ENERGY BULLETIN

United Nations Educational, Scientific and Cultural Organization
Autonomous Non-Commercial Organization
International Sustainable Energy Development Centre
under the auspices of UNESCO

Energy Bulletin
№25, 2019

ON THE THRESHOLD OF THE LOW-CARBON ENERGY ERA

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Educational, Scientific and
Cultural Organization

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ANO “International Sustainable Energy Development Centre” under the auspices of UNESCO (ISEDC)
3rd floor, build. 2, 8, Kedrova Str., Moscow, Russia, 117292
Tel. +7 (495) 641-0426
E-mail: info@isedc-u.com

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Editorial Office

Editor: Irina KEVBRINA
Science consultant: Vladimir KUZMINOV

3rd floor, build. 2, 8, Kedrova Str.
Moscow, Russia, 117292
+7 (495) 641-0426
info@isedc-u.com
kevbrina@isedc-u.com
www.isedc-u.com

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10th ANNIVERSARY OF THE INTERNATIONAL SUSTAINABLE ENERGY DEVELOPMENT CENTRE UNDER THE AUSPICES OF UNESCO

Dear friends!

On the occasion of the 10th anniversary of the International Sustainable Energy Development Centre under the auspices of UNESCO (ISEDC) and the Energy Bulletin we would like to express our gratitude to you.

On September 5, 2008, the Agreement between the Government of the Russian Federation and the United Nations Educational, Scientific and Cultural Organisation for establishment and operation of the Sustainable Energy Development Centre as a category 2 centre under the auspices of UNESCO was signed.

One of the first and key projects of ISEDC being implemented in cooperation with UNESCO is the Energy Bulletin which we wanted to become a source of current and independent information on sustainable energy development.

Your continuous support, professionalism of ISEDC staff and editors of the magazine allowed us to draw the attention of the society to the urgent energy-related problems.

Over 10 years, the magazine managed to become a reputable popular science periodical. On behalf of the Editorial Board and ISEDC staff we express our sincere appreciation to all readers of the Energy Bulletin for your support and attention!

Yury Posysaev,
Executive Director of ISEDC &
Executive Secretary of EB Editorial Board

CONGRATULATION ON THE 10th ANNIVERSARY OF THE INTERNATIONAL SUSTAINABLE ENERGY DEVELOPMENT CENTRE UNDER THE AUSPICES OF UNESCO

Dear colleagues!

I am pleased to congratulate the management and staff of the International Sustainable Energy Development Centre under the auspices of UNESCO on its 10th Anniversary!

Your productive work on increasing affordability and reliability of energy supply, developing the scientific, technical and workforce potential of the fuel and energy industry, the spread of renewable energy sources and other environmentally friendly technologies is greatly appreciated by the entire expert community. Impeccable reputation of the Centre is evidenced by continuous contribution of your experts to solving the sustainable energy development problems both at the level of the Ministry of Energy of the Russian Federation and largest Russian energy companies.

I wish new successes to all of the Centre's staff in implementing the UNESCO's sustainable energy development activities, new breakthrough ideas and large scale projects.

Minister of Energy of the Russian Federation
A.V. Novak

EDITORIAL

In the introduction to the 25th anniversary publication of the Energy Bulletin (EB) magazine, the Editorial Office would like to remind the readers of certain milestones in the history of this periodical that was founded by the International Sustainable Energy Development Centre (ISEDC) under the auspices of UNESCO in 2008. The magazine was one of the first long-term and on-going projects of ISEDC aimed at promoting the better understanding of the sustainable energy development problems and the methods of overcoming them by all members of the international community. Over the ten years of its existence, the magazine has touched upon numerous energy-related issues faced by the contemporary society and presented its pages to prominent scholars, engineers, economists and politicians from more than 50 countries, as well as to representatives of several international organisations to initiate discussions of and clarify the truly complex and challenging tasks of laying the foundation for the sustainable energy and sustainable development of the contemporary society. Being a periodical run by ISEDC under the auspices of UNESCO, EB has paid special attention to social, economic and humanitarian aspects of the energy development primarily related to the problems of eradicating the energy poverty in all continents of the Earth, energy efficiency awareness raising for the general public and training of energy experts, as well as other issues within the Organisation´s scope of competence. The magazine has made a significant contribution to the better understanding of the role and place of energy in the sustainable development of humankind, as well as to the elaboration of the concepts for sustainable development of the energy sector and sustainable energy development of the society by publishing numerous articles by renowned experts who gained worldwide recognition for their work in solving the critical scientific energy problems. The magazine also has presented the work of young researchers, inventors and enthusiasts and their original concepts of energy-generating plants and devices powered by renewable energy sources.

It should also be noted that EB has successfully provided information support to several important international energy forums and conferences held in Russia and abroad. Fruitful cooperation with the Global Energy Association on Development of International Research and Projects enabled the magazine to present to its readers the significant fundamental and applied research achievements in the energy field by the winners of the Global Energy Prize, the most prestigious "energy" award in the world.

Another evidence of the magazine´s prominence is its inclusion in the Russian Science Citation Index of the Scientific Electronic Library, the largest Russian database of academic publications.

Each issue of EB included highlights of the most important events supported by UNESCO, an overview of the work of ISEDC over certain periods of time, as well as information on large scientific energy-related events (forums, conventions, conferences, exhibitions, etc.).

By giving a summary of all topics covered by the magazine over the ten years of its existence it is also necessary to mark the essential role of the EB Editorial Board members in selecting those topics, as well as preparation and presentation by many of them of the most interesting materials for publication which, without any doubt, aroused interest among the readers and made a contribution to achievement of the goals set by EB and ISEDC in general.

The 25th issue of the magazine opened by this editorial is aimed at focusing the being reader's attention on the path for the world energy development and the energy development of the world society in this century which should be based on the sustainable development concepts in the short term. The readers might ask: why does this article introduce two concepts, namely "world energy development" and "energy development of the world society"? To avoid any possible confusion it should be noted that there is a difference between these two concepts and such difference is significant. Whereas the success of the energy development is primarily dependent on the scientific progress in the field of highly efficient use of all types of energy carriers and sources for generation and transmission of energy in its final forms: electricity and heat, as well as the energy sector's shift towards intensive and widespread use of renewable energy sources, "energy development of the world society" means not only what was mentioned above but also the progress in delivering the energy to consumers and efficient use of the energy in production and consumer areas of our society involving all members of the society, young and old.

Such progress will obviously be targeted at enabling "sustainable energy development" that will depend not only on efficiency and "cleanness" of energy, but also, to a great extent, on the energy efficiency of the contemporary society and the generations to come. It means that every member of our society should take part in creating the fundamentals and enabling the sustainable energy development of humankind and, consequently, we all need to possess the required knowledge and skills that are equally important both for those involved in energy generation and those developing the technologies and various equipment for utilisation of energy, and for the massive army of energy users in their economic activities and everyday life. Now we have to emphasise the utmost importance of energy education for all members of the society, including the awareness raising and training of energy experts and technology developers to attain the most effective use of energy and energy carriers.

This qualitatively new knowledge should make it clear for everyone that the methods (technologies) of energy generation and consumption that existed in the 20th century enabled social and economic progress in most countries of the world, but on the other hand they inflicted significant harm on the life of humankind by degrading the natural environment and led to dramatic environmental deterioration of places of living and production activities of people. They also caused an increase in concentration of gases in the air, including, most notably, carbon dioxide, which create the greenhouse effect. According to many specialists, such gases were the reason for atmospheric temperature growth and serious climatic changes on our planet causing natural disasters (tornadoes, hurricanes, floods, droughts, mudflows and landslides, etc.) whose destructive force and frequency increase every year. All this not only leads to tremendous financial losses, but also threatens human lives in several parts of the world, as well as existence of entire island nations as they could go under water due to the Global Ocean rise. All these threats caused by climatic changes are recognised by the international community that has been taking drastic measures to mobilise the intellectual and financial assets on the global and national levels for thirty years to mitigate and, in the long run, eliminate such threats.

In this regard it is necessary to underline an exclusively important initiative by the United Nations (UN) – the UN Framework Convention on Climate Change (UNFCCC) that was adopted on 9 May 1992 at the Rio Earth Summit. This international multilateral treaty was basically declarative and recognised the climatic changes as a growing threat to humankind and calling all countries of the world to combine their efforts in preventing the consequences of such changes and global warming of the Earth surface and atmosphere. It was called "framework" treaty as it lays the foundation for further specific cooperation agreements among the UNFCCC member states. Today, UNFCCC includes 197 member states that have signed and ratified this treaty being governed by the Conference of the Parties (COPs) to the UNFCCC where certain agreements are concluded with respect to performance of the Convention. The latest COP (number 24) was held in Katowice, Poland.

Each COP played its role in achieving the goals set by UNFCCC, but one of them, COP3, held in 1997 in Kyoto, Japan, was of special importance as it proposed to the World community the Kyoto Protocol which became an international treaty supplementing the Framework Convention. It imposed certain obligations on the developing countries and the emerging economies to reduce or restrict the growth of greenhouse gas emissions and offered international economic mechanisms for its implementation. It took quite a long time before this treaty was ratified and entered into force, and today its parties include 192 states. This treaty is seen as the first global agreement on the environment protection that is based on market mechanisms – international greenhouse gases emission trading and joint implementation of emissions reduction projects. Kyoto 1st commitment period started in 2008 and continued until 2012. Kyoto 2nd commitment period runs from 2013 to 2020.

And finally, COP21 held in Paris, France, adopted a new climate agreement called the Paris Agreement which, apart from the Parties' obligations to limit and reduce the greenhouse emissions, included the requirements to adaptation to climatic changes, transfer of technologies and financing.

Currently, this document is seen as the most important international treaty not only within the UNFCCC framework, but on the entire UN level. Today, it is signed by 197 states, of which 185 have ratified it. It took only one year for the agreement to take effect (as compared to 8 years for the Kyoto Protocol).

As at late March 2019, the Paris Agreement was not ratified by Angola, Iraq, Yemen, Kyrgyzstan, Lebanon, Libya, Oman, Russia, Turkey, Eritrea and South Sudan. USA ratified the Paris Agreement in 2016, but declared their withdrawal in 2017 by notifying the UNFCCC Secretariat.

By the way, Russian Federation, being a signatory to the Agreement, has not yet ratified it, and it is expected that ratification will take place soon after the comprehensive evaluation of the social and economic effect of the Agreement on the country.

A peculiar feature of the document is that it does not impose any certain obligations to limit and reduce the greenhouse emissions, but instead requires that the parties determine the volumes of such emissions themselves. This pretty ill-designed aspect of the Agreement was strongly criticised by numerous international experts. In that respect, COP24 held in late 2018 in Katowice, Poland, jointly with the meeting of the Parties to the Paris Agreement, adopted the Rulebook that clearly defined the scope of rights and obligations of member states to enable more efficient implementation of arrangements made in Paris for purposes of ensuring low carbon and sustainable future for humankind (the only rules for joint activities of the Parties that lack approval are those laid down in Article 6 of the Paris Agreement, the so-called Sustainable Development Mechanism). It is implied that all current and future stakeholders must make the respective changes in the nearest future, and the first areas to be changed should be the energy sector and the aspects of energy utilisation by our society.

Sustainable development of the energy sector and energy development of the society must be based on low carbon principles and must be highly efficient in terms of energy utilisation. Considering the success achieved in spreading the use of renewable energy sources, many experts and even entire nations assert that energy production could shift to zero-carbon generation without the use of any fossil fuels by making the energy "renewable". It is implied that fossil fuels will be entirely abandoned by our society and will not be used either directly or indirectly, including any vehicles.

It should be noted that a series of countries have already entered upon the path of this energy development and, possibly, they will be able to declare achievement of low carbon, or even zero carbon energy production in the nearest decades. In particular, Norway expects to attain carbon neutrality by 2030; Sweden, the Netherlands and California, an American state, expect to reach that point by 2045, New Zealand – by 2050. This would be a clear proof that the provisions of UNFCCC and the Paris Agreement are efficiently implemented as such energy systems will inevitably lead to a dramatic reduction, or even phase-out, of greenhouse gas emissions which should positively affect the local and global climatic changes and, most importantly, reduce the risks of further warming the Earth surface and atmosphere.

To sum up, the goals and objectives of international cooperation in this field and plans for their achievement have been clearly defined, and in this respect there are no doubts about the bright future of UNFCCC and the Paris Agreement. But despite almost thirty years of the international community's work guided by UNFCCC and strengthened by a series of agreements and ongoing negotiations as part of COPs and other events, there is not a slightest hint that the desired effect will be achieved any time soon. For example, at the above mentioned COP24, the World Meteorological Organization (WMO) released certain data evidencing an increase in concentration of greenhouse gases in the air that has hit a record high level. It means that global emissions continue to grow despite the requirements of UNFCCC and other agreements. Of course, it is too early to judge on the impact of the Paris Agreement as it is too “immature” to evaluate its efficiency.

By all means, “abandonment” of fossil fuels in the energy sector, primarily coal, or its replacement by more environmentally friendly energy carriers such as natural gas, will clearly lead to certain positive changes in the currently negative trend, but many experts believe that it will not eliminate global warming as greenhouse gases will still be emitted, though in smaller volumes. Obviously, energy-related CO_2 emissions could be ruled out as a main factor of global warming and concomitant climatic changes only when the global need for energy could be satisfied by the use of renewable energy sources and the humankind´s transition to the renewable energy.

But we should be more realistic when analysing the opportunities for such transition as it apparently will take several decades to implement, provided that humankind could attain and maintain low carbon energy production. It means that low carbon and renewable energy will remain the two main elements of the global energy industry for two or three decades with the renewable energy becoming more and more prevalent. Undoubtedly, a sudden transition of humankind from one energy pattern to another is impossible as it requires huge financial costs and a significant economic conversion of many countries and areas primarily related to production of carbon-containing energy carriers. Without any doubt, this process should be accompanied by continuous growth of energy efficiency of our society to significantly reduce energy consumption in all industries and in everyday life of all members of our society. Assumption is that in this respect all countries of the world have significant reserves that should be used to achieve the goals of joint international work aimed at mitigation of the climatic changes and partial, or even entire, liquidation of their causes.

Considering the tremendous importance of the energy industry in solving the problems related to climatic changes on our planet which are considered by many experts to be connected with the excessive consumption of carbon-containing fuels by the global society, Energy Bulletin dedicates its 25th issue almost in its entirety to certain aspects of low carbon energy development and its possible, or even inevitable, transition to zero carbon production which must lead the humankind not only to mitigation of climatic changes on our planet, but also to near-complete sustainable development of humankind. When preparing this issue of EB, the magazine´s Editorial Office asked the members of the Editorial Board to answer some questions related to the energy development in this century and would like to attract attention of our readers to the answers provided by Hans-Josef Fell, President of Energy Watch Group (Germany), expressing his firm confidence that the transition to the global energy based entirely on renewable energy sources should be effected as soon as possible to not only offer environmentally friendly energy to the humankind, but also significantly reduce the risks of further climatic changes on the Earth. Mr. Fell is an “orthodox” supporter of renewable energy and a co-author of the German law on the use of renewable energy sources that defined the energy development vector of the country. The same opinion is expressed in the article by Academician* D.S. Strebkov who believes that further development of the global energy will be based on zero carbon principles. Being a “pioneer” in solar energy conversion to electricity in Russia, he designed a global system for production and distribution of “solar” electricity. He also manages scientific and engineering research work to study the use of various renewable energy sources, thus laying the foundation for renewable energy in the country.

This issue of EB one more time touches upon coal and its non-energy use. As was noted above, de-carbonization of the global energy industry and economy in general will be primarily connected with phase-out of this fossil fuel and its replacement by other energy sources that guarantee significant reduction, or even absolute elimination, of greenhouse gas emissions. This

Sustainable development of the energy sector and energy development of the society must be based on low carbon principles and must be highly efficient in terms of energy utilisation.

principle implies that coal has no energy future of its own, but it is a promising material for production of many valuable products which are used today in various industry sectors, including some more valuable energy carriers that do not generate unwanted gases emissions. It should be noted that 25 countries and territories abiding by the provisions of the Paris Agreement announced at COP23 in 2017 in Bonn, Germany, a new initiative, Powering Past Coal Alliance, aimed at imposition of a moratorium on new coal-powered energy-generating facilities and incremental reduction of energy generated by conventional plants in such countries and territories. The number of members of the Alliance grew to 31 at COP24. Of course, this initiative should promote the reduction of energy used by the members of the initiative most of which are not coal-mining countries or territories and, consequently, they will not face the need to convert the coal industry into a non-coal use of this fossil fuel. At the same time, one should remember that the future of coal is associated with many social and economic problems to which an article published in this magazine issue attracts attention. The call for 100% transition to renewable energy in the nearest two decades made in some articles of this EB issue should clearly be fully supported by our society as all the technical arrangements have been made and it could be readily implemented. But it seems that it is impossible to entirely withdraw carbon-containing energy carriers from the energy industry over the said period of time, and the current and the next generations of people should go through quite a long low-carbon energy period as a transitional phase of the energy development of the society which should meet the criteria of sustainable development to a higher extent.

Presenting the winners of the Global Energy Prize 2018, Academician* Sergey Alekseenko (Russia) and Professor Martin Green (Australia), Energy Bulletin is glad to remind that this prestigious prize has been awarded for several years to outstanding scientists who made their important contributions to sustainable energy development. For example, Academician* S. Alekseenko has received this prize for elaboration of thermophysical fundamentals for development of modern energy-generating and energy-saving technologies, Professor M. Green – for his innovative solar power technologies. The prospects for development of those fields of science and technology are described in their presentations at academic meetings held in Moscow. It is particularly remarkable that the speech of S. Alekseenko at the 7th Russian National Heat Transfer Conference was mainly dedicated to the utilisation of thermal energy of the Earth´s deep interior and, specifically, future development of petro thermal energy.

Professor Rae Kwon Chung (South Korea) a Chairman of the Global Energy International Prize Committee and a prominent international climate change expert, presents here his vision of the ways to decarbonize the World economy and, above all, the energy industry that will certainly lead to mitigation of climatic changes on our planet and minimisation of their negative effects.

Once again, the magazine pays attention to the problems of collecting and utilising solid municipal waste (SMW) by publishing the data on the current state in the Russian Federation as analysed by an ISEDC expert, M. Skonechny. He emphasises the need for separate (differentiated) collection of waste and recycling for further use of SMW basic components (paper, glass, plastics, metals). Another important aspect is the significant energy saving ensured by "reviving" these materials which enable to recover substantial amounts of energy consumed for their initial production. Still, today Russia elects to utilise waste incineration technologies that enable a certain energy output (electricity and heat), but emit various gases, including greenhouse ones. Indeed, this waste management method is progressive as compared to dumping that causes serious environmental problems and makes large territories unfit for economic use and human habitation. At the same time, it should be noted that the waste management problem has grown into a global issue and many countries have achieved certain success in overcoming it, and the waste management is becoming an economically advantageous business.

It should also be noted that, unfortunately, there still exist no innovative or breakthrough solutions related to the use of fundamental research findings in physics, chemistry and biology for formation of efficient and absolutely satisfactory conditions for sustainable development of technologies that would make full use of SMW. For example, a few years ago the Global Energy Prize was awarded to Academician* Philip Rutberg for his plasma technologies developed by him to convert waste into atomic elements and their use for production of materials. This method enables production with very low emission of gases that have low to zero environmental impact. Nevertheless, there exist no data on practical use of this technology. It should be emphasised that as the waste management systems grow into full-fledged and developed economy sectors the scientific research findings will expand and will be used more efficiently.

In his article, Professor Y.M. Bychkov (Russia) attracts attention of our readers to the peculiarities of the innovative wind energy technology developed by him, iWET (Innovation WindEnergyTech), that he believes is capable of taking rightful place in the sustainable energy.

As usual, this issue of EB informs our readers of the most important energy events and news of UNESCO and ISEDC.

Of course, one of such events was the VII Global Energy Summit held on 18 April 2018 at the Energy Centre of the Polytechnic University of Turin, Italy. It was dedicated to the problems of energy transition to non-carbon energy systems and digitisation of the energy industry. The report of this international forum, which our readers will surely find interesting, is published in this issue of EB.

In conclusion, Editorial Office thanks all authors for their generous contribution to development of conditions for sustainable energy development of our society and better understanding the scope of related issues, and the Global Energy Association on Development of International Research and Projects for its substantial contribution to this issue.

* Academician as used herein means a full member of the Russian Academy of Sciences.

The Editorial Board of the "Energy Bulletin" expresses its deep condolences to the relatives and friends over death of a Member of the Editorial Board of the magazine, a Member of the Italian Association of Energy Economists, Professor Ugo Farinelli. The memory of him will forever remain in the hearts of those who knew him personally, or from numerous publications.

ANSWERS TO EDITORIAL QUESTIONS*

Hans-Josef Fell

Energy Watch Group, Germany

fell@hans-josef-fell.de

The Energy Watch Group is an independent, non-profit, non-partisan global network of scientists and parliamentarians. It analyzes global energy developments and commissions independent studies on energy. Its mission is to provide energy policy with objective information. Hans-Josef Fell was a member of the German Parliamentary Group Alliance 90/the Greens from 1998 to 2013. He authored the 2000 draft Renewable Energy Sources Act (EEG), the foundation for the technology developments in photovoltaics, biogas, wind power and geothermal energy in Germany. Hans-Josef Fell is an internationally renowned political advisor on energy and climate change issues, author and speaker.

Key words: renewable energy sources, climate change, low-carbon development.

Let me start with an important opening remark first: "low carbon energy" is not an answer to the challenges, posed by climate change. It does not bring humanity closer to a world, free of greenhouse gas emissions. It does not resolve numerous problems, related to the use of conventional energy sources. A transition to 100% renewable energy is the only option to solve all these problems, to bring peace, decentralized democratic development and poverty eradication.

Low carbon includes nuclear energy, natural gas, efficient crude oil and coal technologies, CCS** and others. All these technologies are no option.

Nuclear energy alone raises several problems: radioactivity, nuclear waste, security problems (e.g. via terrorist attacks or natural disasters), nuclear weapons, and therefore cannot help in solving the great challenges of our planet.

Although natural gas has lower CO_2 emissions, its methane slip leads to high methane emissions in generation facilities and pipelines. Therefore, natural gas facilities have similarly high negative climate impacts as heating oil, hard coal and lignite.

CCS applications are very expensive, so that power generation via coal in combination with the CCS technologies is unable to compete with solar or wind power generation. Moreover, CCS creates uncertainties regarding the safe storage of CO_2.

Meanwhile, energy system based on 100% renewable energy sources is emission-free, free of radioactivity and – with the exception of biomass – does not require raw materials. That means in case of renewables, no conflicts and wars over access to fuels can take place.

As described above, low carbon is no goal worth aspiring for. That is why all my answers refer to renewable energy sources (hydro, solar, wind, geothermal energy, biomass, tidal) and NOT to low carbon energy.

Q: *What period of time will be needed to realise transition to renewables energy in the majority of countries of the world?*

A full energy supply with 100% renewables is technologically and economically feasible within

* Answers to questions were provided to the editor in January 2019.

** Carbon capture and storage. - Editor's note.

10-15 years on a global scale. It might sound unrealistic at first, but there are many examples of technologic revolutions in recent history, which happened within that timespan: from carriage to car, the aircraft industry, personal computers, mobile communications and much more. I do not see any reason to assume that a renewable energy revolution cannot take place with similar pace and scale, including all necessary storage and infrastructure technologies. Therefore, global climate protection is not a question of technical feasibility, but rather political will of the governments, businesses, media and other social groups.

Q: It is clear that fossil fuels and first of all coal and oil should be replaced by renewables and other sources. However, till now world economy demonstrates continuous interest in traditional energy sources and substantial investments are being made to their development and use. How to direct the energy evolution vectors towards renewable energy development in order to make the latter more evident?

Fossil fuels should be replaced only by renewable energy and no other energy sources, especially not other fossil fuels or nuclear energy. Even the most efficient use of fossil fuels leads to more emissions. An emission-free world economy is impossible with fossil fuels energy. In order to solve the climate crisis, we need an emission-free economic system.

Indeed, there are still strong investments in the fossil fuel and nuclear energy sectors. Many investors simply cannot imagine at all making business with emission-free technologies. That is why they keep lobbying for the same high subsidies and markets they have had until now. It is important to make investors aware that this strategy, holding on to the current status quo will have a twofold negative impact. On one hand, it will bring humanity closer to existential abyss. On the other hand, it will result in the (private) financial ruin for investors.

Today power generation from renewable sources is more cost-effective than that from fossil or nuclear ones. This financial difference will continue to grow very fast in favour of renewables in the coming years. Therefore, fossil fuel and nuclear power generation becomes increasingly uneconomical. Already now, there are prominent voices within finance – e.g. HSBC*, Bank of England – warning of investments in fossil or nuclear power because will become stranded assets. A growing number of financial actors are changing their investment strategies. More than $6 trillion worth of fossil and nuclear assets have already been divested. The faster investors become aware, the faster an energy transition towards renewables, green technologies and e-mobility will take place.

In order to establish strengthened and sustainable investments into a 100% renewable energy system, mainly two energy evolution vectors must be realigned:

* The Hongkong and Shanghai Banking Corporation. - Editor's note.

1. We need to raise public awareness that investments in fossil fuel and nuclear energy are of high-risk, meaning they are not only more insecure but also increasingly less profitable compared to investments in renewable energy sources.

2. We need stronger regulation from the political side in order to foster and accelerate climate protection and to create an economic environment, which supports low-risk investments in emission-free technology.

Q: *Renewable energy is called to play a key role in the future. LCE* and renewable energy sources will occupy the principle place in the world energy balance. But what will be the future of other energy sectors such as nuclear, hydrogen energy, etc., which are free of carbon?*

In comparison to renewables, nuclear energy is neither economical nor safe. It is dangerous, threatens world peace and comes with the unsolved long-term problem of nuclear waste. Because of all these reasons, nuclear energy cannot be an option when it comes to climate protection.

Hydrogen however, is not an energy source but technology for energy storage. Therefore, it can play a big role if the stored energy originates from 100% renewable sources like solar and wind power or biomass.

Q: *To what extend could energy saving and increased energy efficiency of our society compensate inevitable decrease of energy production by using coal and if fission follows coal in energy mix?*

Efficiency in energy consumption and energy transport is an important goal along with renewables, because it can accelerate the transition. But, energy efficiency should not be used as an instrument to exchange old inefficient coal plants with new, more efficient ones. That would lead to high emissions in the coming decades. The transition to renewables itself is already the greatest "energy efficiency revolution" possible. Windmills and solar panels generate far less waste heat than fossil fuel utilities. Electric cars are also much more efficient than fossil fuelled combustion engines and would therefore massively reduce energy consumption in the transport sector.

Let me stress again, nuclear fission is not an option as it is not efficient. Uranium mining and fuel fabrication are very energy intensive processes, let alone the fact that nuclear power plants waste two thirds of generated power in their cooling towers.

* Law Carbon Energy. - Editor's note.

Q: *Could fusion energy be realised and commercialized during the course of the 21st century and will it change drastically the world energy balance?*

No. Nuclear fusion energy is not and will never be an option. After 70 years of research on fusion technology, numerous problems remain unsolved, e.g. the preservation of the first wall surrounding the fusion plasma, the high neutron bombardment leads to a rapid material change, so that the extremely high pressure and the extremely high temperatures can not be contained for a long time. Until today, there are no promising technological solutions. Furthermore, it still would produce nuclear waste and cause radioactive contamination. Funds for nuclear fusion research should finally be relocated to support further advancement of renewable energy and storage technologies.

