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SCIENTIFIC REVIEW

Global Solar Energy Market and Female Entrepreneurship after the Covid-19 Pandemic

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A B S T R A C T

The Covid-19 pandemic presents multiple challenges for sustainable development, particularly for female entrepreneurship in the renewable segment. Solar energy is the most prospective segment of renewable energy resources. The share of global female inventors in energy technologies is less than 30%. This article is devoted to prospects of the development of female entrepreneurship in the solar energy market. We analyzed the global impact of the pandemic on the solar energy markets, and assessed the prospects for their development in the post-pandemic period. We used data from leading international analytical agencies, such as IAE and Bloomberg for 2000-2020. We also used results of international case study analyses of the International Energy Agency from 2019 on female entrepreneurship in solar energy. In addition, we investigated the Russian-French case study of female entrepreneurship in the solar energy segment. Based on the results of the analysis, we concluded that the solar energy sector will continue to develop in the future. According to the research results, negative pandemic trends, such as the reduction in the number of commissioned projects and investments in the solar power industry persist in the short term. So far, the pandemic has not had a significant negative impact on the strategic and long-term period, and female

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entrepreneurship will continue to evolve. We argue that it is important to minimize financial barriers currently existing in special funding and grant programs for supporting this trend and increasing the number of women in solar energy entrepreneurship. It is crucial to focus future financial programs for female entrepreneurs in the solar energy sector on rural regions as they are more prospective in terms of solar energy development. In addition, a range of educational programs in soft skills should be developed to strengthen engineering specialists' background in business and negotiations. The research results can be used in future research in the field of sustainable development, renewables, and female employment in the renewable and solar energy sector.

KEY WORDS: *SDGs, low-carbon economy, green economy, renewable energy sources (RES), solar energy, female entrepreneurship, women entrepreneurship, women employment, female employment*

Introduction

In 2019, the fourth energy transition and the development of solar energy were integral parts of the global economic agenda and scientific research around the world (Reagan, et al., 2020). The developed and developing countries focused their medium and long-term strategies on sustainable development (SDG 7 "Cheap and affordable energy" and SDG 11 "Sustainable Cities") and projects dedicated to the transition to renewable energy sources (RES) (Franco, et al., 2020).

The unexpected arrival of the Covid-19 pandemic disrupted the usual economic, social, and educational patterns globally (Salamzadeh & Dana, 2020, Pereira et al., 2021) and was discussed in many scientific papers (Eroğlu et al., 2020). As the results of the pandemic showed, the economies of all countries of the world have been experiencing a deep economic slump since 2020.

The transition of the world economy to a low-carbon model requires systemic changes and time for their implementation. According to Grigoriev and Kryukov (2009), "shifts in scientific and technological progress and increased production of renewable energy sources cannot occur quickly without large-scale capital expenditures, a major change in the lifestyle of the mass middle class of the developed and growing middle class of developing countries".

Consequently, the question is whether the transition to a low-carbon economy and the development of renewable energy is possible in the wake

of fear, uncertainty, and economic crisis associated with the pandemic? How will it influence female employment and entrepreneurship in the energy sector?

Before the pandemic, there was a long-term trend of "an increase in the consumption of energy-intensive goods due to a decrease in the poor and an improvement in the global quality of life" (Grigoriev et al., 2020.). The question is, did this trend continue in the pandemic-stricken world? There is no clear-cut answer to this question. As the previous history of global economic crises shows, different countries and world regions react heterogeneously to a set of various economic challenges providing conflicting evidence.

Thus, a comprehensive assessment is necessary, and the purpose of this study was to search, systematize, and analyze analytical data and academic publications on the prospects for the development of the global solar electricity market post 2020. The objectives of our research were to estimate the prospects of development of female entrepreneurship in the global solar energy market.

Female Entrepreneurship in the Renewable Energy Market

The share of women's employment in the global labor market is about half (about 48%). However, in the traditional industries and in the energy sector in particular, this share is significantly lower. In the energy sector, women account for only 22% (IEA,2020).

Obstacles to realizing the creative potential of women in the energy sector are similar to other traditional industries. As the world is currently undergoing the Fourth Energy Revolution, the transition to clean energy will require innovative solutions.

The number of female inventors is increasing in various technology sectors with the highest rates in health and chemistry. In the classes of patents closely related to the energy sector, such as incinerators, engines, pumps, and energy, women are listed in less than 11% of applications. More than 15% are listed for climate change mitigation technologies, which is comparable to all energy sectors' technologies, including information and communication technologies[1] (Figure 1). To improve this situation, the Clean Energy, Education, and Empowerment Programme (C3E International) was created in 2010 at an initiative of the Clean Energy

Ministerial (CEM). This Programme aims to promote the leadership and participation of women in the clean energy transformation.

