Good signs for sustainable development: Nuclear energy's contributions

In many countries around the world, the goal of sustainable development is focusing attention on the benefits of nuclear-based technologies

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When radioactivity was discovered just over a hundred years ago, no one could foresee its far-reaching consequences. The discovery opened the door to a new and exciting branch of science and technology that has had a tremendous impact on the world, both terrifying and beneficial. Since its formation 40 years ago in 1957, the IAEA has been closely involved with both sides of nuclear energy and its peaceful international development. Its day-to-day work chiefly involves assisting countries in their collective efforts to prevent the terrifying uses of nuclear energy and to foster its safe application for the world's benefit.

Over the past four decades, important achievements have been registered in fields of energy and the environment, medicine, agriculture, and industry, among others, where nuclear and radiation technologies are widely applied. Their use allows us, for example, to detect, trace, image and measure what our own eyes cannot see, to destroy cancer cells and germs, to pinpoint water resources, and to generate large amounts of electricity in an environmentally clean and economically competitive way.

This article looks at the peaceful atom's contributions, especially within the context of the IAEA's activities for promoting sustainable development, and nuclear energy's versatile and varied applications. The beneficial applications of nuclear and radiation technologies have become valuable, and sometimes indispensable, tools for addressing a range of needs and problems in Latin America, Africa, Asia, and other regions of the world.

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Medical and health care needs

Perhaps the most familiar and widely accepted use of nuclear techniques is in the medical fields of diagnosis, imaging, and cancer treatment. Modern medicine, in fact, would be unthinkable without diagnostic radiology and radiotherapy. These techniques have become so common, so reliable and so accurate that, in the Western industrialised world, about one patient in three undergoes some form of diagnostic or therapeutic radiological procedure.

The IAEA's nuclear medicine programme helps countries around the world to maintain a high degree of professional competence for all those who operate these installations, and to maintain the precision and the quality of the equipment they use in both diagnosis and radiation therapy. The Agency also provides assistance for advanced training of medical physicists who are currently working in radiology, radiotherapy, and nuclear medicine. Such assistance helps to assure the development of a high quality radiation diagnosis and treatment in various countries. With the World Health Organization (WHO), the IAEA further works to ensure conformity of radiation measurement in diagnosis and therapy through a global network of laboratories.

Human nutrition studies. Another specific application that is now drawing greater attention is the use of isotope techniques for evaluating human nutritional status and measuring the effects of nutrition programmes. It has many advantages over alternative procedures. It permits non-intrusive early and exact detection of nutritional deficiencies, and thus facilitates devising the proper remedies. The Agency is involved in some pioneering work using these techniques to evaluate vitamin-A

In many ways and forms, people are seeing good signs from uses of nuclear energy. *Clockwise from top left:* Gas emissions into the atmosphere from fossil fuels can be reduced by radiation techniques and avoided by nuclear plants that generate electricity without emitting carbon dioxide. *(Carnemark/World Bank)* Marine scientists use nuclear techniques to analyze samples for contamination from pesticides and other chemicals. *(IAEA-MEL)* In Africa, Latin America, and elsewhere, the nutritional health of children is being evaluated and improved using nuclear-based analytical methods. *(Carnemark/World Bank)* Greener fields are a practical goal of IAEA-supported projects that help farmers study and solve problems affecting food and agricultural production. *(IAEA)* In places where water is in short supply, the tools of isotope hydrology are helping countries to better understand and manage existing supplies, and to assess future sources of water. *(Marshall/IAEA)*

and iron deficiencies, bone disease, malnutrition, and the nutritional requirements of mothers and children. Right now, more than 800 million people around the world are chronically malnourished, and more than a billion are sick or disabled because of nutrient deficiencies.

To help improve this picture, the IAEA is developing and transferring nuclear-based evaluation tools that enable early detection and treatment. Such highly specialized techniques can become "sustainable solutions" in efforts to achieve a better nourished population and Agency-supported projects are helping to put programmes into place in countries of Latin America and elsewhere.

Food, water, and agricultural needs

Water resources. The world has enough water, but not always where it is most needed. Water deficits have become increasingly acute and isotopic techniques are often of great help to trace and measure the extent of underground water resources. Isotopic techniques provide important analytical tools in the management and husbanding of existing supplies of water and in the identification of new, replenishable and exploitable sources of water. The results permit informed recommendations for the planning and management of the sustainable use of these water resources.

