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AGENDA ARCAL 2030

Regional Strategic Profile for Latin America and the Caribbean 2022–2029

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AGENDA ARCAL 2030

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REGIONAL STRATEGIC PROFILE FOR LATIN AMERICA AND THE CARIBBEAN 2022–2029

INTERNATIONAL ATOMIC ENERGY AGENCY
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FOREWORD

This publication sets out the Agenda ARCAL 2030, the title given to the Regional Strategic Profile for Latin America and the Caribbean for the period from 2022 to 2029. It will serve as a key programmatic reference for the formulation of regional technical cooperation projects.

As with previous editions of the Regional Strategic Profile, the IAEA, the Regional Co-operation Agreement for the Promotion of Nuclear Science and Technology in Latin America and the Caribbean (ARCAL) and representatives of Member States collaborated closely on the drafting of this new strategic programming framework. The new framework aims to address those of the region's priority needs and problems where nuclear technology can make an effective and tangible contribution.

Consideration was given to the following aspects when preparing the Agenda ARCAL 2030: evaluation of results achieved during the project cycles for the previous period; identification of conceptual and methodological adjustments required to improve the preparation process for the Regional Strategic Profile; mobilization of the participating institutions and their level of involvement in projects; and communication of project results and their benefits for the region. In addition, the Agenda ARCAL 2030 took into consideration those United Nations Sustainable Development Goals to which nuclear technology can contribute directly.

The Agenda ARCAL 2030 includes projects from the 2020–2021 biennium, the last biennium of the 2016–2021 Regional Strategic Profile; covers projects for the upcoming 2022–2023 biennium, selected according to an assessment of the results of the 2016–2021 Regional Strategic Profile project cycles; and extends as far as the 2028–2029 biennium.

At the end of this ten year period, the regional results and impacts achieved will be assessed, and a new programming period will begin as of 2030.

Through the Agenda ARCAL 2030, it is hoped that ARCAL can expand cooperation with strategic partners inside and outside the region, to address projects with greater regional benefit and impact.

The agenda preparation process was completed in 2019, the year ARCAL celebrated its 35th anniversary, promoting the successful implementation of regional technical cooperation projects and fruitful collaboration with the IAEA.

The IAEA officer responsible for this publication was R. Scamilla Andreo Aledo of the Division for Latin America and the Caribbean.

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1. EXECUTIVE SUMMARY

BACKGROUND

The IAEA and ARCAL have worked closely together to prepare a new strategic programme framework to identify and prioritize the region's most pressing problems and needs that could be addressed using nuclear technologies, within a time frame covering the period 2020–2029.

The new framework was drawn up based on a sectoral assessment using a strengths, weaknesses, opportunities, and threats (SWOT) analysis, which helped not only to identify the most acute regional needs and problems, but also to characterize them in terms of their respective baselines, prioritize them, and identify the objectives and goals to be achieved along with the measurement indicators.

The 44 needs and problems identified were classified into six thematic areas representing the priority sectors within the scope of the new RSP: food and agriculture, human health, environment, energy, radiation safety and radiation technologies. In addition, 15 SDGs were identified that were closely related to the specified needs and problems. This publication also considers the importance of the cross-cutting aspect of gender equality.

The Agenda ARCAL 2030 will be updated periodically as progress is made in achieving the objectives and goals set for the reporting period.

In addition to serving as a programmatic reference of major importance for the preparation of project and programme proposals for both ARCAL and the Agency, it is anticipated that the Agenda will help to attract strategic partners from within the region and outside it, so that projects with a larger scope, benefit and impact can be pursued. All the data presented is this section has been referenced throughout the document and is organized according to each thematic area.

THEMATIC AREAS

1.2.1. FOOD AND AGRICULTURE

Regarding food and agriculture, a number of the characteristics of the SWOT analysis undertaken in the previous RSP still prevail in the region. Nevertheless, important new opportunities associated with the region's great diversity in climate, biology, and natural resources (availability of land, water, etc.) have presented themselves, and these factors will have an impact on the potential increase in the production of high-quality food. The starting point was to determine needs and problems without considering the application of nuclear techniques. Subsequently, following an analysis of possible solutions, nuclear techniques were found to be tools of considerable value in addressing many of the needs and problems identified.

The LAC region produces 14% of all food worldwide and accounts for 23% of global exports of staple agricultural and fishery products. Over the next decade, it is expected that there will be a 22% increase in agricultural production (60% owing to yields and 40% owing to expansion of the area given over to agriculture), triple the global average of 7%. The stockbreeding sector is expected to grow by 16%, eight times the global average of 2%. Regional meat consumption will increase by around 8 million tonnes (Mt), or 17%. Regional meat production will be more export oriented.

Technological change in the region is still insufficient to successfully respond to growing domestic demand for food and take advantage of the opportunities offered by the international trade

liberalization. In this context, it is assumed to also count with a sustainable agricultural development, based on the increasing production and export of agricultural products without concomitant effects for human health or damage to the environment.

There is a lack of technological change to which nuclear technologies could contribute when it comes to development of good practices:

- use and management of soil and water resources;
- genetic improvement of agricultural and livestock species, both traditional and non-traditional;
- prevention, suppression and eradication of transboundary agricultural and livestock pests and diseases;
- management of health-related and genetic constraints in the rearing of livestock species and captive aquatic organisms;
- timely diagnosis of animal diseases;
- control and monitoring of toxic substances in food that pose a risk to health;
- prevention of residues in food that pose a risk to human health;
- strengthening of networks and capacity to support analytical services.

The main challenges to be addressed through regional cooperation in the area of FOOD AND AGRICULTURE are identified in the Agenda ARCAL 2030 and formulated as eight needs and problems, set out below:

A1. Improvement of practices for the management of water, soil, agrochemicals and biofertilizers, including biological nitrogen fixation.
A2. Improvement of food crops of economic importance to cope with various biotic and abiotic stress conditions.
A3. Improvement of animals of recognized economic importance and support for initiatives to improve the yield/production and commercial potential of animals reflecting the region's biodiversity.
A4. Incidence of transboundary diseases, including those with zoonotic repercussions, and of mandatory declarations.
A5. Availability of foods of animal origin (including aquaculture products) and plant origin that meet safety and quality standards.
A6. Damage caused by pests to foods of animal and plant origin.
A7. Supporting initiatives for the development of aquaculture in the region.
A8. Strengthening of mosquito control strategies.

1.2.2. HUMAN HEALTH

The world is currently undergoing dramatic demographic change. Since the beginning of the last century, the global population has increased from 2 billion people to over 7 billion. This figure is expected to reach 10 billion by the end of the 21st century. Furthermore, other substantial population changes relate to new and diverse fertility patterns (including childbearing during adolescence), mortality, migration, urbanization, and ageing.

In 2019, the general health situation in the region was analysed by the Pan American Health Organization (PAHO) in its publication "Health Trends in the Americas". The total population of the

Americas was 1.01 billion inhabitants. In terms of subregion, LAC's population represents more than 60% of inhabitants in the American continent.

Demographic changes, evolving ways of life, and environmental, behavioural, and economic factors have led to noncommunicable diseases replacing or, in some cases, coexisting with, the burden of communicable diseases in LAC. This epidemiological transition explains the heterogeneous behaviour of mortality in the region, where the double burden of communicable and non-communicable diseases is common and imposes an extraordinary cost on the health system.

In the region there is still a heterogeneous distribution of technology along with unequal access to health; there remains a need to expand national noncommunicable disease programmes and to update technology. It is also important to continue training professionals who use advanced radiation technologies, with an emphasis on the training of technicians, the clinical training of medical physicists and paediatrics in nuclear medicine and radiotherapy.

Likewise, consideration needs to be given to the development of new technologies such as theranostics with alpha, beta and gamma emitters, nanomedicine, and artificial intelligence.

The main challenges to be addressed through regional cooperation in the area of HUMAN HEALTH are identified in the Agenda ARCAL 2030 and formulated as eight needs and problems, set out below:

S1. Insufficient number of professionals trained, and clinical guidelines harmonized to enable the use of new multimodal imaging technologies for diagnosis, risk stratification and guidelines for the appropriate treatment of cardiovascular and cerebrovascular diseases.
S2. Insufficient number of professionals trained, and clinical guidelines harmonized to enable the use and development of radiopharmaceuticals and dosimetry for diagnosis and treatment with theranostics.
S3. Insufficient number of professionals trained, and clinical guidelines harmonized to enable the use of new technologies in nuclear medicine and diagnostic imaging, principally hybrid teams and the improvement of existing equipment.
S4. Insufficient human resources qualified in medical physics in the region.
S5. Lack of radiotherapy departments with the appropriate technology and qualified human resources and using the available technology optimally and safely.
S6. Need for technological advancement by adding more brachytherapy units and providing related human resources training.
S7. Need to strengthen quality management systems for radiation medicine in the region.
S8. Insufficient capacity to take the actions needed to improve the nutritional status of the population.

1.2.3. ENVIRONMENT

The 'environment' thematic area of the 2030 ARCAL Agenda is characterized and described by means of a structural and comprehensive approach to soil, air and water, essential parameters for the LAC region's development. As environmental problems and challenges do not confine themselves within national borders, the international cooperation approach can contribute to address, manage and monitor the three environmental elements.

In this regard, the 2019 SDG report pinpoints a range of topics requiring urgent collective attention, as the natural environment is deteriorating at an alarming rate: sea levels are rising, ocean acidification

is accelerating, air pollution is increasing, the last four years have been the warmest on record, a million plant and animal species are at risk of extinction and soils are continuing to degrade uncontrollably.

Many economies in the LAC region make intensive use of material and natural resources, which raises an important question as to unsustainable dynamics involving high carbon emissions and resource depletion, alongside the increasing importance of the global commitment to combat climate change.

The region requires concerted efforts to ensure healthy lives and promote well-being for all and at all ages, in line with SDG 3 Good health and well-being. There is a need to work together, providing universal health coverage, sustainably funding health and tackling environmental factors such as air pollution and the lack of water and sanitation which contribute to poor health.

LAC had a population of over 655 million in 2021, with over 81% concentrated in cities, a trend that is set to increase by 2030. Cities and metropolitan areas worldwide have considerable fossil fuel CO_2 emissions from electricity consumption, ground transportation, residential and commercial buildings and industrial activities. Global urban energy related CO_2 emissions are between 53% and 87% of the CO_2 emissions from global final energy use. Inadequate and overloaded infrastructure and services (such as waste collection, water and sanitation systems, and roads and transport) will represent a clear challenge to the region's environmental policies, with a focus on air pollution caused by unplanned urban sprawl.

There is awareness to take urgent global action to combat climate change and its impacts, as is set out in SDG 13 Climate Action and acknowledged by the United Nations Framework Convention on Climate Change (UNFCCC), main international and intergovernmental forum for negotiating a practical global response to climate change. The effects of climate change are unpredictable and devastating and include an increase in natural disasters, morbidity and mortality, in particular among the poor, young people, and women in general.

In 2016, LAC produced 231 Mt of waste, an average of 0.99 kg per person per day; many of the highest waste generators are island countries with dynamic tourist economies. While approximately 69% of waste is dumped in some form of landfill and more than 50% is disposed of in sanitary landfills with environmental controls, a significant amount is deposited in open dumps (27%), incinerated or used as animal feed. Recycling and composting programmes and practices are on the rise in the region, but implementation varies from country to country. Solid waste is made up of organic material, recyclable waste, dangerous household material, medical and industrial waste, and construction debris. The effects can be seen in human health, with outbreaks of certain diseases, and in the pollution of soil, water, and air, in flora and fauna, and in disasters such as flooding.

As a result of an environmental performance carried out jointly by Economic Commission for Latin America and the Caribbean (ECLAC) and the Organization for Economic Co-operation and Development (OECD) it was highlighted the need for countries to conduct land planning making use of ecological–economic zoning and, to some extent, for them to perform strategic environmental assessments. Additionally, there is a need to develop environmental information systems and set up registers of emissions and of pollutant transfers so that public policy can be framed and implemented based on the appropriate environmental impact assessment systems.

The main challenges to be addressed through regional cooperation in the area of the ENVIRONMENT are identified in the Agenda ARCAL 2030 and formulated as five needs and problems, set out below:

M1. Insufficient knowledge of the availability and inadequate management of water resources.
M2. Insufficient knowledge of water quality and sources potentially contributing to its pollution.
M3. Insufficient knowledge of the main processes affecting coastal zones, oceans and marine resources.
M4. Insufficient knowledge of the concentration of atmospheric particles and aerosols, their composition, and their impact on human health.
M5. Insufficient evaluation of soil degradation and pollution and the impact on human health.

1.2.4. ENERGY

The LAC region comprises 45 countries in an area covering 20.4 million km2. The annual population grows at a rate of 0.7% a year, with the population reaching 655 million in 2021. In 2021, the gross domestic product of the region was US $5.45 trillion at current prices and the annual per capita income was US $8 327. In 2020, life expectancy at birth was 73 years, and the literacy rate of the total adult population (% of people aged 15 years and over) was 94%.

The region's population is forecast to rise to around 720 million by 2030, which poses an enormous challenge in terms of establishing the necessary conditions to meet the welfare requirements of such a population size. In a scenario where current policies are maintained, electricity demand in the region is expected to grow on average by 2.7%.

Latin America has over 47 years' experience in nuclear power generation. Installed nuclear capacity rose to 5 077 megawatt (MW) total net capacity in 2020 (Argentina: 1 641 MW and generation of 10 011 Gigawatt-hour (GW·h), or 7.5%; Brazil: 1 884 MW and generation of 14 053 GW·h, or 2.1%; and Mexico: 1 552 MW and generation of 10 864 GW·h, or 4.9%), distributed among seven units in three countries. Total nuclear power generation increased in these countries in 2020 to 34 928 GW·h. Two new reactors are in construction in the region: one in Brazil (ANGRA 3) with 1 245 MW capacity and the other in Argentina (CAREM SMR) with 32 MW, reaching 1 277 MW of new installed capacity.

The decisions taken under the UNFCCC, derived from the climate regime adopted in 2015 for implementation from 2020 onwards, strengthen the commitments of all countries through mitigation and reduction of greenhouse gases (GHGs).

As the nuclear power reactors in the region are coming to the end of their planned lifetimes, an analysis and evaluation of a lifetime extension needs to be undertaken. These factors expedite the need for a comprehensive evaluation of the nuclear option within energy systems, with a view to identifying the role it could play in the development of LAC.

Regarding research reactors, seven countries in the LAC region have experimental reactors of various types and power levels. The purpose of these reactors is to provide neutron sources for research, experimentation, human resources training, education at the undergraduate and postgraduate levels and radioisotope production.

There have been various cooperation projects and activities involving reactors in different countries in the fields of reactor physics, radioisotope production, training courses, and commissioning of reactors. These initiatives have been implemented as regional and national projects with the support of the Agency, and in a bilateral format. A couple of projects have also been implemented within the framework of ARCAL.

The main challenges to be addressed through regional cooperation in the area of ENERGY are identified in the Agenda ARCAL 2030 and formulated as five needs and problems, set out below:

E1. Incorporation of the subject of energy systems into educational programmes in the region, from school through to university level.
E2. Establishment of a network for the exchange of information and coordination of strategies, from research reactor operators to the radioisotope end user.
E3. Availability of national, subregional and/or regional energy plans that include Sustainable Development Goals (SDGs) 7 (affordable and clean energy) and 13 (climate action).
E4. Incorporation of the Climate, Land, Energy and Water (CLEW) concept into energy planning discussion forums in the region.
E5. Nuclear power plant lifetime extension.

1.2.5. RADIATION SAFETY

Acceptance in society of the risks associated with radiation is dependent on the net benefit from its many different applications. Radiation safety aims to protect workers, the public, patients and the environment from the harmful effects of ionizing radiation and ensure adequate protection of current and future generations from any activity that involves exposure to such radiation.

In order to assess the situation in the region, information in the Agency's Radiation Safety Information Management System (RASIMS) database was primarily used, as was technical advice provided by technical officers (TOs) from the Agency with responsibility in different areas.

From this analysis, it was concluded that significant progress on establishing regulatory infrastructure and programmes has been made in the Latin America region over the last 25 years. This has been a result of the endeavours of the Agency and its Member States and technical cooperation between them. Nonetheless, decisive efforts are required by all parties to consolidate the results achieved as international good safety practice.

The evaluation recognizes the achievements of previous and current national and regional projects as regards all aspects associated with the creation and/or improvement of radiation safety infrastructures.

The main challenges to be addressed through regional cooperation in the area of RADIATION SAFETY are identified in the Agenda ARCAL 2030 and formulated as ten needs and problems, set out below:

R1. Limitations of some regulators as regards control of facilities and activities (medical X rays, new technologies, etc.) and of some governments in establishing and maintaining an appropriate governmental, legal, and regulatory framework for safety.
R2. Insufficient implementation of international safety requirements and recommendations for controlling occupational exposure, with a focus on extremity and lens dosimetry,

internal dosimetry, monitoring of workplaces, laboratory quality systems and national dose registers.

R3. Limitations in the calibration capacities of the region's standards dosimetry laboratories as regards radiation protection, radiodiagnostics and radiotherapy.

R4. Insufficient implementation of international safety requirements and recommendations and of the ten actions in the 'Bonn Call for Action' for controlling medical exposure, with a focus on advanced radiotherapy technologies, interventional and fluoroscopic procedures, digital radiology, tomosynthesis, dental cone-beam computed tomography (CBCT), multi-slice computed tomography, and hybrid single photon emission tomography and positron emission tomography systems (SPECT–CT and PET–CT).

R5. Insufficient implementation of international safety requirements and recommendations for radiation protection of the public and the environment and in the management of radioactive waste. In particular, work needs to focus on national policies and strategies, management of disused radioactive sources, and the identification and resolution of radiological situations due to the presence of Naturally Occurring Radioactive Material (NORM).

R6. Limited capacities in countries for planning, notification, and response regarding radiological emergencies, including systematic analysis of accidents and dissemination of information.

R7. Insufficient implementation of international requirements and recommendations concerning education and training on radiation safety, transport and waste for all staff members involved, with a focus on national strategies.

R8. Insufficient regulatory control of radioactive material in public places (i.e., during transport).

R9. Insufficient implementation of international leadership and management requirements concerning safety among end users, scientific/technical support services and regulators.

R10. Limited capacity for the safety assessment of facilities and activities, with a focus on reactors, cyclotrons, radiopharmacy and existing exposure situations.

1.2.6. RADIATION TECHNOLOGIES

The use of radiation technologies to improve quality of life has numerous applications in different fields, including to tackle a wide range of development issues in the areas of water, the environment, coastal engineering, medicine, cultural heritage, industrial processes and production, processing of advanced materials, natural resources, and inspection technologies.

Although the region comprises countries with different levels of development, it is considered that knowledge needs to be disseminated and these applications developed in all countries to some extent to improve competitiveness.

Radiation technology applications are constantly growing and evolving in areas including exploration and the efficient use of natural resources, mining, the mineral processing industry, metallurgy, development of advanced materials, characterization and preservation of cultural heritage and the environment, and protection of coasts from erosion.

The region has considerable knowledge of and recognized experience in the application of radiation technologies, including in relation to the use of radiotracers in assessing industrial processes and production; radiotracers in the environment, in oil fields and in sediment transport; and nucleonic control systems in industrial quality control, exploration of mineral resources and the environment, non-destructive testing and the use of gamma irradiators and electron beam accelerators.

As experience and confidence in the technology grow, the use of radiation technologies has a pivotal role to play in bringing about significant improvement in almost all countries of the region and as an important contributor to the national economies.

The main challenges to be addressed through regional cooperation in the area of RADIATION TECHNOLOGIES are identified in the Agenda ARCAL 2030 and formulated as eight needs and problems, as follows:

T1. Treatment of domestic, industrial, and pharmaceutical wastewater (drugs, organic compounds, biological contamination, microplastics, etc.) through radiation processing (RP).

T2. Phytosanitary treatment of fresh, frozen, dehydrated, and processed food using ionizing radiation.

T3. Harmonization of Quality Assurance and Quality Control (QA/QC) in irradiators and dosimetric intercomparisons.

T4. Development of innovative, competitive, and environmentally friendly materials with radiation technologies, for use in health, agriculture, and industry (nanotechnology, composite materials, new curable formulas, etc.).

T5. Increase in industrial competitiveness through the optimization of processes and reduction of environmental impact, using radiation technologies such as radiotracers and sealed radioactive source applications, among others.

T6. Characterization and preservation of tangible cultural heritage objects and archived materials using nuclear techniques.

T7. Harmonization of methodologies and training of personnel in accordance with certification schemes and standards for advanced non-destructive testing techniques.

T8. Sustainable processing of the region's renewable non-toxic natural resources (natural polymers) to increase agricultural production and reduce waste and pollution.

2. INTRODUCTION TO THE AGENDA ARCAL 2030

BACKGROUND

The existing RSP for LAC covers the period 2016–2021; for this reason, it needs to be updated and revised, considering the level of progress made in achieving its strategic objectives and the outlook for the use of nuclear technology in the region in the next few years.

The updated and revised RSP will cover 2022–2029, serving as a reference for the promotion and development of cooperation among countries of the region and facilitating the planning of regional projects, since it will give continuity to the planning undertaken based on the 2016–2021 RSP. The national ARCAL coordinators agreed that this new RSP would be entitled 'Agenda ARCAL 2030' to aid in its dissemination and to help coordinate activities with the UN 2030 Agenda. Strategic planning of the projects will cover the period 2022–2029, in accordance with technical cooperation cycles. The results of this strategic framework will be evaluated in 2030.

As occurred with the 2016–2021 RSP, the IAEA and the ARCAL cooperated closely in the preparation of a solid planning framework aimed at addressing the priority needs of the region that were identified while it was being drawn up. During this process, account was taken of the significant advantages that ARCAL offers, as an intergovernmental agreement, in the selection of projects, the mobilization of resources and means to facilitate project implementation, and the evaluation of regional technical cooperation projects carried out under the RSP.

Consideration was given to the following aspects when preparing the 2022–2029 RSP: evaluation of results achieved during the project cycles under the 2016–2021 RSP; identification of conceptual and methodological adjustments required to improve the preparation process; participating institutions and their degree of involvement in projects; communication of project results and their benefits for the region.

In this RSP, the first project cycle corresponds to the 2022–2023 biennium and the call for projects for this cycle was based on the evaluation of the 2016–2021 RSP produced at the RSP Monitoring and Evaluation Group (M&E Group) meeting in Vienna from 1 to 5 April 2019. At this meeting, the RSP M&E Group — with the assistance of Agency thematic experts, TOs and programme management officers— identified the current needs and problems of the RSP to be considered for the 2022–2023 cycle.

In addition to identifying needs and problems for the 2022–2023 cycle, the M&E Group proposed topics and guidelines for the preparation of the 2022–2029 RSP, which are set out in the meeting report. This report is one of the reference documents discussed at the working meeting held in Vienna from 4 to 8 November 2019.

OBJECTIVE OF THE REGIONAL STRATEGIC PROFILE

The objective of the 2022–2029 RSP is to establish a strategic framework for cooperation for countries in the LAC region based on a descriptive analysis of the most pressing problems and needs in the regional context that can be addressed by using and applying nuclear technology.

The framework for cooperation represented by the 2022–2029 RSP will be a programmatic reference of major importance for the preparation of project and programme proposals for ARCAL, and for the Agency in terms of the Technical Cooperation programme for the region.

This RSP will also serve to improve regional cooperation through better communication and dissemination of the impact of Technical Cooperation projects, which could help to attract strategic partners from within and outside the region, with a view to developing projects with greater benefit and impact.

It is important to note that the 2022–2029 RSP provides a dynamic strategic framework — in other words, in view of the conditions, needs and problems of the region at a given time, project proposals that have not been covered in this publication may be put forward if they are in line with the principles, standards and quality criteria of the Agency's Technical Cooperation Programme.

SCOPE OF THE REGIONAL STRATEGIC PROFILE

This RSP includes the following priority sectors for the application of nuclear techniques:

1. Food and agriculture: food security, agriculture, food, veterinary medicine and industrialization;
2. Human health: nuclear medicine, radiotherapy, medical physics, radiopharmacy and nutrition;
3. Environment: atmosphere, sea, water and soil resources;
4. Energy: electricity generation and research reactors;
5. Radiation safety: regulatory aspects and radiation protection, including workers, patients, the public and the environment;
6. Radiation technology: industrial processes, radiation treatment, advanced materials, cultural heritage and inspection technologies.

In addition to these six groups, gender equality is also considered as a cross-cutting aspect in this RSP.

STRUCTURE OF THE REGIONAL STRATEGIC PROFILE

This publication establishes a descriptive analytical profile of the region's most pressing needs and problems[1] and the priority with which they can be addressed using available nuclear technology.

To that end, professionals from various thematic groups were consulted to conduct a SWOT analysis.

To define the prioritization, specific attributes were assigned to the needs and problems in terms of severity, time, extent, relevance and level of difficulty. The resulting values allow for a quantitative comparison among them, while the different levels of development of each country in the thematic areas are also considered. The prioritization methodology is described in Annex 2022–2029 RSP.

When a need and/or problem was characterized, the following aspects were considered:

- Justification of the need or problem setting out clearly the situation to be addressed. This justification establishes qualitative and quantitative baselines of the identified situation;
- An objective at the strategic level that can be achieved during the period 2022–2029, considering that ARCAL and the IAEA's Technical Cooperation programme work based on two-year cycles, and within the limit of available financial resources;
- A results indicator for the objective, so that achievement can be verified;

[1] For the purpose of formulating needs or problems:

- a need may be anything that is desirable and concerns an unsatisfactory situation or a shortcoming;
- a problem is a situation to be resolved.

- A forecast of its possible impact in the region.

METHODOLOGY FOR THE PREPARATION OF THE REGIONAL STRATEGIC PROFILE

The 2022–2029 RSP was prepared based on a regional sectoral analysis, the identification of priority needs and problems, their respective strategic objectives and indicators, and considering the UN SDGs where nuclear technology can contribute.

The SDGs covered by this RSP are:

- SDG 1- NO POVERTY;
  Goal 1: End poverty in all its forms everywhere.
- SDG 2- ZERO HUNGER;
  Goal 2: End hunger.
- SDG 3- GOOD HEALTH AND WELL-BEING;
  Goal 3: Ensure healthy lives and promote well-being for all at all ages.
- SDG 4- QUALITY EDUCATION;
  Goal 4: Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.
- SDG 6- CLEAN WATER AND SANITATION;
  Goal 6: Ensure availability and sustainable management of water and sanitation for all.
- SDG 7- AFFORDABLE AND CLEAN ENERGY;
  Goal 7: Ensure access to affordable, reliable, sustainable and modern energy.
- SDG 8- DECENT WORK AND ECONOMIC GROWTH;
  Goal 8: Promote inclusive and sustainable economic growth, employment and decent work for all.
- SDG 9- INDUSTRY, INNOVATION AND INFRASTRUCTURE;
  Goal 9: Build resilient infrastructure, promote sustainable industrialization and foster innovation.
- SDG 11- SUSTAINABLE CITIES AND COMMUNITIES;
  Goal 11: Make cities more inclusive, safe, resilient and sustainable.
- SDG 12- RESPONSIBLE CONSUMPTION AND PRODUCTION;
  Goal 12: Ensure sustainable consumption and production patterns.
- SDG 13- CLIMATE ACTION;
  Goal 13: Take urgent action to combat climate change and its impacts.
- SDG 14- LIFE BELOW WATER;
  Goal 14: Conserve and sustainably use the oceans, seas and marine resources.
- SDG 15- LIFE ON LAND;
  Goal 15: Sustainably manage forests, combat desertification, halt and reverse land degradation and halt biodiversity loss.
- SDG 17- PARTNERSHIPS FOR THE GOALS;
  Goal 17: Revitalize the Global Partnership for Sustainable Development.

This publication also considers the importance of the cross-cutting aspect of gender equality, linked to SDG 5 – GENDER EQUALITY - Achieve gender equality and empower all women and girls.

Preparation of this RSP was coordinated by the M&E Group, comprising seven national ARCAL coordinators and one representative of the Research Centre for Energy, Environment and Technology (Spain), a strategic partner of ARCAL.

The M&E Group was supported in coordinating the preparation of the RSP by the following:

1. A planning expert;
2. An Agency officer designated by the Director of the Division for Latin America.

The M&E Group was in close contact with the ARCAL Steering Group to provide updates on the work in progress and to receive feedback.

When drawing up the RSP, a working group was formed for each thematic area, comprising:

1. A thematic area coordinator;
2. Agency staff members: a programme management officer designated by the Director of the Division for Latin America to provide project management assistance to each of the thematic sectors, and TOs designated for that purpose by the Agency's technical departments;
3. Two or three experts in the relevant sector providing a mix of technical specialization within one thematic area:
    3.1 Experts from the region nominated by national ARCAL coordinators, to be group leaders.
    3.2 Experts named by regional and/or UN organizations, invited to participate in preparing the new RSP.
    3.3 Agency experts nominated by the Secretariat to participate in thematic working groups.

THEMATIC AREAS

In the 2022–2029 RSP, the six thematic groups identified a total of 44 needs and problems. The specific analysis using the methodology applied is set out in each Section of the publication. The needs and problems are as follows:

2.6.1. Food and agriculture

A1. Improvement of practices for the management of water, soil, agrochemicals and biofertilizers, including biological nitrogen fixation.

A2. Improvement of food crops of economic importance to cope with various biotic and abiotic stress conditions.

A3. Improvement of animals of recognized economic importance and support for initiatives to improve the yield/production and commercial potential of animals reflecting the region's biodiversity.

A4. Incidence of transboundary diseases, including those with zoonotic repercussions, and of mandatory declarations.

A5. Availability of foods of animal origin (including aquaculture products) and plant origin that meet safety and quality standards.

A6. Damage caused by pests to foods of animal and plant origin.

A7. Supporting initiatives for the development of aquaculture in the region.

A8. Strengthening of mosquito control strategies.

2.6.2. Human health

S1. Insufficient number of professionals trained, and clinical guidelines harmonized to enable the use of new multimodal imaging technologies for diagnosis, risk stratification and guidelines for the appropriate treatment of cardiovascular and cerebrovascular diseases.

S2. Insufficient number of professionals trained, and clinical guidelines harmonized to enable the use and development of radiopharmaceuticals and dosimetry for diagnosis and treatment with theranostics.

S3. Insufficient number of professionals trained, and clinical guidelines harmonized to enable the use of new technologies in nuclear medicine and diagnostic imaging, principally hybrid teams and the improvement of existing equipment.

S4. Insufficient human resources qualified in medical physics in the region.

S5. Lack of radiotherapy departments with the appropriate technology and qualified human resources and using the available technology optimally and safely.

S6. Need for technological advancement by adding more brachytherapy units and providing related human resources training.

S7. Need to strengthen quality management systems for radiation medicine in the region.

S8. Insufficient capacity to take the actions needed to improve the nutritional status of the population.

2.6.3. Environment

M1. Insufficient knowledge of the availability and inadequate management of water resources.

M2. Insufficient knowledge of water quality and sources potentially contributing to its pollution.

M3. Insufficient knowledge of the main processes affecting coastal zones, oceans and marine resources.

M4. Insufficient knowledge of the concentration of atmospheric particles and aerosols, their composition, and their impact on human health.

M5. Insufficient evaluation of soil degradation and pollution and the impact on human health.

2.6.4. Energy

E1. Incorporation of the subject of energy systems into educational programmes in the region, from school through to university level.

E2. Establishment of a network for the exchange of information and coordination of strategies, from research reactor operators to the radioisotope end user.

E3. Availability of national, subregional and/or regional energy plans that include SDGs 7 and 13.

E4. Incorporation of the CLEW concept into energy planning discussion forums in the region.

E5. Nuclear power plant lifetime extension.

2.6.5. Radiation safety

R1. Limitations of some regulators as regards control of facilities and activities (medical X rays, new technologies, etc.) and of some governments in establishing and maintaining an appropriate governmental, legal, and regulatory framework for safety.

R2. Insufficient implementation of international safety requirements and recommendations for controlling occupational exposure, with a focus on extremity and lens dosimetry, internal dosimetry, monitoring of workplaces, laboratory quality systems and national dose registers.

R3. Limitations in the calibration capacities of the region's standards dosimetry laboratories as regards radiation protection, radiodiagnostics and radiotherapy.

R4. Insufficient implementation of international safety requirements and recommendations and of the ten actions in the 'Bonn Call for Action' for controlling medical exposure, with a focus on advanced radiotherapy technologies, interventional and fluoroscopic procedures, digital radiology, tomosynthesis, dental CBCT, multi-slice computed tomography, and SPECT–CT and PET–CT.

