Trends in energy industry call for a new paradigm search

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REVIEW

World energy industry is undergoing significant changes. Accidentally or not, the signs of visible change coincide with the beginning of global economic crisis. In this period the United States made a huge technology breakthrough in exploration and production of shale gas which resulted in large increase of gas production. The production of unconventional oil is following the upward trend of unconventional gas output. The growing US hydrocarbons production at competitive costs, enable US industry to enhance competitiveness of exporting goods, thanks to cheaper energy, in comparison with their key competitors: the EU, China and Far East. On the other hand, Europe has opted to take a lead in protection of the environment and curbing harmful emissions. Its commitment in pursuing this policy is reflected in EU energy strategy by 2020 based on 20:20:20 targets of the climate and energy package. The policy involves increase of renewables to 20% in total energy consumption.

Croatia, as a new EU member, must and should follow the objectives of the EU energy strategy. Considering relatively high dependence on energy imports, and deep economic crisis in the past six years, more intensive development of renewable energy sources and their use could provide an impetus to the Croatian industry development, and the share of 20% RES could formally be met.

However, it should be taken into account that renewables are not economically self-sustainable: they need subsidies and back up energy. Research and development results in some technologically advanced EU countries show that some new conceptual solutions are sought and found, which contribute to improved economics of RES and power generation, as for example power-to-gas energy storage concept. The time has come for new energy paradigms to replace the old ones. New challenges cannot be resolved by old patterns. Therefore, the design of the new energy strategy should be seriously considered.

Key words: Renewable Energy Sources (RES), convergence of network energy

1. Introduction

For decades, the two main types of network energy, electricity and natural gas, had their separate development paths. Neither of the two systems had particular need for cooperation. What they had in common was supply of gas facilities with electricity and power plants with natural gas, but these relations were regulated by short-term or long-term commercial contracts, to the satisfaction of one or the other party, rarely both. These transactions were frequently affected by government controlled pricing mechanisms. Although the energy market in Croatia has been formally opened for some time, administrative price regulation suspended actual liberalisation. However, when Croatia became a full EU member, the market became fully opened and new entrants appeared in 2013 as foreign competitors took part in the Croatian electricity and natural gas markets. The old players lost their quasi-monopoly position. Competition contributed to price reductions to the benefit of consumers. A starting position is set for the coming period in which both, electricity and natural gas network systems, could benefit from linking existing power and natural gas grids. Some authors[3] dealing with the concept of improved economics of renewables, use again almost forgotten term convergence that became popular in the 1990s in discussions about convergence of electricity and natural gas industries in operation of gas-driven thermal plants. In the early 2000s the term was abandoned. Nevertheless, the cooperation of the two industries on the European market was quite intensive and dynamic, frequently accompanied by share of risks, contrary to the Croatian energy sector with weak cooperation among the sectors.

Even before introduction of higher share of renewables, gas fired plants were perceived as suitable back up capacity for power generation. Thanks to their ability to respond quickly to power generation needs, gas plants were widely accepted as good solution for providing stand-by capacity in power generation or back-up capacity for intermittent operation of renewables. Recent problems in Germany put in question some expectations in this regard. In 2013 German E.ON with its co-owners N-Energie, Mainova and HSE considered closure of several gas plants (Irsching 4 - 569 MW and 5 - 860 MW, with efficiency rate 60.4% and 59.7%) due to low utilization rate. Other large energy companies like RWE and Norwegian Statkraft expressed fears that some of their gas plants will have to be closed because of low capacity utilization (<10%). Gas prices are still high in Europe, while electricity prices declined as a result of good supply and competition. EU regulation fosters priority purchase of green power which had significant growth, and this is the reason why utilization of gas plants' working capacity declined considerably, in some cases below break even point.

Such developments instigated search for new, innovative technology solutions. They include the projects which have the goal to use surplus electricity obtained from renewable energy sources at the time of lower con-

sumption for transformation in other forms of storable energy; it can be used in the form of pumped storage hydroelectricity (known also as reversible hydro plants), or production of gases suitable for mixing and injection into the gas grids. This refers mainly to methane and hydrogen, as proposed by power-to-gas energy storage concept. It is a new type of convergence. In that case gas systems buy and take over so produced gas for further sale. The development of these projects is gaining momentum.

