OVERVIEW OF INNOVATIONS AND RECOMMENDATIONS FOR EFFICIENT OPERATION OF RES-BASED POWER PLANTS

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Abstract. RES-based electricity production is currently developing at an unprecedented pace. Scientists from various countries are working intensively to further improve the most important indicators of power plants using renewable energy resources. Solar, wind and hydropower plants already have the three first lowest levelled costs of electricity (LCOE) and the best environmental performance among power generation technologies. The goal of this article is to review the latest scientific and technical publications on the measures applied to increase the efficiency of these power plants, reduce the cost of the energy produced, and contribute to the broader dissemination of information and progress in this field. This article mainly reviews the already tested and published innovations in the area of solar, wind, and hydropower plants. Microgrids, green hydrogen and heat pumps are included in this review too because they are closely related to RES-based power generation and usage. They are contributors to solving the challenges of fossil fuels phase-out and the climate crisis. During the first decades of the 21st century, scientists and inventors proposed a pretty number of valuable innovations and recommendations. The abundance of valuable innovations gives hope that the volumes of green power production will continue to increase and that the mentioned problems will be solved successfully. A review of information sources showed that solar and wind power plants, according to all forecasts, will definitely be the first in the field of electricity production after a few years. Electricity needs will grow at least 2-3 times over the next 25 years as it will be used not only in factories, buildings and the illumination of streets but also in transport, hydrogen production, agriculture and elsewhere.

Keywords: renewables, hydrogen, heat pumps, agrivoltaics, efficiency, innovations, microgrids.

Introduction

The development of power and heat production based on renewable energy sources (RES-based) is one of the main tasks of mankind in this century. This problem is fairly well explained and understood in the world. The urgent solution to this problem supports a large majority of the world's state governments and the scientifically sophisticated part of the global society. This problem is ignored only by people who are either scientifically undereducated or run profitable business in fossil fuels and related fields. There is little time left to solve this problem, as environmental pollution from fossil fuel combustion continues at a rapid pace. The path back to a normal climate will be closed if we let pollutants accumulate in the Earth's atmosphere to a large extent.

More and more people understand that now we no longer need fossil fuels that pollute the environment. Our most powerful and clean energy "factory" is not on the planet Earth at all - it is the Sun star. We can convert it into electrical or thermal energy using the free energy of the sun rays, which reach the Earth in just a bit over 8 minutes. Besides, the energy of the sun rays on the Earth is constantly "converted" into thermal, wind, hydro, biomass and other types of renewable energy. Fossil fuel reserves on the Earth were formed over many millions of years also due to the energy of the sun rays. It has been useful for people living on the Earth for thousands of years when the population on our planet was small and they were unable to produce clean thermal energy.

Nowadays, when the population of the planet Earth has already exceeded 8 billion, the world's population can no longer stay with very polluting thermal energy and electricity production technologies and continue to harm the health not only of themselves but also of all animals and nature. As the population on the Earth increased, the volume of thermal energy and electricity production greatly increased, too. The physical labour of humans and animals, animal vehicles were almost everywhere replaced by machinery that required a lot of backward environment polluting energy. Then it became clear that the planet Earth is unable to withstand such a large load of pollutants.

Worried scientists and innovators of the world are working to contribute to the solution of this global problem. They have made many proposals for improving thermal energy and power production technologies, improving their work efficiency, and lowering the prices of technological equipment and produced energy. The proposals are published in the scientific and technical press and submitted in

references. This article reviews the most effective and interesting innovations proposed by scientists and engineers to achieve the aforementioned goals.

The further subsection of this article will also briefly describe some significant previously known proposals to improve the operation efficiency of RES-based power plants. This subsection presents also short descriptions of the latest innovations, and the most important highlights are presented in Table 1 and Table 2.

Materials and methods

The authors used a standard methodology applied to the reviews of scientific articles. In the beginning, the latest scientific and technical literature was searched according to the topic of this article. The necessary relevant information was found, read, analysed and evaluated. The most valuable innovative proposals and recommendations were selected and shortly described in this article. The information regarding the RES-based power plants, microgrids and such green power users as heat pumps and hydrogen production equipment was summarized. Conclusions and suggestions of the conducted review are presented in this paper. A list of the references reviewed by us and recommended to the potential readers of the article is presented to the interested readers. They may be useful as additional information for those readers who would like to learn more about the innovations described in this review.