The IAEA has a dedicated isotope hydrology laboratory that supports development activities. Projects provide assistance to countries with chronic water shortages such as Morocco, Senegal, and Ethiopia. Over the last decade, the Agency has supported almost 160 projects worth US $20 million to help countries develop national capabilities in hydrology isotope applications. Some 550 scientists in these countries have been trained in the relevant skills.

Agricultural applications. The use of nuclear techniques in the field of agriculture is of prime importance for the developing world. Radioisotopes and radiation techniques applied in this field can:

- induce mutations in plants to obtain desired agricultural crop varieties;
- determine conditions for optimizing fertilizer and water use, and biological nitrogen fixation;
- eradicate or control insect pests;
- increase genetic variability of plant species;
- reduce post-harvest losses by suppressing sprouting and contamination and extending shelf life of foodstuffs; and
- help identify the pathway of pesticides and agrochemicals in the environment and the food chain.

Measurement of nitrogen uptake in crops. In co-operation with the Food and Agriculture Organization (FAO) of the United Nations, the Agency has perfected the nitrogen-15 technique to measure how nitrogen is taken up by plants from the atmosphere, from the soil, and applied fertilizers. The technique provides an estimate of the total nitrogen fixed during the entire growing season. By this means, more efficient nitrogen fixing legumes with higher yield and protein content can be identified and selected for breeding. The FAO and IAEA jointly support some 30 projects worldwide on the production and use of biofertilizers for increasing biological nitrogen fixation and yield of grain legumes. Use of these bio-fertilizers has increased production by 25% in countries like Bangladesh, China, India, Malaysia, Pakistan, the Philippines, Sri Lanka, Thailand, and Viet Nam.

Eradication of insect pests. Sleeping sickness is a well known disease transmitted by the tsetse fly. The presence of this insect has prevented settlement and development of large areas of Africa. While some insect pests have been temporarily controlled in West Africa, eradication of tsetse has proved an elusive goal. Along with the FAO, the Agency is now effectively targeting one species that has caused sizeable losses of cattle on the island of Zanzibar, Tanzania, and authorities there are confident that eradication can be achieved.

A key component of efforts in Zanzibar is the Sterile Insect Technique (SIT), a radiation-based technology. It involves the sterilization of factory-reared male insects by irradiation before hatching and thereafter releasing millions of the sterile insects into infested areas. When they mate with flies in the wild, no offspring are produced, thereby gradually reducing and finally eradicating the insect population. The technique is particularly effective in a confined area such as the island of Zanzibar, where the risk of re-infestation from the outside is minimal.

The SIT has also been applied successfully against numerous other insect pests in recent years, including the costly Mediterranean fruitfly that alone attacks 260 varieties of fruits and vegetables in 82 countries and the New World Screwworm that endangers millions of livestock. In Mexico, sterile Medflies are reared in Tapachula at the largest such facility in the world. Mexico also

has a large screwworm rearing facility at Tuxtla, which proved instrumental in its successful fight to eradicate the New World Screwworm in 1991. Over a 30-year period in Mexico, the cost-benefit ratio of the screwworm eradication is conservatively estimated at about 1 to 10. In monetary terms, this means that the benefits to the Mexican economy have been at least US $3 billion over that period of time. Drawing upon the base of SIT experience worldwide, the IAEA, FAO, and Libyan authorities several years ago succeeded in eradicating the screwworm in Libya where a large infestation had occurred. Huge quantities of sterile flies were flown from Mexico to Tripoli and released over the infested area in Libya. Mexico is presently providing sterile screwworm flies for an eradication campaign in Central America and will provide flies for similar campaigns in the Caribbean.

Eradication of such devastating pests by SIT is a major contribution to the ability of any country to feed itself and others in an environmentally sustainable way. The technique protects the quality and quantity of agricultural output without the additional extensive use of chemicals that otherwise would be released into the environment.

Enlarging the genetic variability of crops. Ionizing radiation in the field of plant breeding has been used for several decades as part of efforts to improve agricultural economic conditions in individual regions. Some of this research is done at the Agency's own research laboratories in Seibersdorf, Austria; region-specific or country-specific research is carried out through IAEA-supported agricultural research programmes around the world. By combining mutation with *in vitro* plant propagation strategies, this research has made possible the successful production of new genotypes/mutant lines of sorghum, garlic, wheat, bananas, beans, avocado and peppers, all of which more resistant to pests and more adaptable to harsh climatic conditions.