In 2017, a decision was taken to organize the C3E International's activities as an IEA Technology Collaboration Programme (TCP). TCP, C3E International joined a network of 6 000 experts participating in the Energy Technology Network (ETN), which engages in energy research and development, and assists with the development of best practice sharing to support the programme's goals. The 38 TCPs operating today involve nearly 300 public and private organizations in 53 countries.

All these activities require financial backing and are mainly supported by businesses and governments. The COVID-19 pandemic and a series of economic crises triggered by it could further negatively impact the rate of female involvement in the energy sector.

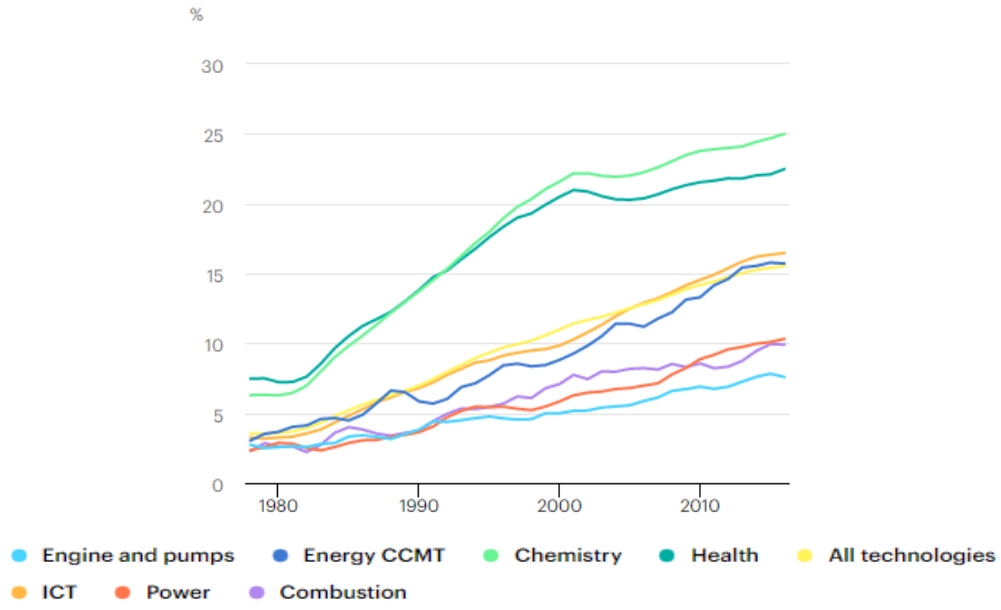
The IEA Gender Diversity Initiative is determined to strengthen data collection and analysis for better understanding as to why women in the energy sector face additional barriers in employment, leadership, innovation, and entrepreneurship (IEA, 2020).

The main challenge for female entrepreneurship is the access to funding. Most of the funding secured by these entrepreneurs does not target women exclusively (IEA, 2020).

However, targeted funding for women would be very helpful for encouraging their participation in the clean energy sector and for leveling the playing field in entrepreneurship between women and men (IEA, 2020).

New educational and training programs in these fields will stimulate females' participation in the energy sector, especially in the greenfield of renewable energy.

Figure 1: Percentage of female inventors in the energy (and control) technologies, 1978-2016

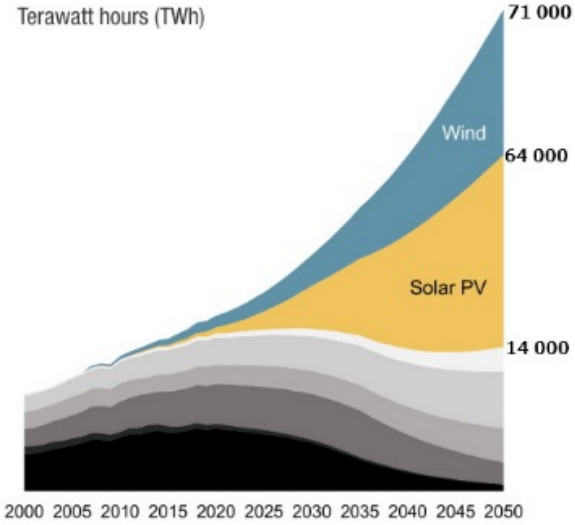


Source: IEA https://www.iea.org/topics/energy-and-gender

Global Solar Market and Covid-19 pandemic

Global Forth Energy Revolution is based on Renewables and the transition to solar energy. According to Rystad Energy (Fig. 2), while maintaining a steady trend towards reducing the costs of using renewable energy sources, it is likely that the share of electricity generated from solar generation using photovoltaic systems (PV) and wind generation will exceed the share of electricity generated from traditional energy sources by 2050 (Rystad Energy. Energy transition report, 2020).