2. FURTHER OPENING OF THE CROATIAN ENERGY MARKET IS NECESSARY, BUT NOT SUFFICIENT CONDITION FOR ENERGY CONVERGENCE

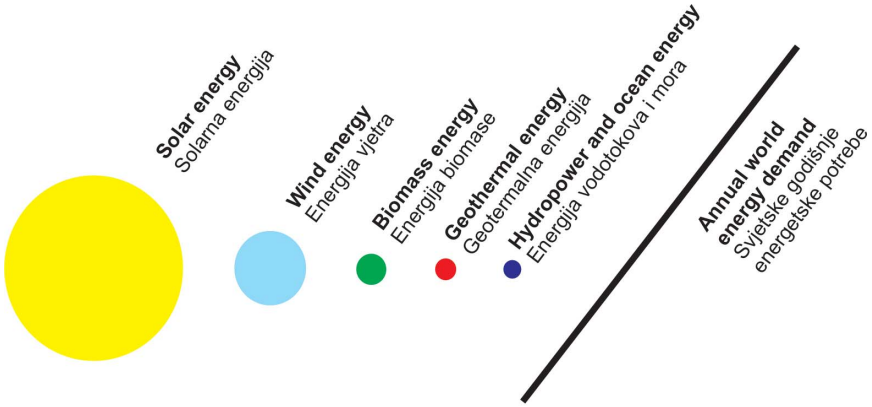
Actual opening of the Croatian electricity market in 2013 resulted in more intensive competition in the power supply segment. HEP Group (Croatian electricity company) has considerable advantage thanks to a large share of hydro power in its portfolio. However, hydro power generation and supply depend on hydrological conditions. In dry seasons significant portion of electricity comes from import because overall power generation capacity is not sufficient to meet the demand. Until new power generation capacity is built, import of electricity will remain unavoidable necessity. Total installed capacity of 4 165.76 MW (according to annual energy statistics "Energy in Croatia" for 2011, p.156) generated 12 676 GWh which could not meet the total demand of 18 527.6 GWh, which was partly covered from imports. From 2006 to 2011 there was rather small increase of power consumption, including increase of imports.

Commitments of EU member states to increase the share of renewable energy to 20% by 2020 are obligatory and must be respected (Note 1). It is not expected that Croatia will have problems in achieving this goal. By 3Q 2013, additional 297 MW from renewable sources was connected to the grid.[2] Croatian Energy Market Operator has signed agreements for new 248 MW capacity.[23] Among renewable energy sources, wind power has the highest share: 13 wind farms with 87 MW capacity are in operation, additional 1 is in preparation. In the near future total wind power capacity will reach 400 MW. It is likely that wind energy will grow further in terms of subsidized renewable energy prices which are about 50% higher than price of electricity from conventional plants (in Croatia wind power price is 71 lipas per kWh compared to 53 lipas from conventional generation), moreover if we take into consideration the fact that investors in wind farms receive subsidies for 14 years after putting the plants into operation. Consequently, the strategic target of 1 200 MW installed wind capacity is within grasp.

Comparisons of various renewable energy sources and their potentials are frequently done in order to find the most effective source. According to some studies solar energy has multiple potentials compared to other renewable sources (Figure 1), but at the current technology level, solar plants have relatively low efficiency rate and high unit costs. Necessary subsidies represent considerable cost for government budget that is a strain even for stronger economies than Croatian economy affected by long crisis.

Energy subsidies are measures that keep prices for consumers below market levels or for producers above market levels. Renewable energy is subsidised in order to compete in the market, increase their volume and develop the technology so that subsidies become unnecessary with the development. However, it needs time. (Note 2)

It is no wonder that European energy strategy foresees phased-out deployment of renewable energy. Even if the



Source: Ref.17 according to Quelle: www.dvgw-innovation.de
Izvor: lit.17 prema Quelle: www.dvgw-inovation.de

Fig. 1. Comparison of different RES potentials
Sl. 1. Usporedni prikaz potencijala raznih izvora obnovljive energije

Note 1: International Energy Agency (IEA) fosters introduction of improved measures for achieving energy efficiency in the world (Nafta 64(2)77-99 (2013), page 82). They consider that the global climate programme, to become effective in 2020, comes too late and that it will not be able to prevent increase of average temperature of 2°C. CO_2 concentration in atmosphere has already exceeded 400 ppm. There are serious concerns that it will be difficult to maintain this concentration below 450 ppm, a precondition for maintaining the increase of average temperature below 2°C. According to IEA statistics, in 2012 CO_2 emissions increased by 1.4%!

