The benefits of synergy between the heating and power system regarding renewable energy sources volatility and balancing

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***Abstract*— The paper presents current researches and examples of good practices regarding synergistic cooperation between the power and heating systems. This cooperation can have several mutualy related goals, namely: to support the integration of a significant share of variable renewable energy sources; to increase energy efficiency; to boost decarbonization of the energy sector and to increase security of supply. Analysis and comparison of different possible practical solutions and novel technologies based on certain geographic and temporal characteristics, the structure and characteristics of producers, heat storages and load characteristics are provided. Authors also propose specific guidelines and suggest solutions for case of Croatia regarding relevant regulatory policies, possible issues and necessary adaptations of Croatian heating and power systems for successful integration of new forms of energy storages and also new forms of energy balancing.**

Keywords—energy storage systems; new balancing technologies; renewable energy sources; combined heat and power (CHP); power system flexibility; heating and power system synergy

I. INTRODUCTION

Goal of limiting the global temperature rise to 2 ° C by the year 2050 combined with introducing a new energy mix and diversification of energy sources requires a drastic reduction in the use of fossil fuels, thus renewable energy sources become the predominant source of electricity by 2050. Renewable energy sources (RES), such as wind and solar energy, are variable in nature, uncertain and site specific energy sources. RES penetration greater than 30% requires also the introduction of certain operating restrictions and seeks for the storage capacities for surplus electricity [1].

The transformation of energy activities from the traditional into the RES dominant energy sector boosts the newest energy storage technologies and increases the storage capacity, ensuring additional system flexibility and better exploitation of electricity surpluses. Although the analyses of advantages and challenges of increasing the share of RES have been well adressed so far, experts in the field have still oposed opinions on the issue of required support storage systems. Over the past 30 years, numerous research has been carried out in this area, resulting in a wide range of energy storage requirements, ultimately complicating the identification of clear recommendations for further energy guidelines. When it comes to energy storage systems, it is also necessary to state different criteria in the selection of methods and storage techniques with regard to the technological interdependence of the power and heating sectors, which is gaining increasing attention in the research. By investigating numerous researches, the main criteria to be taken into account when storing energy are [2]: 1) Available energy resources, 2) Energy requirements and RES acceptance, 3) Energy storage efficiency, 4) Energy storage costs, 5) Energy storage infrastructure and other factors that will be presented in more detail in this paper. The paper will analyze the most recent conducted research, with special focus on the situation in the USA, Europe and more specific Germany. Germany is considered as an international front-runner in the use of wind and solar energy [3].

One of boosters of stronger integration of the RES into the Croatian power system is current usage of centralized heating systems (CTS) in few larger cities (Zagreb, Osijek, Sisak). Only recently, more intensive planning of new storage technologies [4] has been intensified. Consequently, a thermal tank was built in thermal power plant TETO Zagreb. Based on feasibility studies the plan is also to construct thermal tanks in power plant ELTO Zagreb and thermal power plants TETO Osijek and TETO Sisak. The construction of two biomass cogeneration plants in Osijek and Sisak enabled more efficient operational optimization of production costs for CTS and better acceptance and stronger use of RES in the Republic of Croatia. Also, the storage capacities of the hydropower plants and pumped storage power plants enable additional storage of electricity as well as the competitive positioning of HEP Production company in the electricity market, including the market for regulating services. For the needs of the electric power and heat of the Republic of Croatia, the feasibility studies for the construction of high voltage electric boilers was started for CTS Zagreb and CTS Osijek.

The paper also presents the current state of relevant regulation of the Republic of Croatia. Most of the regulation acts have to be aligned and adjusted in accordance to surrounding countries in order to further develop the market and create the preconditions for investments in competitive industry and production facilities.The focus is on thermal storage and its features as a conceptual basis for further research into the synergy of the power and heat sector. The conclusion gives a summary of the latest market trends in the area of energy storage as a basis guidelines for further research.

II. ENERGY STORAGE TECHNOLOGIES

The analysis of the synergy between power and heating systems refers to the most recent and important contributions in the articles published in years 2016 and 2017, the current regulations of the Republic of Croatia and the EU, including changes made in the first part of 2018. The aim was to present the latest, structural and detailed identification of the positive and negative features of the basic technologies for the synergy effect due to an increased share of the RES. The assumptions used in this paper are similar to those used for Australian case, where attempts to point to some of the most common and major neglected energy storage problems are made [4]. In [5] and [6], thermal storage systems were analyzed and it was found that, depending on the amount of energy consumed, thermal storage, due to multiple energy transformation, is better suited to storage of surplus electricity and together with heat pumps have an important future role [7].