Results and discussion

Our review is focused on the latest innovations RES-based power plants, as well as on green hydrogen and heat pumps because they are closely related to the renewable energy generation as significant green power users and are very important players of green revolution too.

The possibilities of increasing the efficiency of solar cells and solar module operation have been interesting since the discovery of the photoelectric effect. In the beginning, it was the selection of azimuth (to southward) and a constant optimal angle of a PV array inclination to the horizontal plane depending on the local geographical latitude. A single-coordinate solar tracking system was developed after that, but the best results were obtained with two-coordinate solar tracking systems, which continuously orient the solar modules in planes so that they were perpendicular to the ever-moving sun beams. Although solar tracking systems increase the work efficiency of PV arrays quite significantly, especially two-coordinate solar tracking systems, they have not been widely used in practice. They are quite expensive to install and maintain, and the electricity produced by the photovoltaic power plants (PVPP) is inexpensive, so this improvement hardly pays for itself.

One of the most important reserves for increasing the operational efficiency of PVPP is the continuous efforts to improve solar cells of all known types. The efficiency of PVPP operation is high, if the efficiency of solar cells is high. The first solar cells were created in 1883 by inventor Charles Fritts from New York. The first-ever solar cells were made by coating selenium plates with thin layers of gold. The efficiency of converting irradiance into power in these cells was low - only 1-2% [1].

New possibilities appeared to significantly increase the energy conversion efficiency of solar cells after the Polish scientist Professor Jan Czochralsi (1885-1953) developed the technology for forming silicon monocrystals in 1918 [2]. Silicon monocrystals are still commonly used to produce the most popular solar cells and then to make solar modules of the required power. But the energy conversion efficiency of solar cells began to improve only 40 years later when the US Company Hoffman Electronics produced PV cells with an energy conversion rate of 9%. The same company achieved 10% efficiency of silicon-based cells in 1959, and 14% – in 1960 [2]. At the beginning, PV cells were more than 100 times more expensive than they are today, but their mass production had already begun. At that time, PV modules were very suitable for powering various devices and other equipment on Earth satellites. Key points of recent innovations improving the use of PVPPs are summarized in Table 1. Scientists from Russia's Far Eastern Institutes and the Far Eastern Federal University have found a way to improve black silicide (b-Si) light-trapping and antireflection properties by treating b-Si with magnesium and silicon compounds. The obtained Mg2Si/b-Si heterostructure has a complex shape. This innovation can significantly increase the operation efficiency of PV cells made on the basis of the new type of black silicon enriched with magnesium [3; 4].