Q: *What should be done to create more favourable attitude of all circles of human society (political, business, public) and of its individual members to process of transition towards LCE which is not smooth and simple?*

First and foremost, it is necessary to raise public awareness that humankind is in danger of extinction, unless we switch to 100% renewable energy, and we should do so very fast. It is also important that more people understand that the climate protection with renewable energy sources is not an economic burden but would bring only economic advantages. That would raise social acceptance dramatically. Public education programs, and campaigns by the private sector, associations, NGOs and the mass-media can help to raise awareness. Campaigns, featuring celebrities from film, music and sports as well as religious leaders can be especially successful. This way a worldwide movement could be created, which would stand up for climate protection and renewable energy. As part of such movement, each person would be able to contribute, by transitioning his/her private environment to 100% renewables and take part in political processes, for instance, to ensure that the best possible framework conditions for 100% renewables are implemented in 15 years at the very latest.

ON DEVELOPMENT OF FUEL-FREE ENERGY*

Dmitry S. Strebkov

Full Member of the Russian Academy of Sciences
Federal Research Agroengineering Centre VIM
(FSBSI FSAC VIM), Russia
nauka-ds@mail.ru

Dmitry S. Strebkov is a Full Member of the Russian Academy of Sciences, Professor, Doctor of Technical Sciences. Federal Research Agroengineering Centre VIM (FSBSI FSAC VIM) - Federal State Budgetary Scientific Institute is the leading scientific research institute for agroengineering, machinery and technology modernisation of the national agricultural sector, deployment of advanced intelligent technologies and new generation robotic equipment in agricultural production.

Abstract: Developing countries increase electric energy production output to improve the quality of life. Development of civilization is accompanied by growing consumption of energy resources and increasing human impact on climate which leads to global warming.

The vital task of governments and international organisations is structural transformation of the energy industry and transition to new, fossil fuel-free energy sources. Energy technologies determining the future of the energy industry in the XXI century and transition of humankind to sustainable development must be based on new physical concepts.

As part of an international project, Russian scientists proposed to build a solar power system in the XXI century to enable production and distribution of electric energy for each inhabitant of Earth throughout the year for millions of years with decommission of all existing electricity generating plants powered by fossil fuels around the world. For purposes of implementing the project, five new technologies were developed and protected by 300 Russian and 60 international patents.

Russia and other countries of the World develop free-running electric energy and heat generators powered by energy of Earth's crust, aerial and aquatic environments, energy of nuclear reactions, electric and magnetic fields, as well as electrical energy of atmosphere. This article dwells upon the current status of the research work and the results obtained.

The XX century was the last century of cheap energy. The era of cheap energy has come to its end and humankind needs new energy carriers to enable sustainable development in the future. Humankind is capable of combining and concentrating the energy resources and technologies to create decent living conditions for each human and implement large-scale scientific projects on Earth and in space.

Key words: fuel-free energy, global energy system, new energy sources, electric power technologies, electrical machinery, hydrogen energy.

Introduction

Almost all energy produced by generators of all kinds is delivered to consumers via transmission and distribution (T&D) systems where a significant portion of energy is lost due to technical or com-

* Some scientific and technical data contained in this article have been published by the author in some periodicals, including the Energy Bulletin. – Editor's note.

mercial reasons. Besides, the energy received by consumers is frequently used inefficiently due to technical deficiencies in the energy-consuming equipment and the lack of respective strategies for rational energy management.

Due to the above-mentioned technical, organisational and commercial reasons, up to 40-50% of energy produced in many countries is used inefficiently. For example, in Russia there is an unused technical potential to save energy of up to 420 million tons of fuel equivalent (i.e. 45% of the entire energy consumption level in 2015).

Besides, electric energy transmission is accompanied by substantial losses (in average, 8.8% of energy produced globally). The total losses in electric energy transmission networks globally exceed its production volumes for example, 3,433.4 TW·h in China.

1. Resonant Electric Energy Transmission and Utilisation Techniques Based on the Nikola Tesla's Technology

Vulnerability of overhead power lines (PL) to the growing environmental impact and ecological problems caused by operation of PL are the main drivers for widespread use of underground cable lines for transmission of electric energy in the future.

It is known that the maximum length of 50-60 Hz AC* transmission lines is 80 km as it is restricted by high capacitive reactance of the line. DC** cable lines are limited in length by Joule losses and are characterised by their high cost that is tenfold higher than the cost of overhead PL.

Today, there exist brand-new Russian technologies for development of a global electric energy network using single-wire and wireless energy transmission techniques based on the ideas and tests of a genious scientist, Nikola Tesla. These technologies allow not only to solve the said problems, but also to build super-reliable global electric energy supply systems.

Resonant waveguide electric energy transmission techniques allow to build single-wire high-frequency lines more than 100 km long protected against external impact for supply of electric energy to remote consumers on the ground and in the ocean, as well as regional and intercontinental energy systems.

Top-priority tasks include "Kamchatka-Sakhalin-Japan" and "Chukotka-China" cable lines for transfer of gigawatt flows of electric power from the Northern wind farms. A significant contribution to research of the wind cadastre of Russia and zoning of gigawatt wind farms in Kamchatka, Sakhalin and Chukotka under the contract with a Chinese company was made by Dr. Sc. (Tech.) V.G. Nikolaev from Moscow. The report prepared for the Club of Rome by Dr. Sc. (Tech.) A.I. Potapov from Chelyabinsk demonstrates that construction of a 10 MW Arctic wind power plant (WPP) would enable reduction of cost of installed capacity to 300–400 USD/kW and bring the cost of electric energy close to 1 ruble/kW-h achieved for solar energy plants (SPP) in Saudi Arabia [1].

Considering that night-time consumption of electric energy in Japan and many other countries is twice as low than during the day, it is necessary to develop "Tokyo-Vladivostok-Moscow-Lisbon" East-West lines to equalise the night and day load patterns and "Arkhangelsk-Baku-Tehran-Delhi" to transfer electric energy from equatorial power systems to the Northern areas and from the Northern wind farms to the South.

As predicted by N. Tesla, resonant techniques will be widely used for non-contact and wireless power supply to ground, marine and air transport, transmission of energy in outer space, extraction of water from air, as well as for lighting and electric therapy purposes.

Our research showed that the most cost-saving technique for highway lighting were resonant single-wire systems, and the use of a non-contact high-frequency trolley would increase the speed of railroad trains from 300 to 600 km/h. Resonant electric energy systems and electrical technologies developed by Russian scientists are protected by 90 Russian patents and are described in the sixth edition of the monograph [1].

In 1915, Tesla wrote [1]:

"Books have already been written on the agricultural uses of electricity, but the fact is that hardly anything has been practically done. The beneficial effects of electricity of high tension have been unmistakably established, and a revolution will be brought about through the extensive adoption of agricultural electrical apparatus. <...> But the time will soon come

* Alternating current

** Direct current

when we shall have the precipitation of the moisture of the atmosphere under complete control, and then it will be possible to draw unlimited quantities of water from the oceans, develop any desired amount of energy, and completely transform the Earth by irrigation and intensive farming".

The fundamentals of the theory and technology for weather modification and smog liquidation have been developed by a graduate of the Faculty of Physics of the Moscow State University Cand. Sc. (Phys.-Math.) L.A. Pokhmelnykh [2]. The work is being carried out by the Atmospheric Ionization International Corporation under scientific supervision of L.A. Pokhmelnykh.

In India, under supervision of L.A. Pokhmelnykh and in cooperation with the Indian Institute of Technology (New Delhi), smog dispersal tests were carried out by discharging electrons into atmosphere. Over 1 hour of tests the air concentration of various pollutants was reduced from 100,000 to 200 relative units.

The Indian project is aimed at building an Indian centre for weather and climate modification by atmospheric electrical charging and entering into contracts for protection of Indian cities against smog and for generation of precipitation in the regions. Today, this technology is used to disperse smog in the most polluted city of China, Xingtai. In China, this work is carried out by two universities with a total annual R&D budget of 1 million USD.

This example shows that promising developments by Russian scientists find no support in Russia and are widely used abroad. The Russian Academy of Sciences support is needed for the development of theory and technology for weather modification by discharging electrons into atmosphere and include the research work in this field into the programme for fundamental research for motorization, electrification and automation of the agricultural sector.

2. Economic Criteria for Transition to Fuel-Free Energy

The average quality-of-life index depends on the scope of energy consumption [2]:

$$I = \frac{PE}{N} ,$$

where I is the average quality-of-life index, P is the total power (capacity) of energy sources, E is the average efficiency of energy conversion when producing consumer products, N is population.

The quality of life grows with an increase of electric energy consumption. Let us make a comparison of the richest and the poorest countries of the World (Table 1). Table 2 presents the data on electric energy consumption in BRICS countries and some continents. 1.2 billion people on Earth (16%) have no access to electricity.

Affordability of electric power in developing and developed countries differs by 100-500 times. Electric power volumes produced in India are 4-9 times lower than in other BRICS countries. It is necessary to increase the electric energy generation in order to improve the quality of life in developing countries, but this will lead to a higher human impact on the climate.

It is known that development of civilization requires systematic control of energy resources consumption [3]. Therefore, it is vital to carry out structural transformation of the energy industry and increase the share of fuel-free energy following the experience gained by Iceland (geothermal energy) and Norway (hydropower).

New energy technologies determining the future of the energy industry in the XXI century and transition of humankind to sustainable development will be based on new physical concepts. Civilization of Earth will shift to new, fossil fuel-free energy sources in the third millennium. But the shift will not be caused by depletion of oil, gas, coal and uranium reserves. There is a concept called "grid parity", i.e. a parity of prices for grid energy. In terms of parity of prices for electric energy, fuel-free energy sources offer cheaper electricity and heat as compared to electric energy offered by grid companies [4]. In September 2016, Sun Edison and Marubeni companies offered a record-low price of 2.42 cents per kW·h of solar energy which is 0.49 cents lower than previously offered in Chile.

The lowest ever price of 1.79 cents/kW·h (1 ruble/kW·h) for tenders in solar energy and fuel energy for all types of power plants was observed in 2017 at the tender in Saudi Arabia for construction of a solar power plant with a capacity of 300 MW with the cost of installed capacity of 1,000 USD/kW*. The winning bidder was a consortium of

* Source: http://elektrovesti.net/56297_na-auktsione-solnechnoy-energii-v-saudovskoy-aravii-tsena-upala-nizhe-2-tsentov-eto-rekord

Table 1. Electricity consumption per capita, kW·h/person per year.

Developed Countries		Developing Countries	
Iceland	52,376	Benin	95
Canada	16,406	Haiti	32
Qatar	16,099	Democratic Republic of the Congo	99
Kuwait	17,876	Myanmar	119
Luxembourg	15,511	Nepal	94
Norway	23,174	Tanzania	92
USA	13,227	Togo	117
Finland	15,742	Eritrea	57
Sweden	14,029	Ethiopia	55

Table 2. Electricity consumption per capita, kW·h/person per year.

BRICS Countries		Continents	
Brazil	2,441	Australia	10,514
Russia	6,533	Asia	823
India	673	Africa	593
China	3,312	Middle East	3,532
South Africa	4,694	Globally	2,993

Masdar (Saudi Arabia) and EDF (a French nuclear power company).

The main criteria for transition to new energy technologies are lower market prices for energy carriers. Reduction of cost of production of products increases the competitive ability of commodities and services, raises the GDP and improves the quality of life.

Russian scientists developed a technology for production of solar modules with a service life of 40-50 years, which is twice as higher than their foreign equivalents [5]. In Germany, service life of solar modules is 20 years and the minimum price for electric energy produced by solar power plants (SPP) under the current contracts is $0.0585 per 1 kW·h. Gas-powered stations and nuclear power plants (NPP) offer electricity for $0.03/kW·h [4].

Let us compare the cost of solar electricity in Germany and the Krasnodar Territory (city of Anapa), Russian Federation, with an assumption that the cost of installed capacity of a solar power plant is the same and equals $800/kW of peak capacity. Operational costs shall be equal to 1% of the investment costs over 1 year (Table 3).

With a service life of 50 year the cost of 1 kW·h in Germany would be $0.0288/kW·h, and $0.0144kW·h in Anapa.

In contrast to central (large) power plants powered by fossil fuels, distributed SPPs have zero capital expenses and zero electricity transmission losses.

A significant portion of the electricity prices is the SPP land fee, therefore the optimal cost-saving solution that leaves out the land fee would be the use of solar energy as part of the One Million Solar Roofs programme that implies the use of solar roofing panels (solar shingles).

According to our estimates, implementation of the One Million Solar Roofs programme in Russia under public private partnership contracts without the use of any budgetary funds would reduce GDP energy intensity by 1.5%, increase the Russian GDP by 0.3%, reduce emission of greenhouse gases by 284 million tons per year [6] and creation of 100,000 new jobs.

3. Environmental Criteria for Transition to Fuel-Free Economy

Environmental criteria for transition to fuel-free economy are even more important and significant than the economic criteria as they determine the opportunities for further development and existence of our civilization. Maximum air temperatures in the shade in several regions of Australia, India, North Africa and Near East exceeded 50°C and continue growing.

Our study shows that the main cause of global warming is human impact on the climate and that there is a climate change point of no return when no physical resources of our civilization could prevent the lethal transformation of Earth atmosphere to the state incompatible with biological life [7-11].

A necessary, yet insufficient condition for preservation of our civilization is modification of the energy structure and a transition to fuel-free renewable energy [12]. A sufficient condition for preservation of our civilization is a change in the radiation balance of Earth and reduction of solar irradiation reaching the surface of our Planet by the amount equal to the anthropogenic impact on the climatic changes. For example, it could be achieved by increasing albedo of deserts and cities, primarily in the equatorial regions between 30° North latitude and 30° south latitude, as well as in Australia. An increase in albedo of Earth would allow to change the radiation balance of our planet, reduce the amount of solar irradiation reaching the surface of Earth and prevent global warming.

Albedo defines the share of total solar irradiation reflected from the surface of Earth. Tables 4 and 5 contain data on albedo of various surfaces and the change ρ throughout the year in Moscow (average monthly values) [6].

Albedo of Earth is 0.06 which is connected with the low albedo of seas and oceans, albedo of clouds is 0.24 [2]. Average albedo of deserts is 0.32, of cities – 0.27.

It is suggested to place reflecting mirrors on the surface of several deserts of Earth with a reflection coefficient of 0.9. In order to preserve the ecosystems of the deserts, mirrors should be installed on supports, 3-4 m above the ground, with a gap between the mirrors equal to 10-20% of their size so as to ensure that a certain amount of solar ir-

Table 3. Cost of 1 kW·h of electricity generated by SPP in Germany and Russia with different service life of SPPs.

Germany	Krasnodar Territory, city of Anapa
Electricity produced by SPP with a peak capacity of 1 kW	
800 kW·h/kW per year	1,600 kW·h/kW per year
Service life: 20 years Depreciation expenses: $\frac{\$800}{20\ \text{years}} = \$40/\text{year}$ Operational expenses: 1% = $ 8/year Total annual expenses: $48	
Cost of electricity $\frac{\$48}{800\ \text{kW·h}} = \$0.0588/\text{kW·h}$	Cost of electricity $\frac{\$48}{1600\ \text{kW·h}} = \$0.0294/\text{kW·h}$
Service life: 40 years Depreciation expenses: $\frac{\$800}{40\ \text{years}} = \$20/\text{year}$ Operational expenses: 1% = $8/year Total annual expenses: $28	
Cost of electricity $\frac{\$28}{800\ \text{kW·h}} = \$0.0338/\text{kW·h}$	Cost of electricity $\frac{\$28}{1600\ \text{kW·h}} = \$0.0169/\text{kW·h}$

Table 4. Albedo of various surfaces.

Type of surface	ρ, relative units
Fresh snow	0.80
Dry asphalt	0.70
Dry plasterwork	0.33-0.50
Settled snow	0.46
Dry vegetation	0.33
Dry concrete	0.35
Dry soil	0.32
Soil after rain	0.16
Vegetation after rain	0.15
Water at β ≥ 40°	0.05
Water at β < 40°	0.05-1.0

Table 5. Change in albedo throughout the year in Moscow (ρ_{year} = 0.27).

t, month	1	2	3	4	5	6	7	8	9	10	11	12
ρ, relative units	0.71	0.72	0.58	0.2	0.2	0.21	0.21	0.21	0.21	0.26	0.38	0.59

radiation reaches the desert surface. On the equator, mirrors should be placed horizontally. In order to attain maximum reflection of solar irradiation throughout the year in the Northern Hemisphere the mirrors should be directed towards the South at angle α to the ground surface:

$$\alpha = \varphi - 10^\circ ,$$

where φ is the latitude of the region.

This formula is also applicable to the Southern Hemisphere, but the mirrors should be turned northwards.

Optionally, reflecting mirrors could be equipped with devices to change their inclination angle to horizon each month or season depending on the solar declination, or turn the mirrors vertically during night time to increase the infrared irradiation of the desert surface. The back side of mirrors could be covered with a heat-absorbing coating with an absorption coefficient of 0.9-0.96 so that the solar irradiation hits the desert surface during winter months and under global cooling conditions when the mirrors are turned 180°. The heat-absorbing coating could be made of silicon photovoltaic solar modules with a current energy conversion efficiency of 22%.

Let us calculate the amount of solar irradiation reflected by mirrors under the following conditions. Area of mirrors is 80% and 90% of the desert's area. Shading coefficient C_{sh} = 0.8-0.9, albedo of desert ρ_d = 0.32, mirrors' reflection coefficient R=0.9. In theory, the maximum value of solar irradiation on a horizontal surface $Э^{г}_{\Sigma}$ (day) on Earth under clear sky conditions is about 6 kW·h/(m²·day) and about 2,200 kW·h/m² per year for a latitude φ= 0°. In practice, zones with these maximum values of solar irradiation throughout the year are poorly distributed on the surface of the planet. The maximum solar irradiation flow on Earth is observed in the following regions: south-west of the North America; northern part of Africa (Sahara); the Arabian peninsula; west of the central part of the South America; south of Africa and central part of Australia. In such regions the annual flow of solar irradiation reaches 7,920 MJ/(m²·day) [6].

Reflected solar irradiation would be as follows:

$$E_{refl} = (2200-(1-C_{sh})\cdot 2200)\cdot R + (1-C_{sh})\cdot 2200\cdot \rho_d .$$

For C_{sh} = 0.9 E_{refl} = 1,852.4 kW·h/m² year.
For C_{sh} = 0.8 E_{refl} = 1,548.8 kW·h/m² year.

Solar energy reflection coefficient would be 0.842 for C_{sh} = 0.9 and 0.704 for C_{sh} = 0.8.

For a desert with an area of 1 km², solar energy reflected by mirrors would be 2,200·10⁶·0.892= 1,852.4·10⁶ kW·h/km² per year at C_{sh} = 0.9 and 1,548.8·10⁶ kW·h/km² per year at C_{sh} = 0.8.

Anthropogenic heat accumulated in the atmosphere over one year is as follows [6]:

E_a=4.92·10²⁰ J/year=1.37·10¹⁴ kW·h/year.

Reflecting mirrors with an area of 1 km² installed in deserts of the equatorial belt would return to outer space 1.8524·10⁹ kW·h/km² per year at C_{sh}=0.9 and 1.5488·10⁹ kW·h/km² per year at C_{sh}=0.8. The area of reflecting mirrors required to decrease the amount of solar irradiation by the amount of anthropogenic heat pollution of Earth would be as follows:

$$\text{for } C_{sh} = 0.9 \quad S^1_{30} = \frac{1,37\cdot 10^{14}}{1,8524\cdot 10^9} = 73.958\cdot 10^3 \text{ km}^2 ,$$

$$\text{for } C_{sh} = 0.8 \quad S^1_{30} = \frac{1,37\cdot 10^{14}}{1,5488\cdot 10^3} = 88.456\cdot 10^3 \text{ km}^2 .$$

Area of African deserts is [6]: S_{Af}=12.24·10⁶km².

The area of mirrors required to prevent global warming would be as follows:

$$C_{sh} = 0.8 \quad S_{30} = \frac{88,456\cdot 10^3\cdot 100}{12,24\cdot 10^6} = 0.72\% \text{ of the desert area;}$$

$$C_{sh} = 0.9 \quad S_{30} = \frac{73,456\cdot 10^3\cdot 100}{12,24\cdot 10^6} = 0.6\% \text{ of the desert area.}$$

There exist certain negative reverse reactions in nature capable of slowing down self-heating of our planet. Global warming could lead to a catastrophic increase in volcanic activity and reduction of solar irradiation reaching the surface of Earth as

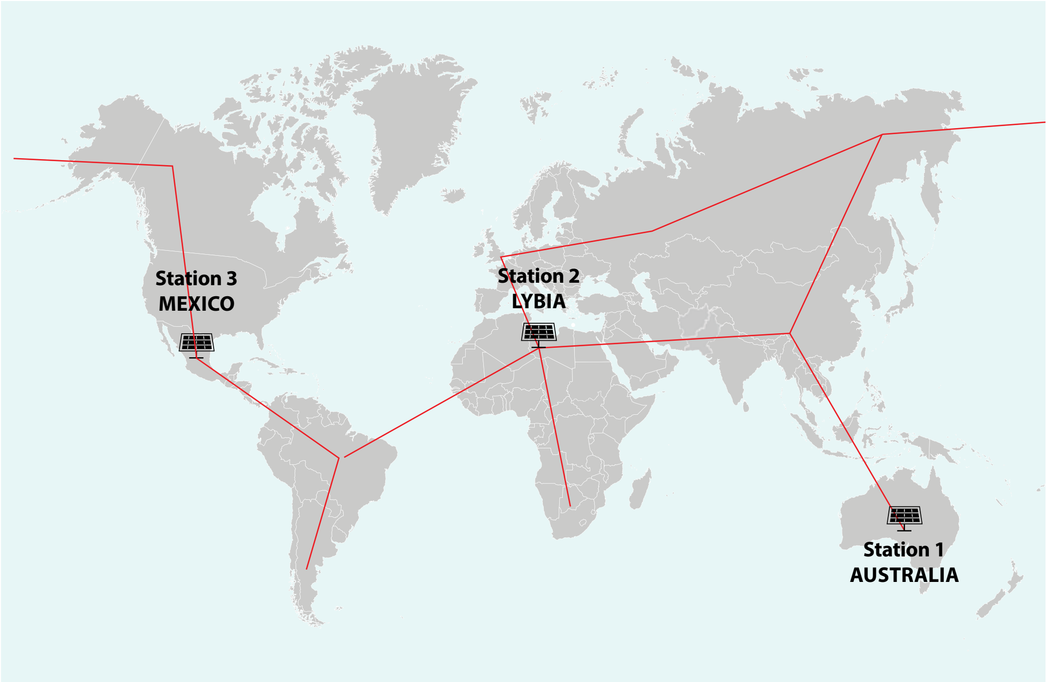

Figure 1. Global solar energy system composed of three solar power plants.

the solar energy would be absorbed by volcanic gases in the atmosphere.

Melting of glaciers and growing amount of fresh water content in oceans could change the direction of meridional ocean currents, such as the Gulf Stream, and a temperature drop in Europe. The rate of global warming is affected by 11-year solar magnetic activity cycles.

The Kyoto Protocol and the Paris Agreement for reduction of greenhouse gas emissions do not have any underlying scientific rationale and do not solve the global warming problems, but still they are useful as they recommend a transition to renewable energy sources and limit emissions of carbon dioxide which decreases the productivity of seas and degradation of the marine biosphere when absorbed by water. In order to return the climate parameters to the equilibrium values that existed fifty years ago humankind needs to arrange production of generators powered by the energy of the environment with its cooldown and transmission of the energy excess over the equilibrium value of Earth's radiation balance in the optical range to outer space [12].

4. Global Solar Energy System (GSES)

A global approach towards fuel-free renewable energy was defined in certain studies [1, 5, 13-15] proposing a GSES that generates electric energy on a 24/7 basis to cover the entire world demand. The energy system is composed of three solar power plants (SPPs) 200×200 km each installed in the deserts of Australia, Africa and Latin America through 120o as latitude and connected by waveguide power transmission lines based on the technology developed by N. Tesla (Figure 1).

Computer modelling of electric power production in the global power system subject to the meteorological data for the SPP locations over the entire period of monitoring showed (Figure 2) that energy production does not depend on the season or time of day or night, does not require accumulation of energy, and all existing petroleum-, gas-, coal-powered and nuclear power plants could be stopped and serve as backup power plants [15].

Scientists of the All-Russian Scientific Research Institute for Electrification of Agriculture (VIESH) developed the following for the GSES:

Figure 2. Electricity generation by the Global Solar Energy System.

1. Resonant techniques for generation, transmission and utilisation of electric energy without any power or distance-related restrictions [1];
2. Non-chlorine techniques for production of several million tons of solar-grade silicon per year [16-17];
3. New solar modules' sealing technologies increasing the service life from 20-25 years to 40-50 years [5, 18];
4. High-voltage silicon solar modules with an energy conversion efficiency of 25% and voltage of 1,000 V instead of 12-48 V for planar solar modules [19];
5. Hybrid solar roofing panels for the One Billion Solar Roofs programme for the distributed national and global solar energy industry [6, 20].

The global solar energy system's technologies have been protected by 300 patents in the Russian Federation and 60 international patents.

The GSES is capable of providing electric energy to the entire global population for billions of years without disturbance of the radiation (energy) balance of Earth. We hope that the global solar energy system will be built in the XXI century as part of an international project involving scientists and businessmen from all countries of the globe, as well as with the support of UN, UNESCO, IEA, IRENA and other international organisations and governments of the states concerned.

5. Technical and Economic Evaluation of the Global Solar Energy System

GSES is composed of three SPPs located in the deserts of Australia, Africa and Latin America with a total peak capacity of 7.5 TW. They are interconnected to a single energy system by intercontinental energy transmission lines based on the N. Tesla's technologies. Its energy generation output is 20,000 TW·h per year, service life is 50 years, energy conversion efficiency of silicon solar modules is 25%, project life is 25 years. Today, the cost of SPP with a peak capacity of 300 MW as proposed by the tender in Saudi Arabia is $800/kW with the cost of electricity of $0.0179/KW·h. The World annual output of SPPs approximates 75 GW.

In order to build GSES over 25 years with a peak capacity of 7.5 TW it is necessary to increase the global energy volumes produced by SPPs by 4 times to 300 GW/year, and capital expenses of building SPPs will drop to $400/KW, and the cost of electricity will be cut down to $0.005/KW·h.

Capital expenses of building GSES will be $3 trillion and $0.5 trillion (or 17% of the cost of GSPS) of constructing intercontinental energy transmission lines based on the N. Tesla's technologies. Total cost of the GSES project will be $3.5 trillion.

Annual costs of construction of GSES over 25 years will be $140 billion, or $70 billion if the project lasts 50 years. To return the investments the cost of electricity should be increased by $0.0175/kW·h to $2.25/kW·h.

If the GSES modules reach a peak capacity of 300 GW during the first year after commissioning, then the return of investments would start during the second year of the project by selling 800 GW·h/year of electricity due to the added value of $0.0175/kW·h (at the rate of $2.25/kW·h) total worth $14 billion.

Over 25 years of the project implementation the return on investments will be $420 billion.

Considering that the added value would be $0.0175/kW·h (at the rate of $2.25/kW·h), the project's payback period will be ($3,500 billion - $420 billion rubles)/$350 billion rubles = 8.63 years.

Building the GSES with zero emission of carbon dioxide and decommissioning of all fuel-powered power plants will enable reduction of damage to the global economy caused by global warming which is currently $200 billion/year and grows each year. If we assume that the contribution of GSPS to reduction of damage caused by global warming is $100 billion per year, then the GSPS project's payback period would be ($3,500 billion - $420 billion)/ $350 billion + $100 billion = 6.84 years.

The modular design of GSPS allows to increase the electricity output in response to the growing global demand by increasing the number of energy units in each of the three SPPs. GSES will include nationally developed solar energy systems of the project member states and distributed energy systems of private independent energy producers, primarily owners of houses with solar roofs under the One Billion Solar Roofs with a total installed peak capacity of 3 TW.

