Value Chain in Croatia; Energy Technology, Systems and Equipment 2016

The central heating, radiator and boiler manufacturing industry, (NACE code C2521) is dominated by agile small and medium firms, while larger firms such as Koncar Group, are active in manufacturing activities across the value chain. Since SMEs dominate the ecosystem, they are more willing to, and capable of, quickly adopting new, innovative solutions in their business operations. During interviews with companies, some such innovative upgrades in product/services that were communicated include the integration of digital and biomass capacities into their product design. Given the national priorities on industry competitiveness, there is need to create an enabling environment for innovative business models in bioenergy projects that would result in reduced biomass supply costs by triggering other ecosystem activities/services.

Biomass stoves for cooking and heating

People living in developing countries worldwide, especially those located in rural areas, rely on solid fuels for cooking and heating. The number of people using traditional biomass fuels will reach 2.8 billion by 2030 (IEA 2010). Most of the population relying on traditional biomass (mostly fuelwood) lives in Sub-Saharan Africa and South Asia. In Europe the percentage of the population using biomass in individual stoves varies between 7% in Croatia and 58% in Bosnia and Herzegovina.

Traditionally, households use agricultural residues and fuelwood for cooking and heating. This poses certain challenges: wood is harvested unsustainably, the lack of sufficient ventilation impairs health and reliance on individual biomass stoves has negative economic and environmental impacts.

There has been considerable progress made towards designing cleaner and more efficient cookstoves. R&D financed by the non-profit organization Global Alliance for Clean Cookstoves helps manufacturers in the development of modern stoves. However, there is an associated challenge to develop high efficiency affordable stoves matching users' preferences. There are three major drivers of biomass stoves development shown in the table below:

Table A4. Ingredients for Cookstove Design[66]

PERFORMANCE	AFFORDABILITY	USABILITY	
• Energy efficiency	• Sale price	• Time saved	• Portability
• Health pollutants	• Unit cost	• Weight	• Maintenance & service
• Greenhouse emissions	• Service life	• User interface	• Cleanliness
• Safety	• Fuel consumption	• Turndown ratio	• Attractiveness
• Durability		• Ease of ignition	
• Time		• Tending requirement	

Performance improvement – increases in energy efficiency and heat output are achieved by reducing the ignition time, and improving air supply and fuel quality. Durability and safety depend on the quality of materials used for the stoves, but it increases the price.

Presently, biomass stoves produced in China dominate the market. Stoves with a capacity of 8 kW, that can heat areas between 40 – 60 m^2, cost between EUR 600 and 800. Although producers claim to achieve an energy efficiency of above 90%, this is not supported by the stoves' design and the materials used. Very cheap, low quality stoves, costing EUR 100 – 200, are also available.

Italy is the European leader in the consumption of pellets. There are many producers of high-quality pellet-fired stoves ranging from EUR 2,000 to 4,000 depending on their capacity and technical parameters. The stoves have an energy efficiency of above 80%.

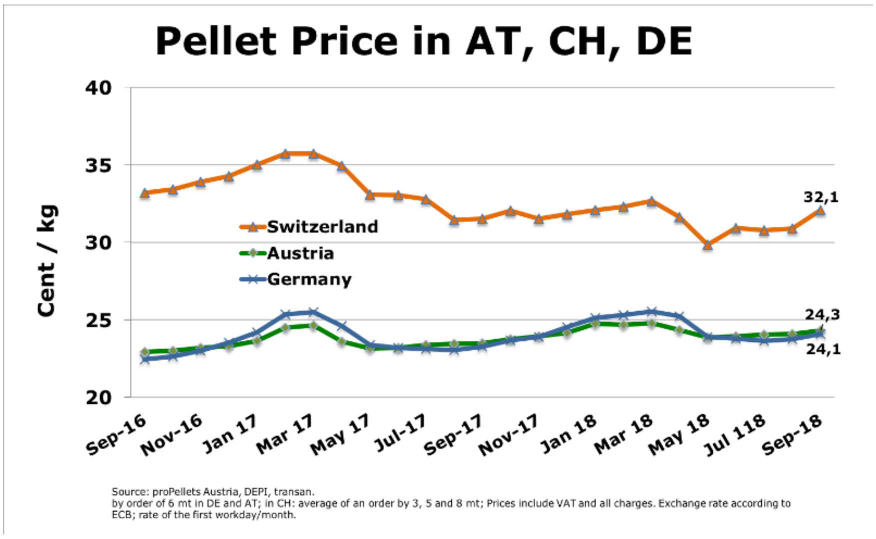
Biomass as fuel and prices

The national and EU standardization of firewood, wood chips and wood pellets was crucial for the positive development of biomass fuels. All biomass fuels quality requirements are set in standards, mainly elaborated in terms of density, size and water content.

Secure supply of biomass requires setting reliable supply chains, based on local resources. The selection of the type of biomass that is to be used in a specific location depends on the heat demand, availability of biomass, required space for a boiler room and storage, as well as on the availability of staff.