Note 2: Investments in various forms of renewable energy differ in size, time of construction and return on investment period. In Croatia, wind farms are predominantly constructed on the coastline due to favourable wind conditions, in the continental parts of Croatia we expect wider use of biomass. The large Desertec project in the Sahara region seems to be on hold. Probably it was discouraged by political and social unrests in the North African regions. In any case, this project could provide strong impetus to the development of new technologies. Wider implementation of technologies in use frequently lead to new solutions - technology push effect.

pace of increase of renewable energy share in total energy consumption could be speeded up from technology aspect, it would be difficult to endure it economically. In Croatia, it is particularly important to take care that the share of renewable energy does not grow above compulsory levels, on one side due to necessary investments in transmission lines, and on the other side because of necessary control of energy costs. For the same reason it is necessary to stimulate (through subsidies) development and implementation of desirable technologies.

3. OLD ENERGY PARADIGMES FALL APART, NEW STARTED TO EMERGE

In the last two or three decades, on international conferences we frequently listened about the increase of the world population which rose to over 7 billion and by the end of the 21st century it is expected to grow to about 10 billion, but even now at least 2 billion people do not sufficient energy in a modern sense. This will create serious problems. However, three main religions do not have concerns about population growth and things are getting out of control. Those who dared to propose certain measures for limitation of uncontrolled population growth, as Mr. Kissinger in the 1970s, were stigmatized as Malthusians. But reality is harsh. It is necessary to ensure energy for two billion people that do not have it, and additional energy for expected increase of 3 billion people.[15]

While developing countries cope with elementary problems, developed countries are concerned about energy intensity (relationship between energy consumption and GDP) which decreased during the 20th century (excluding early 1960s) at the average rate of 1.3%. However, the pressing problems of climate change which gained momentum after 2005, dramatically changed established energy paradigmes. By 2011 Europe set its energy policy principles with very ambitious goals in regard to greenhouse gas emissions and their reduction by 2050.[16] O. Noreng (contributing editor of World Oil) holds that recent calculations indicate that Europe's focus on energy efficiency and renewable energy calls for much larger investments than were anticipated few years ago. Of course, it all comes down to the issue of industrial competitiveness. In addition, there are new strong competitors - China and India - that tend to build their competitive position thanks to non-fulfilment of commitments from international agreements on climate change. On the other hand, the United States already have available energy at 20-40% lower cost than Europe. The EU's orientation toward 'green' energy has significant impact on already high energy costs. They will be further affected by the construction of smart grids. At the moment, oil prices are relatively stable around US$ 90/bbl. Nevertheless, many indicators show that oil prices could go up, along with other energy sources, including some ores and metals, particularly copper.

In this perspective, Croatia should seriously consider designing of a new energy strategy for longer horizon, by the year 2050, that would take into account the new developments and projections of global and local trends (Note 3). It is a must, even more, because the Energy Strategy of the Republic of Croatia designed in 2009 was not implemented, and at the time of its design, the current trends were hardly discernable. In addition, Croatian power generation industry and transmission system operator are faced with huge investments in building required transmission capacity. Construction of smart grids needs time and investments. In addition, it is necessary to ensure back up energy for renewables intermittent production, i.e. for the time when there is no wind and/or sun. If each 1 000 MW RES should be covered with about 95% of stand by capacity from conventional sources, then we are really talking about extensive and costly works. In the mentioned reference, R. Bošković[20] quotes the data that in 2011 Croatian wind farms during 99% operation time had utilization rate of 26.5% of installed capacity! In the meantime the reliance on electricity imports was considerable. In a small economy as Croatia, a variety of goods, equipment and services are permanently sourced from import. However, import of electricity should not be on the list of imported goods. Of course, trading with surpluses and shortages is another thing.