Gigawatt wind farms, hydroelectric and electric energy plants powered by biomass, municipal and agricultural waste will be connected to GSES. The most preferred scenario would be the use of combined-cycle gas and steam turbine power plants with an energy conversion efficiency of 60% as standby plants and facilities for storage of natural gas with 15% hydrogen delivered from GSES using new energy-efficient water electrolysis techniques as accumulating systems. Construction of GSES would accelerate the transition of transport to electric drives and increase productivity of marine biological resources by reducing the acidification of seas and oceans caused by carbon dioxide. An economic evaluation of the above mentioned positive effects of the GSES project on the environment and economy of our civilization would further increase the economic attractiveness of GSES.

6. Ambient Energy Generators

The next step on the path to fuel-free energy development is construction of ambient energy generator.

According to the Nobel Prize winner R. Feynman and J. Wheeler, vacuum inside an incandescent light bulb contains enough energy to boil all oceans on Earth. The objective of scientists is to build a generator capable of producing surplus energy exceeding the energy generated by the energy source using the ambient energy.

The concept of "perfect vacuum" replaced the ether concept previously supported by many prominent scientists. In 1891, during his lecture at the Columbia College, N. Tesla said [22]: "Electricity and ether phenomena are identical... and phenomena of static electricity are the phenomena of ether under strain".

Russia and other countries of the World develop free-running electric energy generators powered by thermal energy of Earth's crust, aerial and aquatic environments, electric energy of atmosphere, energy of nuclear reactions, electric and magnetic fields.

7. Compact Fusion Reactors

In 2019, Lockheed Martin promised to demonstrate the first compact fusion reactor [23]. Using 25 kg of mixture of hydrogen isotopes, deuterium and tritium, the reactor placed inside a shipping container would be capable of creating energy generator with 100 MW of power during one year.

The reactor invented by Andrea Rossi [24] whose patent was purchased in 2014 by Industrial Heat (USA) utilises a nuclear reaction at a temperature of 150-500°C and hydrogen pressure of 2-20 bar:

$$Ni + H \Rightarrow Cu + \Delta E \ .$$

Energy output ΔE = 517 TOE per 1 g of Ni.

In terms of nuclear physics:

$$_{29}Ni^{62} + {}_{1}p^{1} \rightarrow {}_{29}Cu^{63} + \gamma\ (5.36MeV)\ .$$

Considering that World production of nickel is 10^6 tons per year, 10^{-4} of this volume could generate 51,700,000,000 TOE per year [24].

In Russia, electric energy and heat generators based on nuclear reactions are being developed by groups of scientists under the leadership of professor, Dr. Sc. (Phys.-Math.) Y.L. Ratis (Samara) and professor, Dr. Sc. (Phys.-Math.) V.N. Dubovik (Joint Institute for Nuclear Research, Dubna), including I.M. Shakhparonov, A.G. Leontyev, V.Y. Akimov, and a group of Cand. Sc. (Phys.-Math.) E.N. Tsyganov (Ufa) [25], Cand. Sc. (Phys.-Math.) Y.N. Bazhutov, S.M. Godin, Cand. Sc. (Phys.-Math.) A.I. Cherepanov, D.S. Baranov, V.N. Zatelepin (Moscow) and others.

V.M. Dubovik et al. found in 1987 that benzene rings had the so-called electric toroidal dipoles. Experiments showed that when an electromagnetic pulse of low energy but huge power (high time derivatives and spatial gradients) is transmitted to an electrically and spatially unsymmetrical micro-system (which most molecules are), conditions of its internal equilibrium kinetic movement will be disturbed. The quantum system will redistribute the energy received from an external source and the energy of internal movement among its quantum degrees of freedom. In early 2005, V.M. Dubovik et al. found a way to control these energies. It should be noted that physical and chemical properties of a substance change on the atomic and nuclear levels.

8. Advanced Electrical Machines and Propulsion Systems

Most noteworthy developments in the field of advanced electrical machines and propulsion systems were made by Cand. Sc. (Phys.-Math.) V.G. Limanovsky [26-28], S.I. Kireev [29-31] (VIESH), Cand. Sc. (Tech.) V.S. Leonov [32], Dr. Sc. (Tech.) F.M. Kanarev, S.B. Satsarinin and many other Russian scientists.

Electrical propulsion systems are designed on the basis of theoretically predicted and experimentally proven [26-28] new class of forces that are proportionate to the charge density gradient and the mass density gradient, and the advanced electrical machines are primarily designed to decrease the response of stator to rotor by creating a unidirectional inductive interaction between rotor and stator, as well as between the primary and secondary windings.

Designing electrical generators and motors with permanent magnets requires development of technologies for production of sheet materials with magnetic permeability $\mu > 100{,}000$ for a shielded magnetic field.

9. Energy-Saving Hydrogen-From-Water Technologies

It is known that modern electrolytic cells consume 4 kW·h of electricity to produce one cubic metre of hydrogen from water.

In 2008-2012, Russian scientists studied the resonant techniques for production of hydrogen from water using iron, aluminium, carbon and stainless steel electrodes [33-36]. It was demonstrated that resonant technologies enabled reduction of electrical energy consumed per producing 1 m^3 of hydrogen by 2-10 times. A significant contribution to development of energy-saving pulse electrolysis techniques for production of hydrogen from water was made by Dr. Sc. (Tech.) F.M. Konarev, S.B. Zatsarinin [37, 38] and A.O. Buganov. Based on the scientific work results, Russia launched production of "electrolytic cell-boiler" energy converters that generate 25 kW·h of heat while consuming 2.5 kW·h and powered by water of electrical generators for electric vehicles and residential houses produced by Generax Co Ltd (Japan) [39].

Application of new techniques for production of hydrogen from water allows to build hydrogen units for diesel generators and reduce consumption of diesel fuel by 40-70%, and entirely replace fossil fuel in gas powered electrical generator and gas turbine units.

10. Utilisation of Ambient Heat for Electricity Generation

The simplest example of using ambient energy is a pump developed by P.A. Radchenko for water discharge from wells operated under the principle of temperature difference between the ambient air and water from wells [40].

Geothermal power plants use the heat of Earth's crust to produce electrical energy at a temperature of 100-150°C and an energy conversion efficiency of 12-16%. Today, ambient energy generators are being developed for a temperature of 4-30°C to use the heat of the aerial and aquatic environments [41].

As proposed, efficiency will be increased by using thermodynamic systems utilising the heat and heat pump cycle within the same unit. A substantial contribution to the development of monothermal ambient energy converters was made by Y.E. Vinogradov. A possibility of building monothermal converters and defining the limits of cycles that would enable their development is exemplified by a physical and mathematical model.

It was demonstrated that within the defined Stirling cycle limits the energy conversion efficiency of Stirling engines is twice as higher than that of the Carnot cycle, and the the engine's inflation index would be 10% or less when using it with a monothermal converter.

It showed the possibility of building a heat pump with a coefficient of performance twice as higher than its estimates as per the reverse Carnot cycle formula [42].

Another approach implies design of an electronic isothermal converter utilising the Nyquist currents and the energy of thermal motion of electrons in electronic devices [43].

Certain resonant parametric generators were proposed to amplify, due to the parametric resonance, the 10^{-7}–10^{-12}A fluctuating electric currents in conductors and function as a generator and a motor, i.e. reversible electrical machines [44-47].

11. Atmospheric Electricity Generators

Atmospheric electricity is a phenomenon caused by interaction of Earth, the Sun and the outer space. Meteorological processes are dependent on the electrical state of the atmosphere. Climatic changes on Earth are caused by the change in properties of galactic charge-density waves with an oscillation period of 22 years. The Sun and Earth have a space charge. The Sun's charge changes its polarity once in 11 years. Magnetic fields of Earth, the Sun and planets are caused by their space charge, and Earth's interior is heated by eddy currents of the space charge in a geomagnetic field [2].

The new technology is based on the use of atmospheric electricity [1, 48]. It is known that 92% of the space beams carried by the solar wind to the surface of our planet from the space are protons, i.e. positively charged particles, and they give a positive charge to our ionosphere, and Earth, in its turn, has a negative pace charge. The potential difference between Earth and ionosphere is 360,000 V and it changes from 400,000 V during day time to 340,000 V at night. Fluctuations could be seasonal and daily, but what is important is that Earth is a huge capacitor with an average voltage of 360,000 V. One could say that Earth is an electrical machine with a space electrical charge.

According to N. Tesla's estimates, Earth's electrical charge is 300,000–600,000 C, capacity is 220,000 µF and electrical field is 120–160 V/m. He was the first to develop resonant generators utilising the electrical energy of the atmosphere. Using them, N. Tesla transmitted electrical energy via the ground as a conductor. N. Tesla insisted that he could transmit any amount of energy to any point of the globe with an efficiency of more than 96%.

But the parametric resonance theory did not exist when he was completing his work in that field. The theory was developed only in 1930's by Russian scientists, academicians Mandelstam and Papalexi. N. Tesla did not know that his famous energy towers utilised the parametric resonance.

One of his towers was 60 metres high with a metal sphere or a toroid on top of it. In electrical engineering, this structure is called "isolated capacitor". It was this capacitor that generated a series resonant circuit with the high-voltage winding of the Tesla transformer. When the electrical generator transmits high-frequency oscillations through the low-voltage winding to the high-voltage winding, the sphere's potential periodically changes. Back then, Tesla already managed to generate 20 million volts in these electrical modes.

It is known that relative permittivity of air is higher than one due to the presence of vapours of water the molecules of which are composed of atoms of hydrogen and oxygen. Molecules of water are electric dipoles that are polarised in the sphere's electrical field. Due to the presence of water vapours in the air, when the sphere is charged positively the electrical field attracts dipoles of water molecules with their negative side to the surface of the sphere, and when the charge of the field is negative, dipoles of water molecules are attracted to the sphere with their positive side, i.e. the isolated capacitor is recharged. Such recharging occurs due to the controlled synchronised re-orientation of polarised dipoles of water molecules in the air.

These processes change the capacity of the isolated capacitor, and the change of either inductance or capacity with double frequency is exactly what parametric resonance is. All these factors lead to amplification of electrical oscillations in the oscillating circuit.

Parametric resonance is widely used in radio engineering and physics. The same principle is used in the power unit to produce electrical energy from the environment [49-50].

12. Environmentally-Friendly Techniques for Conversion of Wind and Water Flows Into Electrical Energy

The disadvantages of the modern wind turbines are their low-frequency noise, operational failure at the wind speed of 25 m/s, need to warm up the blades in winter and the turbine's direction dependence on the wind flow. These disadvantages have been eliminated in the vertical axis rotor-type wind turbines developed in Russia under supervision of Dr. Sc. (Tech.) A.V. Bolotov and engineer S.A. Bolotov [51–53]. Bolotov's wind turbines have no blades, emit no low-frequency noise and operate at the wind speed of 50 m/s of any wind direction. The wind turbine is placed inside a metal casing with a roof to protect it against snow and ice storm. Modular design allows to manufacture rotor-type wind turbines with a power of 5-30 kW (up to 100 kW in the long run).

A significant contribution to development of damless free-flow micro-hydropower plants was made by Cand. Sc. (Tech.) A.I. Kuskov [54–55]. A promising direction of development of the small scale wind and hydropower energy is creation of eddy currents in the aerial and aquatic environments and the use of special-purpose vertical axis turbines. The technologies and devices for generation and conversion of eddy currents in air and water are being developed by Cand. Sc. (Tech.) E.D. Sorokodum [41], Cand. Sc. (Tech.) R.A. Serebyrakov [56] and S.V. Geller [57].

Most noteworthy developments made by foreign companies are eddy current hydropower turbines by Turbulent, Belgium (www.turbulent.be).

13. Environmentally-Friendly Technologies for Domestic Waste Treatment

On 29 March 2018, the President of the Russian Academy of Sciences (RAS) A.M. Sergeyev announced at the general assembly of RAS that a representative of the Presidential Administration of the Russian Federation had asked to solve a scientific problem of the domestic waste landfill in Yadrovo. A.M. Sergeyev announced: "I would like to never receive such requests. I would like us to be able to identify the problems and propose solutions to solve them instead".

Indeed, the most advanced environmentally-friendly technologies for waste recycling have been developed by Russian scientists. Using the technology developed by Cand. Sc. (Tech.) V.V. Stenin (Moscow), South Korea and China built and commissioned sealed fast pyrolysis plasma reactors for treatment of highly toxic waste [58-61] that significantly outperform the western technologies for waste incineration or landfill gas burning.

Russian technologies discharge zero emissions to atmosphere, and 95% of solid waste and 100% of plastics are converted into gas used for gas engine power plants for generation of electrical energy and heat. High temperature of the plasma reactor with DC plasmatrons allows to neutralise highly toxic waste in airtight conditions, melt metal and glass waste without emission of nitrogen oxides and dioxins.

It is necessary to develop a standard plasma reactor capable of treating 100-500 tons of waste per day, build 100 such reactors and install plasma reactors in each district of the Moscow Region, stop any waste landfilling, remove all dumps and reclaim the land within 5-10 years. This could be a real health care and healthy future of further generations.

RAS needs to build an IT centre for collection of information on existing and new Russian technologies and their authors. The domestic waste disposal and landfilling system is criminalised and flawed as it contradicts the concept of sustainable development, protection of public health and life prolongation as declared in the Message of the President of the Russian Federation.

Russian scientists also developed an environmentally-friendly technology for treatment of sewage effluents, waste of hog farms, poultry farms, meat factories, distilleries with gas production and disinfected process water using sealed reactors. This development was made by Dr. Sc. (Phys.-Math.) S.V. Pashkin [62]. The technology is based on super-crystal water oxidisation of waste to treat liquid effluents into gas and electrical energy with zero emissions to atmosphere, cease discharge of effluents into the sea and improve the sanitary conditions in the Crimea and the Black Sea coast in the Caucasus.

If we continue to widely use fossil fuels, our civilization is going to collapse. The fuel-free renewable energy era is going to replace the fuel age [63].

In Russia, there are no scientific organisations or a scientific journal dedicated to fuel-free renewable energy issues. In 1977, the National Renewable Energy Laboratory (NREL) was established in the USA with a budget of 458 million dollars (2017), 2,200 employees and its own journal called Solar Energy. In 1980, the Solar Energy Institute of the Academy of Sciences of Turkmenistan was established in Ashgabat (USSR), and Tashkent has been publishing the Geliotekhnika magazine founded by the Academy of Sciences of Uzbekistan since 1965.

The Russian Academy of Sciences should build a national laboratory, an institute and, in the long run, a federal scientific centre for fuel-free (renewable) energy in cooperation with the Ministry of Energy and make arrangements to publish the Fuel-Free (Renewable) Energy journal.

Conclusions

1. Developing countries increase electric energy production output to improve the quality of life. Development of civilization causes a growth in consumption of energy resources and increasing human impact on climate which leads to global warming.
2. The vital task of governments and international organisations is structural transformation of the energy industry and transition to new, fossil fuel-free energy sources. If we continue to widely use fossil fuels, our civilization is going to collapse. The fuel-free renewable energy era is going to replace the fuel age.
3. As part of an international project, Russian scientists proposed to build a solar energy system in the XXI century to enable production and distribution of electric energy for each inhabitant of Earth throughout the year for millions of years with decommission of all existing power plants powered by fossil fuels around the world. For purposes of implementing the project, five new technologies were developed and protected by 30 Russian and 60 international patents.
4. Energy technologies determining the future of the energy industry in the XXI century and transition of humankind to sustainable development must be based on new physical concepts. Russia and other countries of the World develop free-running electric energy and heat generators powered by energy of Earth's crust, aerial and aquatic environments, energy of nuclear reactions, electric and magnetic fields, as well as electrical energy of atmosphere. This article dwells upon the current status of the research work and the results obtained.

   The XX century was the last century of cheap energy. The era of cheap energy has come to its end and humankind needs new energy carriers to enable sustainable development in the future. Humankind is capable of combining and concentrating the energy resources and technologies to create decent living conditions for each human and implement large-scale scientific projects on Earth and in space.
5. All electrical machines and systems, methods for generation and transmission of electrical energy described in sections 1-12 are breakthrough Russian technologies protected by more than 500 patents, including more than 165 patents in the previous 10 years. These technologies could be used to solve the tasks under the national scientific development programme.
6. The proposals for creation of the global solar energy system, launch of the One Billion Solar Roofs programme, the intercontinental system for transmission of gigawatt and, in the long run, terawatt flows of electrical energy, the non-contact power supply for electric vehicles, high-speed trains and ships, development of generators powered by ambient energy could be used for creating international Mega Science projects.

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ECONOMETRIC MODELLING FOR DEEP DE-CARBONIZATION

Rae Kwon Chung

Professor, The Global Energy Prize International Award Committee Chairman, Republic of Korea

info@ge-prize.org

Rae Kwon Chung, Professor Emeritus of the Incheon National University, Republic of Korea, the Global Energy Prize International Award Committee Chairman, former member of the Intergovernmental Panel on Climate Change (IPCC) which received Nobel Prize for peace in 2007, is one of the prominent promoters of the concept of low carbon economic development. In 2018 he presented results of his studies of this process on different occasions in Russia as well during the 24th session of Conference of Parties of Framework Agreement on Climate Change held in Katowice, Poland, on 4-14 December 2018.

"Energy Bulletin" (EB) is pleased to draw the attention of its readers to his lecture delivered on 6 June 2018 at the National Research University "Moscow Power Engineering Institute" on Econometric Modelling for Deep De-carbonization.

Abstract: The text presents the major points which could be taken into account by all those involved in different issues of energy development and particularly in areas related to the creation of conditions for sustainable energy development of human society. Moreover the ideas expressed by Professor Rae Kwon Chung in this lecture are closely linked to the major theme of this EB release and considered as an important contribution to the better understanding of problems related to the transition towards the low carbon energy.

Key words: low carbon energy, de-carbonization, climate change.

Transformation for Deep De-carbonization could be realized out under the following assumptions:

- Climate Change is not just "Rising Temperature";
- Our Challenge: Transforming our economy towards clean energy future to remain within 2°C target;
- Clean Energy Transformation will not happen automatically: it is political, ecological, social choice not market choice; a choice for our survival;
- Industrial Innovations powered by coal, oil, electricity, internet happened automatically by technology & market.

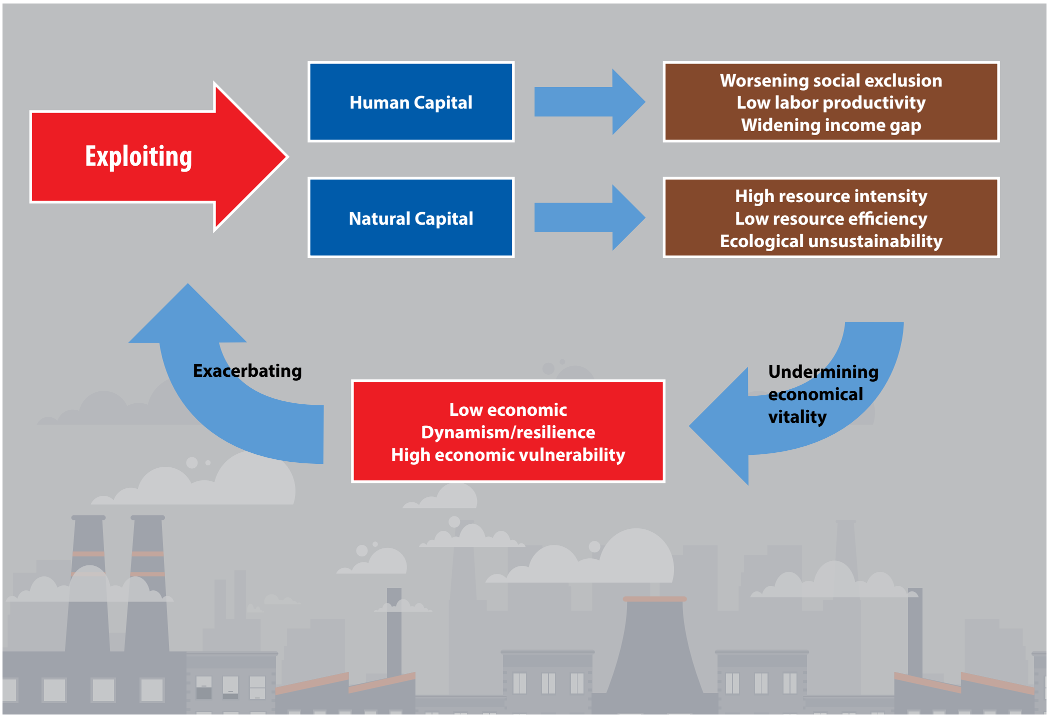
Sadly, extent of long term transformation is limited by short term economic feasibility:

- Unfortunately, success or failure of de-carbonization will depend on economic viability as we are stuck in short term GDP* quantity paradigm;
- Long term Deep De-carbonization requires paradigm shift towards Long term GDP quality of our economic growth.

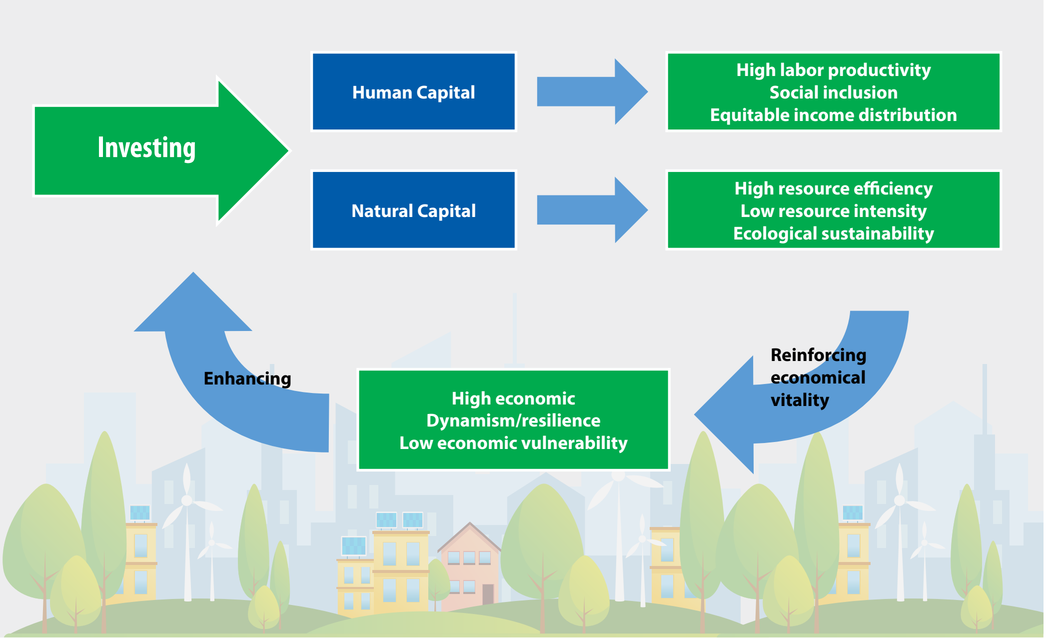
Magnitude of Deep De-carbonization for 2°C:

- CO_2 emission from energy sector should peak by 2020, and then be reduced by 70% from current level by 2050;
- 70% of globally produced energy has to be "clean" energy;
- share of energy from renewables to increase from around 15% in 2015 to 65% in 2050;
- by 2050, nearly 95% of electricity should be "clean" energy, 70% of new cars to be electric, the entire existing building stock has to be retrofitted, CO_2 intensity of industrial sector to be 80% lower.

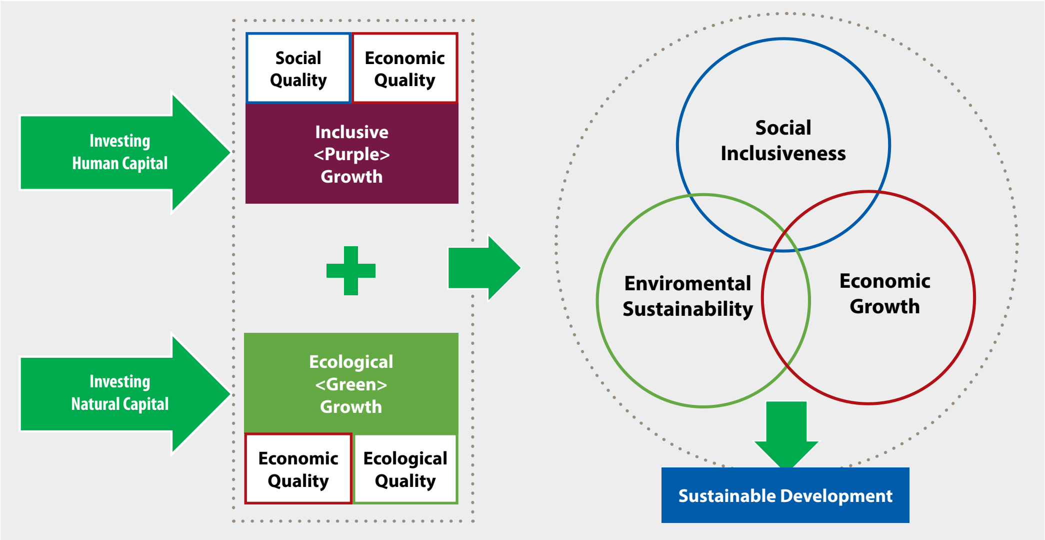
* GDP – Gross Domestic Product.



Vicious cycle/Maximization of Short Term Quantity of Growth (GDP).



Virtuous cycle/Pursuing Long Term Quality of Growth (GDP).



Model for integration of 3 dimensions of sustainable development (SD).

Extent of challenge:

— Fossil fuel share in 2050 will be reduced to a one third of today's level. Oil demand to be reduced to 45% of today's level;

— Even with NDC* of Paris Climate Agreement: by 2050, the energy sector will emit almost 1,260 Gt of CO_2; nearly 60% more than carbon budget of 790 Gt;

— Investment in RE** to be tripled; Net incremental investment of USD 830 billion more per year compared to current plans and policies.

Can Deep De-carbonization be compatible with Economic Growth?

— Green Economy (GE): Deep De-carbonization + Economic Growth,

— contradicting projections on the fate of GE.

Contradicting Projections:

Bjorn Lomborg***: Paris Climate agreement will cost 1 trillion annually, EU GDP will be reduced by 1.6% by 2030, EU will lose £200 billion annually, for global economy to lose £600 billion to £1.2 trillion GDP annually;

IRENA****: Global GDP will be 0.8% higher in 2050, $19 trillion in cumulative economic gains 2015-2050, 26 million jobs in renewables by 2050 from 9.8 million today, Health, environmental, climate welfare investments will be 6 times higher;

OECD*****: G20 GDP will increase by up to 2.8% by 2050. If the positive impacts of avoiding climate damage are taken into account, the net effect on GDP in 2050 rises to nearly 5% across developed and emerging economies of the G20.

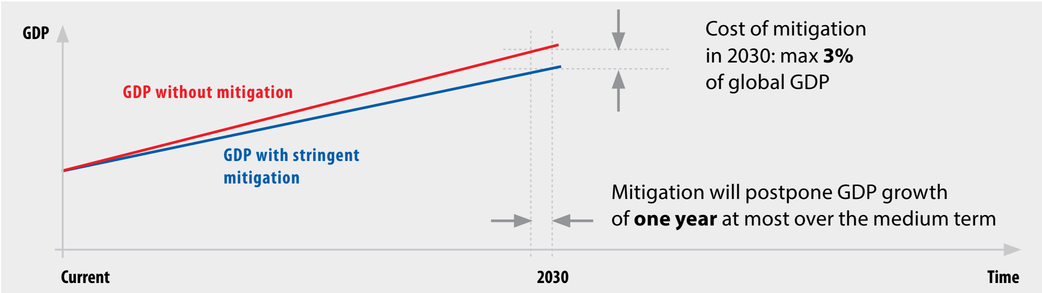
* NDC – Nationally Determined Contribution. NDCs embody efforts by each country-party of the Paris Climate Agreement of 2015 to reduce national emissions and adopt to the impacts of climate change.