R5. Insufficient implementation of international safety requirements and recommendations for radiation protection of the public and the environment and in the management of radioactive waste. In particular, work needs to focus on national policies and strategies, management of disused radioactive sources, and the identification and resolution of radiological situations due to the presence of NORM.

R6. Limited capacities in countries for planning, notification, and response regarding radiological emergencies, including systematic analysis of accidents and dissemination of information.

R7. Insufficient implementation of international requirements and recommendations concerning education and training on radiation safety, transport and waste for all staff members involved, with a focus on national strategies.

R8. Insufficient regulatory control of radioactive material in public places (i.e., during transport).

R9. Insufficient implementation of international leadership and management requirements concerning safety among end users, scientific/technical support services and regulators.

R10. Limited capacity for the safety assessment of facilities and activities, with a focus on reactors, cyclotrons, radiopharmacy and existing exposure situations.

2.6.6. Radiation technologies

T1. Treatment of domestic, industrial, and pharmaceutical wastewater (drugs, organic compounds, biological contamination, microplastics, etc.) through RP.

T2. Phytosanitary treatment of fresh, frozen, dehydrated, and processed food using ionizing radiation.

T3. Harmonization of Quality Assurance and Quality Control (QA/QC) in irradiators and dosimetric intercomparisons.

T4. Development of innovative, competitive, and environmentally friendly materials with radiation technologies, for use in health, agriculture, and industry (nanotechnology, composite materials, new curable formulas, etc.).

T5. Increase in industrial competitiveness through the optimization of processes and reduction of environmental impact, using radiation technologies such as radiotracers and sealed radioactive source applications, among others.

T6. Characterization and preservation of tangible cultural heritage objects and archived materials using nuclear techniques.

T7. Harmonization of methodologies and training of personnel in accordance with certification schemes and standards for advanced non-destructive testing techniques.

T8. Sustainable processing of the region's renewable non-toxic natural resources (natural polymers) to increase agricultural production and reduce waste and pollution.

2.6.7. Gender equality

In addition to these six thematic groups, the following guidelines relating to gender equality are also considered, as a cross-cutting aspect:

- Promoting the full and equal participation of women, in areas related to nuclear science and technology, in particular in decision making processes;
- Addressing the lack of tools for empowering women and girls in these areas, regarding training, access to leadership positions, the establishment of networks and raising the profile of their work;
- Tackling the scarcity of statistical data on the participation of women in these areas to assess the issue and promote policies for gender equality.

GUIDE FOR THE IMPLEMENTATION OF THE REGIONAL STRATEGIC PROFILE

To achieve the long term results of the 2022–2029 RSP, specific objectives and precise indicators are needed, rooted in updated baselines facilitating the establishment of targets to be achieved through Technical Cooperation projects.

Within this framework, the need to develop an implementation strategy for the 2022–2029 RSP was identified, based on the needs and/or problems established for each sector and their prioritization. This strategy will be presented in a complementary document entitled 'Guide for the Implementation of the 2022–2029 RSP' once it is reviewed by the members of the ARCAL Technical Coordination Board (ATCB) and validated by the Board of ARCAL Representatives (BAR).

PROCESS OF PREPARING THE REGIONAL STRATEGIC PROFILE

The 2022–2029 RSP was prepared during meetings of the M&E Group, in accordance with the work timeline as follows:

First meeting of the M&E Group

Location: Vienna
Date: 5 –7 November 2018
Duration: 3 days

At this meeting, the M&E Group established the terms of reference (ToR) for evaluating the RSP for 2016–2021 and the timeline for gathering information on the implementation or status of the projects in the period covered by the current RSP.

Second meeting of the M&E Group

Location: Vienna
Date: 1–5 April 2019
Duration: 1 week

This meeting involved the thematic experts invited to take part in the project evaluation process, and the Agency's technical officers and programme management officers.

During the week, the projects falling under the 2016–2021 RSP were evaluated following the guidelines for project monitoring and evaluation given in the ToR. The meeting report was also drafted, which served as a reference document for the preparation of the 2022–2029 RSP.

XX ATCB meeting

Location: Cuba
Date: 20–24 May 2019
Duration: 1 week

At this ATCB meeting, the proposed ToR for the preparation of the 2022–2029 RSP were discussed, amended, and approved, as was the selection of needs and problems for the 2022–2023 biennium, based on the evaluation conducted at the April 2019 meeting.

XX BAR meeting

Location: Vienna
Date: September 19th, 2019
Duration: 1 day

At this BAR meeting, the proposed ToR for the preparation of the 2022–2029 RSP were discussed, amended, and approved.

First meeting of the thematic groups

Location: Vienna
Date: 4–8 November 2019
Duration: 1 week

Participants at this meeting conducted the strategic sectoral analysis and identified the needs and problems for 2022–2029, along with the strategic objectives, result indicators and prioritization set out in this publication.

The following Sections present the analysis and needs/problems established in each of the thematic sectors of the 2022–2029 RSP.

FOOD AND AGRICULTURE

3. FOOD AND AGRICULTURE

GENERAL ANALYSIS OF THE REGIONAL SITUATION

Regarding food and agriculture, several the characteristics of the SWOT analysis undertaken in the previous RSP still prevail in the region. However, important new opportunities associated with the region's great diversity in climate, biology and natural resources (availability of land, water, etc.) have presented themselves, and these factors will have an impact on the potential increase in the production of high-quality food. The starting point was to determine needs and/or problems without taking into account the application of nuclear techniques. Subsequently, following an analysis of possible solutions, nuclear techniques were found to be tools of considerable value in addressing many of the needs and/or problems identified, as we will see later. The main challenges relate to the following UN SDGs: SDG 1, SDG 2, SDG 3, SDG 7, SDG 8, SDG 13, and SDG 15.

The subsectors covered in this publication are the same as those considered in the previous RSP and fall into four main categories: agriculture, food, animal health and industrialization. They are as follows:

- Mutation induction, selective breeding and genetic improvement of plants;
- Integrated management of soil, water, plants, fertilizers and environmental protection;
- Integrated pest management and control of plant and animal diseases;
- Animal production and health;
- Quality foods, including functional foods that are free from toxic residues and substances harmful to health.

In 2019, the Food and Agriculture Organization of the United Nations (FAO) estimated the world population was over 7 billion, of whom approximately 9% live in LAC [1]. Owing to the increasing exodus to urban areas, only 25% of people on average live in rural areas, although in the poorest countries this proportion exceeds 40%. It is important to note that despite efforts to reduce poverty, rural areas still account for 29% of poverty and 41% of extreme poverty in the region [2], [4]; therefore, efforts in this sector unquestionably contribute to alleviating hunger and ensuring economic progress for millions of people in the LAC region (SDGs 2, 3 and 8) [5].

Agriculture in the region can be divided into two main categories. The first is smallholders, who constitute a large majority but use a small fraction of the total farming land; nevertheless, they are the ones who contribute the most to the production of food consumed daily by the local population, using minimal agricultural technology and extractivist or subsistence farming methods. The other, smaller group is major producers, who are mainly engaged in agribusiness in the region.

The LAC region occupies 12.1% of the global agricultural land area (1592.76 million ha) and has one of the largest areas in the world that could still be used for agricultural purposes (980 million ha). Discounting the land currently being used, approximately 787.27 million ha remain [1]. Therefore, the region could increase its agricultural area at least fourfold. This, together with its high level of biological diversity, means that the region offers a great potential and opportunity for the future development as far as food production is concerned. The potential for the development of regional agriculture and aquaculture, which are growing rapidly, needs to be noted [5], [6]. In this regard, FAO considers that, given that the world population is increasing and could exceed 9 billion in 2050, food production needs to grow by more than 70% [7], [8]. Bearing in mind the potential resources available, the region is expected to increase production to meet more than 30% of the global demand for food. This explains the urgent need to develop sustainable farming techniques in the region to meet SDGs 2 and 3.

Over the last two decades, considerable progress has been made in controlling hunger and undernutrition, with the percentage of the population affected falling from 13.5% to 6.5%. Nevertheless, 42 million people living in the region are still affected by subnutrition, primarily in the Andean, Central American and Caribbean countries. This problem is linked to disparities in the level of agricultural development to produce food (including grains, cereals, meat and milk) between the subregions. A small number of countries, including Argentina, Brazil and Uruguay, produce between 5 and 10 times their current demand for food, while in others there remains considerable room for improvement [9]. This issue relates to the achievement of SDG 2.

It is important to note that since 2011, regional poverty reduction indicators have plateaued, and in some subregions have gone down. If this situation prevails, the regional target under SDG 2 to end hunger and all forms of malnutrition by 2030 will not be met [4]. In contrast, the region has taken important steps to eradicate infant undernutrition and decrease maternal, neonatal and under five mortality rates and deaths due to non-communicable diseases; this suggests that it is on track to meet the first two targets under SDG 3 [10].

The region also has great potential to offer the world new food crops, since it is home to five of the planet's ten mega centres of biodiversity (Brazil, Chile, Mexico, Paraguay and Peru) [11]. The New World, which is where the region is located, has provided the largest variety of agricultural crops that today form the basis of humanity's food supply, including potato, maize, beans, tomato, cassava, cucurbit, avocado, cacao and garlic. Other roots, tubers and cereals, including amaranth, kiwicha and quinoa, are widely used and are being increasingly cultivated. Regarding stockbreeding, the LAC countries have large populations of the main species of livestock, numbering 450 million head and distributed across the different subregions. These constitute the economic basis for various sectors, both in terms of local and regional trade and in relation to large scale industrial exploitation and the export of derivatives. Since they are indigenous species (as in the case of South American camelids) or were introduced at least 200 years ago by European colonizers (as in the case of cattle, sheep, goats, and buffalo), these populations have special and select gene pools that have enabled them to adjust and adapt to the region's different agroecological zones. Therefore, the LAC region is considered a safety net of global food security.

The LAC region produces 14% of all food worldwide and accounts for 23% of global exports of staple agricultural and fishery products. Over the next decade, it is expected that, in the region, there will be a 22% increase in agricultural production (60% owing to yields and 40% owing to the expansion of the agricultural area), triple the global average of 7%. The stockbreeding sector is expected to grow by 16%, eight times the global average of 2%. Regional meat consumption will increase by around 8 Mt, or 17%. Regional meat production will be more export oriented [12]. This contributes to the achievement of SDG 2.

To sum up, although generally positive results have been seen in the area of food production in the region, a series of important challenges need to be overcome in the coming years to achieve sustained development in the food sector that is consistent with higher levels of growth and social well-being and is combined with the conservation and use of biological diversity without harming natural resources. For this development to occur, it is necessary for regional agricultural activity to increase significantly, in a sustainable manner. Numerous specialists in economic development have identified technological change as the variable that contributes most to economic growth. In LAC, for example, it is calculated that approximately 40% of the improvements achieved in agricultural production are attributable to technological change. This is very similar to what has been seen worldwide, where, over the last 50 years, more than 40% of the rate of increase in food production is believed to have

been due to the use of nitrogen fertilizers [13]. Studies are being done to improve the rational use of this important agricultural consumable to minimize any possible negative environmental impact.

Regarding the use of nitrogen, the nutrient with the greatest impact on agricultural production, it is important to note that the region has successfully developed technology relating to biological nitrogen fixation (BNF) by microorganisms that work in symbiosis or are associated with crops, in particular legumes such as soya. Use of the BNF technique ensures that more than 62% of the regional agricultural demand for nitrogen is met. Soya alone, which occupies 60 million ha, produces more than 64 Mt of protein, in addition to oil for human consumption and bioenergy [9]. This contributes to the achievement of SDGs 2, 7 and 13.

As stated previously, the LAC region is home to approximately 9% of the world's population and accounts for 14% of global food production and 23% of global exports of staple agricultural and fishery products. For this reason, while the region boasts one of the world's highest per capita production rates for grains and cereal crops (1.9 kg/person/day), 6.5% of its population (42 million) are highly undernourished, owing primarily to extreme poverty and a lack of economic resources to buy food [12]. Hence, support is needed to develop national policy and strategy to protect and prioritise the population – rather than just enabling export of produce. Except for Argentina, Brazil, Mexico and Uruguay, the majority of countries depend primarily on the development of agriculture. Meeting this challenge would help to achieve SDGs 2, 7 and 13.

It needs to be noted that both developed agriculture, which is based on the intensive use of agrochemicals (fertilizers, pesticides, etc.) and less developed or extractivism agriculture, also known as subsistence agriculture, which is based primarily on the exploitation of poor-quality soils, have been causing significant environmental damage in the region, in particular with regard to the degradation of land, biodiversity and natural resources. There is therefore a high risk that SDGs 12, 13 and 15 will not be met.

On the other hand, it is important to note the high potential for aquaculture in the region. Around 172 Mt of caught and farmed fish and fish derivatives are consumed (annually) worldwide. Global per capita consumption is 20.6 kg/person/year and is expected to reach 21.5 kg/person/year by 2030. Per capita consumption in the LAC region stands at 10 kg/person/year. By 2030, fishery and aquaculture production in the region is expected to grow by 24.2% from 12.9 to 16 Mt. The greatest increase of 49% will be seen in the aquaculture sector, in particular, in Brazil and Peru, with carp, tilapia, salmon, shrimp and oysters being the most farmed species. Accordingly, the region will continue to be the world's second largest producer after Asia [6], [12]. This contributes to the achievement of SDGs 2 and 3.

3.1.1. Challenges that need to be overcome to contribute significantly to food security in the region and worldwide

It needs to be borne in mind that positioning agriculture as a net provider of food and a strategic sector for regional development has brought with it negative consequences, including the progressive degradation and erosion of arable land owing to intensive use, inadequate management practices and inappropriate use of fertilizers and irrigation (risk of soil losses owing to salinity caused by negligent drainage practices); and the ongoing reduction in natural woodland in order to increase the land available for the production of pasture crops and industrial crops for export.

The intensification of agriculture has also been contributing to environmental degradation. This is reflected in a loss of biodiversity due to the replacement of native crops with high-value cash crops and frequent contamination by agrochemicals used in pest control and the post-harvest treatment of

agricultural products. The loss of food products during and post-harvest is also important to note. This is due to problems relating to transportation and inadequate preservation and storage (production of mycotoxins, for example). Meeting this challenge would help to achieve SDGs 2, 3, 7 and 13.

Technological change in the region is still insufficient to successfully respond to growing domestic demand for food and take advantage of the opportunities offered by the international trade liberalization. In this context, it is assumed to also count with a sustainable agricultural development, based on agricultural products without concomitant effects for human health or damage to the environment. Technologies include sustainable management systems, such as direct sowing (zero-tilling) and the integrated crop-livestock farming system, which rotates grain and cereal crop cultivation periods with pasture crop cultivation periods. Such systems are widespread in Brazil, Argentina, and Paraguay, but need to be expanded or adapted for other subregions. It needs to be noted that the integrated crop-livestock farming system could offer better prospects for the recovery of degraded pastureland (amounting to more than 300 million ha), which will help to mitigate the greenhouse effect by reducing methane emissions per unit of product (meat or milk) and increasing soil carbon sequestration. Meeting this challenge would help to achieve SDGs 2, 3, 8 and 13 [5].

In the subregions of South America and the Caribbean there is inadequate control of various agricultural pests, notably flies affecting fruit and vegetables, which cause losses of between 20 and 40%. Pests that affect livestock production, such as the New World Screwworm (NWS) (*Cochliomyia hominivorax*), reduce the yield and quality of meat, milk and leather. Efforts to address this issue will contribute to the achievement of SDGs 2, 3, and 8 [5].

In the subregion of South America, a new pest is emerging; *Lobesia botrana*, which attacks vine fruits, was recently detected in Chile and Argentina and there is a high risk that it will spread to the vine-growing areas of Uruguay, Paraguay, Brazil, Plurinational State of Bolivia, and Peru, affecting fruit production and trade and the South American wine industry. Meeting this challenge will contribute to the achievement of SDGs 2, 3 and 8 [5].

The regional livestock sector is at risk from transboundary diseases such as foot and mouth disease, avian influenza, and bovine spongiform encephalopathy. This is facilitated, among other things, by the huge borders between the countries, which measure more than 50 000 km in length, since in most countries control is minimal. Efforts to address this issue will contribute to the achievement of SDGs 2, 3 and 8 [5].

Progress is being made in regional agriculture in marginalized areas with low productive capacity, poor soils and a lack of crop varieties that are resistant to various forms of biotic and abiotic stress (pests, diseases, constraints relating to moisture, salinity, acidity, etc.). These problems are accelerated by climate change, calling for ongoing efforts in genetic improvement. In this connection, genetic improvement in general considers the need to preserve plant and animal biodiversity. Efforts to address this issue will contribute to the achievement of SDGs 8 and 13.

Regional aquaculture development will depend on improved nutritional strategies, health control, genetic improvement, and the conservation of natural biodiversity in aquaculture (shrimp, various species of fish, oysters, etc.). Efforts to address this issue will contribute to the achievement of SDGs 2, 3 and 8.

Regarding food quality, the intensification of crop and livestock farming, and the industrialization of food production are associated with the increasing use of agrochemicals (fertilizers, pesticides, hormones, and various preservatives). Residues of these substances can exceed established

international limits, posing a high risk that products will be rejected and thereby leading to economic losses for the region. Efforts to address this issue will contribute to SDGs 2 and 3.

There is a lack of technological change to which nuclear technologies could contribute when it comes to the development of good practices:

- use and management soil and water resources;
- genetic improvement of agricultural and livestock species, both traditional and non-traditional;
- prevention, suppression and eradication of transboundary agricultural and livestock pests and diseases;
- management of health-related and genetic constraints in the rearing of livestock species and captive aquatic organisms;
- timely diagnosis of animal diseases;
- control and monitoring of toxic substances in food that pose a risk to health;
- prevention of residues in food that pose a risk to human health;
- strengthening of networks and capacity to support analytical services.

3.1.2. Contribution to the UN SDGs

An assessment of the situation relating to food and agriculture in LAC revealed the main challenges that need to be overcome to contribute significantly to food security in the region and worldwide. These challenges relate mainly to the achievement of SDGs 2, 3, 7, 8, 13 and 15 [5].

SWOT ANALYSIS

3.2.1. Strengths

(1) The existence of local entrepreneurs capable of adopting innovative technologies in the agricultural and aquaculture sectors;
(2) The edaphoclimatic diversity enables the region to be a major world supplier of an extensive range of agricultural products of importance for food and in industry;
(3) The region accounts for a significant percentage of world trade in agricultural and livestock products, including soya, sugar, coffee, fruit, meat, fish and dairy products;
(4) The region has a large amount of unexploited or underused land, amounting to around four times the area currently in use, that if appropriate, could be used to expand agricultural activity. It also has 34% of the world's freshwater, which has considerable potential for use in irrigated agriculture and is expected to significantly increase agricultural production [14];
(5) The region boasts extremely high levels of biodiversity and could offer the global community new agricultural and aquaculture products with economic potential and high nutritional or medicinal value (grains, cereals, roots, tubers, fruits, camelids, fish, shellfish, etc.);
(6) Development and implementation of agricultural techniques, such as BNF, the genetic improvement of animals and plants, direct sowing, the integrated crop-livestock farming system and the biological control of pests for the sustainable production of food in the region, and existence of scientific and technological institutions with trained personnel;
(7) The expansion of sustainable agriculture over vast agricultural areas will help to increase soil carbon sequestration and mitigate the greenhouse effect, thus helping to reduce the effects of climate change;
(8) Increase in national services and subregional agreements for the prevention and control of transboundary pests and diseases, which contribute to the suppression or eradication at the subregional level of agricultural pests and livestock diseases, including the screw worm;

(9) Public policies and strategies to promote food security are being implemented in the region;
(10) The existence of risk management systems relating to agroclimatic factors, emerging diseases, and food and environmental contaminants;
(11) The region has an abundance of water resources (seas, rivers, and lakes) with the potential to increase regional aquaculture by more than 49% by 2030 [6].

3.2.2. Weaknesses

(1) Scientific and technological institutions work in isolation and duplicate activities, and it is well known that there is a lack of ongoing networked studies and research at the regional level;
(2) A clear lack of continuity in research into and the spread of technologies owing to frequent leadership changes in research programmes and national health services;
(3) Insufficient participation of the private sector in initiatives to promote relevant scientific and technological development;
(4) Inadequate coordination among international organizations associated with food security in the region;
(5) Insufficient application of biotechnology in the region to meet the needs of the agricultural sector;
(6) Sufficient production has not been achieved to meet the demand for staple foods in some countries of the region, in particular, in the Andean subregion and part of Central America and the Caribbean, posing a risk that SDG 2 to end hunger and all forms of malnutrition by 2030 will not be met;
(7) The inadequate application of international quality standards relating to food products for domestic consumption and for export poses a potential risk to human health and to the ability to meet market requirements;
(8) Significant food losses in the post-harvest period owing to the lack of appropriate infrastructure.
(9) The potential emergence of new pests and weeds owing to the effects of climate change, and resistance resulting from the irrational use of agrochemicals and medicinal drugs, which exacerbates the contamination of the environment by these products;
(10) Limited ability among rural producers to benefit from the spread and transfer of technology;
(11) Low availability of varieties and breeds of plants and animals that are tolerant to biotic and abiotic stress factors influenced by climate change.

3.2.3. Threats

(1) Introduction and expansion of emerging and re-emerging non-native or endemic diseases and pests in the region, leading to the excessive use of pesticides for their control. For example, a new pest that affects vine fruits (*Lobesia botrana*) was detected recently in Chile and Argentina and there is a high risk that it will spread to the vine-growing areas of Uruguay, Paraguay, Brazil, Plurinational State of Bolivia, and Peru, affecting fruit production and trade and the South American wine industry;
(2) Reduction in arable land to produce staple foods due to increasing production of crops for industrial use (soya, maize, sugar equivalent, etc.);
(3) The existence of non-tariff barriers on the region's agricultural products. Reduction in agricultural productivity because of global climate change.

3.2.4. Opportunities

(1) Growing demand on the international market for agricultural and aquatic products. The region has the potential to help meet global food demand in 2030. According to the FAO, Brazil will have the potential to meet 28% of the global demand for food in 2050 [7].

(2) Growing demand for food products with special qualities, such as functional foods rich in dietary fibre, minerals, vitamins, antioxidants, prebiotics, and probiotics.
(3) Openness on the part of countries to sign cooperation agreements in the area of science and technology, together with local capacity to develop synergistic agreements between the public and private sectors.

NEEDS AND PROBLEMS

Below are the needs and/or problems identified by the working group, accompanied by their respective justifications.

A1. Improvement of practices for the management of water, soil, agrochemicals and biofertilizers, including BNF

Justification: While smallholders in the LAC region produce more than 70% of the food intended for the population, it is precisely this group who are constrained by poor soil quality and the limited use of available technology. Except for countries in the region's subtropical and temperate zone, the soil in most countries in the Andean and tropical zone (particularly Brazil and the countries of Central America) is naturally nutrient-poor or very nutrient-poor and presents toxicity issues caused by high levels of aluminium, iron, and manganese. This results in very low yields of food products, leading to poverty, hunger, and sub nutrition [9], [12].

Considering the poor quality of the soil, one indicator of the level of agricultural technification is the use of fertilizers. While the region consumes 11.5% of the world's fertilizers, Brazil, Argentina, and Mexico alone consume 79% of those used in the region [1], [9], indicating a serious regional imbalance. It be noted that in virtually all countries of the region, agricultural technology is geared primarily towards industrial or export crops (notably soya, sugar cane, coffee, bananas, fruits, and vegetables) and very little towards food crops (beans, rice, maize, potato, cassava, and sweet potato). One technology that has a major impact on intensive agriculture is based on BNF in soya. This is a typical regional technology used by large producers that enables more than 64 Mt of protein to be produced annually, without the use of nitrogen fertilizers, with highly positive impact on the economy and on the environment. Only in the regional soybean crop the BNF process is present in over an area of 60 million hectares distributed across Brazil, Argentina, Paraguay, and the Plurinational State of Bolivia [15], [16]. However, it is very rarely applied to species in the same family as soya, legumes, staple food crops such as beans and peas or cereal crops such as maize and sugar cane, which are very likely to benefit from BNF [17], [18]. There is also a clear need to improve nitrogen availability in the poor soils exploited by smallholders using green manure and organic fertilizers [19], [20]. Recently, it has been demonstrated that simply by increasing the nitrogen content of soil, it is also possible to increase the carbon content, which helps to mitigate the greenhouse effect [21]. Two technologies for the management of sustainable agricultural systems are becoming more widespread across the region, particularly among large producers of grains, cereals, and meat. The first is direct sowing (zero-tilling), which is used over approximately 60 million hectares in Argentina, Brazil, and Paraguay. The other is an integrated crop-livestock farming system, which is fully under way in Argentina and Brazil and involves the rotation every 2 to 3 years of cereal crop cultivation periods with pasture crop cultivation periods [22]. These systems not only have the advantage of contributing to the sustainable production of foods over large areas, but they also have the potential to reduce the degradation of, or indeed rehabilitate, land while significantly helping to mitigate the greenhouse effect and promoting soil carbon sequestration [23]-[25]. In view of the above, there is an urgent need to adapt these technologies based on the technological principles underpinning them and/or to develop new techniques for the region's various agricultural areas.

The use of nitrogen-15 (^{15}N) as a tracer is a fast and economical nuclear technique which offers a way of producing recommendations for efficient fertilizer management (dose factors, sources, localization, fractionation, and application methods) [26]-[28]. The ^{15}N isotope dilution and ^{15}N natural abundance techniques are also extremely useful for evaluating the efficiency of BNF in legumes, allowing more efficient varieties and microbial inoculants to be selected [26]. Techniques using ^{13}C will make it possible to evaluate the efficiency of management systems relating to soil carbon sequestration and its dynamics over time, with a view to promoting the sustainability of the agricultural system [21], [24], [25]. Soil losses due to erosion, which are significant in the region, can be assessed using various tracers, including beryllium–7 (^{7}Be), caesium–137 (^{137}Cs), plutonium-239+240 ($^{239+240}Pu$) and lead-210 (^{210}Pb) [29]-[35].

The efficient use of water in agriculture is a matter of worldwide concern. Agriculture consumes over 70% of fresh water in LAC and, although the region has large reserves of this resource, it is important to optimize its use [36] [37]. In this regard, techniques based on the management of oxygen-18 (^{18}O) and hydrogen–2 (^{2}H) isotopes also present good prospects for studying the efficiency of water use by crops. The neutron probe technique, which is already established, enables soil water content to be monitored and new techniques developed more recently and based on the use of cosmic rays hold promise.

It is also important to note that in certain cacao-producing areas, in the region's volcanic zone in Central America, some soils have naturally high levels of soluble cadmium and arsenic, which can affect the quality of products. It is therefore necessary to find management methods that reduce the bio solubility of these metals. Fortunately, these elements have isotopes that are being used to develop tracing techniques in environmental studies.

The direct beneficiaries will be large and small scale farmers, who will be able to maintain and/or recover the productive capacity of their land, and society in general, which will benefit from the availability of a greater quantity of nutritious foods and the reduced risk of environmental degradation. All of this will have a positive impact on food security.

Objective: To improve systems of agricultural production in the countries of the region while seeking to ensure sustainability.

Indicator: Percentage of increase in crop yields and adoption of sustainable agricultural systems.

A2. Improvement of food crops of economic importance to cope with various biotic and abiotic stress conditions

Justification: Climate change is causing increasing damage to agriculture, putting food production at risk in various parts of the world. The LAC region is vulnerable to climate change, and declining crop productivity will jeopardize food security. Many countries in the region, in particular, those where subsistence farming predominates, produce insufficient quantities of cereals and legumes, which are staple foods for the population. One example is Peru, a vulnerable country located in South America, where it is estimated that crop yields will decrease by 17% by 2050 owing to rising temperatures [38], [39]. This will have a serious impact on food availability in a country that imports many staple foods such as wheat and maize. Therefore, the ability of crops to adapt to climate change has become a critical need.

The application of nuclear techniques to improve plant species could contribute to the development of varieties that are adapted to climate change. The induced mutation technique, mutation detection and the use of biotechnology, including in vitro and molecular techniques, for mutation breeding,

could be used in the development of new varieties that are tolerant to salinity and drought, resistant to pests and diseases and of an appropriate quality.

The application of induced mutation techniques, supported by the Joint FAO and IAEA Division, has had a considerable agronomic and economic impact in many countries. The FAO and IAEA database of mutant varieties illustrates the importance of mutant induction as an effective tool for crop improvement. Information on more than 3 314 officially released and commercial mutant varieties is currently recorded for more than 220 crop species worldwide. In the Andean region, which is located 3 000 to 4 000 metres above sea level, agricultural activities face adverse climatic and soil conditions. In this regard, crop improvement is carried out on quinoa *(Chenopodium quinoa*), amaranth *(Amaranthus)* and kiwicha (*Amaranthus caudatus*), an important food source for the indigenous peoples of the Peruvian Andes. In addition, the barley (*Hordeum vulgare*) variety 'Centenario', produced in 2006 using irradiation techniques for mutation induction is being cultivated today in the valleys of the Peruvian Andes, producing high yields. Other examples can be found in Cuba and Brazil. In Cuba, the mutant rice *(Oryza sativa, L.),* variety INCA LP-7, which is high-yielding and tolerant to salinity and pests, has contributed to national food security for more than 20 years [40]. Brazil has developed improved mutant lines of rice (*Oryza sativa*) that are resistant to aryloxyphenoxypropionate herbicides thanks to induced mutations and are currently being released by farmers [41] .

Another critical need relating to crop improvement is the development of resistance to transboundary plant diseases such as Panama disease, which affects bananas and has significantly restricted banana production around the world for more than a century, including in the countries of Latin America. The disease is caused by a soil-borne fungus called *Fusarium oxysporum f. sp. cubense*. The pathogen (the TR4 strain) remains viable in the soil for decades and is therefore difficult to eradicate. Another major disease in the region is coffee leaf rust, which is caused by the fungus *Hemileia vastatrix*, an obligate parasite that affects the leaves of the coffee plant. This has become a concern for Latin American coffee-producing countries [42]. The Agency and the FAO have launched a coordinated research project focusing on these important diseases. Collaboration with the Agency would therefore be a major asset in supporting the development of new varieties of various plantain and coffee species resistant to such diseases. The mutation technique and biotechnology, combined, can contribute to the development of new banana and coffee varieties that can adapt to the environmental conditions in Latin America [43].

Objective: To increase yields of crops that are adapted to various stress conditions resulting from the effect of climate change.

Indicator: Number of high-yield varieties that are adapted to various stress conditions.

A3. Improvement of animals of recognized economic importance and support for initiatives to improve the yield/production and commercial potential of animals reflecting the region's biodiversity

Justification: The centre of gravity of livestock production is moving southwards and some countries are emerging as powerful new players on the global market [44]. The FAO estimates that the global population could exceed 9 billion by 2050. Therefore, based on the level of livestock production in 2010, chicken meat production will need to increase by 170%, dairy, beef and lamb production by 80–100% and pork production by 65–70% to meet the demand for food products of animal origin in 2050. This represents a significant challenge for LAC if it is to be competitive in meeting future demand for livestock products and ensure food security in the countries of the region [45].

One way to reduce the food deficit in the region is by increasing animal production in a sustainable manner. In recent decades, the genetic improvement of livestock has brought about significant increases in productivity and resistance to diseases and pests. Nuclear techniques are used in the area of animal improvement to control the reproductive cycle to shorten the period between births, using radioimmunoassay techniques to measure the hormonal status of animals; and to ensure nutritional efficiency using isotopic labelling techniques.

Sustainability is based on the general principle that the needs of the present have to be met without compromising the ability of future generations to meet their own needs. The use of sustainable control practices means not only that those practices are maintained over time (technical sustainability) but also that they will not cause adverse environmental effects (environmental sustainability) and that they will ensure human (socioeconomic) sustainability [46].

The need to reduce the vulnerability of domestic animals is both subregional (in the case of South American camelids in the Andean region) and regional (in the case of 'creole' breeds of cattle, sheep, goats, and buffalo). This requires the establishment of plans for the genetic characterization, conservation and use of these breeds in a manner that would allow the germ plasm to be preserved in situ, and the identification of the genes that give these animal populations their adaptive characteristics to carry out selective breeding, thus improving productivity levels in specific environments in the region.

Nuclear energy is extremely important in genetic characterization processes for generating (X ray) irradiated cell hybrid deoxyribonucleic acid (DNA) panels for genetic mapping and/or owing to its use in radioactive labelling processes [phosphorus–32 (^{32}P) and phosphorus–33 (^{33}P)] for the synthesis of radioactive DNA probes in the analysis of genome regions. With the combined use of these nuclear techniques and other biotechnology techniques, it is possible to achieve a better understanding of the processes that control gene activation in animals that have adapted to the different agroecological zones in the region. Once the genes involved in the adaptation process are known, their expression in different physiological and or environmental conditions can be studied simultaneously, generating useful information for the development of tools for the genetic selection of superior animals, and appropriate management strategies for these genetic resources.