Along with the growth of RES penetration it is important to consider the methods and techniques of storing of potential surplus energy in order to maintain an adequate flexibility and stability of the power system. In this sense storages play an important role and can be classified as following: 1) magnetic storage; 2) electrochemical systems including batteries, fuel cells and supercondensers; 3) energy storage in pumped storage hydropower plants; 4) pneumatic systems; 5) mechanical systems or compressors; and 6) thermal systems (Fig. 1).

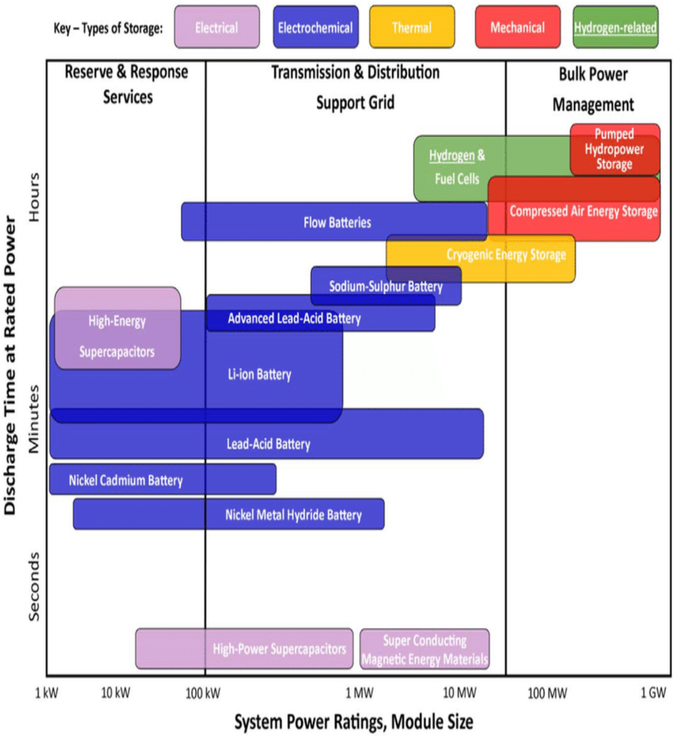

Fig. 1. Different energy storage technologies according to their power and charging/discharging time at nominal power [8]

Given the charging/discharging time, storages can be divided into short-term (few hours), daily and long-term (seasonal) energy storages. Technologies that allow quick charging and discharging are compression coils, ultra capacitors, superconducting magnetic storage tanks and lithium ion batteries. These are also better suited for providing services to distribution operators and residential users. Thermal tanks are primarily applied in microgrids (industrial plants and buildings) for the recovery of waste heat. They also allow storage of significant energy for a period of several days and provide balancing services to the power system transmission network (for example a combination of heat exchangers and peak boilers at weekends at low market electricity prices) and energy management services. Pumped storage hydropower plants and compressed air energy storage (CAES) are used primarly to store energy at medium to long-term levels. The key issue of specific electricity storage system is the ability to simultaneously provide more services to the system. In many countries this will require changes in the market structure and regulations and the creation of new markets for ancillary services. Different requirements, applications and characteristics of individual energy storage systems together with practical and ecological considerations need to be taken into account in order to support the development of storage technology. Also, with the increasing RES penetration arise power quality issues, ie the variability of the frequency and the voltage conditions in some less stable parts of the power system.

III. GLOBAL TRENDS OF ENERGY STORAGE

According to data from mid-2017, pumped storage hydropower plants (PSHP) dominant amog all storage technologies with 96% share of total installed storage capacity in the world, yet other energy storage systems are rapidly developing due to gradual decrease in costs and improved performance. The prices of existing PSHP capacity (operational cost) are rather low (compared to other storages) ranging from 200 USD/MWh to 260 USD/MWh according to [9] (data from 2017). Prices for lithium-ion batteries (investment cost) for the period from year 2010 to 2017 have been reduced from USD 1000/kWh to USD 209/kWh which is a significant decrease of 79% over the considered period. In year 2017 140 MW of new storage capacity was built in UK and 75 MW was built in Germany according to Renews 2018 Report Energy Storage [10]. More than 1.1 GW of new energy storage projects are planned for these two markets during 2018. New Germany government has promised to remove some regulatory barriers to storage facilities and in particular the double charges for charging and discharging energy at storage, which was a major obstacle to the development of storage technology.

