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THE TRENDS OF TRANSFORMING THE ENERGY SECTOR OF UKRAINE IN THE CONCEPT OF SUSTAINABLE DEVELOPMENT WITH USING THE RENEWABLE ENERGY SOURCES IN THE PERSPECTIVE TO 2050

Abstract*. The study presents an approach aimed at assessing trends in the transforming the energy sector of Ukraine in the future until 2050, using renewable energy sources in the concept of Sustainable Development, with taking into account the trends of transforming the energy sectors of World and European Union in the perspective to 2050. Our research is aimed at: analysing of the trends of transforming the energy sectors of the world, the European Union and Ukraine and identifying the benefits of using renewable energy sources in the concept of Sustainable Development in the perspective to 2050, assessment of prospects for the application of innovative technologies based on renewable energy sources in the concept of Sustainable Development. A number of criteria for energy, economic and environmental efficiency of innovative technologies for the use of renewable energy sources are analysed in order to conduct a comprehensive assessment of the effectiveness of energy and resource-saving, environmentally friendly and cost-effective innovative technologies in the concept of Sustainable Development in the perspective to 2050. This approach allows providing a reasonable definition of prospects for the use of energy and resource-saving, environmentally friendly and cost-effective innovative technologies for the use of renewable energy sources in the concept of sustainable development to increase energy, economic efficiency and environmental security of Ukraine's energy sector in the perspective to 2050.*

Introduction.

As it is noted in (Ostapenko, Savina, et al, 2020), Sustainable Development is the basis for global international cooperation. The 2030 Agenda for Sustainable Development, adopted in 2015, is defines the directions of development of humanity in the perspective to 2030. The Sustainable Development concept contributes to sustaining economic progress and protecting the environment in the long term. The concept of Sustainable Development involves a combination of economic, social and environmental trends in the modern world. The concept of Sustainable Development combines the optimal use of scarce natural resources with the application of environmentally friendly nature-, energy- and resource-saving technologies in the production of environmentally friendly products at all stages of the life cycle.

As it is noted in (Ostapenko, Savina, et al, 2020), the concept of Sustainable Development is determinates the 17 Sustainable Development Goals (SDGs), that defined the tendencies of development of sustainable energy and fuel and energy complex of Ukraine in the direction of European integration, ensuring reduction of greenhouse gas emissions and increasing the use of non-traditional and renewable energy sources with the application of energy- and resource-saving, environmentally safe and cost-effective innovative technologies.

The concept of sustainable development, according to (Arkhypova, et al, 2021; Brych and Fedirko, 2018; Emas, 2015; Koval, et al, 2019; Mandryk, et al, 2017; Ostapenko, 2020), aims to maintain economic advancement and progress while protecting the long-term value of the environment. The concept of sustainable development implies the optimal use of limited resources and the use of environmentally friendly nature-, energy- and material-saving technologies at all stages of the life cycle with the production of environmentally acceptable products (Koval, et al, 2017, 2018, 2019).

1 Analysis the trends of transforming the energy sectors of World and European Union in the perspective to 2050 in the concept of sustainable development and determination the trends of renewable energy sources technologies for Ukraine

The analytical work "Forecast of world energy development for the period up to 2035", prepared by the International Energy Agency (IEA), states that in the period 2010 – 2035 there will be an increase in world energy consumption by 35%: the smallest increase in consumption will be use of coal (13%), the largest - for the use of renewable energy sources (RES) (87%). It is noted that fossil energy resources will play a key role in the further development of world energy, however, their share in primary energy consumption in 2035 will be reduced to 75% (today – 81%) ("Foreign experience in improving energy efficiency and introducing new technologies for electricity generation", 2021).

It should be noted that the long-term forecast of the IEA and other international organizations provides for an annual reduction in energy intensity of gross domestic product (GDP), which is planned to increase energy efficiency in all sectors of the economy, especially the most energy-intensive - industry and energy. At the same time, in Ukraine the level of fuel and energy expenditures on GDP production, especially in industry and energy, is declining at a relatively slow pace and as of the end of 2020 significantly exceeded the average level both in the European Union (EU) and in the world as a whole. This indicates a relatively low level of implementation of energy efficient technologies in the sectors of economy and energy in Ukraine. It should be noted, that the long-term forecast of the IEA and other international organizations takes into account the annual decline in energy intensity of gross domestic product by increasing energy efficiency in all sectors of the economy, especially more energy-intensive – in industry and energetics ("Foreign experience in improving energy efficiency and introducing new technologies for electricity generation", 2021).

According to the IEA, world consumption of renewable energy sources (RES) by 2040 will reach almost 3 billion tons of oil equivalent, of which 2,7 billion tons of oil equivalent, including 0,5 billion tons, can be directed to electricity and heat production oil equivalent of hydropower.

In paper (Ostapenko, Savina, et al, 2020) shows that in Ukraine, the percentage of usage of renewable energy and biofuels is 3…4 times lower than in the EU. This indicates the need to increase the share of non-traditional and renewable energy sources in the fuel and energy sector and in the energy sector of Ukraine.

As it is noted in (Ostapenko, 2020) sustainable development of society is possible only in the conditions of energy saving, that is, the development of systems that use energy more efficiently, provide the same or even higher level of transport services, lighting, heating, etc. with less energy consumption. The use of fossil fuels and nuclear energy is contrary to the principle of sustainable development, since these resources are non-renewable, and their use pollutes the environment. Moving towards a sustainable society requires a slow elimination of dependence on fossil fuels. Therefore, the way to overcome the current energy crisis is to switch to the use of alternative (non-traditional) energy sources, in particular, the introduction of heat pump installations. Advantages of application of heat pump installations for the conditions of Ukraine are determined and substantiated on the basis of the results of research, published in a number of national and foreign publications (Ostapenko, 2015, 2016, 2017, 2018, 2019, 2020; Ostapenko, Savina, et al, 2020; Ostapenko, Bakum and Yuschishina, 2013; Ostapenko, Leshchenko and Tikhonenko, 2015; Ostapenko and Portnov, 2018; Ostapenko and Shevchenko, 2011; Ostapenko, Valigura and Kovalenko, 2013), as it is noted in (Ostapenko, 2020).

A number of investigations in recent years were devoted to the studying of efficiency of application of innovative resource-saving technologies in the world and Ukraine (Arkhypova, et al, 2021; Koval, et al, 2019; Ostapenko, 2019, 2020; Ostapenko, Savina, et al, 2020).

Our research (Ostapenko, Savina, et al, 2020) is based on the "Tracking SDG7" – resource, which uses the databases of the International Renewable Energy Agency (IRENA), the International Energy Agency (IEA), the World Bank, the United Nations Statistics Division (UNSD) and others ("Tracking SDG7", "Rise", "Esmap"). We also used statistics from Eurostat and World Bank resources ("Eurostat", "DataBank. WorldBank").

The paper (Ostapenko, Savina, et al, 2020) considers the prospects for the application of innovative resource-saving technologies in the concepts of green logistics and sustainable development. Assessment of the perspectives of application of innovative resource-saving technologies in Ukraine was carried out with taking into consideration the main goals of sustainable development, tendencies of development of sustainable energy and fuel and energy complex of Ukraine in the direction of European integration, ensuring reduction of greenhouse gas emissions and increasing the use of non-traditional and renewable energy sources. The study illustrates the application of principles and objectives of the concept of green logistics in order to increase the level of energy-economic efficiency of the energy sector of Ukraine with the application of energy- and resource-saving, environmentally safe and cost-effective innovative technologies.

Presented research is also based on the "Tracking SDG7" – resource, which uses the databases of the International Renewable Energy Agency (IRENA), the International Energy Agency (IEA), the World Bank, the United Nations Statistics Division (UNSD) and others ("Tracking SDG7", "Rise", "Esmap"). We also used statistics from Eurostat and World Bank resources ("Eurostat", "DataBank. WorldBank").

The scientific results, presented in our study, are based on data from the International Renewable Energy Agency (IRENA) database ("IRENA", 2021).

The International Renewable Energy Agency (IRENA) is an intergovernmental organization that supports countries in their transition to a sustainable energy future, and serves as the principal platform for international cooperation, a center of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy. IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity. The «REmap 2030», developed by IRENA, is a roadmap to double renewable energy use worldwide by 2030 ("IRENA", 2021).

The «Global Renewable Energy Outlook: Transforming Energy by 2050 (April 2020)», developed by the International Renewable Energy Agency (IRENA), shows the path to create a sustainable future energy system. This flagship report highlights climate-safe investment options until 2050, the policy framework needed for the transition and the challenges faced by different regions.

The «Global Renewable Energy Outlook: Transforming Energy by 2050 (April 2020)», shows the outlines the investments and technologies needed to decarbonize the energy system under the Paris Agreement. It is also exploring deeper decarburization options for the heaviest sectors, with the aim of eventually reducing carbon dioxide (CO_2) emissions to zero ("IRENA", 2020, 2021).

With a mandate from countries around the world, IRENA encourages governments to adopt enabling policies for renewable energy investments, provides practical tools and policy advice to accelerate renewable energy deployment, and facilitates knowledge sharing and technology transfer to provide clean, sustainable energy for the world's growing population ("IRENA", 2021).

In Figs. 1 – 15 shows the criteria for energy, economic and environmental efficiency of innovative technologies for the use of renewable energy sourcesin world and European Union (EU), which analysed in order to conduct a comprehensive assessment of the effectiveness of energy and resource-saving, environmentally friendly and cost-effective innovative technologies in the concept of Sustainable Development in the perspective to 2050.

The results of research, shown in Figs. 1 – 15, were obtained by the author with using a database IRENA.

Fig. 1 displays the ranks of countries/areas to their renewable energy power capacity on all renewable sources of energy in 2020.

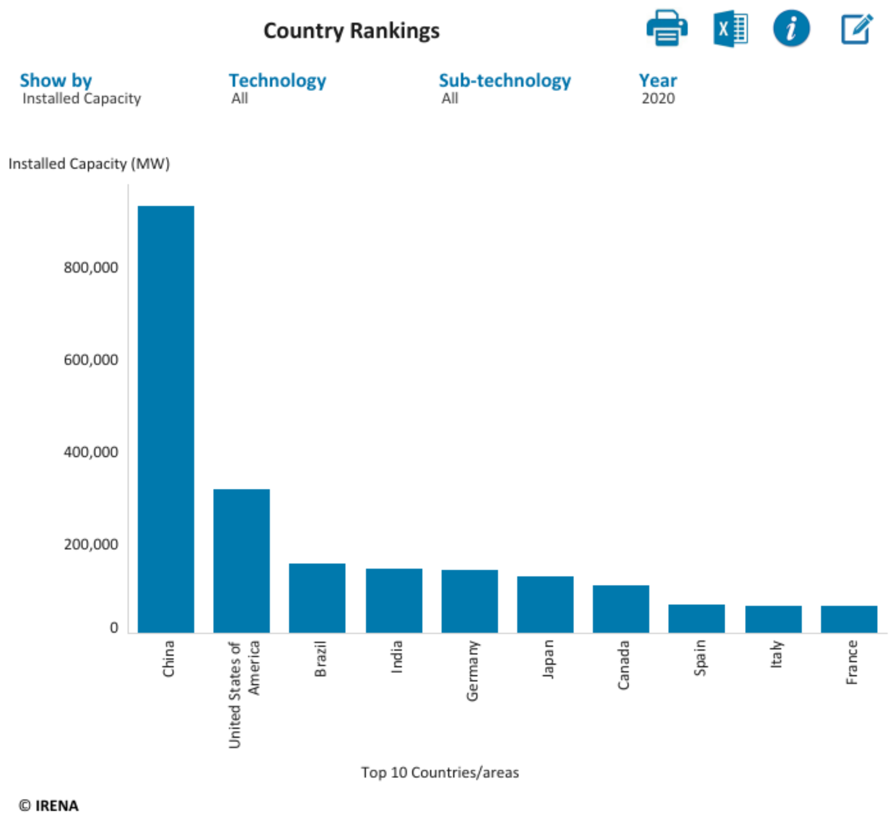


Fig. 1. Data by ranks of countries/areas to their renewable energy power capacity on all renewable sources of energy in 2020
(Source: author's research results with using database IRENA)

Fig. 2 displays the ranks of countries/areas to their renewable energy power capacity on bioenergy in 2020.

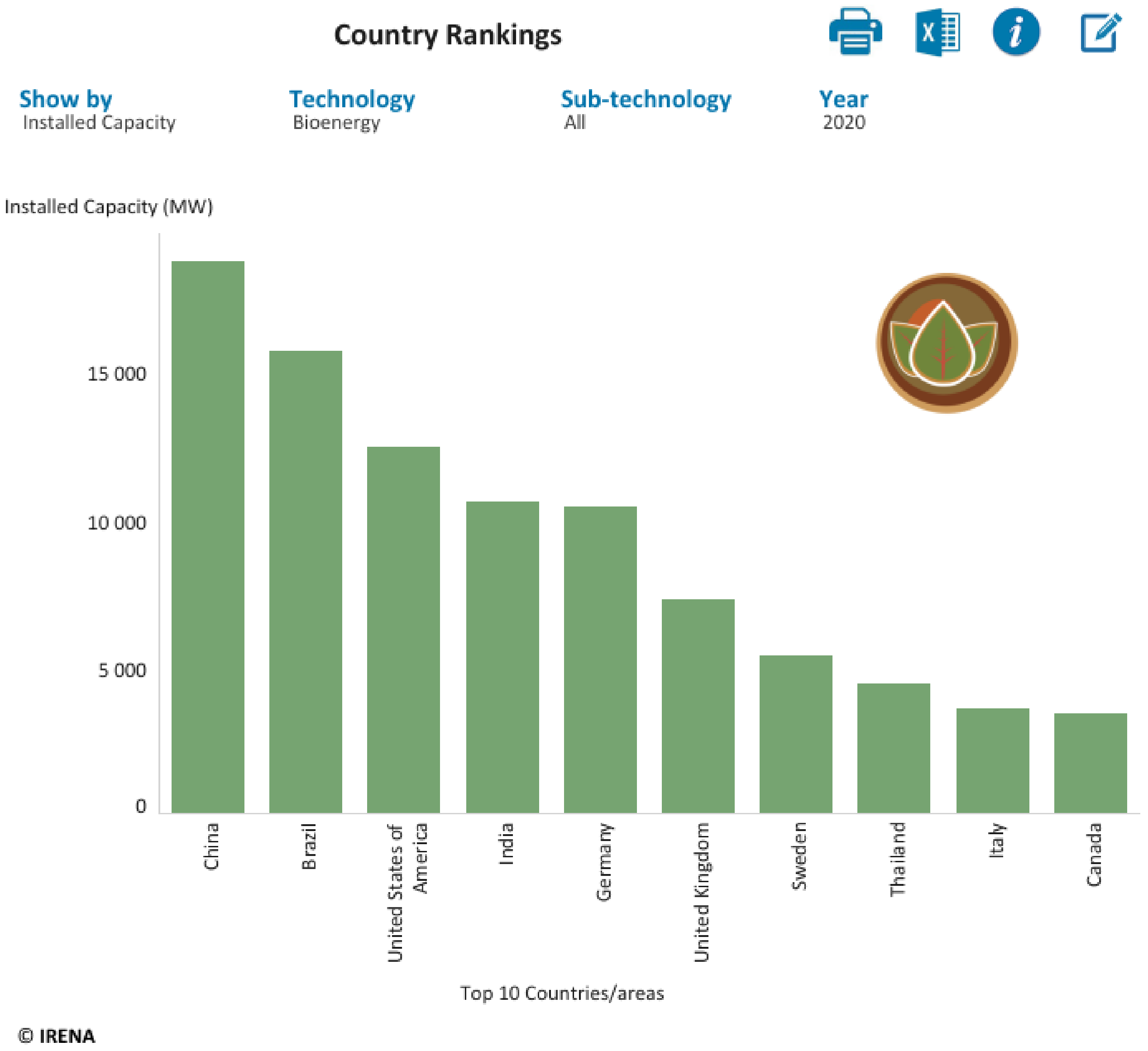


Fig. 2. Data by ranks of countries/areas to their renewable energy power capacity on capacity on bioenergy in 2020
(Source: author's research results with using database IRENA)

Fig. 3 shows a global overview of the renewable energy installed capacity and electricity generated in Europe. It displays progress over time for the selected technology.

