INSTITUTE OF RENEWABLE ENERGY,
NATIONAL ACADEMY OF SCIENCES OF UKRAINE
HISTORY, TODAY AND PROSPECTS

2nd edition extended and updated

Edited by
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The extended and updated edition contains the information about the history of renewable energy development in Ukraine. The establishment process, the structure and core departments, the founders, current state, ways forward and overall perspectives are brought together in one book to present the reader an overarching concept about the Institute of Renewable Energy with the National Academy of Ukraine, its research policy and various activities. The publication provides the most significant outcomes of research and developments during its entire period in operation. All of them contributed much to the scientific and technological progress in overall renewable energy development in Ukraine, including the core of the works and measures performed upon the requests from the national government initiated to boost the national energy policy development in the domain of energy saving due to renewables.

The publication highlights the key achievements in fundamental and applied research of the Institute in the main lines of renewable energy and promising areas for further research. The book provides data on technical standard writing, publications, science and education, training the academic staff and international activities.

Target audience: scholars, postgraduates and higher education institution students majoring in energy and all the interested parties dealing with various aspects in renewable energy of Ukraine.
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ABBREVIATIONS

ISTCWP – Inter-Branch Scientific and Technical Centre for Wind Power, IRE NASU
GW – gigawatt
EE – energy efficiency
GHG – greenhouse gases
IE – Institute of Electrodynamics, NASU
Igor Sikorsky Kyiv Polytechnic Institute – National Technical University of Ukraine ‘Igor Sikorsky Kyiv Polytechnic Institute’
IRE – Institute of Renewable Energy, NASU
IRENA – International Renewable Energy Agency
kW – kilowatt
MW – megawatt
NASU – National Academy of Sciences of Ukraine
NREAP – National Renewable Energy Action Plan
NTUU ‘KPI’ – National Technical University of Ukraine ‘Kyiv Polytechnic Institute’
PV – photovoltaic
R&D – research and development
RES – renewable energy sources
RE – renewable energy
SME – small and medium enterprises
STC – Scientific and Technical Council
UNIDO – United Nations Industrial Development Organization
WPP – wind power plant
FOREWORD

Searching for new energy sources to meet the energy demand of Ukraine’s population and industry is extremely important. Renewable energy sources (RES) offer the most promising technologies in the world’s energy sector addressing a number of challenges associated with hydrocarbons depletion and environmental safety requirements.

The use of renewables today is among key developmental priorities for energy development in the majority of developed countries. In particular, the United States, Germany, Spain, Sweden, Denmark, and Japan plan to bring the share of RES in their total energy balance up to 20–50% in the first half of the 21st century. More and more countries, cities and communities are committing to a long-term 100% renewable energy target.

To meet the SDGs requirements, the United Nations Organisation has declared among the main goals (1) renewable energy development; (2) clean energy provision; (3) combating climate change, and (4) the quality of education. Signed by Ukraine, the United Nations Framework Convention on Climate Change (UNFCC) sets the goal to reduce GHG considerably via RES promotion. The World’s Energy Scenarios stipulate that renewables and biofuels will generate 20% of total electricity in 2020 and 50% in 2040, while at the end of the 21st century the share of RES-based electricity and biofuels may rise beyond 85%. By 2050, the European Union plans to bring the share of RES and biofuels in its total fuel and energy balance up to 50%.

Ukraine, as a party to the Convention, sets the targets to reduce GHG emissions by 25% until 2020, and by 40% until 2030, committing to an ambitious goal to achieve 70% reduction by 2050.

According to the International Renewable Energy Agency, nearly 33% of the total global generation was attributed to renewable energy sources in 2018, with the share of renewable energy installations achieving 34.7% of total installed capacity as of 2019-year end.
The total increment in the use of renewables 2.6-fold surpassed the growth in fossil fuels in 2019, comprising 72% of all new installations. In particular, Europe and North America decommissioned more power plants running on fossil fuel than commissioned new ones. 176 GW of renewable energy capacities were launched in total within the year, with the major share of solar and wind generation. The total installed capacity of green power generation globally has reached over 2,300 GW. The development of renewable power not only decreases the dependence on conventional fuels but also adds to social and economic growth of the countries and helps creating new jobs. The renewable energy sector provide jobs to over 10 million people worldwide; IRENA forecasts say 28 million persons will be engaged in green energy production by 2050.

The energy sector of Ukraine, on the one hand, suffers the equipment problems (mostly obsolete, worn-out and low-efficient equipment) and the shortage in supply of feedstock. Negative trends prevail in the fuel and energy sector of Ukraine, specifically, the growing deficit of domestic primary energy, its growing prices at the world’s market and exportation problems, inefficient use of available fuels and energy sources and almost no diversification in feedstock supply threatening the national security of Ukraine.

The problems in conventional fuel supply catalyze the implementation of power plants running on RES in Ukraine.

The development of renewable energy in Ukraine, where RES are available almost everywhere throughout its territory, is part of the national policy. Specifically, the National Renewable Energy Action Plan until 2020 was adopted in 2014. IRE’s experts were engaged in drafting NREAP as well as in discussions of the draft Energy Strategy of Ukraine until 2035. The Strategy gives a significant role to renewable energy development. To increase diversification of the energy sources, induce investments in the economy and strengthen the energy security and environmental safety, the strategic plans of
Ukraine suppose to bring the share of RES in the total primary energy up to 25% by 2035 that is consonant with the global trends and international commitments of the country. Ukraine has adequate preconditions for further development of the renewable energy. The state provides support to RES development implementing the national system of legislative, financial, economic, regulatory, and analytical and public awareness measures. 2019 saw the total launch of nearly 4,700 MW new renewable energy installed capacities in Ukraine (PV power plants, roof solar, wind power plants, small hydros, biomass/biogas plants), and nearly 3.8 billion Euro investments were raised. The total capacity of wind power reaches nearly 1,170 MW. The largest PV plant with 388.5 MW installed capacity operates in Dnipropetrovsk region. Nowadays, RES account for 3.7% share in total domestic power generation.

In the first two months of 2020, solar, wind and biomass power plants increased their output up to 1.184 billion kWh, and that is 2.68-fold as compared to the similar period last year. It is worth noting that the generating plants operating in and dispatched centrally by the Unified Energy System of Ukraine have increased their generation by 19.2% (288 million kWh). As of April 1, 2020, the total capacity of roof solar panels throughout the regions reached 618 MW, with the energy output being nearly 710 million kWh/year.

However, the rapid growth in RES capacities should go hand in hand with adequate transformation in the Unified Energy System operations. The lack of proper preparation resulted in the range of obvious problems and even gave a handle to the talks about crisis in the energy sector of Ukraine. Among the reasons, we can mention both the growth in green generation without relevant maneuver capacities in place in the energy system, and the conjunction of circumstances: lower demand for electricity, limited maneuverability of hydros due to negative weather conditions, changes in the structure of generation and lack of coordination with the adjacent energy systems. As a result, the relative share of renewable energy in
the energy balance of Ukraine grew disproportionally while reserve generation potential dropped, given that the Unified Energy System was not enough flexible even without RES component. Among the negative factors are the lack of well-functioning forecasting system for wind and solar energy in combination with geospatial location of wind and solar plants in one limited region increasing the uneven total distribution of generation and complicating power dispatching. All of them have been so much talked about in recent years. Relevant validation is required in order to optimize the structure and locations for new power plants, and economic aspects of alternative energy and delivery by energy market players of supplementary services to balance the generation and the consumption. Addressing the above challenges requires proper scientific research and drafting a smart industry development strategy.

At the same time, specifics of the recent renewable energy legislation in Ukraine demand new approaches to RES-based power equipment operation. Safe operation of such power systems with a significant share of renewables will require installing efficient storage units. This is especially relevant in terms of creating balancing capacities for the power obtained from renewables in Ukraine in pursuance of the Law of Ukraine No. 2712–VIII dd. April 25, 2019 ‘On amending certain laws of Ukraine to ensure competition in power generation from alternative energy sources’.

To ensure stable power supply both in Ukraine and all over the world, the range of challenges should be addressed, namely: (1) research and technology problems related to renewable energy; (2) improving the efficiency coefficient of RES-based power facilities and integrated use of various RES; (3) reducing costs of energy generation; (4) creating innovative dispatching patterns: reliable forecasting of electricity and heat generation and introducing energy storage technologies.
Domestic science plays an important role in the implementation of Ukraine’s National Renewable Energy Action Plan. Fundamental and applied research have been conducted to improve technological and economic efficiency of RES-based energy generation systems, specifically: (1) the development of theoretical basis to underlie the use of various energy sources; (2) research and development into, creation and application of new methods and technologies for RES-based power systems; (3) improvements to operating modes of RES-based equipment; (4) creation and application of combined systems with the use of different RES-based equipment and different types of energy storage units; (5) solving the compatibility problem of certain RES-based power installations with the Unified Energy System. To ensure high quality of the activities, state-of-the-art research methods including efficient simulation methods and up-to-date software must be in place.

IRE conducts fundamental and applied research aimed at obtaining new scientific knowledge as concerns new key lines in renewable energy development and introducing RES into practices via actual project implementation. In drafting efficient legislative and regulatory framework, standardization and certification of RES-based equipment, education activities and active international cooperation, we focus on the development of renewable energy as an efficient energy industry of Ukraine contributing to the national energy security.

_Stepan Kudria, Ph.D.,_

_Corresponding Member,_

_the National Academy of Sciences of Ukraine_
Current trends in renewable energy development in Ukraine trace back to the 80s of the last century and were initiated in Kyiv Polytechnic Institute (now ‘National Technical University of Ukraine ‘Igor Sikorsky Kyiv Polytechnic Institute’) by its rector Hryhorii Denysenko, the Corresponding Member of the USSR’s Academy of Sciences, Professor, Doctor of Engineering and Meritorious Scientist of Ukraine.

One can name laying the foundations of domestic renewable energy among Hryhorii Denysenko’s major R&D achievements. In 1979, Kyiv Polytechnic Institute established an R&D Department (NDV-5) inter alia for fundamental and applied research in integrated use of solar, wind, biomass, geothermal and small river energy as one of its key missions. Those days, renewable energy was in its infancy in the world, and it was the first serious step the USSR undertook for renewable energy development.

Furthermore, it was the first time ever when the Soviet Union applied an integrated approach to renewable energy sources with the use of heat and electricity storages and hydrogen-based energy storing. Young researchers and experts in many disciplines were engaged in these activities to create a new domain of science.

Moreover, all departments of the Kyiv Polytechnic Institute provided their comprehensive support.

Looking from the perspective of the modern stage in renewable energy evolution, Hryhorii Denysenko’s farsighted scientific thinking is worth special mentioning. All the trends selected by him in
developing the renewable energy sources, today, after nearly 40 years of research, turned out to be the most energy efficient technologies both globally and locally, in Ukraine, while the integrated approach to the use of RES in combination with various storage technologies further contributes to improving the energy equipment performance.

Hryhorii Denysenko’s unique faith in the future of renewable energy plus his researcher and organizer talents overcame the bias and backwardness among the energy sector officials being more focused those days on extending the nuclear power capacities. Nuclear energy was deemed inexhaustible and safe for humans and the environment. However, the lessons learned throughout the development of ‘peaceful atom’ have demonstrated the operation of nuclear power plants, even at the state-of-the-art technology level, may cause an accident not only of local or regional scale, but a global catastrophe as well. Nuclear fuel reserves are also not limitless, and their production and processing become more and more energy-intensive and more expensive, respectively. In addition, due to the high volumes of generated so far nuclear fuel waste, the problem of disposing spent nuclear fuel in safe manner is growing more urgent.

The team of enthusiasts created by H. Denysenko travelled the path from theoretical and experimental research, and then R&D works to the creation of demonstration equipment models in wind, solar thermal, photovoltaics, hydropower, bioenergy, and energy storage technologies. Particular focus was on improving performance of RES-based power plants via integrated applications combining heat and electricity storages, hydrogen-based storages for RES energy and automated control of their operation modes.

Verifying research findings and testing operating modes were both carried out at ‘Desna’ testing ground, on the border of Kyiv and Chernihiv oblasts. For the first time in the USSR, a 160 kW multi-module wind power plant was built there, it consisted of eight wind
power plants, with a capacity of 20 kW each (pic. 1). In the course of field-testing, wind turbine efficiency was studied trying different designs of blades, reducers, generators, storage systems and auxiliary equipment. The operation modes of the wind farm were researched in parallel operation with the industrial power system and as part of autonomous power supply systems.

Various designs of solar receivers, photoconverters, heat pumps, bioinstallations, wind power and wind mechanical units, heat and electricity storage systems were researched at the testing ground. To the end of identifying the best power generation and cost efficiency indicators via analysis of testing results, the researchers assembled integrated power systems of various components and tested them.
Three laboratory buildings were built and equipped with various systems of integrated energy supply from renewable energy sources and various energy storage units (pic. 2).

![Picture 2. Laboratory buildings equipped with various RES-based integrated energy supply systems](image)

The energy to the greenhouses at the testing ground was supplied from solar and wind technologies, and the system included heat storage, which accumulated low-potential and waste energy from RES-based power plant equipment to supply it in the periods of scarce electricity generation (pic. 3).

It is worth noting that these works were performed in the times when the attitude to renewable energy was quite skeptic, in addition, major hopes were set on conventional energy industry, since nuclear technology was then thought to be the future of the energy sector.

Unfortunately, due to the lack of funding, ‘Desna’ testing ground was decommissioned in 1990s.

*See more details of the equipment’s technological schemes and modes of operation at the testing ground in the following publications:
However, the Institute of Electrodynamics (IE), NASU, continued research and development in this domain. In 1987, IE formed a department for integrated energy systems based on renewable energy sources. Even in the hard economic times of 1990s, Professor Denysenko did his best to preserve the team of researchers who facilitated the development of renewable energy in Ukraine. As a result, the Institute of Renewable Energy was founded in 2003 at the National Academy of Sciences of Ukraine.
FOUNDING THE INSTITUTE OF RENEWABLE ENERGY

In the early 2000s, research into renewable energy in Ukraine was mostly concentrated at the institutes under the National Academy of Sciences of Ukraine (NASU): the Institute of Electrodynamics, the Institute of Technical Thermophysics, the Institute of Mechanical Engineering, the Institute of General Energy and the Institute of Coal Energy Technologies. They researched and developed the technologies and equipment intended for using solar, wind, biomass, geothermal, small river energy, designed demonstration prototypes of fuel cells efficiently converting chemical energy of fuel into electricity, studied potential applications of hydrogen in energy sector.