The growth of RES leads to development of variety of storage and decentralization solutions for electricity supply. These solutions will depend on the resources of individual regions and location specificities, but technologies such as PSHP and battery containers will undoubtedly play an important role in the development and expansion of the RES dominated systems, especially regarding network balancing needs that should be available for activation at shorter intervals. Although nowdays batteries are more cost-effective (compared to PSHP) when delivering small amounts of stored energy in a short time at a relatively high power and can provide a quick response, they need to show their ability to provide a whole range of ancillary services needed to support the network as their power decreases significantly with the discharge time. On the other hand PSHP are more cost-effective in case of storing and releasing larger quantities of energy. These two technologies will continue to be represented for a long time and will play an important role in the development and expansion of the RES dominated networks. Although PSHPs and batteries are the most widely used power storage technologies, further elaboration of this paper will focus on thermal storage technologies that are less represented and investigated in the literature and have already justified their application in different power sector areas (Table I).

TABLE I. Sustainability of storage technologies in different applications [11]

Technologies aggregate in focus	Conventional generation	Renewable generation	Transmission	Distribution	Customers services
Pumped hydro energy storage	🟢	🟠	🟢	🟠	🔴
Compresses air energy storage	🟢	🟠	🟢	🟠	🔴
Electrochemical	🟠	🟠	🟢	🟢	🟢
Chemical	🟠	🟠	🟠	🔴	🟠
Electro-magnetic Energy Storage, Flywheels	🔴	🟠	🟢	🟢	🔴
Thermal energy storage	🟢	🟠	🟠	🟢	🟢
🟢 Suitable					
🟠 Possible					
🔴 Unsuitable					

The Table II shows countries with the current highest storage capacity according to the latest data from mid-2017.

TABLE II. Energy storage systems in the world: capacities, technologies and countries according to data from mid-2017 [8]

COUNTRY	Electro-mehanical [GW]	Electro-chemical [GW]	Thermal storage	PSHP
China	0.0	0.1	0.1	32.0
Japan	0.0	0.3	0.0	28.3
United States	0.2	0.7	0.8	22.6
Spain	0.0	0.0	1.1	8.0
Germany	0.9	0.1	0.0	6.5

IV. THERMAL ENERGY STORAGE

Thermal energy storage (TES) is a technology that allows the storage of heat energy in times of excess energy production (heat or electricity) and it can be made available again lateron a demand request. The thermal storage potential of short-term and seasonal TES systems is extremely useful for balancing RES excess production in a cost-effective manner. TES systems also have minimum negative impact on the environment and are a sustainable energy storage. The stored thermal energy can later be used for space heating, domestic hot water preparation, a technological steam in the industrial sector, cooling and in rare cases for electricity production. TES systems are mostly used in buildings and industrial plants, where about half of the energy consumed is in the form of heat energy.

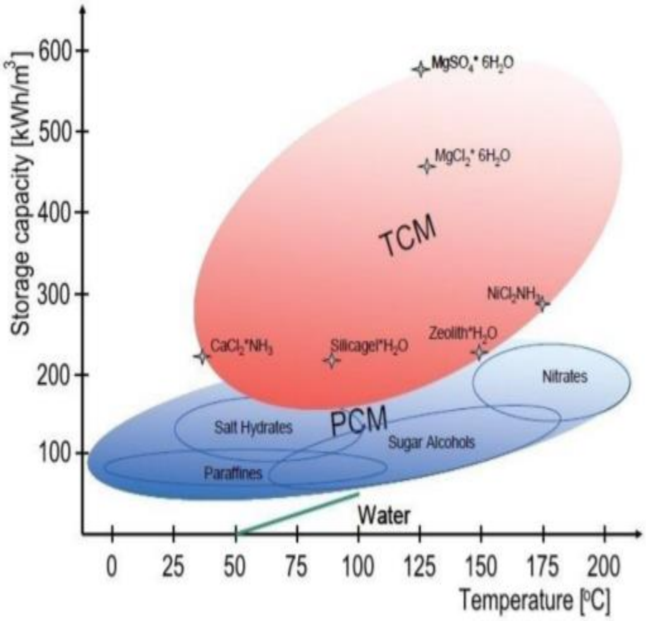

Fig. 2. Dependence of TES storage capacity on temperature [12]

The key property of storing thermal energy is the temperature of stored water (Fig. 2). [13] Low temperature thermal storages usually refer to temperatures below 100 °C and are primarily used to store energy in the form of hot water in households and business premises. High temperature thermal storages are commonly associated with technological processes, chemical engineering and district heating systems where the temperature is 100-150 °C, especially when connected to industrial plants. Thermal storages with temperaturesabove 300 °C can be used in industrial and energy processes. Figure 3 shows the share of each type of thermal storage in the world according to the latest available data in mid 2017.