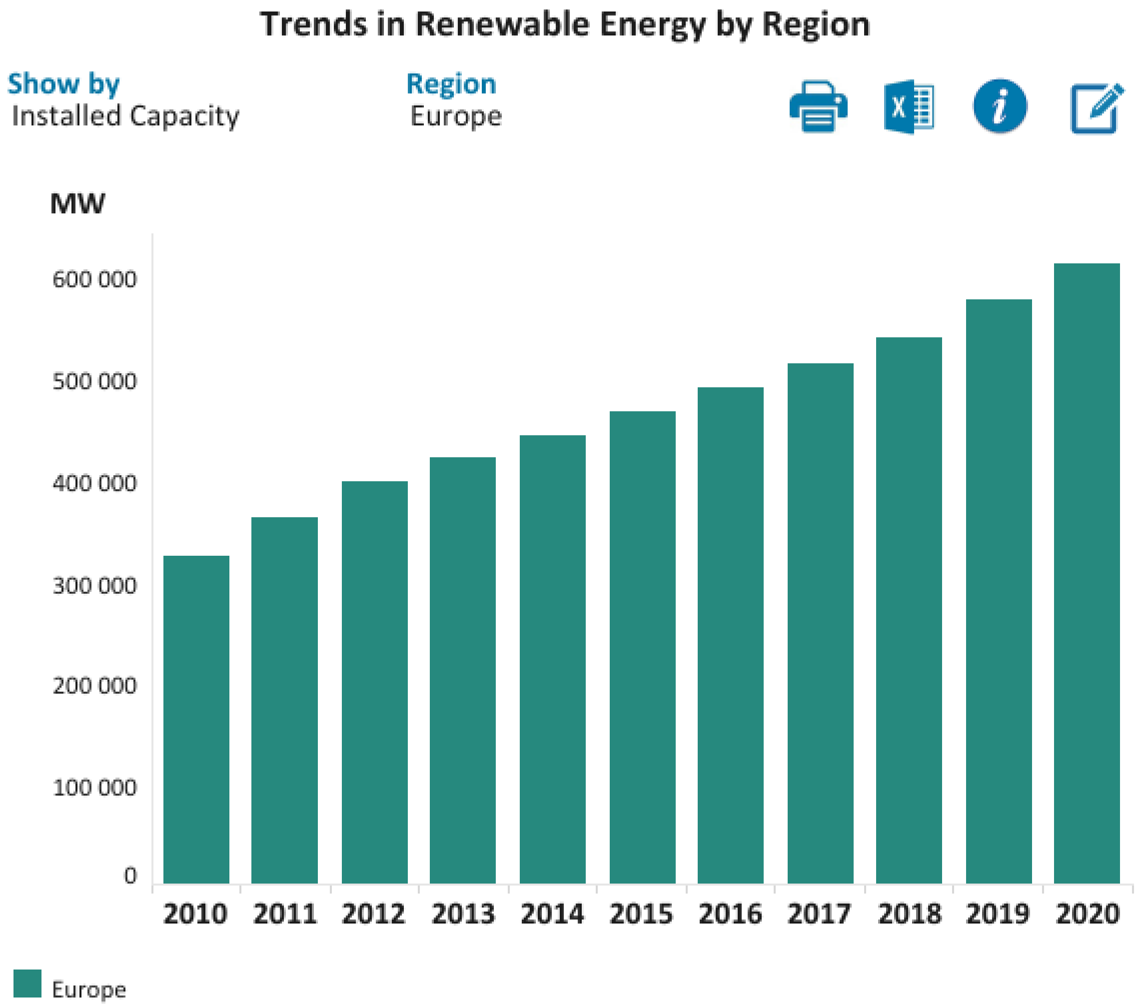


Fig. 3. Global overview of the renewable energy installed capacity and electricity generated in Europe from 2010 to 2020
(Source: author's research results with using database IRENA)

Fig. 4 provides data by employment figures in the renewable energy sector worldwide for different renewable technologies.

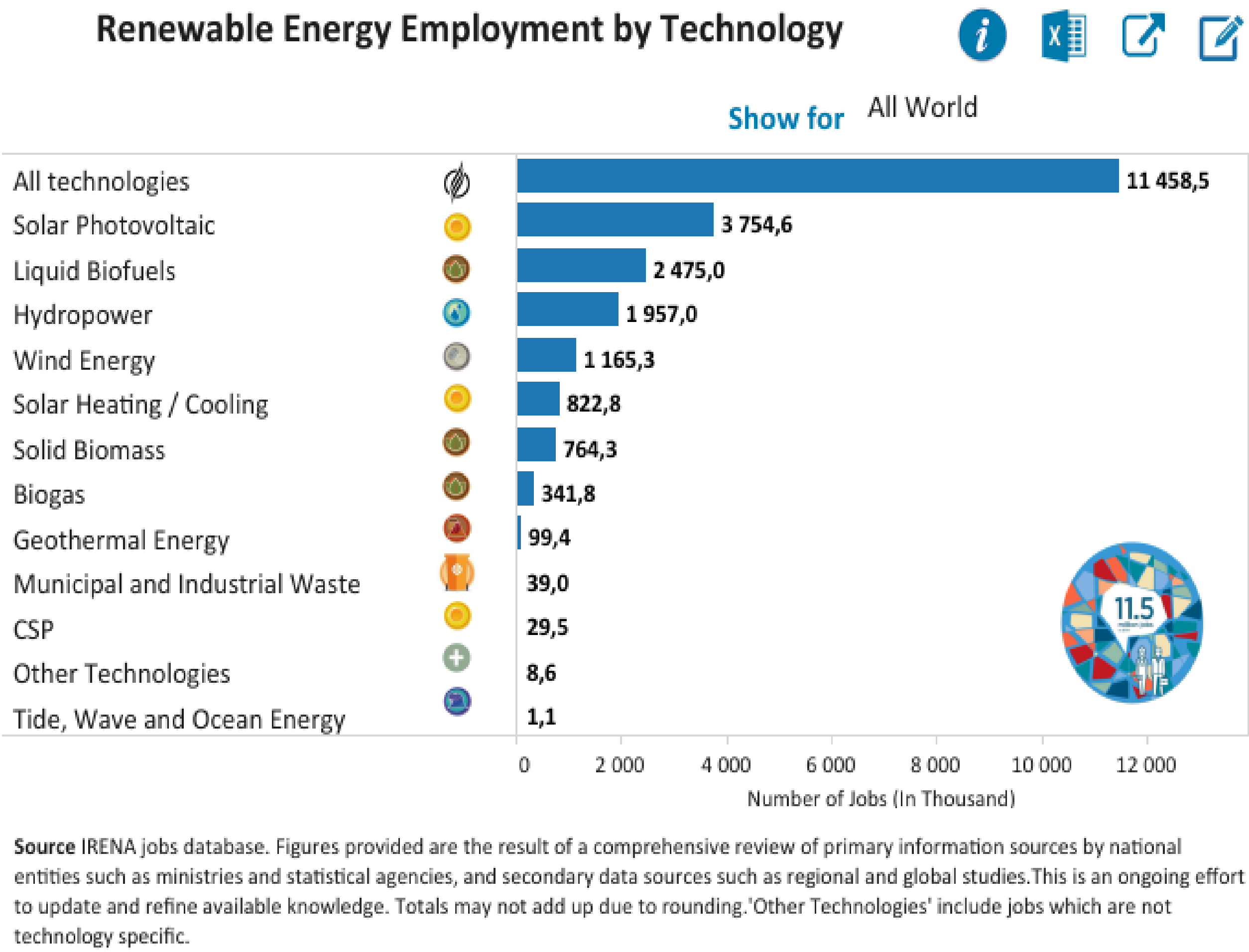
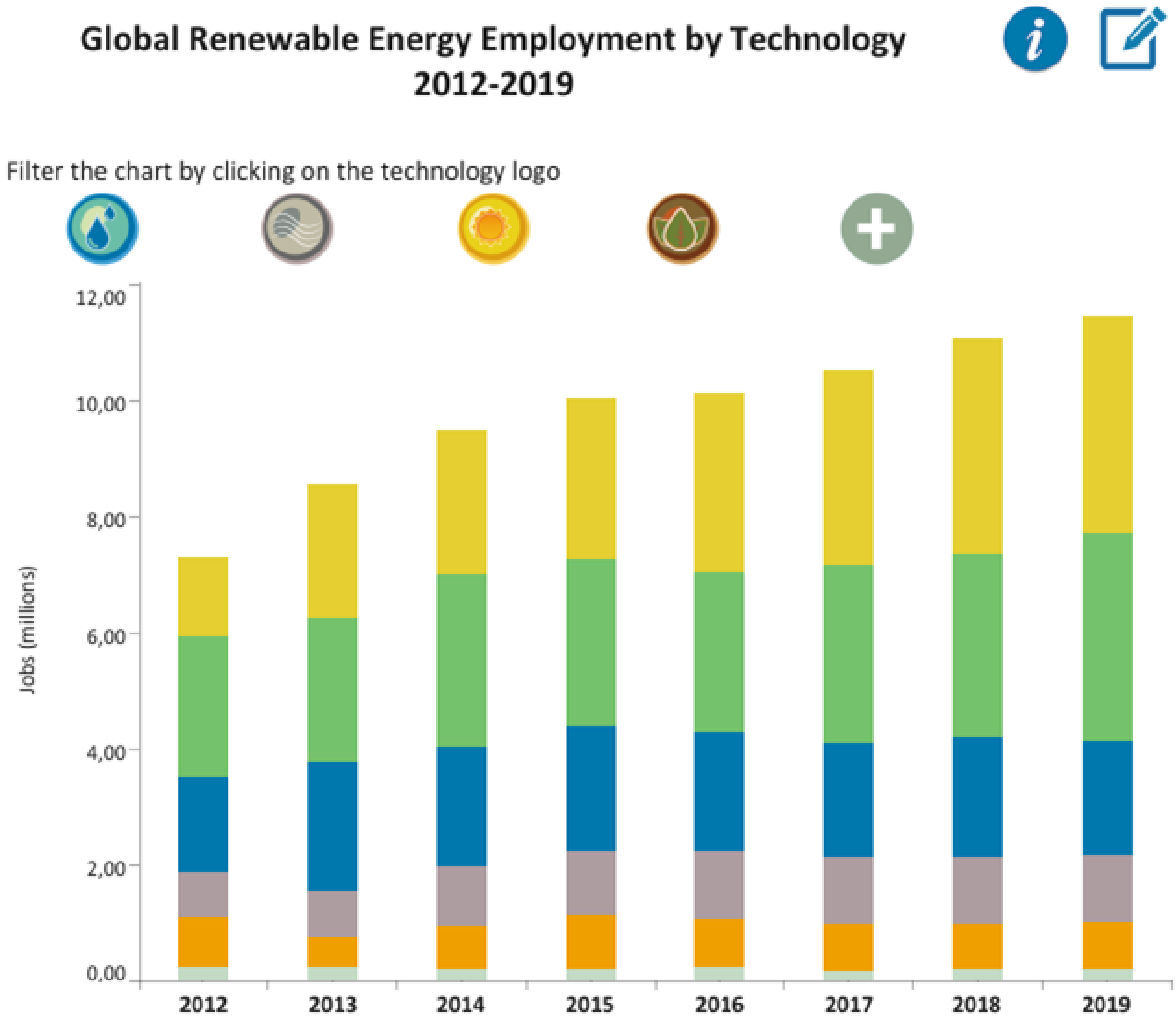


Fig. 4. Data by employment figures in the renewable energy sector worldwide for different renewable technologies
(Source: author's research results with using database IRENA)

Fig. 5 provides an overview on the total employment figures in the renewable energy sector by technology in 2012-2019.



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Source: IRENA jobs database. Note: Except for hydropower, where a revised methodology led to revisions of job estimates, numbers shown in this figure reflect those reported in past editions of the Annual Review. Totals may not add up due to rounding.Bioenergy includes liquid biofuels, solid biomass and biogas. "Other technologies" includes geothermal energy, concentrated solar power, heat pumps (ground-based), municipal and industrial waste, and ocean energy.

Fig. 5. Overview on the total employment figures in the renewable energy sector by technology in 2012-2019
(Source: author's research results with using database IRENA)

Fig. 6 provides information on the annual energy-related CO2 emissions by sector by year for planned energy scenario to 2050 in the world.