Table 1

Innovations and recommendations for improving the performance of PVPPs

Description of innovations	Achieved results	Key indicators
1. Innovations to improve PV module performance		
New black silicon improves light conversion properties	The reflectance spectrum of black silicon (b-Si) cell coated with Mg_2Si shows a strong anti-reflective performance compared to the uncoated b-Si surface	200-1800 nm spectrum (b-Si) – 17.6% (b-Si + Mg_2Si) – 3.7%
Cooling down solar modules with cotton wicks	Cotton wicks immersed in the water to the backside of the PV module for enhancing efficiency (power)	Efficiency – up to 7.25%, power – 16.3%
Algae can boost solar panel efficiency	Algae is added into the encapsulant in Si-based PV modules or into the coating of thin film modules	Efficiency for Si – 4%, for thin film – 36%
New sealant extends the working life of the module twice	Quanex Corporation released the sealant preventing moisture ingress in PV modules and protecting cells	Life of a PV module extends to 10-15 years
Advantages of bifacial solar modules	Bifacial PV modules are more efficient due to the two power producing sides: front and back	Energy gain compared to monofacial: 10-40%
2. Installation options for PV arrays		
Innovative company installed ground-mounted PV array	A new method of mounting PV modules directly on the ground without gaps between strings	Saving of installation costs 20%, land – 50%
Innovative start-up is building 100 MW PV array on ground	A similar PVPP with PV modules on the ground is under construction in the state of Texas, USA	Saving of installation costs 20%, land – 67%
Mounting of PV modules on the ground and flat roofs	Compact mounting of PV modules allowed creation of water storage system for irrigation purposes	Saved mounting costs 30%, materials – 50%
Study confirmed feasibility of PV arrays installation on dikes	The Netherlands has many dikes used for flood protection. They can be also used to install PVPPs	The total power of PVPPs is 11 GW
Solar Tower (ST) – vertical installations of solar modules	Solar tower tested in Canada. They are very good where available land is scarce and expensive	Area for normal PVPP – 100%, for ST – 10%
Decoration of facades and power supply for buildings	Swiss innovators have proposed and tested solar modules of special design for both functions	PV modules: power supply and decoration
Solar modules are replacing the roof tiles in some countries	Specially designed solar modules replace tiles on buildings roofs and also perform two functions	Power supply and protection of building
Deployment of PV modules on railways and highways	Innovators in some countries installed PV arrays on roads. Power supply does not interfere with traffic	PVPPs are tolerant of dual land use
Space-based PV arrays for terrestrial power supply	Solar energy will be collected by 2,000 tons satellite running in a height of 36,000 km above our planet, using large lightweight mirrors (diameter 1,700 m) directed to a solar array made of 60,000 solar	Rated power – 2 GW, initial LCOE – about EUR48·MWH^{-1}. Power supply – by 2040
3. Dual use of land in agriculture		
Eggplants grow better under agri-PV modules	Eggplants grow better under solar modules in plots of land arranged for agrivoltaics	Yield is 50% higher under the PV modules
PV arrays provide better living conditions for sheep and cows	Solar modules in pasture increase well-being of animals, efficiency of land use, reduces heat stress	70% of time in shadow (irradiance > 800W/m^2)
Agriculture, nature conservation and solar systems in harmony	Vertical PV arrays: power peaks in the morning and afternoon (the relief of the electricity grids)	Land: 90% – agro, 10% – nature,1% – PV
4. Solar modules in combination with other technologies		
US startup begins producing thermophotovoltaic (TPV) cells	TPV is energy generation obtained by converting thermal radiation into power in photovoltaic cells	Achieved efficiency of TPV cells – 41.1%
Innovative controller to store excess PV power in hot water	Power of PVPP for self-consumption the controller turns on the water heating at excess power produced	Average savings of EUR338 a year
Hydrogen-producing PV panels nearing commercialization	The PV panel invented in KU Leuven converts water vapour into hydrogen using solar irradiance	Efficiency – 15%, 250 litres of H_2 per day

Simple measures can be taken on hot summer days for decreasing temperature of solar modules mounted in PV arrays. Cotton wicks immersed in cold water and attached to the backside of PV modules reduce the temperature of the modules which results in significantly higher power output from the PV

array. Water supply can be applied to cotton wicks through capillaries in a similar way to vegetable roots. More info on water cooling of PV modules see in publications [5; 6].

Swedish start-up Algae Factory has developed a new material made of algae. The new material is called Algica. The Algica is intended to use for increasing the efficiency of Si-based and thin film PV modules. The Algica will be added to the encapsulant in Si-based PV modules or to the coating of thin film PV modules. The algae shells can also reduce the degradation of PV panels over time caused by UV radiation. The estimated efficiency of Si-based modules would be up to 3.9% more [7].

A very useful innovation was offered by the Quanex Corporation. They tested a new sealant which extends the working life of the modules. The sealant does not allow moisture to enter the inside of the PV modules and significantly extends their working life. So, the PV modules will produce significantly more power over a longer period of for a less expensive price [8; 9].

Bifacial PV modules have been developed and tested quite a long time ago. They are slightly more efficient due to the two power-producing sides: front and back. However, at first, they used to be significantly more expensive than conventional modules. They did not produce much more electricity compared to monofacial modules. But after many years of research and experiments, their efficiency indicators have improved. Demand for these modules has increased, as the peak power of one bifacial module now reaches 700 W. Additional information about these modules can be found online [10-12].

The next three innovations in Table 1 are related to the mounting of PV arrays straight on the ground or on flat roofs. Innovators working in the area of PVPPs came to the conclusion that mounting solar panels on the ground may be beneficial in many aspects – it saves large areas of land, a lot of materials and installation costs. The third innovative way of mounting PV modules on the ground or on flat roofs allows additionally for the collection of water that drains from the PV array. It is also an important benefit for some countries with limited water resources. More information and photos on this installation method can be found using the links provided in the list of references [13; 14].

New ways and new places to install solar modules are constantly being discovered, where they do not disturb anyone or even coexist amicably (as agrivoltaics). Huge areas of absolutely free land on dikes were rediscovered in the Netherlands. 11 GW solar power plants are planned to be installed there [15]. In those countries and areas where there is a lack of land, it is possible to build vertical PV arrays in the form of a tower [16], which take up about 10 times less land than conventional ones.