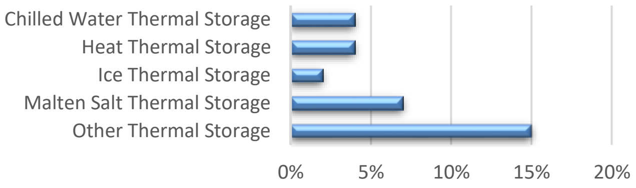

Fig. 3. Share of thermal storage types by mid-2017 [14]

Heat requirements vary depending on the time of day and season (outdoor temperature). That is why TES systems can help to balance variable production and consumption of electricity on a daily, weekly or seasonal level. In addition, they can reduce peak demand, energy consumption, CO2 emissions and increase the overall efficiency of the system. Therefore, converting and storing variable RES power in the form of thermal energy can help increase the RES penetration level. This technology becomes particularly important for the storage of electricity in combined processes with concentration solar power plants (CSP) in which solar heat can be stored for electricity production when solar energy is not available. Thermal energy can be stored at temperatures from -40 ° C to more than 400 °C such as sensitive heat, latent heat and chemical heat (ie thermochemical energy storage) as depicted in Fig. 4.

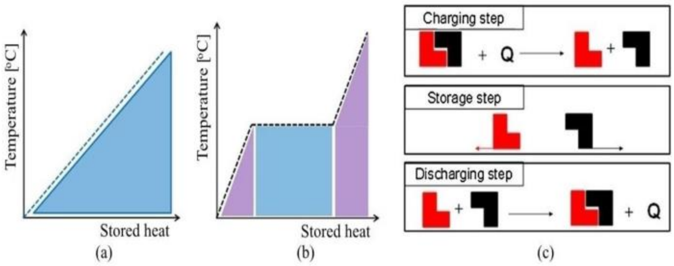

Fig. 4. Methods of thermal energy storage: (a) sensitive heat; (b) latent heat; (c) thermochemical energy storage [15]

Generally, thermal storage is a technology that will bring multiple benefits to the energy sector in the future: increasing the share of zero carbon RES, especially for solar heat and power-to-heat technologies; increasing operational flexibility of power system; the use of waste in industrial processes; and the increase of energy efficiency in industrial plants and buildings.

Sensitive thermal energy storage (Sensitive TES or STES) is the most commonly used thermal storage method based on specific heat storage media, which is usually stored in high thermal insulation tanks in households and remote heating for industrial purposes. The amount of energy that STES can store depends on the difference between the outdoor temperature and the temperature of medium in tank, the specific heat and the amount of medium being heated (or cooled) to store the energy. The storage medium is most often water that has a number of residential and industrial applications due to its purity, low cost and high specific heat. Other media such as bricks, concrete, oil (eg motor oil), organic oils, stone, sand, clay or earth may also be used. Thermal heat storage in the form of sensitive heat is commercially available only in the energy sector, where it is relatively convenient and least complicated. The disadvantage of this form of storage is a low energy density of up to three to five times less than the remaining two forms of heat energy storage. In addition, storage capacity is limited by the specific heat of storage medium. Furthermore, the reviewed literature states that heat recovery systems, by means of sensitive heat, require a proper design for discharging heat at constant temperatures, creating additional issues.

Phase change materials thermal energy storage (PCM TES), same as a thermochemical energy storage, is still mainly in the experimental phase. This method uses thermal energy stored in the form of latent heat and includes storing and releasing energy with changes in the material phase. The phase change allows for greater storage capacity and PCMs also makes much easier setting of a target constant discharge temperature. Latent heat storage in PCM systems enables increased energy density and loss reduction. Thanks to the increased energy density, these systems are the subject of many researches, particularly with regard to integration in building materials for heat and cold storage. PCMs can be used for short-term (daily) and long-term (seasonal) storage of energy using various techniques and materials.

Thermochemical energy storage (TCS) is the latest approach that offers even greater density and storage capacities than PCM TES. Thermochemical storage, as the name suggests, uses chemical reactions to store energy. Thermochemical reactions can be used to store and release heat and cold on demand in various applications using different chemical reactants. These systems allow to achieve very high efficiency with negligible losses over time, but are less advanced than the two previously mentioned technologies since they are mostly in the development and demonstration phase and use extremely expensive technology. The cost of equipment from a thermochemical reactor is larger than the cost of storage material, although the cost of materials is not insignifican. Basic type dependant TES parameters, such as capacity, power, efficiency, storage time and storage costs are shown in Table III.