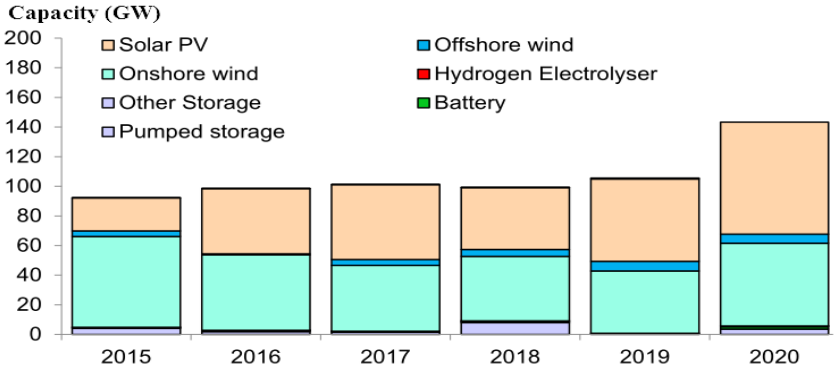
Figure 2: Rystad Energy forecast for global electricity generation



Source: Rystad Energy, Energy transition report

If we analyze the trends in the development of the electric power industry based on renewable energy sources in the shorter term, we can see that, starting from 2020, there is an active commissioning of batteries, solar modules made of polycrystalline silicon (hereinafter polysilicon) for the generation of solar photovoltaic and thermal energy for municipal needs (Figure 3).

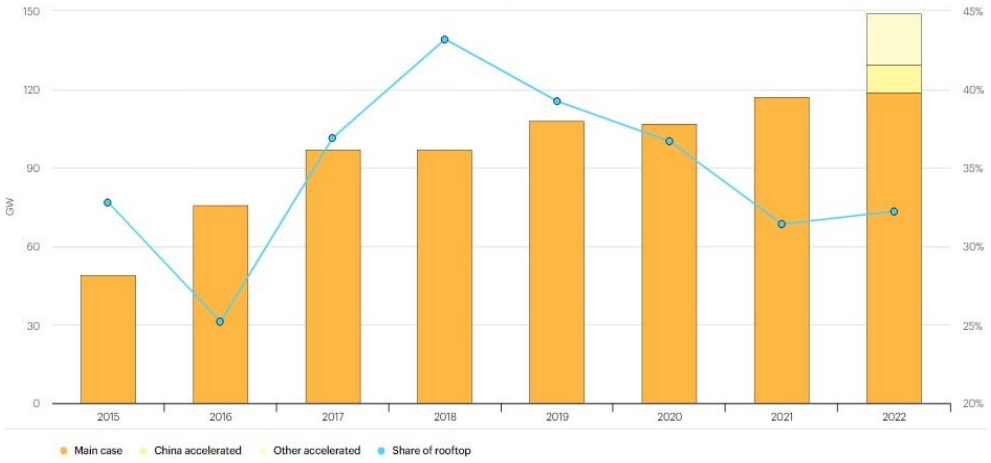
Figure 3: Rystad Energy forecast for new installed capacity for municipal renewable energy generation



Source: Rystad Energy (Renewable Cube)

However, political uncertainty and the temporary suspension of the supply of components as a result of movement restrictions due to the Covid-19 may constrain the growth rate of the solar power industry. According to the International Energy Agency (IEA), the commissioning of deferred projects in markets where construction and supply chains have been disrupted, as well as the implementation of previously auctioned municipal solar photovoltaic projects in China, France and Germany, can mitigate the negative impact of the COVID-19 and increase the total photovoltaic capacity to 150 GW by 2022 (Figure 4).