** RE – Renewable Energy.

*** Bjorn Lomborg is a Danish analyst, author and President of his think tank Copenhagen Consensus Centre. In 2002 Lomborg was cited as one of "The Most Respected Global Warming Skeptics". His issue is not with the reality of climate change but rather with the economic and political approaches being taken (or not taken) to meet the challenges of that change. He is a strong advocate for focusing attention and resources on what he perceives as far more pressing world problems such as AIDS, Malaria and malnutrition. In his critique of 2012 United Nations Conference on Environment and Development, Lomborg stated: "Global warming is by no means our main environmental threat".

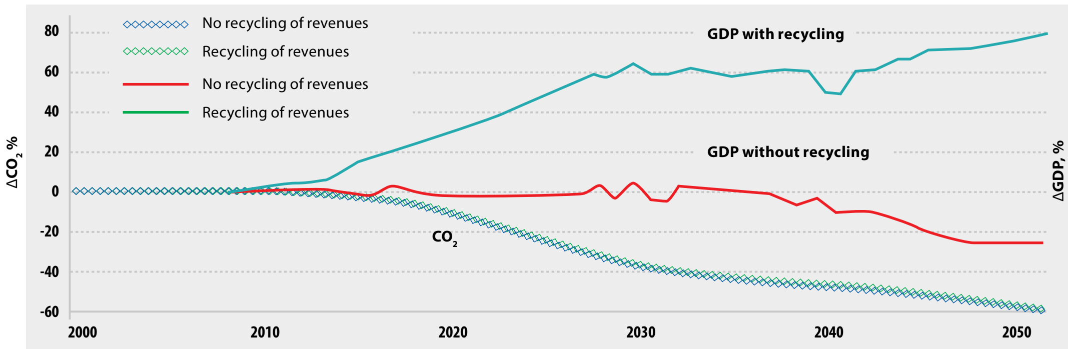
**** IRENA is International Renewable Energy Agency. It is an intergovernmental organization with some 160 member-states. The IRENA Secretariat is located in Abu Dhabi of the United Emirates. The Agency was established in 2011 with the major objective of supporting member-states in their transition to sustainable energy future. For the time being it has not entered the UN family of organizations.

***** OECD is Organization of Economic Development and Cooperation. As an intergovernmental organization uniting 36 member-states in was established in 1961 and located in Paris, France.



IPCC 4th AR*: Global GDP growth -3% by 2030.
Impacts of mitigation on GDP growth (for stabilization scenario of 445-535 ppm CO_2-eq).

UNEP: Green Economy Report projection.
Investments in green economy should bring more benefits and higher GDP growth in comparison with "business as usual" investments.

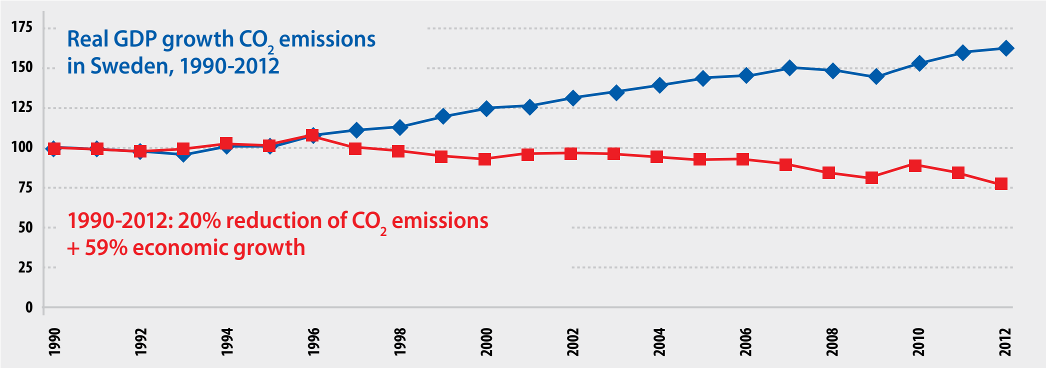


% difference from reference case for the effects of recycling of revenues from carbon prices on global GDP and CO_2 emission 2010–2050.**
*Source: E3MG*** modelling, Barker and Anger, 2013 – work in progress.*

* AR – Assessment Report of IPCC about knowledge on climate change, its causes, potential impacts and response options. 4th AR was issued in 2007. The most recent 5th AR was made in 2014.

** Carbon price is the amount that must be paid for the right to emit one tonne of CO_2 into atmosphere. Carbon pricing usually takes the form of a carbon tax or a requirement to purchase permit to emit, generally known as cap-and-trade, but also called "allowances".

*** E3MG modelling – macro-sectorial econometric model designed to address major and economy-environment policy challenges.



Swedish case of correlation between GDP growth and CO_2 emissions' reduction.
Sources. For CO_2e: Sweden's National Inventory Report 2012, submitted under the UNFCC and the Kyoto Protocol. Preliminary figures for 2012. For real GDP: Statistics Sweden.

According to IRENA RE & Job Annual Review 2018:

— 10.3 Million jobs in Renewable Energy Sector, 500,000 new jobs added in 2017;
— 28 million jobs in RE expected by 2050;
— China leads by 4.19 million jobs, Brazil 1.08 million jobs, 0.81 million in US, 0.72 India, 0.33 Germany, 0.3 Japan;
— Solar PV sector; 3.4 million jobs, 94 GW installed in 2017;
— Wind: 1.15 million jobs.

Deep De-carbonization can be an opportunity for business:

- Net additional investment of $860billion in RE is a huge business opportunity: Business should strategize to seize the opportunity, rather than resist.
- Role of Government: long term predictability, elimination of uncertainty for private investment, & lead technology R&D, level playing field.
- Carbon pricing: IRENA, expects carbon pricing to be at around $190 to meet 2°C target.

Role of States: System Change

- Clean Energy Transformation requires economic & financial system change: which cannot be led by Market, it has to be led by States;
- $860 billion investment annually in RE, carbon pricing of $190 etc. have to be led by States;
- Clean Energy Transformation requires not only Technical Innovations but Policy Innovations; innovative policy tools, such as ETR (Ecological Tax Reform); shifting tax base from Income to Carbon;
- Long Term Vision & Strategy: providing long term predictability and level playing field to minimize investment uncertainty and risk.

For Developing country:

- Transformation to Clean Energy Future: poses extra challenges and opportunities.
- Should set long term vision and strategy to take advantage of the First Mover's advantage; Costa Rica (long term consistency, reforestation, eco-tourism).
- Important policy tool, Eco-Tax Reform, Double Dividend, Revenue Neutrality.

Can we believe in Static Long term economic modeling? We Need Dynamic Modelling

- Don't be fooled by Negative Projection by Static CGE* model that predict Climate Action will reduce Economic Growth!
- It can be in the short run, but in the long run?
- Static CGE model: can it predict qualitative structural change of transformation? Not At All.
- We need Dynamic not static long term economic modelling that internalizes structural & qualitative transformation of economic system.
- We should rather believe in empirical evidence than in Economic Models.

* CGE – Computable general equilibrium being used in economic modelling.

THE GLOBAL ENERGY PRIZE LAUREATES SPEAK

Energy Bulletin is glad to announce that the winners of the Global Energy International Prize* in 2018 were Sergey Alekseenko, Russian expert in thermal physics, full member of the Russian Academy of Sciences (RAS), Head of the Laboratory at the Institute of Thermophysics (Siberian Branch of RAS), and Martin Green, Australian physicist and professor at the University of New South Wales.

Academician Sergey Alekseenko was awarded this prestigious prize for development of thermophysical fundamentals for advanced energy-generating and energy-saving technologies that allow construction of environmentally safe thermal power plants, and professor Martin Green won the prize for his innovative solar energy technologies that improve cost effectiveness and efficiency of photovoltaic solar cells. The Global Energy Prize Award Ceremony was held on 4 October 2018 at the venue of the Russian Energy Week International Forum in Moscow (Russian Federation).

Energy Bulletin traditionally publishes the extracts from the 2018 winners' speeches at two scientific meetings held in Moscow.

The speech of S. Alekseenko at the plenary session of the 7th Russian National Heat Transfer Conference on 22 October 2018 was dedicated to the prospects of geothermal and petro thermal energy development in the contest of resolving thermophysical problems.

Sergey Alekseenko: "Resources of petro thermal energy is enough to keep humankind supplied with energy forever".

Among other things, he underlined that the world energy mix would drastically change in the nearest decades as a result of coal substitution by carbon-free energy sources, and also noted that some states pursued the policy of improving energy production-efficiency and increasing the share of renewable energy sources (RES) in order to create conditions for their sustainable development and overcome the growing problems of climate changes which is a global energy trend of today that should be taken into account for the energy development of Russia.

As a strong advocate for geothermal energy development, academician S. Alekseenko explained that this area was divided into two elements: hydro-geothermal segment utilising the resources of hot underground water with scarce reserves, and petro thermal segment utilising the heat of hot dry rock at the depth of 3-10 km where the temperature reaches 350 degrees. Academician believes that there are enough reserves of deep heat for the next 50,000 years and if humankind develops this field, it can gain access to almost inexhaustible and absolutely "green" resources. Many countries in the world develop pertro thermal energy: USA, France,

* Comprehensive information on the International Prize "Global Energy" established by the Association for Developing International Research and Projects in the Energy Field "Global Energy" in 2002 could be found at the Association site – www.globalenergyprize.org

Great Britain, Japan, Australia, Iceland. Several states adopted the programmes for development of this new type of energy, primarily at the R&D level with a prevalent share of public funding. For example, in 2018 USA spent 51 million dollars on deep heat R&D. Russia has a great potential for geothermal energy development. Western Siberia and Kamchatka are the richest regions of Russia in terms of reserves of Earth's crust thermal energy. But geothermal energy in Russia is underdeveloped due to the lack of the respective infrastructure and availability of 40% of the world's reserves of gas and coal. The cost of drilling also plays an important role. "The cost of construction of geothermal power plants is estimated to be 2 billion rubles", noted S. Alekseenko in his speech.

As regards future energy trends, he also emphasised the necessity to develop environmentally friendly and efficient technologies for organic fuels recycling and utilisation (combined cycle gas turbines, deep conversion of coal) and increasing the share of solar energy in the World energy mix.

Full members of RAS (academicians) Alexander Leontyev and Vladimir Fortov, winners of the Global Energy Prize in 2010 and 2013 respectively, took part in the plenary session of the Conference.

Professor Martin Green delivered a lecture on 5 October 2018 in the Odintsovo Branch of the Moscow State Institute of International Relations (MGIMO). It was dedicated to development and commercialisation of high-performance silicon solar photovoltaic cells. The lecture was given as part of the Energy of Knowledge programme being implemented by the Global Energy association.

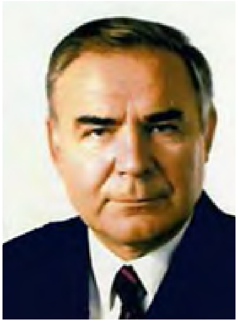
Martin Green: "In the nearest future the cost of energy from the Sun will be just a little higher than the energy produced from coal".

As one of the world's leading silicon photovoltaics and high-performance monocrystalline and polycrystalline silicon cells expert, professor M. Green emphasised that the main world energy trend is the reduction of dependence of the latter on the fossil energy carriers and a transition to widespread use of RES. He noted that it was necessary for the world community to solve the problem of the threshold limit concentration of carbon dioxide in the atmosphere as soon as possible, or by 2030 humankind is going to face serious consequences of climate changes. M. Green expressed confidence that in the next few decades solar energy would prevail in the world energy mix due to aggravation of the environment pollution problem and reduction of cost of production and maintenance of solar photovoltaic panels. Speaking about the prospects of various countries in terms of RES utilisation, he noted that Russia received more solar energy due to its vast territory than any other country of the globe and, consequently, it has exclusive opportunities to develop the solar energy industry. Australia is the world's second country by volume of energy being received from the Sun, and it also has favourable conditions for the use of such energy to produce electricity. Formerly, when solar photovoltaic cells were expensive, for the reduction of their maintenance costs and, consequently, of the cost of electricity generated by them high-density solar irradiation was required. In the world of today, when the number of producers and competition among them grows, the cost of panels and auxiliary equipment, as well as the electricity produced, falls so

quickly that solar electricity will become the cheapest part of energy systems for almost all countries in the next decade. "Prices for photovoltaic cells have dropped by 30% in 2018 and they will continue to drop", noted the winner of the Global Energy Prize.

In his lecture, professor M. Green presented PERC (Passivated Emitter and Rear Cell) solar cells with an energy-efficient element which had been developed by himself and whose production had been launched in 2012. Today, they are the world's second best-selling cells. In 2017, the share of PERC among other elements being used for silicon elements production was above 24%. According to M. Green, sales of PERC cells in 2018 will amount to 20 billion dollars, and will reach 2 trillion dollars by 2040. He emphasised that performance of solar cells and panels composed of such cells grown quicker than expected by experts. In the previous year, solar photovoltaic cells generated 0.1 TW of energy, so, according to the speaker, in seven years this number could reach 1 TW of solar power per year.

COAL REVISITED

Vladimir A. Kuzminov
Fellow, World Academy of Art and Science, Russia
kuzminov.v@gmail.com
Mikhail G. Berengarten
Professor, Moscow Polytechnic University, Russia
berengarten@mail.ru

Abstract: The article dwells upon the history of discovery and use of coal. It presents the data on the reserves of coal and its position in the world energy balance and describes the main fields of non-energy use of coal.
Key words: coal, greenhouse effect, non-energy use of coal, world energy balance.

An article named "Environmental Problems of Coal Production and Conversion"* by a co-author of this article and published in the 23th issue of Energy Bulletin ended with a promise to draw the readers' attention to the aspects of non-energy use of coal capable of serving the humankind for many decades, or even centuries.

Coal as a source of thermal energy has been used by the humankind since immemorial times or, to be more exact, since the migration of people from the warm habitats to the Northern latitudes with colder climate where inhabitation required not only warm clothes, but also dwellings to be heated during the cold season. Of course, initially people used wood, charcoal and various types of biomass in the form of waste as a result of food production and consumption, etc. i.e. everything containing carbon and, consequently that could be burnt and generate heat and light and be picked up from the surface of Earth. Soon people found "black rocks" that burnt better and longer as compared to wood, hence giving more heat to make life more comfortable where inhabitation required reliable sources of heat, and started using them to make household items, as well.

According to the history of fossil and non-fossil coal (hereinafter – coal), people started using it three thousand years ago in China, and the first description of coal was found in the documentary records of ancient China and ancient Greece dating back to the third century B.C. which survived to our days. It took several centuries for the coal to take its important place in the lives of people. For a long time it was losing to wood and wooden products for a number of reasons, primarily because its ignition point is much higher than that of the wood, and due to high content of sulphur compounds and other components whose extraction was impossible for a long time due to the lack of respective knowledge. Large amount of smoke generated by coal combustion was also a serious deterrent to wide use of coal.

At the same time, this energy carrier served as a "drive" for the industrial revolution that has led to formation of the industrial society on our planet. The coal's path to its dominating position wasn't smooth and was associated with certain objective and subjective problems. First of all, the society lacked technological and practical knowledge to efficiently use coal, and secondly, there was an opposition within the society that hindered replacement of wood and charcoal in everyday life due to the above mentioned factors. Construction in Europe of large metallurgical and metal-working plants that initially used charcoal which required massive wood utilisation leading to fast depletion of forests made coal the main source of energy in such production areas. It was also associated with the invention of the coal-to-coke conversion by a German chemist I. Becher

* M. Berengarten, Environmental Problems of Coal Production and Conversion // Energy Bulletin, No. 23, 2017, pp. 34-40.

Proven coal reserves in 2016, million tons.

Country	Bituminous coal*	Brown coal**	Total	%
USA	108,501	128,794	237,295	22.1
Russia	69,634	90,730	160,364	14.1
China	230,004	14,006	244,010	21.4
Australia	68,310	76,508	144,818	12.7
India	89,782	4,987	94,769	8.3
WORLD	816,214	323,117	1,139,331	100

Source: BP Statistical Review of World Energy 2017

in the late XVII century which further revealed its energy and other characteristics.

Since then, the coal industry has been developing rapidly, including search, extraction, transportation and processing of this valuable fossil raw material.

For a long time geological exploration of the Earth's depths was associated with the search for coal, evaluation of its mineable resources and potentially mineable reserves that could not be mined when they were discovered due to the lack of technological and economic capabilities. Therefore, coal reserves on our planet have always been and remain classified as proven and mineable, or potentially mineable. These two types of coal reserves significantly differ from each other, but development of new techniques for geological exploration and extraction of coal bridges this gap, and many fields that were not mineable in the recent past are successfully used nowadays and, naturally, are classified as proven and mineable. Now it is absolutely obvious that coal reserves exist on all continents of Earth and majority of islands of the World Ocean. Of course, they differ by sizes, types and quality of this fossil energy carrier.

Below are the data on proven reserves of coal as of 2016 in the countries with the richest reserves and in the world generally. It should be noted that more than 30 countries on all continents have significant reserves of coal.

Most data divide the coal reserves into two main types of coal, bituminous and brown. As is evident from the table above, they differ by the size of reserves, and in terms of this classification the leader is bituminous coal including anthracite and bituminous substances which are classified as bituminous in general. It has the lead by calorific value, as well. It is assumed that bituminous coal is a derivative of brown coal formed under the influence of geological factors and chemical processes that enrich brown coals with carbon and lead to the loss of such substances as oxygen and aqueous compounds forming carbon oxide, water and methane. As compared to brown coal, bituminous coal is more valuable due to its higher calorific value, reduced ash content, denser structure, low humidity and low nitrogen and sulphur contents. One of the types of brown coal named anthracite is considered to be the best solid fossil fuel and the most valuable raw material for the coal chemical and metallurgical industries.

According to the estimates by the Energy Committee's coal working group of the United Nations Economic Commission for Europe, about 27% of the world's energy is produced from coal today. Its role is even more important in the electric power industry – about 44% of electrical energy is generated from coal [1].

As was described in the above mentioned article published in the 23th issue of Energy Bulletin, global coal production and consumption patterns have not changed significantly in the past 50 years. It indicates at a very strong position of coal in the global energy sector and other industries. Moreover, in the period from the late 1970s to mid-1980s coal, after being forgotten for some time when oil, and then natural gas, entered the energy market, helped the human-

* Bituminous coal here means anthracites and bituminous substances.

** Brown coal means subbituminous substances and brown coal.

kind to overcome the energy crisis and certain economic problems in many countries of the world quite smoothly. According to the BP Statistical Review of World Energy 2017, global production of coal in the period from 2005 to 2015 grew by 2.5% every year, and consumption – by 1.9% annually. But after adoption of the Paris Climate Agreement, a reduction both in production and consumption of coal has begun. In the period from 2015 to 2016, these figures were - 6.2% and -1.7%, respectively. Last year USA, one of the world's leading producers of coal, withdrew, and in 2018 confirmed their withdrawal, from the Paris Agreement which could lead to a change in the above given figures. Germany, on the contrary, more recently declared its intention to adopt a plan for complete cessation of coal use for energy generation in 2019, though it remains unclear how many years it would take to implement the plan.

So, what were the reasons for the world's energy crisis almost half a century ago? First of all, social-economic and geopolitical changes on our planet, as well as establishment of sovereignty over natural resources in several countries possessing significant reserves of oil which remained the main element of the global energy balance for almost a half of the 20th century, and awareness of finiteness of such reserves, have ultimately led to serious difficulties not only in the world energy, but, as was mentioned above, in all economy sectors. This situation forced the global community think of diversification of the energy sector and attraction of renewable energy sources, which back then were called "alternative" together with the nuclear energy development. That was the exact time when most countries recalled about coal, its almost infinite reserves, high calorific value and other quite attractive properties. And despite the fact that back then there was no growth in extraction and consumption of coal, especially in the energy generation, efficiency of coal use grew drastically due to development and introduction of new coal pre-treatment and utilisation technologies in energy generating plants, and due to an improvement in its ecological quality.

Back then a concept for the coal energy development was adopted on the basis of "clean technologies" of coal utilisation which could be laid down as follows: "improvement of ecological suitability of coal requires development and introduction of technologies which, in addition to reduction and full liquidation of "conventional pollutants" of the environment, would lead to an increase in thermal efficiency which would inevitably result in a reduction of emissions of carbon dioxide, one of the main greenhouse gases".

It should be noted that the international scientific and technical community related to the energy sector and adjacent industries, with the support from-policy makers and businesses of most countries, accepted with understanding this concept which resulted in an outburst of research activities promoting its implementation and strengthening of international cooperation in various coal utilisation areas. Indeed, 1970s and 1980s were rich not only in new ideas concerning the "energy" use of coal, but also in scientific and technical developments that, when implemented, allowed to re-equip the coal industry and draw it nearer to compliance with the environmental requirements placed by the society to many industries and other fields of human activities. In this regard it should be recalled that the problems of acid rains and discharge of solid fractions of coal combustion products into the atmosphere were solved, not to mention a significant increase in the efficiency of coal energy plants. In most fields of coal utilisation, combustion products were eliminated from the "conventional" pollutants up to 99%. But, despite a series of quite efficient developments, the problem of CO_2 capture and storage was not solved in its entirety and, apparently, it is still far from being solved.

Another noteworthy thing to mention in this regard is fruitful international cooperation and an important role of several international organisations in its development. Considering that this article will be published in a magazine issued by the International Sustainable Energy Development Centre under the auspices of UNESCO, we shall recall important UNESCO initiatives aimed at improving the international community's understanding of the role and potential capabilities of coal in social and economic development of the humankind. A series of scientific and technical events of various scale held in cooperation with UNIDO*, WEC**, UNEP***, UNECE**** and large energy research centres of the member states really made a significant contribution to development and implementation of the "clean coal technologies" concept. It also enabled preparation of the "Clean Coal Technologies" training module under the auspices of UNESCO to train energy workers and experts involved in the elaboration of solutions related to the energy development.

But in the last decade of the previous century the international community elaborated the sustainable energy development concept with the renewable energy as its key element. The latter demonstrated its growing competitiveness on the energy markets, but what is more important, it is capable of mitigating the consequences of the "greenhouse effect" caused by high concentration of certain gases, including carbon dioxide, in the atmosphere as a result of using carbon-containing fuels. In this regard, coal as an energy carrier finds itself in quite unfavourable conditions, and its energy role will be inevitably decreased as the share of renewable energy in the world energy balance grows. Moreover, today there are certain commitments to transition to low-carbon or even carbon-free or fuel-free economy that are actively developing today with the wide support from our society. It can lead to a reduction or, in some cases, cessation of coal extraction. On the one hand, this phenomenon could be fully compliant with the sustainable development concept aimed at preservation of natural resources, including coal reserves, for the next generations, and on the other hand it could lead to serious social and economic conflicts. It should be noted that there has been no geopolitical conflict over the entire history of the coal industry, though coal miners and the international community will apparently remember for many years the two-year strike of miners in the Great Britain in mid-1980s caused by the decision of the government to close a series of unprofitable mines after which more than 20 thousand workers of the coal industry lost their jobs. The statistics tell about dismissed miners only, but the total number of people affected by closure of mines was much higher as the social and economic frameworks formed around the coal mining facilities also became useless and the people concerned lost their jobs. In this regard, when making a decision to cut the production of coal or close mines one should bear in mind that coal production facilities are the core of industrial areas and the respective social frameworks servicing all economic sectors almost in all coal-mining countries. Therefore, a decline in coal production should be accompanied by conversion of production capacities, scientific and educational institutes and other private and public organisations directly or indirectly related to coal production. All these processes should be taken into account when preparing short-term and long-term plans for development of coal-mining areas.

At the same time, one should bear in mind that coal is a valuable resource not only as a fuel but also as a material containing a huge amount of mineral components, and coal could still serve the humankind for many decades. There is a well-known colourful expression by a famous Russian chemist D.I. Mendeleev about oil: "petroleum is not a fuel, it is possible to heat and with banknotes" that relates to the times when the main petroleum product was lamp kerosene. This expression could be applied to coal, as well. If our society accepts the concept of non-energy use of coal, many generations to come will be provided with the vitally important products.

An incomplete list of such products is given in Figure 1.

For quite a long time coal has been used in the following non-energy fields:
— coal-to-coke conversion;
— coal pyrolysis;
— coal gasification.

The modern development of these fields is also connected with certain new areas similar in their chemical essence but using various types of waste as a raw material, primarily municipal solid waste

Coal-to-coke conversion that implies high-temperature treatment of coal (gradual heating to 950-1050°C) in air-tight conditions was invented in the 18th century when devastation of forest to produce charcoal initially used to smelt iron became threatening and a need emerged to replace charcoal with mineral fuel. In 1735, Great Britain performed the first blast furnace smelting with coke.

* United Nations Industrial Development Organization.

** World Energy Council (during the times mentioned in this article it was called "World Energy Conference").

*** United Nations Environment Programme.

**** United Nations Economic Commission for Europe.

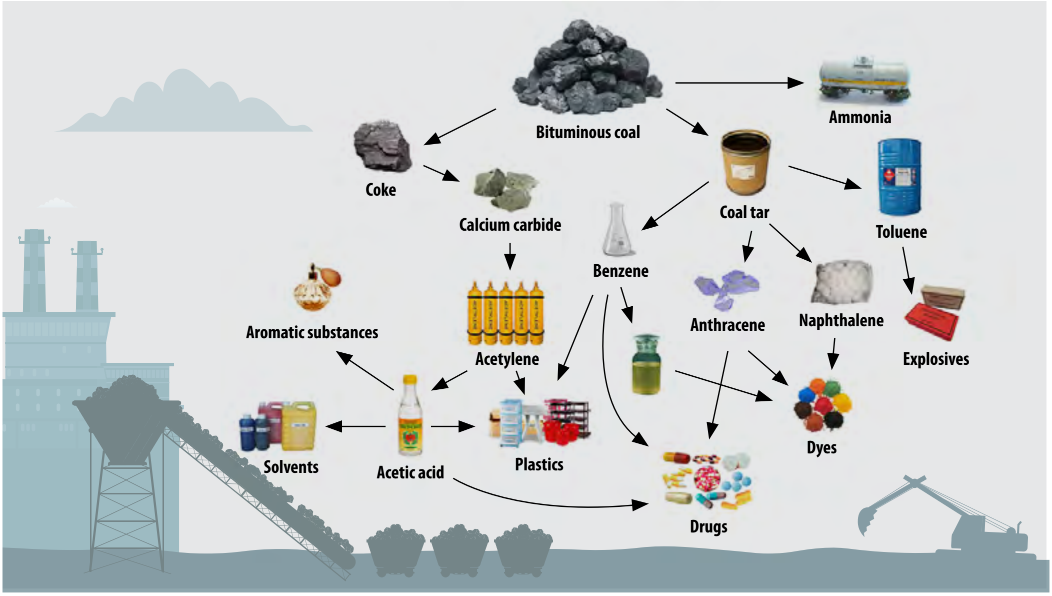


Figure 1. Main products that could be derived from coal.

Apart from coke, another important product of the coal-to-coke conversion is coke gas which, on the one hand, is a source of coal tar, crude benzene and toluene, and on the other hand – a source of fuel gas composed of hydrogen, carbon oxide and methane which is also used as a synthesis gas for various chemical synthesis processes, including synthesis of liquid low molecular weight hydrocarbons.

As a rule, the coal-to-coke conversion takes place in coke ovens in batches due to the length of process (20-30 hours), but there also exist technologies for continuous conversion (for example, see Figure 2). Nevertheless, it should be noted that the main recent developments for continuous coking are aimed primarily at continuous conversion for production of petroleum coke.

Similar to the coking technologies are the coal pyrolysis technologies [2]. In the recent years, municipal solid waste pyrolysis technologies received wide application. Unlike waste incineration, they do not emit gaseous or solid combustion products into the atmosphere, and the hydrocarbon portion of waste is used to produce coke, fuel or synthesis gas.