TABLE III. Parameters of the thermal energy storage methods [14]

TES System	**Capacity [kWh/t]**	**Power [MW]**	**Efficiency [%]**	**Storage period [h, d, m]**	**Cost [€/kWh]**
Sensible (hot water)	10-50	0.001-10	50-90	d/m	0.1-10
PCM	50-150	0.001-1	75-90	h/m	10-50
Chemical reactions	120-150	0.01-1	75-100	h/d	8-100

From an economic point of view, the effects of the TES depend mostly on their specific application, storage media, technical equipment for storing and discharging, operational needs, including the number and frequency of storage cycles according to Table IV.

TABLE IV. Economic sustainability of the TES as a function of the number of storage cycles [14]

	Cycles per year	**5-yr energy savings [kWh]**	**5-yr economic savings [€]**	**Invest. cost [€/kWh]**
Seasonal storage	1	500	25	0.25
Daily storage	300	150.000	7.500	75
Short-term storage (3 c/day)	900	450.000	22.500	225
Buffer storage (10 c/day)	3.000	1.500.000	75.000	750

STES systems are not so expensive because they consist mainly of a simple storage medium and charging or discharging equipment. These storage media are relatively inexpensive but important cost element may be the requirement for effective heat insulation of the storage tank. In general, PCM and TCS systems are more expensive than STES systems and are economically feasible only for applications that require large number of cycles. The cost of the TCS system ranges from 8 to 100 €/kWh. Additional system components, such as heat exchangers, control systems, and the necessary pumps can significantly increase the cost of TCS systems. It is therefore necessary to introduce different tariff models during storage usage, customer rewarding methods and stronger and more dynamic price signals during the time of electricity change, both within days and within the week (working and non-working days) and season (higherl and lower heating season) in order to stimulate the development and introduction of thermal storage technology in the power system. Table V shows different applications of all three types of TES technology.

TABLE V. Applications of different TES technology types [16]

		Sensible	Latent	TCS
Improve District Heating & Cooling performances	Shift heating and cooling productions	+		
	Maximise base load production	+		
	Reduce peak load production	+		
	Improve heat recovery from waste and from "already available excess heat"	+		
	Shifting power to heat	+		
Use and Integration of Low Carbon Energy for Heat Generation	Demand-driven/stabilising heat	+	0	0
	supply from local and district heating	+	+	+
	Demand-driven/stabilising heat supply from solar process heat	+	+	0
	Demand-driven/stabilising heat deployment from solar thermal power plants	+	+	0
	Decarbonisation of the residential heating sector using intermittent renewable energy [e.g. wind, solar PV]	+	+	0
	Utilisation of Power-to-Heat concepts	+	0	0
Increasing Energy Efficiency in Industrial Processes	Use of industrial waste heat	+	+	+
	Decoupling of power, heat and cold generation in cogeneration plants	+	+	0
Increasing Energy Efficiency in Buildings	Balancing heat and cold demand	+	+	+
	Decoupling of power, heat and cold generation in micro-cogen plants	+	+	0
	Balancing daily demand	+	+	+
	Balancing seasonal demand	+	0	+
*PLUS(+)	Typical/favourable application			
**NEUTRAL (0)	Possible application			

V. POWER TO HEAT TECHNOLOGIES

Decarbonization goals, which are mandatory in the heating sector and the required flexibility in the power system are the basis for considering power-to-heat (PtH) technology. PtH solutions are one of the newer solutions that are mainly used in large power plants such as cogeneration plants linking the power and heat sectors. They can also be competitive in providing auxiliary services. This technology decreases fossil fuels usage, emissions in the heating sector and contributes to the stabilization of the power grid. Linking PtH technologies with other technologies and storage systems has already proved to be very profitable. Fig. 5 shows the interconnection of various PtH options with power and remote heating systems.

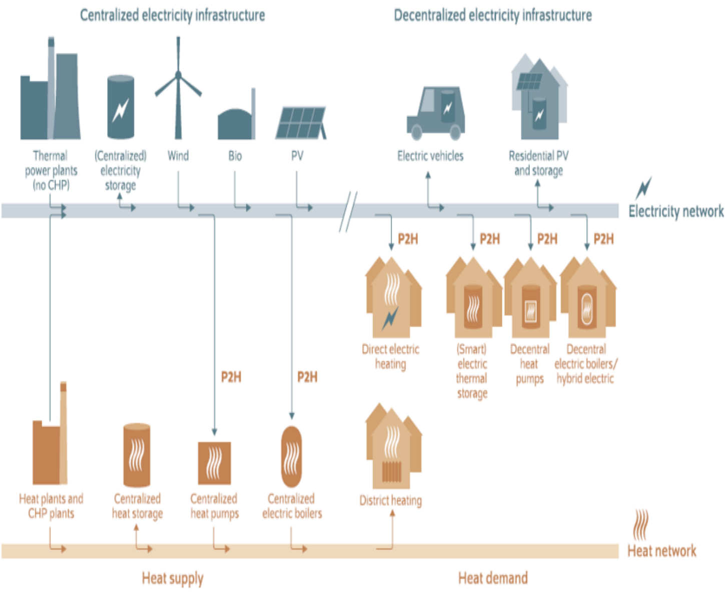

Fig. 5. Interconnection of PtH options with power and heating systems [2]