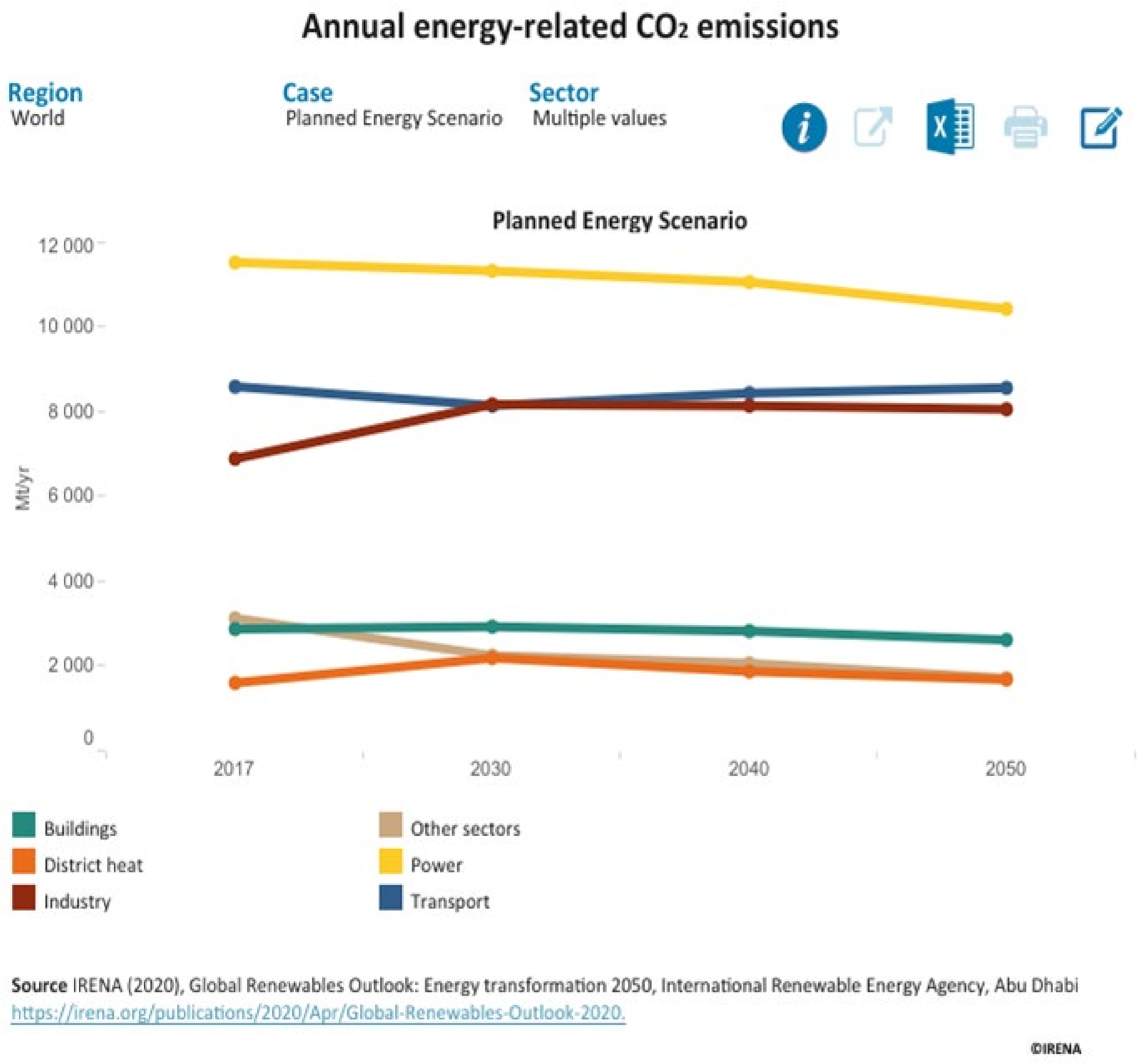

Fig. 6. The annual energy-related CO_2 emissions by sector by year for planned energy scenario to 2050 in the world
(Source: author's research results with using database IRENA)

Fig. 7 provides information on the annual energy-related CO2 emissions by sector (and total) by year for planned energy scenario to 2050 in the world.

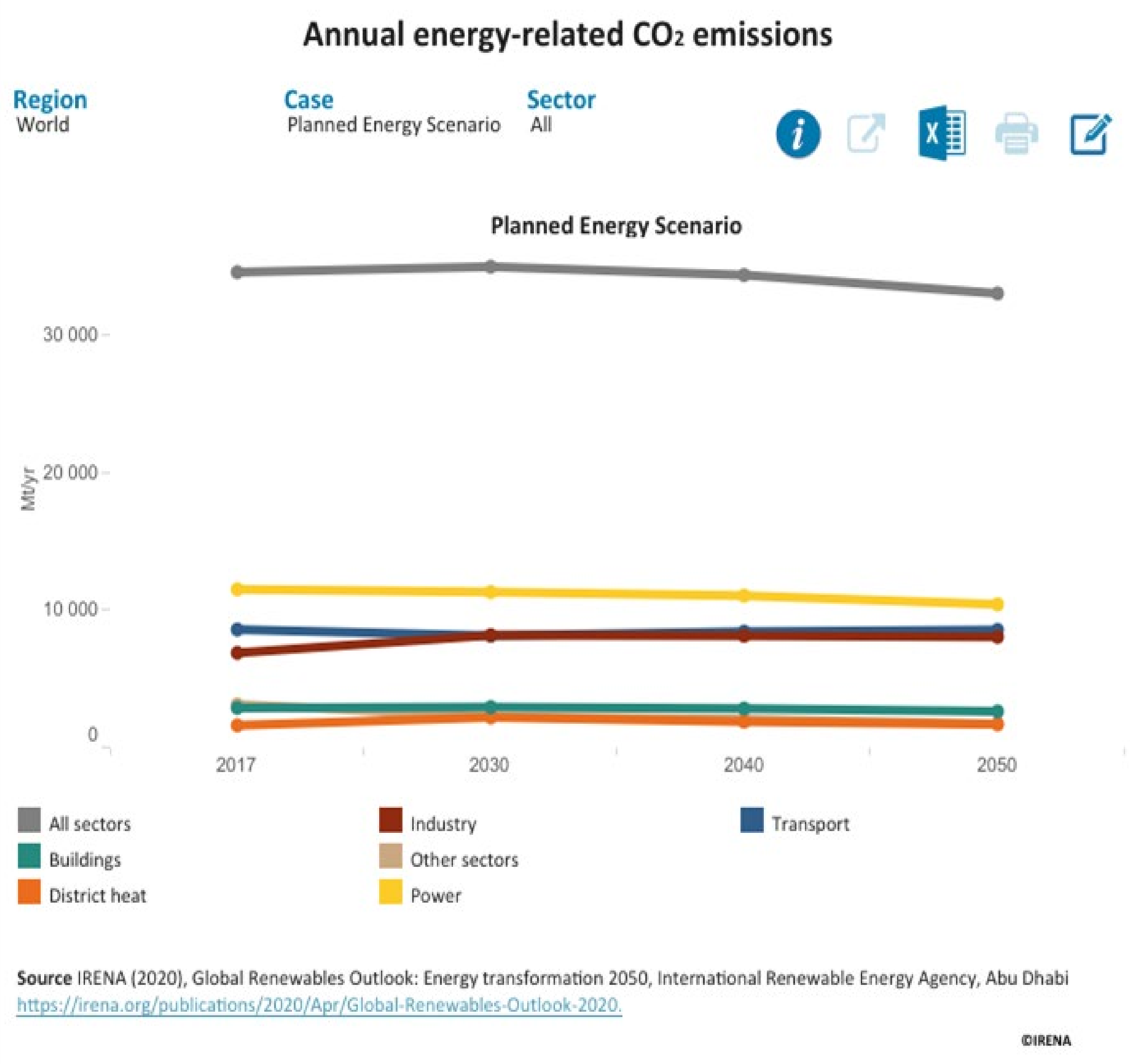

Fig. 7. The annual energy-related CO_2 emissions by sector (and total) by year for planned energy scenario to 2050 in the world
(Source: author's research results with using database IRENA)

Fig. 8 provides information on the annual energy-related CO2 emissions by sector by year for transforming energy scenario to 2050 in the world.

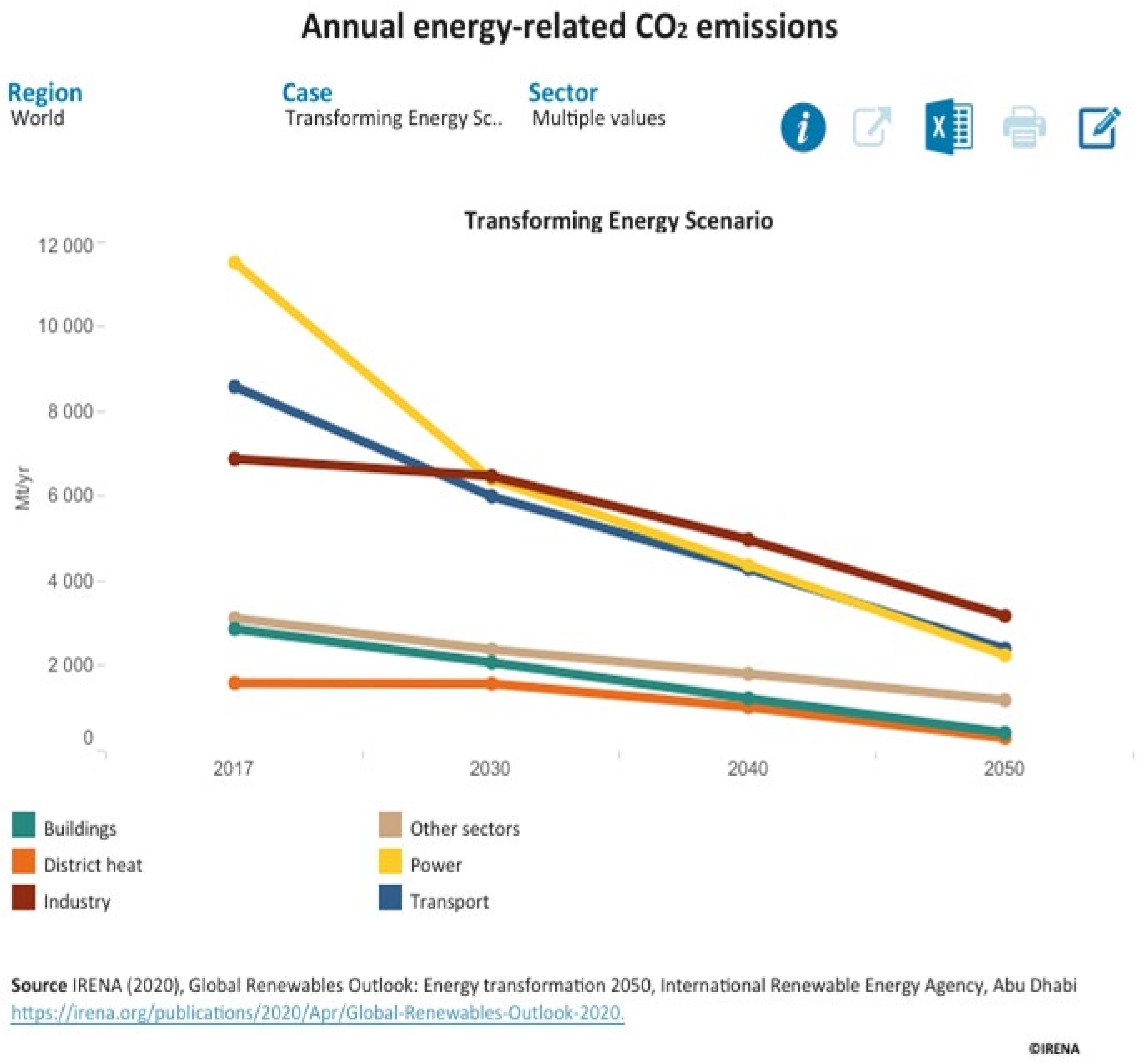

Fig. 8. The annual energy-related CO_2 emissions by sector by year for transforming energy scenario to 2050 in the world
(Source: author's research results with using database IRENA)

Fig. 9 provides information on the annual energy-related CO2 emissions by sector (and total) by year for transforming energy scenario to 2050 in the world.

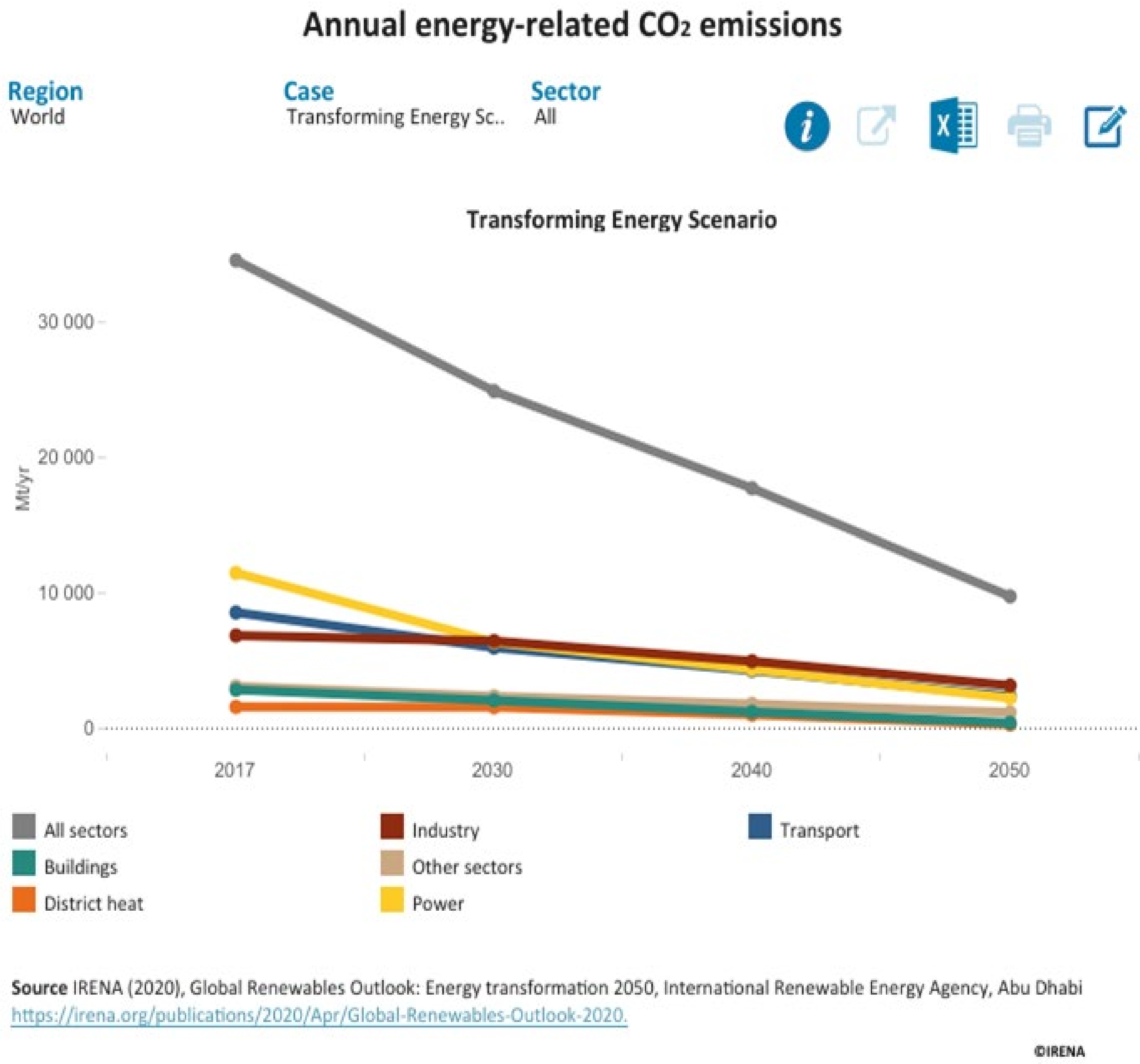

Fig. 9. The annual energy-related CO_2 emissions by sector (and total) by year for transforming energy scenario to 2050 in the world.
(Source: author's research results with using database IRENA)

Fig. 10 provides information of the annual energy-related CO2 emissions by sector and by year for planned and transforming energy scenario to 2050 in the world.