Solid fuel gasification processes that emerged in the early XIX century [3] are also developing widely. Coal gasification that constitutes, unlike coking or pyrolysis, oxidising high-temperature processing of coal (using air, water vapour, their combination or other oxidisers) allows to produce:

— natural gas substitutes;
— synthesis gas for various types of chemical synthesis;
— fuel gases for combustion (for processing and energy generation purposes);
— reducing gas for metallurgy (for example, direct reduction of iron ore).

Many recent researches were dedicated to improvement of the coal gasification process [4, 5, 6].

Active research is being carried out in a very promising field of catalytic gasification of solid fuel [7, 8].

Another promising technology is gasification of municipal solid waste, including such an "exotic" process as gasification of MSW in a layer of molten metal that produces both gaseous substances (fuel gas, synthesis gas) and mineral components in an acceptable form that might be used, for example, for conversion into construction materials [9].

Conversion of solid fuel into a gaseous state by gasification substantially simplifies its further use, especially for new chemical synthesis processes. Considering that the reserves of coal significantly exceed the reserves of natural oil, the Fischer–Tropsch [10] catalytic synthesis is also promising as it enables production of synthetic li-

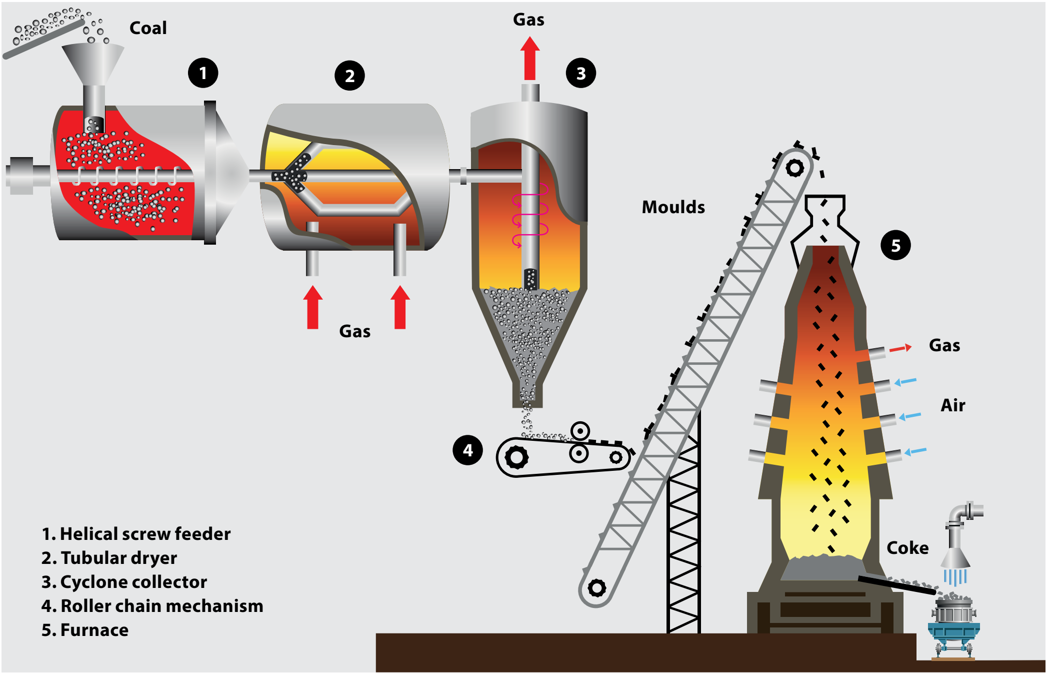


Figure 2. Continuous coking scheme.

quid fuel using the synthesis gas obtained by coal gasification.

In recent years, options to reduce the greenhouse effect by using new type of fuels or new types of energy are being discussed. But it should be noted that combustion of hydrocarbon fuel (both natural and synthetic) always produces greenhouse gases, i.e. carbon dioxide and water vapour. Still, everything depends on the cycle of carbon circulation where these gases exist, i.e. short or long. In case of the short cycle using biomass-based fuel (including biodiesel, biogas, biocoal) the greenhouse effect is not changed, but in case of the long cycle using combustion of fossil fuel reserves the concentration of greenhouse gases in the atmosphere could rise.

One of the proposed options is transition of transport logistics systems to electric vehicles (electric buses, etc.) or the use of hydrogen fuel. Still, production of electric power at thermal power plants or production of hydrogen by reduction from water using hydrocarbon reducing agents emits the surplus of carbon dioxide into the atmosphere, not where the transport is operated, but where the thermal power plants or plants producing hydrogen using steam or steam-air conversion of natural gas, etc. are located. For example, electric bus goes along the Sadovoe Koltso street in Moscow without any emission of CO_2 into the atmosphere, but CO_2 is discharged by the thermal power plant in the Moscow suburbs when producing electric energy to charge the electric bus. As regards carbon dioxide, its total quantity generated during this process will remain the same.

Returning to the problem of non-energy use of bituminous coal, attention should be drawn to the works [11, 12, 13] related to extraction of valuable mineral components from coal, i.e. rare earth elements and other components which will be demanded by the global economy for many years to come.

To sum up, even a brief list of the main fields where coal could be used as a valuable natural resource not only for purposes of its direct, energy use, but first of all as a chemical raw material, shows the prospects of studying these processes to make improvements and prepare for wide non-energy use of coal and make it further to serve the humankind.

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LAUNCH OF THE UNESCO GLOBAL OBSERVATORY OF SCIENCE, TECHNOLOGY AND INNOVATION POLICY INSTRUMENTS PLATFORM

A digital tool to map national science, technology and innovation (STI) landscapes and analyse STI policies and their implementation was launched by UNESCO. The Global Observatory of Science, Technology and Innovation Policy Instruments (GO-SPIN) on-line platform, developed with the financial support of the Swedish government, is a source of information on STI policies and policy instruments for more than 50 developing countries across Africa, Latin America and Asia, but also a tool for monitoring, benchmarking, capacity-building and analysis. It will support evidence-based decision-making and inclusive policies towards sustainable development.

"GO-SPIN is now recognized as an international tool for STI monitoring and evaluation, also as a tool for monitoring the achievement of Sustainable Development Goals," explained Ms Flavia Schlegel, UNESCO Assistant Director-General for Natural Sciences, as the tool was presented to Member States at UNESCO Headquarters on 29 November 2018.

The Platform provides access to a diverse set of legal and policy instruments, quantitative data and qualitative information on different dimensions of STI policies. It focuses on developing countries and their specific characteristics and needs, while linking STI with the Sustainable Development Goals (SDGs). It includes information on policies, development plans, legal frameworks and describes thousands of operational policy instruments. The platform also offers graphic tools to analyse correlations between more than 300 STI indicators and data over 60 years, as well as links to UNESCO databases and a digital library in STI policy.

A panel of experts and policy-makers that have been involved in GO-SPIN projects shared their experiences using the tool, providing diverse viewpoints on its relevance.

For African Group Representative Immo Onuegbu, the platform is an extension of UNESCO's technical assistance, providing "a benchmark we can use as we develop and improve our policies, and where we can share our best practices." Sharifa Al Harthy of the Research Council, Oman, added that the platform will help countries to learn from each other and compare different approaches to building a national innovation system.

"GO-SPIN is a much needed central depository," agreed Dong Wu, of the UN Conference on Trade and Development (UNCTAD), "and a go-to place to find out who are the main players, information on past policy documents and the interactions between different actors in the innovation system."

According to Juan Manuel Brunetti Marcos of the National Council for Science and Technology of Paraguay (CONACYT), the GO-SPIN platform will improve synergy and increased coordination between government offices and STI stakeholders. A GO-SPIN country profile on Paraguay was also launched on this occasion, the 8th in country profile developed since the inception of the project.

Shirley Malcom, of the American Association for the Advancement of Science (AAAS) emphasized the importance of the gender dimension of GO-SPIN, saying "including gender in STI is normative. The gender component in GOSPIN brings gender to the centre and having this element in the platform is vital and key to human resource development."

Member States are all invited to join their efforts with UNESCO to further develop GO-SPIN, to add information and to update the platform as a way to improve governance and capacity-building in STI.

OUR WATER FOR OUR WORLD: THE UNESCO INTERNATIONAL WATER CONFERENCE CALLS FOR A PARADIGM SHIFT TOWARDS WATER SECURITY FOR SUSTAINABLE PEACE

How we manage water, bond of life and fragile resource, will define our success in achieving all goals of the 2030 Agenda for Sustainable Development. Access to water is critical to poverty reduction and human health, impacts gender equality, education, and all human activities. Ecosystems and biodiversity depend on water, it provides three-quarters of the world's renewable energy, and globally three-quarters of it is devoted to food production. Sound water management is a challenge that requires a holistic approach, harnessing expertise across disciplines at all levels. The first UNESCO International Water Conference, held in Paris on 13 and 14 may 2019, was attended by Ministers from 34 States and 1,200 experts from 126 countries.

"I am sure you will all agree that in the challenging years ahead, it is the peaceful and innovative application of science and policy, in a meaningful and understanding cultural context, that will ultimately define our positive development as a global family" said HRH Princess Sumaya bint El Hassan of Jordan, UNESCO Special Envoy for Science for Peace. "UNESCO provides for us all, a nexus of dialogue and engagement, where the concept and practices of water diplomacy and cooperation may transcend the mere transfer of knowledge, to encompass fostering strong partnerships between engaged stakeholders."

Water cooperation, as a powerful lever for peace and sustainable development, was a central theme for this first edition. When discussing their experience of mechanisms to manage shared water resources, Member States' representatives stressed the need for a strong political will for dialogue and cooperation to create effective tools and measures for implementation. They highlighted that such mechanisms must be supported by an improved knowledge-base of water resources and capacity-development to further technical knowledge on this vital resource. They also called for more scientific dialogue between riparian countries of a shared basin and basins across the world.

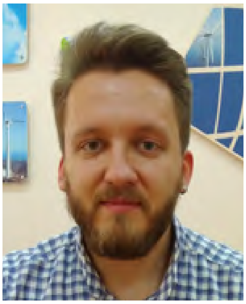
Noting UNESCO's long-standing experience in fostering water cooperation, they remarked that the Organization could provide a platform for such multidisciplinary dialogues, as it is uniquely placed to foster solutions based on intersectoral cooperation combining, through its mandate, the sciences, education, culture, communication and information sharing.

"Promoting water security and sustainable peace were at the heart of the conference's ambitions" said Mr. Xing Qu, UNESCO Deputy Director General, in his closing remarks. "Today we call for a fundamental shift in the way we look at water. Today in Paris, this International Water Conference, convened by the Director-General of UNESCO, calls for a trans-sectoral approach to water that will lead us to achieve the 2030 agenda and its 17 Sustainable Development Goals and related targets. Today, the UNESCO Secretariat commits to fostering collaboration between its sectors towards sustainable water security and peace."

The Conference was organized by UNESCO, with support from the Global Energy Interconnection Development and Cooperation Organization (GEIDCO), the Syndicat interdépartemental pour l'assainissement de l'agglomération parisienne (SIAAP), the Regulation Agency for Water, Energy and Sanitation Services of Federal District of Brazil (ADASA) and the magazine Techniques Sciences Méthodes.

Source: www.unesco.org

COMPARATIVE ANALYSIS OF TECHNOLOGIES FOR DISPOSAL AND NEUTRALISATION OF MUNICIPAL SOLID WASTE IN THE CONTEXT OF OVERCOMING PRESENT WASTE MANAGEMENT PROBLEMS



Mikhail S. Skonechnyy

International Sustainable Energy Development Centre under the auspices of UNESCO, Russia

skonechnyy@isedc-u.com

Michail S. Skonechny is Head of the Applied Research Sector of the Autonomous Non-Commercial Organization "International Sustainable Energy Development Centre" under the auspices of UNESCO. In the frame of his research, he contributes to development of the information analysis system for safe operation of the chemical industry, evaluated performance of obligations under the Stockholm Convention related to the fuel and energy industry in the Russian Federation and contributed to the adaptation of the International Standard of Environmental-Economic Accounting to Russian conditions.

Abstract: Russian MSW* management system is currently experiencing a number of systemic problems. In particular, MSW landfilling, the basic element of the MSW management system, has exhausted itself due to environmental hazard and resource inefficiency. The government proposed the use of MSW thermal treatment as the basis for MSW management system hereafter. The public and a number of experts do not support this proposal. Under the present situation, it is necessary to develop an approach that can help to overcome current crisis as soon as possible, avoid environmental damage and form the basis for the further sustainable functioning of this industrial branch, e.g. waste management.

This article presents a comparative analysis of technologies for landfilling, aerobic composting, anaerobic digestion, thermal neutralisation and separate collection of waste in the context of overcoming the crisis. Comparative analysis has shown that the MSW disposal can not be considered as an approach for solving existing problems of this industrial branch: the widespread use of this method caused the current "waste crisis". MSW aerobic composting is also ineffective in the current circumstances due to low productivity, high cost and environmental hazard of the end product. The use of anaerobic digestion with biogas production is promising, either in combination with waste disposal and extraction of landfill sites gas, or with a deep sorting of MSW. From the perspective of overcoming the crisis, the most effective approach is the use of MSW thermal treatment due to its high productivity.

* Municipal solid waste (MSW) is a waste generated by individual consumption in residential spaces, as well as commodities that have lost their consumer properties in the course of utilisation by individuals in residential spaces for satisfaction of personal and household needs. Municipal solid waste also includes waste generated by businesses, individual entrepreneurs and other waste similar to that generated by individual consumption in residential spaces (as per the Federal Law No. 89-FZ dated 24 June 1998 "On Production and Consumption Waste"). It is understood that such waste contains a significant amount of components containing various liquids and organic elements which are primarily food waste. – Editor's note.

Based on the results of the work, proposals for the development of waste management system were prepared. A wide use of MSW thermal treatment coupled with reclamation of waste landfill sites that have a high level of environmental danger or exhausted capacities can quickly solve the current problems of the industry. After that, it is necessary to use an integrated approach: First, it is necessary to provide modernization of existing waste landfills of wastes disposal and the creation of new ones in strict compliance with existing standards. In addition, it is necessary to provide the possibility of landfill sites gas extraction. Second, it is necessary to ensure the establishment and development of a separate waste collection. It will increase the efficiency of thermal treatment and anaerobic digestion of MSW and provide positive social and economic effects. Implementation of priority measures to solve acute problems of the industry, and the combination of several methods of MSW management in the future will create conditions for the sustainable functioning of this industrial branch.

Key words: municipal solid waste, waste disposal, thermal neutralisation of waste, waste disposal, waste management system.

Introduction

Today, Russia faces a pressing problem of MSW disposal and neutralisation. It is very acute in the Moscow Region due to the high population density and significant volumes of MSW accumulation. Landfilling has been the basic component of the MSW management system for a long time, but the growing volumes of waste, lack of vacant space at the existing landfill sites and lack of lands to arrange new sites renders it almost impossible to further use this approach. In 2017-2018, the current situation caused public protests. On 30 August 2017, the data sheet for the Clean Country* project was approved. This project includes (among other things) construction of four waste incineration plants (hereinafter – incinerators) in the Moscow Region. The public protested against this project once again.

For example, the most widespread waste management method, i.e. depositing, has exhausted itself. MSW volumes grow each year, however no new approach to MSW disposal and neutralisation has been elaborated and the proposed governmental solutions do not satisfy the population needs. Therefore, one may say that the current MSW management system has come to a crisis. In such conditions where the public health and the environment are at risk it is necessary to take steps to overcome the crisis as soon as possible, even if such steps are not feasible or economically effective under normal functioning conditions. The main requirements to implementation of a new approach should be the following: a) public health and environmental safety; b) ability to quickly overcome all problems in this industrial branch; c) laying the foundation for the industry's sustainable development to solve the current and emerging problems in the industry in an economically efficient manner with a minimum damage to the environment and public health.

This article presents a comparative analysis of technologies and approaches to waste management from the perspective of their application to overcome the current crisis. Based on the results of the analysis, proposals for the development of waste management system will be prepared.

Main Points

MSW Landfilling

Considering that the current Russian practice guarantees the lowest financial cost of landfilling, today it is the centrepiece of the waste management system in Russia. More than 90% of all MSW are discharged to landfills and unauthorised dumping grounds [1]. As early as in 2013, the total volume of accumulated MSW in the Moscow Region was estimated to be 120 million tons, and the remaining capacity of MSW landfills was enough for 3 years use [2].

Despite the wide use of the landfilling method, this approach has several serious disadvantages.

MSW landfills exert a significant negative effect on the public health and the environment. For example, they damage the soil by polluting it with heavy metals and inducing erosion, the aquatic environment by inflow of landfill leachate to subsoil water, the aerial environment by emission of landfill gas and its combustion products to the atmosphere. MSW dumping grounds and landfills comprise more than a half of all environmentally dangerous sites. [3]. According to some estimates,

* The Clean Country project was launched during the Year of Ecology in Russia (2017). – Editor's note.

the unsatisfactory ecological conditions nearby MSW landfills remain for 20-50 years after their closure [4]. This is mainly due to non-compliance with the requirements to construction and operation of landfill sites [5] and the growing number of unauthorised dumping grounds.

MSW landfilling is the least rational method for waste management in terms of land use which is specifically critical for the Moscow Region that faces a shortage of such lands. Besides, landfilling does not permit to utilize material and energy resources deposited in MSW [6].

Biological Disposal of MSW

There are two main techniques for biological disposal of MSW: aerobic composting producing compost and anaerobic digestion producing biogas.

These MSW disposal techniques are more preferable as compared to landfilling as they do not exert a significant negative effect on the public health and the environment. But they also have certain disadvantages that substantially restrict their usage.

The only fraction eligible for biological disposal is the organic fraction of MSW which is 30-40% of the entire volume [1]. However, its share is less than 25% in the residential sector of the Moscow Region where such fraction is traditionally higher than others [7]. So, the composting technique is capable of processing only 20-25% of the entire volume of MSW in the Moscow Region, and the rest should be neutralised and disposed by using other methods.

Biological disposal in aerobic or anaerobic conditions requires the use of a certain ratio of carbon, nitrogen and phosphorus [8] which cannot be found in the organic fraction of MSW meaning that such disposal requires addition of animal and chicken manure, as well as activated sludge, i.e. the use of additional resources, logistics and processing costs. As a result, the biological disposal method is mainly used for agricultural waste with high content of organics and lack of any hazardous ballast [9, 10]. The end products of both disposal methods are also characterised by environmental and economic instability. For example, the compost produced by MSW composting often contains a significant amount of pollutants, primarily heavy metals [11] due to the inability to remove ballast fractions from MSW which renders this process environmentally unsafe and economically inefficient [12]. The biogas produced by the anaerobic process contains unstable elements and a large amount of impurities [13], thus requiring additional treatment.

A very promising technique is the biogas production at MSW landfills. Landfill layers are characterised by natural methane digestion of waste with concomitant gas emission (landfill gas). If uncontrolled, this process causes the emission of greenhouse gases and pollutants to the atmosphere, spontaneous combustion and discharge of MSW combustion products, but when controlled the production of landfill gas enables the mitigation of the negative effect on the public health and the environment and an increase in the landfilling efficiency. In theory, during the life of a landfill it emits 150-300 m^3 of landfill gas per 1 ton of MSW at a concentration of methane of 50-60 vol.%, which is an equivalent of 5-6 GJ of energy per 1 ton [14]. According to some estimates [15], landfill gas extracted by well-drilling from landfills with an area of less than 27 ha (for example, area of the closed landfill site in Kuchino is more than 50 ha) under ideal conditions could produce 143 thousand kW·h electricity per day. The landfill gas production technology with further power generation is widely used abroad [16].

Thermal Neutralisation of MSW

Thermal neutralisation of MSW is a widespread waste management method that includes a series of technologies. Very efficient high-temperature processes of MSW neutralisation, such as pyrolysis, are expensive, technologically complex and require a significant pre-treatment of the feedstock, and they are hardly scalable when neutralisation of a large amount of waste is required. The most widespread method for thermal neutralisation of MSW is grate incineration.

The World volume of incinerated waste is 170 million tons per year [17]. This widespread use of the technology is explained by a series of advantages: waste incineration allows to reduce the MSW volume by 90%, its weight by 75% [17] and ensure a treatment depth of about 85% [1] as about 70-80% [18] of MSW is combustible.

A valuable product of waste incineration is the energy, and most existing and emerging incinerators generate heat and electricity. But this energy generation technique is one of the most expensive. Expert estimates of unit costs for the construction of incinerators vary in the range from 374 to 500 thousand rubles/kW [19], while for the gas stations (under the programme agreement for the supply of power), they amount to 42 thousand rubles/kW and for solar stations – 110 thousand rubles/kW.

By-products of waste incineration are slag and ash. Slag is a waste of hazard class 4, i.e. low-hazard, as is most of MSW [20], and its share in the initial MSW mix is about 30%. Traditionally, it is used for construction purposes. Ash is about 3% of the initial MSW weight [21], but it is a hazard class 3 waste that requires landfilling after a pre-treatment (for example, by cementation).

The highest public concerns are raised by the potential hazard to human health posed by incinerators' emissions. Exhaust gases produced by incinerators contain a significant amount of highly concentrated pollutants [11], including acute toxic dioxins and furans. But modern incinerators are equipped with multi-stage treatment systems, devices for continuous monitoring of emissions and are highly automated. Combined with after-burning of gases [11], it can be argued that emissions of incinerators could be restrained within the limits of applicable environmental standards, and in case of emergency the incinerator's operation can be stopped automatically. This thesis is confirmed by experience of developed countries: Müllverbrennungsanlage Spittelau incinerator in the centre of Vienna and Amager Bakke incinerator in the centre of Copenhagen. In 2016, in Moscow [22] no violations of the maximum permissible emissions of pollutants by the two Moscow incinerators were registered. Certain scientific papers [10] present the results of a series of studies carried out by research institutes to analyse the samples of incinerators' exhaust gases that showed that "actual maximum concentrations of harmful substances (fly ash, oxides of nitrogen, sulfur and carbon, hydrogen chloride and hydrogen fluoride) in the bottom layer of air is dozens of times lower than the threshold limit values (TLVs)".

Separate MSW Collection

Separate collection means collection of MSW fraction by fraction at the site of MSW accumulation. It is designed to segregate valuable MSW components and use them as part of the economic turnover as recycled materials. The remaining fractions must be neutralised and disposed of using any other method.

Despite several successful pilot projects [23], separate collection of waste in large cities of Russia has not been introduced. In order to deploy separate collection of waste in the Moscow Region it is necessary to make arrangements to liquidate the garbage chute system in blocks of apartments, upgrade and create new waste collection sites, build public awareness, improve the MSW logistics system, etc. Introduction of a system for separate collection of MSW requires formation of a whole new infrastructure and development of the market for recycled materials which will take 10-15 years [24]. The said implementation period of such project is also confirmed by the European experience where it took more than 10 years to deploy and stabilise the separate collection system in Belgium. Back in 1985, Belgium used to practise uncontrolled waste dumping (a situation similar to that in Russia in 2018), and introduced a separate waste collection and large-scale deep package materials treatment only in 1997.

At the same time, separate collection of waste allows to increase the efficiency of MSW neutralisation and disposal as segregated fractions are delivered to recycling, neutralisation and disposal in a more suitable manner. Besides, development and deployment of a separate collection system would have a multiplicative effect on the economy by developing the existing and creating new branches of industry, and markets for recycled materials.

Results and Discussion

The comparative analysis of approaches to disposal and neutralisation of MSW demonstrated the following.

MSW landfilling in its current form may not be deemed a way out of the today's crisis as it exerts a significant negative effect on the public health and the environment, requires alienation of lands and does not guarantee efficient use of valuable components of MSW.

Nevertheless, it is impossible to instantaneously and entirely abandon MSW landfilling as no technology or a set of technologies enable 100% utilisation of MSW. For example, in Japan where the problem of vacant lands is very acute, about 1% of MSW is deposited in landfills, i.e. about 500 thousand tons, annually [25, 26].

In this regard, the following landfilling approach seems to be practicable:

1. Closure and remediation of MSW landfills which most negatively affect the public health and the environment; closure of unauthorised dumps.

2. Improvement of the remaining landfills in strict compliance with the current technical, environmental, sanitary and epidemiological standards. Besides, the opportunity of introducing a technology for production of landfill gas at MSW landfills should be considered. It does not require large investments, guarantees mitigation of the negative effect on the public health and the environment, and improves the economic efficiency of MSW landfills' operation.

3. Allocation of land for new MSW landfills. Any technology requires depositing of a certain percentage of MSW, and the lack of landfill capacities will lead to a spread of unauthorised dumping grounds. Nevertheless, this clause may only be implemented in combination with a smart urban planning policy guaranteeing that the newly created landfill will not adjoin residential areas.

The aerobic composting technology does not allow to overcome the current crisis due to a number of reasons: it ensures recycling of only a small portion of MSW and does not guarantee environmental safety.

The anaerobic digestion technology with concomitant production of biogas requires that the waste contains a large organic fraction, which is not the case with MSW. Nevertheless, this technology is promising in combination with MSW landfilling or a separate collection system that enables segregation of the organic fraction.

The MSW thermal neutralisation technology looks like one of the most promising solutions to the current problems in this industrial branch: it is characterised by higher productivity, it does not require a brand new waste management system and it can ensure environmental safety. The main disadvantage of incinerators is their very high cost, but this factor could be deemed secondary under the crisis conditions. Besides, introduction of the mechanism of agreements for delivery of electrical energy capacities looks reasonable. Support to electrical energy generation along with RES is a common global practice [17].

At the same time, thermal neutralisation of MSW as the sole solution to the current crisis does not seem rational for the following reasons:

1. Development and deployment of a separate MSW collection system will reduce the cost of incinerators' operation due to homogeneity of the materials being incinerated and the lack of potentially hazardous components in them. On the one hand, removal of the organic fraction would increase the efficiency of combustion processes as the calorific value of the organic fraction is 4 MJ/kg, and stable self-supporting combustion of MSW is attained at 7-8 MJ/kg [27]. On the other hand, anaerobic digestion with concomitant production of biogas is a more efficient way to dispose the organic fraction.

2. One of the declared advantages of the Clean Country programme is formation of a new industry and, as a consequence, creation of new jobs, increase of GDP and other positive social and economic effects. At the same time, parallel development of several approaches to MSW disposal and neutralisation would enable formation of several industrial branches which would be of greater social and economic importance. In this context, the

Clean Country project that only implies construction of incinerators and remediation of landfill is somewhat one-sided. Besides, it seems appropriate to provide the governmental support to not only waste incineration technologies, but also to other MSW disposal and neutralisation techniques.
3. Moreover, the waste incineration technology implies that there is non-combustible waste that still requires dumping. Therefore, as was mentioned above, development of the waste incineration technology requires also development of the landfilling industry. Currently, the Clean Country project pays no attention to development of the landfilling technology apart from liquidation and remediation of landfills, and that seems unreasonable.
4. The life of incinerators to be built under the Clean Country programme is 30 years (2021-2051). In view of the foregoing, it is obvious that the MSW disposal and neutralisation requires integrated development.

Development and deployment of an MSW separate collection system requires a lot of time, therefore this approach may not be deemed as a way out of the current crisis. At the same time, separate collection of MSW is very promising as a basis for further sustainable functioning of the MSW management as it increases the efficiency of other techniques for neutralisation and disposal of MSW and development of the recycling industrial branches.

Thus, the best and the quickest solution to the current waste disposal and management crisis that guarantees safety of the public health and the environment, as well as development of a sustainable waste management system is the integrated approach shown in table 1.