From Fig. 5 it is obvious that most of the options include some kind of storing energy. The authors of numerous studies and reviews [3]-[5] see the future in centralized heat pumps or connection to district heating networks due to their beneficial impact on system costs, RES integration support and decarbonisation of the power sector. Due to short response time PtH technologies are useful in providing auxiliary services. PtH technologies can use negative prices or spend electricity during times of excess electricity production as these are expected to be more commonly occurring in the future.

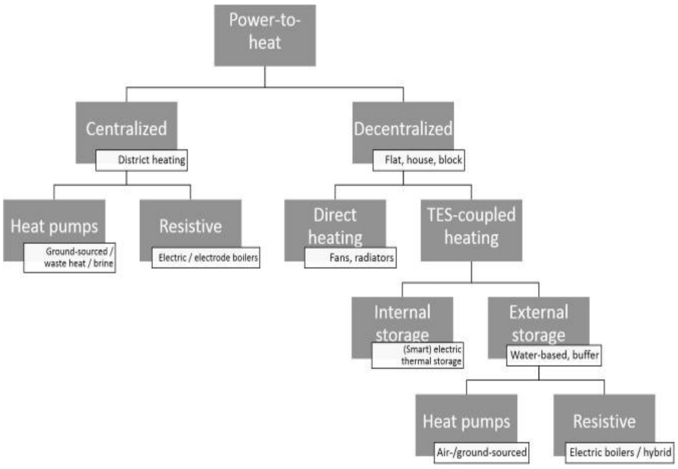

Fig. 6. Categorization of residential PtH options [2]

The biggest PtH drawback is the associated price that is not yet acceptable. The level of implementation is therefore low compared to competitive heating technologies such as gas fired boilers. Although PtH technology contributes to the alignment of the diagrams and the integration of the RES, it is necessary to provide clear market price signals for PtH, flexible network tariffs and tax incentives that would encourage investment in these technologies.

Electricity can be transformed into thermal energy in different ways. Fig. 6 categorizes the most important options for storing electricity in the form of thremal energy for residential heating purposes. According to Figure 6, the most important division is the centralized heat system and decentralized (indoor or stand alone) and distributed plants.

In centralized PtH technology, electricity is extracted from the grid to produce heat by means of large heat pumps or electric boilers. For a centralized approach, electricity is transformed into heat energy at a site that can be away from the actual consumption point and is transported by the district heating network to the distribution network where it is needed. Centralized plants are designed to store waste heat from large industrial processes, conventional power plants, combined power plants and RES such as Concentrated Solar Power plants (CSP). The thermal power of centralized plants ranges from several hundred kilowatts to several hundred megawatts.

In a decentralized approach, electricity is converted to thermal energy very close to the demand for heat. Decentralized solutions are used in residential or business buildings in order to store solar energy for heating water, space heating or cooling purposes. The thermal power of distributed systems ranges from several kilowatts to several dozen kilowatts.

In both cases, thermal systems can reduce energy consumption over the peak period, improve energy efficiency of industrial processes and use of energy in buildings. In reality, the line between a centralized and decentralized approach is not completely clear.

Based on the experience of EU countries, such as Denmark, Germany and France, a comprehensive insight into the technical and economic potentials of PtH technologies can be obtained and conclusions can be drawn for the most of Europe. In Denmark there is a large wind power penetration. Regulations encourage the reduction of electricity production at the time of wind power generation surplus, also encourage the integration of heat pumps and electric boilers on CHP plants in remote heating. The Danish regulatory framework recognizes CHP plants and provides them with subsidies, regardless of their age, especially in hours with low electricity prices. In Germany, PtH technology is one of key technologies for provision of secondary negative power (from variable RES) reserve for the future electricity sector. At the moment, direct use of PtH technology in Germany is not possible due to high state fees. The biggest problem for the implementation of PtH technology in France is the large share of decentralized electricity in the heating system, the sensitivity of the demand for electricity to the air temperature resulting in high electricity prices for several days in the cold winter period. This discourages development of PtH technology in France, as electricity demand can not be moved between few days but only for short periods. An important factor affecting the thermal load per hour in European countries is the outdoor temperature and hence the profiles of the countries need to be differentiated in relation to the appropriate climatic conditions. It is also necessary to take into account the distributions by sectors such as households and industries that have a major impact on analysis for PtH technology implementation [17].