These measures will lay the groundwork for the development of gene-based technologies, the use of genetic markers in the assisted reproduction of species of zootechnical interest in the region and the appropriate use of animals of high genetic merit. These results will facilitate the better use of reproductive biotechnologies, including programmes for artificial insemination and embryo transfer, and improve strategies relating to the use of forage resources for animal feeding and mitigation of the GHGs effects.

During the second half of the 20th century and the early 21st century, the world has undergone a process of accelerated modernization, experiencing growth that is unsustainable in the long term [47]. This makes it necessary to provide agricultural producers throughout the region with these technological and sustainable tools. Knowledge of animal germ plasm with the genetic characteristics of adaptation and high productivity and quality and its use in sustainable environmental management tends to increase the value of animals and their by-products and, consequently, increase the earnings of farmers and the foreign currency revenue of countries.

Objective: To increase food production through the improvement of animals performance.

Indicator: Number of genotyped animals.

A4. Incidence of transboundary diseases, including those with zoonotic repercussions, and of mandatory declarations

Justification: The countries of the American continent are separated by approximately 50 000 km of land borders that were put in place essentially for geopolitical reasons and do not prevent the movement or spread of diseases and pests. In this regard, the Global Framework for the Progressive Control of Transboundary Animal Diseases, the outcome of a formal agreement between the World Organization for Animal Health (OIE) [48] and the FAO [49], addresses the challenge of combating animal diseases from a regional and hemispheric perspective. This represents a major challenge for LAC if it is to compete in meeting future demand for livestock products and ensuring food security in the countries of the region.

Given that the global population is expected to exceed 9 billion in 2050, is expected the increase of animal production to satisfy the growing demand for meat and milk. This undoubtedly creates unique opportunities for the American continent to meet future market demand and ensure optimal health conditions.

The atomized family livestock production system, which is widespread in the LAC region, plays a central role in addressing the issue of hunger and generates food products for the domestic market, improving food security and nutrition, creating jobs for families, and ultimately contributing to national development [45]. The system relies on support from official, highly qualified veterinary services, which provide tools that allow families to ensure that the food they produce meets the minimum safety standards.

In this connection, various steps are being taken in the region that, although isolated, seek to develop and/or improve services for the epidemiological monitoring and control of emerging transboundary animal diseases of economic importance. At the same time, a wide technology gap exists between the countries of the region, despite the transboundary nature of this issue and its major relevance for the regional economy. Moreover, the steps mentioned above are accompanied by limiting factors that hinder full development, such as the presence of animal diseases that decimate livestock resources and increase the cost of production, both in the industrial sector and in the family livestock production system. They include screw worm myiasis, foot and mouth disease, classical swine fever, avian influenza, rabies and bovine spongiform encephalopathy [45]. An outbreak of one of these diseases would lead to losses and cause serious damage to stockbreeding and economic activity in the entire region due to the economic barriers imposed by countries that import animal products and their derivatives.

In recent years, increasing challenges in the area of animal production, including the obligation to declare certain transboundary diseases, in particular, those with zoonotic repercussions, the widespread use of veterinary medicine, the effects of climate change and the overexploitation of agricultural land, call for particular attention to be paid to the issue from a regional perspective. Among the challenges to be addressed is the need to harmonize the criteria used by veterinary laboratories in the region, in particular in relation to tackling diseases that have consequences for and effects on human health. It is therefore vital to establish a regional network for cooperation between official veterinary laboratories, similar to those in place in Africa and Asia. Through the generation and exchange of analytical data relating to these challenges, national and regional authorities are provided with information that enables them to contribute to the creation of public policies and strategies for the control and mitigation of these diseases and reduce their impact on the population. There is an urgent need for counties to produce reliable national and regional analytical information on the presence of diseases subject to mandatory declaration, to draw up a proper risk analysis for the

establishment of control and mitigation policies necessary for the protection of health and the environment.

To be able to tackle transboundary animal diseases with a zoonotic impact that are priority issues for Member States, laboratories in all countries of the region need to develop and enhance their capacity in the use of nuclear and other technologies for the detection and differentiation of animal diseases. They need to also be prepared to provide swift and accurate diagnosis of emerging diseases, using modern and appropriately validated technologies. This work has to include the use of serological and molecular tools for the detection of diseases and support in the use of advanced methods of pathogen differentiation and the implementation and maintenance of relevant international standards (International Organization for Standardization/ International Electrotechnical Commission (ISO/IEC 17025 [50]). Nuclear techniques are utilized in the development and use of radioactive DNA probes for high-sensitivity processes (such as DNA and ribonucleic acid (RNA) blotting) to detect pathogenic agents in field samples; these need to serve as a reference to validate other detection methods involving the analysis of nucleic acids [51]. The use of vaccines and serums that have been inactivated using ionizing (gamma) radiation is an important application of nuclear energy in this subsector, since it allows reference samples to be exchanged among countries and subregions, facilitating the standardization of methods between zones with different health classifications, in line with current international standards.

The primary beneficiaries of this work will be the economies of all countries of the region, whose epidemiological monitoring services will obtain more swift, accurate and efficient methods of detecting these types of pathogenic agent, allowing them to verify their technical and managerial competence in the area of animal health together with the countries that import their livestock products, while also promoting the prevention and control of emerging diseases. Those who use the family livestock production system will also benefit directly, since the control of these diseases will ensure the sustainability of their commercial capacity.

Objective: To improve preparation for and response to transboundary animal diseases.

Indicator: Increase in the number of official laboratories using harmonized protocols and having appropriate interaction with the competent authorities in their countries.

A5. Availability of foods of animal origin (including aquaculture products) and plant origin that meet safety and quality standards

Justification: The LAC region is home to two thirds of the world's available freshwater resources and more than a quarter of the global medium to high potential agricultural land area. As such, it is one of the world's main exporters of food products and its agricultural production continues to increase [52], [53].

To meet increasing demand for food and prevent plant and animal pests and diseases, the use of antimicrobial agents [54] and pesticides cannot be avoided. Residues of these compounds pose risks to human health and the environment, and hinder or compromise trade [55] and the economies of producing countries.

The region produces a wide range of products, including coffee, plantain, grapes and other fruits found in temperate climates (pineapple, cactus pears and citrus fruits), cereals (wheat, maize, rice, soya), meat and milk. All these products are associated in one way or another with residues or contaminants. The risks to health are both acute and chronic. It is also important to note that the

irrational use of pesticides and antimicrobials in agriculture is associated with greater resistance to pests and pathogens that affect agricultural production.

Contaminants such as mycotoxins [56], [57] and toxic elements [58] pose further challenges to health, trade, and agricultural production in the region. Toxic metals such as cadmium, of both natural and anthropogenic origin, have significant implications for health and the trade in agricultural products. In some cases, including in the European Union, exposure to these metals is reduced by establishing strict limits that affect trade [59]. Other elements of concern include methylmercury, arsenic, and lead from various sources [60].

Another serious problem in the region is the habitual use of fumigants to resolve plant health issues and overcome quarantine barriers. Many of these fumigants have been banned around the world (e.g., ethylene bromide) or are in the process of being banned (e.g., methyl bromide), since it has been shown scientifically that their use has negative effects on human health and the environment.

The main international export markets for agricultural products, including the European Union and the United States of America, have made traceability a priority and relevant capability is of critical importance. Traceability relates to the tracking of food products through all stages of production, processing and distribution to identify and address risks and protect public health. Other agricultural products can also be distorted or adulterated with a view to making illegitimate economic gains. Overcoming these challenges will require effective systems to test product authenticity.

Nuclear techniques in conjunction with techniques for chemical and molecular biology analysis are the tools that offer the best prospects for overcoming the problem of pesticide residues, and the use of irradiation treatment is a good alternative to treatment with fumigants. The irradiation of food products helps producers to meet health standards and reduce post-harvest losses.

Systematic programmes to monitor residues and contaminants, which support state of the art analytical laboratories that meet international standards (e.g., ISO/IEC [50]) will help producers and farmers to adopt good farming and production practices. This in turn will contribute to the production of safe, high-quality products and the prudent use of chemicals in agriculture. Well-established laboratories will also support national and international risk assessment and management initiatives, including the establishment of standards and guidelines (e.g., the CODEX Alimentarius) that impact public health and global trade.

Objective: To improve the safety and quality of foods.

Indicator: Increase in number of official, accredited analytical laboratories and food irradiation facilities. Percentage reduction in products rejected for export and percentage of countries in the region with established monitoring plans.

A6. Damage caused by pests to foods of animal and plant origin

Justification: Fruit flies of various species, including *Anastrepha spp.* and *Ceratitis spp.*, are the pests that cause most damage to fruit and vegetable crops in the region. In countries where they are not controlled or control is deficient, they can cause 20–40% losses in production. Moreover, owing to the phytosanitary requirements imposed by the international market, the presence of this pest in a country severely limits that country's fruit and vegetable exports and given the transboundary nature of the problem, can sometimes restrict exports from neighbouring countries.

Because of its high mobility and reproductive capacity, the best way to reduce the losses caused by this pest is to replace traditional means of control using insecticides from orchard to orchard (which pose a high risk of product contamination) with the establishment of areas that have a low prevalence or are free of the pest. To establish low prevalence or fruit fly free areas, the phytosanitary approach *per se* is wide area integrated pest management, one of the main components of which is biological control that includes the use of the sterile insect technique (SIT) involving gamma radiation.

There are currently two regional scenarios that could be considered as specific strategic objectives to be implemented within a time frame of 15 years. The first is the suppression of native fruit flies in localized areas in the Caribbean and Andean subregions; the second is prevention of the re-emergence and transboundary spread of species of fruit fly in Latin America owing to increased movement of agricultural products or the creation of new biological niches as a result of climate change.

Also, regarding foods of plant origin, it appears that the European grapevine moth (*Lobesia botrana*), a pest that is native to Europe and was detected in Chile and Argentina around 10 years ago, has been posing a serious threat to the South American wine industry. Considered worldwide as one of the main soft fruit pests, it is one of the most destructive in terms of its effect on grapevines. Its larvae directly damage grape bunches, from the flowering stage through the ripening phase to the harvest and cause indirect damage by promoting secondary fungal infection. In table grapes this results in a loss of quality, and in wine grapes fungal residues imbue the wine with unpleasant aromas and flavours and occasion technical problems relating to clarification. This, moreover, does not include the indirect damage relating to market restrictions and closures, the application of regulations and crop quarantine measures.

Furthermore, this pest reproduces in vines established in urban areas before migrating to commercial orchards, which is where it causes the greatest economic damage. The fact that it exists in urban areas limits the potential for control using insecticides. Therefore, the most appropriate alternative control measure to protect both the rural and the urban environment is the SIT.

Though it has only just begun to establish itself in Chile and Argentina, the European grapevine moth has already caused considerable economic damage to vineyard production in these two countries. It is vitally important to suppress this exotic pest using the SIT, to prevent it from spreading at the national level and beyond, which could affect wine-producing regions in neighbouring countries such as Uruguay, Paraguay, Brazil, Plurinational State of Bolivia, and Peru,

Regarding the production of foods of animal origin, livestock development is severely hampered in the South American countries and on most of the islands of the Caribbean because of myiasis caused by the NWS (*Cochliomyia hominivorax)*. This affects livestock production and causes significant commercial losses associated with the livestock herd, estimated at over 450 million head (cattle, horses, pigs, sheep, goats, etc.), and a deterioration in the quality of leather. There is an urgent need to control this pest since its negative impact on the livestock sector in the region is clearly increasing.

To reduce losses in the livestock sector and develop production capacity in this area in South America and the Caribbean, specific strategic objectives have been established: first, to maintain areas free from the NWS in Mexico and Central America and, second, to collect and share technical information and build the capacity of national animal health bodies in the use of the SIT. Lastly, a third strategic objective that is being prepared is the long term eradication of the NWS on the American continent.

Objective: To control plant and animal pests and diseases.

Indicator: Percentage of area monitored and where plant and animal pests and diseases are controlled.

A7. Supporting initiatives for the development of aquaculture in the region

Justification: There is considerable potential in the region for the development of aquaculture, thanks to the extensive coastline and large water basins. Furthermore, the animal protein produced in aquaculture is of high economic and nutritional value but continues to be relatively underutilized. Aquaculture today is possibly the fastest-growing food production sector in the world, accounting for almost 50% of the world's fishery products used for food [6]. In Latin America and the Caribbean, notably in Chile, Mexico, Peru, Argentina and Ecuador, aquaculture is the sector demonstrating the most considerable growth. At 18.5%, the rate of growth over the last 30 years has been more than double the global average rate of 8.2%, with salmon, trout, shrimp, tilapia, and mussels being the most cultivated species [6], [11].

However, for the sector to succeed, it is necessary to take various actions including the appropriate development of structured programmes to control the recurrence of diseases in cultivated species. New biotechnologies are being used to promote health in the sector through conventional selective breeding for resistance to disease and the molecular and diagnostic characterization of different pathogen strains. These analyses can provide information on the origin of the pathogen and its presence in tissues, whole animals, water or even soils. Molecular techniques have been used to detect viral diseases in marine shrimps and to detect bacteria and fungi in fish in various parts of the world. Data from the OIE indicates that there is a need to develop laboratories with the skills to provide this type of service, and to establish rules to control the transit of these organisms and their products between countries.

Considering that here is relatively little known about the biology of these organisms and their pathogens, compared to terrestrial domestic animals, and the fact that the cultivation of various aquatic species of economic importance depends on the collection of 'seed' propagating material in natural populations in the environment, with the consequent fish and shellfish genetic deterioration from the intensive cultivation programmes, there is an urgent need to establish monitoring and genetic improvement programmes. Nuclear technologies offer great scope for application and can be used to generate genome region DNA probes with radioactive labelling [phosphorus–32 (^{32}P) and phosphorus–33 (^{33}P)] used in gene mapping.

The immediate beneficiaries of the programme would be the inhabitants of coastal areas and regions with water resources, who would have access to accurate and rapid services for the monitoring of health and production conditions in their systems, which yet do not exist in several subregions.

Objective: To contribute to the development of regional aquaculture.

Indicator: Increase in number of aquaculture producers and increase in the production and quality of aquaculture products.

A8. Strengthening of mosquito control strategies

Justification: The mosquito is currently the world's deadliest disease-transmitting insect, causing more than 700 000 deaths per year. Discounting Zika and chikungunya, dengue alone was contracted by more than 2 million people in LAC in the first seven months of 2019, of whom 723 died of the disease. One of the most well-known species of mosquito is *Aedes aegypti,* a highly invasive anthropogenic species that transmits numerous diseases in the LAC region, including dengue, chikungunya, yellow fever, Mayaro and Zika. The lack of vaccines, growing resistance to insecticides and the public health and environmental implications of the excessive use of chemical products heighten the need to find alternative and sustainable mosquito control strategies.

In February 2016, the UN declared Zika virus infections in the Americas a public health emergency of international concern. Zika is now considered a long term challenge, meaning that it is likely to become an endemic problem in the region. In addition, dengue and chikungunya are exacerbating public health issues throughout the region. The incidence of dengue, for example, increased five-fold in Brazil between 2018 and 2019. Mosquito-borne viruses, in particular dengue, Zika fever and chikungunya, are responsible for the region's high mortality and morbidity rates.

The LAC region faces the emergence and resurgence of these three arboviral diseases that are transmitted by the *Aedes aegypti* mosquito, a species that has adapted well to urban areas and breeds easily in stagnant water around homes. This is a highly invasive species commonly found in the tropics and the region's subtropical areas. The issue of multiple viruses (dengue, Zika and chikungunya) and strains that use mosquitoes as vectors persists throughout the region and takes a considerable toll on people and the economy. Increased resistance to insecticides among mosquitoes of this species also makes it harder to control populations.

In the past, vector control programmes have been enhanced through the integration of innovative technologies such as the SIT as an additional control method. This increases the capacity of Member States to reduce mosquito numbers, thus contributing to the overall reduction of these populations.

The use of the SIT as an additional mosquito control tool involves the sterilization of male insects using ionizing radiation. This currently constitutes a safe and clean method that does not require the use of chemical products or antibiotics. Male insects are bred in large numbers at production facilities and are exposed to ionizing radiation that renders them infertile. These sterile males compete with wild males for wild females and mate without producing offspring, thus gradually reducing the mosquito population.

Objective: To build capacity to integrate the SIT in current mosquito control programmes.

Indicator: Increase in number of pilot tests implemented at selected field sites and in number of sterile mosquitoes released per year.

PRIORITIZATION OF THE NEEDS AND PROBLEMS

The following Table 1 and Fig. 1 reflect the final prioritization grades, determined by the variables outlined, of numerous issues in the food and agriculture sector, followed by a visual comparison of these grades shown in Fig. 1.

TABLE 1. PRIORITIZATION OF THE NEEDS AND PROBLEMS IN THE FOOD AND AGRICULTURE SECTOR

P	Need/Problem	Severity	Time	Extent	Relevance	Total grade	Difficulty	R/D	Final grade
1	A2	4.81	4.63	4.81	4.69	18.94	1.56	3	56.8
	Improvement of food crops of economic importance to cope with various biotic and abiotic stress conditions.	The region needs to address the challenge of increasing food production while adapting to climate change and without impacting the environment (increase the unit yields of plants).	The processes to improve plants are relatively slow, and immediate action is therefore required to achieve the expected results.	This extends throughout the region, with each subregion presenting its own peculiarities (variety of plant species).	In addition to the nuclear methods of mutation induction, the nuclear component also forms part of an extensive chain of biotechnological processes.		Efforts are required to characterize the germ plasm of native plants. The process of improving varieties has been advancing very slowly in general.		
2	A8	4.63	4.88	4.69	45	18.7	1.44	3.12	58.43
	Strengthening of mosquito control strategies.	Discounting Zika and chikungunya, dengue alone was contracted by more than 2 million people in LAC in the first seven months of 2019, of whom 723 died of the disease.	Global warming and increased international trade have promoted the invasion of *Aedes* species, which transmit dengue, chikungunya and Zika. This calls for the immediate use of all tools that will help to suppress populations of these insects, which threaten to become an endemic issue.	All Latin America and the Caribbean.	The lack of vaccines and resulting impact on public health, in addition to increased resistance to insecticides and the implications of their irrational use, heighten the need for alternative and sustainable mosquito control methods such as the SIT.		Public health protection is a service that is sometimes difficult for national institutions in developing countries to finance.		

TABLE 1. PRIORITIZATION OF THE NEEDS AND PROBLEMS IN THE FOOD AND AGRICULTURE SECTOR (cont.)

P	Need/Problem	Severity	Time	Extent	Relevance	Total grade	Difficulty	R/D	Final grade
3	A7 Supporting initiatives for the development of aquaculture in the region.	4.75 Aquatic species are abundant in the region and are still not appropriately exploited.	4.56 The issues of increased productivity, genetic deterioration and the severity of epidemics caused by infectious diseases require urgent action.	4.75 This has a regional dimension in relation to both the sea and water basins, with peculiarities in each subregion (variety of aquifer species).	4.56 The nuclear component forms part of an extensive chain of complex biotechnological processes.	18.63	1.75 Requires specialized training and coordination of a high number of (technical and business) institutions.	2.60	48.54
4	A6 Damage caused by pests to foods of animal and plant origin.	4.38 Loss of economic value of products of animal and plant origin with significant effects on regional economies.	4.38 Lack of attention may lead to an unexpected increase in and/or emergence of pests.	4.56 Pests are present throughout the region (except Chile for the fruit fly), particularly in areas where fruit, vegetables and livestock are produced. It is transboundary in nature.	4.38 Nuclear technology has the advantage of eliminating the problem without the use of agrochemicals.	17.66	2.5 Requires specialized training and coordination of a high number of (technical and business) institutions.	1.75	30.94

TABLE 1. PRIORITIZATION OF THE NEEDS AND PROBLEMS IN THE FOOD AND AGRICULTURE SECTOR (cont.)

P	Need/Problem	Severity	Time	Extent	Relevance	Total grade	Difficulty	R/D	Final grade
5	A1 Improvement of practices for the management of water, soil, agrochemicals and biofertilizers, including BNF.	4.31 The agricultural soils of the region are very poor in nutrients and are subject to degradation because of inappropriate management.	4.5 In view of the global demand for food, there is an urgent need to develop sustainable agricultural systems to increase production and control land degradation.	4.31 It affects the entire region with various degrees of magnitude in the subregions.	4.44 Nuclear tracers help in evaluating the efficiency of agricultural practices, providing for the rational use of inputs, and make it possible to determine the extent of land degradation and monitor the process of rehabilitation.	17.56	1.75 There are some established methodologies, but their use is limited owing to a lack of dissemination and user training and the limited availability of functional laboratories.	2.5	43.9
6	A3 Improvement of animals of recognized economic importance and support for initiatives to improve the yield/production and commercial potential of animals reflecting the region's biodiversity.	4.31 Animal production requires more productive and efficient breeds that are adapted to the region's climatic conditions.	4.62 Animal improvement has long term effects, and immediate action is therefore required to meet the growing demand for meat.	4.38 This extends throughout the region, with each subregion presenting its own peculiarities (breeds of animal species).	4.25 Nuclear techniques form part of an extensive chain of biotechnological processes derived from nuclear technology.	17.56	2.19 Requires the optimization of techniques and integration among the competent authorities of countries for effective action in the dissemination of these technologies.	1.94	34.08

TABLE 1. PRIORITIZATION OF THE NEEDS AND PROBLEMS IN THE FOOD AND AGRICULTURE SECTOR (cont.)

P	Need/Problem	Severity	Time	Extent	Relevance	Total grade	Difficulty	R/D	Final grade
7	A5 Availability of foods of animal origin (including aquaculture products) and plant origin that meet safety and quality standards.	4.19 In addition to permanent risks to human health, the economic losses due to contamination of foods have a serious effect on the region.	4.19 The ongoing existence of established capacity to monitor food contaminants is required, owing to the unpredictable nature of the problem.	4.13 It affects almost all countries.	4.19 Existing nuclear techniques are of key importance in processes to detect contaminants.	16.7	2.5 Limited degree of implementation of active and standardized laboratories in the region.	1.67	27.88
8	A4 Incidence of transboundary diseases, including those with zoonotic repercussions, and of mandatory declarations.	4.0 Diseases are emerging and are transboundary in nature with the potential to inflict serious damage on the economy and public health.	4.12 There is a need to maintain a state of constant vigilance to coordinate rapid and effective responses during epidemics.	4.12 Present throughout the region and transboundary in nature.	3.88 The nuclear component forms part of an extensive chain of biotechnological processes.	16.12	2.06 Requires optimization of techniques and integration among the competent authorities of countries for effective action in the event of an epidemic.	1.88	30.3

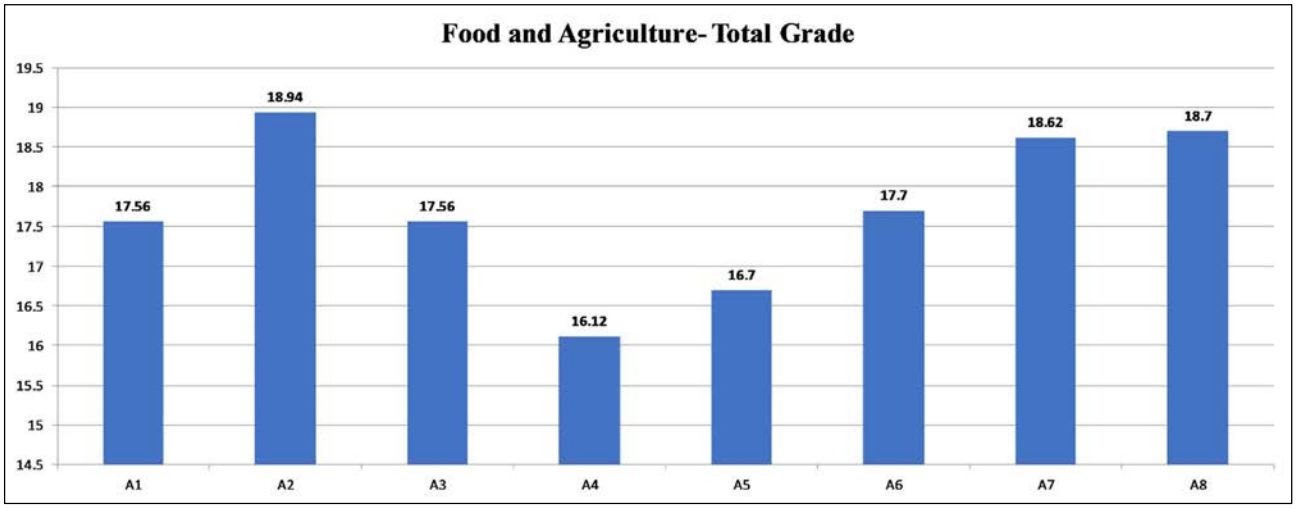

FIG. 1. Needs and Problems in Food and Agriculture vs Total Grade

HUMAN HEALTH

4. HUMAN HEALTH

GENERAL ANALYSIS OF THE REGIONAL SITUATION

4.1.1. Epidemiology

The world is currently undergoing dramatic demographic change. From the beginning of the last century to present, the global population has increased from 2 billion people to over 7 billion. This figure is expected to reach 10 billion by the end of the current century [61]. Furthermore, substantial population changes relate to new and diverse fertility patterns (including childbearing during adolescence), mortality, migration, urbanization, and ageing [62].

In 2019, according to PAHO, in its publication 'Health Trends in the Americas', the total population of the Americas was 1.01 billion inhabitants. In terms of subregion, LAC's population represents more than 60% of inhabitants in the American continent [62].

Two distinctive aspects of the population distribution in the Americas are urbanization and the existence of large megalopolises. The continent had the highest proportion of urban population in the world, estimated at 81% in 2021 [63]. The region has two of the world's six most populated cities: Mexico City and São Paulo, each with around 20 million inhabitants.

Fertility, mortality, and migration are the basic elements that give rise to changes in a population; size structure and distribution are the drivers of demographic change. The fertility rate was 1.9 children per woman in 2020, and life expectancy at birth was 73 years [63].

Regarding population distribution by age and sex, even though the young population (0–19 years) has predominated until now in LAC, at the beginning of the third decade of this century, the largest group is expected to be the young adult population (20–39 years). In 2045, it will be the adult population (40–49 years) and 10 years later, the older adult population (60 years and over) [64]. Another current ageing trend relates to the sex differential. In 2015 in the Americas, there were 83 men to every 100 women in the 60-plus age group, and 62 men to every 100 women in the 80-plus age group. The highest proportion of older adult women is in LAC, in the Southern Cone. This peculiarity, commonly known as the 'feminization of ageing' has major implications for public policies, in particular, those relating to health.

Demographic changes, evolving ways of life, and environmental, behavioural and economic factors have led to non-communicable diseases replacing or, in some cases, coexisting with, the burden of communicable diseases in LAC [65], [66]. This epidemiological transition explains the heterogeneous behaviour of mortality of the region [65], [67] where the double burden of communicable and non-communicable diseases is common and imposes an extraordinary cost on the health system [65].

LAC has the greatest socioeconomic disparity in the Region of the Americas, which has translated into high mortality from non-communicable diseases, including cardiovascular diseases, cancer and diabetes [65]. This reversal of trends in mortality from non-communicable diseases is perhaps the largest challenge faced by the region, and its best chance of achieving SDG 3, to ensure healthy lives and promote well-being for all at all ages in LAC [68].

Ageing, globalization, urbanization and an increase in obesity and physical inactivity have led to cardiovascular diseases becoming the main cause of death and disability in the region [65], [69]-[71]. They are the leading cause of death in Latin America (33.7% of all deaths). In 2016, according to

PAHO data, the age-standardized death rates for cardiovascular disease per 100 000 inhabitants were: 150.7 (total), 185.2 (among men) and 121.6 (among women). The age-standardized death rates for cancer per 100 000 inhabitants were: 105.7 (total), 122.4 (among men) and 93.5 (among women). The mortality rate for cerebrovascular diseases was 38.1 among men and 29.9 among women [71].

According to the World Health Organization (WHO), cancer constitutes one third of the non-communicable disease burden in the region [72]. Malignant neoplasms are the second cause of death in the countries of the Americas. The main cancers in LAC are prostate cancer, lung cancer, colorectal cancer, and stomach cancer among men, whereas breast cancer, cervical cancer, lung cancer, colorectal cancer and stomach cancer are the most common among women [73]. The age-standardized cancer mortality rates per 100 000 inhabitants, for men and women respectively, are as follows: 22.9 and 14.3 for lung cancer; 10.7 and 8 for colorectal cancer; 15.4 for prostate cancer; and 14.5 for breast cancer [74].

At the regional level, a rapid and detrimental change is continuing in the eating habits of broad sectors of the population, especially those with lower levels of income and education. The elevated consumption of processed food that is highly calorific, rich in fat, sugars and salt, together with a significant decrease in the amount of fruits and vegetables consumed and a reduction in physical activity, has led to an alarming overweight and obesity epidemic [75], [76]. It is estimated that, in the region, between 50% and 60% of adults and between 7% and 12% of children under five — as well as a third of adolescents — are overweight or obese [74]. These numbers are rising.

4.1.2. Existing human resources and technology

The following human and technology resources are available to address the regional epidemiological situation in the framework of the ARCAL agreement for the promotion and application of current technology:

a) Nuclear medicine equipment:
   - Planar gamma cameras: 265;
   - SPECT: 1840;
   - SPECT-CT: 165;
   - PET/PET-CT: 309;
   - Positron emission tomography coupled with magnetic resonance (PET-MRI): 4;
   - Cyclotrons: 49.

b) Radiotherapy equipment:
   - Cobalt units: 190;
   - Linear accelerators: 878;
   - 3D simulators: 159;
   - Low dose rate brachytherapy units: 287;
   - High dose rate brachytherapy units: 83.

The situation across the region in terms of the production of radioisotopes and radiopharmaceuticals continues to be very heterogeneous. Countries such as Argentina, Brazil, Peru, and Mexico have research reactors allowing national production of radionuclides for the preparation of radiopharmaceuticals to be used in diagnosis and treatment. Only four countries in the region — Argentina, Brazil, Cuba, and Mexico — produce molybdenum-99/ metastable technetium-99 (^{99}Mo/^{99m}Tc) generators; the others import them. Only Argentina, Brazil, Chile and Uruguay produce reagent kits for the preparation of radiopharmaceuticals for diagnosis. The majority of countries in the region have a radiopharmacy operational level of 1 or 2 in accordance with the Agency's

Operational Guidance on Hospital Radiopharmacy [77]. All radiopharmaceuticals for treatment are imported, with the exception iodine–131 (^{131}I), which is produced in Argentina and Brazil.

c) Human resources:
   - Nuclear medicine physicians: 2063;
   - Medical physicists in nuclear medicine: 158;
   - Radiopharmacists: 93;
   - Technologists: 2062.

Radiotherapy is the non-surgical treatment that produces the most cancer cures (surgery 49%, radiotherapy 40% and chemotherapy 11%). It is used for curative purposes in 60% of cases and is even more effective in combination with surgery and/or chemotherapy and, more recently, with biological therapies. It is an effective option for alleviation and control of symptoms in advanced cancer. In many cases it replaces surgery, achieving higher rates of anatomical and functional preservation of organs and improving the quality of life of the cancer patient, both with curative intent and in the case of oligometastasis with radiosurgery techniques. Radiotherapy is also becoming increasingly important in the treatment of non-cancerous lesions, such as benign tumours, and neurological and functional disorders [78].

Medical imaging to support clinical diagnosis has been one of the areas of medicine that has developed the most over the last decade. Interventional radiology has modified the management of many diseases. Many countries are experiencing a rapid increase in the number of procedures using X ray technology, which gives the patients a high dose of radiation and, in turn, leads to a marked increase in the collective radiation dose.

The region continues to have a heterogeneous distribution of technology and unequal access to health; there remains a need to expand national non-communicable disease programmes and to update technology. It is also important to continue training professionals who use advanced radiation technologies, with an emphasis on the training of technicians, the clinical training of medical physicists and paediatrics in nuclear medicine and radiotherapy.

Finally, LAC countries continue to identify and implement new technologies such as theranostics with alpha, beta and gamma emitters, nanomedicine, and artificial intelligence.

