Radiation in Agriculture and Achievement of Sustainable Development Goals

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***Abstract*—**The authors studied how the use of nuclear power allows solving energy- and climate-related problems as well as enhancing the effectiveness of agriculture. Nine of the 17 Sustainable Development Goals set forth by the UN's 2030 Agenda. The nine SDGs encompass, primarily, those goals that are related to food security, energy security, population health (nuclear medicine), and safe water supply. Therefore, the authors concluded that technologies exploiting nuclear and its radiation make a great contribution to the building of a future we all wish to live in.

The access of the population to reliable and reasonable sources of food, water, and energy is a fundament upon which almost all the SDGs rest. Safe and well-coordinated use of nuclear and radiation technologies can dramatically increase the expectancy and quality of lives of people all over the world. And the last but not the least, nuclear is key to solving the global climate change issue due to the fact that carbon footprint of energy harnessed at an NPP is between 200 and 220 times lower than that of energy generated at a coal-fired power plant.

***Keywords*—** Sustainable Development Goals (SDGs), nuclear, radiation, nuclear technology, radiation technology, agriculture.

In 2015, the UN General Assembly adopted resolution Transforming Our World: The 2030 Agenda for Sustainable Development.

The content of the Resolution is well known, and all the seventeen Sustainable Development Goals (SDGs) are in one way or another related to the increasing need for resources and energy as well as to the ongoing debate about which energy and food resources are the most effective for implementing the SDGs. Nuclear is not just the solution to energy problems, its radiation can play a vital part in SDGs related to the fight against hunger and social problems.

Table 1 shows nine most important goals and their assessment by the IAEA, which actively aids the international community in the achievement of seventeen SDGs, helps countries use nuclear and isotopic methods and thereby contribute directly to the achievement of the nine SDGs.

Table 1. Influence of the nuclear power industry on achieving SDGs

Sustainable Development Goal	The assessment given by IAEA
Ending hunger, achieving food security and improving nutrition, promoting sustainable agriculture	The IAEA together with the UN Food and Agriculture Organization (FAO) support countries around the world in improving food security and agriculture using nuclear and isotopic techniques to protect plants against pest insects and to cultivate new varieties of plants, which are characterized, for example, by improved crop yields, and resistance against diseases or drought
Promoting healthy lives and well-being for all ages	To help achieving the goal of reducing mortality from noncommunicable diseases by one third, the IAEA helps countries in the fight against cancer, helping them to develop comprehensive programs of cancer control, to create nuclear medicine, radiation oncology, and to design radiological units, as well as supporting education and training for specialized professionals in the field of health service
Ensuring access and sustainable water and sanitation management for all	Water is essential for life. As populations grow and economies expand, access to clean and safe water must be ensured. Isotopic techniques shed light on water quality and age. Some countries use this to implement integrated water resources' management for the sustainable use of resources and the protection of water and water-related ecosystems
Providing access to affordable, reliable, sustainable, and modern energy for all	The IAEA promotes the efficient and safe use of nuclear energy by supporting existing and new nuclear programs around the world, promoting innovation and building capacity in planning, analysis and nuclear information in the field of the power industry and knowledge management
Building sustainable infrastructure, promoting inclusive and sustainable industrialization, and stimulating innovation	Nuclear science and technology can make an important contribution to economic growth and play an important role in supporting sustainable development. With the IAEA assistance, several countries have increased the competitiveness of their industries, using these technologies, for example, nondestructive testing for safety and

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	quality tests, as well as irradiation methods to improve the durability of various products starting from automobile tires to pipelines, and from medical devices to cables
Taking urgent measures to combat climate change and its impacts	Nuclear power, along with wind power and hydropower, is one of the low-carbon technologies, which can be used to produce electricity. The IAEA is working to raise global awareness of the nuclear energy role in connection with climate change, in particular, to ensure that the role, which nuclear power can and does play in helping countries to reduce greenhouse gas emissions, is duly recognized
Preserving and using sustainably the oceans, seas, and marine resources for sustainable development	For sustainable management and protection of the oceans and, in turn, supporting coastal communities, many countries, with the support of the IAEA, are using nuclear and isotopic methods for better understanding and monitoring the ocean condition and marine phenomena, such as seawater acidification and blooms of harmful algae.
Protecting, restoring and promoting the sustainable use of terrestrial ecosystems, sustainably managing forests, combating desertification, stopping and abolishing land degradation and halting biodiversity loss	Isotopic techniques provide an accurate assessment of soil erosion and help to identify hot spots of erosion that is an important tool to combat land degradation and soil restoration. Support of the IAEA in this field has helped many countries to collect information using these methods in order to develop agricultural practices ensuring more sustainable land use and, ultimately, to increase revenue, and to improve the methods of preserving and protecting resources, ecosystems, and biodiversity
Strengthening implementation means and global partnerships for sustainable development	Partnership with member states is at the core of the IAEA's activities. Close cooperation between the IAEA, the UN organizations, other international ageneses, and civil society organizations helps to maximize the effectiveness of the support of the IAEA in achieving the development priorities of member states

Today, nuclear has not reached its full potential, mainly the lack of public consensus on nuclear facilities and energy and on prospects for the development of the nuclear industry.