4. GAS AND POWER INDUSTRIES FACE STRONG COMPETITION

Acceptance and implementation of the Third Energy Package pose new challenges to energy industry, particularly network energy like natural gas and power. It was generally considered that the Croatian energy industry was in monopoly position and for this reason it has a hard time to adapt to ongoing changes. Actually, we can talk about quasi-monopoly position. Prices of natural gas and electricity were regulated until recently, in average they were below EU market level.

Croatian economy is heavily burdened with fiscal and para-fiscal charges, therefore energy producers and all other participants in energy chain supply to end customers, have no cost advantage that would enable them to sell their products (electricity or gas) at lower prices compared to majority of other EU states.

By October 2013, 54% of Croatia's demand for natural gas was met from indigenous production and the remaining volumes were imported. The demand for electricity was met by combined supply from domestic power generation and import. It is most likely that domestic gas production will be able to adjust its pricing with competitors. In case of electricity, there are some new, unexpected developments (during 2013) taking place in some EU states, particularly Germany. In the situation marked with high natural gas prices and low electricity prices, obligation to purchase 'green' energy as priority, low utilization rate of gas fired power plants led to their

Note 3: In the last three years the director of Energy Institute "H. Požar" and his collaborators published several studies in which they raised the issue of new energy strategy by 2050.[6,7]

underperformance. For these reasons the owners of gas fired power plants are forced to shut them down temporarily. However, it poses considerable risks for endurance of the entire energy system. In order to mitigate this risk and to keep coal and gas fired power plants in operation, various incentives tend to increase consumption of electricity at very low prices, up to special offerings to consumers able to absorb overproduction in critical time. In such circumstances, with growing electricity supply from import, Croatian power generation industry is faced with new challenges that were unknown until this year.

If we look back, energy prices had steady growth even in the US, which traditionally have lower energy prices than their competitors from the Far East or EU countries.[1] This topic was discussed in the World Oil editorial article by Roger Bezdek where he confirmed that despite lower energy prices than in other parts of the world, the United States witnessed steady growth. Between 2001 - 2010 the share of energy cost in total family expenditures for citizens with lower income grew by 75%, so the share of energy cost grew from 6% in 2001 to 10.4% in 2010. (The author's comment referred to concerns on additional penalization of CO_2 emissions which will cause additional rise of energy prices.)

For households with annual income of 10 000 $, energy costs account for 36-39% of their income. The segment with annual income ranging from 10 000 to 30 000 $ has the 14-22% share of energy costs in total income. For those with annual income ranging from 30 000 to 50 000 $ this share drops to 10-16%. In author's opinion, in case of households with annual income over 50 000 $/g, this share falls to acceptable level of 5-8%.

The EU energy strategy, which sets obligations for the Member States, including Croatia, regarding the share of RES and schedule of their introduction, will certainly affect energy prices. The above mentioned problems in Germany are early warning and call for measures to avoid such situation. At present, we are facing discontinuity of the old energy paradigm while the new one is only emerging. In the Croatian energy sector we also have to cope with development discontinuity. Former energy strategy was not implemented. Slowdown is most conspicuous in the power sector, with strong effect on the entire economy. The problem will become even greater if timely overview and actions are not taken on both, company and government level.

5. TRENDS IN ENERGY SECTOR ARE REFLECTED IN THE ENTIRE ECONOMY

Some new trends in the energy sector are already reflected in other sectors of economy. This is primarily the successful unconventional gas production in the United States, to be followed by unconventional oil. This trend became visible after 2005 when the US natural gas production started to grow. It was preceded by extensive research and development of new technologies for more than 10 years before their application. Growth of natural gas production in the US is reflected in the world economy in three main areas:

1. Increase of oil and gas reserves,
2. United States become self-sufficient in energy supply with decreased dependency on imports, which has significant impact on global geopolitics and international relations,
3. Lower energy prices in the US influence global crude oil market and segmented natural gas market.