SWOT ANALYSIS

4.2.1. Strengths

(1) In the area of nuclear medicine, the region's installed capacity of highly complex equipment (SPECT–CT, PET–CT, PET–MRI) has increased;
(2) Four countries have infrastructure that meets international quality requirements to produce radionuclides and radiopharmaceuticals for diagnosis and treatment, with the potential capacity to export to other countries of the region;
(3) In the area of radiotherapy, there has been an increase in the number of treatment departments and units available, and in the complexity of treatment techniques;
(4) The national standards in most countries of the region address aspects related to quality in the provision of health services. In some, there are specific regulations for quality in radiotherapy, nuclear medicine and radiology services, including association with medical physicists and systematic quality control for equipment and procedures;
(5) In the area of nuclear cardiology, existing inter-institutional, national and international agreements have been strengthened, resulting in better regional integration;

(6) Professional societies exist nationally in some countries and regionally in all areas, and there are functional scientific and strategic support networks;
(7) Regional capacity for conducting quality audits in radiation medicine has been enhanced;
(8) Various virtual training programmes are being implemented in the region, in the nuclear medicine and diagnostic imaging sector, with a view to their introduction in radiotherapy. There are opportunities to participate in training activities (webinars and access to sessions of international congresses);
(9) Some countries of the region have national postgraduate programmes to train human resources in all areas of interest;
(10) There is an advanced radiotherapy master's programme for radiation oncologists within the region, backed by the Agency;
(11) The region has centres with the capacity to offer skills improvement programmes (short-stay) and experts in all disciplines relating to applications of radiation in the health sector. National, regional and international scientific events are held periodically for refresher training, sharing of experience and ongoing education;
(12) The Agency has helped to increase the quality and quantity of professionals trained in all areas;
(13) Most countries of the region speak the same language, which facilitates sharing of experience and ongoing training;
(14) Capacities for the assessment of nutritional problems using stable isotope techniques have been established in most countries of the region as a result of regional and national projects;
(15) Studies of reference dose levels in radiology have been evaluated in some countries.

4.2.2. Weaknesses

(1) Equipment heterogeneity, geographic distribution, difficulties in accessing nuclear techniques and qualified human resources within the region;
(2) Lack of formal recognition in many countries of the region of the various professionals working in radiation medicine;
(3) Lack of harmonized programmes offering general and specific training for nuclear medicine and radiotherapy technicians;
(4) Insufficient number of nuclear medicine and radiotherapy technicians, which affects the quality of the service provided;
(5) Lack of harmonization of postgraduate academic programmes in medical physics;
(6) Lack of clinical training programmes in medical physics following international guidelines in most countries of the region;
(7) Lack of regional guidelines on the education and training of medical physicists in the region;
(8) Unawareness on the part of institutions regarding the roles and responsibilities of medical physicists as health professionals;
(9) Shortage of medical physicists associated with nuclear medicine and diagnostic imaging departments;
(10) Limited access of potential beneficiaries to projects in some countries of the region because national coordinators and project coordinators do not always disseminate information properly;
(11) In the area of nutrition, it is difficult to obtain an objective measurement of nutrient absorption either in the healthy population or in chronic patients;
(12) Deficient or no mechanisms for health authorities to monitor the implementation of radiotherapy and nuclear medicine quality assurance programmes at institutions providing health services;
(13) Limitations in the follow-up of radiotherapy patients and in research capacities to establish results indicators;
(14) Continued use of adult diagnosis and treatment protocols in paediatric patients, which results

in children receiving unnecessary radiation doses and risks and inadequate treatment;
(15) Lack of institutional guidelines and failure to use existing international guidelines in radiotherapy procedures, the implementation of which are fundamental to introducing advanced technologies;
(16) Unawareness of the value of introducing new technologies such as nanomedicine and artificial Intelligence;
(17) Lack of reliable statistics on radiotherapy machines and human resources because the countries have no reporting;
(18) Lack of integrated (team) training programmes for radiation oncologists, medical physicists and radiotherapy technicians.
(19) Optimization remains a challenge in radiation medicine in the region.

4.2.3. Threats

(1) Lack of awareness among decision makers and even medical professionals that cardiovascular diseases and cancer are the main causes of death in the region;
(2) Inadequate use of existing resources or insufficient investment in health in the region, which jeopardizes the continuity of programmes and improvement in the quality of health care;
(3) Speculative overpricing by providers of equipment and inputs, in terms of both sales and maintenance;
(4) Inadequate relationship between medical professionals and the media to provide appropriate information on the issues surrounding chronic non-communicable diseases;
(5) Unawareness of, and limited access to, nuclear cardiology diagnostic procedures, principally using PET and hybrid imaging, including to help evaluate cardiotoxicity in cancer patients;
(6) Limited knowledge — among referring physicians and administrators of health institutes — of the sensitivity, specificity and benefits of nuclear techniques in diagnostic procedures for risk stratification and guidance of treatments;
(7) Flawed mechanisms for health authorities to monitor the implementation of quality assurance programmes in institutions providing health services;
(8) Exodus of human resources trained by the Agency and countries of the area to other sectors or regions;
(9) Dependence on remote systems in making clinical decisions, especially when planning treatment;
(10) Economic and working conditions that prevent families from feeding their children properly in early infancy;
(11) Climate change is altering the composition of foodstuffs, making them less nutritious;
(12) The food industry has developed advertising campaigns that promote unhealthy food among children and young people;
(13) Accelerated increase of overweight and obesity in the region;
(14) Some countries continue to lack national programmes to control non-communicable diseases;

4.2.4. Opportunities

(1) International organizations and national and regional professional scientific societies offer technical cooperation to conduct joint activities, provide training and make quality protocols and guidelines available;
(2) National professional societies in the region can participate in legislative processes and the development of public policies relating to the health sector;
(3) The possibility of improving the performance of radiodiagnosis, nuclear medicine and radiotherapy departments through quality audits organized by international organizations and national dosimetry laboratories;
(4) In most countries, the communications technologies are sufficiently developed for use in virtual learning activities and telemedicine;
(5) In most countries, information technologies are sufficiently developed to allow the increased automation of hospital services and the introduction of elements of artificial intelligence;
(6) Cooperation among international organizations [United Nations Children's Fund (UNICEF), PAHO, WHO] to address the issue of nutrition in early infancy and its influence on the epidemiological problems affecting the population;
(7) Existence of the Programme of Action for Cancer Therapy (PACT) at the Agency;
(8) The possibility of evaluating existing resources and needs of countries, using international databases, such as the Directory of Radiotherapy Centres (DIRAC);
(9) The growing number of professional specialists trained by the Agency in all areas of radiation medicine, who commit to passing on what they have learnt to their peers;
(10) Possibility of professional exchanges to hone skills in the various areas of radiation medicine.

NEEDS AND PROBLEMS

S1. Insufficient number of professionals trained, and clinical guidelines harmonized to enable the use of new multimodal imaging technologies for diagnosis, risk stratification and guidelines for the appropriate treatment of cardiovascular and cerebrovascular diseases

Justification: Cardiovascular diseases are the leading cause of mortality in the region. In women, because the clinical presentation is often atypical, diagnosis is not easy and requires appropriate imaging techniques. Bearing in mind that the region is introducing new technologies at a rapid rate and that technology in the area of radiation medicine is evolving fast, the use of nuclear techniques, including assessment of coronary flow reserve using PET, with an appropriate cost–benefit approach in the current context of multimodal imaging, is of vital importance. Breast cancer is the most common cancer among women in the region. The cardiotoxicity of chemotherapy and radiotherapy treatments necessitates the use of nuclear techniques and echocardiography to evaluate and monitor heart function.

The global prevalence of dementia in LAC is currently 8% [79]. Atherosclerotic artery diseases (the most common being coronary disease) increase the risk of dementia and may lead to cognitive impairment among older people. They both have common causes and risk factors, such as hypertension, smoking and hypercholesterolemia. Owing to their similar pathological mechanisms, prevention of cardiovascular disease can help to reduce the incidence or slow down the onset of dementia. Bearing in mind the value of imaging — with an emphasis on nuclear techniques — in the diagnosis and risk stratification of these patients, it is vital that professionals and technical staff are appropriately trained in this area.

Objective: To ensure that human resources (referring physicians, nuclear medicine physicians, medical physicists, hospital radiopharmacists, radiologists, technicians and nurses) are trained and up to date in the use and benefits of complex technologies in nuclear cardiology and nuclear neurology.

Indicator: Increase in number of professionals trained in the use of complex technologies in nuclear medicine, cardiology and neurology departments.

S2. Insufficient number of professionals trained, and clinical guidelines harmonized to enable the use and development of radiopharmaceuticals and dosimetry for diagnosis and treatment with theranostics

Justification: The development of new pharmaceuticals to treat certain cancer pathologies and the enhancement of other widely used isotopes such as ^{131}I have led to the creation of a discipline known as theranostics, in which diagnostic techniques are combined with targeted therapy using radionuclides; in many cases, the same molecule is used and only the radioactive isotope is changed. Along the same lines, there is a current focus in nanotechnology on developing new theranostic pharmaceuticals.

Objective: To have human resources that are trained with updated knowledge for the development and use of radiopharmaceuticals for theranostics.

Indicator: Increase in number of professionals trained in the development and use of theranostics.

S3. Insufficient number of professionals trained, and clinical guidelines harmonized to enable the use of new technologies in nuclear medicine and diagnostic imaging, principally hybrid teams and the improvement of existing equipment

Justification: The increase in the incidence of chronic non-communicable diseases and the key importance of the appropriate use of diagnostic and therapeutic procedures through nuclear medicine and diagnostic imaging makes it necessary to build the capacities of professionals in a multidisciplinary team and to have more and better equipment.

Objective: To ensure that human resources (referring physicians, nuclear medicine physicians, medical physicists, hospital radiopharmacists, radiologists, technicians and nurses) are trained and up to date in the use and benefits of complex technologies.

Indicator: Increase in number of professionals trained in the use of complex technologies.

S4. Insufficient human resources qualified in medical physics in the region

Justification: The region has the capacity to train medical physicists at the level recommended by international organizations, through structured regional clinical training programmes. However, there is need of regional guidelines taking into account regional specificity. A larger number of medical physicists qualified in nuclear medicine, radiotherapy and radiodiagnosis are required, considering the growing complexity of the procedures used and the increasing number of facilities. This implies establish clinical training programmes in all specializations of medical physics.

Objective: To develop regional guidelines and establish clinical training programmes in all specializations of medical physics.

Indicator: Increase in number of medical physicists clinically qualified and formally recognized by their countries as health professionals, practising in nuclear medicine, radiotherapy and radiodiagnosis in accordance to regional guidelines.

S5. Lack of radiotherapy departments with the appropriate technology and qualified human resources and using the available technology optimally and safely

Justification: In recent decades, advances in radiation oncology with real patient gains have been so rapid that the low- and middle-income countries of LAC have been left behind with respect to the state of the art of both technology and human resources training. Although there has been some technological progress in the countries of the area, there is still a considerable amount of old equipment in operation in the region. Against this backdrop, it is essential to promote technological advancement and to have qualified human resources, regardless of the type of technology used, that can provide effective, efficient, safe and high-quality treatment. A reliable system has to also be introduced to monitor treated patients.

Objective: To contribute to the region's technological advancement and the professional retraining and team training of radiotherapy professionals (radiation oncologists, medical physicists and technicians) through continuing vocational training, comprehensive quality management and strengthened leadership.

Indicator: Increase in number of radiotherapy centres where the technology has been updated, human resources trained, and quality management systems developed and implemented.

S6. Need for technological advancement by adding more brachytherapy units and providing related human resources training

Justification: Cervical cancer is highly prevalent in the region. Locally advanced cervical cancer needs to be treated using brachytherapy. Although technological advancement has begun, with the introduction of high dose rate brachytherapy, many radiotherapy centres still do not have this technology or are using low dose rate brachytherapy — a less effective method that entails problems with radiation protection and source management and is less suitable in terms of comorbidities and quality of life. Moreover, high dose rate brachytherapy is a cost effective treatment for other tumour sites, such as prostate cancer, breast cancer, bronchial cancer, soft tissue sarcoma and childhood cancer, among others.

Objective: To contribute to professional training and to the technological advancement of radiotherapy departments by promoting the addition of high dose rate brachytherapy units that will allow for the appropriate treatment of cervical cancer and other tumours that can be treated with brachytherapy.

Indicator: Increase in number of high dose rate brachytherapy units operational with associated qualified human resources in the region.

S7. Need to strengthen quality management systems for radiation medicine in the region

Justification: The growing complexity of the various types of radiation medicine requires comprehensive quality management to ensure that these medicines comply with international standards and are therefore effective, efficient, and safe for the end user.

Objective: To build capacities for the development and implementation of radiation medicine quality management systems.

Indicator: Increase in number of centres that have implemented a quality management system audited in accordance with the Agency's Quality Assurance Team for Radiation Oncology (QUATRO) [80], Quality Assurance in Nuclear Medicine (QUANUM) [81] and Quality Assurance Audit for Diagnostic Radiology Improvement and Learning (QUAADRIL) [82] methodologies.

S8. Insufficient capacity to take the actions needed to improve the nutritional status of the population

Justification: The economic and working conditions in the region prevent families from feeding their children properly in early infancy. It can also be noted that climate change is altering the composition of foodstuffs, making them less nutritious, and that the food industry has developed advertising campaigns that promote unhealthy food among children and young people. This has all contributed to an accelerated increase of overweight, obesity and malnutrition among the region's entire population. It is difficult to obtain an objective measurement of nutrient absorption either in the healthy population or in chronic patients; this can be resolved by using stable isotope techniques that are already available in the region.

Objective: To build capacity to take the measurements and the actions needed to improve the nutritional status of the population and assess their effectiveness.

Indicator: Increase in number of countries with the capacity to use stable isotope techniques to assess nutritional status.

PRIORITIZATION OF THE NEEDS AND PROBLEMS

The following Table 2 and Fig. 2 reflect the final prioritization grades, determined by the variables outlined, of numerous issues in the human health sector, followed by a visual comparison of these grades shown in Fig. 2.

TABLE 2. PRIORITIZATION OF THE NEEDS AND PROBLEMS IN THE HUMAN HEALTH SECTOR

P	Need/Problem	Severity	Time	Extent	Relevance	Total grade	Difficulty	R/D	Final grade
1	S5 Lack of radiotherapy departments with the appropriate technology and qualified human resources and using the available technology optimally and safely.	4.75	4.0	4.75	4.75	18.25	2.0	2.38	43.34
		Great need for technological advancement and trained human resources.	The gap with respect to the state of the art in cancer treatment be urgently closed.	This problem affects the whole region.	Nuclear techniques are an essential part of radiation treatment.		The region is receptive to improvements in specialization and major investment is not required.		
2	S4 Insufficient human resources qualified in medical physics in the region.	4.5	4.75	4.75	4.0	18,00	3.0	1.33	24.00
		The absence of medical physicists has a direct and fundamental impact on the quality of patient diagnosis and treatment.	Urgent, as the development of new technologies has been faster than the training of medical physicists, with a direct impact on appropriate patient management.	This problem is common to all countries of the region.	Quality and safety (protection of patients, workers and the environment) in diagnosis and treatment depend heavily on the qualified training of medical physicists.		Identification of candidates for training, limitations in academic and clinical training programmes, lack of formal professional recognition.		

TABLE 2. PRIORITIZATION OF THE NEEDS AND PROBLEMS IN THE HUMAN HEALTH SECTOR (cont.)

P	Need/Problem	Severity	Time	Extent	Relevance	Total grade	Difficulty	R/D	Final grade
3	S1 Insufficient number of professionals trained, and clinical guidelines harmonized to enable the use of new multimodal imaging technologies for diagnosis, risk stratification and guidelines for the appropriate treatment of cardiovascular and cerebrovascular diseases.	4.5	4.0	4.75	4.5	17.75	2.0	2.25	39.94
		Cardiovascular diseases, which are mostly atherosclerotic in nature, are the most common cause of mortality in the region. There has been an increase in both cardiovascular and cerebrovascular diseases, owing to demographic and risk factors.	This situation has to be addressed as a priority. Patients who already have the disease need an early and accurate diagnosis to guide their treatment.	This is a substantial health problem affecting the whole region.	Nuclear techniques are essential for detecting ischaemia and play an essential role in evaluating cardiotoxicity in breast cancer patients treated with cytostatic and/or radiotherapy.		It is neither complex nor costly to resolve the issues of training professionals and developing harmonized clinical guidelines. Information needs to be disseminated and replicated in the countries of the region.		
4	S6 Need for technological advancement by adding more brachytherapy units and providing related human resources training.	4.5	3.75	4.75	4.5	17.5	4.0	1.13	19.69
		Major need to increase the number of high dose rate brachytherapy units.	Large number of radiotherapy departments without brachytherapy.	Cervical cancer has high prevalence and high mortality rates in the region.	Nuclear techniques are an essential part of radiation treatment.		Moves required for practical clinical training in brachytherapy units.		

TABLE 2. PRIORITIZATION OF THE NEEDS AND PROBLEMS IN THE HUMAN HEALTH SECTOR (cont.)

P	Need/Problem	Severity	Time	Extent	Relevance	Total grade	Difficulty	R/D	Final grade
5	S3 Insufficient number of professionals trained, and clinical guidelines harmonized to enable the use of new technologies in nuclear medicine and diagnostic imaging, principally hybrid teams and improvement of existing equipment.	3.75	3.5	3.75	45	15.50	2.0	2.25	34.88
		Cardiovascular diseases and malignancies are the leading causes of morbidity and mortality in the region. In this connection, diagnostic and therapeutic techniques in nuclear medicine and radiology play a fundamental role in patient management.	This situation has to be addressed in a prompt and sustained manner because diagnostic imaging techniques are progressing; however, their increased use over time will not depend solely on the training of professionals.	This is a widespread problem in the region owing to advances in technology.	Nuclear medicine can make a substantial contribution in the context of multimodal imaging, principally hybrid teams for the management of patients suffering from these diseases in the region.		It is neither complex nor costly to resolve the issues of training professionals and developing harmonized clinical guidelines. Information needs to be disseminated and replicated in the countries of the region.		

TABLE 2. PRIORITIZATION OF THE NEEDS AND PROBLEMS IN THE HUMAN HEALTH SECTOR (cont.)

P	Need/Problem	Severity	Time	Extent	Relevance	Total grade	Difficulty	R/D	Final grade
6	S2 Insufficient number of professionals trained, and clinical guidelines harmonized to enable the use and development of radiopharmaceuticals and dosimetry for diagnosis and treatment with theranostics.	3.25	4.0	3.5	45	15.25	3.5	129	19.61
		This need has medium importance because the incidence of some of the pathologies that benefit from this technology is lower than other, more common, tumours.	The development and use of new drugs for theranostics in other regions has been much faster than in LAC; this results in inequality for the patients of the region who do not have access to this technique.	This problem is common to all countries that are using or planning to use theranostics as a tool to tackle cancer.	With progress in nuclear medicine, the theranostic approach is a critical step forward in the integral management of cancer patients.		Difficulties in accessing and developing drugs, lack of trained staff, lack of training centres/theranostics producers.		

TABLE 2. PRIORITIZATION OF THE NEEDS AND PROBLEMS IN THE HUMAN HEALTH SECTOR (cont.)

P	Need/Problem	Severity	Time	Extent	Relevance	Total grade	Difficulty	R/D	Final grade
7	S7 Need to strengthen quality management systems for radiation medicine in the region.	3.75	3.0	4.0	4.0	14.75	4.0	1.0	14.75
		Growing complexity of the types of radiation medicine	Requires continuity over time regarding the quality management programmes that are being launched.	This problem affects the whole region.	Important requirement for the effective and safe application of nuclear techniques.		Requires time, resources and coordination within a department.		
8	S8 Insufficient capacity to take the actions needed to improve the nutritional status of the population.	3.0	3.0	45	3.0	13.5	4.0	0.75	10.13
		Nutritional deficiencies owing to economic conditions and climate change affecting food quality.	Technique that takes a long time to implement.	Affects the whole population in the region.	Does not depend solely on nuclear techniques.		Depends on political decisions and use of resources beyond the scope of ARCAL.		

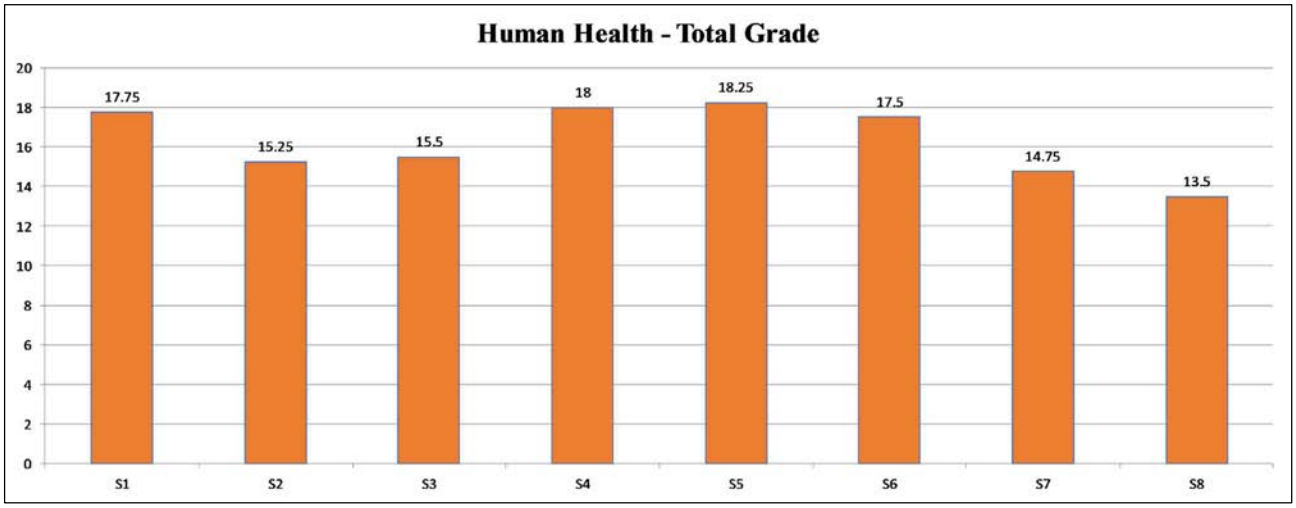

FIG. 2. Needs and Problems in Human Health vs Total Grade

ENVIRONMENT

5. ENVIRONMENT

GENERAL ANALYSIS OF THE REGIONAL SITUATION

The ‘environment’ thematic area of this RSP is characterized and described by means of a structural and comprehensive approach to soil, air and water, essential parameters for the LAC region’s development. As environmental problems and challenges do not confine themselves within national borders, the international cooperation approach can contribute to address, manage and monitor the three environmental elements.

To address the region's needs and problems, it was necessary to examine the implementation of the 2016–2021 RSP, including the results achieved by the ARCAL regional projects. In addition, the experiences shared among LAC countries through their national technical cooperation projects in the peaceful uses of nuclear technology for environmental improvements were analysed to contribute to a better approach of the current regional situation, in terms of improvements and capacities in this field.

In addition, this new period for the 2022–2029 RSP identifies methodologically varied SDGs related to the 2030 Agenda for Sustainable Development, with the aim of incorporating a new planning and monitoring tool to help improve the design and implementation of regional projects resulting in economic, social and technological impact.

Lastly, trends and scenarios for LAC were identified using various relevant qualitative reports and statistical reviews published by international organizations, with a view to updating regional structural data to better describe the status of environmental matters.

There is a clear need for a much faster, further reaching, and more ambitious response is clearly needed to bring about the socioeconomic transformation required to achieve the goals of the 2030 Agenda [83]. The 2019 report on the SDGs provides an empirical forecast for the region [84]. Many countries are taking specific measures to protect the planet, including protecting marine zones, working together in a concerted manner to tackle illegal fishing, ratifying the Paris Climate Change Agreement and communicating their initial nationally determined contributions [85]. Financing, sustainable, and inclusive economies, more effective institutions, better use of data, and the harnessing of science, technology and innovation could, therefore, help to spur progress on all SDGs relating to the area of the environment as identified in this RSP.

Despite the before mentioned progress, the 2019 SDG report pinpoints a range of topics requiring urgent collective attention, as the natural environment is deteriorating at an alarming rate: sea levels are rising, ocean acidification is accelerating, air pollution is increasing, the last four years have been the warmest on record, a million plant and animal species are at risk of extinction, and soils are continuing to degrade uncontrollably. All these problems are not divorced from the reality or negotiable for the region.

In this regard, the 2030 Agenda is a transformative programme with the equality and dignity of people at its heart. It calls for our style of development to change, to become more environment friendly.

According to another ECLAC report — ‘Latin American Economic Outlook 2019’ — after the remarkable progress experienced at the turn of the 21st century, economic growth and socioeconomic advancement in the region had weakened since 2011 [86]. Potential gross domestic product (GDP) growth is lower than expected, at around 3% annually, which reflects low labour productivity and, in

turn, insufficient productivity to further reduce poverty and income inequality. While economic growth in LAC is expected to improve, it remains relatively weak.

Many economies in LAC make intensive use of material and natural resources, which raises an important question as to unsustainable dynamics involving high carbon emissions and depletion of these resources, alongside the increasing importance of the global commitment to combat climate change [87].

Whereas LAC is the global region that emits the lowest amount of GHGs and possesses a major share and high potential in terms of renewable energy, the region is extremely vulnerable to natural disasters and, in the case of the Caribbean, to extreme hydrometeorological events [88], [89]. Several countries within the region are confronted by chronic phenomena, such as desertification, decreasing rainfall, deforestation of the Amazon and exposure to rising sea levels.

The World Meteorological Organization (WMO), in its 2019 annual bulletin, warned that the atmospheric concentration of the main GHGs (CO_2, CH_4 and N_2O) broke a new record in 2018, suggesting that future generations will face increasingly serious effects of climate change [90].

The region requires concerted efforts to ensure healthy lives and promote well-being for all and at all ages, in line with SDG 3. Therefore, a need to work together, providing universal health coverage, ensuring sustainable funding, and tackling environmental factors that contribute to poor health such as air pollution and the lack of water and sanitation.

As stipulated by SDG 6, sanitation for all and the availability and sustainable management of fresh water — an essential and valuable resource for human health, food and energy security, poverty eradication and many other aspects of sustainable development —need to be guaranteed. However, like all existing natural resources, water is under threat owing to high demand in a context of demographic growth on the one hand, and acute scarcity during at least one month per year on the other hand.

LAC possesses one third of the world's renewable water resources, with major river systems that are used for water supplies, electricity generation, transport, recharging aquifers, and as a source of food resources via the products obtained from these large rivers and tributaries. The region has the largest pluvial system in the world, the Amazon, which covers 7.5 million km^2 and, together with other pluvial systems such as the Paraná-Plata and the Orinoco, carries more than 30% of the planet's fresh water to the Atlantic Ocean [91]. More than 70 hydrographic basins in the region are shared by two or more countries, and 60% of the territory of South America is made up of transboundary basins.

Most rivers in LAC are more polluted now than in the 1990s, and this has been exacerbated by the fact that, over the last 100 years, some 50–70% of natural wetlands are estimated to have been lost worldwide [92]. There are many wetlands in continental or coastal environments in the region that depend on groundwater, surface water and/or precipitation. They contribute to water supply, the production of food resources and raw materials, hydrological regulation, and water purification.

Moreover, the region has a significant volume of groundwater resources, which are intensively used by some countries. The Guaraní aquifer which is located in Argentina, Brazil, Paraguay and Uruguay, is one of the largest bodies of groundwater in the world — 1200 km^2 in extent, with an average thickness of 300 m.

Given how important it is to coordinate the better use of water resources, implementing integrated plans to manage them, LAC needs to step up commitments to enhance efforts to increase access to

water and sanitation services, boost wastewater treatment, improve efficient use, foster operational cooperation in transboundary water basins and protect and restore freshwater ecosystems.

This management requires new measures to counteract the worsening challenges for water security that arise out of population growth and climate change. Nature-based solutions provide an innovative response [92]. Nature-based solutions can involve conserving or rehabilitating natural ecosystems and/or the enhancement or creation of natural processes in modified or artificial ecosystems, which requires both intersectoral collaboration and the knowledge base to be improved.

Nature-based solutions have considerable potential to contribute to achieving most targets of SDG 6 (on water) and, via water security, could have a positive effect on other SDGs, such as support for sustainable agriculture (SDG 2), healthy lifestyles (SDG 3), building resilient infrastructure (SDG 9), sustainable urban settlements and reduced risk of disasters (SDG 11), and in relation to climate change (SDG 13).

Meanwhile, LAC — in line with global trends — is making progress towards SDG 7, with the aim of ensuring that the entire population has access to affordable, reliable, and sustainable energy. Access to electricity has started to accelerate in the poorest countries, positive results have been achieved in relation to energy efficiency, and new sources of clean energy have been incorporated into or planned for future energy mixes.

Water as a source of electric power plays a central role in the development of LAC. The region hosts some of the world's most dynamic renewable energy markets, with more than a quarter of its primary energy generated using renewable sources, double the global average [93]. More than 200 GW of its power (56% of the total) is derived from renewable sources, mainly large scale hydropower, which will continue to play a critical role in the region's renewable energy scale-up and in consistency with the integration of various renewable energy resources.[2]

However, questions are increasingly being asked about the sustainability of the current growth pattern, in the energy sector, which is giving rise to a new paradigm of economic and technological development. LAC has more than 10% of the world's oil reserves; it accounts for approximately 14% of production and only 8.3% of global consumption [94], [95]. Oil extraction has a high environmental cost and contribute to global warming, through irreversible transformation of terrestrial and marine ecosystems from which it is extracted and the serious effects of spills. Unconventional hydrocarbons raise the most questions and constitute the major challenge for the region: they show significant potential in several countries, meaning that a regulatory regime favouring the exploration, development and production of these resources needs to be adopted, in turn requiring environment-friendly regulatory and technological frameworks to ensure environmental protection.

The increase in energy consumption and the concomitant need for generation, together with the lack of technology to control emissions and transport are the main causes of air pollution in urban areas, in LAC as elsewhere.

LAC had a population of over 655 million in 2021, with over 81% concentrated in cities [63], a trend that is set to increase by 2030. Cities and metropolitan areas worldwide have considerable fossil fuel CO_2 emissions from electricity consumption, ground transportation, residential and commercial buildings and industrial activities. Global urban energy related CO_2 emissions are between 53% and

[2] Hydropower has the potential to constitute 22% of global power generation, with a regional potential of over 582 GW per year, of which only approximately 24% is being utilized.

87% of the CO_2 emissions from global final energy use [96]. Inadequate and overloaded infrastructure and services (such as waste collection, water and sanitation systems, and roads and transport) will represent a clear challenge to the region's environmental policies, with a focus on air pollution caused by unplanned urban sprawl.

Combustion processes produce a complex mix of pollutants that include primary emissions (particulate matter) and those coming from atmospheric transformations (ozone, sulphates), which increases air pollution, worsens air quality, and causes health problems. Rural areas are also exposed to anthropogenic and natural emissions, both produced locally and transported over a long distance.

Problems related to air pollution have a direct impact on human health. Particulate matter under 2.5 microns is especially harmful, and concentrations of such matter are correlated with the incidence of various pulmonary ailments. Recent estimates by the WHO indicate that over 100 million people in LAC are exposed to outdoor air pollution, with amounts exceeding the WHO's recommended guideline values [97]. Air pollution in the region causes 2.3 million cases of chronic respiratory disease in children and 100 000 cases of chronic bronchitis in adults every year [98]. Meanwhile, more than 217 000 deaths were attributed to air pollution in 2019; Brazil was the worst affected, with an estimated figure of over 66 000 deaths [99].

The WHO also highlights the importance of pollution in enclosed spaces, in connection with the use of traditional fuels (cooking, heating), which emit breathable particles, carbon monoxide and oxides of sulphur, nitrogen and benzene [100]. In some regions of LAC, 50% of the rural population and 8% of the urban population still use solid fuels for cooking, and their exposure may be much higher than the ambient (outdoor) level for highly polluted cities [99].

In 2016, LAC produced 231 Mt of waste, an average of 0.99 kg per person per day; many of the highest waste generators are island countries with dynamic tourist economies. While approximately 69% of waste is dumped in some form of landfill and more than 50% is disposed of in sanitary landfills with environmental controls, a significant amount is deposited in open dumps (27%), incinerated or used as animal feed. Recycling and composting programmes and practices are on the rise in the region, but implementation varies from country to country [101]. Solid waste is made up of organic material, recyclable waste, dangerous household material, medical and industrial waste and construction debris. The effects can be seen on the health of the population, through the tendency towards certain diseases, pollution of soil, water, air, and flora and fauna, and disasters such as flooding [102].