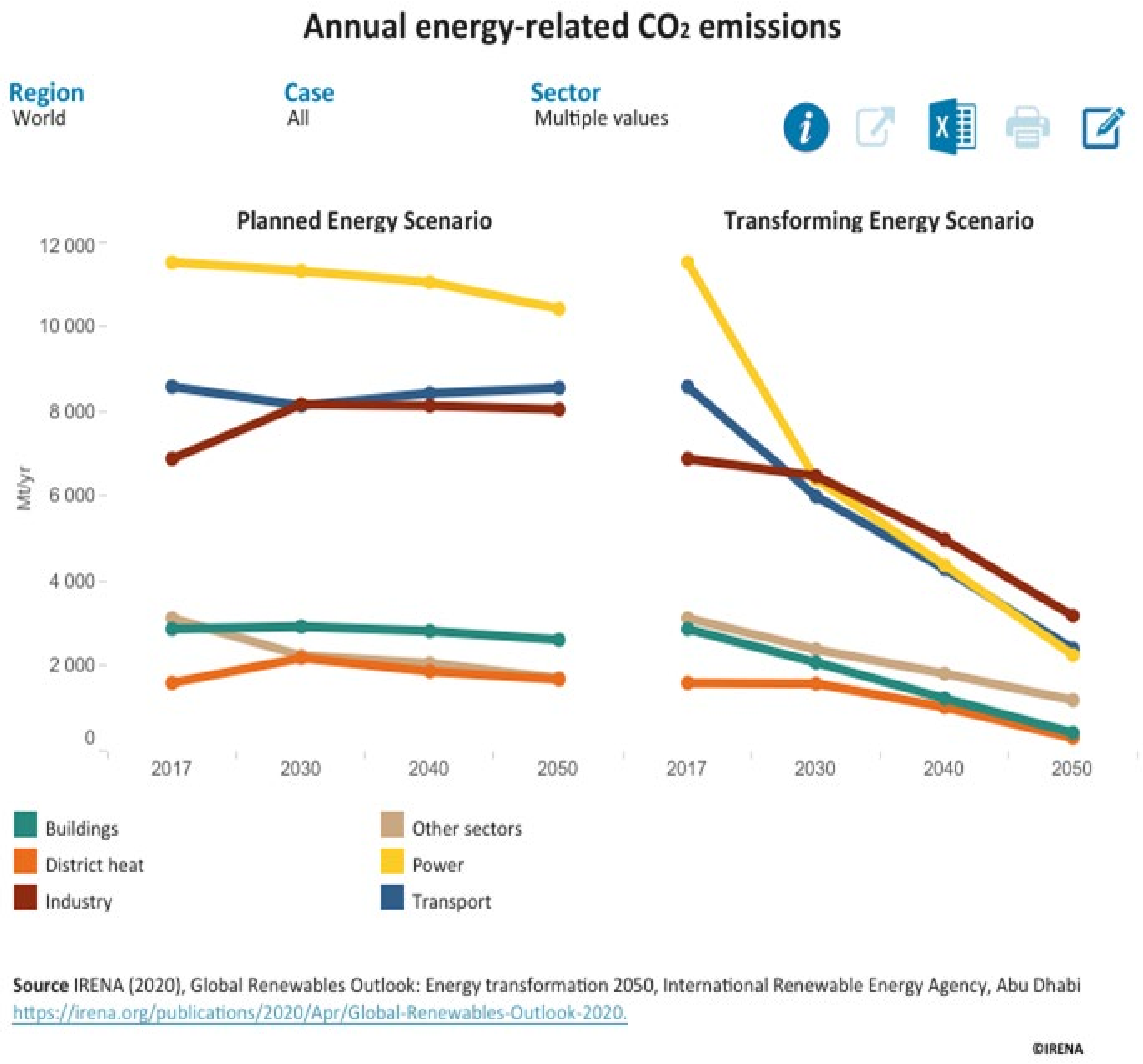

Fig. 10. The annual energy-related CO_2 emissions by sector and by year for planned and transforming energy scenario to 2050 in the world
(Source: author's research results with using database IRENA)

Fig. 11 provides information of the annual energy-related CO2 emissions by sector by year for planned energy scenario to 2050 in EU-28

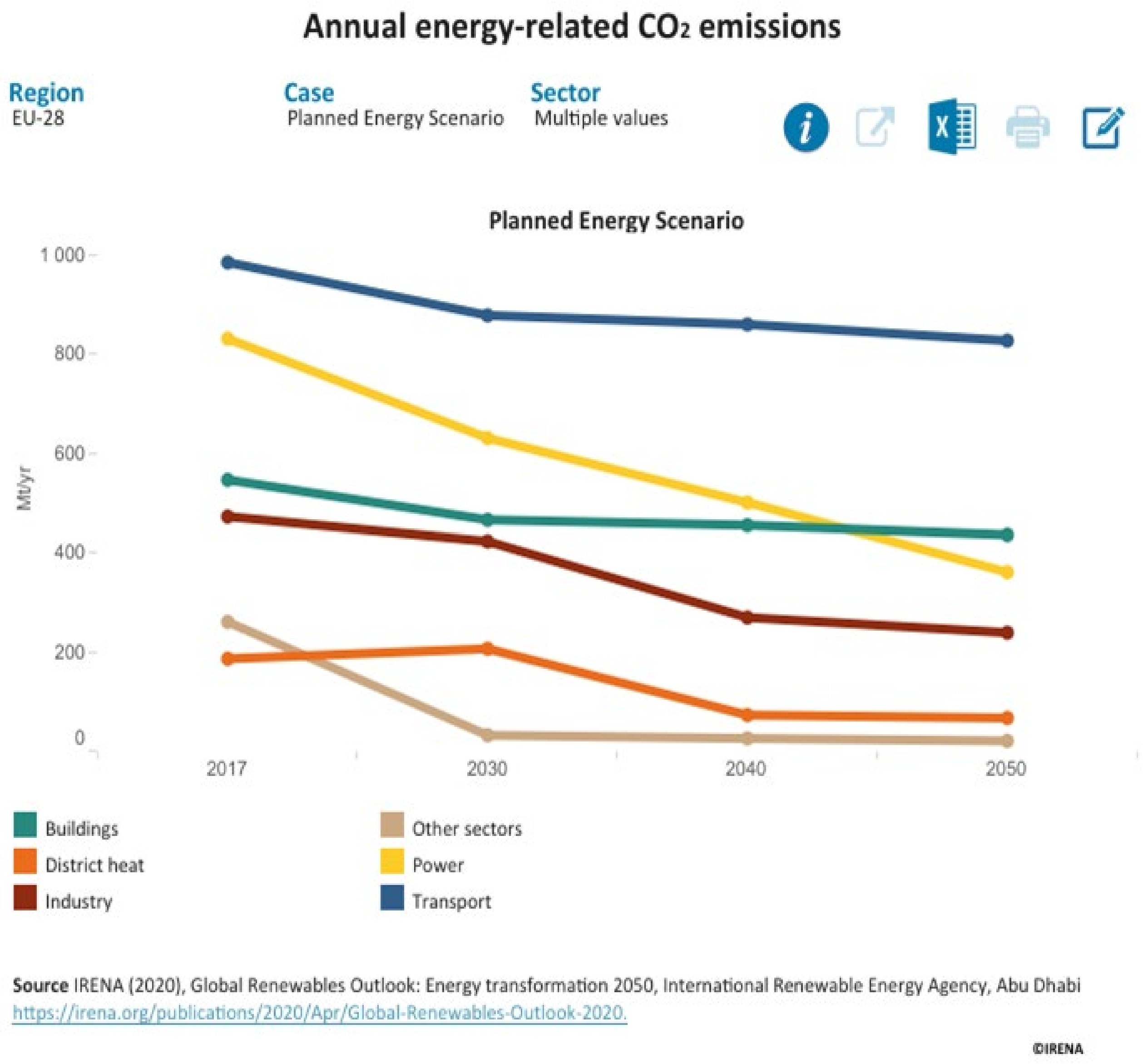

Fig. 11. The annual energy-related CO_2 emissions by sector by year for planned energy scenario to 2050 in EU-28 (Source: author's research results with using database IRENA)

Fig. 12 provides information of the annual energy-related CO2 emissions by sector by year for transforming energy scenario to 2050 in EU-28.

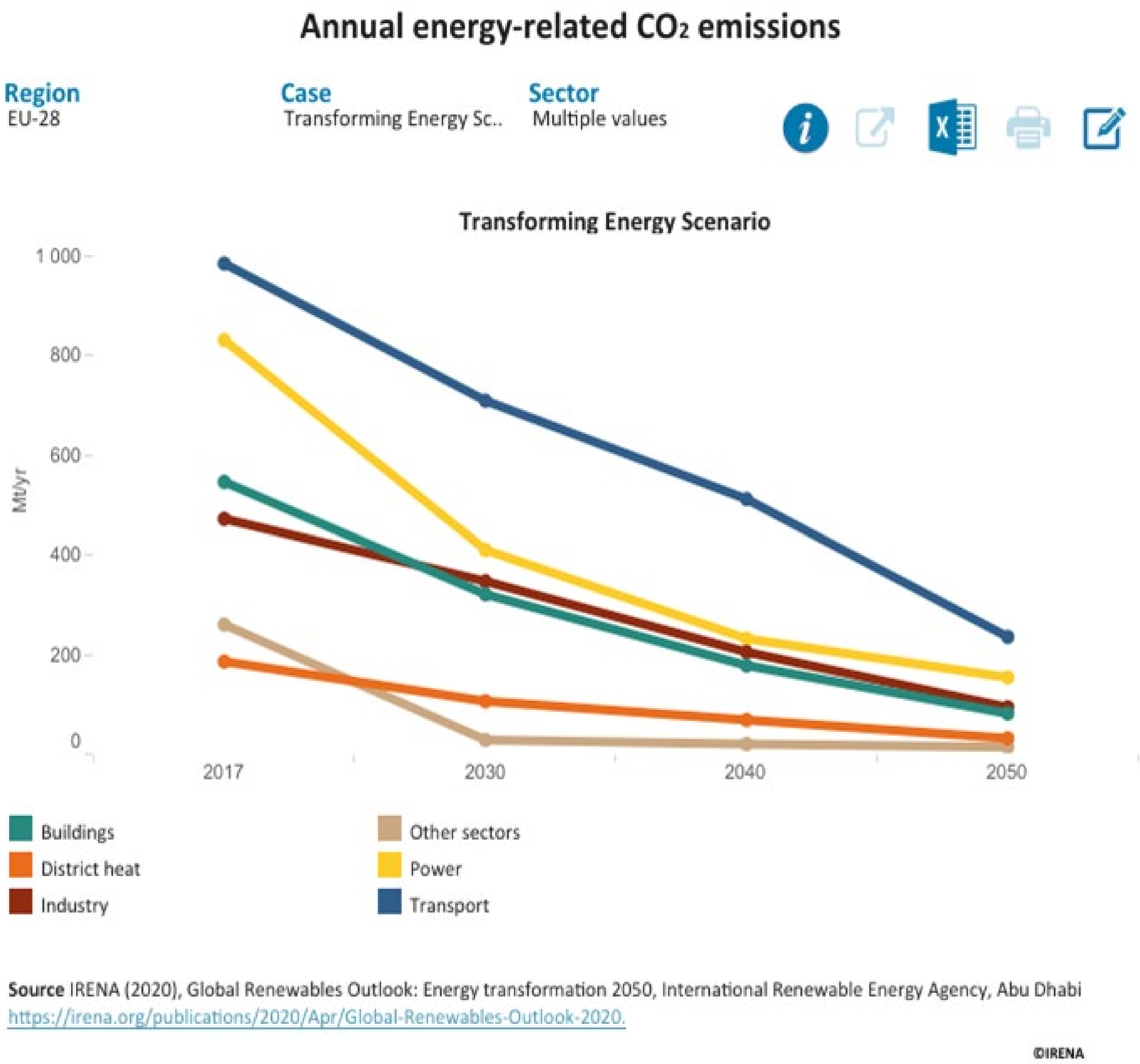

Fig. 12. The annual energy-related CO_2 emissions by sector by year for transforming energy scenario to 2050 in EU-28 (Source: author's research results with using database IRENA)

Fig. 13 provides information of the annual energy-related CO2 emissions by sector (and total) by year for planned energy scenario to 2050 in EU-28.

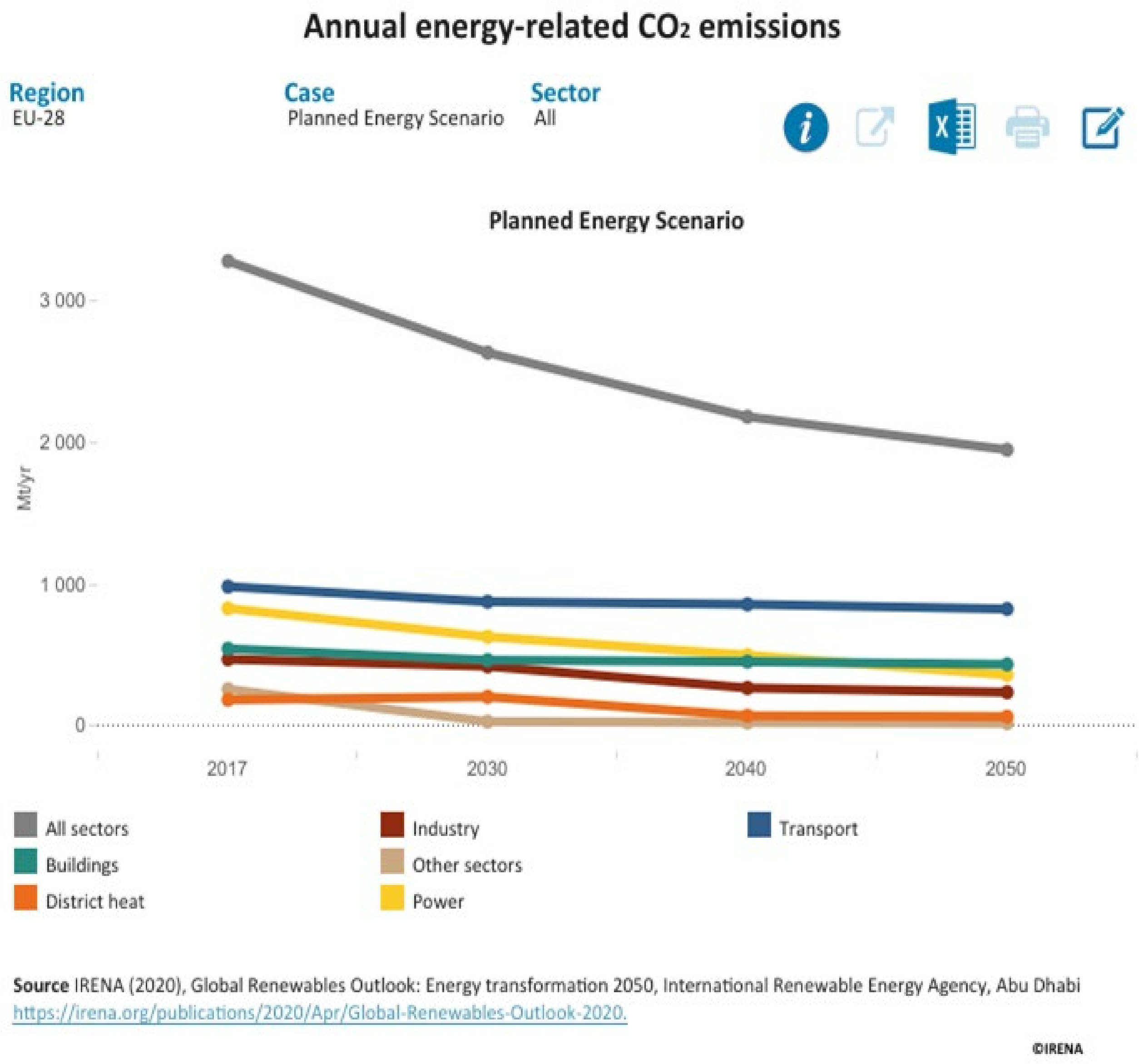

Fig. 13. The annual energy-related CO_2 emissions by sector (and total) by year for planned energy scenario to 2050 in EU-28
(Source: author's research results with using database IRENA)

Fig. 14 provides information of the annual energy-related CO2 emissions by sector (and total) by year for transforming energy scenario to 2050 in EU-28.