Deep recession in the recent past (if past) and expected recovery will not have equally positive impact on all energy sectors. For example, decreased consumption of oil derivatives is affected by lower car sales. When car sales recover, new generation of car engines will have lower fuel consumption, purchasing power of consumers will recover slowly and oil derivatives consumption will hardly resume pre-crisis levels ever so soon. Thanks to increased production of unconventional gas and oil, the US suspended import of derivatives (gasoline) from Europe. The effects have already been felt across the European refining sector. In 2011 there were 92 fuels refineries in operation in the EU including Norway and Switzerland.[2] One third of all refineries were located in Germany, France and Italy. Some other sources (table presentations from various sources: CIEP Analysis, Purvin&Gertz, WGI, IHS Global Insight, Bloomberg, Barclays Capital) reported on changes in the EU refining sector from 2008-2012. The reports mentioned that in the North-Western Europe 11 refineries were sold, 4 were in negotiations for sale, 2 were shut down, 4 were out or operation and 2 refineries were converted into storages. This trend will affect Croatia's refining sector too (Note 4).

These challenges are well presented in the paper written by Vice President of Shell Global Solutions International BV.17 The author points to the growing expansion of refinery capacity in the US where the number of refineries halved since the 1980s, while average single refinery capacity increased four times to benefit from economies of scale. On the other side, in Europe, we have large number of smaller refineries and the problems such as size, configuration, location and the size of a market affect their competitiveness. All these factors become growingly important (Note 4).

In 2011 oil and gas had 67.81% share in the Croatian energy market. In absolute size, in that year consumption of crude oil was 3.4 million mt (of which 2.8 million mt was imported) and 3.2 billion cm of natural gas, (of which 2.5 billion cm indigenous production). Oil deriva-

Note 4: More than 3 years ago in an interview with periodical J.L. Megawatt, Mr. Peter Chmurchiak, Executive Director of INA's Refining till 2012, warned that after several-year growth (2003 - 2008) the demand for fuels in Europe started to decline, along with the demand for refining capacity. The recession resulted in declined consumption and declined capacity utilization, which caused serious problems to European refiners. Mr. Chmurčiak mentioned example of sale of Total's refinery in Dunkirk (137 000 bbl/day or 21 800 cm/day) due to $176 million loss in 2009, but also potential sale of refineries owned by Shell, ENI, Chevron and Conoco Phillips. These were early signals of downward trend that started in 2008. He also quoted possible repercussions for INA's refining segment, mentioning that delay in modernization might result in lost business cycle and market share shrinking.

tives consumption declined (city of Zagreb accounts for 60% of total consumption). In an overview of the Croatian oil and gas industry performance in 2012, Dr. Gordana Sekulić[18] reminds that negative trends in oil derivatives consumption in Croatia began in 2008 with considerable impact on INA's performance. According to the data, in 2012 INA generated total revenues of HRK 29.895 billion (similar to previous year), but net profit was 62% lower, which can be attributed to withdrawal from the Syrian production fields. In 1H 2013 INA's revenues declined by 8% compared to previous year. In the same period (1H 2013) INA's natural gas sales declined by 19% compared to 2012. According to the author, in addition to lower consumption, the decline was also affected by growing competition in the market.

About ten years ago, EU recorded downsizing of fuel retail outlets. In Croatia there are more than 800 petrol stations, about half of them operated by INA, while remaining 414 petrol stations belong to Petrol, Lukoil, Tifon, Crodux and individual dealers. In the 1H 2013 INA processed 1.9 million mt of crude oil in its refineries, and sold 1.6 million mt of oil products. Operating conditions for retailers are ever more stringent with low margins, declined sales and strong competition. Just as a remainder, in the period from 2005 to 2013 BP downsized its petrol stations network by 7%. Few years ago, Nafta journal published an article on closure of around 15 000 petrol stations in Germany.

It would be useful to carry out a more detailed research and analysis of the current trends to make sure what are in(significant) changes and what are key trends. Moreover, since energy industry as a whole plays such an important role in the Croatian economy.

6. ENERGY INDUSTRY'S EFFECT ON ECONOMY IS VERY STRONG

The US economy is successfully recovering. Increased production of indigenous oil and gas contributes to the recovery through competitive energy prices. As energy prices in Far East remain high, while other production costs grow in comparison with the level that prevailed twenty years ago when the United States (and other EU countries) moved considerable part of their production capacities to China and other Far East countries, it is likely that outsourced production capacities will go back to their originating countries. Businesses benefit from recovery and dollar position as global currency. Contrary to this situation, European Union pays higher energy prices, particularly for oil and gas. Energy prices are not Europe's competitive advantage. Implementation of the current EU strategy and policy will certainly not result in decline of energy prices. Croatia now shares this destiny, however with much worse starting position.