Although there is scarce information about the presence of contaminants (e.g., hormones, antibiotics, natural radioactive emissions, additives), and their effect on people and the environment has not been properly evaluated, work on national urban plans underpinned by relevant technical information and reliable statistics raises the prospect that cities and human settlements in LAC will in future be inclusive, safe, resilient, and sustainable, in line with SDG 11.

There is awareness to take urgent global action to combat climate change and its impacts, as is set out in SDG 13 Climate Action and acknowledged by the UNFCCC [103], main international and intergovernmental forum for negotiating a practical global response to climate change. The effects of climate change are unpredictable and devastating and include an increase in natural disasters, and morbidity and mortality, in particular among the poor, young people, and women in general [103].

The Andean high glaciers and three ice fields in southern South America are important for the region, as they could be severely affected by global warming [103]. The retreat of glaciers and decrease in water availability is currently one of the biggest concerns for Andean countries, where 95% of the

world's tropical glaciers are found (producing 10% of the planet's water). Climate change has been causing most of the world's glaciers to retreat over recent decades. If this decrease continues at the present rate, some low-altitude glaciers in the Tropical Andes could lose 78–97% of their volume by the end of the century, depriving residents in the region of their water resources. Meltwater from glaciers is an essential source of water for millions of people for those living in the Andean highlands of Plurinational State of Bolivia, Chile, and Peru [104].

The conservation and utilization of oceans, seas and marine resources in a way that contributes to sustainable development is a regional aspect that is essential to achieving SDG 14. Life depends on the oceans, which are the planet's largest ecosystem, cover more than two thirds of the earth's surface, provide food and livelihoods to billions of people, and generate around half of the oxygen that we breathe.

The coastline of LAC, where many of its largest human settlements are located, is over 70 000 km long, and the sea makes up at least 60% of the sovereign territory of 22 countries in the region. It is essential for the food security of small island developing States and makes a significant contribution to tourism in the Caribbean [105].

However, several decades of increasing carbon emissions have caused heat to accumulate in the oceans and have changed their chemical composition. The adverse effects of ocean acidification, climate change (including rising sea levels), extreme weather events and coastal erosion exacerbate the ongoing threat to marine and coastal resources posed by overfishing and commercial overexploitation of valuable species, pollution, and habitat degradation. For example, analysing the indicator of clean water — an average of the degree of oceanic pollution — demonstrates that water quality problems are extremely widespread, and are a very serious issue for our region.

Pollution of the marine environment degrades water quality, has adverse effects on biological resources, jeopardizes human health, impairs natural attractions, and hampers economic activities. One of the factors that is most alarming, complex, and difficult to manage is microplastics owing to their incorporation at the various stages of the food chain. Microplastic are particles under 5 mm resulting from the breakdown or direct manufacturing of industrial materials.

Higher levels of nutrients found on coasts could be a result of coastal upwelling, natural animal waste or agricultural run-off from nitrogen fertilizers, which can contribute to the development of red tides, also known as harmful algal blooms. One of the most significant effects of harmful algal blooms is the production of toxins by certain species of algae, which can build up in seafood products and constitute a health risk for consumers, in addition to producing negative economic impacts [105].

It is important to note that, in 2020, the region has made progress in the conservation and protection of wildlife protected areas and the marine and coastal zones by at least 10%, in line with the Aichi Biodiversity Targets under the Convention on Biological Diversity (CBD) [106].

LAC is establishing important measures to conserve, restore and make sustainable use of these valuable natural resources. This has included the protection, restoration, and promotion of the sustainable use of terrestrial ecosystems, the sustainable management of forests, the fight against desertification and the halting of degradation, which are central aspects of SDG 15. These measures include adopting legal mechanisms to guarantee that the benefits of genetic resources are distributed fairly, protecting more key biodiversity areas and implementing sustainable management plans. At the same time, these efforts are being urgently stepped up, with immediate measures to halt biodiversity loss and protect regional ecosystems.

Changing soil use and agriculture are responsible for 42% of the region's GHGs emissions, compared to a global level of 18%; meanwhile, the forested area of LAC decreased by almost 10% between 1990 and 2020 [89], [107], [108]. According to the FAO, there are 16.5 million family farms in the region (80% of the total number of farms), employing over 60 million people and constituting the main source of agricultural and rural employment [109]. This information is even more relevant given that the consumption of agrochemicals in LAC has risen markedly in recent decades; the region is facing problems relating to pesticide residues and their resulting impact on the food industry, both domestic and regarding exports. The excessive use of fertilizers, irrigation practices and the intensive use of natural resources are causing changes in the soil, such as pollution, nitrification, salinization and depletion of nutrients, with desertification, the most extreme manifestation of this [110], [111].

In South America, this dynamic affects all soil uses to a greater degree than the global average. Desertification, soil degradation and ecosystem loss are reducing the availability of water — and by 2050, it is estimated that between 79 and 178 million inhabitants in LAC will be affected by the increase in the water deficit [112].

Protected areas on land cover almost one quarter of the region: 4.85 million km^2, of which 2.47 million km^2 are in Brazil [113]. This network of protected land areas is the largest in the world, providing one fifth of terrestrial ecosystems' carbon sequestration and supporting water systems that are essential to production and consumption.

In terms of mining and its link to the environment, even small-scale mining has an impact on soil and water pollution in various areas of the region. The entire region is affected by pollution from heavy metals and other toxic elements, in particular Andean countries, where most mining sites are to be found for example, Argentina (gold, uranium, lithium), Plurinational State of Bolivia (antimony, tin, gold, lithium), Brazil (mercury, uranium), Chile (arsenic, copper, lithium), Ecuador (arsenic, cadmium, zinc, copper, mercury), Mexico (arsenic, lead), Peru (arsenic, cadmium, zinc, copper) and Uruguay (lead). Small scale mining is currently expanding rapidly in many developing countries and causing considerable damage to the environment, owing to a lack of or failure to comply with any legal or regulatory framework [114].

Mining is a sector that makes a major contribution to global warming. Given the manifold activities related to extraction, it is difficult to measure the GHGs emissions produced by mining. Indeed, most emissions do not come from the sector's activities themselves, but rather from the energy required for such activities [115].

The risks of mining include causing damage to ecosystems and ecosystem services[3]; the issue of the environmental liabilities of mining (including uranium mining) in the region also needs to be considered. Examples of groundwater resources being affected include the extraction of lithium from salt flats and the potential impact of oil extraction using hydraulic fracturing technology (fracking).

As a result of an environmental performance carried out jointly by ECLAC and the OECD, it was highlighted the need for countries to conduct land planning making use of ecological–economic zoning and, to some extent, to perform strategic environmental assessments. Additionally, there is the need to develop environmental information systems and set up registers of emissions and of

[3] Ecosystem services are the benefits people obtain from ecosystems. These include provisioning services such as food, water, timber, and fiber; regulating services that affect climate, floods, disease, wastes, and water quality; cultural services that provide recreational, aesthetic, and spiritual benefits; and supporting services such as soil formation, photosynthesis, and nutrient cycling. The human species, while buffered against environmental changes by culture and technology, is fundamentally dependent on the flow of ecosystem services.

pollutant transfers so that public policy can be framed and implemented based on of the appropriate environmental impact assessment systems.

SWOT ANALYSIS

5.2.1. Strengths

(1) Increase in social awareness of environmental problems and their effect on the preservation of ecosystems and human health at regional level;
(2) Consolidation of an international institutional framework based on environmental agreements, conventions and protocols to which countries in the region are parties, including: Convention on Biological Diversity, UNFCCC, United Nations Convention to Combat Desertification (UNCCD), Basel Convention, Rotterdam Convention, Stockholm Convention, Minamata Convention, Regional Seas Programme, Forum of Ministers of Environment of Latin America and the Caribbean, Vienna Convention for the Protection of the Ozone Layer, and Montreal Protocol on Substances that Deplete the Ozone Layer;
(3) Existence of regional reference centres and thematic networks related to the environment that enable synergy in different areas, providing logistical technical support for the transfer of technology through horizontal cooperation among countries of the region, promoting access to information via databases, and also acting as training centres [e.g. Marine-Coastal Research Network (REMARCO, for its acronym in Spanish), Network for the Analysis of Environmental Quality in Latin America (RACAL, for its acronym in Spanish), Latin American and Caribbean Analytical Network (RALACA, for its acronym in Spanish), Inter-American Water Resources Network (IWRN), Latin American Association of Underground Hydrology for Development (ALHSUD, for its acronym in Spanish)];
(4) Strengthening of laboratories' capacities with equipment and trained personnel for the use of tracers (stable and radioactive isotopes) and for the quantification of pollutants in environmental samples using nuclear and related analytical techniques (alpha and gamma spectrometry, liquid scintillation, neutron activation analysis, isotope ratio mass spectrometry, inductively coupled plasma mass spectrometry, X ray fluorescence and ion beam analysis, among others). There are laboratories with established quality control systems and standardized protocols, which is essential for the mutual recognition of analytical results achieved. Some of these laboratories have ISO/IEC 17025 [50] accreditation.

5.2.2. Weaknesses

(1) Insufficient prioritization, budgeting and continuity for implementing national and regional policies and programmes related to environmental protection;
(2) Insufficient interaction between governmental institutions responsible for environmental management (water management, pollution and healthcare, fishing, tourism) and institutions that can provide support in furnishing the information required for responsible management and decision making, using nuclear techniques;
(3) Difficulty in forming strategic partnerships within the scientific community to enable a comprehensive approach to environmental studies;
(4) Scant scientific information to serve as a basis for evaluating environmental problems (air, water, soil and marine/coastal zones) affecting the region, understanding their causes and mitigating their impact on public health;
(5) Lack of effort and measures to ensure compliance with environmental quality standards.
(6) Insufficient interaction between the Agency and agencies of the UN system and/or regional entities on topics related to environmental protection;

(7) Limited dissemination, awareness and understanding of the potential offered by the use of nuclear techniques as an advantageous — and often the only — tool for assessing and monitoring the environment. As this potential is often restricted to the scientific and/or academic field, there is a need to raise awareness among the general public and areas of government responsible for environmental management;
(8) Insufficient replenishment of personnel trained in the application of nuclear techniques, in view of the scale of the task of tackling environmental issues and the need for specific training to undertake certain environmental studies;
(9) Lack of availability of required laboratory equipment and, in many cases, technological obsolescence of instrumentation;
(10) Disparity in the use of techniques and in the quality of analytical results generated within the region.

5.2.3. Threats

(1) Political changes that might affect the sustainability of environmental projects, including conflicts of interest between polluting companies and society;
(2) Negative social perception and lack of understanding of the benefits of nuclear techniques. The peaceful uses of nuclear applications and techniques need to be better publicized among the general public and in government circles;
(3) Lack of institutional sustainability and stability in terms of qualified staff;
(4) Limited resources for the effective maintenance, repair and ongoing modernization of equipment in facilities and/or laboratories;
(5) Insufficient knowledge and perception of the possibilities of nuclear techniques, limiting their broader use at regional level.

5.2.4. Opportunities

(1) UN approval of the 2030 Agenda for Sustainable Development and by extension of the SDGs, setting out a transformational social, economic and environmental vision and strengthening programmes;
(2) Identification of critical problems affecting the environmental situation in the region;
(3) Sectors of society with greater unmet environmental demands, requiring different levels of government to take effective institutional measures to address these problems, which are common to the region (including increasing modernization of regulatory frameworks, such as in the water sector);
(4) Increase in the use of nuclear techniques in environmental studies at global level, and a greater contribution made by them to such studies;
(5) Multiplication and consolidation of global networks for specific studies, strengthening cooperation in this area;
(6) Increase in academic exchanges at global and regional levels, with corresponding knowledge transfer, contributing to a substantial improvement among professionals.

NEEDS AND PROBLEMS

M1. Insufficient knowledge of the availability and inadequate management of water resources

Justification: Although LAC is the region with the highest water availability per head, many of its urban centres and rural areas do not have guaranteed access to water to meet growing demand due to population growth and economic development. Many countries lack reliable estimates of the availability of surface water and groundwater resources. Meanwhile, expected changes in precipitation patterns linked to global climate change (e.g., floods and periods of prolonged drought) might have a serious impact on people's access to water resources.

Objective: To produce hydrological information necessary for integrated water resource management in the region, considering factors relating to availability.

Indicator: Increase in number of hydrological studies using isotopic and nuclear techniques incorporated into plans for water resource management aiming to increase the availability of water that are implemented in the region in 2022–2029.

M2. Insufficient knowledge of water quality and sources potentially contributing to its pollution

Justification: Many natural and anthropogenic sources contribute to lower water quality, driving up costs in terms of the use of water treatment plants and ensuring the quality of the resource for various uses, while affecting supply for human consumption, food security and industrial development. The lack of knowledge of sources of pollution and the vulnerability of the various sources is hampering the adoption of preventive and corrective measures to improve water quality. The inadequate management of water resources has a high economic and social cost and affects both availability and quality.

Objective: To produce information, using isotopic and nuclear techniques, on sources of pollution and processes affecting the quality of water resources, for incorporation into management plans.

Indicator: Increase in number of hydrological studies incorporated into plans for water resource management aiming to improve the quality of water that are implemented in the region in 2022–2029.

M3. Insufficient knowledge of the main processes affecting coastal zones, oceans and marine resources

Justification: The LAC region has a maritime territory of 16 million square kilometres and more than 70 000 kilometres of coastline, for 22 countries in the region, with the sea representing 60% or more of their sovereign territory. The importance of coastal activities such as tourism and fisheries are vital for the economies and prosperity of many LAC countries. In the Caribbean the importance of tourism as a fraction of the GDP reaches 20% or more in 10 Small Island Developing States (SIDS). The importance of oceans to LAC livelihoods and food security of LAC people explain most of the actions towards blue sustainable development policies with oceans playing a source of potential solutions and innovation indispensable for the prosperity of SIDS coastal communities [105].

Regarding the exploitation of marine resources, the growth in marine aquaculture, the increase in toxic algal blooms, ocean acidification, the rise in sea levels, coastal pollution (nutrients, chemicals, plastics etc.) and climatic changes have led to biodiversity and habitat loss and have caused a

deterioration in the region's marine and/or coastal zone, undermining ecosystem services and the development of countries in the region.

Despite their economic contribution and ecological value, knowledge of the status of the region's coastal zones, seas and oceans is limited.

Objective: To develop integrated information, including through the use of nuclear and isotopic techniques that can help conserve and sustainably use the oceans, seas and marine resources for sustainable development in LAC.

Indicator: Increase in number of countries producing reports containing integrated information for the sustainable management of the region's coastal zone, seas and oceans.

M4. Insufficient knowledge of the concentration of atmospheric particles and aerosols, their composition and their impact on human health.

Justification: Most cities in the region — home to 81% of its population — have serious problems with air pollution. Rural areas are also exposed to anthropogenic and natural emissions. In all cases, the sources emitting these particles and aerosols may be local, regional or transboundary.

High levels of particulate matter in the air, and especially matter smaller than 2.5 μm have been associated with different illnesses and constitute a risk to human health. The chemical characterization of particulate matter and aerosols enables both the concentration of the various pollutants to be determined and their sources to be identified [63], [97].

Objective: To help to improve the management of air quality by incorporating nuclear analytical techniques (NATs) for the chemical characterization of particulate matter as part of monitoring studies and for the determination of pollution sources and their contribution to identified inventories.

Indicator: Increase in number of cities with studies on identified pollution sources and their adverse effect on human health, to enable mitigation measures to be implemented to reduce the mortality rate attributed to air pollution.

M5. Insufficient evaluation of soil degradation and pollution and the impact on human health

Justification: A significant percentage of the region's soil is polluted with heavy metals and other toxic elements, pesticides and other substances, which are then transferred to plants and animals. In addition, only 35% of solid waste is managed using sanitary landfills, which causes soil pollution and affects human and animal health [116]. Sales of pesticides and fertilizers in the region account for 17% and over 10% of the total global. Countries in the region are faced with problems related to pesticide residues in food for local consumption and export, which in many cases exceed the legal limits, as well as causing an impact on the environment [116]. There is not enough information available and/or analytical capacities to determine the pollutants and their impact on human health, plants and animals.

Objective: To help to improve the evaluation of the impact of pollutants in soil, generating information about levels, type, distribution and dispersion of pollutants, making use of nuclear techniques.

Indicator: Increase in number of diagnostic reports on pollutants in soil using nuclear techniques contributing to the drafting of legislation to significantly reduce the number of deaths and illnesses caused by hazardous chemical products and soil pollution.

5.4. PRIORITIZATION OF THE NEEDS AND PROBLEMS.

The following Table 3 and Fig. 3 reflect the final prioritization grades, determined by the variables outlined, of numerous issues in the environment sector, followed by a visual comparison of these grades shown in Fig. 3.

TABLE 3. PRIORITIZATION OF THE NEEDS AND PROBLEMS IN THE ENVIRONMENT SECTOR

P	Need/Problem	Severity	Time	Extent	Relevance	Total grade	Difficulty	R/D	Final grade
	M1	5.0	5.0	5.0	4.0	19.0	4.0	1.0	19.0
1	Insufficient knowledge of the availability and inadequate management of water resources.	Availability of water per capita in LAC countries — an essential factor for human development — has been constantly decreasing for several decades, in many cases constraining economic development and affecting human health and ecosystems. The lack of sustainable water management policies based on comprehensive hydrological studies means that the problem of access to water is seen as a source of conflict in the immediate future.	LAC countries are facing specific problems in continuously supplying high-quality water to their populations to satisfy rising demand, which is linked to economic development and population growth. Climate change scenarios — with an increase in extreme weather events — suggest that the situation surrounding access to water will probably deteriorate in the medium to long term.	All LAC countries, to different degrees, face problems of varying seriousness in connection with the continuous availability of water resources to meet the needs of supply, food production, industry, and ecosystem maintenance.	The integrated use of nuclear and isotopic techniques (together with other hydrological tools) in evaluating surface water and groundwater systems furnishes indispensable information for adopting measures to manage water resources sustainably.		A great deal of progress has been made regarding producing information and the management plans drawn up in the region, but greater involvement of government figures who are able to make decisions is required if implementing these plans is to have a positive impact.		

TABLE 3. PRIORITIZATION OF THE NEEDS AND PROBLEMS IN THE ENVIRONMENT SECTOR (cont.)

P	Need/Problem	Severity	Time	Extent	Relevance	Total grade	Difficulty	R/D	Final grade
	M2	4.5	5.0	5.0	3.5	18.0	3.0	1.17	21.0
2	Insufficient knowledge of water quality and sources potentially contributing to its pollution.	In addition to water availability problems, water resource managers are increasingly concerned about water quality: many human activities result in progressively worse water quality, owing to the exposure of bodies of water to a growing number of pollutants. Lower water quality impairs economic development, causes human health problems and has a negative impact on ecosystems' biodiversity.	Intensive exploitation of surface water and groundwater sources together with population growth and economic development have led to a progressive deterioration in water resource quality in LAC, making it increasingly difficult for the authorities to supply high-quality water to meet all the needs of their populations and ecosystems.	All LAC countries, to different degrees and extents, face problems in connection with deteriorating water resource quality, involving several sources of natural and anthropogenic pollution.	Nuclear and isotopic techniques make it possible to obtain essential information on pollution sources and physicochemical processes affecting the cleanliness of water, enabling corrective or palliative measures to be taken.		There are disparities between countries of the region as regards infrastructure and trained human resources for analysing water quality and identifying potential sources of pollution. Not all data produced by laboratories operating management systems are of similar quality.		

TABLE 3. PRIORITIZATION OF THE NEEDS AND PROBLEMS IN THE ENVIRONMENT SECTOR (cont.)

P	Need/Problem	Severity	Time	Extent	Relevance	Total grade	Difficulty	R/D	Final grade
	M3	4.5	4.75	4.5	3.5	17.25	3.0	1.17	20.48
3	Insufficient knowledge of the main processes affecting coastal zones, oceans and marine resources.	Marine/coastal zones (70 000 km) in 22 countries in the region are currently experiencing constant deterioration, causing losses in terms of habitat, biodiversity and ecosystem services and impairing tourism, fishing and food security in the region.	Degradation of the coastal zone is worsening rapidly, owing to both anthropogenic activity and the effects of climate change, meaning that urgent action is required to improve understanding of these phenomena and to generate information for drawing up management, adaptation and mitigation plans.	The coastal zone of LAC accounts for 60% of the territory of 22 countries. The Caribbean Sea is shared by 17 countries, making it a regional ecosystem. Pollution, harmful algal blooms, and ocean and sea acidification are problems with a transboundary dimension, shared by all countries in the region.	Nuclear and isotopic techniques have been shown to be very useful in studying the various problems associated with the deterioration of the coastal zone, seas and oceans. The use of environmental radiotracers, stable isotopes and NATs are techniques that are available or accessible to a number of countries in the region. The existence of the REMARCO network is an opportunity for the region and in terms of support to decision makers.		The complexity of the processes to be studied requires research designs to be formulated and the use of a variety of complementary techniques.		

TABLE 3. PRIORITIZATION OF THE NEEDS AND PROBLEMS IN THE ENVIRONMENT SECTOR (cont.)

P	Need/Problem	Severity	Time	Extent	Relevance	Total grade	Difficulty	R/D	Final grade
	M4	4.0	4.5	4.25	4.0	16.75	4.0	1.0	16.75
4	Insufficient knowledge of the concentration of atmospheric particles and aerosols, their composition and their impact on human health.	As well as being home to 81% of the region's population, cities are where most industrial activity and pollution from other anthropogenic sources (including heating and vehicle emissions) are concentrated. Rural areas are affected by these pollutants being transmitted, locally and regionally, through the atmosphere. Airborne matter with particles under 2.5 microns is especially harmful, and concentrations of such matter are correlated with the incidence of various pulmonary ailments.	The deterioration in air quality and its negative impact on human health are worsening rapidly. There is a need for information on pollution sources to propose control and mitigation measures.	Pollutants are transmitted across borders, affecting more than just the polluters themselves. It is important to understand the profiles of each source to identify long-range transmission and assess the origin of the pollution.	NATs enable the concentration of a large number of elements to be pinpointed, thereby enabling different pollution sources to be identified.		Not all countries in the region possess analytical capacities. Although a number of laboratories operate quality management systems, not all the data that they generate are of similar quality, which can affect the identification of pollution sources. A culture of cooperation is not always present at institutional level to enable other types of analysis required for a comprehensive characterization of samples to be incorporated.		

TABLE 3. PRIORITIZATION OF THE NEEDS AND PROBLEMS IN THE ENVIRONMENT SECTOR (cont.)

P	Need/Problem	Severity	Time	Extent	Relevance	Total grade	Difficulty	R/D	Final grade
	M5	3.5	4.5	4.75	3	15.75	4.0	0.75	11.81
5	Insufficient evaluation of soil degradation and pollution and the impact on human health	A significant proportion of the region's soil is polluted with toxic elements and organic pollutants. These pollutants affect the quality of agricultural products and contribute to nutritional and health problems. Some soil pollution enters groundwater and food chains, affecting plants and animals.	The indiscriminate use of fertilizers and pesticides and the increase in mining and industrial activities exacerbate soil pollution.	Soil pollution affects practically all countries in the region. Transmission of pollutants via water currents means that pollution sometimes spreads over long distances.	NATs enable the concentration of toxic elements to be determined. The use of chromatography techniques coupled with mass spectrometry enables a large number of organic pollutants to be analysed.		Not all countries in the region possess analytical capacities. Although a number of laboratories operate quality management systems, not all the data that they generate are of similar quality, which can affect the identification of pollution sources. A culture of cooperation is not always present at institutional level to enable other types of analysis required for a comprehensive characterization of samples to be incorporated.		

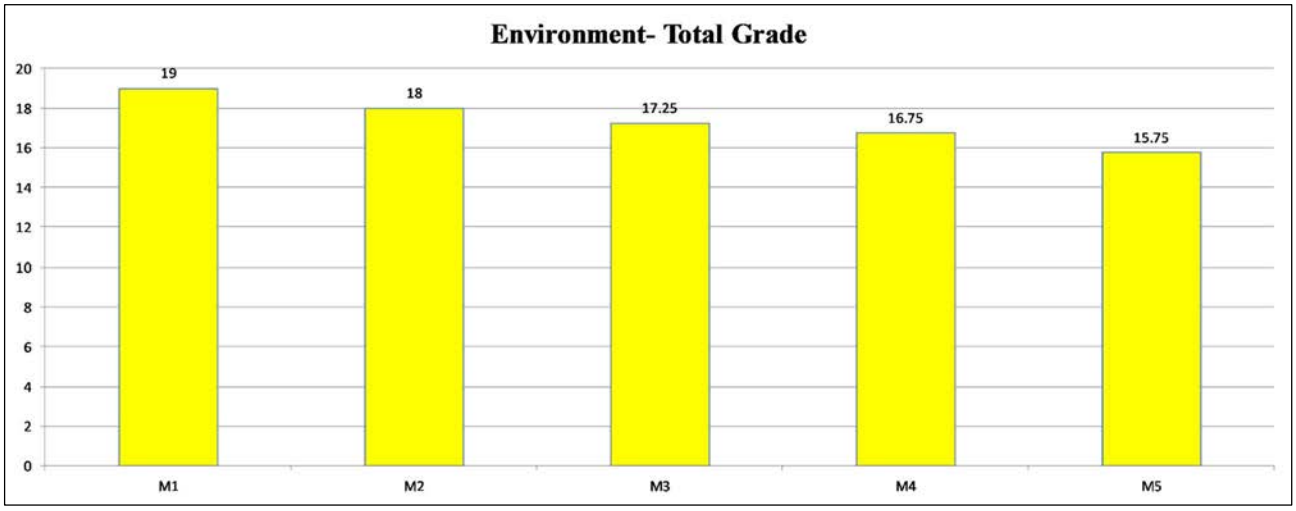

FIG. 3. Needs and Problems in Environment vs Total Grade

ENERGY

6. ENERGY

GENERAL ANALYSIS OF THE REGIONAL SITUATION

6.1.1. Summary of the current situation regarding nuclear energy in the region

The LAC region comprises 45 countries in an area covering 20.4 million km^2 [117]. The annual population grows at a rate of 0.7% a year, with the population reaching 655 million in 2021 [63][118]. In 2021, the gross domestic product of the region was US $5.45 trillion at current prices and the annual per capita income was US $8 327 [63]. In 2020, life expectancy at birth was 73 years [63], and the literacy rate of the total adult population (% of people aged 15 years and over) was 94% [119].

Primary energy demand in 2018 was 702 million tonnes of oil equivalent (Mtoe), and it is estimated that this figure will increase by at least 1.8% per year cumulatively [120].

Proved oil reserves (including shale oil) in the region have risen to around 334.5 billion barrels of oil, which is 20% of global reserves [121]. The main oil producers are Bolivarian Republic of Venezuela, Brazil, Ecuador, and Mexico. Oil production in the region has declined from 3 500 million barrels of oil in 2009 to 3 142.6 million barrels of oil in 2018. LAC have 8% of the world's installed refining capacity [121].

Regarding natural gas, in 2018, the region had 8200 billion m^3 of proved reserves, which was 4.2% of global reserves [120]. Mexico, Bolivarian Republic of Venezuela, Brazil, Peru, Trinidad and Tobago, Argentina and the Plurinational State of Bolivia have traditionally been the region's main gas producers. In 2018, 176.7 billion m^3 of this fuel was produced, which was 4.6% of global production [120].

The region has 14 016 Mt of proved carbon reserves, which is 1.3% of global reserves. In 2018, production was 60.4 Mt, having begun to decline in 2015, with Colombia the largest producer in the region [120].

Installed electricity generation capacity in the region rose to 341 GW in 2018 [122]. Electricity consumption in Latin America and the Caribbean in 2018 was 1305 terawatt-hour (TW·h) [120]. Its generation distribution comprises 56% hydroelectric plants, 30.3% thermal power plants, 1.7% nuclear and 12% renewable, which represented 4.9% of global consumption. Regarding CO_2 emissions, the global total at the end of 2014 was 1912 million tonnes of carbon dioxide (Mt CO_2). LAC had a per capita carbon dioxide emission of 3.1 tons of carbon dioxide (t CO_2/inhabitant). Even though the values of CO_2 emissions per inhabitant are lower in LAC than in industrialized countries, they grew 1.4% between 2010 and 2014 [120].

Gross electricity generation capacity additions between 2012 and 2035 in LAC are expected to reach 269 GW, a figure similar to installed capacity in 2009 [123]. It is estimated that 97 GW of these additions will come from hydroelectric plants, 78 GW from gas, 25 GW from wind, 21 GW from solar photovoltaics, 16 GW from bioenergy, 7 GW from nuclear, 3 GW from concentrated solar power plants and 2 GW from geothermal plants [120].

In a scenario where current policies are maintained, electricity demand in the region is expected to grow on average by 2.7% [123].

The region's population is forecast to rise to around 720 million by 2030 [124], which poses an enormous challenge in terms of establishing the necessary conditions to meet the welfare requirements of such a population size.

Total primary energy demand would rise to 1483.23 Mtoe in 2030. Accordingly, electricity demand would grow to 2621 TW·h, which would be double the current level or more. As regards CO_2 emissions, trend scenarios predict figures of 2 680 Mt CO_2. The new scenarios for each country include an evaluation of the mitigation of GHGs emissions, climate change and achievement of the goals set by countries on The Paris Agreement under the UNFCCC and the SDGs.

Latin America has over 47 years' experience in nuclear power generation. Installed nuclear capacity rose to 5 077 MW total net capacity in 2020 (Argentina: 1 641 MW and generation of 10 011 GW·h, or 7.5%; Brazil: 1 884 MW and generation of 14 053 GW·h, or 2.1%; and Mexico: 1 552 MW and generation of 10 864 GW·h, or 4.9%, distributed among seven units in three countries. Total nuclear power generation increased in these countries in 2020 to 34 928 GW·h [122]. Two new reactors are in construction in the region: one in Brazil (ANGRA 3) with 1 245 MW capacity and the other in Argentina (CAREM SMR) with 32 MW, reaching 1277 MW of new installed capacity [125].

Despite the negative impact of the Fukushima Daiichi accident on nuclear investment, plans for new nuclear power plants continue and the lifetime of a CANDU nuclear power plant in Argentina has been extended for a further 30 years period. This is the first plant life extension successfully carried out in the region. The Latin American and Caribbean countries with nuclear power plants are planning to expand their nuclear generation capacities.

Nonetheless, some countries that abandoned their plans to include the nuclear power option in their energy matrices because of the Fukushima Daiichi accident might reconsider it between 2020 and 2035, although wind and solar photovoltaic power were introduced on a large scale in the region since 2018 [122].

The decisions taken by UNFCCC, derived from the climate regime adopted in 2015 for implementation from 2020 onwards, strengthen the commitments of all countries through mitigation and reduction of greenhouse gases.

As the nuclear power plants in the region are coming to the end of their planned lifetimes, an analysis and evaluation of a lifetime extension needs to be undertaken. This also expedites the need for a comprehensive evaluation of the nuclear option within energy systems, to identify the role it could play in the development of LAC.

6.1.2. Summary of the current situation concerning research reactors in the region

Research reactors are simpler than reactors for electricity generation and operate at lower pressures and temperatures. They consist of a core made up of fuel elements with uranium (^{235}U) enriched up to 20%. The only reactor in the region to still use 90% enriched uranium is at an advanced stage of conversion to low enriched uranium (see Table 4). The range of applications for which these reactors can be used depends on the power level or neutron flux. In general terms, reactors under 250 kilowatts (kW) may be categorized as low power and those over 2 MW as high power.

Seven countries in the LAC region have experimental nuclear reactors of various types and power levels, as shown in Table 4 [126], [127]. Table 5 contains information on experimental reactors under construction [128].