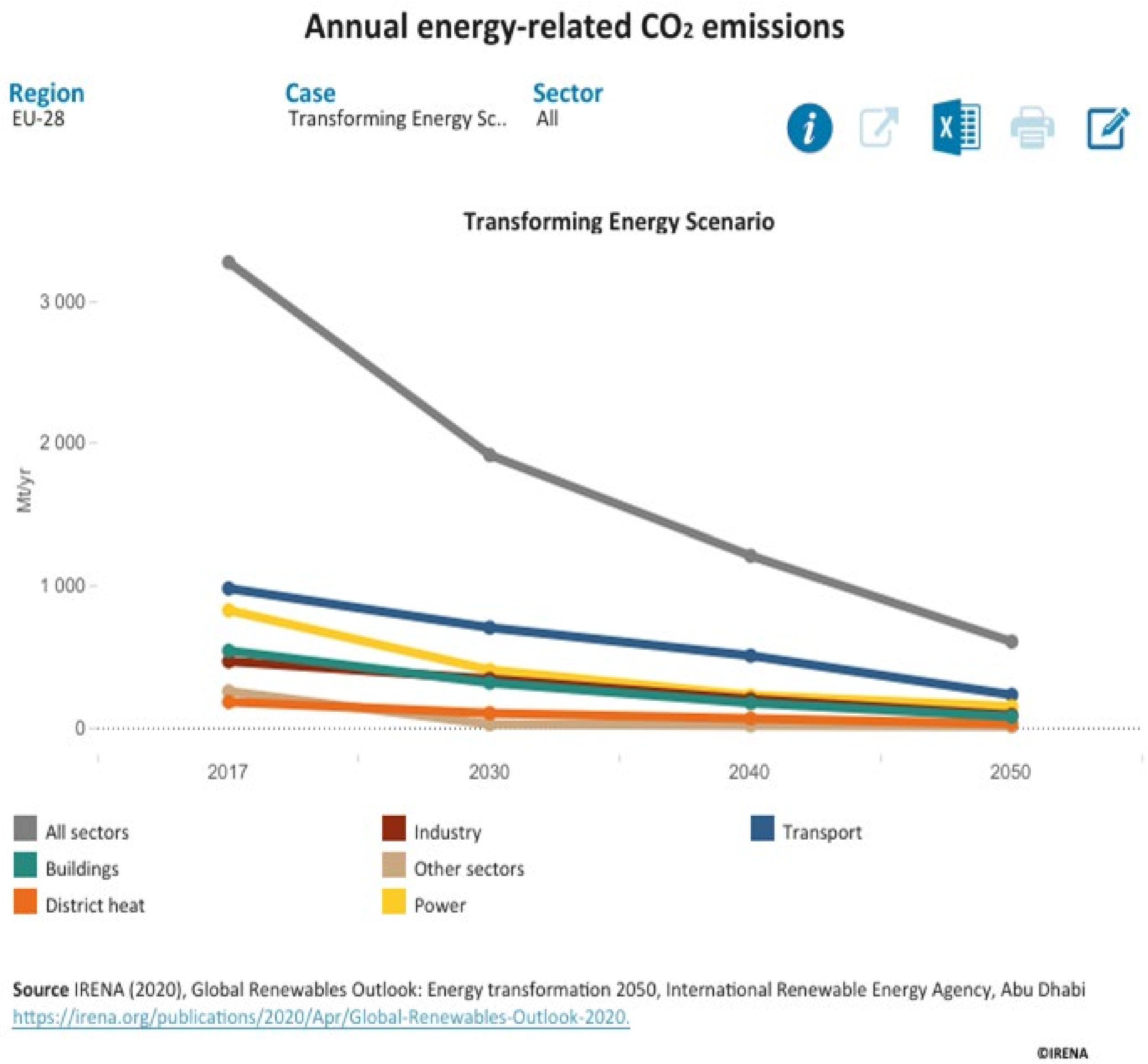

Fig. 14. The annual energy-related CO_2 emissions by sector (and total) by year for transforming energy scenario to 2050 in EU-28
(Source: author's research results with using database IRENA)

Fig. 15 provides information of the annual energy-related CO2 emissions by sector and by year for planned and transforming energy scenario to 2050 in EU-28.

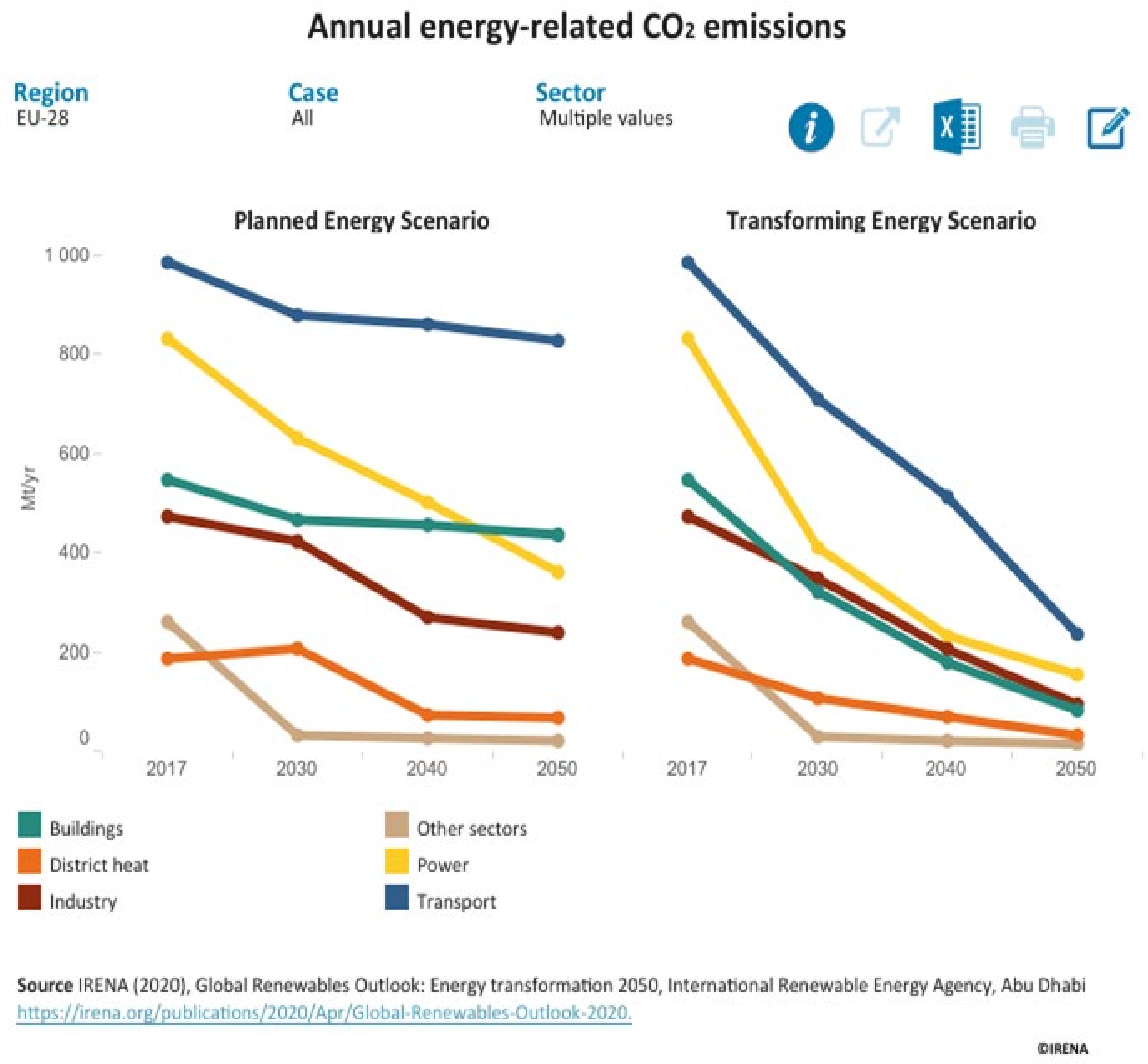

Fig. 15. The annual energy-related CO2 emissions by sector and by year for planned and transforming energy scenario to 2050 in EU-28
(Source: author's research results with using database IRENA)

2 Analysis the trends of transforming the energy sector of Ukraine with using renewable energy sources in the concept of Sustainable Development in the perspective to 2050

In Figs. 16 – 28 shows the criteria for energy, economic and environmental efficiency of innovative technologies for the use of renewable energy sources in Ukraine, which analysed in order to conduct a comprehensive assessment of the effectiveness of energy and resource-saving, environmentally friendly and cost-effective innovative technologies in the concept of Sustainable Development in the perspective to 2050.

The results of research, shown in Figs. 16 – 28, were obtained by the author wuth using a database IRENA.

The scenario of the transformation of the energy system of the World and the European Union in the perspective to 2050, analyzed in Chapter 1, in combination with an additional deeper perspective on reducing carbon dioxide emissions provides a sustainable, environmentally friendly and climate-friendly basis for stable long-term economic development. According to research ("IRENA", 2021), this perspective will reduce global emissions carbon dioxide (CO_2) associated with energy production by 70% by 2050. More than 90% of this reduction will be achieved through renewable energy sources and measures to increase energy efficiency.

According to research ("IRENA", 2021), the ultimate global climate target will be zero emissions. This perspective also looks at ways to reduce CO_2 emissions from 2050 to zero energy balance and possibly even zero. Hydrogen and synthetic fuels, direct electrification, modern biofuels and carbon reduction measures gas will be critical along with innovative business models, structural changes and behavioral adaptation.

Fig. 16 displays data by employment figures in the renewable energy sector of Ukraine for different renewable technologies.

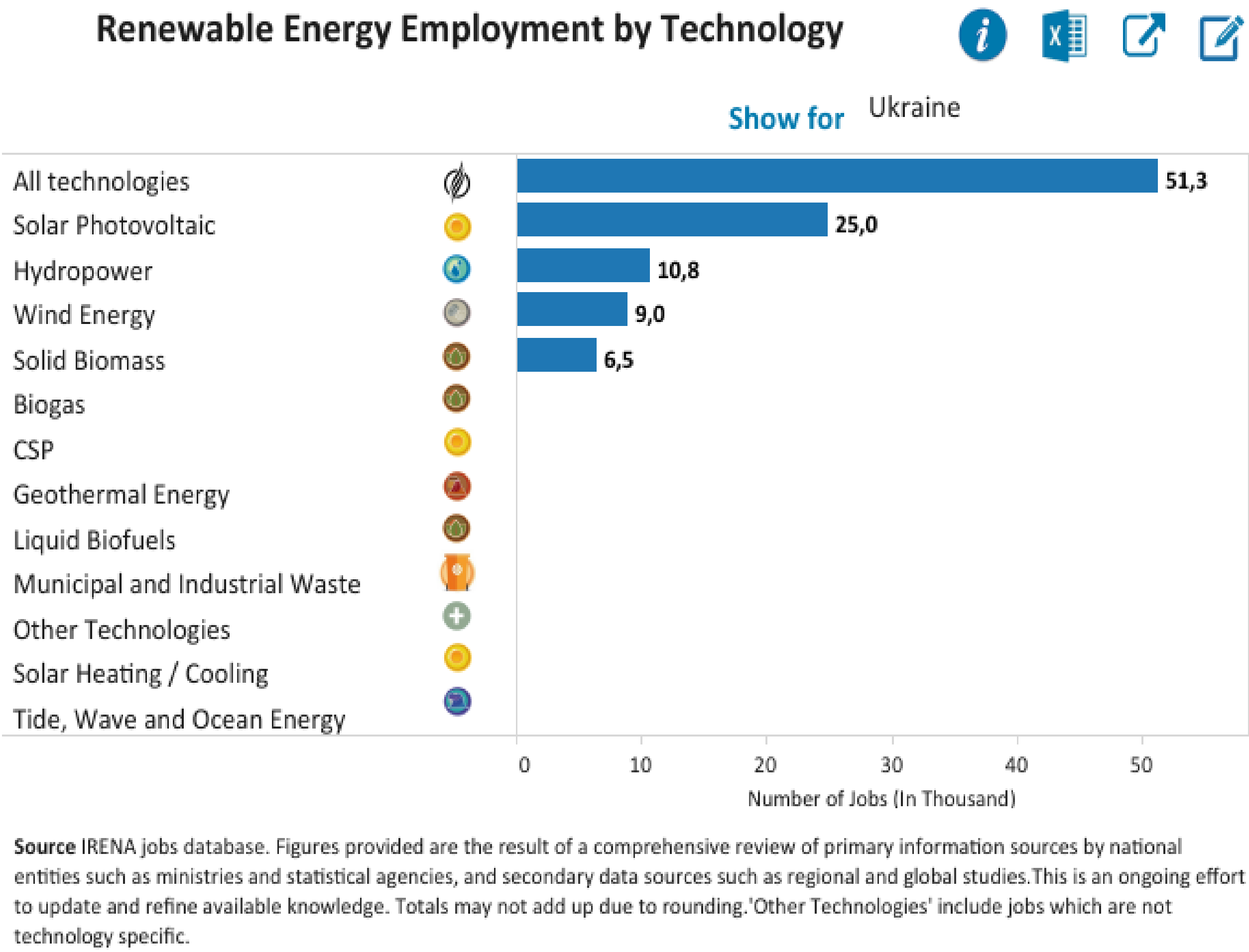

Fig. 16. Data by employment figures in the renewable energy sector of Ukraine for different renewable technologies
(Source: author's research results with using database IRENA)

Fig. 17 displays information on renewable electricity generation in Ukraine for different renewable technologies in 2015-2018.
Fig. 18 displays information of installed capacity in Ukraine for different renewable technologies in 2016-2020.