Conclusion

The use of targeted efforts such as closure of MSW landfills and widespread waste incineration as proposed by the Clean Country project will enable the fastest crisis recovery due to mitigation of the negative effect both on the public health and the environment (closure of MSW landfills) and rapid neutralisation of a significant portion of MSW (formation of the waste incineration industry). But this approach does not lay the foundation for further efficient and sustainable functioning of the entire waste management system and has a short-term effect only. This approach would enable a way out of crises but there is a risk that it provokes another one.

The only way to solve the problem of municipal solid waste neutralisation and disposal problem, including the problem faced by the Moscow Region, is utilisation of an integrated approach. Such approach would enable development of an efficient and sustainable waste management system. The centrepiece of such system should be separate MSW collection as it increases the efficiency of other techniques for neutralisation and disposal of MSW, enables involvement of MSW into the economic turnover by waste recycling and formation of new industrial branches which, in aggregate, lead to a significant positive effect on the national economy as a whole. Waste incineration should be the key technology for MSW neutralisation due to its very high productivity. It does not seem possible to entirely abandon MSW landfilling, therefore the practice of using this method should be significantly changed. The other technologies for MSW neutralisation and disposal should ensure improvement of the above listed basic technologies.

Table 1. Action plan to solve the current MSW management industry's problems and lay the foundation for its sustainable functioning in the future.

	MSW Landfilling	Anaerobic digestion of MSW with biogas production	Thermal Neutralisation of MSW	Separate MSW Collection
Priority efforts to overcome the MSW neutralisation and disposal industry's crisis	1. Closure and remediation of the existing MSW landfills which most negatively affect the public health and the environment and MSW landfills which exhausted themselves		1. Incineration of the overall mix of MSW with concomitant generation of electric power and use of non-hazardous incineration waste as part of the economic turnover and safe dumping of hazardous incineration waste	
Efforts required to create a sustainable MSW management system	1. Upgrade of the existing MSW landfills subject to all statutory requirements; arrangement of landfill gas production at such landfills	1. Landfill gas product at MSW landfills	1. MSW incineration after pre-sorting	1. Creation, development and deployment of a separate collection system
	2. Allocation of lands for new MSW landfills subject to all statutory requirements in combination with a smart urban planning policy	2. Building separate MSW disposal facilities generating biogas from the organic fraction of MSW		2. Development of the recycling industry

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iWET* WIND ENERGY TECHNOLOGY

Yury M. Bychkov
Professor, Doctor of Technical Sciences (D.Sc.Tech.), Russia
globmera@mail.ru

Professor, Doctor of Technical Sciences Yury M. Bychkov is the author of over 300 scientific works and inventions.

Abstract: The article dwells upon the new capabilities offered by the iWET Wind Energy Technology and the feasibility of their use as part of the energy turnover to solve numerous world energy-related problems. It provides a detailed description of the operating principle and composition of the wind energy unit, a layout and general view pictures. It also gives an analysis of measured electromechanical and thermal properties and tests of iWET powered by a 7.5 kW electric motor.

Key words: wind energy, wind energy unit, iWET technologies, innovations, alternative energy sources, RES, climate, polyenergetic process.

Irrational, irresponsible activities of the modern human have led to a series of man-made threats to life on Earth in all its forms and manifestations. Today, the most dangerous threats and top-priority remedies have been defined and stipulated in the following documents:

1. Programme SEFA (Sustainable Energy for All) adopted by UN in 2011;
2. Paris Climate Agreement entered in force on 4 November 2016;
3. "20/20/20" European Energy Policy Programme.

SEFA is designed for development of a solid foundation for sustainable energy for all by ensuring public access to modern and cheap energy services, doubling the efficiency and doubling the share of renewable energy sources in the world energy balance. This Programme contains certain indicators to be achieved to implement the above-mentioned strategic goals.

Unfortunately, the Paris Climate Agreement has not been "digitised". It merely provides for adoption of national plans to reduce emissions of greenhouse gases into atmosphere and by 2020 elaborate national strategies for transition to "green" technologies and non-carbon economy.

The "20/20/20" European Energy Policy Programme is aimed at reducing by 2020 the level of carbon dioxide emissions into atmosphere by 20% as compared to the level of 1999, increasing by 20% the share of renewable energy sources in the World energy balance and cutting the energy-related costs by 20%. The 20/20/20 Policy Programme is being developed by the "European Roadmap 2050" which implies that the level of greenhouse gas emissions into atmosphere must be reduced by 80-95% by 2050 to radically improve the environmental ecology in Europe.

Thus, the prospect of global climate change and catastrophic consequences for the environment on our planet caused by a growth in its temperature by 1.5-2°C recognised by humankind is the first outcome of the irrational functioning of the World global fuel energy that consumes inconceivable amounts of hydrocarbons and emits into atmosphere the greenhouse gases leading to accumulation of excessive thermal energy in atmosphere above all possible thresholds. If the slow, yet continuous temperature growth reaches the critical limits of about 3.7-4.8°C as per the forecast, then life on Earth will be impossible by 2100.

* Test findings described in this article were initially presented at the Investments in Green Energy conference, EXPO 2017, Republic of Kazakhstan, Astana, 21-23 June 2017, and published as part of its proceedings.

Regrettably, the present generation will be fully accountable to the next generations of humankind for this ecological "crime".

Today, the World energy innovations policy is built on various implementation mechanisms with priority given to the search for alternative energy sources and energy-efficient technologies for their use. In this context, most noteworthy is the World atmosphere with the thermal energy accumulated due to greenhouse gas emissions which is still a not-so-popular source of alternative energy for fuel-free green energy whose inclusion into the useful energy turnover would create real opportunities to not only stop the temperature growth, but also, most crucially, initiate its progressive reduction to normal values of the pre-industrialised time. For example, simple calculations based on reference data show that when the temperature drops by only 0.01°C annually the atmospheric air of Earth weighing 5.3×10^{15} tons could generate about 2,000 kW·h of heat for each inhabitant of our planet with the population of 7,5 billion people as of 2017, if we set an attainable goal of reducing the temperature of our planet by only 1°C during the next 100 years. This is a compelling argument that we could not only avoid the "thermal death" threat to our planet, but also substantially improve its ecological well-being if we provide generally accessible and cheap energy services.

This article describes new opportunities and feasibility of their use as part of the alternative energy turnover as exemplified by iWET (innovation WindEnergyTech) to solve numerous energy-related problems of the World energy, including, above all, those that give rise to understandable concerns of the World community.

iWET is based on a phenomenon that was experimentally observed [1-3] and theoretically justified according to the fundamentals of the contemporary thermodynamics [4].

According to a law of thermodynamics [2], over-unity energy could be generated and accumulated as part of irreversible cyclic processes in systems of any type (open, closed and isolated) as a result of uncompensated transformations subject to steady growth of temperature and pressure in the multiphase gas-liquid flows accelerated to hypersonic speeds.

Theoretical analysis of this phenomenon of over-unity transformations of energy in irreversible cyclic processes could be potentially performed subject under the following conditions:

1. iWET is a multi-energy process involving several near-concurrent processes: hydromechanical and aeromechanical, thermochemical, direct and reverse phase transition and other processes whose thermodynamic state is characterised by existence of standard entropies;
2. the multi-energy process is cyclic and irreversible;
3. the system where the multi-energy process takes place is an open system that exchanges both energy and substance with the external environment.

By relying on the second law of thermodynamics, let us present the change in entropy of the irreversible process as follows [4]:

$$dS = d_e{\cdot}S + d_i{\cdot}S \ ,$$

where $d_e{\cdot}S$ is the change in entropy caused by the substance and energy exchange between the open system and the external environment, and $d_i{\cdot}S$ are the changes in entropy caused by irreversible processes inside the system that are, according to Clausius, could only be positive, as a result of uncompensated transformations:

$$N = S - S_0 - \int \frac{dQ}{T} > 0 \ .$$

Here S and S_0 shall mean entropy of the initial and final states, respectively, Q is the quantity of heat and T is the absolute temperature.

The irreversible process is to be identified with the inequality of Clausius as follows:

$$dS \geq \frac{dQ}{T} \ .$$

The second law of thermodynamics describes the change in entropy inside the system as an aggregate of changes caused by irreversible flows dX_k:

$$\frac{d_i{\bullet}S}{dt} = \Sigma_k F_k \frac{dX_k}{dt} \geq 0 \ ,$$

where F_k is a thermodynamic force expressed as a function of such variables as temperature and consistency.

In this case, a very important role is played by the change in entropy of open systems d_eS that exchange substance and energy with the external environment:

$$d_eS=\frac{dQ}{T}+(d_e{\cdot}S)_B=\frac{dU+p{\cdot}dV}{T}+(d_e{\cdot}S)_B \text{ and } d_iS\geq 0 \ .$$

In this ration, dQ is the quantity of heat exchanged by the system with the external environment over time t; $(d_e{\cdot}S)_B$ is exchange of entropy caused by the flow of substance; p, V and U are pressure, volume and energy, and function (U+p·V) (a function of temperature only) is nothing but enthalpy H, i.e. H=U+p·V.

The most important conclusion based on equation is that condition $d_iS\geq 0$ is always met not only in the entire system, but also in all subsystems included in it, i.e.:

$$(d_i{\cdot}S)_1+(d_i{\cdot}S)_2+...+(d_i{\cdot}S)_n\geq 0 \ ;$$
$$(d_i{\cdot}S)_{1,...,n}=(d_i{\cdot}S)_1+(d_i{\cdot}S)_2+...+(d_i{\cdot}S)_n \ .$$

Relation $(d_i{\cdot}S)_1+(d_i{\cdot}S)_2+...+(d_i{\cdot}S)_n\geq 0$ is fundamental for multi-energy systems: it means that the general system's entropy could grow by additional contribution made by entropy of each subsystem included in such multi-energy system.

What is crucial is that the following condition is always met in each subsystem:

$$(d_i{\cdot}S)_1\geq 0 \ ; \ (d_i{\cdot}S)_2\geq 0 \ ; ... ; \ (d_i{\cdot}S)_n\geq 0 \ .$$

And there are no situations when the following relation could occur:

$$(d_i{\cdot}S)_1>0 \ ; \ (d_i{\cdot}S)_2<0 \ ; ... ; \ (d_i{\cdot}S)_n<0 \ .$$

Whenever a system, either as a whole or as a set of subsystems, exchanges energy and substance with the external environment, it may cause quite complex scenarios arising out of the following apparent relations:

$$[(d_e{\cdot}S)_B\leq 0 \ ; (d_e{\cdot}S)_B\geq 0] \ ; [\frac{dQ}{T}\leq 0; \frac{dQ}{T}\geq 0] \ ; [T_1\leq T_2 \ ; T_1\geq T_2] \ ;$$
$$[(p{\cdot}V)_1 \leq (p{\cdot}V)_2 \ ; (p{\cdot}V)_1 \geq (p{\cdot}V)_2] \ .$$

In any other event there will be either an outflow of heat from the system to the external environment, if $T_1>T_2$, or an inflow of heat from the external environment to the system, if $T_1<T_2$. Similarly, substance will move from the system to the external environment, if $(p{\cdot}V)_1 > (p{\cdot}V)_2$, and vice versa, from the external environment to the system, if $(p{\cdot}V)_1 < (p{\cdot}V)_2$. And, finally, the exchange processes could be multi-directional when there is a concurrent heat outflow from the system to the external environment and movement of substance from the external environment to the system, and, vice versa, when there is an inflow of heat from the external environment to the system and movement of substance from the system to the external environment. Another possible scenario is that there is a concurrent outflow of heat and movement of substance from the system to the external environment or inflow of heat and movement of substance from the external environment to the system.

The fundamental assumption based on the above is that there is no system in nature that could undergo a cycle of energy transformations without any losses and return to its initial state without any change in the external environment's entropy. According to I. Prigogine, the entropy caused by the internal system processes will be "discharged from the system when the heat is transferred to the external environment".

Quantity of heat Q generated by the temperature rise in the medium circulating inside the internal energy process with specific heat capacity at constant pressure C_p, kJ/(kg·K) in the range between temperature T_1 to temperature T_2 is expressed by the formula:

$$Q=G{\cdot}C_p{\cdot}\,(T_2-T_1) \ ,$$

where G is the mass flow rate of the medium, kg/h.

The quantity of heat E generated by entropy to be transferred out of the system will be as follows:

$$E=G{\cdot}S{\cdot}\,(T_2-T_1) \ ,$$

here S is specific entropy expressed as specific heat capacity at constant pressure, kJ/(kg·K)

It is known [5, 6] that when the temperature of water rises above 20°C at the pressure of 100 kPa its specific heat capacity at constant pressure rises from 4.185 to 4.205 kJ/(kg·K), i.e. by 1.0048 times only, but its specific entropy increases from 0.2965 to 1.1926 kJ/(kg·K), i.e. by 4.0223 times. But most impressive are the thermophysical properties of moist air in the temperature range of 5…95°C at the pressure of 99,325 Pa [7]. For example, when the temperature of air with relative humidity of

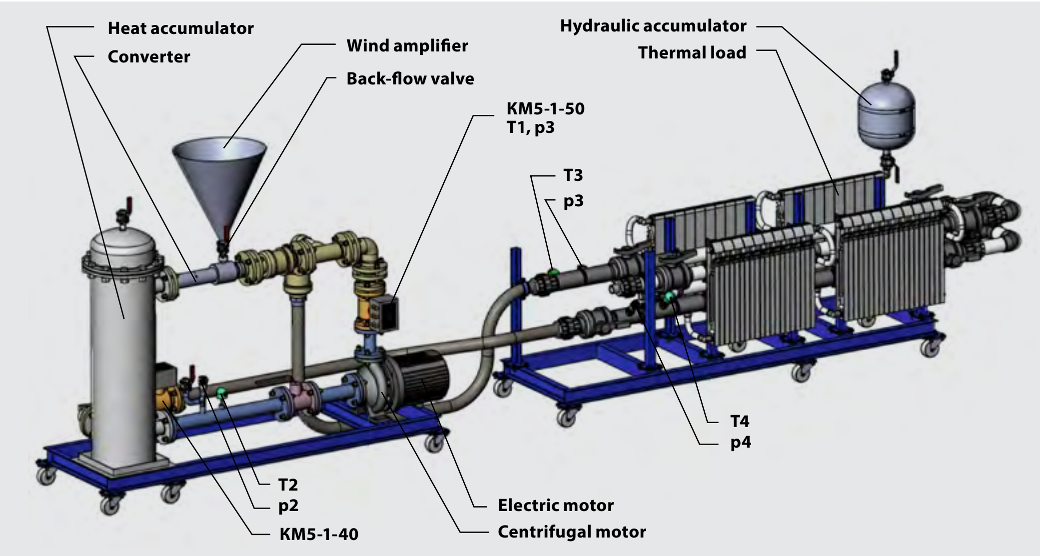

Figure 1. iWET wind unit with thermal load.

0.4 changes, specific heat capacity at constant pressure increases from 1.020 to 1.674 kJ/(kg·K), i.e. by 1.641 times, but specific entropy increases from 0.163 to 3.888 kJ/(kg·K), i.e. by 23.853 times. But when relative humidity of air is 0.8, i.e. 2 times higher, specific heat capacity at constant pressure will change from 1.028 to 2.623 kJ/(kg·K), i.e. by 2.551 times, and specific entropy will increase from 0.214 to 8.634 kJ/(kg·K), i.e. by 40.346 times within the same range of temperatures (20°C to 80°C). However, for example, when the temperature is 90°C, specific entropy of air with relative humidity of 0.8 is greater than specific entropy of water by (8.634:1.1926) = 7.24 times.

Thus, analysis of thermophysical properties of substances forming the internal environment of the multi-energy process allows to determine its most efficient over-unity modes by accumulating the entropy in the internal environment and subsequently using it as part of the useful energy turnover, but not discharging it into the external environment as a "dysfunctional" (according to Helmholtz) part of energy.

Let us have a look at the composition and operating principle of the iWET wind energy unit where the multi-energy thermodynamic process occurs with over-unity energy conversion efficiency ratios. Schematic image of the unit is given in Figure 1, and Figure 2 demonstrates its general view.

The unit is composed of a hydraulic device to which a pressurised water flow is fed by centrifugal pump via pipeline to converter and water jet pump with a special-design moving part. Air flow is fed concurrently to converter via converging duct of wind amplifier with no blade wind turbine. The converter is designed to generate a hypersonic air-water mixture. It is known that the hypersonic flow rate of a two-phase medium depends on its gas content. For example, if the volume concentration of air in water is 0.5, then the local speed of sound inside the two-phase mixture would be 21.8 m/s, and its flow rate will be higher in a hypersonic mode with temperature and pressure surges caused by phase transformations generating excessive energy of water and air required for their over-unity transformations into pneumo-hydro-mechanical, thermal (heat/cold) and electrical energy in various combinations and quantitative ratios depending on the required energy mix.

Wind amplifier is capable of accelerating the air flow within a wide range of values from abnormal low wind speeds of 0.1-03 m/s at the wind amplifier's inlet to excessively high to near-sonic wind speeds at the inlet of converter. Wind acceleration could be derived from the following formula:

$$V_k = \alpha \cdot k_y \cdot V_y \ ,$$

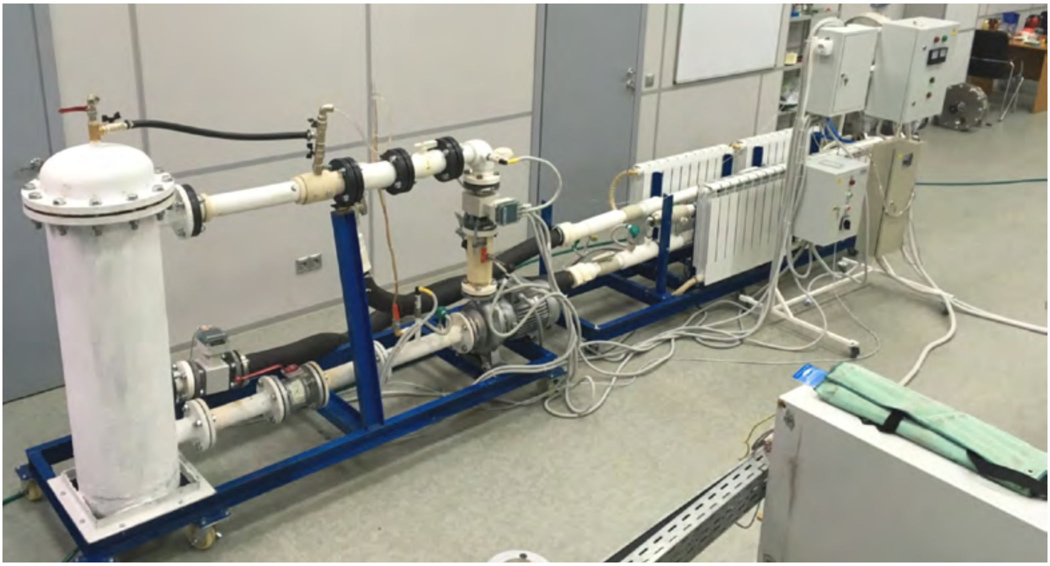

Figure 2. General view of the iWET wind unit with thermal load.

where V_k and V_y are the speeds of the air flow at the inlet sections of the converter and the wind amplifier, respectively; α is the empirical correction for slowdown of the air flow due to aerodynamic loses (α<1); k_y is the wind speed acceleration factor equal to the following relation:

$$k_y = f_y / f_k \quad ,$$

where f_y and f_k are areas of the inlet sections of the wind amplifier and the converter, respectively.

For example, if the area of the converter's inlet section is 0.01 m^2 and k_y=100 and correction α is 0.5, then the wind speed of 0.3 m/s at the inlet section of the wind amplifier will increase at the inlet section of the converter to 15 m/s and will remain optimal for aerodynamic and thermal energy processes.

Another noteworthy feature of the unit is that it is capable of operating in a stand-alone mode irrespective of the wind in poor weather conditions (low temperature, snowfall, etc.). Under such circumstances the air flow from the surrounding air space could be forced-fed by a fan or a compressor, or ejected by the converter's water jet pump. Besides, the compressed air accumulated in the receiving tank could also be used in the closed circulation mode.

After the converter, hypersonic air-water flow is transformed into subsonic air flow and forwarded under pressure via pipe section to receiving tank where it is divided into two hot media – compressed air and water, each under excessive pressure, in the upper and lower parts of the receiving tank, respectively, with an interface between them. Thus, in this case the receiving tank functions as an accumulator of excessive thermal and mechanical energies.

Hot water being a heat carrier is returned via intake line to centrifugal pump, and hot compressed air is accumulated in receiving tank, and generation and accumulation of excessive energy occur continuously which is confirmed by simultaneous growth of temperature and pressure both of water and compressed air.

When the temperature grows to the required level, excessive thermal energy of the hot water is discharged into the closed circuit of heat supply system composed of hot-water radiators via direct feeding line and returned via return line. The water heat supply system could be more sophisticated and include a boiler and an auxiliary hot water supply system for drinking and household purposes. Excessive mechanical energy should be used to recover electrical energy using an additional hydraulic turbine coupled with an electrical generator to be built into the unit.

In this case, compressed air functions as a pneumatic accumulator of excessive mechanical and thermal energy of air. Excessive thermal energy of hot compressed air could be used for hot air heating and various processes (drying, operating medium heating, etc.), and mechanical energy of cooled compressed air could be used for operation of various pneumatic tools and pneumatic motors, including pneumatic motors of electrical generators to produce energy.

The energy-generating system is equipped with measuring unit composed of electromagnetic heat meter KM-5-1 with an inside nominal diameter of 50 mm, thermocouple T1-T2 and pressure couple p1-p2. Similarly, the heat-consuming system is composed of measuring unit with the second electromagnetic heat meter KM-5-1 with an inside nominal diameter of 40 mm, thermocouple T3-T4 and pressure couple p3-p4. Temperature measurement points T1-T2-T3-T4 and pressure measurement points p1-p2-p3-p4 are shown in Figure 1. The electrical energy consumed is measured by multi-function electrical energy meter ПСЧ-4ТМ.05МК.

As described above, iWET is a multi-energy unit where quite complex energy exchange processes occur with a continuous growth of thermodynamic properties (temperature, heat and thermal power), dynamic properties of the circulating water flow (pressure and hydromechanical power), dynamic properties of the air flow (speed, pressure and aeromechanical power), while continuously being mechanically powered by an external centrifugal pump.

According to the results of tests of iWET with an installed motor power of 7.5 W, over 7 hours of operation the unit consumed 35.92 kW·h of electrical energy and generated 172.79 kW·h of thermal energy, including only 44.42 kW·h of thermal load, i.e. about 25%. Consequently, in this case the energy generating system has a threefold store of thermal energy and the electric motor has excessive power which should be recovered.

Thus, 4.8 kW·h of heat were generated per each 1 kW·h of electrical energy consumed by the centrifugal pump's electric motor, and the centrifugal pump's useful mechanical energy (25.79 kW·h) conversion efficiency ratio was 6.7.

Worldwide novelty, relevance and commercial utility of the proposed iWET technology have been ascertained under the European patent validated by Austria, Belgium, Switzerland, Germany, Denmark, England, Italy, Sweden, Slovenia, Turkey and the Russian national patent RU 2551145 as per the PCT International Patent System (application PCT/DE 2012/00041). Convention priority of patents dated 27 April 2011.

In conclusion, it should be noted that the impressive results obtained in the process of heat generation and heat consumption are far from exhausting the hidden reserves of iWET that is capable of increasing the energy efficiency even higher by utilising the excessive mechanical and heating energies accumulated in the air-water medium in the multi-energy process for purposes of electrical energy generation and consumption.

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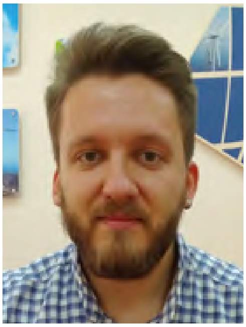
SOLID MUNICIPAL WASTE AS A RENEWABLE ENERGY SOURCE. RUSSIAN AND EUROPEAN APPROACHES



Mikhail S. Skonechnyy

International Sustainable Energy Development Centre under the auspices of UNESCO, Russia

skonechnyy@isedc-u.com

Abstract: This article dwells upon the Russian and European approaches towards classification of solid municipal waste as renewable energy sources. The article analyses the effect of the said approaches on the emerging Russian waste management industry and the renewable energy sector. It contains certain proposals on adjustment of the Russian approach and further improvement of the system for collection, treatment, disposal and neutralisation of waste.

Key words: waste management, renewable energy sources, solid municipal waste.

Introduction

Today, waste management is one of the major social and economic problems in the Russian Federation. 6,220.6 million tons of production and consumption waste were generated in 2017*. There are no official statistics regarding generation of solid municipal waste (SMW), but in 2014 the Ministry of Natural Resources of Russia declared that the volume of SMW was 71 million tons**. Despite the substantial share of SMW in the total mix of waste, disposal and neutralisation of SMW is particularly acute as it is SMW that significantly and adversely affects the environment and public health.

Today, SMW dumping still remains the most widespread method for waste management: the share of all SMW discharged to landfills and unauthorised dumping sites is above 90%***.

At the same time, according to the current EU's SMW management policy, landfill dumping is the least preferred method****. It requires alienation of significant territories, does not unlock the resource potential of waste, damages the environment and deteriorates public health.

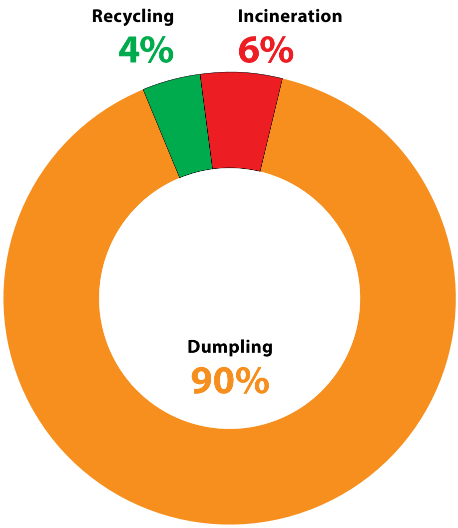


Figure 1. SMW management methods, %.
Source: https://www.greenpeace.org/russia/Global/russia/report/toxics/obsor_othodi_msk.pdf

* http://www.gks.ru/free_doc/new_site/oxrana/tabl/oxr_otxod3.xls

** https://rg.ru/2017/07/03/glava-minprirody-rasskazal-kak-izbavit-stranu-ot-poligonov-dlia-othodov.html

*** Waste in Russia: Garbage or a Valuable Resource. Solid Municipal Waste Management Sector's Development Scenarios. Final Report. Moscow: IFC-World Bank Group, 2013, 92 p.

**** https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32008L0098

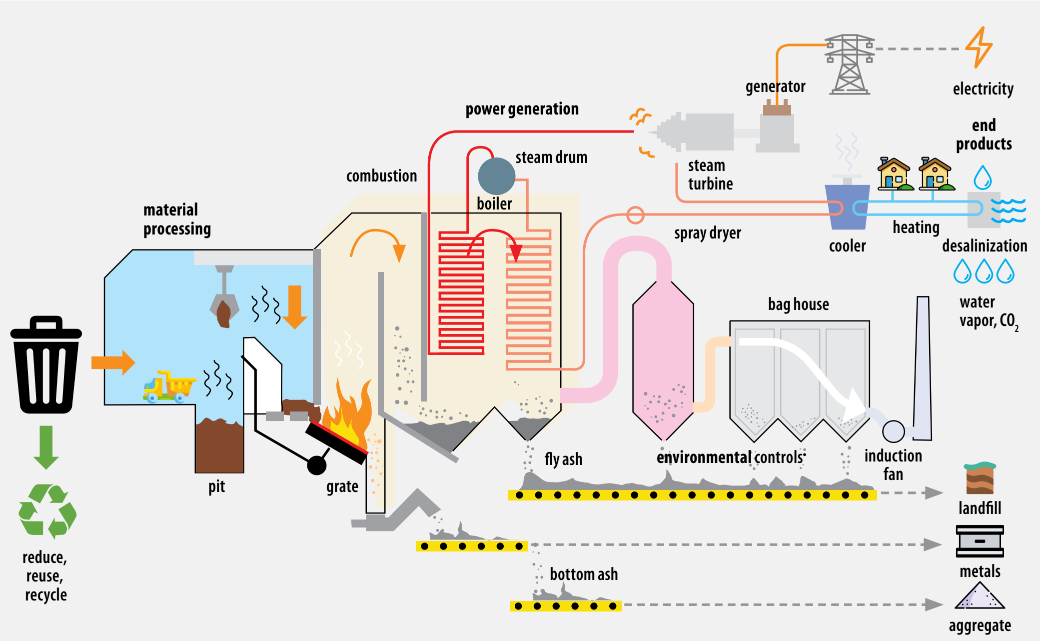


Figure 2. Generalised WTE process chart.