TABLE 4. RESEARCH REACTORS IN THE REGION

Country	Reactor	Type	Power kW	Enrichment %	Regime h/month	Owner
ARGENTINA	RA-0	Pool	0.001	19.8	16	University of Cordoba
	RA-1	Pool	40	19.8	Not available	National Atomic Energy Commission (CNEA)
	RA-3	Pool	10 000	19.7	266	CNEA
	RA-4	Pool	0.001	19.8	16	University of Rosario
	RA-6	Pool	500	19.75	180	CNEA
	RA-8	Pool	0.01–0.1	1.8-4.3	0	CNEA
BRAZIL	Argonaut	Pool	0.5–5	19.9	Not available	Nuclear Engineering Institute (IEN) – National Nuclear Energy Commission (CNEN)
	IEA-R1	Pool	2000–5000	19.9	256	Institute for Energy and Nuclear Research (IPEN)– CNEN
	MB-01	Pool	0.1	4.3	Not available	IPEN– CNEN
	IPR-R1	Pool	250	Triga 19.9	Not available	Nuclear Technology Development Centre (CDTN)- CNEN
CHILE	RECH-1	Pool	5000	19.75	96	Chilean Nuclear Energy Commission (CCHEN)
	RECH-2	Pool	10 000–15 000	19.75	0	CCHEN
COLOMBIA	IAN-R1	Pool	100	Triga 19.9	0	Colombian Institute of Geology and Mining (INGEOMINAS)
JAMAICA	SLOWPOKE	Pool	20	90 (in the process of conversion to low enriched uranium (LEU))	Not available	International Centre for Environmental and Nuclear Sciences (ICENS)
MEXICO	TRIGA	Pool	1000–2000	Triga 19.9	60	National Institute for Nuclear Research (ININ)
PERU	RP 0	Pool	0.001	19.75	96	Peruvian Institute of Nuclear Energy (IPEN)
	RP 10	Pool	10 000	19.75	30	IPEN

TABLE 5. RESEARCH REACTORS UNDER CONSTRUCTION IN THE REGION

Country	Reactor	Type	Power kW	Enrichment %	Owner and Location
ARGENTINA	RA-10	Pool	30 000	19.75	CNEA - Buenos Aires
ARGENTINA	CAREM 25	Pressurized water reactor (PWR) Propulsion	100 000	3.4	CNEA - Buenos Aires
PLURINATIONAL STATE OF BOLIVIA	RNI	Pool	200	<20	Bolivian Nuclear Energy Agency, Ministry of Energy – La Paz
BRAZIL	RMB	Pool	30 000	19.75	CNEN - São Paulo

The purpose of these reactors is to provide neutron sources for research, experimentation, human resources training, education at the undergraduate and postgraduate levels and radioisotope production.

For more than 60 years, experimental reactors in the LAC region have been centres of production and innovation for nuclear science and technology. On January 17, 1958, the first controlled nuclear reaction was reached in the core of the RA-1 reactor in Argentina. The achievement was carried out by scientists from the National Atomic Energy Commission and was a true milestone, as it was the first reactor to start up in Latin America and the southern hemisphere [129]. The reactors have assisted multidisciplinary research covering new developments in the production of radioisotopes for medical and industrial use, research involving neutron beams, human medicine, development of materials, testing and qualification of components, computer code validation, etc.

There have been various cooperation projects and activities involving reactors in different countries in the fields of reactor physics, radioisotope production, training courses, and commissioning of reactors. These initiatives have been implemented as regional and national projects with the support of the Agency, as well as in a bilateral format. A couple of projects have also been implemented within the framework of ARCAL.

At the bilateral level, there has been noteworthy collaboration between Argentina and Peru on the design and construction of the RP-0 and RP-10 reactors.

In the field of fuel development and fabrication, there has been collaboration between Argentina, Brazil and Chile.

Regarding the design and construction of experimental and production reactors, several reactors have been designed and constructed in Argentina (RA -3, RA-6, and RA-8), and reactors have also been exported to Peru (RP-10, 10 MW, 1988), Algeria, (Nuclear Research Unit (NUR), 1MW, 1989), Egypt (Experimental Training Research Reactor (ETR)-2, 22MW, 1997) and Australia (Open Pool Australian Lightwater (OPAL), 20 MW, 2006).

The region's reactors have been converting to low enriched fuel and some of them have had power uprates and/or have had their instrumentation and control systems upgraded.

Within the framework of the Agency, from 2001 to present, several meetings have been held to promote, make closer and broaden regional cooperation on reactor utilization, safety, and fuel.

Human resources development, which includes activities such as outreach, education, training, and coaching, can be conducted at any of the region's reactors.

In the field of operation, maintenance and radiation protection of these reactors, regional cooperation could be achieved to enhance standard practices and provide mutual assistance in these tasks.

As regards documentation and quality assurance, cooperation in implementing the modifications to safety guidelines at the reactors would be advisable.

In the field of instrumentation and control, most of the instrumentation for research reactors is obsolete and there is a lack of components on the market. There is the possibility to develop and manufacture parts using the experience acquired in the region, where Argentina, Brazil, Chile, Colombia, Mexico, and Peru have formed a reliable instrumentation and control group.

The region has capacity as regards neutron physics calculation tools and experimental techniques in connection with design optimization and use of experimental reactors, for problems such as: core management; design and characterization of irradiation devices and experimental configurations; shielding; dosimetry; configuration of irradiation beams; design and characterization of irradiation facilities (Boron Neutron Capture Therapy, Neutron Radiography, Prompt gamma neutron activation analysis); critical combination as regards the arrangement of irradiated fuel elements; reactor lifetime management; and calculation validation tools.

The results of project RLA/0/037 (ARCAL CXIX) show that one of the main uses of research reactors is radioisotope production [130]. The radioisotopes produced in nuclear reactors are, in order of volume of demand in the region, ^{99}Mo, followed by ^{131}I, Iridium-192 (^{192}Ir), Lutetium (^{177}Lu), Samarium (^{153}Sm), Yttrium-90 (^{90}Y), Iodine-125 (^{125}I) and ^{32}P. Regional demand for radioisotopes produced in nuclear reactors was around US $21.6 million in 2012, with fission-produced ^{99}Mo having the greatest relative importance, accounting for 77% of the total, followed by ^{131}I accounting for 13% and ^{192}Ir accounting for 6% [124].

Regional demand was worth around US$ 28 million in 2017, with a 7% increase in fission-produced ^{99}Mo for generator production according to trends estimated between 2010 and 2012. Demand for ^{99}Mo and other radioisotopes has remained stable until present, with a temporary drop in exports owing to regular international flight restrictions caused by the COVID-19 pandemic [124].

Regional production meets 52% of the demand for fission-produced ^{99}Mo, 37% for ^{131}I and 23% for ^{192}Ir. This production generates approximately US $10.3 million, or 48%, of the value of regional demand [124].

SWOT ANALYSIS

6.2.1. Strengths

(1) Energy planning capacities at the local, subregional and regional levels, to perform comprehensive sustainable energy development studies;

(2) Plans to expand and diversify electricity matrices, considering climate change, nationally determined contributions and the SDGs;
(3) Existence of a production chain for project development and implementation in the electricity sector;
(4) Countries with nuclear institutions retain the knowledge of their strategic and energy planning teams over time;
(5) High level of electrification and interconnection projects under way in the region;
(6) Plans to expand nuclear power generation capacity in the region;
(7) Nuclear power plant operating experience that can be shared at the regional level;
(8) Experience in nuclear power plant lifetime extension projects that can be shared at the regional level;
(9) Existence in the region of institutes with undergraduate and postgraduate training programmes in the nuclear field;
(10) Local development of innovative nuclear power plants in some countries of the region;
(11) Mastery of the technology for power reactor and research reactor fuel fabrication;
(12) Scientific and technological capacities in research reactor operation and radioisotope production in some countries of the region;
(13) Scientific and technological capacities in research reactor design and construction in some countries of the region;
(14) Uranium potential, technological and professional capacities in uranium development and production.

6.2.2. Weaknesses

(1) Teams of trained staff dedicated to energy planning are reduced in some countries, with a high turnover rate;
(2) Large land area and existence of geographical barriers, which involves major costs for interconnection processes;
(3) Insufficient knowledge about the potential of energy resources in some countries in the region.
(4) Local economic restrictions that affect large scale energy projects;
(5) Weak statistical database structures for energy planning in some countries of the region.
(6) Not enough university degrees that include energy planning;
(7) Lack of information at the basic and intermediate levels of education on the advantages and disadvantages of the various electricity generation technologies;
(8) No long term structural nuclear plans in some countries of the region;
(9) Insufficient incentives to attract and maintain the highly qualified human resources required in the nuclear sector;
(10) Few taught training courses that cover the uses, benefits and risks of power generation, including nuclear power;
(11) Insufficient budget for the management, maintenance, and upgrade of research reactors;
(12) Poor integration of the use of land, energy and water, in connection with climate change;
(13) Lack of knowledge at the social level of the benefits of nuclear power plant and research reactor applications;
(14) Under utilization of research reactors;
(15) Inadequate method of passing on acquired skills.

6.2.3. Threats

(1) International geopolitics which constrain the scope of funding for nuclear projects;

(2) Growth of international and national movements, including non-governmental organizations in favour of environmental preservation, which do not take into account the contributions made by nuclear energy;
(3) Unfavourable public opinion owing to a negative perception of the risks associated with the use of nuclear energy;
(4) Social rejection of the transport of radioactive material and final disposal of radioactive waste;
(5) International competition with other suppliers in selling radioisotopes and radiopharmaceuticals;
(6) Insufficient resources allocated from national budgets to nuclear development;
(7) Discrepancy between public policies for the use of energy and non-energy resources;
(8) Governmental restructuring that affects the continuity of teams trained in energy planning in some countries of the region;
(9) Discontinuity in the bilateral or multilateral technical cooperation agreements among countries of the region;
(10) The need for further capacity building is not understood or considered by decision makers.

6.2.4. Opportunities

(1) Existence of the SDGs and adoption of their concepts on a global scale;
(2) Strategic link between the International Renewable Energy Agency (IRENA) and the Agency to facilitate the synergy between renewable energies and nuclear energy by generating hybrid systems (renewable energy and nuclear based);
(3) Existence of the CLEW concept, which enables the nuclear sector to seek partnerships with the United Nations Department of Economic and Social Affairs (UNDESA) and other international organizations (IRENA), Economic and Social Commission for Asia and the Pacific (ESCAP), United Nations Economic Commission for Africa (UNECA) in integrating the use of land, energy and water in connection with climate change;
(4) The revival of nuclear programmes in Argentina and Brazil opens up the possibility of developing the nuclear industry in the region;
(5) The existence of national policies to diversify the energy matrix and the need to strengthen security of electricity supply;
(6) Nuclear power plant lifetime extension;
(7) Increase in the global costs of the system for the large scale penetration of intermittent renewables;
(8) Existence of an organization such as the Agency, which provides support to its member countries for energy planning;
(9) Demand for radioisotopes, services and advanced techniques that can be met by the region's research reactors.

NEEDS AND PROBLEMS

E1. Incorporation of the subject of energy systems into educational programmes in the region, from school through to university level.

Justification: Basic topics related to energy, its connection with climate change, or the advantages and disadvantages of electricity generation technologies are scarcely included in school curricula at primary and secondary level. Very few university degrees cover these topics either. Moreover, they need to be included in the training of teachers and instructors. This would help to disseminate the benefits of nuclear energy, improving social perceptions and promoting collaboration on SDG 4.

Objective: To have adequate material to raise awareness, provide training and increase knowledge of topics related to energy and its relationship with climate change.

Indicator: Increase in number of countries that have trained teachers and lecturers disseminating the material produced.

E2. Establishment of a network for the exchange of information and coordination of strategies, from research reactor operators to the radioisotope end user

Justification: Efforts have been made in the region to exchange experience among various interested parties involved in the safe operation of research reactors and their use to produce radioisotopes as well as research. The balance of needs in terms of production of radioisotopes and radiopharmaceuticals has also been determined. However, the required and effective exchange of information between the whole chain of interested parties has not been achieved.

The establishment of a network facilitating the exchange of information and coordination of strategies from research reactor operators to the radioisotope end user will help to increase the implementation of strategic plans for reactor utilization. This assumes greater importance in the light of the plans for two new reactors that are due to begin operation during the period of the RSP.

Objective: To establish a network that will help to increase research reactor users in the region.

Indicator: Increase in number of countries participating in the network.

E3. Availability of national, subregional and/or regional energy plans that include SDGs 7 and 13.

Justification: The high level of turnover of human resources previously trained causes discontinuity in the drafting and review of energy plans. Therefore, support is needed to develop studies that aid decision making to achieve homogeneous energy planning in the countries of the region. Additional detailed studies could be carried out through the analysis of lessons learned and the use of integrated models to analyse energy supply and demand that can support the development of national, subregional, and regional scenarios. These scenarios consider current energy resources, fuel prices, economic growth, population growth, structure, and evolution of the energy system, as well as the incorporation of distributed generation of energy and environmental impact. Efforts need to be made to determine the role that nuclear energy will play in electricity supply and reduction of GHGs.

Objective: To maintain homogeneous energy planning in the countries of the region.

Indicator: Increase in number of countries that develop comprehensive long term energy plans that take account of SDGs 7 and 13.

E4. Incorporation of the CLEW concept into energy planning discussion forums in the region

Justification: The LAC region has no plans that include a comprehensive analysis of variables such as the use of land, energy and water, in connection with climate change. To integrate these aspects and develop short term capacities in the countries of the region related to achievement of the five associated SDGs: SDG 6; SDG 7; SDG 15; SDG 2; and SDG 13 — as defined in the 2030 Agenda.

There is motivation within the Agency to ensure the integration of these four factors of climate, land energy and water (CLEW). Owing to the diversity of the topics and the scale of the project, major

efforts are required, along with the relevant budget and human resources with different capacities and specializations.

Most countries in the region do not have multidisciplinary teams for the integration of CLEW, and in some countries, the specialized staff are spread among different local organizations, which leads to a lack of multidisciplinary teams to develop and analyse integration aspects at the national and regional level.

Some of the Agency's planning tools, such as Model for Energy Supply Strategy Alternatives and their General Environmental Impact (MESSAGE) and Model for Analysis of Energy Demand (MAED), and the tools of various institutions need to therefore be explored, as they could be used to analyse soil use, clean energy and water demand [131].

Objective: To have national and/or subregional and/or regional plans in the countries of the region that integrate CLEW.

Indicator: Increase in number of countries that develop comprehensive long term energy plans that include the achievement of the six associated SDGs: SDG 6, SDG 7, SDG 15, SDG 2, SDG 13 and SDG 17.

E5. Nuclear power plant lifetime extension

Justification: Most of the reactors in the region are coming to the end of their currently agreed operating lifetime, and the political will for extension has been expressed. Although there is experience of these processes in the region, it has not been disseminated; it would therefore be important to share it with the teams from interested countries. For the period under consideration, the exchange of experience among personnel responsible for extending the lifetime of the reactors, and support for these processes using the experience accumulated at the Agency, are key factors in this objective.

Objective: To consolidate regional experience in processes to extend the operating lifetime of nuclear power plants.

Indicator: Increase in number of countries in the region that have exchanged experience of nuclear power plant lifetime extension processes.

6.4 PRIORITIZATION OF THE NEEDS AND PROBLEMS

The following Table 6 reflects the final prioritization grades, determined by the variables outlined, of numerous issues in the energy sector followed by a visual comparison of these grades shown in Fig. 4.

TABLE 6. PRIORITIZATION OF THE NEEDS AND PROBLEMS IN THE ENERGY SECTOR

P	Need/Problem	Severity	Time	Extent	Relevance	Total grade	Difficulty	R/D	Final grade
1	E3	4.0	4.0	5,0	4.0	17.0	2.0	2.0	34.0
	Availability of national, subregional and/or regional energy plans that include SDGs 7 and 13.	Ongoing support needs to be maintained to have studies that aid decision making in energy policies, to achieve homogeneous planning that takes account of the SDGs in the countries of the region.	Work needs to be ongoing throughout this period to ensure that the SDGs are met.	Action needs to be taken in all Spanish-speaking countries of Latin America and the Caribbean.	Effective action is needed to uphold the global model of the SDGs.		Implementation depends on countries' national energy policies.		
2	E4	4.0	4.0	5.0	3.5	16.5	4.5	0.78	12.83
	Incorporation of the CLEW concept into energy planning discussion forums in the region.	It is important to integrate these four aspects owing to competition for natural resources for energy and non-energy purposes.	Addressing this topic will lead to the rational use of natural resources.	Action needs to be taken in all Spanish-speaking countries of Latin America and the Caribbean.	Effective action is needed to integrate these four aspects.		Implementation depends on the inclusion of this topic in countries' energy planning agendas.		

TABLE 6. PRIORITIZATION OF THE NEEDS AND PROBLEMS IN THE ENERGY SECTOR (cont.)

P	Need/Problem	Severity	Time	Extent	Relevance	Total grade	Difficulty	R/D	Final grade
3	E5 Nuclear power plant lifetime extension	4.0	45	2.0	4.0	14.5	3.5	1.14	16.57
		Most of the nuclear power plants in the region need their lifetimes extending if they are to last more than 30 years.	The plant life extension licensing process is lengthy and needs to be handled by the national nuclear regulatory authority.	Action needs to be taken in countries whose nuclear power plants have been in operation for over 30 years.	Contributes to countries' technological development, maintains or preserves the contribution of nuclear energy to the diversification of electricity matrices, and prevents GHGs emissions.		Although there are no technical difficulties, major national budgetary resources are required for this project.		
4	E1 Incorporation of the subject of energy systems into educational programmes in the region, from school through to university level.	3.0	2.0	5.0	3.5	13.5	3.5	1.0	13.5
		Public opinion on nuclear energy needs to be clarified.	Work can be carried out in the medium term.	Action needs to be taken throughout Latin American society.	Addressing this need will help to change public opinion.		No difficulties in implementation foreseen.		
5	E2 Establishment of a network for the exchange of information and coordination of strategies, from research reactor operators to the radioisotope end user.	3.0	2.0	3.0	3.75	11.75	2.0	1.88	22.03
		The creation of a network would improve the radioisotope situation to reduce underutilization.	No changes identified that require short term action.	It would be positive for the region to have better integration among the countries with radioisotopes.	It is important to explore the full potential of the radioisotopes available in the region.		The institutes that have radioisotopes need encouragement to cooperate with one another.		

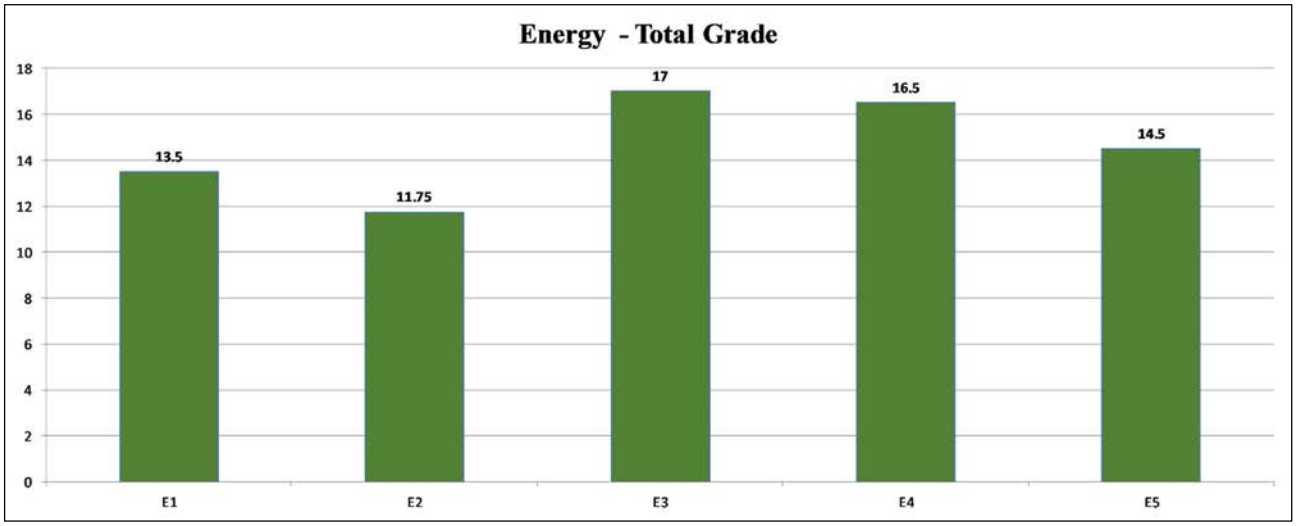

FIG. 4. Needs and Problems in Energy vs Total Grade

RADIATION SAFETY

7. RADIATION SAFETY

GENERAL ANALYSIS OF THE REGIONAL SITUATION

Acceptance in society of the risks associated with radiation is dependent on the net benefit from its multiple applications. Radiation safety aims to protect workers, the public, patients, and the environment from the harmful effects of ionizing radiation and ensure adequate protection of current and future generations from any activity that involves exposure to such radiation.

In accordance with Article III of its Statute, the Agency is authorized to establish and facilitate the application of Safety Standards to protect health and minimize the risks to life and property associated with the application of ionizing radiation [132]. The Agency's standards cover nuclear safety, radiation safety, safe transport of radioactive material, radioactive waste management decommissioning and environment remediation.

The Fundamental Safety Principles stipulate that Member States need to have a national system for effective control of all radiation sources, including a regulatory body, with clear responsibilities and powers, and sufficient resources, that allow it to fulfil its mandate to regulate, authorize, control and sanction, as well as to ensure compliance with international commitments laid down in international agreements, arrangements, protocols, and conventions [133]. States need to also have the necessary arrangements in place so that, if needed, the capacity exists for intervention and mitigation in the event of accidents and emergencies.

In the area of radiation safety, the 2016–2021 RSP used as a reference point the information provided by the Agency, such as expert missions, reports from evaluation missions [Integrated Regulatory Review Service (IRRS), Occupational Radiation Protection Appraisal Service (ORPAS), Emergency Preparedness Review (EPREV), Education and Training Appraisal (EduTA), and others], information from international meetings and congresses, country reports presented or regional coordination meetings, national profiles relating to the safety of radiation sources and radioactive waste (RASIMS), Emergency Preparedness and Response Information Management System (EPRIMS), country programme frameworks for the technical cooperation programme, surveys and other sources of information.

Based on the needs identified in the RSP, the Agency has been managing technical cooperation projects that have contributed significantly to improving the regulatory infrastructure, occupational radiation protection, radiation protection of patients and the public, radiological emergency preparedness and response, education and training in radiation safety, management of radioactive waste and safety of transport of radioactive material.

The following reference documents were consulted when preparing this RSP:

- Report of the 2nd meeting of the Monitoring and Evaluation Group, April 1st -5th, 2019;
- Report of the XX coordination meeting of the ATCB meeting, May 20th – 24th, 2019;
- Report of the XX meeting of the BAR meeting, September 19th, 2019;
- ARCAL: Regional Strategic Profile for Latin America and the Caribbean (RSP) 2016–2021 [134];
- Guide for the Implementation of the Regional Strategic Profile for 2016–2021;
- Call for projects;
- Governmental, Legal and Regulatory Framework for Safety. General Safety Requirements, Part 1 [135];
- Leadership and Management for Safety. General Safety Requirements, Part 2 [136];

- Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards. General Safety Requirements, Part 3 [137];
- Safety Assessment for Facilities and Activities. General Safety Requirements, Part 4 [138];
- Predisposal Management of Radioactive Waste. General Safety Requirements, Part 5 [139];
- Decommissioning of Facilities. General Safety Requirements, Part 6 [140];
- Preparedness and Response for a Nuclear or Radiological Emergency. General Safety Requirements, Part 7 [141];
- Regulations for the Safe Transport of Radioactive Material. Specific Safety Requirements No. SSR-6 (Rev. 1) [142].

Additional supporting documents were given consideration:

- Background, Methodology and Process for Preparation of the RSP for LAC;
- UN SDGs.

To assess the situation in the region, information in the Agency's RASIMS database was primarily used, as was technical advice provided by TOs from the Agency with responsibility in different areas.

From this analysis, it was concluded that significant progress on establishing regulatory infrastructure and programmes has been made in the LAC region over the last 25 years. This has been a result of the endeavours of and technical cooperation between the Agency and its Member States. However, decisive efforts are required by all parties to consolidate the results achieved as international good safety practice.

It is also important to note that the new Agency safety standards (General Safety Requirements (GSR) Part 1 (Rev. 1), GSR Part 2, GSR Part 3, GSR Part 4 (Rev. 1), GSR Part 6 and GSR Part 7) with their new structure and content clearly reflect the responsibilities of governments and regulatory bodies in the development and application of regulatory infrastructure and systems [135]-[138], [140]-[141]. The Agency has to therefore encourage Member States' governments to put the safety requirements set out in the Agency Safety Standards into practice to ultimately ensure the establishment of effective and sustainable regulatory and radiation safety infrastructures.

The evaluation recognizes the achievements of previous and current national and regional projects as regards all aspects associated with the creation and/or improvement of radiation safety infrastructures.

The following human resource management-related observations can be made regarding the staff of the regulator, end users and technical services:

- In some cases, shortages in terms of the intake of new professionals, causing working groups in the area to lose capacity
- In other cases, excessive staff rotation undermines the sustainability of radiation safety infrastructure, making knowledge management more difficult;
- Most countries do not have the human and financial resources to fulfil all their designated responsibilities under applicable regulations and legislation;
- There is an absence of proper knowledge management.

The evaluation of the current radiation safety situation in countries of the Latin America region was updated in the following areas:

- Regulatory infrastructure (Thematic Safety Area TSA 1);
- Radiological protection in occupational exposure among end users (TSA 2);
- Radiological protection in occupational exposure for technical services (TSA 2);
- Radiological protection in medical exposure (TSA 3);

- Radiological protection of the public, the environment and in radioactive waste management (TSA 4);
- Emergency preparedness and response (TSA 5);
- Education and training in radiation safety (TSA 6);
- Safe transport of radioactive material (TSA 7);
- Safety of nuclear reactors.

Details of the analysis of each of these areas are given below.

7.1.1. Regulatory infrastructure

- It is noted that some of the governments in the region still do not know enough about the role of the regulatory body, which could adversely affect the sustainability of the national radiation safety system;
- Important aspects need to be addressed in order to establish effective regulatory bodies, with sufficient competencies and technical expertise;
- Existing laws and regulations do not always meet IAEA safety requirements. In some countries, regulations do not cover recently introduced practices and technologies;
- Regulations need to be updated in line with the Agency's Safety Standard Principles and Requirements;
- There are no documented safety policies that addresses the fundamental safety objective, fundamental safety principles and a long term commitment for safety, as required in GSR Part 1 (Rev. 1) Requirement 1;
- There is a lack of guidance on implementing exemption and clearance requirements;
- There continue to be deficiencies in the establishment and implementation of integrated management systems as required by GSR Part 2;
- There are no specific regulatory requirements to ensure the establishment of a programme to promote and implement a safety culture in the area of radiation safety;
- In some countries regulatory control of research reactors, do not follow IAEA Safety Guides;
- Control of the imports and exports of radiation sources carried out between countries in the region does not comply with the criteria in the supplementary guidance to the Code of Conduct on the Safety and Security of Radioactive Sources;
- There is no strategy to inform and consult interested parties and the public of possible radiation risks associated with facilities and activities, and processes and decisions of the regulatory body;
- Countries are unprepared for the increase in licensing of facilities housing cyclotrons used to manufacture radiopharmaceuticals and new technologies already in use in many countries of the region.

7.1.2. Radiation protection in occupational exposure among end users

- The safety assessment process and its tools are limited for meeting the requirements of GSR Part 4 [138];
- External exposure monitoring is practically limited to whole body dose measurement [143];
- Single national registers of all occupational doses are not available or are under used in all countries of the region;
- Lack of proper implementation of the radiation protection programme in all countries, with respect to the Agency's recommendations;

- Lack of processes for registrants and licensees to ensure optimization of protection and security;
- Promotion and encouragement of a safety culture are limited at all levels of management, organizations and workers;
- Not all industries and activities using NORM that require an occupational radiation protection programme have been identified;
- Limited application of management systems including elements of radiation protection for end users, as required by GSR part 2;
- There are limited services and items of equipment available for workplace monitoring in connection with end users' facilities and activities (measurement of radiation fields, surface contamination and ventilation systems);
- Lack of distance learning (e-learning) materials for programmes on safety assessment, radiation protection and optimization for end users. These programmes need to be aimed at radiation protection officers (RPOs);
- Lack of distance learning (e-learning) materials on the role, functions and tasks of the persons technically competent in the area of radiation protection for a specific type of activity, designated by the licensee or the employer to oversee the application of regulatory requirements at the facility or to the activity.

7.1.3. Scientific and technical services supporting the radiation safety infrastructure

- Limited and unsustainable services for individual monitoring, workplace monitoring and assessment of exposure in emergencies;
- Limited implementation of management systems in technical services, based on ISO 17025:2017;
- Limited network among technical support services (Network for the Optimization of Occupational Radiation Protection in Latin America (REPROLAM, for its acronym in Spanish) and Latin American Biological Dosimetry Network (LBDNet));
- Lack of distance learning (e-learning) materials on radiation measurement methods and types of monitoring;
- Limited possibilities for intercomparison exercises and performance tests;
- Failure to designate collaborating centres to facilitate regional training on new methodologies, dosimetry services and calibration;
- Standards dosimetry laboratories do not meet all the region's needs in terms of calibrating gamma, X ray, neutron, and alpha and beta radiation beams;
- The services of the standards dosimetry laboratories in the region are limited in terms of levels of radiation protection and the need to calibrate equipment for workplace monitoring;
- Insufficient calibration capacity within standards laboratories for diagnostic radiology, radiotherapy and nuclear medicine;
- Limited dissemination of the international code on calibration in radiation protection, at present this is document SRS-16 which is currently being updated [144]. Additionally, there is no international code on calibrating activity meters for nuclear medicine.

7.1.4. Radiation protection in medicine

- While the region has worked on the development of specific health guidance regarding justification for all types of medical practices, not all medical associations or healthcare institutions are properly applying this principle;
- Lack of implementation of radiation protection programmes in some cases;

- Lack of implementation processes and guidance to optimize radiation protection for patients in all practices, with a particular focus on interventional and fluoroscopic procedures;
- Lack of a strategy to optimize occupational radiation protection in medicine, in line with General Safety Guide Nr. GSG-7 [145];
- Promotion and encouragement of a safety culture are limited at all levels of management, organizations and workers;
- Countries of the region are incorporating advanced radiotherapy technologies, requiring radiation protection measures to be adapted;
- Insufficient implementation and promotion of systems for reporting on and learning from incidents;
- Insufficient regional and national implementation of diagnostic reference levels. In most medical institutions, doses from medical studies are not recorded;
- There is insufficient training on programmes to optimize radiation protection in most practices, with a focus on new technologies (digital techniques; tomosynthesis; dental CBCT; multi-slice computed tomography; hybrid SPECT–CT and PET–CT systems);
- There is also insufficient training for medical and paramedical staff on radiation protection programmes for treating children and pregnant women in specialities with greater radiation risk, such as radiotherapy and interventional procedures.

7.1.5. Radiation protection of the public, the environment and in radioactive waste management

- Although steps to improve capacities for timely detection and safety measures have been taken, orphan sources continue to appear in material to be recycled, which can give rise to radiological emergencies;
- Most countries in the region took part in the Agency's activities to identify existing exposure situations associated with industries that involve NORM and to assess their impact on the public and the environment. Exceptions aside, an effective regulatory framework to address NORM has not been developed;
- Most countries have not formalized their national radioactive waste management policies and strategies;
- Most countries have not formalized their national environmental remediation policies and strategies in line with GSG-15 [146];
- Most countries have not formalized their national decommissioning policies and strategies in line with GSR Part 6 [140];
- Most countries took part in the Agency's activities on exemption and clearance, but do not include regulations and guidance for their implementation;
- In some cases, lack of adequate systems for monitoring environmental discharges and adequate environmental monitoring programmes.

7.1.6. Emergency preparedness and response

- The protection strategy, mitigation of non-radiological consequences and the management system have been identified as the main areas for improvement. Similarly, some countries in the region have not formally reported on the real situation regarding preparedness for and response to nuclear and radiological emergencies;

- There are also other areas for improvement, such as systematic accident analysis, dissemination of information, medical response, retrospective dosimetry and first responders' capacities.

7.1.7. Education and training in radiation safety

- Most countries lack a national strategy on education and training in radiation safety, transport and waste;
- Most countries have some regulatory requirements in relation to education and training on radiation safety. However, they do not cover all categories of staff requiring education and training in this area;
- Not all facilities and activities possess RPOs or qualified experts;
- Most countries experience difficulty in training RPOs, officers working in medical and industrial facilities, and qualified radiation protection experts.

7.1.8. Safe transport of radioactive material

- In most cases, transport regulations have not been updated in line with the Agency's latest principles and requirements. In some cases, there are no regulations specifically applying to the safe transport of radioactive material;
- Evidence of compliance with transport regulations is, in general, lacking;
- Regulatory control of sources in shipments between the various countries of the region is deficient;
- All countries have several authorities involved in controlling the transport of radioactive material, in addition to the nuclear regulator. In most countries, the staff of other authorities (transport ministry/secretariat, customs, police, etc.) lack training, and it is often the case that the attribution of specific responsibilities is unclear and suffers from gaps or overlaps.

7.1.9. Safety of nuclear reactors

- Most of the reactors in the region have been operating for decades, and the challenge is whether to engage in an effective lifetime extension or to begin dismantling and decommissioning;
- The development of new reactor projects in some cases requires adapting part of the infrastructure for safety, in line with the Agency's Safety Standards;
- The development of new reactor projects in some cases requires the regulator's competencies for safety assessment and for review and assessment to be enhanced.