However, despite certain progress, R&D organization and funding, scope, level and performance those days did not meet the then state-of-the-art requirements. It was time to give a new impetus to progress in this domain by creating a specialized institute to tackle renewable energy issues. A new profile institute was expected to concentrate dispersed, tiny in number and low in capacity teams developing separate technologies those days into a single goal-oriented institution, to create a research and experimental base appropriate to state-of-the-art level, provide targeted information support, raise additional funding, organize broad international cooperation, coordinate research outside NASU. To meet one of the objectives declared in ‘Program of state support for the development of non-conventional and renewable energy sources, small hydros and thermal technologies’, specifically ‘the creation of specialized infrastructure based on existing training, design and research organizations’, Institute of Renewable Energy (IRE) was established in December 2003. IRE joined those separate lines in the renewable energy studies into a single organizational structure. IRE NASU was founded as a component of the Department of Physical and Technical Problems of Power Engineering.
Its mission was to further develop and coordinate renewable energy research and ensure application of their outcomes in practices (pic. 4). Its manning table was completed with researchers via transfer of the team for RES-based integrated energy systems from the Electrodynamics Institute and the teams from the structural units of Technical Thermophysics Institute, plus RE experts, and young scientists from other Ukraine’s research institutions.

The Resolution of NASU Presidium No. 299 of December 10, 2003 approved the key lines for IRE’s research and development activities as follows: technologies and systems for integrated use of RES; physical and technical basis of solar energy conversion and use; scientific basis of wind energy transformation and use; thermophysical basis of geothermal energy use; scientific basis of small river and tidal energy transformation and use; scientific basis of organic RES transformation and use.

IRE’s mission is to carry out fundamental and applied research to the end of gaining new scientific knowledge on RE physical and engineering problems to the end of shaping the promising areas for studies into the use of alternative and renewable energy sources, transformation and stabilization of energy parameters, improving efficiency and reliability of energy conversion processes, automation and optimization of RES-based energy system modes of operation.

Between 2003 and 2015, Nver Mkhitarian Ph.D. headed the Institute of Renewable Energy actually created on his initiative as a component of the the Department of Physical and Technical Problems of Power Engineering with the National Academy of Sciences of Ukraine. Under his direction, the priority lines in fundamental and applied research for IRE’s six research
departments were identified, specifically, integrated energy systems, solar energy, wind energy, small hydro energy, geothermal energy, bioenergy and those for the Crimean Research Center for Energy Saving and Renewable Energy.

Nver Mkhitarian, Ph.D., managed the creation of IRE’s laboratory and experimental base for fundamental and applied research as well as its experimental production base and a testing ground for field tests related to all lines of the Institute’s activities.

During his term at the IRE Director’s post, the Corresponding Member of NASU, Nver Mkhitarian proved to be a skilled organizer and research supervisor. His activity contributed to the acquisition of new scientific knowledge in renewable energy and the introduction of fundamental and applied research findings in the national economy of Ukraine.

The development of new energy-saving technologies based on the use of non-conventional and renewable energy sources held a prominent place in Prof. Mkhitarian’s research. This laid the basis for launching a new line in the development of architecture, design and technology systems for housing construction. The huge wealth of knowledge and research expertise opened the door for their practical implementation in actual projects.
The findings of his research are presented in over 200 publications. The whole range of fundamental and applied research in generation, conversion, storage and integrated use of renewable energy sources were performed under his direct supervision.

Prof. Mkhitarian headed the Academic Board D26.249.01 on award of the PhD and candidate degrees in specialty 05.14.08 ‘Renewable Energy Conversion’ at IRE. He also chaired the Organizing Committee of Annual International Conferences ‘Renewable Energy of the 21st Century’ and was the Editor-in-Chief of ‘Renewable Energy’ quarterly. Nver Mkhitarian was actively involved in RES-related international activities, in particular, he participated in international conferences, meetings, facilitated the conclusion of international agreements with domestic research and industrial organizations. He paid great attention to creating a legal framework promoting the development of renewable energy in Ukraine, participated in the development and adoption by the Verkhovna Rada of the laws on RES development, which contributed to the national energy independence improvement.

For his outstanding contribution to the development of renewable energy, Nver Mkhitarian was elected a corresponding member of NASU in the field of ‘Alternative and Renewable Energy Sources’ (2003). He was granted many national and international awards; Prof. Mkhitarian is a cavalier of the Order of Merit of the 1st, 2nd and 3rd degree and a cavalier of the Order of the Holy Prince Volodymyr. He was awarded the Gold Medal of Honor of the Second Millennium and the International Diploma of Honor ‘For the outstanding contribution to the world’s science in solar energy’.
INSTITUTE OF RENEWABLE ENERGY AND ITS STRUCTURE

A directorate of eight persons manages IRE: a director, three deputy directors for research, an academic secretary, a deputy director for general issues, an assistant director for marketing and a chief engineer.

Stepan Kudria has been heading IRE since 2015. NASU Corresponding Member, PhD in Engineering, Professor. Kudria has been engaged in renewable energy research since 1978. The research findings are presented in 395 research papers, including 23 monographs, 46 patents of Ukraine and inventor’s certificates for new technological solutions.

For his research findings and applications thereof, Prof. Stepan Kudria was awarded the State Prize of Ukraine in science and technology (2002), ‘Leader of the fuel and energy sector’ diploma (2001 and 2009), diploma of the NASU Presidium and the NASU Trade Union’s Central Committee (2008), ‘Badge of Honor’ of the National Agency for Efficient Use of Energy (2008), NASU’s Inventor of the Year title (2008), the Badge of Honor on the occasion of 130th anniversary of the Power Engineers and Electrical Engineers Research and Technology Union of Ukraine for his significant contribution to the Ukraine’s energy sector development (2010), for a significant contribution to the development of domestic science, conscientious work and high professionalism (2013), second-class diploma of NTUU ‘KPI’ award winner for the textbook ‘Unconventional and renewable energy sources’ (2014), Honorary Golden Badge of the Headquarters of the Poland’s Research and Technical Federation for active participation in establishing and organizing of the joint Ukrainian-Polish RE and EE Improvement Center (2015).
His active participation in the international cooperation of renewable energy scientists was awarded by EUROSOLAR, a European solar award (2004).

Stepan Kudria has achieved personal fundamental and applied research outcomes in creation, application and efficiency improvement of energy equipment based on various RES types, renewable energy storage systems and combined RES-based systems where electricity and heat storage systems are combined with hydrogen energy storage. S. Kudria Ph.D. headed and took part in drafting and implementing of the state renewable energy development programs of Ukraine.

With the academic guidance of Prof. Kudria, methods for researching and mapping the energy potential of renewable energy sources were developed, which underlie the RES Potential Atlas for the Territory of Ukraine. The use of the Atlas is one of the determining factors in the large-scale development of renewable energy in Ukraine, with its growth rate in recent years being at the same level as in the EU countries.

Prof. Kudria chairs the Specialized Academic Board D26.249.01 on award of the PhD and candidate degrees in the specialty 05.14.08 ‘Renewable Energy Conversion’.

Prof. Kudria initiated establishing a department of renewable energy sources at National Technical University of Ukraine ‘Igor Sikorsky Kyiv Polytechnic Institute’, which he has headed since 2002. He participates in training and advanced training for researchers and technology engineers at Folkecenter for Renewable Energy (Denmark) and Renewable Energy Centre (Germany).
Viktor Rieztsov is a Deputy Director for Science. After graduating from Kharkiv Aviation Institute (KHAI) with a degree in LRE-N (liquid rocket engines with nuclear reactor) in 1971, V. Rieztsov worked at KHIMAVTOMATIKA (Voronezh-based), a design bureau, where he was engaged in thermal hydraulic calculations for assemblies with heat release, research into moderators, reflectors and protection of nuclear reactor units for space engines with hydrogen working fluid and published the articles on the theory of charge transfer in low-temperature plasma in Voronezh Polytechnic Institute’s collection of scientific articles.

The main stage in his research activities took place (1973–2003) at the Electrodynamics Institute, where he step-by-step run the gamut of research, from post-graduate studies (1973–1976), to junior researcher, senior researcher, head of the department, head of the division for integrated energy systems with the use of RES.

While V. Rieztsov chaired Solar Energy department at IRE, he focused on developing this technology. For the series of research papers titled ‘Elements of Theory and Build Methods of PV Systems for Spaceship On-Board Technology Installations’, co-authored with PhD in Engineering M. Yurchenko, he was awarded Proskura prize by NASU (2004).
Since 1987, V. Rietzsov has been working in renewable energy, where his major focus was on developing the theory of energy conversion processes based on synergy ideas. In this area, together with his colleagues and subordinates, he has developed the theory of nonlinear formation of spatially inhomogeneous structures in nonlinear related processes: propagation of electromagnetic waves (optical radiation) + thermal conductivity; hydrodynamics + thermal conductivity; charge transfer of unlike signs in low-temperature plasma, semiconductors and electrolytes; thermal conductivity + diffusion; nonlinear elasticity + thermal conductivity; electrothermoelasticity; relaxation-type unbalanced heat and mass transfer.*

Viktor Rietzsov has been a Deputy Chairman of the Academic Board D26.249.01 on award of the PhD and candidate degrees in the specialty 05.14.08.

Since 2005, he has been a Professor at the Renewable Energy Department with National Technical University of Ukraine ‘Igor Sikorsky Kyiv Polytechnic Institute’.

*For all the processes taking place in various elements of power plant equipment, as well as during renewable energy conversion, the basic physical properties of reversibility/irreversibility and reciprocity/non-reciprocity from the standpoint of ideas are presented in A.K. Shydlovskiy doctoral thesis and in the monograph: A.N. Miles, A.K. Shydlovskiy. The principle of reciprocity and reversibility in electrical engineering. – K.: Naukova dumka, 1967.
In 1978, Mykola Kuznietsov graduated with honors from Kyiv Shevchenko State University, majoring in mechanics. 1980–1993, he worked at HYDROPRYLAD Research Institute (Kyiv-based).

Since 1993, he had been working as a leading specialist with AtikaWest JV. Since 1996, he had been employed with KVER renewable energy company (AtikaWest successor) where he was in charge of elaborating investment projects for wind farms construction. Since 1998, he had been a part-time specialist of BUDSHLYAKHMASH Design Bureau (at Wind Energy Department). In 2000, he got a permanent job with the same design bureau, and the same year, all the team was transferred to UKRENERGOMASH, the State Research and Industrial Enterprise where he was hired to the position of a leading research engineer with the main responsibility to provide scientific support to the State Comprehensive Wind Farm Construction Program.

Between 2008 and 2015, he occupied the position of a Senior Researcher with the Wind Energy Department at IRE, since 2015, he had headed IRE’s Integrated Systems Department.

Mykola Kuznietsov, Deputy Director for Science since 2017.

Ph.D. in Engineering, Senior Researcher. He has been engaged in renewable energy since 1993. The outcomes of his research activities are presented in 80 research papers, including 5 monographs.
Anastasiia Moroz joined the IRE team in 2008 and had occupied the following positions: Technician (2008–2012), Engineer (2012–2016) and Senior Researcher (2016–2020) with Hydro Energy Department. In March 2020, she was appointed a Deputy Director for Science.

In 2012, Anastasiia Moroz graduated with honors from the National Technical University of Ukraine ‘Igor Sikorsky Kyiv Polytechnic Institute’ majoring in Unconventional Energy Sources and got a Researcher/Engineer qualification. The same year she took an active part in the development of the National Standard of Ukraine ‘Small Hydro Power Plants. Terms and Definitions’ (issued in 2015), where she acted as one of the key performers.

During 2017–2018, she supervised one of the projects that won the NASU contest among young scientists.

In 2018, she was elected a member to the Technical Committee on International Hydroenergy Standards with the International Small Hydros Network for a five-year period.
Tamila Surzhyk, an Academic Secretary with IRE since 2004.

Candidate of Engineering, Senior Researcher. She has been engaged in renewable energy since 1988. The outcomes of her research activities are presented in 198 research papers, including 2 monographs, 27 inventions and 22 state standards of Ukraine.

Tamila Surzhyk has personal fundamental and applied research results in designing, applications and efficiency improving of solar power plant equipment, systems and installations that allowed creating the whole range of new technological solutions, energy-efficient solar energy methods and technologies (including passive solar).

She is an Academic Secretary with the Specialized Academic Board D26.249.01 on award of the PhD and candidate degrees in the specialty 05.14.08 ‘Renewable Energy Conversion’.

She took part in drafting the National Solar Energy Industry Development Programs and National Standards of Ukraine.

Since 2005, she has been an Associate Professor at the Renewable Energy Department, Igor Sikorsky Kyiv Polytechnic Institute.

He held the position of the Chief Engineer with the Solar Energy Department (2004–2005), the Head of the Logistics Department (2005–2008). Since 2008, he has been chairing the Department for Technology Transfer, Innovation and Intellectual Property.

In December 2008, he was appointed the acting Deputy Director for General Issues with IRE, and in 2017, he was approved at the position of the Deputy Director for General Issues with IRE.

In terms of its structure, IRE consists of six research and development departments: Integrated Energy Systems Department (I), Solar Energy Department (II), Wind Energy Department (III), Hydro Energy Department (IV), Geothermal Energy Department (V), and Bioenergy Department (VI).

The Inter-Branch Scientific and Technical Centre for Wind Power and its project team operate at IRE.
IRE’s structural units for R&D and science organization:

Scientific and Technical Information Department; Department for Technology Transfer, Innovation and Intellectual Property Department; Metrology Department; Editorial Board of the *Vidnovliuvana Energetyka* Scientific Journal, Health and Safety Department, Planning and Production Department.

**Back-office units:**

Chief Power Engineer Service, Chief Mechanic Service, Accounting Department, Post-Graduate Department, Scientific and Technical Archives, Civil Protection Department, Fire Safety Service, Logistics Department, Personnel Department, Administrative Department, Legal Service, Scientific and Technical Library, and Economic Department.