Preserving foodstuffs. The use of irradiation technology to preserve food is increasing around the world. In 37 countries, health and safety authorities have approved irradiation of over 40 kinds of food items, ranging from spices and grains, to deboned chicken, fruit, and vegetables. Today, consumers can safely enjoy irradiated strawberries as they can in France, or irradiated sausage, as is locally done in Thailand.

Here, too, rules and standards are needed to control the safe application of the technique. A worldwide standard for irradiated food was adopted as long ago as 1983 by the Codex Alimentarius Commission, which is a joint body of the FAO and WHO representing more than 130 countries. An expert committee further has reported to the Commission that the irradiation of any food commodity up to an overall average dose of 10,000 grays presented no toxicological hazard, required no further testing, and introduced no special nutritional or microbiological problems.*

Governmental interest in the process stems from a variety of reasons:

- high losses of food after harvesting (typically 25% of all food production) due to infestation, contamination, and spoilage;
- concern about foodborne diseases;
- growing international trade in foodstuffs that must meet stringent import standards of quality and quarantine.

While the Codex Alimentarius Commission exercises oversight regarding the foodstuffs themselves, international radiation protection regulations govern safe operation of installations where irradiation takes place. The IAEA helps in formulating such regulations, and it has frequently provided assistance to countries wishing to test or use this technology.

Livestock health, productivity, and disease control. Livestock are vital to sustainable agriculture in most developing countries but their productivity is often much lower than in the industrialized world. Livestock production can be improved if attention is given to animal nutrition, reproductive performance, and health, particularly the control and prevention of diseases. This can be done using nuclear and related techniques. Along with the FAO, the European Union, and other partners, the IAEA is helping countries in Africa and other regions to control, monitor, and ultimately eradicate rinderpest from their territories. In Africa, the campaign has been effective so far and the 34 countries engaged in the campaign now agree that eradication can be achieved over the next five years.

Energy and electricity needs

In the energy field, nuclear applications carry significant environmental benefits, and they go beyond the clean production of electricity.

Investigation of geothermal resources. Thanks to the analytical capabilities of the IAEA isotope hydrology laboratory in Vienna and its global partners, investigation of geot-

* 1 gray = 1 Joule per kilogram, the unit of measurement for the energy absorbed by the irradiated material.

Green sides of nuclear power

Using nuclear fuels, rather than burning fossil fuels, to power electricity plants may be part of the answer to the threat of global warming. Nuclear's role is already sizeable in helping countries to cut back or hold in check their emissions of carbon dioxide (CO_2), a gas linked to global climate changes. If the nuclear power plants in operation worldwide today were replaced by fossil-fired power plants, the CO_2 emissions from the energy sector would increase by more than 8%. This level almost equals the avoidance of CO_2 emissions by hydropower. Avoided CO_2 emissions are demonstrably greater in countries that have substantial nuclear shares in their electricity production — those like France, Sweden, Belgium, Spain, Switzerland, and the United States. In France, CO_2 emissions have been reduced by a factor of eight and sulphur dioxide emissions by a factor of ten between 1980 and 1993. During that time, France's total electricity generation roughly doubled, owing mainly to the increase of nuclear's share in electricity generation from some 25% to more than 75%. Similarly, in Sweden, a drastic reduction of atmospheric emissions was obtained mainly by substituting nuclear power for oil and other fossil fuels for electricity generation. Overall for industrialized countries of the Organization for Economic Co-operation and Development, it's been reported that nuclear power accounted for the greater part of the lowering of carbon intensity of the energy economies over the past 25 years.

Such achievements show that an objective comparison of different options for generating electricity is needed, and that the environmental advantages of nuclear power can be well documented. Given the interest of its Member States in such comprehensive comparisons for energy planning purposes, the IAEA has developed and distributed a package of computer tools and databases that comprise an analytical framework for analyzing the economic, health, environmental, and social aspects of all energy chains for electricity generation.

hermal systems can be improved and the use of their resources optimized. In some countries, like Costa Rica and Nicaragua, isotope techniques provided by the Agency have been used to map geothermal resources and to decide on the best location of installations.

Abatement of gaseous emissions. With the use of accelerator-generated electron beams in the chimney stacks of conventional coal-burning power plants, sulphur and nitrogen emissions to the environment can be virtually eliminated. Indeed, with the addition of ammonium, these potentially polluting flue gases are transformed into fertilizers — ammonium sulphate and ammonium nitrate — and water. This ingenious and original method is currently being demonstrated in a project which the IAEA is supporting near Warsaw in Poland. Where once the alchemists rosily dreamed of transforming lead into gold, today's energy planners are realistically seeing the transformation of polluting gases into useful food for crops.