Specially designed solar modules are suitable for decorating building facades [17] and covering roofs [18; 19] (efficiency of tiles – 19.5%), while semi-transparent modules are suitable for glazing windows [20]. Here, the modules also perform two functions - they replace building materials and additionally generate electricity for the house. Solar modules can also be launched into a stationary orbit in space, where a high-power solar module and some other necessary equipment can be installed. There are no clouds and no nights, so such a power plant could work all the time and supply the Earth with stable electricity. Such a possibility of installing a power plant has already been foreseen. The constant power of the first such power plant will be 2 GW. The supply of electricity to the Earth could be started before 2040 [21; 22].

Agrivoltaics shows how PV arrays can use the same agricultural land without significantly affecting the yield of different crops. On the contrary, there are also cases when the yield increases, for example, in eggplants [23; 24], because they need less solar irradiation. In animal husbandry, PV arrays provide better conditions – when ruminating, animals like to lie down in the shade of PV modules on a hot day. They drink less water when they are under the modules, and the grass is richer there because the sun does not burn it [25; 26]. In short, agriculture and solar systems coexist in harmony [27]. It can be recognized that the innovation of agrivoltaic systems has proven itself.

There are also innovations that aim to connect PV modules directly with other technologies. A US start-up has started producing thermophotovoltaic solar cells (TPV) that produce electrical and thermal energy [28]. The aim was to use solar irradiance for supplying buildings with power and domestic hot water. One of the innovations in the field of PVPPs is power plants for self-consumption. This is a good idea because such PVPP can be installed by yourself for self-using without a project and connected to the internal network of your house or apartment. Such PVPP is not convenient in the case when power is not used often in the house, and it goes to the main electric grid for free. An innovative controller was proposed to turn on the water heating in order to prevent your power from leaving your home [29-31].

Roof-top hydrogen-producing PV panels are developed at the Catholic University of Leuven for atmospheric water vapour conversion into hydrogen using solar irradiance [32]. One panel can produce small quantities of H2 per day (250 litres).

Many valuable innovations have been proposed in the last decade of this century in the fields of wind farms, microgrids, heat pumps and green hydrogen. The superiority of RES-based power plants is now evident [33]. Descriptions and key indicators of some innovations are presented in Table 2.

Table 2

Innovations in the field of WPP, microgrids, heat pumps and hydrogen technologies