[66] Handbook for Biomass Cookstove Research, Design, and Development, Global Alliance for Clean Cookstoves, D-lab

Figure A3. Pellet prices in Austria, Germany and Switzerland



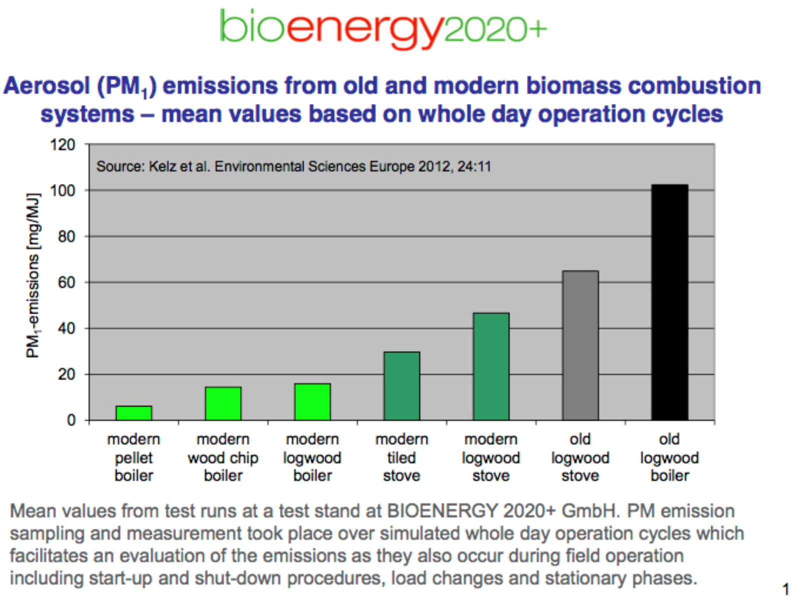
The pellet prices based on proPellets Austria website[67] in Austria, Germany and Switzerland are shown in the graph above. Price level in Austria and Germany is about 24 Euro cents/kg, (240 Euro/ton). Prices in countries producing pellets in Central and Eastern Europe are lower.

Environmental emissions from small biomass boilers

Another crucial factor in modern pellet-fired boilers is the reduction of emissions compared to the old wood log-fired boilers and stoves. The below graph is from same, the prePellets Austria website, as the previous price information.

[67] www.propellets.at

Figure A4. Emissions from old and modern biomass combustion systems.



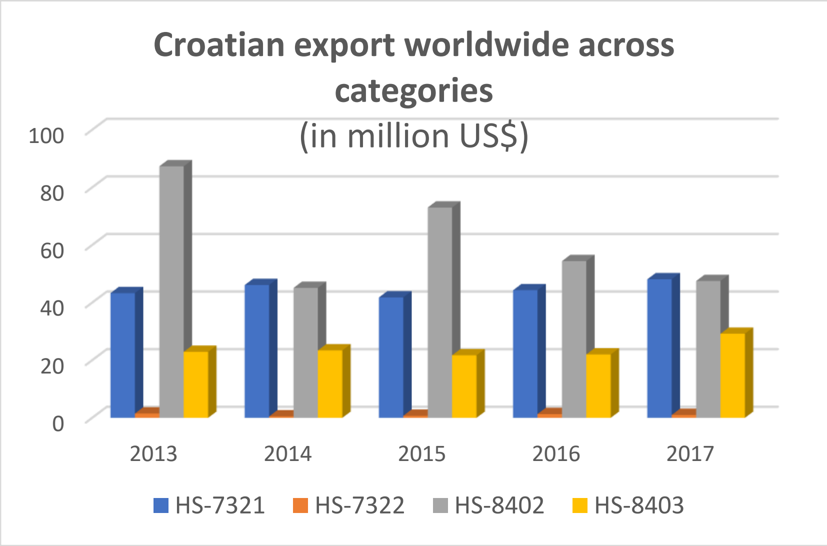
Emissions from small biomass fired boilers and stoves

Croatian exports

Export data provides a viable source of industry information, partly because of the precision of customs data. Export data for this purpose is obtained from the UN COMTRADE database and the open-access World Integrated Trade Solution (WITS) platform[68].

[68] http://wits.worldbank.org/

Figure A5. Croatian export worldwide across categories



The products are classified by their 4 digit Harmonized System (HS) codes.[69] A notable manufacturer of biomass boilers in Croatia is Centrometal Ltd. They export to over 30 countries, but their main markets are neighboring countries (Serbia, Bosnia & Herzegovina, and Macedonia).