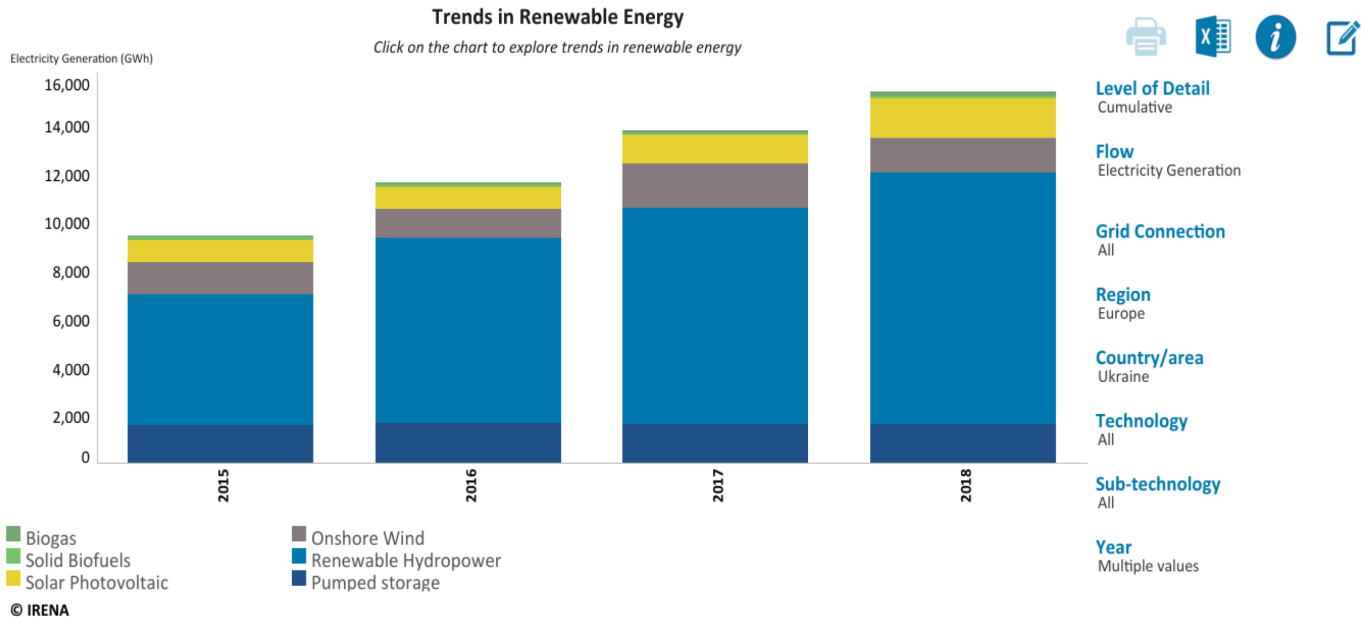

Fig. 17. Information on renewable electricity generation in Ukraine for different renewable technologies in 2015-2018 (Source: author's research results with using database IRENA)

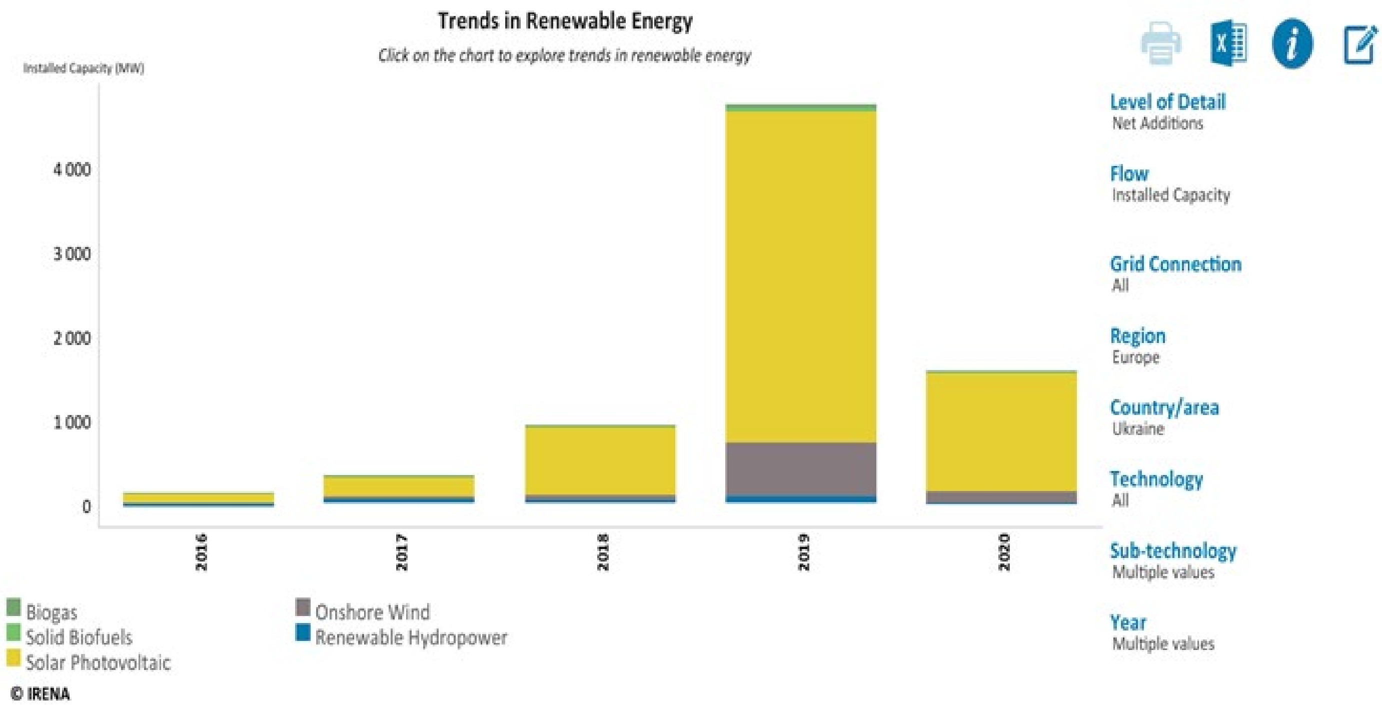

Fig. 18. Information of installed capacity in Ukraine for different renewable technologies in 2016-2020 (Source: author's research results with using database IRENA)

Fig. 19 displays information of total installed capacity in Ukraine for different renewable technologies in 2015-2020.

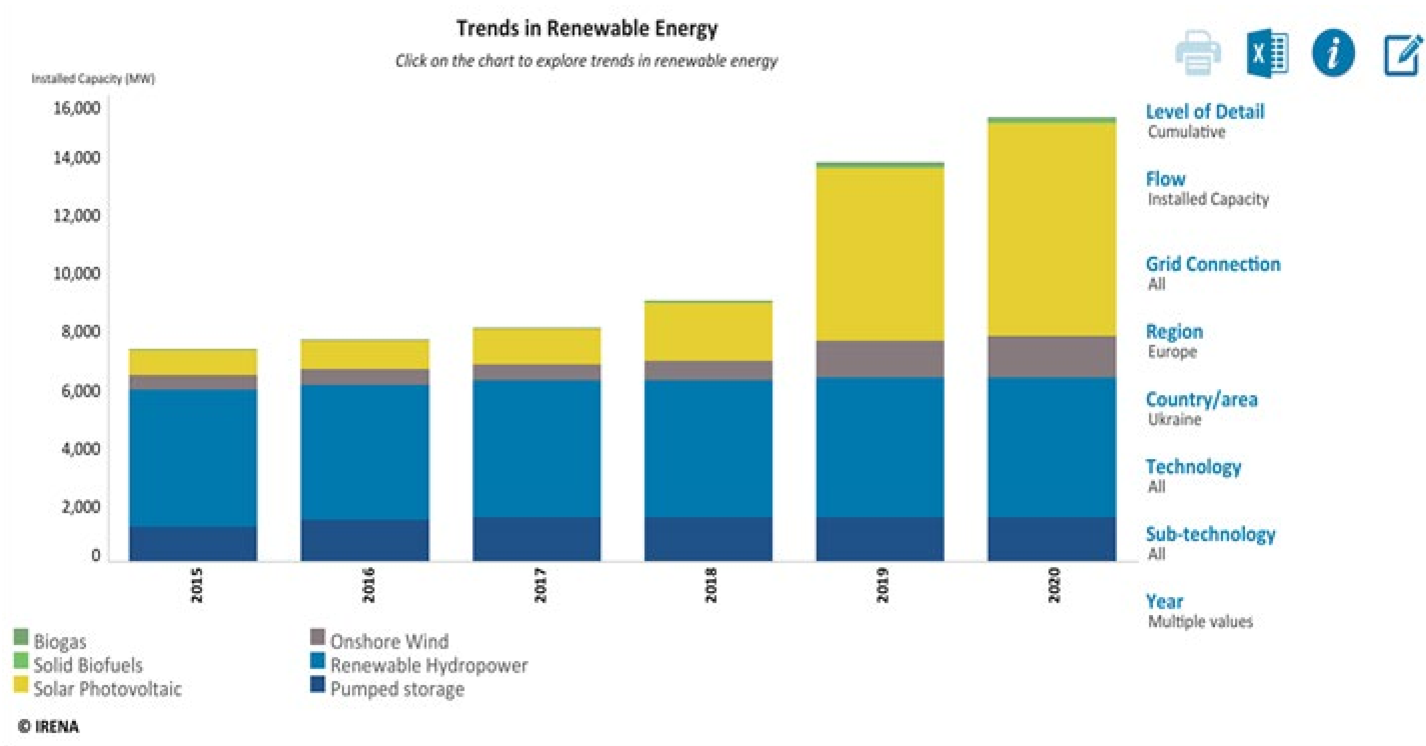

Fig. 19. Information of total installed capacity in Ukraine for different renewable technologies in 2015-2020
(Source: author's research results with using database IRENA)

Fig. 20 displays the country roadmap of Ukraine by REmap to renewable energy (an overview of the total final energy consumption by sector (TFEC), electrical capacity and energy demand by sector) for the reference case and REmap case to 2030 in Ukraine

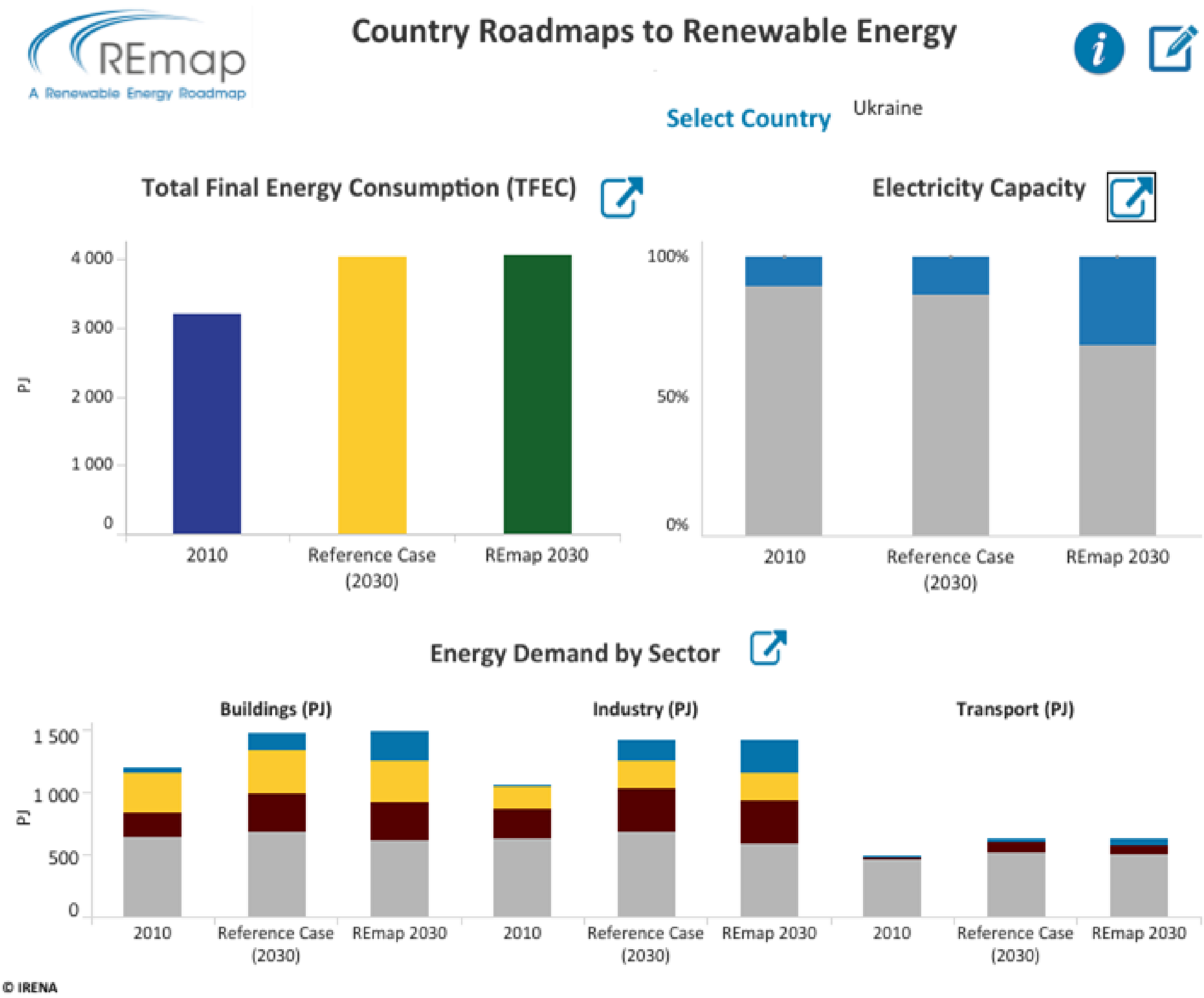

Fig. 20. The country roadmap of Ukraine by REmap to renewable energy (an overview of the total final energy consumption by sector (TFEC), electrical capacity and energy demand by sector) for the reference case and REmap case to 2030 in Ukraine (Source: author's research results with using database IRENA)

Fig. 21 displays information of total installed capacity in Ukraine for wind renewable technology in 2016-2020.

Fig. 22 displays information of total installed capacity in Ukraine for biogas and solid biofuels renewable technologies in 2015-2020.