Figure 4: Increasing solar photovoltaic capacity, baseline and accelerated scenarios

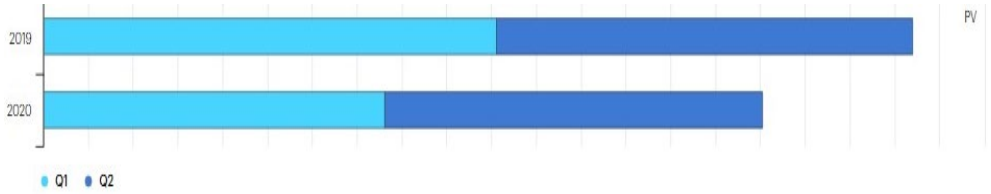


Source: IEA. Renewables 2020, Analysis and forecast to 2025.

When comparing the growth rate of solar photovoltaic capacity in 2019 and 2020, it is evident that in the first quarter of 2020 there was an almost 20% reduction in total capacity compared to the same period in 2019.

The main reasons for it was a decrease in construction activity and a shortage of labor in China due to restrictive measures in the fight against the spread of COVID-19 infection. As the pandemic in China began to recede and preventive measures were relaxed, China was able to restore the pace of commissioning of new municipal photovoltaic capacity to pre-pandemic values (Figure 5).

Figure 5: Comparison of PV capacity in the first and second quarters of 2019 and 2020

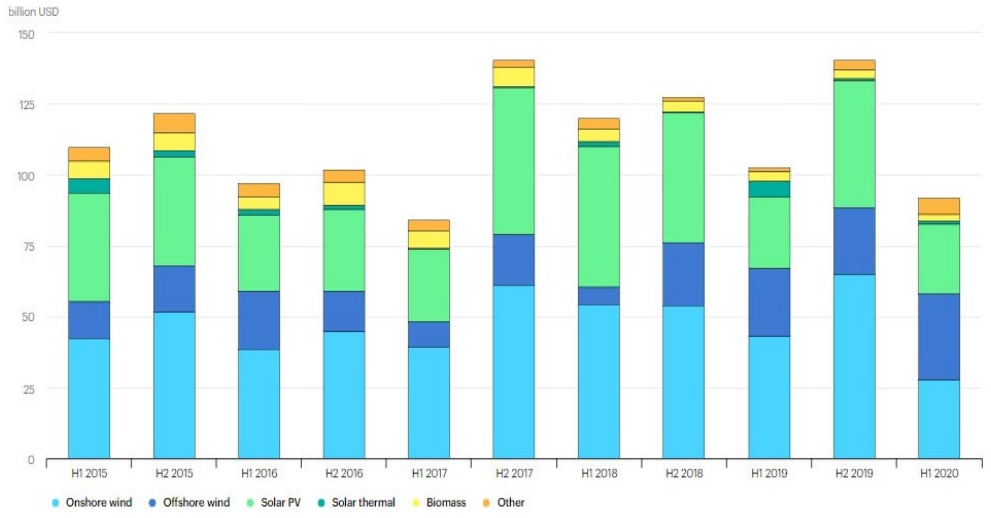


Source: IEA. Renewable 2020, Analysis and forecast to 2025.

To assess the interest of investors in the implementation of solar energy projects, it is advisable to analyze the dynamics of making final investment decisions (FIDS), which are the last step before the construction of a power plant or other infrastructure facility. In practice, solar photovoltaic projects usually start operating 6-12 months after a positive investment decision was made.

The IEA data (Figure 6) demonstrates the presence of seasonality in making final investment decisions. During the analyzed time period, investors tend to be more active in the second half of the year, which is due to the necessary condition for passing the qualification of projects - the commissioning of objects by the end of the year.

Figure 6: Final investment decisions for new municipal renewable power plants, 2015-2020



Source: IEA. Renewables 2020, Analysis and forecast to 2025.

The initial shock of the Covid-19 pandemic in February-March created economic uncertainty, and risk aversion by investors reduced their willingness to invest in new projects, including renewable energy projects. As a result, the first half of 2020 recorded the lowest total quarterly investment volume since 2017.

Despite the negative trend, the FID for municipal solar photovoltaic and thermal projects was at a fairly stable level, the volume of investment in the first half of 2020 decreased by about 4% compared to the same period in 2019 (IEA, 2020).

This change in investment activity can be explained by the delay and cancellation of projects in the world's two largest solar energy markets, namely China and India. Thus, we see that the Covid-19 has a restraining effect on the development of the global solar electricity market. However, it is necessary to study in more detail the factors that affect this segment of the global renewable energy market.