Table 1. Structure of Croatian export in 2012

Region	%	Value (HRK billion) kn)
EU	58.00	42.119
EFTA	1.3	0.950
CEFTA	21.00	15.153
OPEC	1.83	1.326
BRIC	4.78	3.454
ZND	0.63	0.458

Source: Obzor (V.L.) of 25.05.2013., str.8-9

Croatian energy industry represented by about fifty companies: INA, Plinacro, PSP, JANAF, 35 gas distribution companies, fuel retailers, has important role in the economy. In the situation marked with falling exports, imports of crude oil, natural gas and electricity, burden national export-import balance. Many economists call for urgent action aimed at reversing export downward trends. Nevertheless, the situation has not changed much. If we look at the geopolitical structure of exports, 58% of Croatian export goes to EU countries - Table 1 below. Consequently, it is not likely that any significant improvement will be made unless major changes are introduced in economic policy, primarily industrial policy.

According to the data, about 80% of Croatian exports in 2012 went to the EU, EFTA and CEFTA countries. After Croatia joined the European Union in July 2013, export to CEFTA countries declined, and it will be reflected in 2013 data. The fact that Croatian export is too small is quite notorious. Only 13% of companies export their goods and services (Note 5). Why export matters in the context of energy issues? According to the author of this article, there are three main reasons. It should be recalled that in the early 1980s INA became large exporter, the largest in Yugoslavia. The value of its exports exceeded US$ 500 million. Although INA went through significant transformations and focussing on its core activities, in the past decade it was a major exporter again with exports over € 500 million, despite the fact that the Group did not include petrochemical industry, fertilizer plant and tourism industry as was the case in the early 1990s. On the other hand, now electricity emerged as a new import item with value of imports rising to several hundred million Eur.

The second reason could be drawn from the past; it is worth mentioning that during economic difficulties in the 1970s and again in the 1980s, import of energy became (too)large burden for the economy. Energy import restriction introduced in 1983 caused considerable harm to the economy, particularly to industry.

Note 5: D. Radusinović: Economy Collapse, article published in Jutarnji list of 30 October 2013, p.7 and R. Bošković: Devaluation might save export but it would impoverish citizens, Jutarnji list Magazine of 23 November 2013, p. 22-23 referred to the interview with one and the same expert, Prof. Boris Cota (also adviser to the President of Croatia) who talked on several occasions about the most pressing issues of Croatian economy. His comment on the structure of exports is particularly interesting. Only 6.4% of total exports are complex, value added products, compared to 22.4% of simple, low value added products. The ratio is quite different in German export: value added products account for 39.6% and simple only 3.4%. Spain is somewhere between with export of 24.2% of value added products and 11.2% simple products. Hence, in addition to export volumes, it is important to have favourable structure.

The third reason is related to the author's opinion that political leaders of this country, primarily the government, should focus their efforts on creating conditions that will enhance export and provide incentives for substitution of imports by new power generation. Anyway, electricity is a product with guaranteed market. In addition, power generation can become a driving force for other sectors of economy with multiple effects. If proper industry strategy was in place, large energy investments could have helped organizing clusters of equipment producers and providers of services, cooperation with foreign equipment suppliers in the form of offset arrangements. Such arrangements could be useful for building expertise for production of complex energy products including hydro and thermal plants, and possibly their export to the countries in the region.