Source: https://serc.carleton.edu/details/images/46447.html

An ambitious reform was launched in 2014 to improve the waste management system, including the Clean Country project for construction and commissioning of waste incineration plants with concomitant generation of electric energy and heat (Waste-to Energy (WTE) plants).

Utilisation of waste incineration as the basic technology of the waste management system provokes discussions not only among the general public, environmental experts and waste treatment specialists, but also among the renewable energy stakeholders. This is due to the fact that WTE plants' operation is seen as energy generation from renewable sources. According to the renewable energy stakeholders*, WTE plants' operation will cause redistribution of financial flows between different fields of activities as a result of utilising the same funding mechanism, i.e. Capacity Delivery Agreements (CDA) to support both the operation of WTE plants and energy generation based on "traditional" renewable energy sources (RES).

At the same time, the SMW management system faces serious challenges today. Volumes of SMW grow annually**, massive landfill dumping does not meet the environmental, sanitary and epidemiological requirements thus creating discontent among the population and leading to closure of landfills, but the new and efficient waste management system has not been implemented yet as commissioning of additional and more efficient WTE plants capable of recycling significant volumes of SMW is scheduled for 2021. The current state of affairs could be called a crisis, and the problem needs to be solved as soon as possible.

In view of the above, the following analysis seem important to be made:

— Russian approach to classification of SMW as RES.

— Effect of the approach on development of the waste management industry and the renewable energy.

* https://events.vedomosti.ru/media/materials/materials_0-3416623171743751/download

** https://iz.ru/723299/valeriia-nodelman/sor-v-izbu

— Comparison of the analysis results with the European approach as it is considered that in the European Union (EU) both the waste management system and the renewable energy are being successfully developed.

Main Points

1. Status of SMW in the Renewable Energy in the Russian Federation

One of the key RES documents in Russia is the Federal Law "On Electric Power Industry" No. 35-FZ dated 26 March 2003. It introduces the conception of "renewable energy sources" and contains a list of them including "production and consumption waste apart from waste generated by the use of hydrocarbons and fuel".

At the same time, the Federal Law "On Production and Consumer Waste" No. 89-FZ dated 24 June 1998 defines SMW as a type of production and consumption waste. Thus, all SMW in Russia are classified as RES. This approach has several important consequences both for the renewable energy and the waste management system.

1.1. Effect of SMW classification as RES on the Renewable Energy

As it follows from classification of SMW as RES, energy generation on the basis of SMW is supported by the government similar to other types of RES-based generation. For example, a series of decrees and instructions adopted by the Russian Government allow to spread the governmental support for renewable energy sources to the facilities generating energy from waste incineration[*]. The main form of support for RES-based energy production to be utilised at WTE plants will be CDA.

Renewable energy stakeholders oppose this funding mechanism. For example, NP Market Council[**] stated that such support would prejudice the use of "traditional" RES due to inter-industry cross-funding. Energy efficiency of WTE plants is low, and their main function is disposal of waste, but not generation of electricity and thermal energy and, consequently, the problems of one industry (waste management) will be solved at the cost of another (renewable energy). Besides, waste incineration will be a competitor to "traditional" RES in terms of accessibility of funding. In this regard, it was proposed to separate energy production based on "traditional" RES and waste-to-energy production[***]. But first of all, it remains unclear what the support mechanism for WTE plants as a separate category will look like, and secondly it is conceivable that construction and operation of WTE plants as energy-generating facilities will be funded via the Ministry of Energy which will still affect the renewable energy development.

1.2. Effect of SMW classification as RES on the Waste Management

SMW classification as RES has a complex effect on the waste management. On the one hand, funding the waste management system at the cost of the renewable energy could be deemed justified if this approach solves the most acute problems in this field. At the same time, this solution creates a direct dependence on the renewable energy sector. For example, RT-Invest, the principal investor to WTE plants, declared that allocation of WTE plants into a separate category "could significantly slow down the development of both the waste management industry and RES in general" (meaning "renewable energy" (author's note)[****]. Considering that the waste management industry is still emerging, this situation could have serious negative consequences.

Classification of unsorted SMW as RES lays the ground for certain legislative inconsistencies. For example, the Federal Law "On Production and Consumer Waste" No. 89-FZ dated 24 June 1998 defined the top-priority governmental waste management policies. According to them, waste incineration is less preferred than waste recycling. Nevertheless, currently SMW is seen more as an energy source, but not as a source of recycled materials. Combined with the priority goal of operating the WTE plants which is, to some degree,

* http://government.ru/docs/26648/

** https://events.vedomosti.ru/media/materials/materials_0-3416623171743751/download

*** http://www.finmarket.ru/main/article/4876800

**** Ibid.

explained by classification of all unsorted SMW as RES, this leads to waste incineration becoming more preferred as compared to recycling of SMW which contradicts the top-priority policies of the government. As a result, apart from inconsistencies between the governmental policies and the methods used, classification of unsorted SMW as RES slows down the development of the waste management sub-sectors, i.e. their separate collection, sorting and recycling. Considering that incineration of all SMW could be financed by the government "green" subsidies, there is no motivation to develop separate waste collection and sorting systems. It should be noted that introduction and widespread use of separate waste collection methods will have a multiplicative effect as it will not only drive the development of a waste recycling system due to availability of the required materials, but will also increase the efficiency of WTE plants due to the lack of fractions with low calorific value in the feedstock.

2. Status of SMW in the Renewable Energy in the EU

The key document governing the renewable energy sector in the European Union is the Directive 2009/28/EC[*] defining the list of renewable energy sources with "biomass" which includes "a biodegradable fraction of industrial and municipal waste". Thus, the EU does not classify the overall mix of unsorted SMW as RES. "Green" is the production based only on the biodegradable fraction of SMW, and this is the only type of production that is eligible for government subsidies under the RES support programmes. This approach to classification of SMW as RES promotes separate waste collection and sorting.

At the same time, this approach is criticised in the EU by some non-governmental organisations[**]. Waste management in the EU is based on the hierarchy of waste treatment methods[***].

Overall, it is similar to the Russian national priorities and defines waste incineration as the least preferred method for disposal and neutralisation of waste as compared to waste recycling, waste prevention, etc. But classification of the biodegradable fraction of SMW as RES could disturb this hierarchy. Apart from the food waste, the biodegradable fraction includes paper, cardboard, textile materials[****], i.e. fractions characterised by high calorific values, yet having a high potential to be used as recycled materials. Therefore, in some cases incineration of the biodegradable fraction of SMW with concomitant production of electrical and thermal energy to be funded by government subsidies could turn out to be more economically advantageous than recycling.

Thus, under certain circumstances the European approach to classification of the biodegradable fraction of SMW as RES does not readily create conditions to engage a wide range of types of waste to recycling.

Certain proposals are made in this regard to entirely remove all waste from the list of RES in the EU[*****]. If implemented, such proposals will give momentum to development of such waste recycling on the one hand and reduction of waste being incinerated on the other hand. It should be noted, though, that the European Union's waste incineration policy is quite conservative and does not provide for entire rejection of waste incineration. For example, an official letter on the role of waste conversion into energy in the close loop economy[******] states, among other things, that waste incineration could be part of such economy without disturbing the hierarchy of waste management methods if the only alternative to incineration is dumping, and recycling of a certain type of waste is impractical, etc.

Discussion

To sum up, the current approach to classification of the entire mix of SMW as RES in the Russian Federation and, as a consequence, approaches towards waste management funding negatively affect both the renewable energy due to an ex-

* https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32009L0028

** https://zerowasteeurope.eu/wp-content/uploads/2016/10/REcasestudy_final8.pdf

*** https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32008L0098

**** http://ec.europa.eu/environment/waste/compost/index.htm

***** https://zerowasteeurope.eu/wp-content/uploads/2016/10/REcasestudy_final8.pdf

****** http://ec.europa.eu/environment/waste/waste-to-energy.pdf cessive financial burden, and the waste management due to the lack of motivation for the latter development. On the one hand, the European approach is more progressive as it lays the foundation for sorting biodegradable waste into a separate fraction, thus promoting separate waste collection and sorting. On the other hand, it has the same disadvantage as the Russian approach since in some cases waste incineration prevails which contradicts the top-priority development goals in this industry both in Russia and the EU.

Considering that today the Russian waste management industry is undergoing modernisation and is still emerging, it is advisable to elaborate a well-defined approach to classification of SMW as RES. There can be two such approaches:

1. Capturing in legislation the priority of waste incineration over other means of waste usage due to the high efficiency of incineration which is especially important under the current crisis conditions. This approach would allow to eliminate the inconsistency between the declared priorities and the methods actually applied. But efficiency of this approach is limited in time as it does not create the conditions for development of other sub-industries, i.e. separate collection, sorting, recycling, etc.

2. Exclusion of unsorted SMW from the list of RES. This approach seems to be more preferable as it enables overall development of economy in the long term. It lays the groundwork for all waste management sub-industries and does not contradict the current governmental policies. But this approach is less efficient when it comes to quickly solving the problem of disposing of a large volume of SMW which is very important under present conditions. For example, according to some estimates, development of a separate collection and recycling of waste system in Russia will take 10-15 years*.

Both approaches have certain pros and cons. The first offers short-term advantages, the second is more efficient in the long term. It could be assumed that the most rational solution would be the use of their combination as follows:

1. The current approach both to classification of the overall mix of SMW as RES and CDA funding should remain in effect in order to quickly overcome the current problems of the waste management in the country. This is because any changes will take time which is inadmissible under conditions of growing harm to the environment and public health as a result of the lack of any efficient waste management industry.

2. At the same time, formation and development of systems for sorting, separate collection and recycling of waste should be supported as in the long run they would increase the efficiency of WTE plants and establish an efficient waste management industry.

3. As soon as the waste management industry functions steadily as might be indicated by a reduced size and number of landfills and illegal dumps, unsorted SMW should be excluded from the list of RES. This solution would give an additional momentum to development of SMW recycling and will conform to the national priorities and global trends.

Conclusion

In Russia, the entire mix of unsorted SMW is classified as RES. As a result, WTE plants are funded under the CDA scheme which negatively affects both the renewable energy due to an excessive financial burden, and the emerging waste management industry due to the lack of motivation for its development. In the EU, RES include only the biodegradable fraction of SMW which promotes waste recycling. At the same time, both the Russian and the European approaches create conditions where waste incineration prevails over other methods for disposal and neutralisation of waste which contradicts the national priorities. In Russia, the sudden change of status of SMW among RES will slow down the development of the waste management industry which is inadmissible under the present crisis conditions. But if the current approach is not changed, no efficient waste management system could be developed in the future. In this regard, it seems that the most rational way is to use the modern practice to quickly solve the SMW disposal and neutralisation problem, and when the most acute problems are solved, unsorted SMW should be excluded from the list of RES, and separate waste collection, sorting and recycling systems should be developed so as to build an efficient waste management industry.

* https://iz.ru/683935/valeriia-nodelman/sergei-donskoi-vvedenie-razdelnogo-sbora-musora-potrebuet-10-15-let

WORLD FUTURE ENERGY SUMMIT

13-16 January 2020
Abu Dhabi, UAE

The annual World Future Energy Summit in Abu Dhabi is the leading global industry event and marketplace for future energy, cleantech and sustainability. Bringing together government and business leaders, 800 specialist exhibitors and 33,500 visitors from 170 countries, it showcases pioneering technologies and ground-breaking thinking in energy and energy efficiency, water, solar, waste, smart cities and more.

For details see:
www.worldfutureenergysummit.com

SOLAIRE EXPO MAROC 2020

25-27 February 2020
Casablanca, Morocco

Solaire Expo Maroc - the leading exhibition in the field of solar energy and energy efficiency in Morocco, Africa and around the Mediterranean.

The exhibition will include conferences, workshops, round tables and the University competition of research and innovation "CURI".

For details see:
www.solaireexpomaroc.com

PV EXPO TOKYO 2020 & WIND EXPO 2020

26-28 February 2020
Tokyo, Japan

PV EXPO is Japan's largest show for the PV industry. The latest technologies, materials, manufacturing technologies, and solar cell/module will be exhibited from across the globe.

WIND EXPO is Japan's largest wind energy show. From components, devices, various services to wind turbines...a wide range of cutting-edge products and technologies will be exhibited.

For details see: www.pvexpo.jp/en-gb.htm, www.windexpo.jp/en-gb.html

RENWEX. RENEWABLE ENERGY AND ELECTRIC VEHICLES

21-23 April 2020
Moscow, Russia

RENWEX. Renewable Energy and Electric Vehicles features an international exhibition and specialized forum. It runs under the slogan “Creating the future of renewable energy together”.

The exhibition and forum will allow to unlock the potential of companies and come up with implementation of the projects which will undoubtedly serve as the foundation for growth of RES technologies.

A series of supporting events will become a platform for discussions with representatives of key Russian ministries, departments and industry associations on the most pressing and relevant issues of the renewable energy sector.

For details see: www.renwex.ru

THE VII GLOBAL ENERGY PRIZE SUMMIT. FINAL REPORT

Energy Center, Politecnico di Torino, Italy. 18 April 2018

The Global Energy Prize Summit – starting from 2012 is an annual meeting of high level energy experts who are the Global Energy Prize laureates, members of the Global Energy Prize International Award Committee, prominent experts working under the auspices of the project as well as renowned scientists, engineers, economists and politicians closely linked with energy development of human society. These annual meetings are organized in various countries of the world by the Global Energy Association for developing international research and projects in the energy field. The Summit is called upon to contribute to world-wide discussions of the most important world energy issues and to the latter clarification.

The VII Global Energy Prize Summit 2018, entitled "Modelisation & simulation of energy mix in the future digital world", has provided a contribution to the scientific debate on the possible future evolution of the global energy on the basis of two main pillar concepts:

— The energy transition towards decarbonized energy systems.

— The digitalization of the energy sector.

1. The energy transition

The energy transition identifies the mid-/long-term evolution of the energy systems towards a scenario characterized by a significant increase in the penetration of renewable energy sources wind, solar, hydro, biomass and geothermal) and a correspondent reduction in the use of fossil fuels.

The need for this transition is driven by climate change phenomena, which include the global temperature rise and the consequent effects on the natural environment, in particular:

— The reduction in the Artic sea-ice extent.

— The increase in the global mean sea level.

As stated by international bodies and institutions, like the Intergovernmental Panel on Climate Change (IPCC), the causes of these changes are related to the increase in anthropogenic greenhouse gases (GHG) emissions with respect to the pre-industrial era. These emissions have led to atmospheric concentrations of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) that have not been reached during the last 800,000 years.

Focusing, in particular, on the CO_2 emissions, it can be noticed that the majority of them (which, at the global level, accounted for 32.3 Gt in 2015, i.e. 57.3% higher than the 1990 level) is due to six countries or regions. In fact, according to the data provided by the International Energy Agency (IEA), China (28%), the United States (15%), the European Union (10%), India (6%), Russia (5%) and Japan (4%) are responsible for 68% of the overall CO_2 emissions.

Long-term agreements and targets

This underlines how, especially for the above countries, effective strategies for mid-/long-term de-carbonization are needed.

Among the most relevant international agreements, is the 2015 Paris Agreement, established in the framework of the COP (Conference of the Parties) 21 of the United Nations Framework Convention on Climate Change (UNFCCC). The main goal of this Agreement is to counteract the impact of climate changes by limiting the increase in the global average temperature well below 2°C above pre-industrial levels, pursuing efforts to keep it below 1.5°C. To reach this target, the parties have been requested to set and implement their own national de-carbonization targets (expressed in the so-called Nationally Determined Contributions, NDCs), within the general aim of the Agreement. According to these goals, for instance, the EU pledged to reduce its GHG emissions by 40% from the 1990 level by 2030, while Russia proposed – for the same year (2030)

– a decrease in its GHG emissions by 25-30% with respect to 1990.

During the summit, the relevance of the climate issues and the need for counteracting them has been emphasized by dr. Marta Bonifert, Member of the Global Energy Prize International Award Committee, Head of the Environment and Sustainability of the Hungarian Business Leaders Forum (HBLF), Hungary, who recalled that on "spaceship earth" there are no passengers, but we are all part of the crew. Bonifert stressed the need of considering that the amount of available resources is limited and consequently it is necessary to use and reuse them in and efficient and rational way. By the end of last Century, the humankind came to a crossroad: either to continue business as usual that might lead very soon to major environmental catastrophes or to re-think our way of life and establish a new way forward.

She reminded the audience that 17 of the 18 hottest years have occurred since 2001. Furthermore, according to the German insurance company Munich RE, natural disasters caused more damage in 2017 than in the previous five years, with many extreme weather events linked to climate change, including severe hurricanes, flooding and fires. Last year, natural disasters caused damages that can be quantified as nearly 330 billion USD, which is almost double the amount recorded in 2016 (175 billion USD) and second only to the year 2011 when 354 billion USD of damage was recorded. According to the UNFCCC:

— In August 2017, Tropical Storm Harvey (which led to torrential rains falling on Texas) caused damages of approximately 85 billion USD.
— Hurricane Irma, which impacted Florida, Hurricane Maria, which impacted the Caribbean, and the huge forest fires in California, have also been particularly severe in terms of economic damage.
— In Asia, the monsoon was unusually intense and caused the death of 2,700 people and a damage of 3.5 billion USD.
— In Europe abnormally low temperatures in April 2017 caused 3.6 billion USD in damage to agriculture, of which only 650 million were covered by insurance.

The mega-trends currently ongoing (like fast urbanization, climate change, shift in global economic power, demographic and social changes and rapid technological innovation) requires visionary long- term actions driven by transformational leaders, governments, scientists, businessmen and by the society as a whole. Regarding this point, two positive examples can be mentioned:
— The previously described Paris Agreement, and
— The UN 2030 Agenda for Sustainable Development, entered into force on January 1, 2016.

The 2030 Agenda, in particular, proposes 17 goals that represent, according to the former United Nations Secretary-General Ban Ki-moon, "a to-do list for people and the planet, and a blueprint for success". Among these goals, the following can be cited as highly relevant:

— Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.
— Ensure access to affordable, reliable, sustainable and modern energy for all.
— Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.
— Make cities and human settlements inclusive, safe, resilient and sustainable.
— Ensure sustainable consumption and production patterns.
— Take urgent action to combat climate change and its impact.
— Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development.

Both the Paris Agreement and the UN 2030 Agenda show that humankind (stakeholders, state and non-state actors, etc.) could and should work together for building a better world for generations to come and leave no one behind. Trust, partnership and cooperation are three key pillars required to face effectively the climate and energy issues in the sense of a strong global transition.

The technological options for the energy transition

The energy transition and the achievement of these environmental targets require significant structural changes in the whole energy chain, from production to the final uses of energy as well as its transmission and distribution.

For this reason several possible strategies, pathways and scenarios are currently proposed and investigated worldwide by scientific research institutions, in order to asses from a qualitative and quantitative point of view their technical feasibility and their pros and cons.

During the Summit, some of these possible perspectives and options have been described and critically discussed by the participants.

In particular, prof. Francesco Profumo, the Global Energy Prize expert, Chairman of Compagnia di San Paolo, Italy; highlighted the possible crucial role that electricity could play, according to the "electricity triangle", which couples electricity production from renewables, transmission and distribution of electricity through ad hoc connection systems and electrification of the final users of energy (buildings sector, industrial production, and mobility by means of electric vehicles penetration).

For doing this, two possible extreme paradigms can be followed: micro (smart) grids and large (global) interconnections:
— Micro grids allow the exploitation of locally available resources.
— Global interconnections aim to link large world production zones (like Artic for wind and deserts for solar) with consumption areas through Ultra High Voltage Direct Current (UHVDC) grids for long distance (2000-5000 km) connections.

Electrification coupled to energy efficiency could represent an effective option for reaching the global de-carbonization goals, even if technical, geopolitical, market and regulatory issues have to be carefully considered under a holistic perspective. The energy transition can be considered a global challenge, to be addressed through innovation and cooperation, which can be assumed as keywords also for the Summit.

The role of electrification has been explored also by dr. Klaus Riedle, the 2005 Global Energy Prize laureate, honorary Professor at the University of Erlangen-Nuremberg institute of engineering thermodynamics, Germany. In particular, he investigated one of possible key element for the achievement of de-carbonization goals, i.e. the so-called "sector coupling" which makes electricity from renewables the backbone of all energy related services.

As for Prof. Profumo, in this approach the key commodity of the energy mix is electricity generated from renewable sources. Electricity, supported by storage systems, can allow the following options:
— "Power-to-heat": electricity is converted into heat by means of heat pumps, thus heating houses directly or through heat storage systems.
— "Power-to-gas": electricity can be converted into hydrogen or methane, which can be stored and/or fed into the gas pipelines and ultimately used for producing power when renewable generation is not available. A part of this gas could also be used for heating houses when requested.
— "Power-to-chemicals": electricity is used for producing feedstock for chemical production, like ammonia, methane or hydrogen.

— "Power-to-liquid": electricity is used for producing liquid transportation fuels, like methanol.
— "E-mobility": electricity is used for charging batteries of electrical vehicles.

Even if theoretically simple, this process to be fully implemented requires enormous efforts, as all the existing infrastructures have to be replaced by new (and probably more expensive) ones.

Riedle analyzed the effects of a possible future complete "sector-coupling" with reference to Germany. Several studies – base on different models – are available investigating the "sector coupling" in the long-term (up to 2050). The comparison among them, however, shows a huge variety in the obtained results: for instance, the expected gross electricity demand in 2050 ranges between 450 TWh and 1100 TWh (and in one model even rising to 3000 TWh); moreover, the installed capacity of wind and solar can rise from the current value of 100 GW to 160-540 GW. This demonstrates that the "sector coupling" approach is not fully settled yet. Form the cost perspective it is difficult to provide reliable numbers, but some analyses speak about 1.5-2.5 trillion euros, i.e. a really high cost, comparable to the cost of a country's reconstruction after a war.

On the basis of these findings, Riedle suggested the need for testing the "sector coupling" at a demonstration scale (in terms of development of the requested components and subsystems and assessment of their interaction, bringing them to maturity and competitive costs), in order to understand if this holistic solution could really represent a feasible long-term de-carbonization strategy to be implemented.

Even if a strong enhancement in renewables penetration is a mandatory requirement for the implementation of energy transitions, it has to be highlighted that at least in the near future, the global energy mix will be characterised by a strong dominance of the fossil fuels, as put into evidence by Professor of Hydrogeology and Engineering geology at Polytechnic University of Turin Stefano Lo Russo, Italy.

Lo Russo, in fact, recalled that currently about 40% of the world energy consumption is supplied by oil and about 25% by both natural gas and coal. Furthermore, future outlooks forecast an increase in the energy demand, mainly driven by the expected simultaneous growth in population and in urbanisation.

In 2050, more than 66% of the human population will live in cities. Urbanisation usually supports an increase in people's quality of life (which is positive), but also an increase in their energy consumption. A key role in this possible scenario will be played by European and Asian countries. Eurasia includes large energy consumers but also producers. For this reason, a strong integration between Europe and Asia is needed to face future energy challenges. Projects like those related to the Chinese Belt and Road Initiative (or "new silk road") – in particular, to the economic corridor linking Eastern China and Europe – and the Artic Northern Sea route could represent a significant step forward in this sense. As for prof. Profumo, also for prof. Lo Russo, however, even under a different perspective, the sharing of knowledge and the technological and scientific cooperation are crucial elements for ensuring a full efficacy in defining suitable strategies related to the evolution of energy demand and production patterns.

Like Lo Russo, dr. Rodney Allam, the 2012 Global Energy Prize laureate, Member of the Intergovernmental Panel on Climate Change (IPCC), awarded with the Nobel Peace Prize in 2007, Chairman of the Global Energy Prize International Award Committee, Great Britain, emphasized that future increase in population and urbanization will lead to a relevant increase in energy demand, which – in turn – will still rely on fossil fuels. In fact, renewable sources, hydro and nuclear account together for about 15% of the global final energy consumption, and their forecasted contribution seems not adequate for counteracting the continuously increasing emissions of CO_2, whose atmospheric concentration is presently higher than 400 ppm. For this reason, an effective de-carbonization strategy cannot avoid the introduction of technologies able to prevent the CO_2 from entering the atmosphere.

Current technological options for cleaning the power generation from fossil fuels through CO_2 sequestration and storage (oxy-fuel combustion, pre-combustion capture by means of gasification, post-combustion capture via flue gas scrubbing) are characterized by a high economic impact, increasing the electricity cost by as much as 50-70%.

For this reason, Allam developed a novel power cycle (called "Allam Cycle"), which is based on the capture and use of CO_2 as working fluid. A demonstration plant is presently in the start-up phase in Texas. In this innovative cycle, the fuel (natural gas, gasified coal, or another carbonaceous fuel) is burned in a combustor using pure oxygen instead of air. The mixture of CO_2 (which represent 97.25% in mass of the total) and water (2.75%) is used in a turbine and the exhaust gas cooled in a heat exchanger. The steam is then condensed and separated from the CO_2, which – in turn – is compressed. 3.25% of this CO_2 is captured (in order to balance the amount continuously added by the combustion process) and it is ready for transmission via pipeline. The remaining 94% of CO_2 is reheated in the heat exchanger and recycled as working fluid. This cycle allows for capture of more than 97% of carbon produced and it is characterized by a high efficiency (up to 59%) and by a power generation cost that is the same as that of conventional gas turbine combined cycle systems and about 20% lower than that of of coal fired systems. This is due to the fact that this cycle require only one turbine and relatively minor other components (because it operates at high pressures and, consequently, at high power density).

Furthermore, Allam proposed another strategic option for decarbonizing one of the most critical sectors of the energy system, i.e. the transport sector. In the U.S., the contribution of the transport sector to CO_2 emissions is larger than the contribution of the power sector. A possible way for solving this issue is investing in hydrogen technologies. Hydrogen can serve as an option for feeding fuel cells vehicles, which are commercially available from Japanese car manufacturers and will be soon available from Korean and Chinese manufacturers. Hydrogen can be produced in high-pressure units (at 90 bar), where natural gas and steam combined can operate with 100% CO_2 capture, and it can also be used in gas turbines for power production. The production of this commodity can be integrated with a large-scale Allam cycle: such a plant could be thus able to ensure power generation with 100% CO_2 capture and hydrogen production for other purposes, like transportation.

Dr. Tom Blees, the Global Energy Prize International Award Committee member, President of the Science Council for Global Initiatives (SCGI), USA, also underlined the limits of carbon sequestration technologies as possible strategy for implementing an effective de-carbonization. He emphasized, in particular, that – even if the technical and economic issues related to large-scale sequestration could be solved – the focus should be not only on the use of fossil fuels, but especially on their production. In fact, mining and transportation of fossil fuels can have relevant climatic impacts:

- Coal mines release an amount of GHG that can be even higher than the amount of GHG produced by the coal combustion, and
- Methane (i.e. natural gas) has higher greenhouse effect than CO_2, and thus methane leakages during mining and transport phases constitute an important issue.