Growth Challenges of Global Solar Power Market

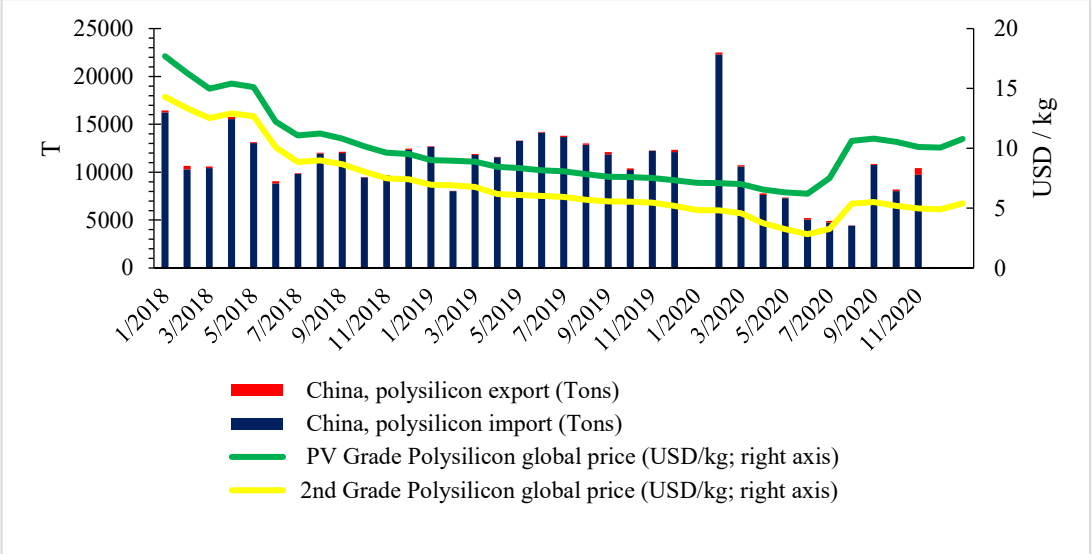
The development of photovoltaic solar energy is inversely dependent on the world prices for polysilicon, which is the main raw material for the creation of solar modules that convert solar energy into electricity.

Imports of polysilicon declined in June-August as a result of the temporary blocking of production and the closure of international borders due to the escalation of the COVID-19, but in September 2020, the volume of imports almost recovered to pre-pandemic values.

An alternative way to convert solar energy into electricity is to use lithium-ion batteries (Figure 7). According to the information portal Bloomberg, the COVID-19 pandemic has not significantly affected the trends towards increasing demand for lithium-ion batteries while reducing the cost of equipment (Figure 8).

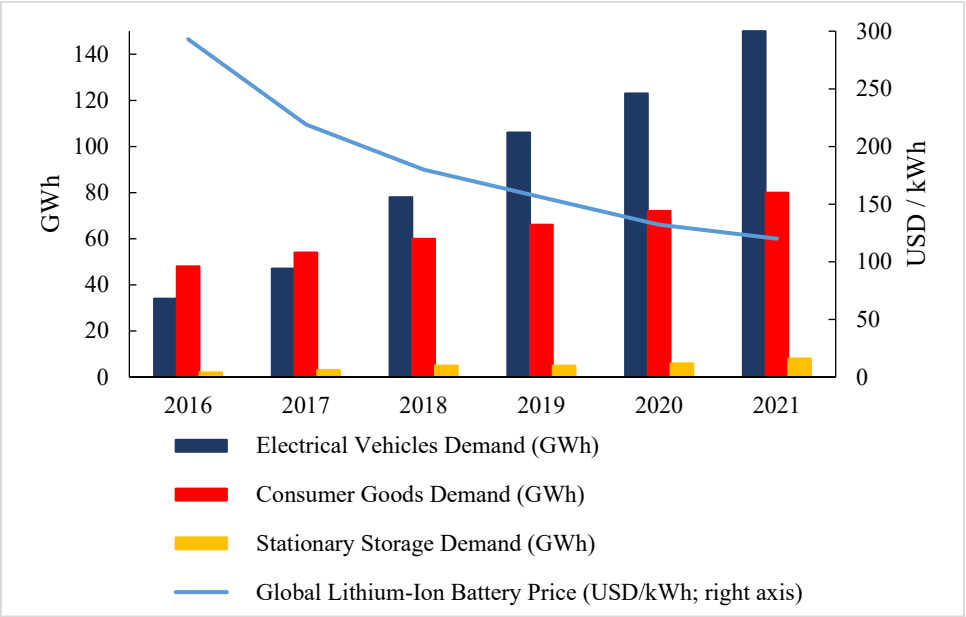
A more detailed analysis of the electric vehicle market as the main source of demand for lithium-ion batteries shows that electric vehicles are currently most popular in China and the United States (Figure 9).