IRE has a mandate to form ad hoc research teams for a certain period to tackle specific tasks, including under contracts and agreements. IRE may establish branches and research departments, theory schools, design, technology and project bureaus, as well as other structural unincorporated units.
RESEARCH DEPARTMENTS, ACTIVITIES AND FINDINGS

Integrated Energy Systems Department

Mykola Kuznietsov, Ph.D. in Engineering and a Senior Researcher has headed the Integrated Energy Systems Department since 2015.

The Department conducts fundamental and applied research into physical and technological problems of the RES integrated use aimed at the below listed targets:

- Improving energy efficiency of energy supply systems via combined use of renewables and non-conventional energy sources
- Improving reliability of electricity and heat supply systems based on renewable energy sources via the use of various energy storage systems
- Mathematical simulation of processes in integrated power supply systems and their individual elements for the rational choice of parameters and characteristics of power supply systems and their operation modes
- Analysis of the current state of renewable energy in Ukraine and worldwide, identifying the key challenges in using renewable energy sources in Ukraine, substantiation of ways to address them in the short-term and long-term perspectives

Combined heat and power generation through renewable energy and its integrated storage achieve high process performance indicators of RES technology applications, stable operating parameters of energy equipment and stable energy supply to consumers. Efficient combined power systems with the integrated use of various energy storages have proved to improve energy efficiency of RES by 30–50%, better the parameters of generated energy and ensure the stability of energy
supply to consumers. The key objectives while creating integrated RES-based energy systems are to equip them with energy storage units and auxiliary equipment reducing fluctuations of power system parameters and supporting desirable performance characteristics as well as creating devices for automatic operational mode control.

The key functions of energy storage in RES-based energy systems are as follows:

- Ensuring uninterrupted energy supply to consumers through waste energy accumulation and its further use in the periods, when power generation is lacking or insufficient
- Ensuring the optimal mode of RES use and consumers by balancing fluctuations in the power system
- Improving the energy potential to required quality during low-potential energy accumulation
- Converting one type of energy into another type depending on consumer needs

The major lines in integrated RES-based energy system research:

- Developing the theory of integrated use of renewable energy sources and power and heat storages
- Developing the methods to identify the best composition of combined RES-based energy systems for various types of facilities
- Creating efficient integrated energy systems with the use of various RES combinations and electricity and heat storage units including those based on salts with phase transition and hydrogen energy storages
- Forecasting renewable energy development trends in Ukraine and in the world considering the potential of various renewable energy technologies
• Mathematical and physical modelling of parameters, characteristics and operational modes of integrated cogeneration systems their energy technology assemblies with the use of RES
• Mathematical and physical simulation of parameters, characteristics and modes of processes and energy storage systems

The Department’s experts performed the research aimed to improve the efficiency of energy supply systems through the combined use of various renewable energy sources and enhance reliability of RES-based cogeneration systems thanks to the use of various energy storage systems.

The research findings were utilized in the development and introduction of the renewable energy projects, construction materials, and RES-based energy equipment and demonstration facilities. The most well-known of them are the wind farm projects in Ukraine, the first in Europe combined wind-hydrogen power plant at the Danish Folkecenter (pic. 5), the range of isolated integrated energy systems based on renewable energy sources and electricity-and-heat storage units for farms.

Picture 5. The first in Europe wind-and-hydrogen power plant at Folkecenter

The department also jointly implemented the range of RES-fuelled combined system developments, in particular: combined wind-and-solar installations jointly with the Thermophysics Institute, Frantsevych Institute for Problems of Materials Science, Igor Sikorsky
Kyiv Polytechnic Institute, Pidgorny Institute for Mechanical Engineering Problems.

The key elements of integrated energy supply system on IRE’s building No.2 based in Hryshko National Botanical Garden, Kyiv, Ukraine, consisting of a 5 kW autonomous photovoltaic system, two solar thermal power plants 5 kW each, and a 0.75 kW wind power plant. Each of the systems is equipped with an electricity and heat storage units.

An advanced system of integrated energy supply fuelled by RES has been created at the Renewable Energy Department with National Technical University of Ukraine ‘Igor Sikorsky Kyiv Polytechnic Institute’, and the University takes advantage of the system in the educational process (pic. 6).

Creating the RES-based energy supply system on the newly built IRE’s buildings located at 48-50 Metrolohichna Street, Kyiv is on the plans. The system will be equipped with heat pumps and geothermal energy storages and, in the longer term, with biomass power plants too.

Picture 6. The systems of integrated energy supply installed on building No.20, National Technical University of Ukraine ‘Igor Sikorsky Kyiv Polytechnic Institute’, and on newly built IRE’s buildings at 48-50 Metrolohichna Str.
Moreover, several prototype electric vehicles have been developed. They are intended for use in recreational areas: botanical gardens, parks, and recreation, health and holiday centers.

Upon analyzing the parameters and operation modes of the above equipment, technical proposals have been articulated related to the creation of new environment-friendly equipment and technologies for energy supply to similar facilities based on combined use of renewable energy sources in Ukraine.

**Solar Energy Department**

Since 2004, Professor Viktor Rieztsov, Ph.D. in Engineering and the Corresponding Member of the National Academy of Sciences of Ukraine has been the Chief of the Solar Energy Department.

The scope of department’s activities cover research into physical and technical problems of solar energy, specifically aimed at:

- Shaping the promising lines in the use of solar energy
- Mathematical modelling of processes of solar energy conversion into electricity and heat
- Developing materials and energy efficient structures of photovoltaic panels and solar collectors; creating energy supply systems on their basis

As of today, the following main lines of solar energy research are maintained:

- Using solar energy for power generation based on PV converters
- Using solar energy for heat production in solar collectors of various designs
- Using solar energy for electricity and heat cogeneration
Based on scientific research findings, the pilot test facilities have been produced, in particular, those of solar thermal modules and systems of autonomous power supply fuelled by PV cells (pic. 7).

The range of fundamental research has been completed on analytical and computational simulation of processes characterizing the interaction of solar irradiation with active PV cell surfaces, arrays, and their electric and thermal conditions with the help of synergetic tolerance analysis methods.

The researchers developed the synergetic method to analyze the status of current channels in photoconverters and its stability. Their research findings were used to articulate the requirements to the structure and parameters of secondary power supply sources for various loads of power supply.

Here are the examples of the developed PV power plant designs: Dobrovlianska PV power plant, 4.17 MW capacity, based in Zalishchyky district (Ternopil oblast), Sychivska PV power plant, 2.0 MW, Khrystynivka district (Cherkasy oblast), design for the PV power plant for ‘Artek’, 1.0 MW, with automated dispatching and visualization service based on Artek international children’s camp, village of Guzuf (Autonomous Republic of the Crimea) and the first in Kyiv industrial solar roof photovoltaic power plant (pic. 8).
Wind Energy Department

Professor Stepan Kudria, Ph.D. in Engineering and the Corresponding Member of NASU has been the Chief of the Wind Energy Department since 2004.

In the scope of scientific-technical and fundamental research on the introduction of wind energy technologies, the following research activities are ongoing:

- Shaping promising lines in the use of wind energy
- Developing efficient methods of wind energy conversion and parameter stabilization of electricity generated
- Automation and optimization of wind power plants and systems
- Scientific support to development, design, construction and operation of wind power installations and wind power plants
- Comprehensive support to scientific-and-technical, social-and-economic development of wind energy

Picture 8. The first industrial roof photovoltaic power plant in Kyiv
The two main lines in research into the methods of wind energy utilization have been identified:

- Using wind energy for electricity generation combined with industrial electric grids
- Using wind energy for electricity generation and mechanical works in autonomous energy systems

The key research findings achieved in the area of searching solutions to physical and technical problems of wind energy:

- Computer database has been created for wind characteristics in Ukraine, and it underlies the wind energy potential atlas, which has been compiled
- Methodology and software have been developed for long-term forecasting of power generation by a wind power installation on site
- Economic and mathematical models for the wind farm construction investment process have been developed, the models may analyze the investment project efficiency, and optimize profit reinvestment
- The structure of an automated wind-solar power plant for the Tendrivskyi lighthouse have been developed, as well as that of other wind power plants in Ukraine

The studies have proved there are large areas in Ukraine characterized by high wind energy potential. State-of-the-art wind power plants, if they are located in high-potential areas, can generate electricity at over 0.35 nominal power utilization rate, which is consistent with the best world practices (pic. 9, 10).
The draft project titled ‘Supplements to the Energy Strategy of Ukraine until 2030 as Concerns Wind Energy Development’ compiled by the joint efforts of NASU and National Space Agency of Ukraine presupposes building the wind farms in Ukraine for a total installed capacity of 16,000 MW by 2030.

Our calculations show if wind power plants are manufactured domestically, this will reduce the costs of wind generation by 20% as compared to the costs of power generated at wind power plants made of imported components.

To achieve the best, targeted choice of wind power plant models and their components, the following works are ongoing:

- Performance characteristics databases are created and maintained for state-of-the-art wind power plants made in the countries where this industry is well-developed, namely, Germany, Denmark, the USA, etc.
• Information is collected about the operation of the same wind power installations in various countries

• Wind power plant performance parameters are analyzed and forecasted considering the energy potential of the regions of Ukraine

The indicators of power generation by wind power plants are assessed by local wind parameters. The main objective in this area is to minimize methodological calculation errors. To this end, special mathematical simulations and methods are developed. Specifically, the efforts are put in developing the methods of high-precision mathematical simulation of wind power plant nominal capacity. The research is on the way into the methods to allow for wind flow turbulence phenomenon in the computation.

The department carries out research in the area of small wind power plants to ensure reliable operation of autonomous and local wind energy system. Their operation in practice requires providing energy supply to consumers within a certain working hours to enable operation of their production machinery. As for large wind power facilities, they are targeted to achieve maximum electricity generation to feed the general power grid.

The key objectives of scientific research works in the scope of wind energy line include:

• Determining the extent, in which topography of Ukraine’s current meteorological station network comply with the objectives of assessing the country's wind energy resources

• Forming the system of wind energy resource indicators and the system of factors underlying wind energy patterns of the territories and regions (global and local atmospheric flows, geographic factors, relief)

• Developing methods for quantification of these indicators and factors influencing the wind energy patterns of the territories
• Establishing a permanent information collection system to assess and plan the use of wind energy in Ukraine
• Designing mathematical support and software for planning the use of wind energy in Ukraine

One of the department’s line of activities is scientific, technical and organizational support to construction and operation of wind power plants in Ukraine. The department’s experts have extensive expertise in comprehensive solutions for any problem that may arise in preparing construction projects of wind power generation facilities.

Hydro Energy Department

Petro Vasko, Chief of the Hydroenergy Department since 2004.

Doctor of Engineering, Senior Researcher.

Author and co-author of 258 research papers, in particular, 16 inventions and 8 renewable energy state standards.

The Department carries out the following activities:

• Analyzing the potential and promising ways to develop hydro energy of Ukraine’s small rivers considering the environmental restrictions imposed on the use of areas for the construction of small hydropower plants and the use of water for electricity generation
• Developing efficient methods and systems to convert hydro energy into electricity considering variable hydrological parameters
• Scientific and technical support to the development, design, construction and operation of small hydropower plants
- Analytical support to the strategy of small hydropower plant development and reconstruction in Ukraine

The key objectives in the studies into energy conversion in small river hydraulic flows:

- Development of mathematical simulations and methods for calculating the hydropower potential of small rivers, taking into account the imposed environment protection constraints and based on scenario analysis of watercourses hydrological parameters and location ecological value criteria, and aerospace sounding and digital cartography findings

- Mathematical simulation of parameters, characteristics and operation modes of hydropower units with variable rotational speed at variable hydrological parameters

- Development of methods and principles to adjust and control operation modes of hydroelectric facilities during peak loads in the power grid

- Scientific and technical substantiation of the means and methods to improve energy efficiency of small hydropower plants in the process of construction or reconstruction (pic. 11)
Based on the research findings, the following outcomes have been achieved:

- **Technical hydropower potential of Ukraine’s small rivers** has been estimated at 375 MW and the corresponding annual electricity output potential at 1,270 million kWh, in accordance with the applicable regulatory framework in effect in the electricity industry and environment protection.

- **Scientifically grounded potential to improve energy efficiency** of the process of hydro energy mechanical conversion at variable pressures and water consumption rates, which are typical for small rivers of Ukraine, by applying the technology of variable speed of hydropower units.

- **Scientific substantiation** have been drafted for determining the optimal laws of rotation speed control and blade adjustment to ensure maximum energy efficiency, which allows turbine efficiency improvement by 15% compared to standard solutions.

Department’s promising developments in the domain of small hydropower are energy efficient technology for variable speed of small hydropower plant’s hydraulic units and the system of automatic monitoring of generated electricity parameters, which implementation is on the way at the domestic small hydros (pic. 12, 13).

We continue our research in this area of domestic hydropower equipment development and creation.

Further development of the department's work is the application of variable speed technology for hydraulic pumps (which are manufactured in our country) for use as hydro turbines at small hydropower plants and storage power plants, for photovoltaic and wind power plants. Therefore, domestic enterprises can use a chance to boost commercial production output of state-of-the-art power equipment for small hydropower plants in Ukraine and for entering
the world market. Another promising application of variable-speed hydraulic units is the room to improve energy efficiency of small hydropower plants while respecting the environment protection restrictions applicable to the use of river flow for electricity generation.