However, radiation is important for the life and development of mankind. As described in the IAEA review Rio + 20: Nuclear Technology for a Sustainable Future [2], population growth, accelerated economic development, and rising living standards require more and more resources from the planet. Excessive use of resources forces us to find a compromise between the aforementioned needs and biodiversity, clean air and water, and the volume of arable land, which threatens sustainable development. To help its government members adapt to the situation, the IAIE has been developing a new methodology to model such a complex interaction called CLEWS (Climate, Land-use, Energy, Water Strategies) that allows developing technologies systematically (including radiation technologies) in the area.

The IAEA review states that, in addition to the production of clean and affordable electricity, nuclear contributes to "building the desired future" [2].

Broader access to clean water has become possible due to the use of nuclear radiation, which allows, for example, mapping groundwater much faster and cheaper than by using any other means.

Access to stable food sources will remain a top priority for decades to come. Based on existing trends, agricultural production has to grow by 70% by 2050 in order to meet the demand. Through its extensive Technical Cooperation Programme, the IAEA also helps make these achievements accessible to developing countries.

Developing countries exploit radiation to boost production by breeding and disease monitoring, to increase grain crops yields, food safety, and production, and to improve livestock nutrition. Moreover, radiation can be used to assess the state of the soil and groundwater. Furthermore, radiation helps monitor shifts in the chemical balance in the ocean and provide accurate diagnostic medical information. In developing countries, epidemics, as well as malnutrition, create social and economic problems, which jeopardize sustainable development. Safe and well-coordinated use of radiation in agriculture and medicine contributes to improved health and social stability all around the world.

Among the radiation technologies used in various fields of science and engineering, radiation-biological methods are the most actively developing today. This is due to the fact that radiation-biological technologies can be used in a wide variety of human activities, different in scale and nature: agriculture, food, medical, microbiological, fishing, environmental protection [3],[4].

The use of radiation in the agriculture and food industry is imperative due to long distances between the majority of consumers (urban residents) and food production sites, hence the need to develop and apply means and methods for their storage. Unlike chemical methods, UV irradiation, special food packaging, and heat treatment (which in some cases cause loss of nutritional value) that are often unsuitable for widespread use, and sometimes are unbeneficial [4]-[6], ionization requires less energy and can replace or dramatically reduce the use of food preservatives and fumigants that are not always safe for the health of consumers. The use of radiation allows cutting losses during transportation and storage of fruit and vegetables without creating special conditions, extending the storage time of meat, fish, and a range of meat products, increasing the shelf life during food storage, and managing biological contamination of food causing diseases.

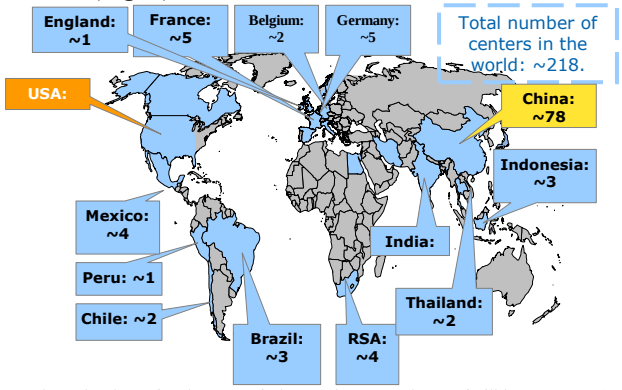
By 1994, radiation processing of food products had been permitted and used in 38 countries, and pilot and industrial

installations for the irradiation of food had been operating in 27 countries [6]. The USSR had been producing powerful experimental (MRX-gamma-20, Stebel, EGO, GUBE, etc.), experimental-industrial (Sterilizator, "Stavrida), and industrial (Kolos, Sterilizatsiya) γ-assemblies. They were brought into wide use at research institutes, universities as well as under workshop and production conditions [4].

The current level of development of radiation technologies is a result of several earlier developmental stages: fundamental and applied research (from the invention of X-rays and discovery of radioactivity in 1895 to the 1960s); pilot implementation and development of design solutions (1960–1980); "fragmented" up-scaling of technologies (large-scale application of radiation in 1990–2010).

Today more than 60 countries around the world expose agricultural and food products to radiation processing. According to the UN FAO, over 200 thousand tonnes of irradiated products are annually put on the market in Europe alone. About 40 different food products are processed using this method. Optimal modes of radiation processing have been determined for a range of food products, long-term studies of suitability and safety of these methods have been conducted, and radiation equipment has been created for many types of products.

In 2012, there were more than 218 food irradiation centers in the world, more than half of them were located in the USA and China (Fig. 1).



Based on the data of "Directory of electron beam accelerator facilities ", IAEA (2008); "Food Irradiation Facilities Database", IAEA (2008); "List of approved facilities for the treatment of foods and food ingredients with ionizing radiation in the Member States", Commission of the European Communities (2003); "Directory of gamma processing facilities in member states", IAEA (2004); "The development of food irradiation to-date in Asia Pacific, the Americas, Europe and Africa", C. Deeley; Int. Meeting on Radiation Proc. in Kuala Lumpur (2006); Bain & Company analysis

Fig. 1. Locations of centers for radiation exposure of food in the world

According to expert estimates, significant traditional market growth for the use of radiation technologies will occur in the coming years. For example, the monetary market for food irradiation is estimated to be 2.5 times higher by 2020 compared to 2010, and 6 times higher by 2030 compared to 2010 [5].

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