Figure 7. Impact of the Covid-19 pandemic on China's import policy in the polycrystalline silicon (polysilicon) segment)



Source: compiled by the authors based on Bloomberg data

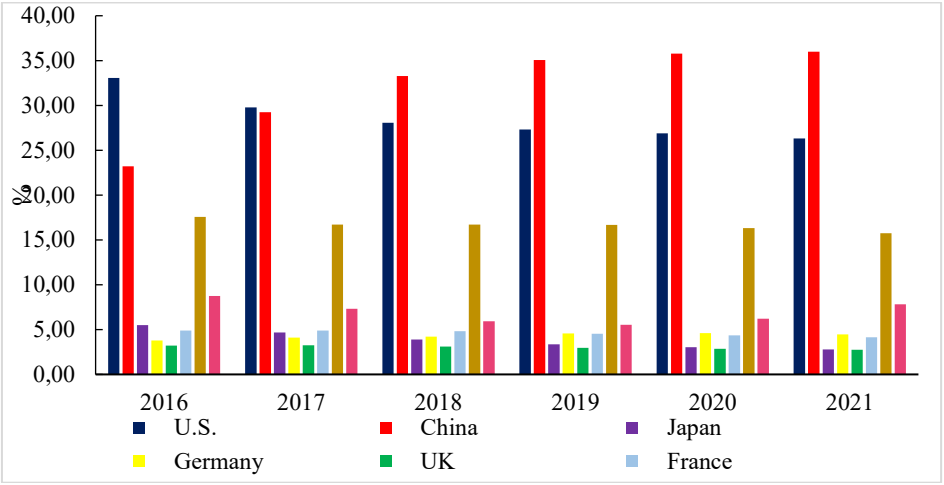
Figure 8: Dynamics of the global lithium-ion battery market



Source: compiled by the authors based on Bloomberg data

The low elasticity of the lithium-ion battery market can be explained by the fact that the supply of lithium-ion batteries for the production of electric vehicles is carried out on the basis of long-term contracts at fixed prices, which allows you to hedge the risks of adverse changes in market conditions.

Figure 9: The share of countries in the world electricity consumption by electric vehicles, %



Source: compiled by the authors on the basis of Bloomberg data

Table 1 presents analytical indicators for the solar energy market. It can be noted that in the current unstable epidemiological situation in the world, the growth rate of demand for batteries and electricity consumption by electric vehicles in 2020 decreased, but there was still a positive trend, which indicates the stability of the solar electricity market to short-term supply and demand shocks.

Table 1: Development of solar electricity market in the electric vehicles segment

Year	USA					China				
	Electricity consumption by electric vehicles, GWh	Growth rate, %	Lithium-ion batteries demand for electric vehicles, GWh	Share in the global demand,%	Growth rate, %	Electricity consumption by electric vehicles, GWh	Growth rate, %	Lithium-ion batteries demand for electric vehicles, GWh	Share in the global demand,%	Growth rate, %
2016	2360,93	-	4,37	21,75	-	1659,05	-	9,75	48,54	-
2017	3286,72	39,21	4,52	15,11	3,40	3227,35	94,53	17,92	59,94	83,81
2018	4869,59	48,16	7,38	15,54	63,29	5775,45	78,95	28,44	59,90	58,71
2019	6961,89	42,97	15,91	20,75	115,63	8929,16	54,61	43,19	56,35	51,87
2020	9380,46	34,74	28,16	22,89	77,01	12475,52	39,72	70,98	57,71	64,33
2021	12141,2	29,43	42,02	21,26	49,23	16601,77	33,07	117,05	59,23	64,91
Year	Germany					France				
	Electricity consumption by electric vehicles, GWh	Growth rate, %	Lithium-ion batteries demand for electric vehicles, GWh	Share in the global demand,%	Growth rate, %	Electricity consumption by electric vehicles, GWh	Growth rate, %	Lithium-ion batteries demand for electric vehicles, GWh	Share in the global demand,%	Growth rate, %
2016	271,15	-	0,60	2,97	-	348,86	-	1,16	5,78	-
2017	452,37	66,83	1,02	3,41	70,78	540,77	55,01	1,20	4,03	3,86
2018	729,72	61,31	1,80	3,79	76,87	835,00	54,41	1,62	3,42	34,62