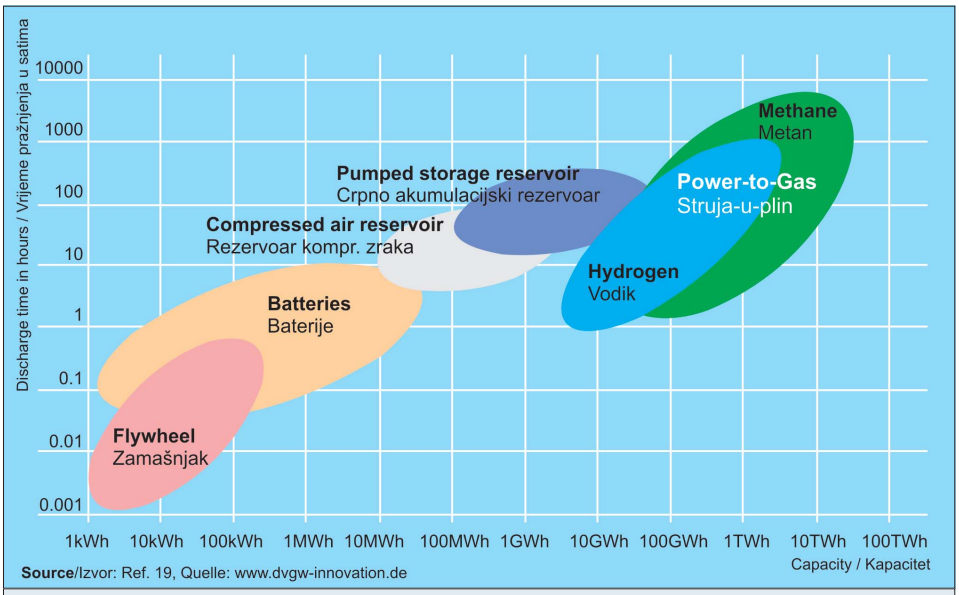


Fig. 2. Presentation of possible solutions for use of RES generated electricity surplus
Sl. 2. Prikaz mogućih tehničkih rješenja za iskorištenje viškova struje

Unlike energy rich countries, Croatia cannot base competitiveness of its export goods on cheap energy. However, it should work hard to make its energy sector more efficient and competitive. The year 2020 is not distant, together with the EU targets to be met: 20% share of renewable energy and very soon after that 30% by 2030. New energy strategy could help in meeting the set goals timely with properly defined implementation milestones, and help us to ensure that investments in energy plants and the structure of energy production do not undermine rather poor competitiveness. Far stronger economies and energy entities than Croatia's, work intensively on resolving problems which started to emerge as a result of higher share of renewables in total energy production. Germany has no problem in meeting the 20% share of renewables, they already fulfilled it, however they are facing new challenges in the form of electricity surpluses and economics of gas fired thermal plants.

7. INTERMITTENCY OF RENEWABLE ENERGY AND UNSTORABILITY OF ELECTRIC ENERGY CALL FOR NEW CONCEPTUAL SOLUTIONS

Intermittent operation of wind and photovoltaic plants due to changing weather conditions (change in wind speed or direction, clouds), cause changes in electricity output. At the same time, there is frequent discrepancy in timing of electricity consumption and production. The highest electricity production may occur at the time of the lowest consumption. Figure 2 presents possible concepts of resolving these problems. Proposed solutions are placed on co-ordinates denoting energy volume and time of use.

The growing input of renewable energy, probably tens of MW generated by wind or solar plants, which cannot be used at the time of production, call for new solutions which can be found in transformation into another energy form or storage (pumped storage hydroelectricity, known also as reversible hydro plants) or production of gas (hydrogen, methane) which can be injected into gas grids. The latter solution is known as Power-to-Gas-Storage[14] (PTGS). The group of scientists and experts from DVGW[14], published a series of useful information about this innovative concept. Hydrogen production is foreseen by a process of electrolysation. German gas industry has considerable experience with injection of hydrogen into gas grids back from the times of energy shortages after the Second World War. It is considered that mixing of 10-20% hydrogen does not cause any harmful consequences, but its share will depend on specified calorific value and Wobbe index.

Figure 3 gives a schematic presentation of the linked technologies in the function of an integrated system that would allow seasonably adjusted storage of significant amounts of power in the form of renewable energy source gas.

As an alternative to hydrogen generation, the scientists consider methnation process of carbon monoxide (CO), by hydrogen use. In case the source of carbon dioxide is not available within economically viable distance, it can be taken from atmosphere. The conversion process takes place at high temperatures in reactors which would be fed by produced energy.