*Picture 12. Variable-speed hydro turbine for a small hydro*

*Picture 13. Electricity parameters automatic monitoring system for generators of small hydros*
The Department carries out fundamental and applied research in geothermal energy and integrated use of geothermal sources aimed at:

- Scientific support and practical implementation of heat and electricity generation technologies based on the use of geothermal potential
- Studying heat-mass-exchange processes and geothermal energy conversion systems
- Shaping promising lines, provision of scientific support and engineering design supervision over introduction of new integrated technologies and installations for geothermal cogeneration in the domestic energy sector
- Creating new geothermal plant types and optimizing the operational parameters of existing geothermal installations and systems (energy industry, agro-industrial technologies, refrigeration technologies, balneology, etc.) (pic. 14)
- Developing and launching new technologies to extract associated useful chemical components from the geothermal waters to meet the needs of other economic sectors
• Research and substantiation of the prospects for underground heat accumulation

• Assessment of economic prospects and impact of geothermal energy facilities on the environment, status and parameter dynamics of underground thermal areas

• Developing state standards to regulate research, developments and operation of geothermal installations and systems

The major lines of research in geothermal energy extraction and use:

• Developing methods to analyze geothermal gas-containing water extraction systems and experimental studies of thermal processes in underground heat exchangers

• Developing methods to determine energy efficiency of geothermal heat and related heating gases from geothermal deposits in Ukraine

• Developing methods to analyze technological processes in efficient systems where thermal potential and associated heating gas are used in combination for power generation

• Developing methods to determine the parameters of integrated production, storage and use of geothermal and solar energy

• Developing energy efficient systems to extract geothermal resources and their combined use for heat and electricity generation using underground storage, identifying priority territories for their implementation in Ukraine

The Department’s most promising areas of scientific research and developments are as follows:

• Determining energy potential of domestic geothermal deposits based on available hydrogeological and geothermal data of gas and oil deposits

• Feasibility study and selecting locations to build pilot production systems of geothermal heating and geothermal power plants
- Development and computation of geothermal heat extraction systems which operation is energy-efficient and safe for the environment

In the scope of the studies into the use of heat from the upper layers of the Earth and heat storages, the following installations were created at NASU’s Hryshko National Botanical Garden: an experimental installation for research into thermal and hydrodynamic processes in the system of extraction and accumulation of heat in rock; experimental installation ‘Thermal process research in solid material having strong heat accumulation properties’. Similar plants will also be installed in new buildings of the Institute located at 48-50 Metrolohichna Str., Kyiv.

Bioenergy Department

**Serhii Klius**, Candidate of Engineering, Chief of Bioenergy Department, since 2020.

*An author and a coauthor of 30 research papers and 5 patents. He has been working in renewable energy since 2010.*

The following types of research are ongoing in the area of development and introduction of bioenergy:

- Shaping promising lines in the use of bioenergy sources for energy generation
- Creating new types and optimizing operational parameters of available bioenergy installations
- Assessment of economic viability and impact on the environment of the energy supply systems where bioenergy sources are employed
• Scientific support in launching bioenergy installations in the energy sector of Ukraine

The following experimental and analytical research has been completed:

• Updating the energy potential of biomass and organic waste to consider the changes in economic activity scale, deeper processing and expanding the use of biomass to cover non-energy needs, agro-environmental and environmental restrictions on the energy use of biomass and biofuels

• Kinetics of thermolysis of solid biofuel particles (chips, wooden and straw granules) depending on the temperature, moisture content in the fuel and geometric parameters of the particles (pic. 15, 16)

• Kinetics of carbon drop from coke ash of solid biomass, depending on biomass type and taking into account anisotropy of the particles, impact of temperature inside the furnace on overheating of the burning coke-ash residue particles

• Concentration conditions for forced ignition of air and volatile
substances mixtures being released during thermolysis of solid biomass, depending on the excess air and fuel moisture content.

The data received is the basis for further creation of intensive technologies for solid biomass incineration with low emissions of air pollutants.

The experimental research into joint fermentation of manure waste with liquid waste from biomass gasification proved the gas generator condensate processing with biogas production is possible.

A synergetic method for analyzing the stability of the fermentation process during biogas production to small perturbations of ambient temperature and organic matter concentration has been developed, which enables determining the relationship between the factors of thermal diffusion system at which self-oscillating modes are possible in a reactor, namely fluctuations in ambient temperature and concentration of organic matter with time, and at which dissipative structures may form. The obtained ratios can be used for forecasting and selecting the operating modes of biogas plant equipment.

Experimental studies into process modes of laboratory and industrial plants for the production of liquid biofuels have been completed. The properties of the produced biofuels and by-products have been studied.

In 2019, the department’s research team developed the technology of organic waste partial pyrolysis and entered the finals of MHP RadarTech 2.0 contest for innovative startups. This event was covered in the profile mass media that published three articles and broadcast one video piece in ‘The World of Opportunities’ TV program at ICTV channel.

The promising areas of bioenergy research:

- Thermochemical conversion of biomass by partial and full gasification into combustible gas, biochar and torrefied biomass fuel
• Recycling and disposal of organic waste (solid domestic waste, sewage sludge, paper shavings, poultry droppings)

• Development of scientific basis for straw and plant refuse incineration processes

• Anaerobic treatment of wastewater contaminated with high-molecular organic compounds, and studying conditions for the production of biogas with high methane content (over 70%).

**Inter-Branch Scientific and Technical Centre for Wind Power**

In fact, the development of wind energy industry in Ukraine dates back to 1994 when the decisions were adopted to launch commercial production of wind turbines at domestic manufacturing facilities and build wind farms on their basis. In 1997, the Resolution of the Cabinet of Ministers of Ukraine No.137 approved ‘The Comprehensive Program for the Wind Power Plant Construction in Ukraine’ and the country started its implementation.

The Program’s key goal was to develop domestic wind power engineering. Mass manufacturing of high-tech wind power plants was organized in Ukraine under licenses from foreign companies. Twenty-three national industrial enterprises organized a full production cycle and manufactured USW56-10 (107.5 kW) wind turbine model, under the license from Kenetech WindPower – the then well-known US-based wind power equipment manufacturer.

The Comprehensive Program for WPP Construction in Ukraine budgeted the funds (within three percent of the total appropriations) for regulatory, scientific and technical support, including research and piloting. To coordinate the research and provide the scientific support, the decision was made to establish the Inter-Branch Scientific and Technical Centre for Wind Power (ISTCWP) at the Institute of Electrodynamics in accordance with the Resolution of NASU’s Presidium No.128 of April 28, 2000.
The key activities of ISTCWP were to shape promising scientific and technical lines for the development of wind energy in Ukraine; organize and perform expert examination of scientific, technical, socio-economic programs and projects in this domain; feasibility studies for wind energy projects with consideration of the key wind parameters (pic. 17), power generation and costs, required investments, etc.

In 2004, after the Institute of Renewable Energy was established, the Centre was renamed into the Inter-Branch Scientific and Technical Centre for Wind Power with IRE NASU.

In the scope of scientific and technical support to the Comprehensive Program for WPP Construction in Ukraine, the territories were identified where construction of wind farms was promising, feasibility studies were performed for the construction of wind farms, optimum arrangement of wind turbines on power plant sites were simulated, follow-up analysis and optimization of their operation with due consideration of novel technologies and IT were performed (pic. 18).
The solutions to make wind farms compatible with the power grid were among important lines of the research as well as the solutions aimed at power factor compensation for wind farms. The overvoltages of wind farm equipment in operation were reduced.

The key research outcomes in that period were as follows:

- The wind potential of Ukraine was researched
- The promising sites were identified for the construction of wind power plants for a total capacity of 16,000 MW
- Cooperation was organized with 30 machine-buildings facilities (former defense industry enterprises) where nearly 800 wind turbines were manufactured, for 100 kW and 600 kW capacity each
- Seven wind power plants were designed and built for a total capacity of 87 MW and connected to the Unified Energy System of Ukraine

At present, the ISTCWP objectives cover the range of promising areas for the introduction of scientific research results in practices and for building new renewable energy facilities:

- Creating the database of wind power plant technical parameters, performing relevant analytical and forecasting computations using the database information
- Maintaining the database of wind parameter observations at the weather stations of all available types in Ukraine
- Data validation and shaping the arrays of valid data for correct wind energy computations
- Full cycle of computations for a long-term production output forecasting by input data for given models of wind turbines and given sites
• Full cycle of preliminary investment and investment calculations with assessing energy efficiency, cost effectiveness, environmental and feedstock components of WPP investment projects

• Analysis of WPP operational performance indicators and drafting recommendations how to improve their performance

ISTCWP along with partner organizations have launched the creation of the educational system for training and advanced training of renewable energy experts

UNIDO is implementing ‘Improving energy efficiency and promoting renewable energy in agro-food and other small and medium enterprises in Ukraine’ funded by Global Environmental Facility (GEF) and partially by private capital (pic. 19).

The main goal of the Project is to develop the market for improving energy efficiency and scaling-up renewable energy technologies to transit to alternative types of energy and fuel at small and medium enterprises in Ukraine as the basis for boosting their competitiveness and ensuring the integrated approach to GHG emission reduction, enhancing production and decreasing negative impact on the environment.

In the scope of Project’s Component 4 ‘Raising public awareness and capacity building at energy-intensive SMEs’ the trainings were planned for industry, national governmental agencies and local self-governments, energy service companies, equipment suppliers on identifying and seeking the room for launching energy efficient solutions, energy management and energy standards as well as industrial applications of renewable energy solutions at agro-food and other energy-intensive SMEs (pic. 20).

ISTCWP was responsible for organizing and holding of the training courses.

In the scope of preparing to the trainings, the organizers planned a series of train-the-trainer events for potential trainers who will deliver in future the training course on the RES applications and energy efficiency improvements in agro-food industry. International and national experts took part in the event.

Presentations and methodologies were drafted and the range of training events were delivered on partners’ sites at Igor Sikorsky Kyiv Polytechnic Institute, National University of Life and Environmental Sciences and Advanced Training Institute at the
National Food Technologies University. Upon due completion of the training course, the participants received the state-recognized diplomas and UNIDO’s certificates.

**Design Team**

The Institute of Renewable Energy has formed a design team responsible for designing works for potential construction of RES-based industry-scale power plants. The team members are renowned scholars and certified designers. This fact enables the team to provide certified designing for every component of a new construction project.

The Design Team is implementing several photovoltaic plant projects and is responsible for the entire scope of designing works on a turnkey basis, i.e. starting with selection of sites, obtaining the green tariff and ending with the facilities commissioning.

Economic contracts on elaboration of design documents contribute to IRE’s objective as set forth by the Cabinet to scale up the use of renewable energy sources in Ukraine. Such contracts provide the scope of works and additional incomes to the Institute’s staff that is important in the times of economic hardships and insufficient governmental allocations to budget-funded institutions. Volodymyr Khilko and Benmenni Mouhoub are the responsible experts in the Design Team.
Benmenni Mouhoub has been upgrading his qualifications on a continuous bases taking part in the advanced trainings on construction, conferences, workshops and debates on the draft laws, including in the Parliamentary Committees. He has published the articles on renewable energy in the major media outlets.

Volodymyr Khilko has over 25 years’ experience in renewable energy, in particular, he has been working in economic analysis, operation, designing and strategic planning of construction, identification of energy potential on site and strategic development of RES-based power plants.
THE MOST SIGNIFICANT RESEARCH FINDINGS

The Institute of Renewable Energy has achieved the following important outcomes in its fundamental scientific research:

- State-of-the-art in renewable energy in Ukraine and the world has been analyzed, the major challenges in the renewable energy technologies have been identified and the solutions to them for the future have been proposed and substantiated

- The principles of synergetic approach to simulating and analyzing conversion of energy from non-conventional and renewable sources have been proposed and substantiated

- Energy conversion processes have been researched in solar collectors and photovoltaic batteries to intensify the energy exchange, and the prospects have been substantiated for the solar thermal cogeneration applications

- Specific time-related and geospatial parameters characterizing the wind energy potential distribution in Ukraine have been studied and the best sites have been identified for building large and medium-sized wind power plants

- A new principle for hydro energy mechanic conversion has been offered and scientifically validated; this principle includes variable turbine speed to increase energy conversion factor and extend the range of loads in generation and pump operation modes

- Hydrothermal potential of Ukraine has been researched, in particular, that of abandoned oil and gas wells, new methods to improve their energy efficiency via capture of associated gases and reclamation of useful substances from mineral waters have been proposed

- The biomass energy potential of Ukraine has been analyzed and the dynamics have been forecasted taking into consideration the expected rise in energy crops growing on low-productive lands; general technologies for integrated utilization of the potential with domestically-manufactured energy equipment have been
developed and they underlie the concept of the National Program on the Development of Fuel Production from Biological Feedstock and were included in the Roadmap of Bioenergy Development until 2020

- Science-based methods have been proposed to improve capacity utilization factor of the RES-based plants thanks to the integrated use of energy generation equipment and energy storage systems

IRE have developed the range of new technological solutions and created new energy-efficient RE machinery and technologies.

The most important achievements in the **applied scientific research**:

- The integrated RES-based power supply systems have been built (building No.2 of IRE at Hryshko National Botanical Garden, and the building of Igor Sikorsky Kyiv Polytechnic Institute)

- The schemes and structures for solar-cell arrays and photovoltaic cells based on polymers have been created, with the new technology developed by IRE for construction materials manufacturing for solar-cell arrays

- Computer database has been created containing the wind parameters for the territory of Ukraine and relevant methodological tools, on this basis the Ukraine’s wind energy potential atlas has been elaborated

- Hydro energy potential of the Ukraine’s small rivers have been identified as well as its distribution throughout the territory broken down by the administrative regions

- Scientific justification has been provided for energy efficiency improvement of hydro energy applications for Ukraine’s small rivers; the applications offer variable speed technology for hydroelectric power units; IRE’s researchers provided the scientific justification for the discrete changes in hydro turbine speed at
small hydros, for the speed to be harmonized with the scale of synchronous rotation of asynchronous electric machinery, which demonstrates the prospects for the application of asynchronous generators with alternating poles and generators with several armature windings

• Upon analysis into operation of the geothermal plants based in Crimea and Zakarpattia, the major lines for geothermal plant improvements have been determined
• Designing methodology for biomass-run integrated power plant systems have been developed
• Methodology for drafting regional and sectoral energy efficiency programs have been created
• Methodology for environmental impact, cost-effectiveness and performance assessment has been drafted for stand-alone biomass power plants

IRE’s major developments and outcomes in the creation of new energy-efficient machinery and technologies in renewable energy domain are:

• An automated wind-and-solar power plant at Tendrivskyi Lighthouse, island of Tendrivska Kosa
• RES-based integrated stand-alone power supply systems on the islands of Tuzla and Zmiinyi
• A mobile stand-alone 1 kW wind power plant for local consumers
• Parametric range of power generators with permanent magnets for stand-alone wind power systems – capacity: up to 10 kW, plus the test facilities to study energy and aeromechanic parameters of the same systems
• An experimental model of automated electricity parameter monitoring system for small hydros based on microprocessor
multimeters DMK40 with RS-232 and RS-485 information ports (Modbus RTU protocol)

- An experimental batch of automated reactive-power compensators for asynchronous generators with DCRJ-12 microprocessor controllers
- Environment-friendly electric cars powered by photovoltaic panels and biofuel- and hydrogen-run vehicles
- Biochar production plants with 25-30% biochar yield by weight of biomass feedstock plus 1.0-1.6 m³/kg of combustible gas

The Inter-Branch Scientific and Technical Centre for Wind Power developed efficient methods to simulate mathematically capacity parameters of modern wind power plants. It carries out systemic analysis of all industrial wind power plants in operation in Ukraine. To support the analysis, a software package has been developed. The Centre performs investment efficiency assessments in wind power plant construction and operation. The assessment tool comprises the system of economic and mathematic simulation of WPP construction and operation developed in joint projects with participation of IRE’s experts.