Subject of innovation	Achieved results	Key indicators
1. Wind turbines (WT)		
Innovative high power very efficient offshore wind turbines	Colossal, contra-rotating offshore wind turbines developed by the World Wide Wind company	Up to 40 MW, height – 400 m, LCOE – USD50 MWh
Innovative wind power plant of the German company Skysails	A new type of WPP without any wind rotor has been developed. A sail (kite) is used instead	The kite is flying in height of strong winds (~ 400 m)
Small-scale bladeless wind turbine designed for rooftops	Aeromine smart bladeless WT can be installed on a building's roof in parallel with PVPP	Makes 1.5 more kWh as PVPP at the same cost
Smart innovative, low noise and efficient domestic WT	The Dutch company The Archimedes has built an innovative small-scale WT for household	1500 $kWh \cdot a^{-1}$ (wind – 5 m/s),
2. Microgrids		
Advantages of solar and wind hybrids, floating solar and wind microgrids, islandable microgrids	Onshore and offshore solar and wind hybrids (microgrids), floating PV and WT microgrids, and islandable microgrids are more reliable	All mentioned microgrids supply more energy and at a lower price
New trends: microgrids powered by solar, hydro and wind energy sources and working in the main electric grid or autonomously	The mentioned microgrids are based on free energy, their installation and maintenance are simple, the working time is long, so their LCOE are now the lowest among all power plants	LCOE: PVPP – 37 $USD \cdot MWH^{-1}$, WPP – 40 $USD \cdot MWH^{-1}$, HEPP – 50 $USD \cdot MWH^{-1}$
Innovative rooftop system with PV array and mini wind turbines	WTs are installed inside the frame on the roof of building, PV array – on the top of frame	The system produces 40% more power than PV alone
3. Heat pumps (HP)		
US company Johnson Controls developed HP for cold climate	The air-source HP is intended for locations with temperatures up to –29 °C	Refrigerant for the new air-source: HP – R-454B
New air source HP to cover heat and DHW needs of buildings	Mitsubishi Electric produced a HP system which capacity can be from 7.8 kW up to 640 kW	The HP can operate at air temperatures (-25) + 43 °C
Thermo-acoustic HP working on air, water and geothermal sources	French startup Equium developed innovative refrigerant-free HP only for DHW	1 kW of power produces 3-4 kW of heat power
4. Green hydrogen technologies		
PEM electrolysers with novel stack design will be cheaper	Cost of PEM water electrolyser was reduced by changing expensive titanium bipolar plates with plates of stainless steel coated by niobium (Nb)	The price of electrolysers has fell down 60%, the price of hydrogen has decreased
Device of concentrated artificial photosynthesis for cheap green hydrogen production	A functioning experimental device has already been designed, tested and is being further developed at the University of Michigan	Present efficiency of the experimental device do not exceed 7-9%
Electrolyser efficiently splitting seawater into H_2 and Li	Nanjing Tech University developed a small-scale experimental electrolyser for sea water	Efficiency – about 71%, productivity – 386 litr./h
Biotech startup targets cheap hydrogen production from depleted wells	Cemvita Inc, Houston, Texas, has recruited its microbes from the lab to hydrogen production by moving them into depleted oil and gas wells	The forecast price of the microbial hydrogen is less than 1 $USD \cdot kg^{-1}$
A breakthrough in clean energy production by using atmospheric air for power production	Interesting bacteria are found and studied. They can produce power (when are hungry) from hydrogen found in the atmosphere (0.00005%)	Initially power will be used for small appliances, LED lights, PCs, and maybe EVs
The way for green H_2 storage is "hydrogen powder"	Israeli startup to make "hydrogen powder" in chemical compounds rich in hydrogen	The best and cheapest way to store H_2 without losses
Surging of global green hydrogen production capacity in 2022	Green hydrogen production capacity grew up in 2022 mostly because of significant investments	The hydrogen production capacity grew up by 44%

The World Wide Wind company from Norway recently developed unique and powerful floating wind turbines for offshore applications [34]. The turbines have two contra-rotating rotors. The key parameters of the floating wind turbine are presented in Table 2. Offshore wind turbines will not be expensive anymore. LCOE of power produced by this type of wind turbine will be about USD50 MWh. Another unique experiment - the powerful WPP was created by the German company Skysails [35; 36]. It does not have the wind rotor typical of other WTs, but only a sail that is dragged by the wind between the altitudes of 200-400 m.

The Texas-based startup Aeromine Technologies has developed a new bladeless small-scale rooftop wind energy harvesting system [37; 38]. It can be connected in parallel to a common system with PVPP installed on the roof. The Dutch company The Archimedes has built an innovative small-scale wind turbine for rooftops of buildings [39]. Small-scale wind farms are increasingly connected to a common system with PVPP in order to increase the stability of electricity supply to buildings. Some small WTs are installed in cylinders with shrouds (diffusers), which act as wind speed amplifiers and significantly increase the power generated by the wind turbine [40]. Similar speed amplifiers can be arranged in hydrokinetic turbines [41]. One more recommendation: maximum power point trackers are useful to be used not only for PVPP but in WT and hydrokinetic turbines if the wind (or water flow) speed varies significantly [42].

The advantages of local microgrids are becoming clear. Hybrid RES-based power plants and microgrids (solar and wind hybrids, floating solar and wind microgrids, and islandable microgrids) can supply energy to the main power grid in a more stable and reliable manner. The price of power produced in the local microgrid for self-consumption will be significantly lower compared with the power from the main grid. A new trend is emerging in the field of microgrids. The aim is to create microgrids from RES-based power plants and use them either as autonomous systems independent of the main grid or as systems connected in parallel with the main grid with the possibility of working in island mode when an accident occurs in the main grid [43; 44].

The French startup Unéole has developed an innovative solar and wind energy microgrid for flat-roof buildings. The small wind turbines are installed close to the edge of the roof, the entire PV array is closely mounted on the upper plane above the wind turbines [45]. In this way, wind turbines can receive higher wind speeds and more modules can be placed on the free top plane above the roof. This creates the conditions to produce more electricity.