2019	1162,05	59,24	3,26	4,26	81,14	1156,94	38,56	2,18	2,85	34,61
2020	1603,06	37,95	4,79	3,90	46,87	1513,62	30,83	3,28	2,66	50,08
2021	2061,35	28,59	7,34	3,71	53,10	1913,23	26,40	5,42	2,74	65,51

Year	Japan					UK				
	Electricity consumption by electric vehicles, GWh	Growth rate, %	Lithium-ion batteries demand for electric vehicles, GWh	Share in the global demand,%	Growth rate, %	Electricity consumption by electric vehicles, GWh	Growth rate, %	Lithium-ion batteries demand for electric vehicles, GWh	Share in the global demand,%	Growth rate, %
2016	393,43	-	0,67	3,34	-	230,66	-	0,66	3,27	-
2017	514,78	30,85	0,86	2,88	28,62	357,87	55,15	0,80	2,68	21,64
2018	672,49	30,64	1,09	2,29	26,29	539,44	50,74	1,23	2,59	53,47
2019	850,71	26,50	1,52	1,98	39,18	753,36	39,65	2,18	2,84	77,55
2020	1052,83	23,76	2,26	1,84	49,10	990,75	31,51	3,24	2,64	48,84
2021	1281,38	21,71	3,22	1,63	42,28	1260,67	27,24	5,08	2,57	56,60

Year	Rest of Europe					Rest of World				
	Electricity consumption by electric vehicles, GWh	Growth rate, %	Lithium-ion batteries demand for electric vehicles, GWh	Share in the global demand,%	Growth rate, %	Electricity consumption by electric vehicles, GWh	Growth rate, %	Lithium-ion batteries demand for electric vehicles, GWh	Share in the global demand,%	Growth rate, %
2016	1253,90	-	2,56	12,76	-	625,25	-	0,32	1,58	-
2017	1844,78	47,12	3,11	10,40	21,32	806,78	29,03	0,47	1,56	46,53

2018	2900,98	57,25	4,51	9,50	45,13	1026,07	27,18	1,41	2,96	201,76
2019	4250,15	46,51	6,68	8,72	48,13	1413,12	37,72	1,73	2,25	22,68
2020	5694,81	33,99	9,27	7,54	38,73	2171,11	53,64	1,00	0,82	-41,88
2021	7255,04	27,40	14,74	7,46	58,93	3601,19	65,87	2,75	1,39	174,45

Source: compiled by the authors based on Bloomberg data

Main Barriers for Female Entrepreneurship in Energy Sector

Nowadays, the energy sector's greenfield is the renewable energy resources market which is rapidly developing. Naturally, entrepreneurs have more opportunities for success and development in this part of the energy sector.

In 2019, the International Energy Agency analyzed 7 of the best international cases of female entrepreneurship in the solar energy sector: "they share common key personal characteristics, such as passion and persistence, and face similar barriers in securing funding, building partnerships, and educating stakeholders about the benefits of clean energy technologies. Key proposed actions to close the gender gap include targeted funding, access to networks, and supportive policies for gender equality" (IEA, 2020).

The IEA report concluded that: "Securing access to funding is the barrier common to each case study. Setting up funding or grants specifically for women would be a useful strategy to encourage their productive engagement in the renewable energy sector" (IEA, 2020).

Establishing new funds and financial programs supporting women entrepreneurship in RES will provide enormous impetus to the development of women entrepreneurship in RES and the solar sector.

Another challenge for women entrepreneurship is the geography of the solar energy market, because it is mainly located in rural areas. Mukhopadhyay (2020) argues that: "the work concludes with an objective to contribute to policy discussions as well as build an empirical knowledge of how women-led solar technology-based enterprises are built, managed, sustained and scaled in rural areas". Mahajan and Bandyopadhyay (2021) corroborate these conclusions in their research. Currently, there are two options to tackle these challenges: to develop rural sustainable entrepreneurship for women who live in these regions, or to financially attract urban female population to establish start-ups in rural areas.

Entrepreneurship in the solar energy market demands a lot of engineering skills. We argue that solar energy entrepreneurship will require individuals with an engineering educational background. In such cases, it is important to stress the importance of new programs developing soft skills. Mingaleva and Shpak (2015). pointed out that: "the main tasks in modern education, is to establish the compliance of educational products with the labor market requirements and transform the structure of vocational

education, providing training for professional specialists required by specific employers. Conclusions are drawn about the important role of soft skills for engineering education in Industry 4.0."