The Institute of Renewable Energy got the license from the Ministry of Construction, Architecture and Housing of Ukraine for construction activities. Moreover, IRE’s experts are certified energy auditors and may perform energy audits and designing of RES facilities.

To implement Ukraine’s ambitious targets to achieve the high share of renewable energy sources, a single information and analysis system with extended functions is being created that enables to fast address the issues related to efficient introduction of RES-based power plants on specific sites.

IRE has created and continuously updates the renewable energy potential atlas. The atlas presents the collection of maps and
explanations arranged by major RES technologies, which launch in Ukraine is promising, specifically, solar, wind, small hydro, biomass, geothermal and ambient energy technologies.


Today, the information and analytical mapping system evaluates the Ukraine’s renewable energy potential to the end of annual monitoring and updating of the renewable energy potential throughout Ukraine by quantitative parameters. The outputs are available in the form of maps with the outputs visualized as a cartographic and attributive database. Tracking and analyzing current and historic information is also aimed at issuing recommendations for the use of both mature and new renewable energy sources throughout Ukraine.

The goal of the latest version of Ukraine’s RES Potential Atlas was to assess the annual technically achievable renewable energy potential of Ukraine benchmarking it against state-of-the-art by all types of renewable energy technologies. Updated quantitative parameters of the technically achievable RES potential for the entire territory of Ukraine and power plant equipment parameters shows that, in terms of technical achievability, the 10 times higher use of RES is possible.
Based on estimated data, the Atlas presents the updated figures of national technically achievable RES potential – the share of total national RES potential that may be unlocked at the state-of-the-art level in the following RE technologies: wind, solar, small hydros, geothermal and biomass.

Moreover, it presents the information where the operating RES-based facilities are located in the regions of Ukraine.

The Atlas software provides for operational processing of annual and auxiliary information without destruction of current information. The energy parameters of renewable energy facilities presented in the Ukraine’s Atlas are targeted to energy installation customers and designers as they may use them as input data with due regard of annual updates. Planning a new RES plant construction project, the following infrastructure, local and structural prerequisites along with energy potential should be considered:

- Primary energy availability level
- Structure of energy supply system and energy use of specific facilities
- Requirements to electricity and heat qualitative parameters
- Type and parameters of energy load
- Requirements to hourly energy supply schedule
- Economic and environmental factors

Ukraine’s RES Potential Atlas is designed to help in the processes of research and development, exploration and design works while planning, designing, building and launching renewable energy facilities.

The use of data from Ukraine’s Renewable Energy Potential Atlas will contribute to spreading the information about the possibilities to
launch RES facilities all over the country and upgrading their design level thanks to the right choice of equipment components and their combination. It is important to disseminate information not only among the stakeholders engaged in development, manufacturing and launching of renewable energy installations but also among public authorities, both at the national and local level to overcome prejudice to new energy technologies and scale-up renewable energy applications.

The annual technically achievable energy potential figures by major RE technologies and annual potential of power generation from renewable energy sources for Ukraine as identified by IRE’s experts for 2020 and its distribution by regions of Ukraine are demonstrated in Tables 1 and 2, pictures 21 and 22.

*Picture 21. A map from the Atlas of RES Potential in Ukraine*
Picture 22. Annual potential of power generation from renewable energy sources in Ukraine
**Table 1. Installed capacity potential for renewable energy by regions of Ukraine, MW**

<table>
<thead>
<tr>
<th>By regions</th>
<th>Solar</th>
<th>Wind</th>
<th>Small hydro</th>
<th>Geothermal</th>
<th>Biomass</th>
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<td>840</td>
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<td>120</td>
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<td>32,387</td>
<td>5</td>
<td>200</td>
<td>2,835</td>
<td>39,072</td>
</tr>
<tr>
<td>Zhytomyr</td>
<td>4,102</td>
<td>10,640</td>
<td>8</td>
<td>50</td>
<td>4,575</td>
<td>19,374</td>
</tr>
<tr>
<td>Zakarpattia</td>
<td>1,757</td>
<td>1,163</td>
<td>132</td>
<td>1,400</td>
<td>1,209</td>
<td>5,661</td>
</tr>
<tr>
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<td>3,737</td>
<td>33,196</td>
<td>0</td>
<td>40</td>
<td>3,646</td>
<td>40,620</td>
</tr>
<tr>
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<td>1,911</td>
<td>2,416</td>
<td>59</td>
<td>600</td>
<td>1,671</td>
<td>6,658</td>
</tr>
<tr>
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<td>3,868</td>
<td>11,983</td>
<td>3</td>
<td>40</td>
<td>4,961</td>
<td>20,855</td>
</tr>
<tr>
<td>Kirovograd</td>
<td>3,381</td>
<td>21,226</td>
<td>15</td>
<td>40</td>
<td>4,482</td>
<td>29,144</td>
</tr>
<tr>
<td>Luhansk</td>
<td>3,669</td>
<td>32,591</td>
<td>2</td>
<td>80</td>
<td>2,042</td>
<td>38,384</td>
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<tr>
<td>Lviv</td>
<td>3,002</td>
<td>8,015</td>
<td>46</td>
<td>1,400</td>
<td>2,672</td>
<td>15,135</td>
</tr>
<tr>
<td>Mykolaiv</td>
<td>3,382</td>
<td>30,043</td>
<td>3</td>
<td>80</td>
<td>3,435</td>
<td>36,943</td>
</tr>
<tr>
<td>Odesa</td>
<td>4,580</td>
<td>34,719</td>
<td>1</td>
<td>240</td>
<td>4,912</td>
<td>44,453</td>
</tr>
<tr>
<td>Poltava</td>
<td>3,953</td>
<td>14,522</td>
<td>6</td>
<td>1,400</td>
<td>5,662</td>
<td>25,544</td>
</tr>
<tr>
<td>Rivne</td>
<td>2,756</td>
<td>7,745</td>
<td>3</td>
<td>40</td>
<td>2,594</td>
<td>13,139</td>
</tr>
<tr>
<td>Sumy</td>
<td>3,277</td>
<td>11,096</td>
<td>2</td>
<td>560</td>
<td>5,009</td>
<td>19,945</td>
</tr>
<tr>
<td>Ternopil</td>
<td>1,901</td>
<td>6,983</td>
<td>12</td>
<td>80</td>
<td>3,019</td>
<td>11,995</td>
</tr>
<tr>
<td>Kherson</td>
<td>4,320</td>
<td>27,119</td>
<td>10</td>
<td>1,300</td>
<td>5,160</td>
<td>37,908</td>
</tr>
<tr>
<td>Khmelnitksyi</td>
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<td>34,761</td>
<td>1</td>
<td>1,300</td>
<td>3,360</td>
<td>43,335</td>
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<tr>
<td>Chernihiv</td>
<td>4,381</td>
<td>12,311</td>
<td>1</td>
<td>800</td>
<td>5,932</td>
<td>23,425</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>82,768</td>
<td>438,000</td>
<td>376</td>
<td>10,810</td>
<td>92,078</td>
<td>624,033</td>
</tr>
</tbody>
</table>

| Territorial waters and inland water bodies | 250,000 |

| **Total** | 82,768 | 688,000 | 376 | 10,810 | 92,078 | 874,033 |
### Table 2. Average annual potential of power generation from RES in Ukraine, million kWh/year

<table>
<thead>
<tr>
<th>By regions</th>
<th>Solar</th>
<th>Wind</th>
<th>Small hydro</th>
<th>Geothermal</th>
<th>Biomass</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>AR of Crimea</td>
<td>4,323</td>
<td>60,090</td>
<td>3</td>
<td>6,255</td>
<td>5,236</td>
<td>75,907</td>
</tr>
<tr>
<td>Vinnytsia</td>
<td>4,375</td>
<td>36,371</td>
<td>83</td>
<td>298</td>
<td>25,327</td>
<td>66,453</td>
</tr>
<tr>
<td>Volyn</td>
<td>3,324</td>
<td>19,510</td>
<td>4</td>
<td>298</td>
<td>8,310</td>
<td>31,446</td>
</tr>
<tr>
<td>Dnipropetrovsk</td>
<td>5,266</td>
<td>105,849</td>
<td>7</td>
<td>894</td>
<td>20,646</td>
<td>132,662</td>
</tr>
<tr>
<td>Donetsk</td>
<td>4,375</td>
<td>87,949</td>
<td>16</td>
<td>1,489</td>
<td>11,673</td>
<td>105,502</td>
</tr>
<tr>
<td>Zhytomyr</td>
<td>4,922</td>
<td>28,893</td>
<td>27</td>
<td>372</td>
<td>16,619</td>
<td>50,834</td>
</tr>
<tr>
<td>Zakarpattia</td>
<td>2,108</td>
<td>3,157</td>
<td>439</td>
<td>10,424</td>
<td>4,180</td>
<td>20,308</td>
</tr>
<tr>
<td>Zaporizhzhia</td>
<td>4,485</td>
<td>90,148</td>
<td>1</td>
<td>298</td>
<td>14,089</td>
<td>109,020</td>
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<tr>
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<td>6,562</td>
<td>196</td>
<td>4,468</td>
<td>6,415</td>
<td>19,935</td>
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<tr>
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<td>32,540</td>
<td>11</td>
<td>298</td>
<td>20,116</td>
<td>57,606</td>
</tr>
<tr>
<td>Kirovograd</td>
<td>4,057</td>
<td>57,641</td>
<td>53</td>
<td>298</td>
<td>17,724</td>
<td>79,773</td>
</tr>
<tr>
<td>Luhanski</td>
<td>4,403</td>
<td>88,503</td>
<td>7</td>
<td>596</td>
<td>8,032</td>
<td>101,540</td>
</tr>
<tr>
<td>Lviv</td>
<td>3,602</td>
<td>21,766</td>
<td>153</td>
<td>10,424</td>
<td>10,428</td>
<td>46,373</td>
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<tr>
<td>Mykolayiv</td>
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<td>81,584</td>
<td>11</td>
<td>596</td>
<td>13,448</td>
<td>99,697</td>
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<tr>
<td>Odesa</td>
<td>5,496</td>
<td>94,283</td>
<td>5</td>
<td>1,787</td>
<td>19,693</td>
<td>121,264</td>
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<tr>
<td>Poltava</td>
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<td>39,437</td>
<td>22</td>
<td>10,424</td>
<td>22,425</td>
<td>77,051</td>
</tr>
<tr>
<td>Rivne</td>
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<td>21,033</td>
<td>10</td>
<td>298</td>
<td>9,396</td>
<td>34,045</td>
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<tr>
<td>Sumy</td>
<td>3,933</td>
<td>30,133</td>
<td>8</td>
<td>4,170</td>
<td>19,445</td>
<td>57,689</td>
</tr>
<tr>
<td>Ternopil</td>
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<td>18,963</td>
<td>42</td>
<td>596</td>
<td>12,301</td>
<td>34,182</td>
</tr>
<tr>
<td>Kharkiv</td>
<td>5,183</td>
<td>73,645</td>
<td>33</td>
<td>9,680</td>
<td>20,171</td>
<td>108,713</td>
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<tr>
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<td>94,397</td>
<td>2</td>
<td>9,680</td>
<td>13,212</td>
<td>121,987</td>
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<td>298</td>
<td>18,719</td>
<td>50,774</td>
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<tr>
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<td>28</td>
<td>298</td>
<td>16,964</td>
<td>49,410</td>
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<tr>
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<td>298</td>
<td>5,714</td>
<td>12,982</td>
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<tr>
<td>Chernihiv</td>
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<td>33,433</td>
<td>2</td>
<td>5,957</td>
<td>22,879</td>
<td>67,528</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>99,323</td>
<td>1,189,433</td>
<td>1,273</td>
<td>80,494</td>
<td>362,161</td>
<td>1,732,683</td>
</tr>
<tr>
<td>Territorial waters and inland water bodies</td>
<td></td>
<td></td>
<td></td>
<td>984,337</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>99,323</td>
<td>2,173,770</td>
<td>1,273</td>
<td>80,494</td>
<td>362,161</td>
<td>2,717,021</td>
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</table>
Today, the use of hydrogen as a universal environment-friendly energy source becomes more and more widespread in the world helping to address important energy and environmental challenges and reduce the risk associated with growing carbon dioxide content in the atmosphere. Hydrogen applications make it possible to create both short-term and long-term off-season energy reserves for both RES-based energy systems and conventional energy systems. In the present state of the art in hydrogen energy, the applications of solar, wind and hydropower as primary energy sources are considered.

The expanded renewable energy facilities may generate electricity and heat and also create long-term energy reserves in the form of hydrogen. The Institute together with ‘Ukrainian Hydrogen Council’ Energy Association deal with determining the energy potential of hydrogen production and identifying its promising applications, including for creating balancing capacities in the energy sector of Ukraine.

‘Ukrainian Hydrogen Council’ Energy Association addresses the issue of building a new hydrogen-based economy and development of hydrogen energy in Ukraine as well as integrating the country into the European hydrogen energy space. In 2018, Ukraine was the first non-EU country that joined Hydrogen Europe, a European Commission’s unit, as its member.