In terms of the nine Sustainable Development Goals related to the Agency's activities (SDGs 2, 3, 6, 7, 9, 13, 14, 15 and 17), the field of radiation safety contributes directly to SDG 3, and to the cross-cutting SDG 17; at the same time, given its horizontal nature, this field would in fact contribute to all sectors.

SWOT ANALYSIS

7.2.1. Strengths

(1) Existence of legislative and regulatory frameworks in almost all countries. Most countries also have established an operational authorization and inspection systems;

(2) Improvement of the regulatory bodies' skill and preparation levels;
(3) Signature of international conventions on emergencies and other safety conventions.
(4) Countries' adherence to the Code of Conduct on the Safety and Security of Radioactive Sources [147] and its supplementary guidance 148, [149];
(5) Existence of national inventories of radioactive sources from Category 1 to Category 3, radioactive waste and disused radioactive sources;
(6) Better knowledge on the part of countries as regards their need to develop regulation and control infrastructure;
(7) Existence of essential technical services to determine occupational exposure and aspects of radiation measurement during environmental discharges and emergency response;
(8) A cultural and linguistic identity that facilitates exchange of experience, information and professional support, helping to bring countries to the same level in various areas relating to safety;
(9) Existence of a shared vision to resolve radiation safety issues;
(10) Countries have identified the main problems they face in the area of radiation safety;
(11) Involvement of the private sector in aspects of radiation protection;
(12) Recognition by countries of the need for authorized centralized radioactive waste storage facilities and disused radioactive sources;
(13) Existence of organizations for conventional emergency management that can collaborate in radiological emergency situations;
(14) Legislation in most countries of the region sets out basic responsibilities concerning planning, preparation for and response to radiological emergencies;
(15) Existence of experienced professionals trained, although limited in number, in almost all fields of safety who can collaborate within a bilateral framework.

7.2.2. Weaknesses

(1) High rotation rate of trained professionals, within regulatory bodies;
(2) Some regulatory bodies have limited trained human resources and infrastructure to meet their responsibilities under national legislation;
(3) Many countries do not have an up-to-date nuclear safety law;
(4) Lack of officially established cooperation and coordination between different national authorities, where there is more than one;
(5) Lack of actual independence of the regulatory body in some countries where the regulators are subordinate to the same organization that promotes practices requiring regulation;
(6) In some cases, regulations in the area of radiation safety are lacking or not up to date. In particular, GSR Part 1 (Rev. 1), GSR Part 2, GSR Part 3, GSR Part 4 (Rev. 1), GSR Part 6 and GSR Part 7 [135]-[138], [140]-[141];
(7) In many countries, regulatory measures do not apply a graded approach to optimize their resources and thereby cover all activities and practices. Most regulations do not clearly set out the application of safety assessment requirements;
(8) Insufficient coverage of regulatory control in diagnostic radiology and interventional practices.
(9) Rarity of up-to-date registers of radiation sources, and limited use to properly organize regulatory bodies' work;
(10) Lack, weakness or limited application of enforcement measures;
(11) In many regulatory bodies, management systems — including registers, authorization, implementation of standards, inspections, information and cooperation — are not established, implemented, evaluated and continuously improved;
(12) Failure to require implementation of management systems in facilities and regulated activities, in many countries;

(13) Failure on the part of the authorities to require internal dosimetry;
(14) Lack of harmonization concerning processes and criteria for authorizing, approving and verifying the competence of technical services;
(15) Limited implementation of unified national occupational dose registers (16 countries currently have a national dose register);
(16) Poor regulation and practical application of the concepts of exemption and clearance;
(17) Coverage of external personal dosimetry is not sufficient to encompass all workers and all types of radiation to be measured;
(18) The number of laboratories providing internal dosimetry services is insufficient, despite possession of the methods and trained staff for such services;
(19) There are limited services and items of equipment available for workplace monitoring e.g measurement of radiation beams, surface contamination and ventilation systems;
(20) The services of the standards dosimetry laboratories in the region are limited in terms of levels of radiation protection and the need to calibrate equipment for workplace monitoring;
(21) Management systems in technical support services are not fully implemented;
(22) Scant implementation and control of safety assessment programmes and radiation protection, and optimization of the latter in facilities and activities;
(23) Lack of knowledge management to enable institutional memory of radiation safety issues to be maintained;
(24) Ageing of human resources specialized in radiation safety, and failure to replenish them;
(25) In some cases, knowledge acquired during specific courses provided by international organizations is not shared internally or used for training at national level;
(26) Insufficient awareness-raising on radiation protection issues among professionals working with ionizing radiation, and lack of information provided to the general public;
(27) Absence, or limited dissemination, of formal programmes for the development and promotion of a safety culture among users, support services and regulators;
(28) Countries' dependence on the support, resources and programmes of international organizations, especially the Agency, for training and procurement of equipment;
(29) Limited use of the tools, such as RASIMS and EPRIMS, developed by the Agency to assess the effectiveness of regulatory programmes and monitoring systems;
(30) Poor clarity at governmental level regarding the importance, need for and scope of national policies and strategies pertaining to radioactive waste management;
(31) Poor clarity at governmental level regarding the importance, need for and scope of national policies and strategies pertaining to decommissioning;
(32) Poor clarity at governmental level regarding the importance, need for and scope of national policies and strategies pertaining to environmental remediation;
(33) Interested parties and the public insufficiently informed and consulted concerning possible radiation risks associated with facilities and activities, and concerning processes and decisions of the regulatory body;
(34) Insufficient coverage of regulatory control regarding the transport of radioactive material in cases where the radioactive material is more vulnerable owing to being in a public place, where failure to comply with the requirements would affect workers and the public;
(35) Insufficient coverage of regulatory control in NORM industries and identification of existing exposure situations in the countries;
(36) Insufficient capacities for the timely detection and control of material to be recycled (orphan sources in scrap);
(37) Limited use of incident reporting systems;
(38) Few notification systems with formalized coordination for all organizations that have to be involved in emergency response;

(39) Shortcomings, in most countries, in threat evaluation for planning response to radiological and nuclear emergencies;
(40) Most countries do not possess an approved and implemented national strategy on education and training in radiation safety that covers the various categories of staff and practices;
(41) Lack of coordination between regulatory bodies regarding international shipments of radioactive material.

7.2.3. Threats

(1) Low level of awareness and commitment among governments regarding supporting, strengthening and establishing an effective, governmental, legal, and regulatory framework for safety;
(2) Little attention paid by governments to strengthening regulatory bodies as regards control of certain areas of medical practice, in particular diagnostic X rays and equipment that emits radiation;
(3) Changes in national authorities (changes in governments), which, owing to a lack of appropriate information and training, compromise the established infrastructure and the continuity of trained personnel and national regulatory projects and programmes;
(4) Economic difficulties in countries in connection with prioritizing radiation safety, given the other risks facing governments and their other development plans;
(5) Reduction or elimination of external financing for developing radiation protection activities, such as responding to radiological and nuclear emergencies;
(6) Limited ability to communicate in English, restricting opportunities for global exchanges and assistance and underlining the need to train regional experts in all areas of radiation safety.
(7) Healthcare resources in the region to treat those injured in emergency situations are not properly identified;
(8) No systematic analysis has been performed of the accidents that have occurred in the region, nor are all accidents officially reported;
(9) The region does not have enough experts to advise on the medical response in the event of nuclear and radiological emergencies or on the safe transport of radioactive material;
(10) Inadequate control of the conditions under which radioactive material is transported, potentially increasing the risk of theft of sources or limiting response capacity in the event of a radiological emergency in a public place owing to a lack of proper notification.

7.2.4. Opportunities

(1) Access to expertise, regulatory documents, procedures and outputs developed through the Ibero-American Forum of Radiological and Nuclear Regulatory Agencies;
(2) Existence in the region of essential technical services to support radiation safety infrastructure.
(3) Availability of tools (software) that serve as a basis for training personnel and other activities in the area of radiation safety;
(4) Offer of specialized international [IAEA, PAHO, International Labour Organization (ILO)] and bilateral cooperation on radiation protection, aimed at supporting the development of radiation safety infrastructure in the countries;
(5) Existing capacity in some countries of the region for training of trainers and producing multiplier effects;
(6) Existence in the region of a group of experts and access to LBDNet services to respond to radiological emergencies;
(7) Existence of two regional training centres for the provision of postgraduate courses in radiation protection recognized by the Agency;

(8) Availability of training packages developed by the Agency, such as online courses, allowing the information imparted in training to be standardized;
(9) Existence of international conventions on safety and emergency response [150-[152] and codes of conduct147, [153].
(10) Capacity of the private sector to collaborate, support, promote and finance new initiatives, and strengthening of current ones;
(11) Interest, in some countries of the region, in nuclear power generation.

NEEDS AND PROBLEMS

R1. Limitations of some regulators as regards control of facilities and activities (medical X rays, new technologies, etc.) and of some governments in establishing and maintaining an appropriate governmental, legal, and regulatory framework for safety

Justification: All Member States in the region have a legally established regulatory body. However, this does not always guarantee a sustainable national regulatory system for radiation protection that provides the regulatory body with sufficient resources to discharge its responsibilities concerning regulation, authorization, inspection and enforcement. In addition, the level of commitment of governments to support, strengthen and implement regulatory programmes for radiation safety can be improved. Most countries have limited human and financial resources to fulfil all their designated responsibilities under the legal framework.

Objective: To ensure that an effective governmental, legal and regulatory framework for radiation safety and the safe transport of radioactive material at the national level is prioritized and sustained.

Indicator: Increase in number of countries documenting that they have increased the degree of implementation of RASIMS 2.0 performance indicators associated with a legal, budgetary and human resources framework, enabling them to ensure the stability and sustainability of the regulatory programme for radiation safety and the safe transport of radioactive material.

R2. Insufficient implementation of international safety requirements and recommendations for controlling occupational exposure, with a focus on extremity and lens dosimetry, internal dosimetry, monitoring of workplaces, laboratory quality systems and national dose registers

Justification: Although the number of technical services for external dosimetry has increased in the region, there is still a lack of coverage, in particular concerning neutron and beta dosimetry. Due to the lack of internal dosimetry services in most countries, it is not possible to evaluate the occupational exposure of those working in nuclear medicine and the production of radionuclides. Furthermore, the services and equipment available to monitor radiation beams and surface contamination in workplaces remain limited. Quality systems for such services have not been implemented in all countries of the region, nor their technical competencies recognized by the respective regulatory body. Need to participate in interlaboratory comparison exercises, making it necessary to strengthen REPROLAM.

Objective: To increase the coverage of dose control for workers occupationally exposed through technical services with recognized quality systems in place in the countries (individual internal and external monitoring, and workplace monitoring). To establish national occupational dose registers in countries of the region and keep them updated.

Indicator: Increase in number of countries offering proof that they have stepped up implementation of the RASIMS 2.0 performance indicators associated with occupational monitoring, considering ORPAS mission reports.

R3. Limitations in the calibration capacities of the region's standards dosimetry laboratories as regards radiation protection, radiodiagnostics and radiotherapy

Justification: Equipment calibration and verification services in the standards dosimetry laboratories in the region are not sufficient to meet the needs of end users in terms of levels of radiation protection (extremities, lens, surface contamination), in radiodiagnostics, nuclear medicine (activity measurement) and radiotherapy. This is mainly due to the lack of infrastructure and equipment, obsolescence of equipment and a shortage of trained technical staff. In addition, problems often arise at customs when transferring equipment between countries.

Objective: To identify proposals for a solution and start implementing them in the short and medium term, with the aim of ensuring that dosimetric calibration services required in the region for calibrating equipment and dosimeters are modernized.

Indicator: Increase in number of countries demonstrating that they have increased implementation of the RASIMS 2.0 performance indicators associated with calibration, considering ORPAS mission reports.

R4. Insufficient implementation of international safety requirements and recommendations and of the ten actions in the 'Bonn Call for Action' [154] for controlling medical exposure, with a focus on advanced radiotherapy technologies, interventional and fluoroscopic procedures, digital radiology, tomosynthesis, dental CBCT, multi-slice computed tomography, and SPECT–CT and PET–CT.

Justification: The wide range and high number of people exposed during medical practices, and the sometimes partial implementation of international radiation safety requirements [135] and recommendations [154], mean that these practices still require efforts from all involved parties, so as to avoid unnecessary exposure among patients and, occasionally, workers and the public. While awareness of radiation risk and safety culture has increased, work still needs to continue at all levels. New practices and advanced technologies are being introduced in most countries, requiring particular attention.

Objective: To improve the level of implementation of radiation protection requirements [135] and recommendations [154] with emphasis in high-risk medical practices, with a focus on the specific needs identified.

Indicator: Increase in number of countries documenting that they have increased the degree of implementation of RASIMS 2.0 performance indicators associated with medical practices.

R5. Insufficient implementation of international safety requirements [135] and recommendations [155] for radiation protection of the public and the environment and in the management of radioactive waste. In particular, work needs to focus on national policies and strategies, management of disused radioactive sources, and the identification and resolution of radiological situations due to the presence of NORM.

Justification: Lack of formal approval in most countries of national policies and strategies for the safe management of radioactive waste that identify responsibilities for the waste management programme

and capacities for the conditioning, storage and disposal of radioactive waste and disused sources. Failure to incorporate the use of the concepts of exclusion, exemption and clearance tools for radioactive waste into national regulations. Lack of mechanisms in most countries for the early detection and safe management of orphan sources in the metal (scrap) recycling industry. In most countries of the region, the obligation to identify existing exposure situations due to NORM and to assess their radiological impact, to implement regulatory control measures, has not been incorporated into national regulations. In most countries, while progress has been made in establishing centralized radioactive waste storage facilities, the disposal of disused sources that cannot be returned to their country of origin has not been addressed.

Objective: To implement by governments their national policies and strategies to guarantee the safe and sustainable management of radioactive waste. To put in place regulations to improve the safety of managing radioactive waste, the remediation of contaminated areas and disused sources. To increase the capacity to detect and manage orphan sources, identify, and solve exposure situations due to NORM, along with the plan to develop national capacities for the final disposal of disused sources that cannot be returned to the country of origin.

Indicator: Increase in the number of countries in the region approving national policies and strategies for the safe and sustainable management of radioactive waste, with licensed centralized radioactive waste storage facilities; incorporating clearance tools for radioactive waste into regulations; launching programmes to study the disposal of disused radioactive sources; and finalizing the identification of exposure situations due to NORM and a plan of action to resolve them.

R6. Limited capacities in countries for planning, notification, and response regarding radiological emergencies, including systematic analysis of accidents and dissemination of information

Justification: By means of EPRIMS, Member States have identified limitations in the capacity for planning, notifying and responding to radiological emergencies in the region in some of the areas set out in EPRIMS, in particular modules 5, 16 and 26.

Objective: To achieve an adequate level of preparedness and response for a nuclear or radiological emergency by applying the general and functional requirements and requirements for infrastructure identified in the Agency's GSR Part 7. These requirements need to be implemented by the corresponding national authority by enacting laws, setting regulations, and adopting other arrangements, in particular assigning responsibilities to all relevant bodies (e.g., the operating organization, local or national officials, response organizations or regulatory bodies) and verifying effective compliance.

Indicator: Increase in number of countries documenting that they have increased the degree of implementation of EPRIMS performance indicators associated with modules 5 (protection strategy), 16 (mitigating non-radiological consequences of an emergency) and 26 (quality management programme) and updated their self-assessment via EPRIMS.

R7. Insufficient implementation of international requirements and recommendations concerning education and training on radiation safety, transport and waste for all staff members involved, with a focus on national strategies

Justification: In most of the countries, there is absence of sustainable national strategies for education and training. Radiation safety can be ensured only if there are enough personnel with expertise in this area.

Most countries have some regulatory requirements in relation to education and training. However, they do not cover all categories of staff requiring expertise in this area. The lack of comprehensive requirements suggests that staff with responsibilities for radiation safety and occupationally exposed personnel probably do not possess the necessary expertise, which jeopardizes the safety of facilities and their activities.

Most countries have RPOs in medical facilities with higher radiation risk. The function of qualified expert, as set out in the Agency's safety standards, has not been fully rolled out. In some countries' higher risk medical facilities, some of the qualified expert's functions are performed by the RPO, in other cases, by service providers. Most industrial and medical facilities and activities with lower radiological risk in the countries do not have an RPO or qualified expert.

Since countries need a very large number of qualified experts and RPOs (in the order of one per facility in the case of RPOs), online training (e-learning) has to be considered as an appropriate tool.

Objective: To develop and implement national strategies for education and training; and complete, and ensure the implementation of, education and training requirements for all staff with responsibilities for radiation safety and occupationally exposed personnel.

Indicator: Increase in number of countries documenting that they have increased the degree of implementation of RASIMS 2.0 performance indicators associated with: regulatory requirements for education and training for all categories of staff; verifying the regulatory body's compliance with these requirements; implementation of the requirements; and the design and implementation of the national strategy for education and training.

R8. Insufficient regulatory control of radioactive material in public places (i.e., during transport)

Justification: There is a shortcoming in most countries as regards updating the regulations applying to the transport of radioactive material. Some countries are still following the 1985 edition of the Agency's Transport Regulations; this uses a definition of radioactive material for the application of the Transport Regulations that is different to the current definition, which would affect the decision to apply regulatory control to the transport of a quantity of radionuclides. Some countries in the region do not even possess regulations that enable the regulatory control of the transport of radioactive material.

In most countries, no inspections that encompass transport operations take place; as such, regulatory bodies are not in a position to guarantee that radioactive material is transported safely.

In all countries, regulatory activities as regards the transport of general cargo, dangerous goods and radioactive material overlap. These overlapping responsibilities mean that, for effective regulatory control during transport, good communication is required between the different authorities — something not seen in the region. The lack of this communication can lead to the various authorities imposing different conditions for the same shipment, or, at the other extreme, can mean that a shipment is not subject to any requirements. There are shortcomings in the training and development of staff within the authorities involved in regulating transport, which are distinct from the regulatory body.

The different countries' regulators rarely communicate with each other, thereby making it more difficult to control sources when radioactive material is shipped between countries in the region. This

is conducive to the loss of sources, the nationalization of sources in more than one country simultaneously, and the theft of sources during transport.

Objective: To update the regulations governing the transport of radioactive material in countries of the region; include inspections of the transport of radioactive material; establish a system for communication between authorities involved in controlling the transport of radioactive material within one country; assess and implement the training required by the staff of the various authorities; and establish a system for communication between regulators to enable the tracking of international shipments of radioactive material.

Indicator: Increase in number of countries that have updated/implemented their regulations governing the transport of radioactive material. Increase in number of countries documenting that they have increased the number of inspections of activities relating to the transport of radioactive material. Increase in number of countries that have instituted memorandums of understanding between various authorities. Increase in number of countries that have undertaken training and development of staff of other authorities involved in controlling the transport of radioactive material, also including customs, civilian forces and emergency responders. Increase in number of countries documenting that they have implemented systems for communication to track international shipments of radioactive material.

R9. Insufficient implementation of international leadership and management requirements concerning safety among end users, scientific/technical support services and regulators

Justification: Management system is one of the main elements of a regulatory framework. In Latin America countries, there is a lack of implementation in the regulatory authorities' strategies and programmes on management systems as well as at the technical services and end-users level.

The management system integrates all elements of an organization into one coherent system to enable all the organization's objectives to be achieved. These elements include the organizational structure, resources and processes; personnel, equipment and organizational culture as well as the documented policies and processes.

Objective: To achieve broader implementation of all aspects of management systems within national organizations of infrastructure for safety.

Indicator: Number of countries with regulatory management system established, implemented and operational.

R10. Limited capacity for the safety assessment of facilities and activities, with a focus on reactors, cyclotrons, radiopharmacy and existing exposure situations

Justification: The safety assessment process and the availability of IT tools to carry it out are limited, with respect to the requirements of GSR Part 4. In most countries, neither end users nor regulatory bodies possess the tools required to perform this assessment, meaning that there is a lack of information concerning levels of exposure associated with different applications of radiation during planned and potential exposure situations. This means that radiation protection programmes are incomplete and is a situation not conducive to actions to optimize protection. General Safety Guide GSG-7 [145] contains a requirement for a prior radiological evaluation, which is not implemented. REPROLAM needs to be strengthened as regards safety assessment and optimization.

Objective: To conduct safety assessments and radiation protection programmes for all facilities and activities in countries of the region and keep them updated.

Indicator: Increase in number of countries demonstrating that they have stepped up implementation of the RASIMS 2.0 performance indicators associated with safety assessments, considering ORPAS mission reports.

PRIORITIZATION OF THE NEEDS AND PROBLEMS

The following Table 7 reflects the final prioritization grades, determined by the variables outlined, of numerous issues in the radiation safety sector, followed by a visual comparison of these grades shown in Fig. 5.

TABLE 7. PRIORITIZATION OF THE NEEDS AND PROBLEMS IN THE RADIATION SAFETY SECTOR

P	Need/Problem	Severity	Time	Extent	Relevance	Total grade	Difficulty	R/D	Final grade
1	R8 Insufficient regulatory control of radioactive material in public places (i.e., during transport).	4.5 Jeopardizes public safety.	5.0 These requirements need to be implemented at the earliest opportunity.	5.0 This problem affects most countries in the region.	5.0 Regulatory control of radioactive material during transport is relevant for protection of both workers and the public. Those potentially affected by poor management of safety during transport include all residents of the location where an accident might happen. Poor management of safety during transport would also impair the delivery of supplies to the end user.	19.5	4.0 Linked to the nuclear regulator's willingness to implement measures applying to other areas of radiation safety, and to improve cooperation with other national authorities and communication with counterparts in the region. Modernization and implementation of the regulatory framework will be influenced by governments' political will to establish an effective legal framework, the lack of which means that GSR Part 1 is not being fulfilled.	1.25	24.38

TABLE 7. PRIORITIZATION OF THE NEEDS AND PROBLEMS IN THE RADIATION SAFETY SECTOR (cont.)

P	Need/Problem	Severity	Time	Extent	Relevance	Total grade	Difficulty	R/D	Final grade
2	R4 Insufficient implementation of international safety requirements and recommendations and of the ten actions in the 'Bonn Call for Action' for controlling medical exposure, with a focus on advanced radiotherapy technologies, interventional and fluoroscopic procedures, digital radiology, tomosynthesis, dental CBCT, SPECT–CT and PET–CT.	4.0 Seriously affects the protection of patients and workers.	5.0 It is advisable that these requirements be implemented as soon as possible.	5.0 This problem affects all countries in the region.	5.0 Crucial for the protection of patients and those workers involved with it.	19.0	4.0 Linked to the wide range and number of practices in each country and the need to comply with requirements set by qualified regulatory bodies.	1.25	23.75

TABLE 7. PRIORITIZATION OF THE NEEDS AND PROBLEMS IN THE RADIATION SAFETY SECTOR (cont.)

P	Need/Problem	Severity	Time	Extent	Relevance	Total grade	Difficulty	R/D	Final grade
3	R3 Limitations in the calibration capacities of the region's standards dosimetry laboratories as regards radiation protection, radiodiagnostics and radiotherapy.	4.5	4.5	5.0	4.5	18.5	4.0	1.13	20.91
		Affects the quality of radiation protection of workers, patients, the public and the environment.	Have to be addressed relatively soon given its importance for radiation protection.	This problem affects all countries in the region.	Important for the protection of occupationally exposed workers and crucial for the protection of patients and the public involved with it.		Linked to investment in expensive laboratories, equipment, and trained personnel in the region. It has been shown that this activity has not been able to be sustained in some countries where these laboratories have been established.		
4	R2 Insufficient implementation of international safety requirements and recommendations for controlling occupational exposure, with a focus on extremity and lens dosimetry, internal dosimetry, monitoring of workplaces, laboratory quality systems and national dose registers.	4.0	4.0	5.0	4.0	17.0	4.0	1.00	17.0
		Limit monitoring of the level of safety of workers and facilities.	It is desirable that these requirements be implemented as soon as possible.	This problem affects all countries in the region.	Crucial for occupational radiation protection.		Regulatory bodies need to require their practical implementation. Considers established techniques and services that require quality systems.		

TABLE 7. PRIORITIZATION OF THE NEEDS AND PROBLEMS IN THE RADIATION SAFETY SECTOR (cont.)

P	Need/Problem	Severity	Time	Extent	Relevance	Total grade	Difficulty	R/D	Final grade
5	R10 Limited capacity for the safety assessment of facilities and activities, with a focus on reactors, cyclotrons, radiopharmacy and existing exposure situations.	4.0	4.0	4.75	4.0	16.75	3.0	1.33	22.28
		A highly relevant element of safety on which little work has been done in the region.	Have to be resolved in the medium term, taking into account new requirements, in view of the complexity of the topic.	This problem affects most countries in the region.	Implementing capacities to conduct safety assessments is very pertinent to the safety of nuclear applications.		Linked to knowledge and use of the software tools required to conduct safety assessments.		
6	R7 Insufficient implementation of international requirements and recommendations concerning education and training on radiation safety, transport and waste for all staff members involved, with a focus on national strategies.	4.5	4.0	4.0	3.75	16.25	5.0	0.75	12.19
		Compromises the sustainability of the radiation protection infrastructure.	Quickly find a solution to ensure the availability of trained staff in the near future.	This problem affects a large group of countries in the region.	Considerable, in order to have trained technicians and professionals in post and ensure effective continuity of radiation safety.		Requires coordination in order to benefit from established and available national and regional services and capacities.		

TABLE 7. PRIORITIZATION OF THE NEEDS AND PROBLEMS IN THE RADIATION SAFETY SECTOR (cont.)

P	Need/Problem	Severity	Time	Extent	Relevance	Total grade	Difficulty	R/D	Final grade
7	R1 Limitations of some regulators as regards control of facilities and activities (medical X rays, new technologies, etc.) and of some governments in establishing and maintaining an appropriate governmental, legal, and regulatory framework for safety.	4.0	4.0	4.0	4.0	16.0	5.0	0.80	12.80
		Affects users' effective fulfilment of regulatory responsibilities and requirements.	Control needs to be strengthened in the near future.	This problem affects many countries in the region.	It is important to apply a regulatory framework in line with international standards for the protection of workers, the public and the environment.		Linked to governments' political will to establish an effective framework and regulatory infrastructure.		
8	R9 Insufficient implementation of international leadership and management requirements concerning safety among end users, scientific/technical support services and regulators.	4.5	3.0	4.0	4.0	15.5	5.0	0.8	12.40
		Affects fulfilment of radiation protection requirements among end users and technical services and affects regulatory control.	It is recommended that these requirements be implemented in the medium term.	This problem affects a group of countries in the region.	Required for the application of a management system by end users, technical services and regulators.		Linked to the political and organizational will of end users, technical services and regulators to implement international leadership and management requirements concerning safety.		

TABLE 7. PRIORITIZATION OF THE NEEDS AND PROBLEMS IN THE RADIATION SAFETY SECTOR (cont.)

P	Need/Problem	Severity	Time	Extent	Relevance	Total grade	Difficulty	R/D	Final grade
9	R6 Limited capacities in countries for planning, notification, and response regarding radiological emergencies, including systematic analysis of accidents and dissemination of information.	4.0	3.0	4.0	4.0	15.0	4.0	1.00	15.0
		There is still a need to improve established capacities in most countries.	The plan of action to improve capacities needs to be implemented in the medium term.	This problem affects a large group of countries in the region.	Coordination will increase the level of protection of the personnel affected and the public.		Mainly linked to coordination to make use of established capacities and training in some areas.		
10	R5 Insufficient implementation of international safety requirements and recommendations for radiation protection of the public and the environment and in the management of radioactive waste. In particular, work needs to focus on national policies and strategies, management of disused radioactive sources, and the identification and resolution of radiological situations due to the presence of NORM .	3.0	3.0	4.0	4.0	14.0	4.5	0.89	12.44
		Affects the protection of the public and the environment, and regulatory mechanisms.	It is advisable that these requirements be implemented as soon as possible.	This problem affects most countries in the region.	Implementation will ensure the safety and sustainability of the management of radioactive waste and disused radioactive sources, and, ultimately, protection of the public and the environment.		Linked to governments' political will to establish an effective legal framework and effective infrastructure.		

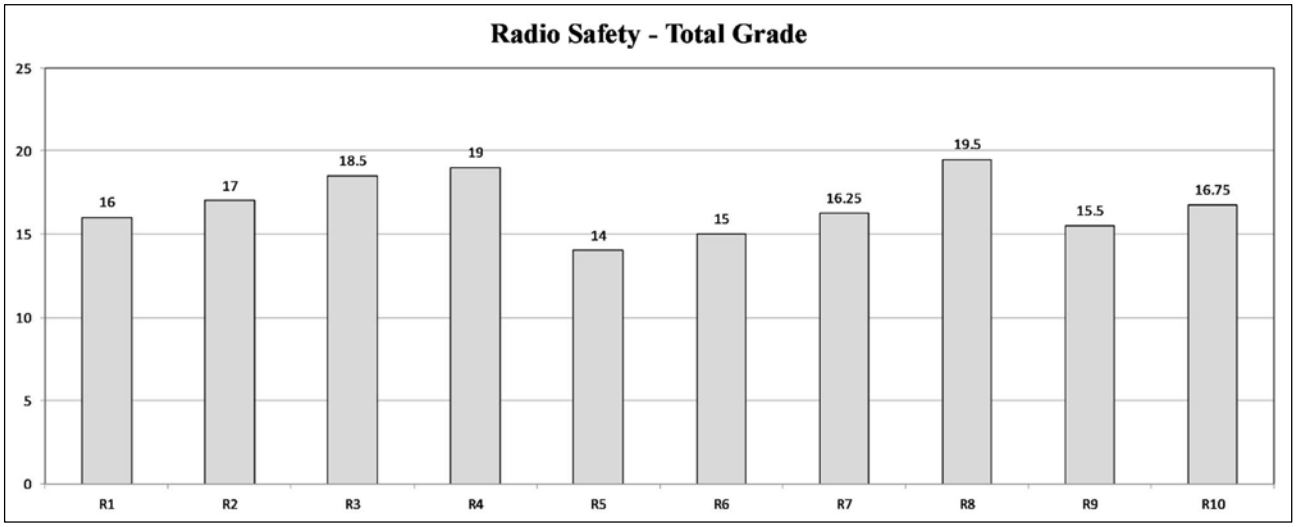

FIG. 5. Needs and Problems in Radiation Safety vs Total Grade

RADIATION TECHNOLOGIES

8. RADIATION TECHNOLOGIES

ANALYSIS OF THE REGIONAL SITUATION

The use of radiation technologies to improve quality of life has numerous applications in different fields, including to tackle a wide range of development issues in the areas of water, the environment, coastal engineering, medicine, cultural heritage, industrial processes and production, processing of advanced materials, natural resources and inspection technologies. The principles and applications are outlined briefly below.

Radiation processing (RP) technology is based on the use of high-energy radiation from gamma sources (mainly cobalt–60 (^{60}Co)), electron beams or X rays to induce biological, chemical and physical changes in materials. This technology is used mainly for the sterilization of medical products, irradiation of food and agricultural products, irradiation of blood to prevent graft versus host disease, decontamination of soils, modification of industrial polymers (cables, tyres, semiconductors, foam, films, tubes, etc.), gemstone colouration, disinfection and disinfestation of cultural heritage objects, archives and books, consolidation of culturally valuable objects and preservation of the environment (treatment of industrial wastewater, combustion gases and sludge).

Short lived radiotracers , such as Natrium-22(^{22}Na), Brom-82 (^{82}Br), Lanthanum-140 (^{140}La), ^{99m}Tc, ^{131}I, etc., are used for diagnosis in industrial processes, including efficiency, troubleshooting, underground leaks, residence time distribution, flux patterns and flow rates, etc. This category includes the use of sealed sources for the scanning of industrial components, such as distillation columns, including through use of gamma transmission and neutron backscattering.

Regarding nucleonic control systems (NCS), there are various systems for quality control of industrial processes and products to obtain significant gains in industry, for example in controlling the thickness of laminated steel or the filling of bottles in the food industry, and mineral content. These systems use radiation sources such as americium–241 (^{241}Am), ^{137}Cs and X ray or neutron generators coupled with detectors that provide the signal used for process control. There are also gamma scanning applications for evaluating distillation columns and chemical reaction systems using sets of gammas emitting mobile sources such as ^{60}Co or ^{137}Cs and scintillation detectors to receive signals that are interpreted and that show the internal condition of the system's components (plates, packed columns, etc.). Computed industrial tomography applications are used to study systems related to industry.