Nuclear power. There is no doubt that global energy use will increase sharply, in part because the world population is increasing so much, in part because energy — and especially electricity use — is a vital part of the higher living standard that people seek. Bangladesh and Tanzania annually use less than 100 kWh electricity per capita. Sweden uses 15,000 kWh and Mexico uses about 1250. Given the inevitable growth in world population, a global striving for economic development, and growing trends towards urbanization, it is not surprising that the World Energy Council predicts that the world use of electricity will increase by 50% to 75% by the year 2020.

At present 63% of the world's electricity comes from thermal power (coal, oil and gas), 19% from hydro, 17% from nuclear, 0.5% from geothermal, and less than 0.1% from solar, wind power and biomass. This mix will clearly change as resources are developed and new technologies appear over time, and as environmental concerns become more effective. Rational energy production and use will necessarily be a major aspect of sustainable development. Based on experience so far, nuclear power should play an important part of any future energy mix.

Nuclear prospects. In the 1970s there was great enthusiasm for nuclear power and expectations for rapid growth, not least to reduce dependence on oil. With high inflation and slower economic growth in the following decade, energy demand grew more slowly than expected and became more price sensitive. The large construction programmes contemplated in some countries, such as Mexico and Brazil, for instance, were not realized. With the many safety related changes required after Three

Mile Island, nuclear power also lost some of its economic competitive edge.

These economic factors, along with growing political opposition to nuclear power, slowed the expansion of the industry. Concerns over safety and waste disposal, part of a larger environmental movement, have stymied further nuclear investments in a number of countries. There is at present a stagnation in the construction of further nuclear plants in Western Europe and in the Americas, where slow economic growth and over-capacity in the generating industry have resulted in very little major baseload construction of any kind in recent years. Construction of nuclear plants is continuing vigorously only in East Asia, specifically in Japan, Republic of Korea, and China.

Nonetheless, nuclear power remains a viable part of our energy future for several reasons:

Economic competitiveness. The economic competitiveness of energy options remains important to countries, utilities and the consumers. From the economic point of view nuclear power is at present roughly on par with coal, and in some cases, gas. However, nuclear plants require larger up front investments, which is a drawback in capital starved developing countries. As nuclear technology is relatively young there should be scope for rationalisation, standardisation, modular construction, higher burnup, simplification — all resulting in greater efficiency and lower cost. Moreover, relative fuel prices are likely to change over time. Nuclear generation should remain an attractive option especially for countries lacking domestic fuel resources.

Safety. The objections advanced to nuclear power on the grounds of safety may gradually be answered by positive experience. No accidents in the world have had more publicity than those at Three Mile Island and at Chernobyl. This has tended to overshadow the fact that by now the world has the experience of some 7700 reactor years of operation without any other major accidents. Through national regulatory organizations, through the World Association of Nuclear Operators and through the Agency these many years of experience are made available for all to learn from. The Three Mile Island accident in 1979, even though it released little radioactivity into the environment, triggered extensive safety reviews, strengthening nuclear safety in the non-communist world. And the Chernobyl accident, which occurred 10 years ago, similarly led to reviews and new safety measures in Russia and Eastern Europe. Thus these two major nuclear accidents, which provoked so much opposition to nuclear power, also set in motion determined and extensive action in the field of safety. Nuclear power safety became even more of an important international concern and the Agency became a central instrument through which governments cooperate to establish important elements of what is now termed an "international nuclear safety culture". The impact of this effort can be seen in the improved production figures for nuclear power plants around the world, lower doses to their personnel and fewer unplanned stoppages. New types of advanced reactors, some of them available in the market today, have new safety features and can be expected to have even better records on reliability and safety than the current dominant reactor types.

Energy security. Energy independence is an important factor. Not all countries have abundant energy resources — hydrocarbons or waterfalls. To France, Japan, the Republic of Korea, Sweden and Finland, all without oil and gas, the measure of self-reliance and the measure of immunity against international crises which nuclear power offers, has been and remains important.

Environmental protection. Another important factor for a nuclear revival will be the environment. Nuclear power may be viewed as the least damaging, most emissions-free of the realistic energy options. Indeed, it is not nuclear power plants — but an excessive burning of fossil fuels — that have caused acid rains, dead forests and a threat of global climate change. Nuclear power does not generate airborne emissions, and helps fight global air pollution. Indeed, if the world's 437 nuclear power reactors were to be replaced by coal plants of equivalent capacity, some 2600 million tons of CO_2, and millions of tons of associated sulfur and nitrous oxides, would be added to the world's atmosphere each year.