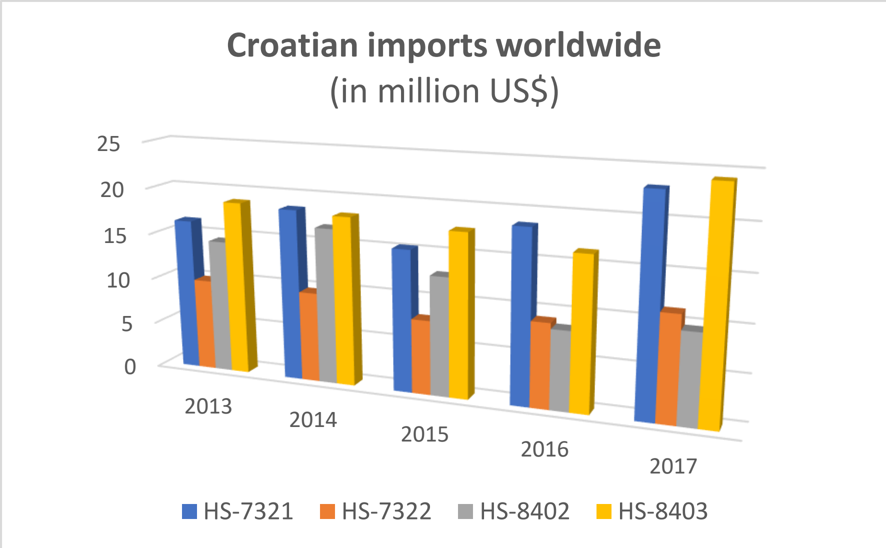
The main export trading partners of Croatia are the neighboring countries and the EU.

Croatian imports

Unlike the comparably small export figures for stoves, Croatia imports a significantly higher dollar value in stoves and cookers which may or may not be biomass fired.

[69] **HS-7321** – Stoves, ranges, grates, cookers (those with subsidiary boilers for central heating), barbecues, braziers, gas-rings, plate warmers and similar non-electric domestic appliances and parts, of iron or steel.
HS-7322 – Radiators for central heating, not electrically heated and parts thereof, of iron or steel; air heaters, hot air distributors not electrically heated, with motor fan or blower
HS-8402 – Boilers; steam or other vapour generating (other than central heating hot water boilers, capable also of producing low pressure steam), super-heated water boilers
HS-8403 – Central heating boilers; excluding those of heading no. 8402

Figure A6. Croatian imports worldwide



SENKO is a Croatian producer of pellet stoves (for cooking, heating and central heating) with all the certifications to assure their products comply with efficiency standards of 91% to 96% and have low levela of environmental pollution.

Energy saving potential in Croatia by modern biomass boilers in family houses

In Croatia the specific heat consumption of buildings varies depending on the location of the buildings and the year of construction. The specific heat consumption in the continental part of Croatia is double the consumption (of the same type and aged buildings) in the coastal part of Croatia. Based on the statistics presented in Government's 2014-2020 program for energy refurbishment of family houses[70] the specific consumption of single-family houses constructed between 1945-1970 is in the continental part 320 kWh/m^2 per year and in costal part 150 kWh/m^2 per. More details in the table below.

Table A5 Family houses and their specific energy consumption in Croatia

Year of Construction	Heat consumption [kWh/m^2, year]		Building area [million m^2]	
	Continental Croatia	Costal Croatia	Continental Croatia	Costal Croatia
Before 1945	300	141	7.39	6.88
1945 - 1970	320	150	17.15	7.22
1970 - 1980	304	143	14.18	7.29
1980 - 1990	288	135	11.40	6.62
1990 - 2006	240	113	9.91	5.18
2007 - 2008	144	68	1.65	0.98
2009 - 2010	112	53	1.14	0.70

From the above table it easy to see that the main potential for energy savings is in single-family houses constructed after 1945 and before 2006. These houses have a high specific energy consumption and the number of houses is large, with a total floor area of more than 50 million m^2 in the continental part of Croatia and above 25 million m^2 in the coastal part of Croatia.

[70] https://narodne-novine.nn.hr/clanci/sluzbeni/dodatni/431066.pdf

In these buildings, heating system replacements and the improvement of the use of biomass pellets would result in significant energy savings and environmental benefits. The same program (mentioned in Footnote 63) has an estimated energy saving potential in single-family houses is shown in the table below.

Table A6. Overview of measures for family houses

Name of the measure	Planned annual investments		Annual energy savings	CO_2 emission reduction
	[Million Kuna]	[Million US$]	[GWh/year]	[1000 t/year]
Outer shell refurbishment (roof, insulation, windows)	87,5	13.9	15,2	4,24
Heating system replacement	40	6.3	27,3	6,44
Incentivizing use of renewables	80	12.6	13,5	3,78
Total	**207,5**	**32.8**	**56**	**14,46**

The above results from the heating system replacement and utilization of renewable energy and wood pellets in an effective way in modern heating systems should be achievable. The fuel usage efficiency would improve with modern pellet and fire wood boilers by about 30%, from the current level about 60% to 90%.

A house with a floor area of 200 m^2, for example, that was constructed between 1945 and 1970 in the continental Croatia, would use about 100 MWh per year fire wood, but after modernization about 66 MWh.

A similarly-constructed house located in in coastal Croatia would reduce the fuel consumption from 50 MWh per year to about 33 MWh per year. These numbers are estimates without any building envelope energy efficiency measures. If implemented simultaneously, energy consumption would be further reduced.

Main biomass industry constraints in Croatia

The main constraints forestalling the advancement of the industry include:

- Sluggish and convoluted administrative procedures
- Biomass supply logistics and routes to market issues for private forest owners
- A lack of knowledge and technologies for market development
- Capacity deficiencies at all levels (policy makers, businesses, customers, etc.)
- Institutional quality control issues (certificates are not always a guarantee of pellet & wood quality)

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