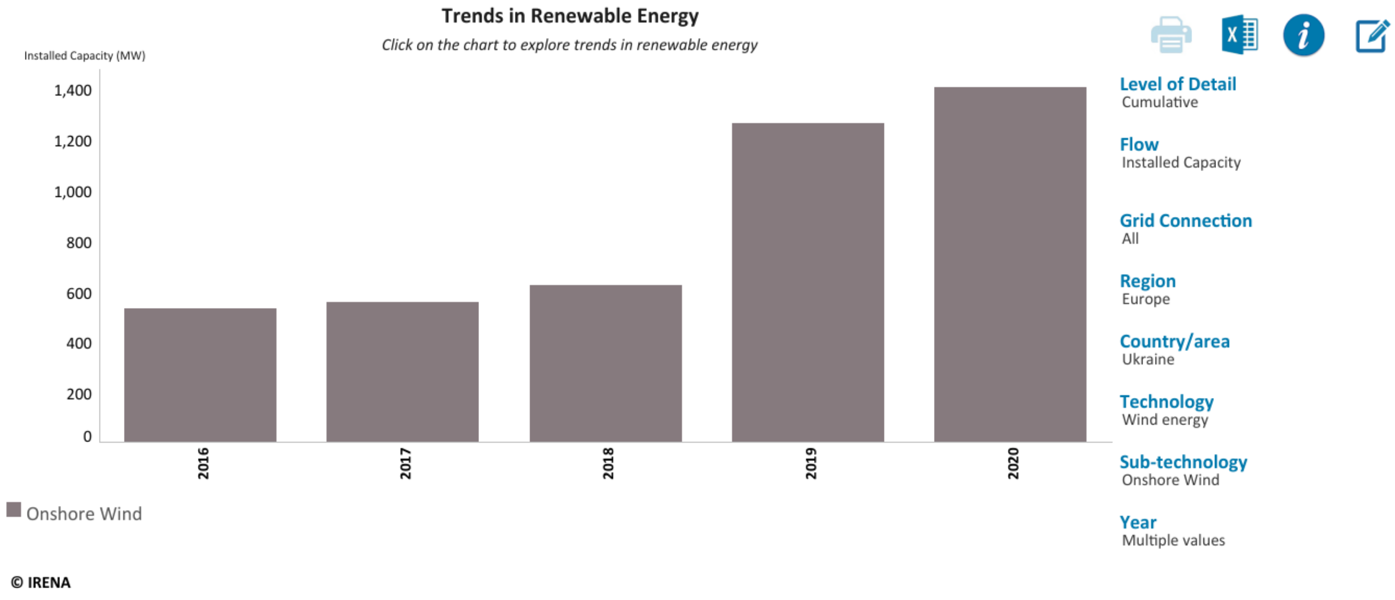

Fig. 21. Information of total installed capacity in Ukraine for wind renewable technology in 2016-2020
(Source: author's research results with using database IRENA)

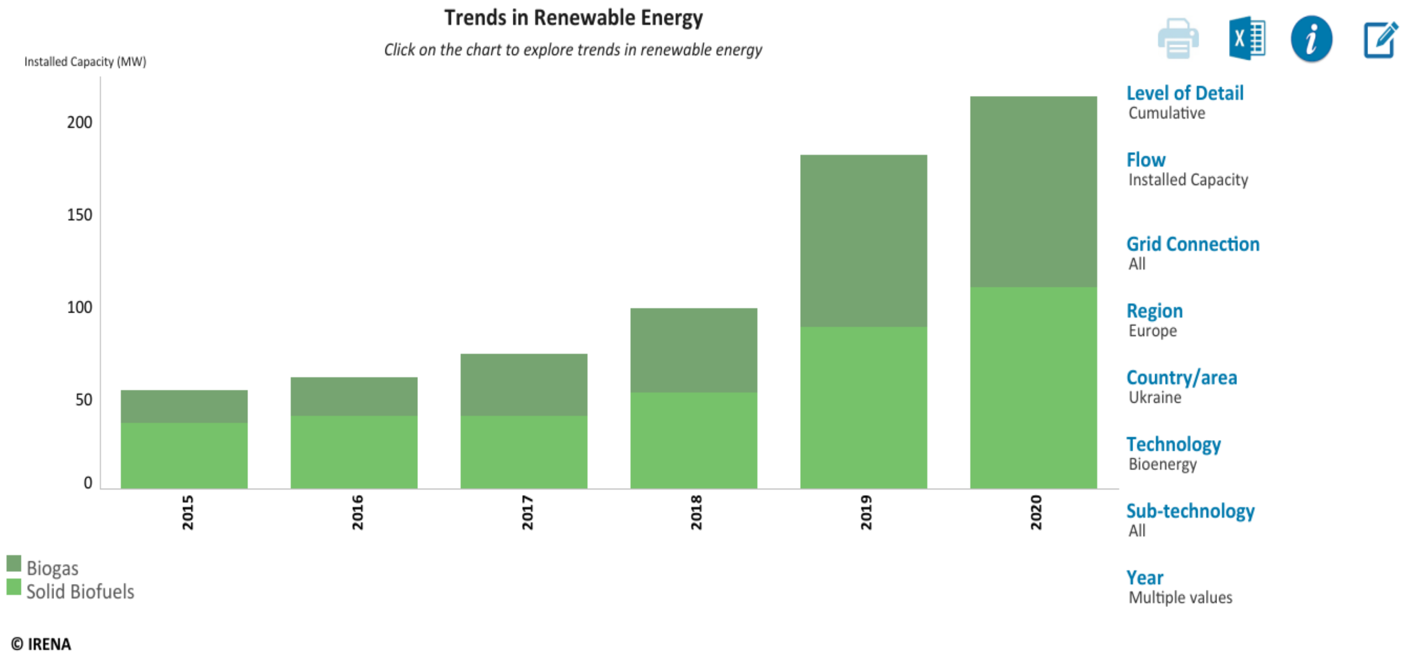

Fig. 22. Information of total installed capacity in Ukraine for biogas and solid biofuels renewable technologies in 2015-2020
(Source: author's research results with using database IRENA)

Fig. 23 displays information of total installed capacity in Ukraine for solar photovoltaic renewable technology in 2016-2020.

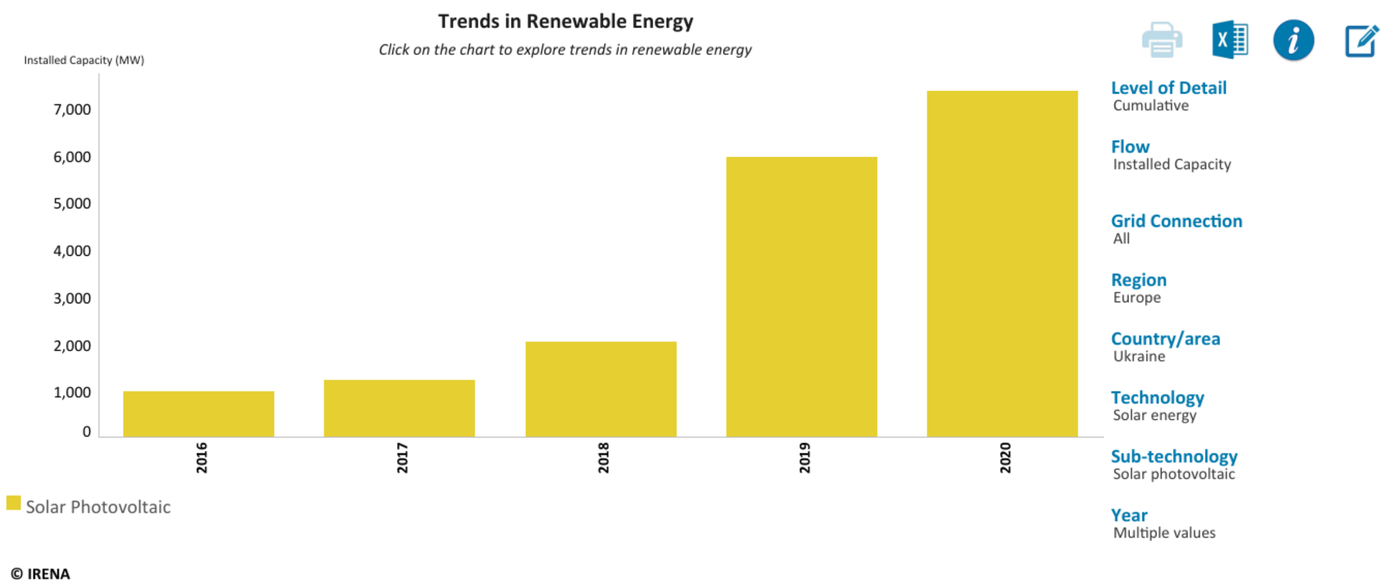

Fig. 23. Information of total installed capacity in Ukraine for solar photovoltaic renewable technology in 2016-2020.
(Source: author's research results with using database IRENA)

Figs. 24 – 28 estimates the greenhouse gas emissions avoided in Ukraine due to a renewable electricity generation in a given year compared to various fossil fuel generation scenarios.

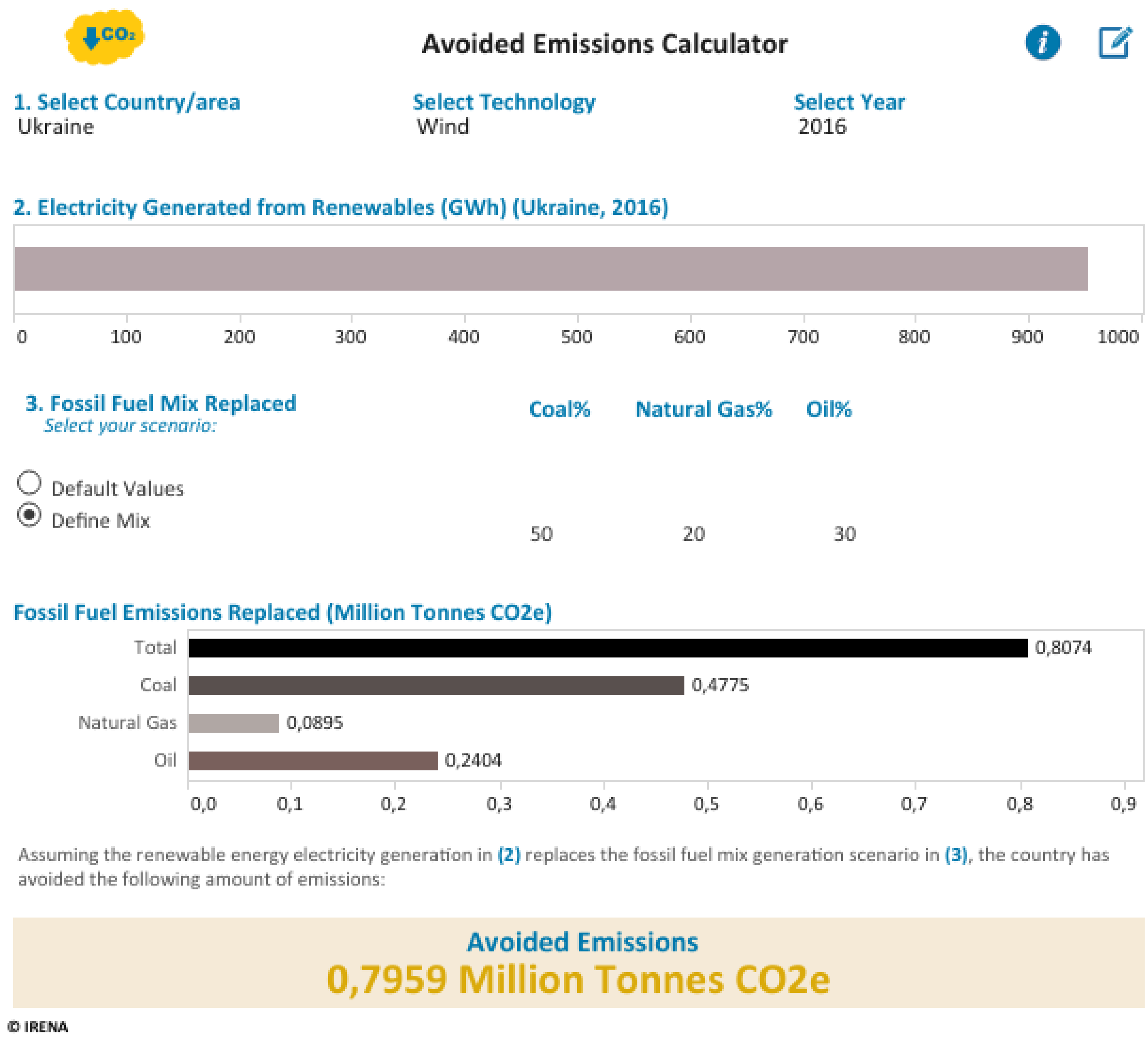

Fig. 24. Greenhouse gas emissions avoided in Ukraine due to a renewable (wind) electricity generation in 2016 compared to various fossil fuel generation scenarios (Source: author's research results with using database IRENA)

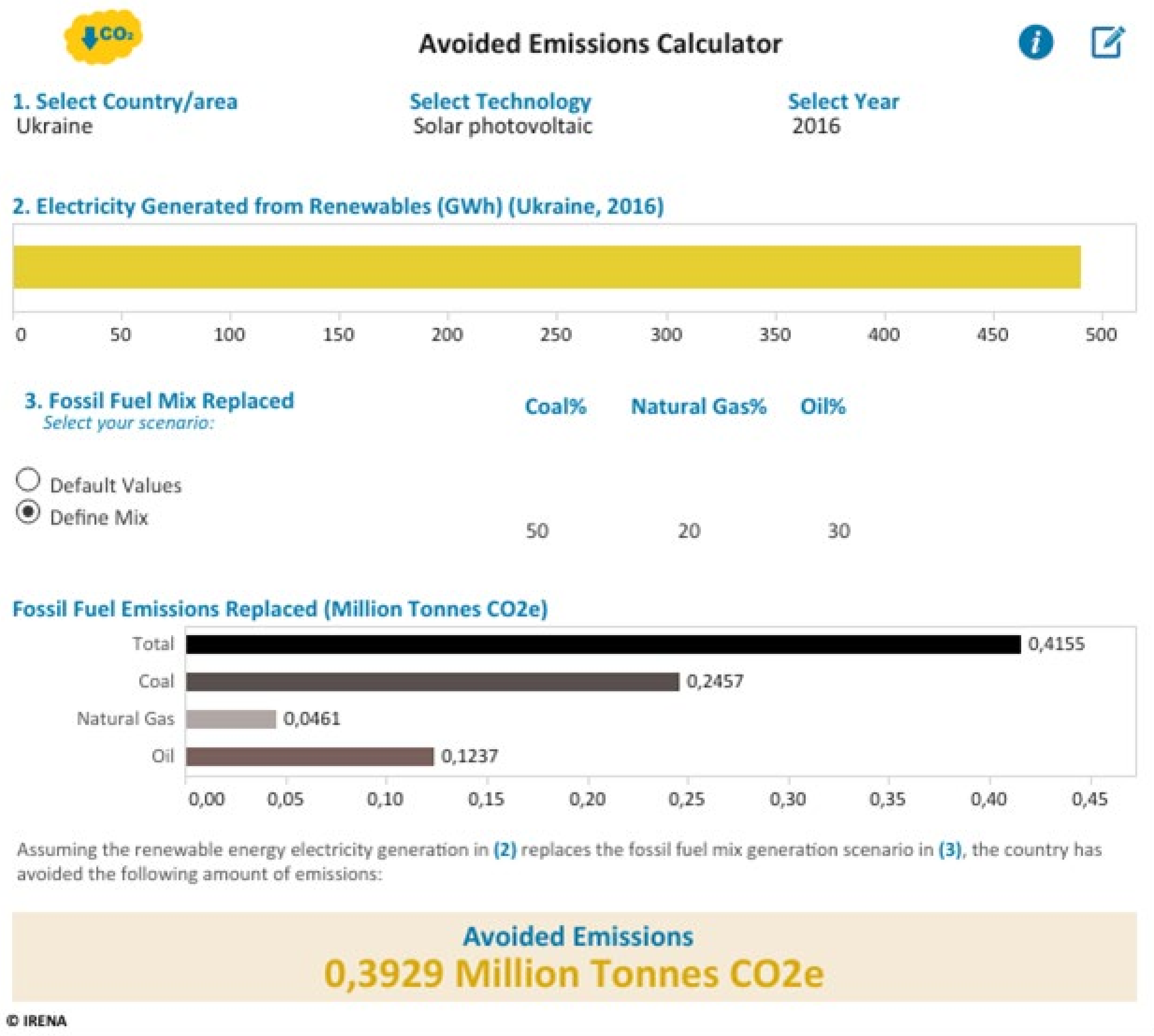

Fig. 25 Greenhouse gas emissions avoided in Ukraine due to a renewable (solar photovoltaic) electricity generation in 2016 compared to various fossil fuel generation scenarios (Source: author's research results with using database IRENA)