‘Ukrainian Hydrogen Council’ represents Hydrogen Europe interests in Ukraine and promotes Ukraine in the European Energy Community. Over 20 official international meetings were held. The members of the Council took part in the annual meeting of the European Commission (in Brussels) on ‘Hydrogen Economy and Energy of the European Union’. They signed memoranda of cooperation with Germany, the Czech Republic, and Latvia.

On May 17, 2018, ‘Ukrainian Hydrogen Council’ in Kyiv initiated and organized one of the largest hydrogen energy forums in Europe titled
'Wind and Hydrogen Energy 2018’ and the first scientific and practical conference ‘Renewable and Hydrogen Energy 2018’. Thus, in 2018, over 20 scientific and public awareness events became the part of hydrogen energy development profile.

‘Ukrainian Hydrogen Council’ and IRE jointly put forward the initiative to integrate hydrogen and energy solutions in the legislative framework of Ukraine. They are developing a sectoral practice program for hydrogen integration into the national economy. In particular, the roadmap drafting for the introduction of hydrogen technologies in the major sectors of Ukraine’s economy is at the final stage. Back in April 2019, at the largest European exhibition of hydrogen technologies in Hanover, Hydrogen Europe representatives initialed the Ukraine’s national roadmap on hydrogen energy development.

The modern package of hydrogen energy technologies comprises hydrogen production, its accumulation and storage, transportation and use. The electrolytic method of water decomposition is most efficient for obtaining hydrogen for energy needs. The modern electrolysis plants have high technological characteristics and are easy to operate and maintain. They can use both excess electricity from renewable energy sources and peak generation energy from conventional power plants as a primary source. Moreover, the creation of hydrogen energy storage systems based on renewable energy installations is promising as they may be located in remote areas where power supply is a challenge.

Where wind and solar energy applications provide supply to the entire economic sectors, the industry may face insurmountable problems unless these solutions are supplemented by hydrogen storages. Hydrogen will play a leading role in integrating large amounts of renewable energy in transport, heating and cooling sectors, which are difficult to decarbonize today.
Hydrogen productions generate zero carbon emissions during electrolysis, hydrogen can be transported over long distances, which allows transborder energy transmission, hydrogen can store energy for long periods, serving as a necessary system buffer and providing stability. Hydrogen will help decarbonizing a wide range of final applications, providing green electricity and heat for mobile and stationary applications.

Hydrogen will become the main energy vector enabling ‘Zero-emissions Europe’. The potential of ‘green hydrogen’ in Ukraine is presented in Table 3 and in pic. 23.

IRE’s research findings were used in the scope of development and implementation of the projects related to renewable energy, construction materials, power equipment and demonstration facilities based on RES: the number of wind farm projects in Ukraine, Folkecentre, the number of stand-alone combined power units, including integrated cogeneration systems based on renewable energy sources and storage units for the farms. IRE participated in designing and building of over 300 wind power plants, their capacity ranged from 1 to 10 kW, most of them are in operation in Germany, Canada, Hungary, Macedonia, and Poland.

The outcomes of the Institute’s research activities contribute to the reduction in fossil fuels consumption, continuously decreasing Ukraine’s dependence on primary energy exports. As a result, the volume of hazardous emissions from generators will decrease; more jobs will be created, thus improving the environmental and social situation in our country.
<table>
<thead>
<tr>
<th>No.</th>
<th>Region</th>
<th>million nm$^3$</th>
<th>Thousand tons</th>
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<tbody>
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<td>1</td>
<td>AR of Crimea</td>
<td>14,314</td>
<td>1,274</td>
</tr>
<tr>
<td>2</td>
<td>Vinnytsia</td>
<td>9,055</td>
<td>806</td>
</tr>
<tr>
<td>3</td>
<td>Volyn</td>
<td>5,074</td>
<td>452</td>
</tr>
<tr>
<td>4</td>
<td>Dnipropetrovsk</td>
<td>24,692</td>
<td>2,198</td>
</tr>
<tr>
<td>5</td>
<td>Donetsk</td>
<td>20,516</td>
<td>1,826</td>
</tr>
<tr>
<td>6</td>
<td>Zhytomyr</td>
<td>7,515</td>
<td>669</td>
</tr>
<tr>
<td>7</td>
<td>Zakarpattia</td>
<td>1,170</td>
<td>104</td>
</tr>
<tr>
<td>8</td>
<td>Zaporizhzhia</td>
<td>21,029</td>
<td>1,872</td>
</tr>
<tr>
<td>9</td>
<td>Ivano-Frankivsk</td>
<td>1,968</td>
<td>175</td>
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<tr>
<td>10</td>
<td>Kyiv</td>
<td>8,263</td>
<td>735</td>
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<tr>
<td>11</td>
<td>Kirovograd</td>
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<td>1220</td>
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<tr>
<td>12</td>
<td>Luhansk</td>
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<td>1837</td>
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<td>Lviv</td>
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<tr>
<td>14</td>
<td>Mykolaiv</td>
<td>19,032</td>
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<td>Odesa</td>
<td>22,173</td>
<td>1,973</td>
</tr>
<tr>
<td>16</td>
<td>Poltava</td>
<td>9,818</td>
<td>874</td>
</tr>
<tr>
<td>17</td>
<td>Rivne</td>
<td>5,409</td>
<td>481</td>
</tr>
<tr>
<td>18</td>
<td>Sumy</td>
<td>7,570</td>
<td>674</td>
</tr>
<tr>
<td>19</td>
<td>Ternopil</td>
<td>4,721</td>
<td>420</td>
</tr>
<tr>
<td>20</td>
<td>Kharkiv</td>
<td>17,517</td>
<td>1,559</td>
</tr>
<tr>
<td>21</td>
<td>Kherson</td>
<td>22,021</td>
<td>1,960</td>
</tr>
<tr>
<td>22</td>
<td>Khmelnytskyi</td>
<td>7,051</td>
<td>628</td>
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<td>23</td>
<td>Cherkasy</td>
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<tr>
<td>24</td>
<td>Chernivtsi</td>
<td>1,753</td>
<td>156</td>
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<tr>
<td>25</td>
<td>Chernihiv</td>
<td>8,598</td>
<td>765</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>286,390</strong></td>
<td><strong>25,489</strong></td>
</tr>
<tr>
<td>26</td>
<td>Territorial waters and inland water bodies</td>
<td>218,742</td>
<td>19,468</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>505,132</strong></td>
<td><strong>44,957</strong></td>
</tr>
</tbody>
</table>
Picture 23. Distribution of average annual ‘green’ hydrogen production potential
The Institute of Renewable Energy provides postgraduate and doctoral training (according to the Resolution of NASU’s Presidium No.223 of February 23, 2004). In the period 2004–2015, the postgraduate school delivered the training on speciality 05.14.08 ‘Renewable Energy Conversion’.

On April 29, 2015, the Cabinet of Ministers issued the Resolution No.266 approving the list of knowledge fields and specializations for higher education. Since 2016, postgraduates have been admitted to the speciality 141 ‘Electricity industry, electrical engineering and machinery’, as part of Electrical Engineering (science field No.14).

In accordance with Article 6, paragraph 1, part 2 of the Law of Ukraine ‘On licensing economic activities’, the Licensing Commission (with the Ministry of Education and Science) passed a relevant decision on December 19, 2016 (Minutes No. 31/2) and IRE got a license to carry out higher education activities at the third level of science and education.

Overall, 53 people have studied in IRE’s postgraduate school since its foundation.

The Institute has sufficient capabilities to provide its postgraduate students with highly qualified scientific guidance, six scientists out of IRE’s staff have the doctor of engineering degrees (two out of those are NASU’s corresponding members) and 16 scientists are the candidates of science. Upon graduation and successful defense of postgraduate thesis, the Institute provide further employment to junior researchers.
IRE’s Administration facilitates the improvement of postgraduate training performance. The Institute has highly qualified research, and pedagogical staff, modern research and experimental base, i.e. there are all necessary preconditions in place to provide high-standard postgraduate training for young specialists majoring in renewable energy, one of the leading and most promising subsectors in Ukraine’s current national economy.

A ‘Council of Junior Scholars and Specialists’ has been established at the IRE as part of its research activities. A Specialized Academic Council D 26.249.01 for the defense of doctoral theses in the specialty 05.14.08 ‘Renewable Energy Conversion’ (engineering sciences) is operational as well.

For the whole period of its operation, the Specialized Academic Council approved 34 dissertations, including 6 doctoral and 28 candidate theses. IRE’s staff members have defended 16 dissertations including 2 doctoral dissertations and 14 candidate dissertations. The specialists coming from other organizations defended 17 dissertation papers, namely 4 doctoral and 13 candidate theses.

The Institute’s junior scholars receive scholarships from the National Academy of Sciences of Ukraine and President of Ukraine. The Institute’s staff delivers lectures on the specialty ‘Renewable Energy Sources’ at higher educational institutions of the Ministry of Education and Science. Students from the higher educational institutions undertake internship and prior-to-diploma practical training at the Institute.

**Publishing Activities**

Since 2004, IRE has been publishing ‘Vidnovliuvana Energetyka’ journal quarterly that is on the list of professional scientific journals publishing the key findings of doctorate and candidate theses (pic. 24). The journal covers the findings of fundamental and
applied research in renewable energy domain, as well as the latest information about the use of renewable energy sources in Ukraine and worldwide, domestic experience and new achievements in the field, development and introduction of energy-saving equipment and technologies, improvements as adopted to the renewable energy legislative and regulatory framework, etc.

In addition, joint projects have been carried out with the international journal ‘Alternative Energy and Ecology’ (ISSN 1608-8298), where over 100 research papers of the Ukrainian authors have been published (pic. 25).

The collected articles dedicated to the International Scientific-Practical Conference ‘Renewable Energy and Energy Efficiency in the XXI Century’ (until 2014 entitled ‘Renewable Energy of the XXI Century’) are published annually. The publication presents the problems and solutions, pathways and promising lines in the development of all renewable energy technologies. 2018 also saw the publication of collected articles from the scientific and practical conference ‘Renewable

In 2004–2019, IRE’s staff published 793 articles, including 646 in domestic and 147 in international periodicals. 188 articles were published in profile scientific journals being the part of international databases. IRE’s staff members produced 27 monographs, 7 tutorials, 23 methodology guidance and 895 report theses published in 32 collected articles, including in 16 collected articles in follow-up of the International scientific and practical Conference ‘Renewable Energy and Energy Efficiency in the XXI Century’ (until 2014 entitled ‘Renewable Energy of the XXI Century’) and ‘Renewables and Hydrogen Energy 2018’.

Conferences and Exhibitions

Since the IRE’s foundation, its researchers have been organizing the International scientific and practical conference ‘Renewable Energy of XXI century’, starting from 2015 the conference has been renamed into ‘Renewable Energy and Energy Efficiency in the XXI century’.

The representatives from the CIS countries, France, Turkey, Belgium, Germany, China, the Czech Republic, Poland, Denmark and other countries took part in the conference. (pic. 26). To attract young people to studying the conference topics, a junior section was created where university students, postgraduates as well as the students from the Junior Academy of Sciences may deliver their reports (pic. 27).

The key goal of the conference is to analyze the problems and prospects in the development of renewable energy, the findings of renewable energy research, as well as the implementation of energy saving and energy efficiency measures. The topics of the conference embrace the following research areas: integrated RES systems,
The conference annually publishes a book of abstracts, and presentations of the conference participants are posted on the Institute’s website: www.ive.org.ua.

All the conferences held by the Institute promote the coordination of research and information exchange in the alternative and renewable energy study and development.

The Institute joins all the events organized by the NASU’s Presidium (exhibitions, forums, workshops, round table discussions, etc.), as well as takes part in commercial events organized by the Ministry of Fuel and Energy of Ukraine, the State Agency on Energy Efficiency and Energy Saving of Ukraine, etc.
IRE demonstrates its research and developments in the renewable energy technologies at the exhibitions on a regular basis. This brings new partners to implement IRE’s research findings in practice (pic. 28).

The Institute has been awarded multiple diplomas and certificates for active participation in the following events:

- National science festivals, exhibitions presenting scientific and technological solutions developed by NASU’s institutions
- International specialized exhibitions ‘HI-TECH EXPO. HIGH TECHNOLOGIES’ for substantial research developments and facilitation to science development

*Picture 28. IRE displays its research achievements at the exhibition of information systems and technologies. Stepan Kudria, the IRE Director meets Borys Paton, the former President of NASU*
- International forum ‘INNOVATION MARKET’
- Showcase of Kyiv-based industrial manufacturers’ products ‘Made in Kyiv’
- International specialized exhibition ‘Energy in Industry’
- Exhibition of NASU’s innovations and research developments
- International agroindustrial exhibition ‘AGRO’
- National exhibition action ‘Colorful Ukraine’

In the period 2004–2020, which is 16 years already, the IRE’s research staff was conferred various rewards and decorations 49 times.

The participation in the above promotional events helps establishing new contacts, facilitating further cooperation and bringing scientific and technical developments up to the higher national and international level, taking into account the political trends in energy supply in our country; accelerates the introduction of renewable energy sources in private companies and industry.