VI. LEGISLATION IN CROATIA AND EU COUNTRIES

Energy storage provided by specific network user (a prosumer), who can produce and consume electricity is not yet fully defined within the Croatian regulation. It is also a fact that other network users (storage, energy conversion facilities and storage facilities) have not also been identified in the energy Croatian regulation, nor have adequately been solved their connection cost to the transmission or distribution network. The exception are PSHPs, which are the only form of storage whose status was resolved in early August of 2018 by the entry into force Amendments to the law: '*Zakon o tržištu električne energije*' *(eng. Electricity Market Act)* [18]. The combination of amendments to the law stipulates that PSHP can purchase electricity for pumping on the wholesale market, but also it should, when withdrawing power from the grid, pay compensation for the use of the grid, in similar way as final consumers. The introduction of the network fee for the PSHPs in Croatia is discriminatory in relation to the PSHPS from the market environment (Slovenia, BiH). Other energy storages in the Croatia are not recognized as a special category of network users - they are still categorized as final consumers.

The most important current regulatory barrier to the implementation of the energy storage system in the world, including the EU, is the unrecognized need for energy storage classification as a producer. The lack of common EU legislation allows each country to determine the policy of pricing energy storage alone and does not force them to regulate energy storage in the same way. On the other hand, the creation of a regional market and ultimately the creation of a single integrated EU energy market is set as a goal. The definition of electricity storage proposed by the UK is quite controversial [19]: "*the conversion of electrical energy into a form of energy which can be stored, the storing of that energy, and the subsequent reconversion of that energy back into electrical energy*". Namely, the problem arises because this definition can inadvertently include equipment such as network measuring devices. Paper [19] proposes the following definition: *"A means of converting imported electricity into a form of energy that is stored and can be reconverted into electrical energy, that is unable to produce a positive net flow of electrical energy from the device, and for which, given sufficient storage capacity headroom and footroom, the timing of imports and exports can, under normal operating conditions, be controlled independently of each other and the voltage at the point of connection to the power system.*"

In the Czech Republic, Spain, Italy, Poland, Portugal and Slovakia, there is no charge for energy storage, while countries such as Austria, Belgium and Greece apply charging and discharging fees for energy storage. For example, in England, energy storage bidders have to pay double tariffs, one for their role as a producer and the other as a consumer, as well as fee for the distribution network use in case that energy storage is less than 100 MW, as is the case with most of today's new storage technologies. System operators, who are the owners of the transmission and distribution grid, are in the best position to capitalise energy storage revenues only if the operation of the energy storage system is independent of the operation of the network, which in practice is not the case due to the variability of the operating voltage levels. In order to overcome these problems, it is necessary to establish a market that recognizes the flexibility provided by the energy storage, where storage systems need to be seen as an upgrade rather than as a rival to operators and producers. The requirements for smart metering, and real-time network management are a prerequisite for solving this problem. Energy storage technologies can contribute to production (balancing, reserve), transmission network (frequency control, investment delay), distribution network (voltage control, capacity support) and end-users (peak-time savings, cost reduction and management).

VII. ECONOMIC INDICATORS AND FUTURE DEVELOPMENT

The most important barriers to the development of storage technologies in the EU markets are: the lack of clear classification of storage or ownership of storage; double and/or uncertain fees for network access, connection and network use; lack of recognition of benefits from storages across the energy system including cost-effectiveness of auxiliary services, undefined consequential and fair balancing costs for actual services that do not include energy storage; differences in market rules between neighboring countries; lack of a uniform and mature EU regulation; lack of a fast and competitive auxiliary services market and public opinion, ie lack of clear incentives for investment and direct support. The basic four barriers are marked red in Fig. 7. These barriers refer to the allocation of financial resources, distorted remuneration mechanisms, lack of realistic price signals, bureaucratic issues and delays in implementation of storage technology. Energy storages are obliged by contracts to certain predefined capacities according to which they have to deliver a certain amount of electricity in case of the "stress" in the system. This capacity can be requested at any time during the contract period. Such "open" obligation is certainly not suitable for storage service. Such delivery time definition would provide safer sources of income for the storage service provider and improve its integration within the system.