In the references[14] the authors provide some projections of required investments and their structure for the production of hydrogen by electrolysis. The presented CAPEX of € 10 million refers to construction of 5 MW electrolysis plant, which includes 23% contingency costs. The structure of CAPEX is presented in Table 2.

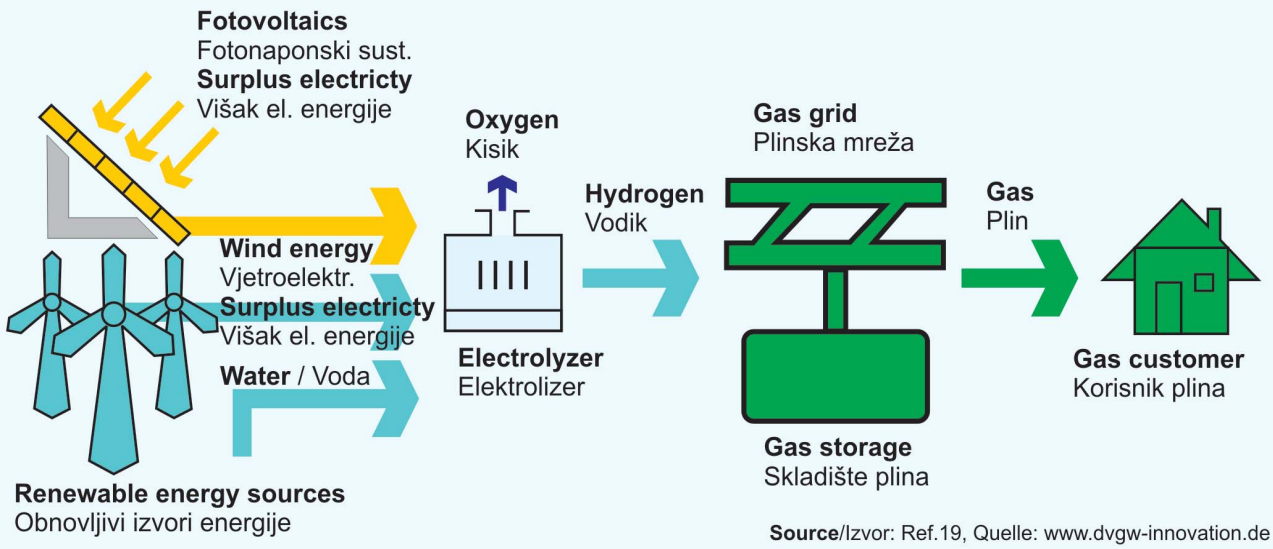


Fig 3. Technology system for processing surpluses of renewable electricity and transformation into storable energy
Sl. 3. Sustav tehnologija za iskorištenje viška el. energije i transformaciju u uskladištive oblike

Table 2. Structure of CAPEX in construction of hydrogen plant by use of electrolysis process

Plants and equipment	Share in total CAPEX (%)
- electrolysis plant (1 000 m^3/h H_2)	50
- compressor (60 bar)	3
- buildings	14
H_2 tank (1 300 m^3)	8
H_2 injection into grid equipment	2
Contingency costs	23

8. Conclusion

Considering the fact that total capacity of renewable energy in 2020 could be at 1 000 - 1 200 MW, necessary stand-by energy capacity would range from 900 to 1 080 MW. Final size and structure of installed capacities and RES capacities will determine the stand-by capacity. The hourly rate of RES operation and utilization of their capacity will strongly impact the choice of technology for stand-by energy.

The need for search of the most appropriate technology solutions to ensure economic sustainability of renewables by resolving the challenges caused by their intermittent work and production of gases (CH_4 or H_2), that could be injected into the grid and used by consumers, recalls cooperation between the two network energy sources - electricity and natural gas. Intermittency of renewable energy generation, frequent discrepancy in time of peak RES production and peak consumption, and unstorable feature of electric energy, lead to convergence of the two energy systems. However, the convergence process requires that both sides identify and quantify their interests.

Past experience from implementation of large and complex projects, that need proper coordination in time and space, teaches us that it would be more than useful to have in place a well designed energy strategy. The objective of such a document is not only the design and implementation of national strategy, but also optimisation of technology solutions and projects with the aim to achieve lowest possible energy costs. This should be in the best interest of the entire community.

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