**Joint Renewable Energy Chair**

Governed by the Laws of Ukraine ‘On Education’, ‘On Higher Education’, ‘On Scientific and Technological Activity’, regulatory acts of the NASU’s Presidium and the Ministry of Education and Science of Ukraine, on June 17, 2016, Igor Sikorsky Kyiv Polytechnic Institute and the Institute of Renewable Energy signed the contract establishing a research and educational association ‘Joint Renewable Energy Chair’ on the basis of Renewable Energy Department at the Electric Engineering and Automation Faculty. The Joint Chair is a science and education association focused on capacity building for the experts training and joint research and educational activities in renewable energy.
The major objectives of the Chair:

- Integration and coordination of Igor Sikorsky Kyiv Polytechnic Institute and IRE joint efforts on establishing an efficient research and educational system capable of delivering high-standard training services
- Promoting high-quality education that ensures students may obtain higher education of due quality in relevant specialities. The department delivers a Bachelor's degree training program
- Promoting scientific activities via the efficient use of technical, institutional and economic base of both institutions: IRE and Igor Sikorsky Kyiv Polytechnic Institute, students’ and professors’ R&D and creative activities at this platform in the framework of educational process, applying the R&D outcomes in the educational process
- Ensuring synergy between academic, research and innovative activities in the framework of the educational process
- Participating in domestic social and economic development
- Holding joint scientific conferences, round-table discussions, etc.
- Creating due prerequisites for the educational process and scientific and technological activity
- Facilitating the students from Igor Sikorsky Kyiv Polytechnic Institute to do their internship at IRE
- Promoting onsite training for RES Department professors at the Institute as well as IRE’s researchers at Igor Sikorsky Kyiv Polytechnic Institute, RES Department, Electrical Engineering and Automation Faculty
- Personality formation through patriotic, legal, ecological education; establishing moral values, social activity, civic position and responsibility among students, healthy lifestyle among the participants of the educational process; development of the ability to think freely and the ability to self-organize in modern context
• Awareness raising among population, raising the educational and cultural level of citizens

• Promoting renewable energy and career guidance among schoolchildren

• Assistance in employment of the Renewable Energy Department graduates

For two years of the Chair’s operation:

• Six IRE’s research staff members trained the students at the Renewable Energy Department

• Four professors from the Renewable Energy Department (Electrical Engineering and Automation Faculty at Igor Sikorsky Kyiv Polytechnic Institute) trained postgraduates at IRE

• One IRE’s researcher have completed his internship at Igor Sikorsky Kyiv Polytechnic Institute

• One professor from Renewable Energy Department (Electrical Engineering and Automation Faculty at Igor Sikorsky Kyiv Polytechnic Institute) has completed his internship at IRE

• 37 students from Renewable Energy Department have completed their internship with the research departments at IRE

IRE’s research staff participated in the Doors Open Days at the Renewable Energy Department, Electrical Engineering and Automation Faculty, Igor Sikorsky Kyiv Polytechnic Institute. They contributed much to preparing and holding the conferences for young scholars in Ukraine.
Engaging Schoolchildren in Science and R&D

Starting with 2017, IRE jointly with Igor Sikorsky Kyiv Polytechnic Institute RES Department and the Junior Academy of Sciences of Ukraine is proactive in engaging young students in scientific and research activities. During this period, the range of joint activities were performed:

- XVIII International Scientific and Practical Conference ‘Renewable Energy and Energy Efficiency in XXI century’ at Electrical Engineering Faculty, Igor Sikorsky Kyiv Polytechnic Institute saw the first meeting of the Junior Section. 206 schoolchildren from the Junior Academy of Science and the managers of their research projects came to the conference from various regions of Ukraine. They delivered scientific reports on the challenges and perspectives in RES development and use; electricity industry, bioenergy and hydro energy, geothermal; solar and wind thermal applications, energy saving and energy efficiency measures implementation. 108 schoolchildren sent their reports to the conference and the book of abstracts was published presenting the schoolchildren’s reports.

- World Science Day was celebrated at the Kyiv Engineering Gymnasium. The Kyiv City Employment Center was engaged in the event where high school students listened to the lecture by Professor Stepan Kudria, Doctor of Engineering Sciences, Corresponding Member of NASU, who presented the topic ‘Renewable Energy’

- ‘Introduction to Renewable Energy’ training was delivered at the RES Department, Igor Sikorsky Kyiv Polytechnic Institute within the framework of the All-Ukrainian Scientific and Educational Project ‘Innovative Educational Technologies’
Implementation at Junior Academy of Sciences of Ukraine’. Professor Stepan Kudria, the Doctor of Engineering and the Corresponding Member of NASU delivered the lecture to the schoolchildren on the topic ‘Modern Status Quo and Promising Lines in RES Development’. Vasyl Budko, the Candidate of Engineering, Associate Professor and Deputy Chair of RES Department delivered the lecture on the topic ‘Solar Energy Conversion to Electricity and Heat’. The schoolchildren took part in the training and performed a research assignment to assess conversion of solar irradiation to electricity in practice (pic. 29).

*Picture 29. The participants in ‘Introduction to Renewable Energy’ training session*
• Participation in the Final Schoolchildren’s Conference dedicated to the Science Day at Gymnasium No.261, Darnytsa District, the city of Kyiv (pic. 30);

• IRE jointly with Frantsevych Institute for Problems of Materials Science and ‘Ukrainian Hydrogen Council’ organized the Scientific and Practical Conference ‘Renewable and Hydrogen Energy 2018’. The conference was dedicated to the 100th anniversary of the National Academy of Sciences of Ukraine, the 100th anniversary of the Electrical Engineering and Automation Faculty, the 120th anniversary of NTUU ‘Igor Sikorsky Kyiv Polytechnic Institute, the Day of Science in Ukraine. Junior scholars came from ten regions of Ukraine, specifically: Volyn, Donetsk, Dnipropetrovsk, Kirovohrad, Poltava, Ivano-Frankivsk, Luhansk, Kherson, Chernihiv and Kyiv. They presented their reports at the junior section.
The above events are designed to engage the youth, namely, postgraduates, students, university students, schoolchildren and the members of the Junior Academy of Sciences of Ukraine to discuss the development of renewable energy, take part in scientific and research activities on the issues of renewable energy in Ukraine, which, ultimately, will allow junior scholars becoming worthy professionals in their major discipline.

*Picture 31. ‘Renewables and Hydrogen Energy 2018’ conference, the Junior Section*
In its major activities, IRE inter alia focuses on the development of the national renewable energy policy towards the implementation of Ukraine’s plans to integrate into the European Union (pic. 32).

_Picture 32. Discussions about the renewable energy use at Hryshko National Botanical Garden. IRE’s top management meets Borys Paton (right), the Academician and the former President of NASU. Viktor Rieztsov (left) and Nver Mkhitarian (middle), both are the Corresponding Members of NASU_

In the scope of this activity, the works have been performed upon request of the Ukraine’s governmental bodies: the Cabinet of Ministers, the Ministry of Education and Science, the State Agency on Energy Efficiency and Energy Saving. The Institute participates in the development of governmental programs, renewable energy
roadmaps and development strategies. IRE prepares analytical and information reports and provides support while implementing the renewable energy governmental programs as well.

The main goal as set forth in the governmental programs on renewable energy development is to create favorable environment for the development and implementation of energy efficient technologies and equipment based on renewable energy sources. RE and EE development will:

- Bring the reduction of fossil fuel consumption and contribute to the national energy security
- Help Ukraine to meet its obligations before the EU related to higher RES share in total primary energy supply
- Facilitate harmonization of Ukraine's electricity industry system with the EU power generation infrastructure
- Create the preconditions for raising private funds
- Improve the environmental situation in the state, including thanks to decarbonization of the atmosphere
- Improve social situation in the state via creation of new jobs and raising living standards to boost overall well-being of the population

The Program of Governmental Support to the Development of Unconventional and Renewable Energy Sources was among the important governmental measures aimed at the development of renewable energy in Ukraine. The specialists of IRE (then the Institute of Electrodymanics) took an active part in drafting the Program. The Cabinet of Ministers approved the Program with its Resolution No.1505 of December 31, 1997. To scale-up the use of unconventional and renewable energy sources in Ukraine, the Supplemental Measures to the Program were also adopted. The priorities in the implementation of the measures were the launch
of RES-based efficient power plants, which had been already created by IRE to enable fast achieving energy savings as well as performance of promising research developments in the key renewable energy technologies.

IRE provided research support to the Comprehensive Program for Wind Power Plant Construction in Ukraine drafted in pursuance of the Presidential Decree of March 2, 1996 No.159 and approved by the Cabinet’s Resolution of February 3, 1997 No.137. The measures implemented in the scope of the Program contributed much to the development of renewable energy in Ukraine. The Program implementation facilitated additional electricity supply to some regions of the country, reduction of fossil fuel consumption, prevented GHG emissions thanks to green energy generation, improved competitive ability of local wind power plant manufacturers and reduced the demand for power equipment imports.

The Program key objectives were as follows: (1) to identify the areas for balanced development of wind energy industry and the measures to boost wind power generation; (2) to create favorable environment for domestic manufacturing of wind power plants and equipment at the restructured enterprises; (3) to develop regulatory framework; (4) to set the priority tasks for scientific, research, design works and operation of wind power plants; (5) to create conditions for decreasing environmental pollution.

The Comprehensive Program for WPP Construction in Ukraine allocated the funds (approx. 3% of the total allocations) for regulatory, scientific and technological support, including for research works. To coordinate research and scientific support under the Program, the Council decided to establish the two institutions: Inter-Branch Scientific and Technical Centre for Wind Power based at the Institute of Electrodynamics and the Scientific and Technical Council at the Intersectoral Coordination Council. Doctor of Engineering Stepan Kudria was appointed to chair ISTCWP and STC. In 2000, the Council reviewed and approved ISTCWP main activities,
structure, staffing, cost estimates for equipment purchase and maintenance. The main activities were: shaping promising research and development lines for wind energy development in Ukraine; organizing and holding expert research, technology, socio-economic programs and projects in this area; feasibility studies in wind energy based on major parameters of wind, energy generation, costs, investments, etc.

The Scientific and Technical Council was established as an advisory and expert body with the Intersectoral Coordinating Council to the end of making a sound unified technical policy for the development of wind energy scientific and technological potential, application of the cutting edge domestic and foreign science and technology. STC operates on a voluntary basis and its members represent the core science and technology areas in the wind energy as well as the ministries and agencies of Ukraine. Its main objectives are as follows:

- Ensuring the implementation of a single scientifically sound technological policy in the wind energy domain
- Forecasting the development of wind energy, drafting the proposals for the implementation of the Comprehensive Program for the Wind Power Plants Construction
- Determining the areas for R&D in wind energy subsector, professional assessment of the wind energy research status and prospects
- Expert assessment of the domestic and foreign experimental design projects for wind energy applications
- Reviewing the reports on the outcomes of research, experimental and design projects, analysis of their research and technological level, issuing recommendations how to launch them in future
- Review and assessment on ad-hoc basis of individual feasibility studies and WPP construction designs
• Review and assessment of production facilities for manufacturing of complex wind energy equipment

• Review research and technology parts of ISTCWP reports

• Review of proposed projects to design and introduce novel wind energy equipment

To the end of ensuring high scientific and technical level in the implementation of wind power plant construction works at all stages, the scientific and technological support program to the Comprehensive Program for WPP Construction in Ukraine was developed. The main lines of scientific and technical works were first considered by the Scientific and Technical Council and then submitted for approval to the Intersectoral Coordination Council. The Program provided for engaging institutions and individual experts (doctors and candidates of engineering, researchers, as well as high-end professionals) with profile expertise to perform the planned works. The first objectives of the program were as follows: (1) wind energy potential; perspective wind farm sites; (2) wind farm economics; (3) wind energy investment projects; operation of wind farms and their operational performance; (4) wind turbines, prospects for their use and production opportunities; (5) regulatory documentation for wind turbines and wind farms; (6) general issues in wind energy.

Since the Institute of Renewable Energy was founded in 2004, its Wind Energy Department has been the main coordinator and performer of these works, along with ISTCWP. The works performed by IRE’s specialists have brought important scientific and practical outcomes, and as a result new innovative electromechanical systems for wind energy technology have been created.

In 2009, IRE drafted ‘Program to Improve Energy Efficiency in the Autonomous Republic of Crimea for 2010-2014’. It was approved by the Resolution issued by the Parliament of the Autonomous Republic of Crimea No. 691569-5 / 10 of February 17, 2010. IRE’s
experts studied, identified and substantiated basic forecast indicators for the development of wind, solar and geothermal, small hydro, biomass technologies, heat pumps, and alternative fuels in Ukraine for the period up to 2030.

The outcomes of these works will improve performance during design and implementation of the investment projects and in drafting state programs and measures on renewable energy. In addition, they will increase the savings of fossil fuels and energy thanks to the use of energy from renewable sources.

IRE has elaborated the section ‘The Lines and Levels to Develop Unconventional, Renewable and Off-balance energy sources’ in the Energy Strategy of Ukraine until 2030 and for a longer term, developed the regional programs for wind energy development in AR of Crimea, Donetsk, Zaporizhzhia, Mykolaiv and Kherson oblasts.

To the end of promoting the development of renewable energy in Ukraine, the Institute participates in drafting the legislative framework for renewable energy via various mechanisms, primarily IRE provides information support in the form of inquiries, analytical reports, consultations etc.

The vital landmarks in promoting renewable energy development are the adoption of the Law of Ukraine ‘On Amendments to Certain Laws of Ukraine Promoting Energy Saving Measures’ No.760-V (2007) (which introduced certain benefits in the use of renewable energy sources and alternative fuels) and the Law Of Ukraine ‘On Amendments to Some Laws of Ukraine’ establishing the ‘green tariff’ No.601-VI (2008) and thus regulating the purchase of electricity generated at RES-based electricity generation facilities. In follow-up of the analytical note ‘Problems of R&D support to the development of renewable energy sources in Ukraine as the basis for future environment-friendly energy sector and national energy security’ compiled by IRE and submitted for consideration to the Interdepartmental Commission on Scientific and Technological
Security under the National Security and Defense Council of Ukraine, and the report at the meeting, the NSDC issued a decision on the pathways and mechanisms to promote the development of renewable energy in Ukraine.

In 2017, IRE jointly with Frantsevych Institute for Problems of Materials Science NASU drafted ‘The Roadmap of Integrated Development of Wind Energy and Machine Building in Ukraine’. That was a policy document seeking to address comprehensively the energy sector crisis and, simultaneously, the crisis in machine-building. The policy document was reconciled with all stakeholder national executive authorities and Presidium of NASU and then approved by the Ministry of Economic Development (Pic. 33). The First Vice Prime Minister of Ukraine instructed that the Roadmap provisions should be taken as the core principles while drafting the State Comprehensive Target Program of Renewable Energy Sector Development as a Component of the Low-Carbon Economy.

The implementation of the Roadmap will provide profile public authorities with the tools for multi-criteria optimization and coordination of energy, environmental, economic and investment policies for the energy sector development, which should accommodate the interests both of the state and private investors.

INTERNATIONAL ACTIVITIES

The geography of IRE’s international R&D collaboration is broad: Academies of Sciences of Armenia, Vietnam, China, Uzbekistan, renewable energy research centers based in Germany, Denmark and the United States, the Institute of Electrical Engineering from Poland, the Ministry of Ecology of Macedonia and others.