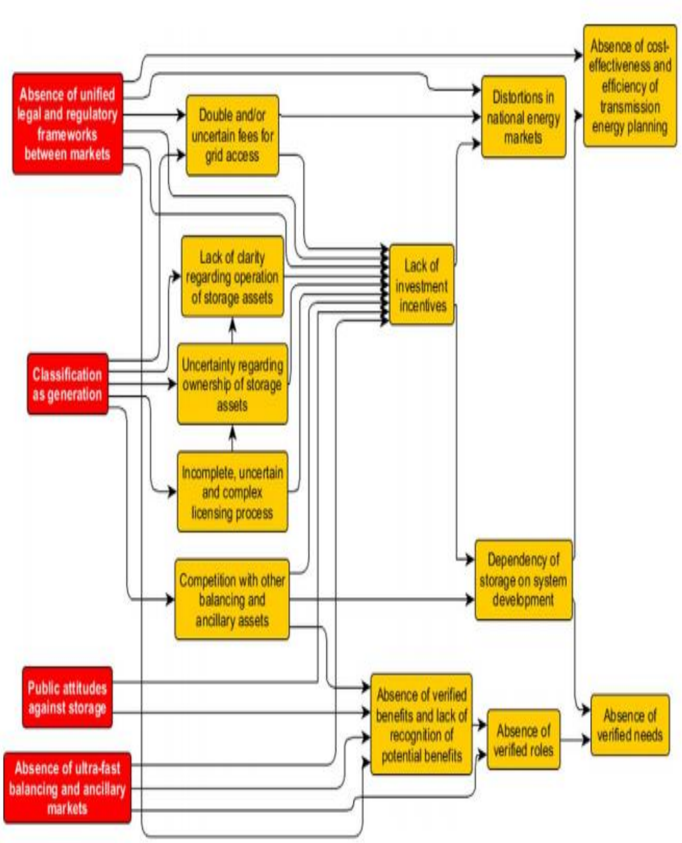

Fig. 7. Barriers for energy storage implementation [19]

TES technologies are currently facing some barriers to competitive market access such as, investment cost, stability of material properties, especially in case of TCS systems. TES technology development and implementation varies greatly depending on the application area and the region. Integration in the construction sector in Europe is very slow with the rate of construction of new buildings of about 1.3% per annum. At the same time the renewal rate is only 1.5% per annum. Integration can be greater in developing countries with high rates of new facilities and buildings construction. For the development and research of complex thermal storage systems, such as PCM and TCS, a better understanding of the integration of these systems and process parameters is necessary. According to estimates from the literature [14], for the observed period from 2016 to 2030, the cost of thermal storage is expected to decrease (Table VI).

TABLE VI. Expected decrease in the cost of thermal storage between 2016 and 2030 [14]

TYPE OF STORAGE SYSTEM	**2016**	**2030**
	[USD/kWh]	[USD/kWh]
Sensible high-temperature heat storage in liquids	22-27	-
Sensible high-temperature heat storage in solids	17-44	-
High-temperature storage (not specified)	39	<15
Molten salt storage	34	10

VIII. CONCLUSIONS

Although the European Union advocates use of energy storage, so far no significant measures or policy decisions have been taken to facilitate the deployment of energy storage technology. In practice, the new rules of the EU electricity market are focused on the transmission network and the RES with little emphasis on linking storage technologies. In line with the energy policy, EU guidelines, due to a certain continuation and the trend of increasing the share of electricity production from the RES, it is necessary to overhaul the existing energy regulation and to establish new ones and adapt the existing technical regulations in the field of heat and electricity. Geopolitical differences, social aspects, the availability of particular technologies and the inability to synthesize or apply a technology to all areas are still very pronounced issues and are currently the basic factors that make it difficult to implement new energy storage technologies. Above all, it is necessary to study and replicate in some way regulatory definitions of energy storage in those countries that have recognized and included storage technologies, removed network barriers, adressed property related issues, storage operation issues, balancing and capacity design issues. Two objectives in the electricity market that need to be fulfilled in order to encourage the implementation of energy storage are: 1) short-term incentives to further reduce prices; and 2) long-term optimal deployment and increase of the value of energy storage in the system. The choice of potential technology for synergistic action between power and heating system needs to be based on clear and promising technical and economic indicators. Significant investment costs of energy storage and related infrastructure, the need for development and implementation of new optimization tools with operational staff capability which are continually adapted to new market circumstances are a driving forces for strengthening the synergies of the power and heat system. Thermal energy storage supports increase the RES by enabling better overal efficiency, balancing and system stability. Potential effect of increased capacity of thermal storage is very high, as almost half of the total energy consumption in Europe is for heating purposes.

ACKNOWLEDGMENT

This work has been supported in part by the Croatian Science Foundation under the project WINDLIPS-WIND energy integration in Low Inertia Power System (grant, No. HRZZ-PAR-02-2017-03).

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