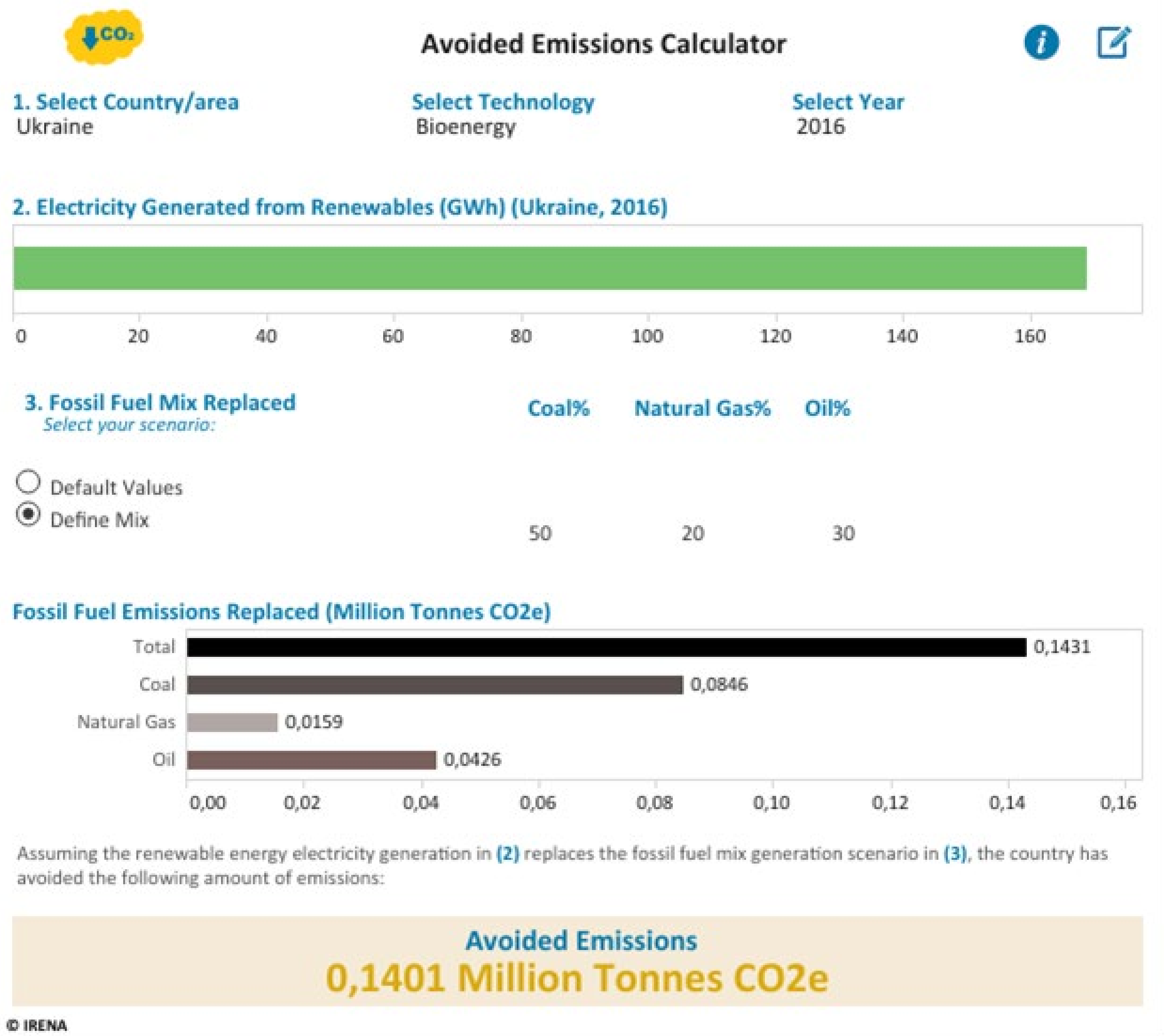

Fig. 26 Greenhouse gas emissions avoided in Ukraine due to a renewable (bioenergy) electricity generation in 2016 compared to various fossil fuel generation scenarios (Source: author's research results with using database IRENA)

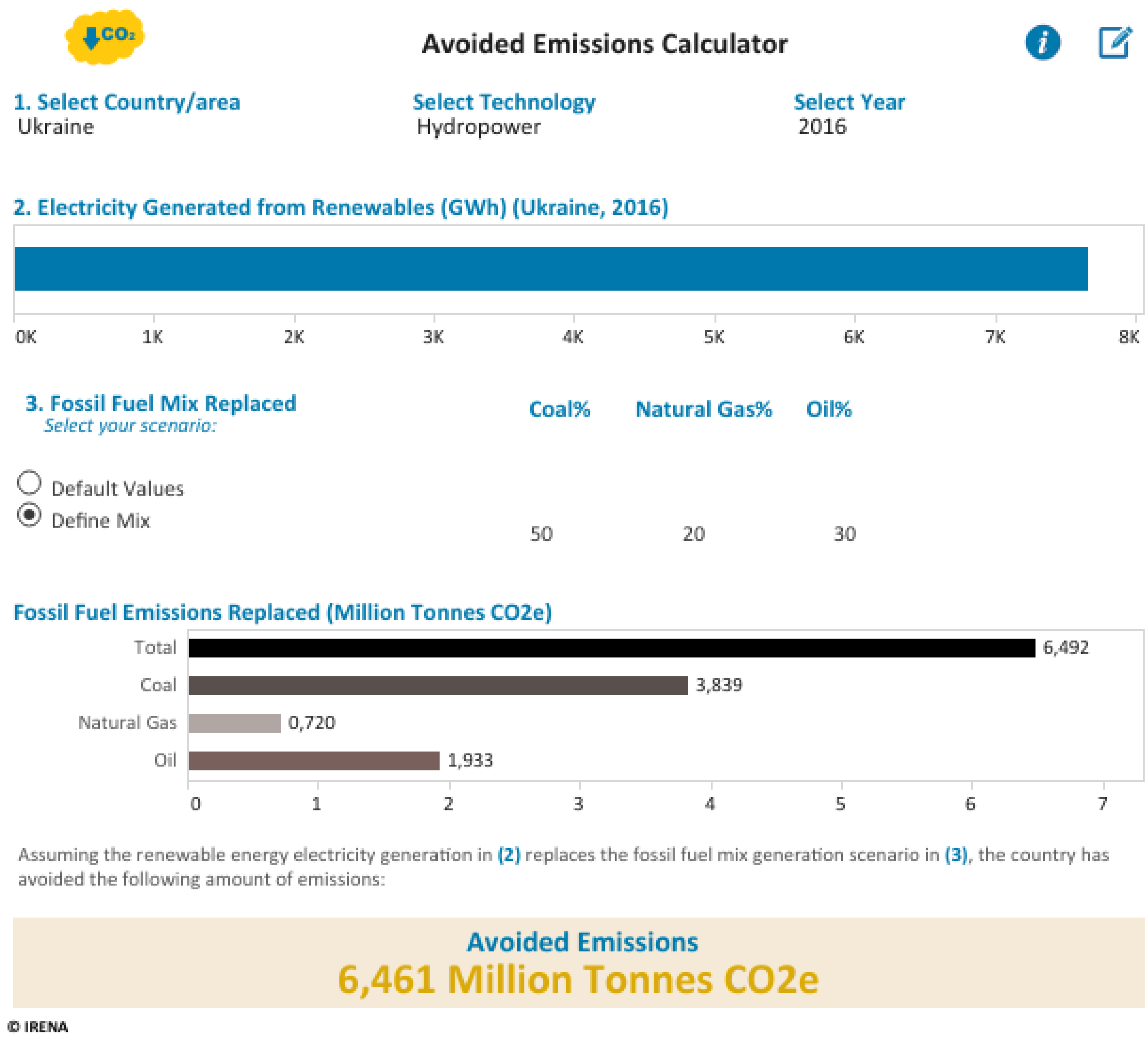

Fig. 27 Greenhouse gas emissions avoided in Ukraine due to a renewable (hydropower) electricity generation in 2016 compared to various fossil fuel generation scenarios (Source: author's research results with using database IRENA)

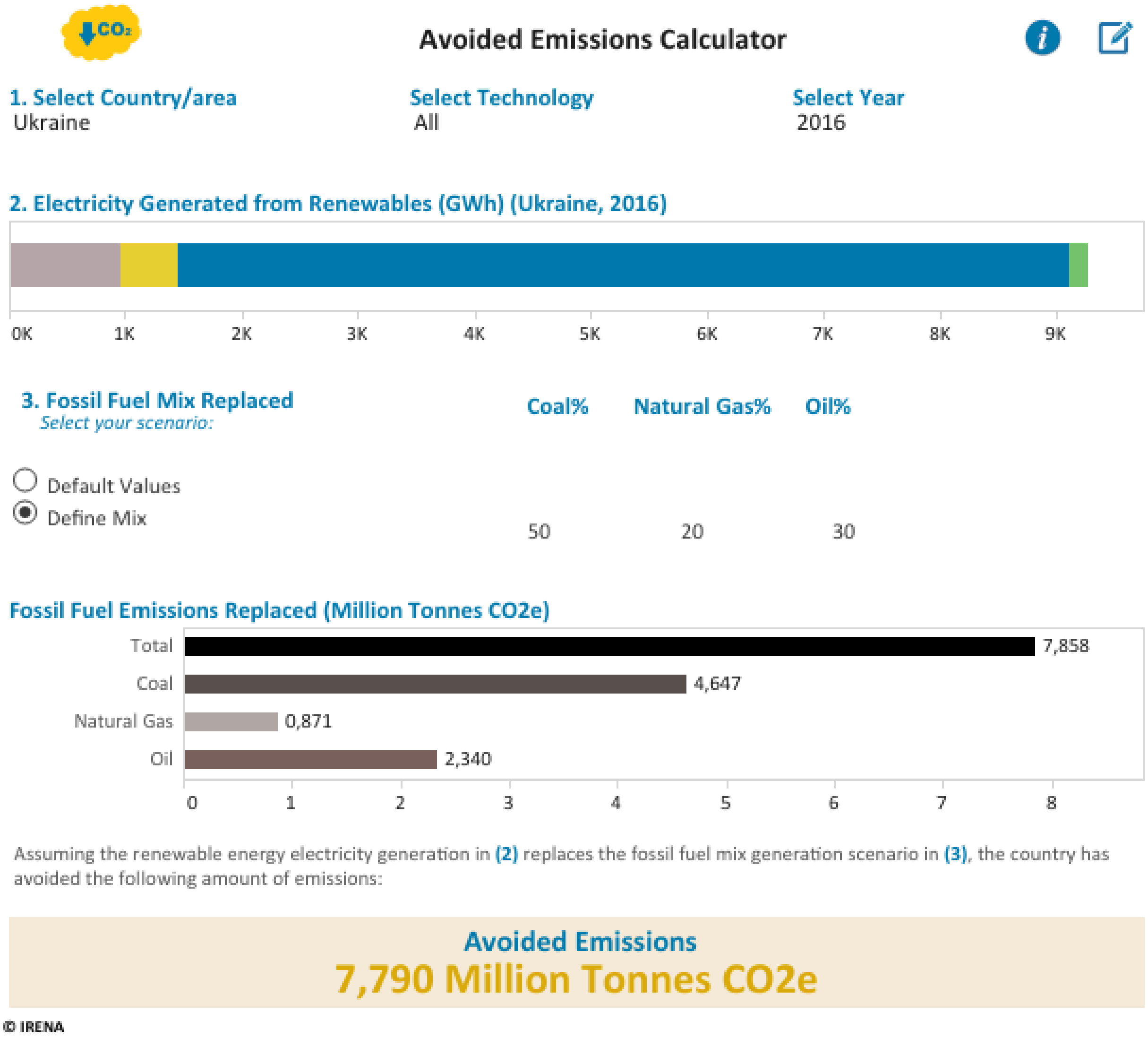

Fig. 28 Greenhouse gas emissions avoided in Ukraine due to a renewable (wind, solar photovoltaic, bioenergy and hydropower) electricity generation in 2016 compared to various fossil fuel generation scenarios (Source: author's research results with using database IRENA)

Conclusions.

The investigation presents an approach aimed at assessing trends in the transforming the energy sector of Ukraine in the future until 2050, using renewable energy sources in the concept of Sustainable Development, with taking into account the trends of transforming the energy sectors of World and European Union in the perspective to 2050.

Our research is aimed at: analysing of the trends of transforming the energy sectors of the world, the European Union and Ukraine and identifying the benefits of using renewable energy sources in the concept of Sustainable Development in the perspective to 2050, assessment of prospects for the application of innovative technologies based on renewable energy sources in the concept of Sustainable Development.

A number of criteria for energy, economic and environmental efficiency of innovative technologies for the use of renewable energy sources are analysed in order to conduct a comprehensive assessment of the effectiveness of energy and resource-saving, environmentally friendly and cost-effective innovative technologies in the concept of Sustainable Development in the perspective to 2050.

This approach allows providing a reasonable definition of prospects for the use of energy and resource-saving, environmentally friendly and cost-effective innovative technologies for the use of renewable energy sources in the concept of sustainable development to increase energy, economic efficiency and environmental security of Ukraine's energy sector in the perspective to 2050.

According to research ("IRENA", 2021), this perspective will reduce global emissions carbon dioxide (CO_2) associated with energy production by 70% by 2050. More than 90% of this reduction will be achieved through renewable energy sources and measures to increase energy efficiency. According to research ("IRENA", 2021), the ultimate global climate target will be zero emissions. This perspective also looks at ways to reduce CO_2 emissions from 2050 to zero energy balance and possibly even zero. Hydrogen and synthetic fuels, direct electrification, modern biofuels and carbon reduction measures gas will be critical along with innovative business models, structural changes and behavioral adaptation.

It is determined, that in Ukraine, the percentage of usage of renewable energy and biofuels is 3…4 times lower than in the EU. This indicates the need to increase the share of non-traditional and renewable energy sources in the fuel and energy sector and in the energy sector of Ukraine.

The application of the methods of Sustainable Development and sustainable energy in order to increase the level of energy-economic efficiency of the energy sector of Ukraine with using of renewable energy sources in the perspective to 2050 is presented in given paper.

The justification of the application of the methods of green logistics and sustainable development for the analysis of perspectives of application of innovative technologies is presented in the research (Ostapenko, Savina, et al, 2020).

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