IRE researchers maintain international cooperation with Eurosolar (European Association of Renewable Energy Sources), Solarzentrum Mecklenburg-Vorpommern, Germany, Folkecentre (Denmark), the International Center for Small Hydropower, Beten (France), Antap-Ukraine, Apogee GmbH, in the context of improving efficiency of RES-based systems.

In the framework of cooperation for the studies into novel technologies and their applications, the ‘Ukrainian-Polish Center for Renewable Energy and Energy Efficiency’ has been established, where new technologies and equipment have been launched (pic. 34–36).

IRE performs joint research and shares information with foreign partners (Germany, Spain, Austria, Denmark, Macedonia, Montenegro, Belarus, China, UAE and others) by bilateral cooperation agreements. IRE’s Integrated Energy Systems Department cooperates with Folkecentre (Denmark) on the launch of wind-and-hydrogen technology.

Picture 34. The energy systems at the Ukrainian-Polish Centre for RE and EE
In the framework of bilateral cooperation, IRE carried out joint scientific, R&D and technological activities with the institutions from Belgium (NOVOSTAR spr) and Macedonia (VODOVOD).

Under the memorandum of cooperation and partnership between IRE and NOVOSTAR spr (Belgium), the recommendations were drafted on the economic feasibility of using renewable energy to create environment-friendly technologies for energy supply to recreational areas, reserves, botanical gardens (based on the best practice of Hryshko National Botanical Garden, Kyiv, Ukraine) and establishing a bioclimate training center on the basis of the National Botanical Garden.

Within the framework of the agreement on scientific and technical cooperation between IRE and VODOVOD, a state-owned enterprise (Macedonia), the feasibility study into potential RES use on the territory of the town of Kochany has been completed and the following facilities have been built: solar-powered traffic lights; 10 park lights powered by solar photovoltaics; 1.5 kW wind turbine electricity generator.
According to the contract between IRE and Simak Engineering Duel, Skopje (Macedonia), calculations of the theoretical potential of solar, wind, geothermal and biomass energy sources have been carried out, proposals have been drafted for a strategy for economic development of the Vardar region. The priority facilities to use these energy sources and technology solutions have been proposed. According to IRE, the use of renewable energy sources in the Vardar region may reduce the annual consumption of fossil fuels by 580,000 tons and thus may reduce the region’s carbon dioxide emissions by 422,000 tons.

Since 2004, junior researchers of the Institute have been engaged in educational programs of the ‘Open World’ American Council founded in 1999 and sponsored by the US Congress (pic. 37).

IRE has been active in the implementation of the international projects. A striking example is the implementation of ‘Improving energy efficiency and promoting the use of renewable energy in agro-food and other small and medium enterprises of Ukraine’ Project.

The project is implemented by the United Nations Industrial Development Organization and funded by the Global Environmental Facility. IRE is a key executing agency for the Project.
In 2015, an environment-friendly and energy-saving International Information and Demonstration Centre for Renewable Energy Technology Implementation and Technology Transfer was established (pic. 38).

The Centre focuses on the following main lines in its activities: (1) demonstration of novel technologies in renewable energy and energy efficiency; (2) holding raising awareness events to share information on science and technology aspects of improving energy efficiency and promoting the use of renewable energy in various economic sectors; (3) technology transfer and studies; (4) integration of renewable energy and energy efficiency innovative solutions in the energy system infrastructure all over Ukraine; (5) demonstration of energy efficient renewable energy technologies in civil engineering. To the end of implementing this project, a consortium is founded with international partners and donors’ grant programs.

IRE’s international scientific research activities facilitate establishing new contacts, concluding agreements on cooperation thus bringing the Institute up to higher domestic and international level in science and technology, shaping current political and social trends in energy supply in our country towards incorporating the launch of renewable energy sources (wind, solar, small hydro, geothermal energy and bioenergy) in private companies and in industry.
During 2004-2020, IRE developed and approved 39 renewable energy standards.

The full list of these standards is as follows.


The Institute of Renewable Energy has been taking an active part in creating intellectual property items. The key intellectual property products created by IRE’s experts are inventions and utility models.

In 2008, Presidium of NASU issued a resolution ‘On Technology Transfer, Innovation Activities and Intellectual Property Units’. And, in pursuance of the Law of Ukraine ‘On State Regulation of Technology Transfer Activity’, the Department on Technology Transfer, Innovation Activities and Intellectual Property was established at IRE.

During its existence, IRE obtained 20 patents of Ukraine for inventions and 84 patents of Ukraine for utility models. Among all the intellectual property items created by IRE’s experts, there are many innovative and attractive technological solutions in all areas of IRE’s activity, in particular:

- Patent of Ukraine for invention No. 82692 ‘Separator for separating gas from liquid’ (May 12, 2008, journal No. 9, author: I. Kravchenko). The proposed device belongs to geothermal energy and can be used in oil and gas, oil refining and chemical industries, in water supply for the purpose of liquid separating from associated or dissolved gas, as well as for further use of the separated gas as energy carrier or industrial feedstock;

- Patent of Ukraine for utility model No. 42421 ‘Method of heating and hot water supply in buildings with the use of solar energy and low-potential thermal energy of water’ (December 12, 2009, journal No.13, authors: I. Pukhovyj, T. Kudria), in which the seasonal change in the location of solar collector absorber provides a reduction in peak loads in conventional heating and hot
water supply system, reducing the costs of air conditioning and reducing capital investment in the heating system;

- Patent of Ukraine for invention No.90986 ‘The technique of heat transfer to remote consumers and the device for its implementation’ (June 10, 2010, journal No.11 author: I. Kravchenko), where the device can be applied both in normal conditions and where a heat consumer is located so far from the heat source that conventional heating pipeline is unfeasible in terms of technology and cost-effectiveness due to high investment required for its building and maintenance, especially in remote areas;

- Patent of Ukraine for invention No.93941 ‘Solar collector’ (March 25, 2011, journal No.6, authors: V. Kuchynskyi, V. Rietzso, O. Surzhyk), where the invention is aimed at improving the design of the solar collector main components by using state-of-art high-strength and durable polymeric materials, which will provide high thermal performance of the collector, simplification of manufacturing technology, installation and repair; this improves reliability, cost-effectiveness and durability of the solar collector. All of the above allows to recover the costs of building and maintaining a solar collector within one or two operation seasons;

- Patent of Ukraine for invention No.99965 ‘Wind turbine’ (October 25, 2012, journal No.20, authors: V. Kokhanievych, M. Shykailov, V. Holovko). The model of a wind turbine is aimed at efficient orientation of the installation with the wind given a reduced length of the tail beam due to the higher pitching moment of the nacelle. Wind turbine comprising a tilt nacelle, a rotor, a support and a wind-relative positioning system, which differs in that the positioning system is made in the shape of a Savonius rotor mounted on a tail beam with the possibility of rotation in the vertical plane. The use of a rotating Savonius rotor as a feathering blade plane will reduce the overhang of the tail beam and provide additional electricity output from the generator, the shaft of which is rigidly connected to the Savonius rotor;
• Patent of Ukraine for utility model No.81015 ‘Wind turbine’ (June 25, 2013, journal No.12, authors: N. Mkhitarian, S. Kudria, I. Kravchenko), where the expected technical result is achieved, specifically: improved utilization factor of wind energy, efficiency and capacity of the turbine due to almost double the wind impact per one connected mechanism, which is determined by the area covered by each wind wheel, lower total weight of the nacelle because the weight of the integrating gearbox is significantly lower than the weight of the connected mechanism, the bearing load is reduced, and conditions for maintenance of the connected mechanisms are improved;

• Patent of Ukraine for utility model No.87910 ‘Two-circuit combined solar system’ (February 25, 2014, journal No.4, authors: A. Hamarko, Yu. Zaporozhets, V. Rietzsov, T. Surzhik, V. Pundiev, V. Shevchuk), where the expected technical result is achieved, specifically: an improved two-circuit solar system to the added contour of combined photovoltaic modules with an electricity storage and an invertor, a desalinator with water level sensors and solar energy concentrators for solar collectors, which will ensure the conversion of solar energy into electricity to feed the pump, desalination of sea water, bringing the heat transfer agent’s temperature to the value as required for the desalinator operating process;

• Patent of Ukraine for invention No.109496 ‘Wind turbine for thermal energy generation’ (August 25, 2015, journal No.16 authors: V. Holovko, V. Kokhanevych, M. Shyhailov, Yu. Perminov). The problem is solved via a thermal generator designed as an electric induction heater, where the heat is generated by Foucault currents emerging in a stationary disc due to permanent magnets passing over it. The permanent magnets are rigidly fixed on the first disc circle wise in the pole alternation order. The alternating magnetic flow is known to generate eddy currents (Foucault currents) in ferromagnetic surface while passing over it, which in its turn results in Joule losses. These
losses are proportional to the square of the magnetic polarity reversal frequency. In addition, the proposed design enables adjustment of the rotor angular velocities and its power by increasing the load on the rotor with increasing angular velocity of the rotor. This is an automatic process thanks to the lower gap between the discs;

- Patent of Ukraine for utility model No.111927 ‘Energy efficient house with a combined solar system for hot water supply and air conditioning’ (November 25, 2016, journal No.22, authors: V. Rieztsov, T. Surzhyk, V. Kuchynskyi). The utility model addresses the task to create an energy-efficient structure that would, along with high thermal efficiency and the availability of a solar hot water system, ensure the efficient operation of an autonomous solar cooling system based on an absorption solar cooler. The problem is solved by adding a hot water supply system to an energy-efficient house built with the insulated walls and roof;

- Patent of Ukraine for utility model No.117987 ‘Geothermal water separator’ (July 10, 2017, journal No.13, authors: V. Oliinichenko, V. Velychko). The utility model is aimed at improving the geothermal water separator by changing the regime of the gas-water mixture flow prior to the separator, providing suppression of additional dynamic, cyclic, alternating loads that occur during the slug regime mode of the gas-water mixture, which may swing the separator. To achieve this goal, an additional tank is placed prior to the geothermal water separator connected to the production well and installed vertically. The tank is connected to the separator through gas and water channels.
IRE will be bringing up to the new level its fundamental and applied research and implementation in practices of the latest research findings and technologies. The priority objectives are:

- Development and launch of integrated RES-based energy systems with various energy storage types to improve performance of renewable energy applications
- Development of the framework to underlie a brand new energy strategy focused on a transition to a low carbon economy using the innovative renewable and hydrogen energy technologies and relevant roadmaps to implement the strategy;
- Improvements to operating modes of the available RES-based equipment
- Development of new machinery, technologies and materials

The new fundamental and applied science problems to be addressed in the short term and in the longer term:

- Forecasting the trends in RES development in Ukraine and the world taking into consideration potentials of various renewable energy sources
- Annual updating of technically achievable energy potential by the types of renewable energy sources, which use in Ukraine is promising
- Developing scientific and technological principles and methods to improve efficiency of RES-based applications
- Developing analysis methods for renewable energy processes
- Developing methods to assess the resource of energy supply systems
• Developing optimization methods for the integrated systems to the end of ensuring their reliable operation given stochastic parameters of primary energy source

• Creating new machinery and technologies for conversion of renewable energy

• Creating new materials and technologies for manufacturing renewable energy equipment; development of efficient heat and electricity storages for the energy obtained from RES and hydrogen energy storages

• Improving performance of RES-based energy systems via the integrated use of renewable energy sources, energy storages and heat pumps

• Creating environment-friendly electric vehicles running on photovoltaic batteries, biofuel and hydrogen-fuelled vehicles

• Developing mathematical models and analysis into thermal and hydrodynamic processes in the systems extracting geothermal heat taking account of thermoviscoplastic filtration in underground permeable layers

• Developing scientific and technological principles and techniques for improving energy efficiency of the bioenergy applications

• Creating mathematic models to assess economic and social efficiency of the RES technologies implementation

Among important lines in IRE’s activities is its efforts focused on the development of national energy policy, specifically renewable energy policy in Ukraine, to facilitate Ukraine’s European integration plans. To this end, the Institute continues the works it performs by request of the national agencies – the Cabinet of Ministers, the Ministry of Education and Science, the State Agency on Energy Efficiency and Energy Saving.
DESNA testing ground. A zero-energy building with the supply of energy from RES

YUZHMApH machine-building plant. The production facilities manufacturing USW 56-100 and Turbowind T600 wind turbines
The workday at the Inter-Branch Scientific and Technical Centre for Wind Power (2003)

2004. The meeting of Nver Mkhitarian, theIRE’s Director with the Member of the German Bundestag Hermann Scheer, one of the green tariff system founders
Joint meeting of IRE’s top management, representatives of National Technical University of Ukraine ‘Igor Sikorsky Kyiv Polytechnic Institute’ and Hermann Scheer from Friedrich Ebert Foundation

Study tour to Germany in the scope of UNIDO/GEF Project
2006. Stepan Kudria, Ph.D., at the International Conference on Solar Energy at SolarZentrum-MV, Germany

IRE’s and ISTCWP’s expert Oleksandr Pepelov on a visit to Hannover Messe with the Ukraine’s delegation in 2006
IRE and National Technical University of Ukraine ‘Igor Sikorsky Kyiv Polytechnic Institute’ top management meeting with the representatives of the Embassy of Poland to Ukraine

Integrated power supply system, IRE’s building at Hryshko Botanical Garden (Kyiv)
Hybrid ecomobile equipped with electricity and biodiesel motor, modified GAZ Sobol model, developed with participation of IRE’s experts

Electrocycle prototype developed with participation of IRE’s experts, based on Dnipro-300 standard model manufactured at Kyiv motorcycle plant
One year prior to the Crimea annexation, International Scientific and Practical Conference ‘Renewable energy in XXI century’, AR of Crimea, Mykolaivka town

Karin Stehlyk, the Director of Czech Hydrogen Technology Platform, Oleksandr Riepkin, the Chairman of Ukrainian Hydrogen Council, Stepan Kudria, the Corresponding Member of NASU at the solemn opening of the Scientific and Practical Conference ‘Renewable and Hydrogen Energy 2018’

Stepan Kudria, Ph.D., Director of IRE, Corresponding Member of NASU holding a speech at the Presidium of NASU