Minimizing the impact of possible global climate change has become one of the principal goals of the sustainable development movement. There is much talk about the need to reduce CO_2 emissions, though scientists are not yet certain or agreed that there will indeed be an irreversible global warming as early as 50 years from now as a result of CO_2 emissions from fossil fuels such as oil, gas, and coal. Questions remain about global warming trends, and the uncertainty leads many observers to advocate that the world should pursue so-called "no regret" policies. By this they mean energy policies which we would not regret even if the fear of global warming were to prove unfounded. The nuclear power option fits the requirement of a no regret policy,

Comparing energy sources: The Decades programme

The IAEA and other international, regional, and national organizations are working together through a co-operative programme to assist energy planners in assessing electricity options.

Known as "Decades", the programme features a set of tools for comparative assessment of electricity generating sources throughout the entire energy chain. It includes databases with health, economic, and environmental aspects to support comparative assessments; integrated software packages for electricity system planning and analysis; and training and support services. The programme is carried out jointly by the IAEA and eight international organizations: the European Union, the Economic and Social Council for Asia and the Pacific, the Nuclear Energy Agency of the Organization for Economic Co-operation and Development, the International Institute of Applied Systems Analysis, the Organization of Petroleum Exporting Countries, the United Nations Industrial Development Organization, the World Health Organization, and the World Bank. The programme is under the supervision of a Joint Steering Committee composed of representatives of all nine participating organizations and co-ordinated by the IAEA's Planning and Economic Studies Section at the Agency's headquarters in Vienna.

as it does not contribute to global warming and is roughly competitive with the fossil fuels.

By contrast, renewable energy from solar, wind and biomass sources will not become commercially competitive on a wide scale in the foreseeable future. They are forecast to play only a minor role in the decades to come, though their development is certainly and appropriately being encouraged. Great strides in energy efficiency, meaning both a more efficient generation and use of energy, have been made and they remain very important to restrain demand. However, even as we become more efficient in our electricity generation and use, the world's total energy demand is increasing. This is not to suggest that nuclear power, alone, is a solution to the threat of global warming. Many different approaches may be used as needed, including renewable and conservation. But nuclear power can certainly be a viable and promising component of sustainable development in the response policies which need to be worked out.

Waste management. When it comes to nuclear power, concern is usually focused on the highly toxic and radioactive spent fuel and nuclear waste. What is characteristic of these, however, in addition to their toxicity and radioactivity, is that they are so limited in volume, which facilitates waste disposal. This contrasts sharply with the waste disposal problem for fossil fuelled plants, whose emissions are volumnous and directly enter the environment. When the problems of safely disposing of long-lived nuclear wastes are put into context, the comparative picture becomes clearer. Due to its limited volume, nuclear waste can technically and economically be safely taken care of and be put into the crust of the earth from where the uranium originally came. Not everyone, however, shares this confidence in "high tech" solutions. The "not-in-my-backyard" attitude has affected nuclear waste management programmes in every major nuclear country, just as it has the siting of almost every industrial and energy-related facility. The siting of such facilities is a major part of sustainable development. Blocking the disposal of waste does not make it go away or stop its generation: it just prolongs direct environmental exposure unnecessarily.

Comparative assessments of nuclear power and other forms of electricity generation highlight some of these interesting waste generation and disposal issues. Consider, for example, the case of a country that decides not to operate a nuclear plant and builds instead two coal-fired units of about the same capacity. The nuclear plant would consume about 30 tons of low-enriched uranium *per year*, while the coal plant would consume about five train loads of coal *per day*. The limited volume of nuclear waste from the uranium can be isolated in its entirety. The coal plant will produce huge quantities of CO_2 and ashes containing heavy metals which remain toxic forever. The disposal site for all this waste from burned coal — as from other fossil fuels — is our atmosphere and the surface of the earth.

Achieving sustainable solutions

The international goal of sustainable development requires the co-ordinated actions of people around the world, and all the scientific and technological tools at their disposal. In various fields, nuclear energy and its diverse applications have proved to be important components of steps to achieve sustainable solutions to practical problems affecting our social, economic, and environmental development.

To make the right choices in the months and years ahead, governments will need an objective record of experience and facts with which to evaluate their options, set priorities, and marshal the needed resources. Through its range of services and projects, the IAEA will be assisting countries in their efforts to constructively and safely apply nuclear and radiation technologies where they can be most beneficial, and to plan their energy and electricity development. ❐