If fossil fuels are excluded, power generation should be based on four options: solar, wind, hydroelectric and nuclear. However, the actual potential of hydro is significantly limited by the geographical constraints. Referring to wind and solar, it should be highlighted that, in order to bring every citizen in the world to the current per capita energy use of Germany, an area corresponding to the whole South America should be covered by solar panels and wind turbines.

Germany is one of the countries that most considerably devoted efforts for supporting the penetration of renewable sources, through the so-called "Energiewende". Despite this, during winter, even if Germany had 100 times as many solar panels as they currently do, it would still not able to cover its electricity demand. In the same way, the non-dispatchability of wind does not allow for complete reliance on this source. The estimated high costs of the Energiewende transition, coupled with the fact that Germany is opening coal-fired power plants burning lignite, put into evidence that the choice of shutting down nuclear plants seems not to be the best option.

According to Blees, in fact, nuclear power, which is characterized by a low carbon footprint, can represent a crucial solution for de-carbonization strategies. If wind and solar require a surface area equal to the whole South America to power a world where every citizen has very good access to energy, a surface area approximately corresponding to just the city of Buenos Aires is sufficient if nuclear power reactors were used instead. Among the future options of nuclear plants, he highlighted the role that low-pressure thorium molten salt reactors could play. According to a project that is currently ongoing, these units can be located on ships (that could be built – for instance – by Russia, China, Saudi Arabia, India or Korea) and moved where it is necessary to deliver electricity. They can thus be a relevant possibility especially for developing countries that have no money for building their own nuclear plants: in this way, they could access in a more easy way to electricity, enhancing the quality of life of their citizens and improving the productive sector of the country.

Dr. Rae Kwon Chung, the Global Energy Prize International Award Committee Chairman, Adviser to the Chair of UN Secretary-General's High-level Expert and Leaders Panel (HELP) on water and disasters, South Korea, shifted attention from the technical dimension of the energy transition to the policy dimension of the problem. For example, the "Energy Technology Perspective 2017" published by the IEA states that, in order to reach the Paris Agreement targets, strong policy actions have to be set. Those policies are needed, for instance, for doubling the rate of global energy efficiency improvement by 2030.

In general, however, the discussion about decarbonization policies is characterized by a negative message spread by all the media regarding the economic sustainability of climate policies. In fact, the main question is related to the coherence between economic growth and emissions reduction and a common opinion is that investments in climate policies are too expensive, with an extremely long payback time, and may undermine economic growth.

Chung underlined instead that environmental policies can represent not a limitation but a drive force for economic growth. To reach this goal, thus coupling economic development and environmental targets, it is necessary to deepen the discussion about policies effectively able to support the energy transition and to clearly identify which kind of policies should be considered most crucial. These policies should be capable to turn the zero-sum game among the three "E" (energy, economy and environment) nexus into a win-win positive cycle among the same three "E". An example is the current price structure of the energy systems, which favours fossil fuel, which are four times more subsidized than renewables. In this sense, remove of such fossil energy subsidies and implementation of a carbon tax can be a valuable policy option for supporting a transition in the energy mix. According to several studies – that are not under the attention of media –the introduction of such a carbon tax can actually drive economic growth, new investment opportunities, job creation and the energy transition. This is contrary to the common assumption that a carbon tax would hurt economic growth.

2. The digitalization of energy systems

The second main topic discussed during the Summit was the digitalization of energy systems. Digitalization is a broad topic that encompasses a number of technologies and their applications. Generally, however, digitalization relates to the collection and translation of data into an analyzable format, analysis of the data to gain actionable insights for both situational awareness and business foresight and, finally, the transformation of the insights gained into business value. In essence then, digitalization is the convergence of the digital and physical worlds to enable entirely new business capabilities and value propositions.

Digitalization has grown rapidly in recent years because of enhanced access to data, improved analytical capabilities and advances in computing and communications hardware. According to IBM, more than 90% of the world's data has been created since 2015 and the world's internet traffic has already surpassed 1 zettabyte annually, which is equivalent in size to about 250 billion high-definition movies. On the hardware side, microprocessors for desktop computers are now available that are computationally as powerful as supercomputers built just two decades ago. In analytics, machine learning algorithms have rapidly evolved to provide holistic solutions to problems that cannot be solved through reductionist models.

The specific set of technologies that fall under the framework of digitalization can be classified in a number of ways. However, the following list is nearly, if not fully, inclusive of the key technologies:
— Internet-of-Things (IoT).
— Big data analytics.
— Robotics and autonomous systems.
— Augmented and virtual reality.
— Blockchain.
— Additive manufacturing (also called 3D printing).
— Artificial intelligence (A.I.).

Among the listed digital technologies, Artificial Intelligence, otherwise referred to as just A.I., has rapidly become perhaps the most important development. Andrew Ng, one of the most influential minds in A.I., has stated that "A.I. is the new electricity" due to the unprecedented potential that it has to dramatically change society. Fundamentally, A.I. is the provision of computer-based systems with human-like ability to reason, plan, solve problems, think abstractly, comprehend complex ideas, learn quickly and learn from experience. Practically speaking, A.I. is often associated with deep learning, which is a class of machine learning techniques that utilize huge amounts of data to train multi-layered neural networks to do things like identify faces and recognize spoken words. Although a number of experts argue that deep learning and other state-of-the-art analytical techniques may themselves never

produce truly human-like cognitive abilities, such methods have nonetheless already begun to demonstrate the incredible potential for A.I. to provide economic value in the public and the private sectors. In the race to capitalize on this potential, multiple countries have already published A.I. strategies and more than USD 15.2 billion was invested in A.I. startups globally in 2017.

The prominence of A.I. and other forms of digitalization in the energy sector is apparent from the growing importance placed on it by stakeholders in industry and government. For instance, the 2017 World Energy Issues Monitor published by the World Energy Council ranks digitalization as one of the most impactful topics for the future of the energy sector.

The specific impacts that digitalization is having and will continue to have on the energy industry are improved effectiveness, efficiency and safety. We may consider, for example, the following specific impacts that digitalization is having or will have on end-use energy sectors:

— **Buildings**
- o Heating and cooling: smart thermostats and sensors are being used to optimize the supply of heating and cooling through demand reduction and demand shifting.
- o Lighting: sensors and software integrated into lighting systems are providing occupancy detection to reduce the use of lighting when not needed while also providing new services to enhance the value of real estate and building occupant well-being.

— **Transportation**
- o Personal vehicles: shared, autonomous and electric vehicles are expected to substantially reduce transportation fuel demand while improving the travel experience of consumers.
- o Commercial vehicles: drone delivery services and 3D printing are expected to reduce the need for both long-haul and short-haul shipping services, thus reducing overall energy demand from these supply-chain services.

— **Industry**
- o Energy efficient manufacturing: the industrial internet of things (IIoT) and artificial intelligence are enabling predictive maintenance for improved efficiency of manufacturing plant machinery and operations.
- o Product development and production: 3D printing is allowing for the rapid design of products that require reduced energy consumption during manufacturing and that ultimately are more energy efficient in their final applications.

Digitalization is additionally at the core of an electricity system transformation in which renewables play a leading role. In order to effectively de-carbonize our global energy system, by 2050 the share of electricity in final energy consumption will need to more than double and the share of renewables in electricity will need to more than triple from today's levels. Much of this new renewable electricity production capacity will come from intermittent solar and wind energy technologies, which in many cases will be distributed rather than centralized. Digitalization will be essential to providing the system flexibility needed to accommodate high shares of intermittent and distributed renewable energy. Coordinated flexibility will come from supply side measures, demand side measures, energy storage and electricity grid infrastructure.

In sum, the role of digital and, more generally, ICT technologies in the energy sector is currently growing and is expected to substantially increase during coming decades. For this reason, analysis of the benefits and challenges of digitalization should be embedded in the planning and design phase of new energy infrastructure.

The urban dimension of digitalization

Regarding these aspects, dr. Steven Griffiths, the Global Energy Prize International Award Committee member, Senior Vice President for Research and Development of the Khalifa University of Science and Technology (KUST), United Arab Emirates, showed that urbanization and digitalization are mega trends that, when considered collectively, can support the need for sustainable and smart cities.

As Lo Russo, also Griffiths underlined the expected high relevance of urbanisation (more than 65% by 2050), which highlights the importance of smart cities in future energy systems. Cities will become "smart" thanks to the adoption of digital approaches and technologies, like internet-of-things, big data analytics, artificial intelligence, robotics and drones, blockchain, augmented reality, virtual reality and 3D printing.

In particular, through the internet-of-things, this approach is able to connect the physical world (people, machines, materials, buildings, environment, etc.) to the world of information, represented by big data analytics and the related cybernetic loops, which allow for analysis of data from the real world to gain situational awareness and foresight. The internet-of-things can consequently transform information into knowledge.

Artificial intelligence, in particular, can find several applications along the energy chain, helping – for instance – the predictive maintenance in oil and gas production plants (production section) and allowing the development of autonomous driving vehicles (end-use section).

Digitalization in cities could make urban systems more affordable, environmentally friendly and liveable, in particular impacting on building and transportation systems, by increasing their efficiency. Future cities can thus be seen as a series of overlapping layers: four physical (from the bottom to the top: infrastructure, public realm, mobility and buildings) and one digital.

According to the IEA, a result of digitalization in the buildings sector will be a cumulative reduction in energy consumption equal to approximately 65 PWh by 2040, which is about twice the energy consumed by the entire global buildings sector in 2017. Moreover, digitalization could support energy demand response measures, like the shifting of heating loads, cooling loads and use of electrical appliances and optimal charging strategies for electric vehicles. By 2040, 20% of electricity demand could be met by demand response, which will allow the maximisation of the value of intermittent renewable sources (such as wind and solar) and the minimisation of the need for generation capacity dedicated to load balancing: this could reduce solar and wind curtailment from 7% to 1.6% in the EU by 2040.

Referring to the transport sector, digitalization is likely to result in a significant reduction in the demand for refined oil products, due to the deployment of high numbers of autonomous, shared and electric vehicles. The urban environment is, in fact, ideal for such a transportation system and, according to Bloomberg New Energy Finance, the penetration of these vehicles could lead to a decrease in the global oil demand by more than 5 million barrels per day by 2035.

In general, Griffiths emphasised that digitalization will probably have a deep impact on the future (but also on the current) global energy system. A large part of world urban population will certainly take advantages from it, while some industries (like the as oil and gas ones) will need to modify their business models in order to accommodate the profound effects that digitalization will have across sectors.

The impact of digitalization in the electricity systems

Dr. Sauro Pasini, the Global Energy Prize expert, President of the International Flame Research Foundation, Italy, focused his presentation on the evolution of the electricity systems and on the impact of digitalization on the electricity sector. The three main pillars of this evolution are represented by:

— **Investment in renewables:**

Presently they are starting to be competitive in certain areas of the world with respect to conventional sources; in 2016 they corresponded to 62% of the newly installed capacity worldwide and to 90% in Europe, and are expected to become more than 70% of the newly installed capacity in the period 2017-2040.

— **Decentralization:**

Renewable energy is very often decentralised. For instance, during the last 10 years Italy has invested in 20 GW of renewable energy. These 20 GW correspond to about 730,000 power plants, which means that the average size of each plant is around 27 kW, i.e. very small.

— **Electrical mobility:**

Currently its penetration it is quite low, but by 2040 the annual sales of electric cars are expected to exceed the sales ICE vehicles, Annual sales of electric vehicles may reach more than 50% of all new light-duty vehicle sales by 2040, resulting in approximately 33% of the total global light-duty vehicle fleet being electric.

According to this possible evolution, the management of the electrical networks will become more and more complex and crucial: intermittency of generation from renewables, decentralised generation, the presence of prosumers, automation and control of connected systems are some of the most relevant aspects that have to be considered in this new management perspective.

In this sense, a strategic role could be played by digitalization. Data generation through ad hoc sensor systems, data acquisition by means of communication protocols and data processing through big data analytics approaches, coupled with the availability of artificial intelligence for machine learning are key opportunities created by digitalization.

Dr. Pasini presented four examples showing how digitalization has been already developed and is being used:

— **Home energy management:**

It is the combination of an energy management system, that manages the sharing of electricity among the various home devices and the integration with the self-electricity production and storage (solar photovoltaic, batteries, vehicle-to-grid system), and of a data management system, which optimises the energy consumption.

— **Demand response:**

It is a temporary change in the electricity consumption in response to market or reliability signals, in order to shift electricity use across the daily hours in order to solve the issue of balancing generation and demand arising from the intermittency of renewables like solar and wind.

— **Virtual power plant:**

It is a control centre that integrates several types of distributed power sources to give a reliable overall power source (dispatchable and non-dispatchable distributed generation, controlled by a central authority).

— **DER management system:**

It allows to integrate more distributed solar, energy storage, demand response and other energy resources on the grid, in order to improve its operation.

In this way, the energy system could evolve according the so-called "internet of energy", a sort of electricity network in which generation, distribution and demand are optimised at an entire system level. In this vision, everything is connected, and – even if electricity is the main commodity in this interconnected and digitalised world – also other commodities like natural gas and heat can enter into this system, making it even more complex but more useful as well.

3. Energy transition and digitalization: advantages and possible issues

Uncertainties and critical aspects

In his speech, dr. Dominique Fache, the Global Energy Prize expert, Chairman of the Board of Directors of RTF*, France, synthesised some of the crucial aspects that emerged during the different interventions in the Summit.

The first one is the radical transformation in the energy system that is already ongoing and that will increase in the future. This transformation leads to several uncertainties regarding the long-term investments in the energy sector. For instance, Germany decided the nuclear phase-

* Russian technological fund.

out. In France (where about 70% of electricity is produced through nuclear power stations), the government is thinking about a possible closure of some nuclear plants. Investments in traditional fossil sources are strongly affected by geopolitics over long time horizons. Consequently, energy companies have to face these dilemmas and will have to change their business models to survive. For example, more than a year ago Total bought Saft, a lithium batteries manufacturer that does not belong to the oil business, while Elon Musk, CEO of Tesla, is building a giant battery plant.

In fact, technological innovation can create new business and job opportunities, leading to the rise of new companies but also to the disappearance or modification of others.

Regarding the strategies for counteracting climate change issues, according to Fache a price on CO_2 emissions around 100 USD/ton should be put in order to make international targets like the Paris Agreement really effective.

Finally, Fache underlined that digitalization – besides the positive aspects put into evidence by the other speakers – it is characterised by some criticalities that have to be carefully taken into consideration when forecasting and planning energy system.

For instance, a single transaction bitcoin block creation transaction results in energy consumption corresponding to the daily consumption of an average home. This could represent a huge problem for future energy systems (and, consequently, for the related emissions) if this digital cryptocurrency market should increase significantly in its current form.

Referring instead to the digitalization of the energy systems, it could open the door to new threats, in particular terrorist threats. Smart technologies and digital power engineering can thus make energy systems more open to cyberattacks, which can especially affect the electrical grid, leading to possible sudden power outages and wide scale impacts.

Coupling and implementing de-carbonization strategies and energy digitalization: a challenge for a cooperative world

The Global Energy Prize Summit 2018 allowed investigation of the main benefits but also the most relevant issues that can arise from the expected future transition of the global energy mix. Two key aspects, energy transition towards de-carbonization and digitalization of energy systems, have been analysed according to their different technological dimensions, exploring the possible long-term alternative scenarios. In consideration of these scenarios the role that electrification of final energy uses can play, and the technical, security and political issues that this evolution may encounter must be highlighted.

Some of the crucial aspects of the energy transition that must be taken into account through high level scientific researches and debates include:

— significant penetration of intermittent renewables in the power sector coupled with that result in the need for a radically different structure of power networks, such aslarge global interconnections or small-scale decentralised systems,
— the relevance that fossil fuels could still have, at least in the near future,
— the effectiveness of the carbon capture and utilization options,
— the role of nuclear in future power systems,
— the need for ad hoc policies (like carbon taxation) able to support the transition phase.

Furthermore, the digitalization of energy is strongly related to the energy transition and complementary to it. In fact, electricity-based systems will be increasingly coupled with digital systems for their management and optimisation.

Digitalization could thus ensure an effective support to the energy transition, allowing the control of complex systems and – at the same time – the enhancement in overall system efficiency. From the opposite perspective, digitalization could represent an issue with respect to new kind of threats, like the "energy terrorism".

In general, however, the most important element that emerged from the debate is the need for a wide- scale cooperation among all the involved actors: scientists, research bodies and institutions, energy companies and decision makers.

Only an actual sharing of knowledge and best practices and the identification of commons standards from both the technical and regulatory point of view will lead to the development and implementation of a long-term strategic energy planning that is beneficial at a global level and relevant to all the of the key perspectives: environmental, technological and economic.

12th SESSION OF THE UNESCO/ISEDC CO-SPONSORED FELLOWSHIPS PROGRAMME

The 12th session of the UNESCO/ISEDC Co-Sponsored Fellowships Programme for specialists from developing countries and countries in transition was held from October 1 to 26, 2018 in Moscow at the premises of the International Sustainable Energy Development Centre (ISEDC) (hereinafter referred to as the Fellowships Programme).

19 young specialists from 17 countries of Africa, Asia and the Pacific, Latin America and the Caribbean, Europe and the Arab States took part in the 12th session of the Fellowships Programme.

A wide range of issues related to the sustainable energy development was analysed during the training course of the Fellowships Programme, including energy saving and energy efficiency in municipal and industrial buildings, ensuring effective management of energy resources consumption, use of renewable energy sources, development of innovative energy technologies, as well as issues related to international cooperation in the energy field.

This session was held with the support of the academic teaching staff of the leading higher education institutions: Lomonosov Moscow State University, Peoples› Friendship University of Russia, Gubkin Russian State University of Oil and Gas, and others, which have a rich experience of conducting scientific and design works in the fields of energy, research, utilisation and conservation of natural resources, environmental and energy management as well as experts of the UNDP-GEF* Project «Building Energy Efficiency in the North-West of Russia».

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* UNDP - United Nations Development Programme, GEF - Global Environmental Facility. - Editor's note.

According to past practice, the four-week course was conventionally divided into two modules:

- Module 1 – theoretical and practical classes at the premises of ISEDC;
- Module 2 – participation in thematic conferences and meetings and visits to exhibitions, laboratories, educational institutions and centres.

At the end of the Fellowships Programme, its participants presented their examination papers regarding the current state of affairs and the prospects for the energy development in their countries, and were awarded with the graduation certificates.

Vitaly Bekker and Andrey Dodonov, experts of the UNDP-GEF Project "Building Energy Efficiency in the North-West of Russia", gave lectures and held practical sessions dedicated to municipal and industrial energy management.

October 22, 2018. Visit to the scientific laboratories of the Moscow State University of Civil Engineering (MSUCE).

PRACTICAL EXPERIENCE IN MANAGING THE NATURAL RISKS FOR COMPANIES OF WEATHER-DEPENDENT INDUSTRIES

On November 9, 2018, the International Sustainable Energy Development Centre under the auspices of UNESCO held a workshop called «Practical Solutions for Natural Risk Management for Companies of the Weather-Dependent Industries».

The spokespersons demonstrated the opportunities for the use of the RISK-WEATHER Information Analysis System (IAS), the modern solutions for process and expert support of business in terms of insurance, projects risk management specific to the companies of the weather-dependent industries, analysed case studies and made proposals regarding the taxation and budgetary optimisation of the RISK-WEATHER IAS.

Today, the problems related to natural risks are still ones of the most complex, expensive and difficult issues to be regulated and interpreted. Therefore, they are of special interest to researchers, experts and regulatory authorities.

The RISK-WEATHER IAS is based on the data provided by Roshydromet (Federal Service for Hydrometeorology and Environmental Monitoring) and has access to all archived data for each selected territory, all types of observations in agrometeorology, hydrometeorology and hydrology in an easy-to-use format: tables or graphics. The developers made the system capable of receiving, adapting, processing and distributing various messages from weather stations, including non-formatted messages. The system is designed for super-fast (within 15 minutes) online collection and updating of information following receipt of data transmitted by weather stations with a 3 hours update cycle.

In order to ensure practical solution of the problems related to the management of natural risks, the IAS offers to its users a comprehensive set of actual and predicted data on the state of elements of the environment, and includes technologies allowing to obtain such data on a 24-7-365* basis and a service which provides documentation for review and online help for examination purposes.

Each industry and company is characterised by its safety criteria, which do not necessarily match those, used by the Ministry of Emergency Situations but, nevertheless, are critical to the company. The IAS allows to promptly and properly receive storm warnings within the range of the company's safety criteria and select the requisite types of forecasts.

Dilyara Karimova, Director of the Environmental Development Department of ISEDC; Sergey Luchinin, General Director of Nauchno-Metodichesky Tsentr-Sibir LLC; Denis Martyniuk, Risk and Financial Intelligence Counsel at Kollegia Ekspertov; Ludmila Khaibullina, lead expert at Siberian Regional Hydrometeorological Research Institute Federal State Budgetary Institution, Deputy Director of Zapadno-Sibirskoe Meteoagentstvo ANO.

ISEDC SIGNED AGREEMENTS ON COOPERATION AND INFORMATION EXCHANGE

The International Sustainable Energy Development Centre under the auspices of UNESCO signed cooperation and information exchange agreements with the Autonomous Non-Commercial Organisation “Environmental Investments Centre” and the Federal State Budgetary Institution “Institute of Global Climate and Ecology” named after academician Y.A. Izrael in December 2018 and February 2019, correspondingly.

According to the agreements, cooperation takes place in a series of key fields:

– development and implementation of long-term strategies and certain efforts in the fields of mutual interest;

– implementation of joint scientific research, educational and innovative programmes and projects;

– training a new generation of highly qualified experts;

– arrangement of joint efforts and training.

* Means at any time, all year round. - Editor's note.

OPEN LESSON FOR STUDENTS OF THE RUSSIAN STATE GEOLOGICAL PROSPECTING UNIVERSITY NAMED AFTER SERGO ORDZHONIKIDZE (MGRI-RSGPU)

On April 3, 2019, ISEDC held an open lesson for students of the Geography and Geoecology Faculty of the MGRI-RSGPU. The ISEDC experts presented their reports and shared practical experience in the matters related to climate changes, ecological safety and protection of the environment.

Dr. D. Karimova, Director of the Environmental Development Department of ISEDC, presented results of her analysis of the Report of the Club of Rome «Extracted: How the Quest for Mineral Wealth is Plundering the Planet», and the Blue Ocean strategy as exemplified by Elon Musk's Tesla, while keeping focus on the important role of engineering research for the problems of ecological forecasting and fulfilment of application tasks in the field of ecology, and also explained the interrelation between ecological tasks, ecology and ecological damage.

In the practical part, students were asked to apply knowledge, skills and abilities to solve problems in engineering geodesy and geology in the part of calculating MPD and MPE* with the possibility of predicting potential environmental damage.

Grigory Yulkin, Director of the ISEDC Department of Strategic Planning and Partnership, during his lecture, demonstrated the evolution of understanding the climate change conventions from the Kyoto Protocol to the Paris Agreement, told about the reasons, trends and scale of climate change, models of its behaviour depending on various scenarios, and the current research and expected results, interrelation of climate and energy as one of anthropogenic activities.

Besides, a series of questions related to the climatic system of Russia, natural and anthropogenic effects by regions, scale of dependence of temperatures and concentrations of CO2 emissions and the chronology of those events were also discussed.

In conclusion, the ISEDC experts wished the students to become demanded specialists in their fields capable of preventing appearance of global threats to humanity.

ARWE 2019 FORUM. PROSPECTS OF DEVELOPMENT OF RES IN RUSSIA

On May 22-24, 2019, International Forum on Renewable Energy ARWE 2019 was held in Ulyanovsk. The business programme of the Forum involved the experts of ISEDC, Grigory Yulkin, Director of the ISEDC Department of Strategic Planning and Partnership, and Fariza Esieva, Head of the Energy Efficiency and Renewable Energy Sources Sector.

During his presentation at the panel discussion «Ratification of the Paris Agreement by the Russian Federation: Potential Impact on RES Development» Mr. Yulkin told about the prospects of renewable energy development of in the context of low-carbon trend in Russia with strengthened control of anthropogenic emissions of greenhouse gases (GHG).

«The World, including Russia, is facing a growing demand for highly-efficient energy based on such types of fuels, sources and methods for energy generation that do not emit greenhouse gases. It is connected with the opportunities to gain benefits from projects, primarily in the energy sector, whose implementation without regard for climate risks is postponed to a distant future,» considers the expert. «The national policy must take into account the flow of capital from more carbon-intensive industries to less carbon-intensive sectors as the key element of the GHG emissions control

* MPD - maximum permissible discharge, MPE - maximum permissible emissions. - Editor's note.

model to be developed. If implemented, large energy companies could have new opportunities to reduce their climate risks by participating in the energy development projects with the low level of GHG emissions, including those based on RES utilisation».

The panel members noted that the action framework envisaged by the national climate policy was not effective enough and today it is «a means for building new opportunities for decarbonisation of the energy sector generally and RES development particularly».

Fariza Esieva spoke at the panel discussion called «Renewable Energy for Isolated and Arctic Territories» during which she presented the results of the research dedicated to the adaptation of fuel and energy industries to the climate changes performed by ISEDC in cooperation with the Institute of Global Climate and Ecology, and paid a particular attention to the analysis of prospects and risks related to the wind energy development in Russia under the climate change conditions.

The panel members actively discussed the experience in implementing the wind energy projects in isolated territories and the challenges faced during construction and operation of such facilities, as well as the technical particularities of wind turbines operation under low-temperature and icing conditions which are peculiar to the Arctic areas.

Apart from participation in the Forum discussion programme, ISEDC experts also joined the technical tour and visited the Ulyanovsk wind farm.

At the end the event, the ISEDC experts presented their proposals regarding the refinement of the national climate policy and the policy for development of energy generation based on RES utilization for their inclusion into the Forum's final report.

EDUCATIONAL LECTURE COURSE FOR IMPLEMENTATION OF SUSTAINABLE DEVELOPMENT IDEAS

Established under the Agreement between the Government of the Russian Federation and UNESCO, ISEDC is effectively engaged in the field of sustainable energy development, one of the most important UN's areas of interest.

Along with the scientific work the Centre promotes the UN Sustainable Development Goals is and also serves as a communication platform for direct dialogue, exchange of experience, best practices and means for raising awareness of the sustainable development ideas as a global initiative.

In this regard, ISEDC launches an educational set of lectures and invites professionals and future leaders in the area of sustainable development to take part in this initiative.

On June 5, 2019, the first lecture was given by Mikhail Yulkin, General Director of the Autonomous Non-Commercial Organisation "Environmental Investments Centre". The lecture was dedicated to "Global Climate Change and Its Fight: Consequences for the World and Russia".

The educational set of lectures will be focused on the following important and urgent problems: the shift of the global energy and economy to the low-carbon future, global warming trends and challenges, increasing the standard of education, waste management and ecological safety, sustainable development principles, urgency of the problem of improving the quality of life and protection of humanitarian values globally in the 21 century.

INVITATION TO COOPERATION ON ENERGY BULLETIN PAGES

Ladies and Gentlemen,

The Editorial Board invites experts, governmental and non-governmental, both public and private, organisations to cooperate on the pages of our periodical. The objective of the Energy Bulletin is to facilitate development of international scientific discussions on sustainable energy development, utilisation and exchange of clean energy technologies, climate change mitigation as well as to attract attention of energy experts, politicians and representatives of various economy sectors to the most important energy problems facing our society.

It is extremely important today to hold a continuous international dialogue at the experts, politicians and public levels on the issues of strengthening interdependency in the fields of energy, ensuring of energy security, energy efficiency and energy conservation, environmental responsibility during development and use of energy resources, reduction of energy poverty.

We would be pleased to publish materials on the actual energy and related problems in the coming issues of the Bulletin. For additional information you may contact Irina Kevbrina, Editor.

Tel.: +7 (495) 641-0426, +7 (926) 081-7029
E-mail: kevbrina@isedc-u.com, info@isedc-u.com