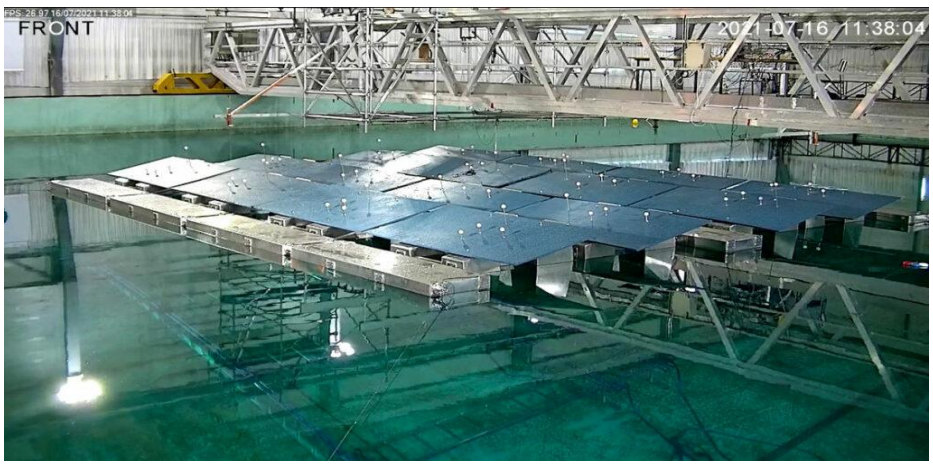
Successful international case study of female entrepreneurship in energy sector

One of the most successful global cases of female entrepreneurship is the project consisting of 2 start-ups based on HelioRec know-how in Russia and France. The Russian market is very promising due to the existing climate conditions for solar energy projects (Mingaleva & Shpak, 2015), especially concerning the specifics of heating systems in Russia's eastern regions (Mingaleva, Vukovic & Radovanovic, 2017).

The climate conditions in France are different from those in Russia, but promising for solar energy generation (Kabir, et al., 2018, Fontaine, 2020).

Polina Vasilenko's start-up with HelioRec know-how is implemented in the field of the floating solar power plant. Polina has many international awards. The most significant, in the context of female entrepreneurship, was awarded in December 2019, "Women in Tech, Global Movement" (S.Petersburg, Russia).

Figure 10: HelioRec testing its floating solar system at Ecole Centrale de Nantes (Screenshot/Video by HelioRec)



Sources: https://www.offshore-energy.biz/heliorec-crosses-another-milestone-on-its-way-to-floating-solar-commercialisation/

In her interview Vasilenko said that typical problems in female industrial entrepreneurship in Russia and France are the same, and sometimes connected with the existing gender stereotypes in the energy sector (Daily, 2020). Despite facing traditional conservative problems compounded by the Covid-19 pandemic, Vasilenko continues developing her start-ups in Russia and France successfully.

In 2020, she started a new project in rural Russia (Dagestan region) and continued her urban project in France (Nantes). It is important to point out that HelioRec project was supported by the start-up financial accelerator in France and by Innovative Center Skolkovo Fund in Russia, corroborating the IEA research conclusion concerning the existing barriers and challenges for female entrepreneurs in the energy sector.

Conclusion

Based on the results of our analysis, it can be concluded that renewable energy and solar power will continue to develop despite the many challenges presented by the Covid-19 pandemic. However, negative trends towards a reduction in the number of commissioned projects and investments in the solar power industry will persist in the short term period. So, the pandemic has not had a significant negative impact on the dynamics of the global renewable energy and solar markets. Female participation in the global solar energy market will remain consistently low unless the current conditions change. According to our case study and IEA international case study research, the main barrier for female entrepreneurship in the solar energy market is the shortage of financial funding. So, to increase the overall female involvement in the solar energy sector, it is important to continue the development of new supportive financial programs, grants, and funds. It is also pivotal to implement future programs for rural regions.

These areas are the most prospective in terms of solar energy entrepreneurship. Also, it is important to develop new educational programs that incorporate elements of soft skills because they contain an enormous potential for the success of future startups. Renewable and solar energy sources markets offer multiple opportunities for female entrepreneurship as the IEA's 2019 international case studies demonstrated. This sector is less competitive and has not been monopolized to such an extent as the traditional energy sources market. This sector has demonstrated sustainable

growth in the past thirty years and it demands flexibility, innovativeness, and agility from state and business actors alike. Naturally, female entrepreneurs will be a valuable asset as they also possess these highly demanded and competitive skills. We plan to further research these topics in our future academic endeavors.

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