Thanks to innovations, the operational efficiency of heat pumps is rapidly improving. The US Company Johnson Controls developed an air source heat pump (HP) for cold climates. Its coefficient of performance (COP) is quite good even at -29 °C [46]. A series of innovative high-efficiency air source heat pumps with different capacities was developed by Mitsubishi Electric Company. They also perform well in low outdoor temperatures and are designed for heating premises and DHW in houses of different sizes [47].

The French startup Equium developed a new type of HP which needs no refrigerant. HP can run on three heat energy sources: ambient air, water and geothermal. The HP core is powered by acoustic waves generated by a high-precision electric speaker in a sealed pressure vessel filled with helium gas. This new HP can produce hot water up to + 80 °C. The current COP of this thermo-acoustic HP is 3-4. The thermal power of these HPs is to be increased to 8-10 kW in the future [48].

German researchers have found a way to replace the precious metals of the titanium and platinum group used in the production of PEM electrolyser plates with steel coated with niobium. Parts with precious metals make up to 60% of the total price of a PEM electrolyser. This innovation will make it possible to reduce the price of green hydrogen as well [49]. Researchers at the University of Melbourne are also conducting research to improve the efficiency of water electrolysis. They discovered that high-frequency vibrations can release 14 times more hydrogen than standard electrolysis methods [50].

The next interesting idea for the production of cheap green hydrogen is artificial photosynthesis. Researchers at the Michigan University created an inexpensive converter of concentrated artificial photosynthesis for green hydrogen production. The researchers wanted to replicate and improve as much as possible the photosynthesis process taking place in nature in order to create a device using solar irradiance for the cheapest production of green hydrogen from water including seawater in future [51, 52]. Seawater is already used in scientific experiments to produce hydrogen. The China’s Nanjing

University of Technology has developed an experimental electrolyser for splitting seawater to produce green H2 and lithium, a scarce metal much needed by modern industry [53; 54].

Bacteria are preparing to join the production of cheap green hydrogen. The biotech startup Cemvita Inc from Houston, Texas, is preparing to employ bacteria to produce cheap hydrogen by moving them into depleted oil and gas wells. Oil and gas residues will be used by bacteria as feed. The price of green hydrogen obtained in this way will be well below 1 USD·kg^{-1} [55]. The Monash University in Australia conducts tests with bacteria that can produce power (when they are hungry) from hydrogen found in the atmosphere. Mycobacterium smegmatis is used that processes the consumed hydrogen and outputs it as electricity. At the beginning, such power can be used for small devices, LED lights, small personal computers, and in the future maybe in EVs [56].

An Israeli startup aims to produce "hydrogen powder" from chemical compounds rich in hydrogen. This is the best way to store and transport hydrogen. The following methods have been used to store and transport hydrogen: compressed, liquefied and ammonia (NH_3). Hydrogen in such forms occupied large volumes (especially compressed) and posed safety problems. The "hydrogen powder" method occupies the smallest volume per unit weight, has no storage losses and is safe [57; 58].

Interest in and production of green hydrogen has grown rapidly in the world over the past year. According to GlobalData, green hydrogen production capacity grew by 44% in 2022 [59]. The most significant developments took place in the United States, Denmark, Egypt, Canada, and Portugal. Such great pace of the world's green energy revolution, including hydrogen technologies, confirms that the majority of the Earth population has already finally decided which direction they need to go in the field of power and heat engineering.

Conclusions

1. During the last 10-15 years, scientists and inventors from various countries have proposed many valuable innovations. The abundance of innovations creates excellent conditions for the rapid development of RES-based power plants and the reduction of energy prices.
2. Dissemination of information in the field of RES-based technologies is another important factor for faster achievement of EU and global goals in the fields of energy, climate change and environmental protection.
3. Thanks to innovations, power production is coming at least partially to agricultural farms, residential houses, buildings, small companies, shops, and vehicles and is becoming a kind of electrical device that helps provide electricity for self-consuming at the lowest price.
4. Many countries around the world have already gone more than half of the way to RES-based electricity production, including Latvia. This country has a good chance to reach the finish line as one of the first in EU, if solar and wind-based power production will be sufficient.

Author contributions

Conceptualization, formulation of the idea of the article, search for information sources and their analysis, evaluation of the significance of information sources (V. A. and G. Š.), writing and draft first version preparation (V. A), editing of the article (G. Š.), preparation of the final version (V. A), acquisition of financing, preparation of slides, presentation of the report at the conference (G. Š).

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