NATs are available for laboratory analyses and can also be configured for online analysis for process control or even in situ analysis of non-transportable or valuable objects. The most important analytical techniques are neutron activation analysis, X ray fluorescence and diffraction, electron microscopy, prompt gamma neutron activation analysis and particle-induced X ray emission.

The non-destructive testing (NDT) category includes nuclear and non-nuclear techniques to determine the status of industrial components; the most widely used nuclear technique is radiography, e.g. for detecting welding defects in pipework and tanks, using gamma rays and X rays [156-[164]. Computed tomography and neutrography are also important. Non-nuclear techniques include ultrasound, induced current, liquid penetrant and magnetic particle testing. The main challenges will be addressed by the following UN SDGs tailored to LAC: SDG2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture; SDG 6: Ensure availability and sustainable management of water and sanitation for all; SDG 9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation; SDG 13: Take urgent action to combat climate change and its impacts; SDG 15: Protect, restore and promote sustainable use of

terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss; SDG 17: Strengthen the means of implementation and revitalize the global partnership for sustainable development [165].

As set out in section 6, the LAC region comprises 45 countries in an area covering 20.4 million km^2 [117]. The population was over 655 million as of 2021, the GDP of the region was US $5.45 trillion, the annual per capita income was US $8 327. The life expectancy at birth was 73 years in 2020 [63]. School enrolment for primary education was approximately 108% [119]. It is forecast that the region's population will increase to approximately 784 million in 2050 **Error! Reference source not found.** Table 8 shows the percentage of the total population employed in industry in 2019 [167].

TABLE 8. PERCENTAGE OF THE POPULATION EMPLOYED IN INDUSTRY IN 2019

Country	%	Country	%	Country	%
Argentina	21.8	Ecuador	17.20	Panama	17.71
Plurinational State of Bolivia	19.4	El Salvador	22.51	Paraguay	18.13
Brazil	19.98	Guatemala	18.72	Peru	15.19
Chile	22.25	Honduras	21.38	Uruguay	18.82
Colombia	20.12	Mexico	25.54	Bolivarian Republic of Venezuela	15.34
Costa Rica	18.79	Nicaragua	16.23		

Although the region comprises countries with different levels of development, it is considered that knowledge needs to be disseminated and these applications developed in all countries to some extent to improve competitiveness.

The following tables present the situation in the countries of Latin America in terms of the use of radiation technologies. Table 9 shows the situation of the countries regarding the use of radiotracers in: diagnosis of industrial production and processes; radiotracers in the environment, in oil fields, in sediment transport; and nucleonic control systems in industrial quality control and in exploration of mineral resources and the environment. Table 10 presents the situation regarding non-destructive testing by country. Table 11 contains a list of the gamma irradiators and electron beam accelerators in Latin America, including the type of dosimetry system used and the status of quality control and assurance.

TABLE 9. USE OF RADIOTRACERS IN COUNTRIES OF THE REGION

Country	Tracers in processing and production industries	Tracers in the environment, oil and sediment transport	NCS in industrial quality control	NCS in exploration of mineral resources and the environment
Argentina	X	X		X
Brazil	X	X	X	X
Colombia		X		X
Chile	X	X	X	
Costa Rica	X			
Cuba	X			
Dominican Republic	X			
Ecuador	X			X
El Salvador	X			
Guatemala	X			
Mexico	X	X	X	X
Panama	X			
Paraguay	X			
Peru	X	X		X
Uruguay	X	X		
Bolivarian Republic of Venezuela	X	X		

TABLE 10. USE OF NON-DESTRUCTIVE TESTING TECHNIQUES IN COUNTRIES OF THE REGION*

Country	Basic level	Advanced level
Argentina		X
Plurinational State of Bolivia	X	
Brazil		X
Colombia	X	
Chile	X	
Costa Rica	X	
Cuba	X	
Ecuador	X	
Guatemala	X	
Haiti	X	
Mexico		X
Paraguay	X	
Peru	X	
Uruguay	X	
Bolivarian Republic of Venezuela	X	

* By 2030, an additional four countries are expected to have reached an advanced level, with ISO 9712 certified systems: Chile, Costa Rica, Ecuador and Peru.

By RLA1014 Argentina, Chile, Mexico y Peru received training and experts to establish four NDT reference centres (civil structures).

TABLE 11. GAMMA IRRADIATORS AND ELECTRON BEAM ACCELERATORS IN LATIN AMERICA

Country	Facility type	Use	Routine dosimetry	Reference dosimetry	Calibration capacity	ISO certification
Argentina	Co-60 plant, CNEA. Current activity 600 kCi	Service, research, and development	Polymethyl methacrylate (PMMA)	Fricke, Alanine, Dichromate	Yes	No
	02 Private Co-60 plants (IONICS). Current activity 1070 kCi	Service	PMMA	Dichromate/CNEA	No	No
Brazil	3 Private Co-60 plants (Sterigenics) Average activity 6000 kCi	Service and development	PMMA	Alanine	Yes	Yes
	01 Electron accelerator, 10 MeV (Sterigenics)	Service	Radiochromic, Cellulose Triacetate (CTA)	Alanine	Yes	Yes
	12 Private electron accelerators from 0.3 a 10 MeV	Service	Alanine, CTA	Alanine	Yes	
	01 Multipurpose Co-60 irradiator, IPEN. Current activity 400 kCi	Service, research and development	Radiochromic, PMMA Alanine	Fricke, Alanine	Yes	No
	2 Electron accelerators, IPEN (1.5 MeV – 37.5 mA and 70 mA)	Service, research, and development	CTA, Radiochromic	Alanine	Yes	No
	02 Gamma cell activity: < 10 kCi, IPEN	Service and development	Perxpex	Alanine	Yes	No
	01 Mobile electron accelerator, IPEN (0.7 MeV – 20 kilowatt)	Service, research, and development	CTA, Radiochromic	Alanine	Yes	No

TABLE 11. GAMMA IRRADIATORS AND ELECTRON BEAM ACCELERATORS IN LATIN AMERICA (cont.)

Country	Facility type	Use	Routine dosimetry	Reference dosimetry	Calibration capacity	ISO certification
Chile	Co- 60 plant, 360 kCi	Service and development	Red Perspex, Amber Perspex, Gammachromic	Fricke	No	Yes
Costa Rica	7.5 MeV electron beam (Baxter)	Service				
	10 MeV electron beam (Beam One)	Service				
	Gammacell 220 OIRSA	Phytosanitary testing	No	No	No	No
	Gammacell 220 University of Costa Rica	Out of use for cell treatment				
Cuba	Irradiator MP-γ- 30. Current 1.7 kCi	Service, research and development	Red Perspex, Amber Perspex	Fricke, Ceric/Cerous	Yes	Non-certified quality system
Dominican Republic	Electron beam Sure Beam 10/15 (FENWAL)	Service	GEX B3	NPL	Yes	ISO 13485 and ISO 11137
	Electron beam Integrated model (FENWAL)	Service	GEX B3	NPL	Yes	ISO 13485 and ISO 11137
Uruguay	Co-60 equipment Experimental EMI 9,80 kCi	Began operation in July 2009	Red Perspex	No	No	No
	Gammacell 220	Tissue bank	Amber Perspex			
	Gammacell UdelaR	Not used				

TABLE 11. GAMMA IRRADIATORS AND ELECTRON BEAM ACCELERATORS IN LATIN AMERICA (cont.)

Country	Facility type	Use	Routine dosimetry	Reference dosimetry	Calibration capacity	ISO certification
Ecuador	Co-60 plant, capacity 150 kCi. Current activity < 4 kCi	Research and service	No	No	No	No
	Accelerator, 5–10 MeV	Research and service	PVC	Radiochromic; calorimetric	No	No
	Gammacell JL Shepherd 109 Initial activity 11 kCi. Current activity <0.7 kCi	Research	Fricke	No	No	No
El Salvador	JS 7500 plant 1974 accident 1991 18 kCi	Closed	No	No	No	No
Peru	Gammacell 220 Excel 220 IPEN 11.4 kCi	Service	Ethanol chlorobenzene, Fricke	Fricke	No	No
	Multi-purpose Co-60 plant (PIMU) 3.1 kCi	Service	Ethanol chlorobenzene, GEX film	Fricke	No	No
	Gamma Beam-127, Nordion. Current 14 kCi, SENASA	Flies and services	Gafchromic, Fricke	Fricke	No	No
	Irradiator tipe I, Shepherd & Associates model 109-68, 1.5 kCi	Flies	Gafchromic, Fricke	Fricke	No	No
	Irradiator tipe I Shepherd & Associates model 109-68, 0.8 kCi	Flies	Gafchromic, Fricke	Fricke	No	No
	Irradiator Cs-137, 8.6 kCi	Flies		Fricke	No	No
Bolivarian Republic of Venezuela	IR 216 irradiator PEGAMMA Co-60 design 1000 kCi. Current 85 kCi	Service	Red Perspex, Fricke	No	No	No

TABLE 11. GAMMA IRRADIATORS AND ELECTRON BEAM ACCELERATORS IN LATIN AMERICA (cont.)

Country	Facility type	Use	Routine dosimetry	Reference dosimetry	Calibration capacity	ISO certification
Mexico	Plant Co JS 6500. Current 800 kCi, (ININ)	Services	Red Perspex	Alanine / NIST	No	ISO 9001: 2008
	Gammacell 125 Ci, (ININ)	Research and services	Red Perspex	No		ISO 9001: 2008
	Transelektro LGI-01 3247, (ININ)	Research and services	Red Perspex	No		ISO 9001: 2008
	VickRad 3 Ci, (ININ)	Research and services	Red Perspex	No		ISO 9001: 2008
	UNAM. 100 kCi	Services and research	No information	No information	No information	No information
	Sterigenics 3000 kCi. Current 1000 kCi	Service	No information	No information	No	No information
	Benebion 300 kCi	Service, fresh fruit	No information	No information	No	No information
	Self-shielded Co-60, SAGARPA Tapachula (closed)	Fruit fly	No information	No information	No	No information
	Self-shielded Co-60, SAGARPA Tapachula (closed)	Medfly	No information	No information	No	No information
	Horizontal self-shielded Cs-137, SAGARPA, Tuxtla Gutiérrez (closed)	Service	No information	No information	No	No information
	01 Electron accelerator, Tijuana (Avantti Medi Clear) 10 MeV Mevex	Service	Radiochromic	No information	Yes	Yes

Radiation technology applications are constantly growing and evolving in areas including exploration and the efficient use of natural resources, mining, the mineral processing industry, metallurgy, development of advanced materials, characterization and preservation of cultural heritage and the environment, and protection of coasts from erosion.

As experience and confidence in the technology grows, the use of radiation technologies has a pivotal role to play in bringing about significant improvement in almost all countries of the region and as an important contributor to the national economies. In view of the needs, possibilities and capacities of the region, the areas in which radiation technologies may be of benefit have been identified by group below.

a) Water (treatment):
   (i) Treatment of water for reuse or discharge (RP);
   (ii) Treatment of sludge (RP);
   (iii) Optimization of water treatment processes [radiotracers (T)];
   (iv) Measurement of precipitation (T);
   (v) Areas of protection for hydrographic basins (T);

b) Agriculture (treatment):
   (i) Soil sterilization (RP);
   (ii) Plant growth promoters (using natural polymers) (RP);
   (iii) Water super absorbers (using natural polymers) (RP);
   (iv) Biocides (using natural polymers) (RP);
   (v) Soil erosion studies (T, NAT);
   (vi) Studies of fertilizer and pollutant transfer (T);
   (vii) Sanitization of animal feed (RP);
   (viii) Sanitization of agricultural products (flowers, wood, tobacco, seeds, etc.) (RP);

c) Food (treatment):
   (i) Quarantine treatment, phytosanitary treatment, sanitization, ripening time, extended shelf life (RP);
   (ii) Quality control (NCS);
   (iii) Development of packaging using natural polymers (RP)
   (iv) Optimization of processes (T, NCS);

d) Environment (treatment of emissions and waste):
   (i) Treatment of gaseous effluents (RP);
   (ii) Industrial discharges (RP, T);
   (iii) Sediment transport (T);

e) Coastal engineering:
   (i) Protection of coasts from erosion (T, NCS);
   (ii) Ports and dredging work, optimization and administration (T, NCS);

f) Advanced materials:
   (i) Polymer modification and treatment (RP, NAT);
   (ii) Processing of advanced materials (RP);
   (iii) Measurement of wear using thin layer activation with protons (T);

g) Medicine:
   (i) Sterilization of disposable medical products and instruments (RP);
   (ii) Sanitization of cosmetics (RP);
   (iii) Preparation of hydrogels (RP);
   (iv) Sterilization of blood (RP);
   (v) Sterilization of biological tissues (human and animal), prostheses, etc. (RP);

h) Mining:
   (i) Exploration (T, NCS, NAT);
   (ii) Processing and optimization (T, NCS);

i) Cultural heritage objects (characterization, conservation and preservation):
   (i) Disinfestation and disinfection of culturally valuable objects and archived materials (RP);
   (ii) Consolidation of culturally valuable objects using curable resins (RP);
   (iii) Authentication, characterization and determination of the origin of cultural heritage materials (NAT);
   (iv) Dating of objects (NAT);
   (v) Object analysis using non-destructive techniques (NAT, T, NDT, NCS);

j) Industrial processes:
   (i) Optimization of processes (T, NCS);
   (ii) Quality control (NCS);
   (iii) Modification and improvement of products (PR);
   (iv) Inspection technologies (NDT, NAT)\;
      - Metals, welding, pipework, energy plants, oil and gas, aerospace industry, etc.;
      - Concrete, roads, bridges, buildings (civil structures), etc.;
      - In-service inspection of power plants, in particular nuclear power plants;
      - Harmonization of training and certification of operators;
      - Digital training of operators.

SWOT ANALYSIS

8.2.1. Strengths

Water:
(1) Water is a strategic and limited public resource in any country;
(2) Technologies have been tested and introduced in some countries of the region;
(3) Nuclear techniques help to clean wastewater for its discharge or subsequent reuse;
(4) Nuclear techniques help to increase the availability and quality of drinking water;
(5) The advantages of using radiotracers for water studies are that they are more accurate and less costly than conventional techniques;
(6) Existing experience in several countries of the region;
(7) Capacity to improve the efficiency of existing water treatment facilities;

Environment:
(8) The entire region has a shared interest in protecting the environment;
(9) Nuclear technologies are effective for the high-precision characterization of environmental simples;
(10) Treatment of combustion gases with electron beams, support for the simultaneous elimination of pollutants, without generating waste;
(11) Most of the countries of the region have groups that specialize in the use of radiotracers and nucleonic control systems;
(12) With the development of mobile irradiation systems, it will be possible to treat waste sludge in situ;

Coastal engineering:
(13) Coastal management is important for the region;
(14) Accessible and validated technology in some countries of the region;
(15) High cost–benefit ratio;

Advanced materials:
(16) Nuclear techniques add value to various materials;
(17) Energy efficient and environmentally friendly processes;
(18) Improvement in the quality and safety of processes and products;
(19) Infrastructure available in some countries of the region;

Medicine:
(20) Well established irradiation technology available in the region, with widespread acceptance;
(21) Large commercial demand for the sterilization of disposable medical products and instruments;
(22) Compared to other techniques, irradiation technology is more effective and competitive, and does not leave residues in the treated products;

Cultural heritage:
(23) Latin America has a very rich cultural heritage which spans the entire region;
(24) At least six countries have and use applicable nuclear technologies;
(25) The Agency supports the use of nuclear techniques for the characterization and preservation of cultural heritage;
(26) Various nuclear techniques are accessible and effective;

Industrial processes and production:
(27) There is regional interest in improving and optimizing production processes;
(28) Nuclear techniques help to boost industrial competitiveness;
(29) Commercial nucleonic control systems for industrial applications are used widely in the region because of their high cost–benefit ratio;
(30) There are universities, research institutes and companies that can offer services involving nuclear techniques to industry;

Natural Resources:
(31) The region is rich in natural resources (agriculture, marine products, minerals, hydrocarbons);
(32) There is nuclear technology available in the region that does not generate waste;
(33) Nuclear technology allows waste to be transformed into useful materials;

Inspection technologies:
(34) In order to have four reference centres in NDT (civil structures), personnel are being trained and the countries are receiving equipment;
(35) These techniques help to improve the quality of products and the safety of industrial facilities and equipment;
(36) High cost–benefit ratio;
(37) There are companies that provide these services.

8.2.2. Weaknesses

Water:
(1) Improvements in wastewater treatment have not kept pace with the rate of population growth.
(2) Most of the region's rivers are more polluted now than they were in the 1990s;
(3) Only one country in the region has facilities to demonstrate the application of nuclear technology for water treatment;
(4) Poor dissemination of this nuclear technology and high initial investment costs;
(5) Potential stakeholders have limited information about the nuclear technologies;

Environment:

(6) Limited dissemination of this nuclear technology and high initial investment costs for some technologies;
(7) There are research groups working with nuclear techniques in the region, but there have not been the necessary innovations to allow them to reach the end user;
(8) There are few facilities to demonstrate the nuclear technology;
(9) Lack of legislation related to nuclear technology applications in the environment;

Coastal engineering:

(10) Governmental concern and limited public acceptance;
(11) Lack of dissemination of the potential of nuclear technology in this area;
(12) Research in this area is carried out principally using conventional techniques;

Advanced materials:

(13) Lack of dissemination of the potential of nuclear technology in this area;
(14) Lack of technology transfer;

Medicine:

(15) Some countries of the region do not have irradiation facilities;
(16) The sterilization of disposable medical products with toxic gases (ethylene oxide) is widely practised in the region with respect to ionizing radiation;
(17) Lack of dissemination of the potential of nuclear technology in the irradiation of biological tissues;
(18) Need to improve the mechanisms for updating the national standards in force in the region applicable to the sterilization of medical products using ionizing radiation;

Cultural heritage:

(19) Lack of dissemination of the potential of nuclear technology in this area and lack of acceptance among cultural heritage preservation and conservation professionals;
(20) Lack of experience and knowledge regarding the proper use of the technologies;
(21) Weak collaboration networks connecting nuclear institutions with cultural heritage preservation and conservation professionals;
(22) Incomplete reference figures on the use of the technologies in the region;

Industrial processes and production:

(23) Limited availability of radiotracers;
(24) Restrictive regulation;

Natural Resources:

(25) Early stage of development in the region;
(26) Lack of continuity in radiotracer application groups;
(27) Lack of standardization of certain processes and products (for commercial use);

Inspection technologies:

(28) The certification of personnel is not harmonized between international standards ISO 9712 and SNT-TC-1A.

8.2.3. Threats

Water:
(1) Negative public perception and unawareness of the advantages of water resources management using radiation technologies;

Environment:
(2) Negative public perception and unawareness of the advantages of radiation technologies;

Coastal engineering:
(3) There are alternative technologies with lower performance but less regulation;

Advanced materials:
(4) Unawareness of the advantages of the use of nuclear technology;

Medicine:
(5) Lack of sufficient infrastructure in the region to cover the need for sterilization processes using ionizing radiation;

Cultural heritage:
(6) Unawareness of the advantages of the use of nuclear technology;

Industrial processes and production:
(7) Negative public perception and unawareness of the advantages of radiation technologies;

Natural Resources:
(8) Negative public perception and unawareness of the advantages of radiation technologies;

Inspection technologies:
(9) Unawareness of the advantages of the use of nuclear technology.

8.2.4. Opportunities

Water:
(1) More stringent policies on the environment and drinking water and sanitation services;
(2) The increase in wastewater from human and industrial activities have to be addressed;
(3) Regional need to improve the quality and availability of water resources;

Environment:
(4) Industrialization increases the release of pollutants, which leads to a growing demand for technologies to reduce them;

Coastal engineering:

(5) Better understanding of the effects of climate change on the coasts (rise in sea level) increases the need for sustainable coastal management;
(6) Effect of population growth and activities near the coast;
(7) Better sediment management is required because of the impact of deforestation on soil erosion.
(8) The increase in foreign trade makes it necessary to develop, improve and manage port infrastructure;
(9) Better coastal management has indirect effects on tourism;

Advanced materials:

(10) Existing facilities can be used for the development of advanced materials specific to countries' needs;
(11) As the region is an exporter of raw material, there is an opportunity to create added value;
(12) Development of new advanced materials for new applications (for example, nanogels, nanocomposites of graphene oxide, new formulations of cable insulating materials, new formulations of curable polymers);

Medicine:

(13) In recent years, acceptance of the use of ionizing radiation as a sterilization technique has risen in the region;
(14) There is growing demand for the sterilization of disposable medical products in the region;
(15) Some medical products can only be sterilized using ionizing radiation (prostheses, surgical thread of animal origin);

Cultural heritage:

(16) Awareness of the need to characterize and preserve the region's cultural heritage has improved;
(17) Opportunity to build collaborative partnerships between nuclear institutes and the bodies responsible for preserving cultural heritage;
(18) Opportunities to build partnerships and collaboration with Brazil, France, the Netherlands, Italy, Croatia and Romania (countries that already use this technology) and with international organizations [European Commission, United Nations Educational, Scientific and Cultural Organization (UNESCO), etc.];
(19) High potential visibility of nuclear techniques for the public and impact on tourism;
(20) The region's climate furthers the deterioration of cultural materials and objects, lending appeal to the use of nuclear techniques;

Industrial processes and production:

(21) Industrial development requires the use of nuclear technologies;
(22) More stringent regulations in industrial processes demand the use of clean and efficient technologies;

Natural Resources:

(23) The agriculture and industry sectors are very important in the region. Considerable potential exists to use natural polymers for processing raw materials into industrial products;
(24) Growing economic incentive to use nuclear technology as an advantageous option in the region;
(25) Possibility of co-funding from international organizations for the introduction and use of radiation technologies;

Inspection technologies:

(26) Growing recognition of the capacities of non-destructive techniques;
(27) Possibility to increase knowledge transfer and training through the region's four existing NDT reference centres.

NEEDS AND PROBLEMS

T1. Treatment of domestic, industrial, and pharmaceutical wastewater (drugs, organic compounds, biological contamination, microplastics, etc.) through RP

Justification: Statistics show that wastewater contains a high level of contamination of various origins. Excessive use of analgesics, contraceptives, and antidepressants generates waste that is difficult to treat using conventional techniques. Likewise, the presence of microplastics in water is a global problem that has to be tackled. The indiscriminate use of agrochemicals and other organic compounds makes the treatment of wastewater (domestic, industrial, etc.) more complex. The lack of sanitation infrastructure contributes to the biological contamination of water resources. Technology that makes use of ionizing radiation is an effective alternative in these cases. The potential of using such technologies for sustainable wastewater treatment needs to be disseminated and promoted (among users, service providers and decision makers).

Objective: To present to decision makers of the assessment and study of the feasibility and effectiveness, based on local conditions, of the use of advanced technologies to treat wastewater by electron beam irradiation.

Indicator: Increase in number of conceptual designs finalized. Increase in number of scientific publications and news articles drafted by the respective communications departments (technical-journalistic outreach).

T2. Phytosanitary treatment of fresh, frozen, dehydrated, and processed food using ionizing radiation

Justification: Studies performed in recent years have shown that food wastage is very high. Technologies are needed that will help to increase shelf life and eliminate problems related to pathogenic microorganisms. Global trends are fostering a rise in quality and food safety. Latin America and the Caribbean have a high capacity for exporting food, especially fresh products. In these cases, RP of food for phytosanitary purposes helps to strengthen the economy and the health of the population, creating more competitive processes for the agro-industry sector. The potential of using such technologies for the treatment of food needs to be disseminated and promoted (among users, service providers and decision makers).

Objective: To present to decision makers irradiation protocols for new products, showing the improved quality and shelf life of foods that are important to the countries of the region.

Indicator: Increase in number of irradiation protocols for new products. Increase in number of scientific publications and news articles drafted by the respective communications departments (technical-journalistic outreach).

T3. Harmonization of Quality Assurance and Quality Control (QA/QC) in irradiators and dosimetric intercomparisons.

Justification**:** Quality management procedures (QC/QA) in irradiators needs to be harmonized to reduce deficiencies and commercial barriers in the region within the context of international trade. At present, international trade is very strict, requiring certification in line with ISO standards (9001:2015 — customer satisfaction, 11137 — sterilization of medical materials, 14470 — food). The region has no primary standards metrology centre to measure high radiation doses. The potential of using such technology needs to be disseminated and promoted (among users, service providers and decision makers).

Objective: To implement harmonized procedures for quality control, quality assurance and quality management when using radiation technologies in the region. To perform regional dosimetric intercomparisons.

Indicator: Increase in number of countries that implemented harmonized procedures for using radiation technologies, in line with international standards. Increase in number of facilities that participated in dosimetric comparisons. Increase in number of scientific publications and news articles drafted by the respective communications departments (technical-journalistic outreach).

T4. Development of innovative, competitive, and environmentally friendly materials with radiation technologies, for use in health, agriculture, and industry (nanotechnology, composite materials, new curable formulas, etc.)

Justification: The fourth revolution of engineering requires the production and use of new composites, nanomaterials and formulations. Technologies that use radiation (gamma, electron and ion beams, X rays, etc.) bolster the development, production, and enhancement of the mechanical and physicochemical properties of polymers, nanomaterials, polymers, and new formulations. The development of alternative clean and renewable energies (solar cells). The region's automobile, aerospace and electronics industries need materials that are lightweight and resistant to temperature and corrosion. This type of technology reduces the use of chemical products that may be harmful to health and the environment. The potential of using such technology needs to be disseminated and promoted (among users, service providers and decision makers).

Objective: To increase the use of new materials obtained through ionizing radiation technology in the region.

Indicator: Increase in number of methodologies transferred. Increase in number of materials developed. Increase in number of scientific publications and news articles drafted by the respective communications departments (technical-journalistic outreach).

T5. Increase in industrial competitiveness through the optimization of processes and reduction of environmental impact, using radiation technologies such as radiotracers and sealed radioactive source applications, among others

Justification: Efforts are under way to make the current production processes more efficient and environmentally friendly. Non-invasive assessment methods are required in areas such as oil, petrochemistry, mining/metallurgy, river and sea dredging, hydrology, etc. to take appropriate solution-driven technical measures. In this regard, the use of radiation technologies such as tracers and sealed sources help to optimize industrial processes. The potential of using such technology needs to be disseminated and promoted (among users, service providers and decision makers).

Objective: To expand the use of radiation technologies to optimize production processes, thus reducing the environmental impact.

Indicator: Increase in number of production processes optimized with nuclear techniques. Increase in number of scientific publications and news articles drafted by the respective communications departments (technical-journalistic outreach).

T6. Characterization and preservation of tangible cultural heritage objects and archived materials using nuclear techniques

Justification: Radiation technologies and NATs can contribute in an effective and affordable manner to the characterization, conservation and restoration of cultural goods (paintings, documents, artefacts, objects, etc.) throughout the region. The technologies exist in the region, with varying levels of implementation and infrastructure, and there are successful cases that could be used as a reference. The potential of using such technology needs to be disseminated and promoted (among users, service providers and decision makers).

Objective: To increase the use of irradiation treatment, analytical techniques and non-destructive testing to help preserve the tangible cultural heritage of LAC.

Indicator: Increase in number of works processed and characterized; cultural heritage effectively preserved in accordance with international good practice (substantial increase in the use of radiation technologies). Increase in number of scientific publications and news articles drafted by the respective communications departments (technical-journalistic outreach).

T7. Harmonization of methodologies and training of personnel in accordance with certification schemes and standards for advanced non-destructive testing techniques

Justification: Non-destructive testing technologies play an important role in general quality control programmes and are essential to improve the safety of infrastructure and civil structures and the competitiveness of regional industries within the international regulatory framework. The potential of using such technology needs to be disseminated and promoted (among users, service providers and decision makers).

Objective: To improve the use of advanced technologies, harmonize methodologies and train personnel in accordance with certification schemes and standards (ISO 9712:2012).

Indicator: Increase in number of countries that have established methodologies and an established structure for the training of personnel, in accordance with the new standard ISO 9712:2012 for NDT and the certification of processes involving radiation technologies. Increase in number of scientific publications and news articles drafted by the respective communications departments (technical-journalistic outreach).

T8. Sustainable processing of the region's renewable non-toxic natural resources (natural polymers) to increase agricultural production and reduce waste and pollution

Justification: Materials processed using techniques that involve ionizing radiation support the reuse of agricultural waste (post-harvest), thus reducing environmental impact. In the same way, these techniques help to preserve productive conditions (minerals) in agricultural soils. The potential of

using such technology needs to be disseminated and promoted (among users, service providers and decision makers).

Objective: To contribute to agricultural soil conservation with less environmental impact by making use of the benefits of techniques involving radiation.

Indicator: Increase in number of people trained in the management of waste for reuse using RP. Increase in number of scientific publications and news articles drafted by the respective communications departments (technical-journalistic outreach).

PRIORITIZATION OF THE NEEDS AND PROBLEMS

The following Table 12 reflects the final prioritization grades, determined by the variables outlined, of numerous issues in the radiation technology sector followed by a visual comparison of these final grades shown in Fig. 6.

TABLE 12. PRIORITIZATION OF THE NEEDS AND PROBLEMS IN THE RADIATION TECHNOLOGY SECTOR

P	Need/Problem	Severity	Time	Extent	Relevance	Total grade	Difficulty	R/D	Final grade
1	T2 Phytosanitary treatment of fresh, frozen, dehydrated, and processed food using ionizing radiation.	4.5 Urgent need to increase the competitiveness of industrial processes that affect health and safety.	5.0 Need to increase the competitiveness of the regional industry and improve product quality and food safety.	5.0 Affects the whole region. Gamma irradiation is the most highly recommended technique.	45 Nuclear techniques do not leave behind toxic residues, preserving the nutritional value and sensory properties.	19.0	3.0 Irradiation facilities are limited in the region.	1.50	28.50
2	T3 Harmonization of Quality Assurance and Quality Control (QA/QC) in irradiators and dosimetric intercomparisons.	4.5 It is necessary to harmonize procedures and reduce trade barriers in the region.	5.0 To contribute to the economic development of the region.	5.0 This is a need in all the facilities of the region that carry out this process.	4.5 Good practices in irradiation processes ensure reliable results.	19.0	3.5 The introduction and certification of international quality standards is a long and costly process.	1.29	24.43

TABLE 12. PRIORITIZATION OF THE NEEDS AND PROBLEMS IN THE RADIATION TECHNOLOGY SECTOR (cont.)

P	Need/Problem	Severity	Time	Extent	Relevance	Total grade	Difficulty	R/D	Final grade
3	T1	4.5	4.0	5.0	5.0	18.5	3.0	1.67	30.83
	Treatment of domestic, industrial, and pharmaceutical wastewater (drugs, organic compounds, biological contamination, microplastics, etc.) through RP.	Evident problem in the region, affecting the environment and health.	To contribute to the economic development of the region by reducing environmental impact and improving health.	Affects the whole region.	Nuclear techniques are the only ones that can be used to treat this resource in the necessary conditions.		Radiation technologies for wastewater treatment are scarcely used in the region.		
4	T6	4.5	4.0	4.0	5.0	17.5	3.5	1.43	25.0
	Characterization and preservation of tangible cultural heritage objects and archived materials using nuclear techniques.	The region's cultural heritage has been lost owing to a lack of advanced techniques for characterization, preservation and conservation.	These actions need to be taken immediately to preserve the tangible cultural heritage of the region.	Most of the region does not have nuclear technologies that are used routinely.	Nuclear techniques have a wide range of uses in characterization and conservation.		Lack of dissemination of technologies, infrastructure, and human resources training. Lack of cooperation between nuclear institutes and those responsible for conservation.		

TABLE 12. PRIORITIZATION OF THE NEEDS AND PROBLEMS IN THE RADIATION TECHNOLOGY SECTOR (cont.)

P	Need/Problem	Severity	Time	Extent	Relevance	Total grade	Difficulty	R/D	Final grade
5	T7 Harmonization of methodologies and training of personnel in accordance with certification schemes and standards for advanced non-destructive testing techniques.	4.5 Urgent need to raise the competitiveness of industrial processes.	4.5 There is a clear need for qualified personnel and standardized, up-to-date NDT techniques.	4.5 Few countries of the region use the techniques with good practices in accordance with international standards.	4.0 Nuclear and conventional techniques are complementary.	17.5	3.0 Lack of dissemination of technologies, infrastructure and human resources training.	1.33	23.33
6	T4 Development of innovative, competitive, and environmentally friendly materials with radiation technologies, for use in health, agriculture, and industry (nanotechnology, composite materials, new curable formulas, etc.).	3.5 Technological changes require the production and use of new materials.	4.0 Technological changes require immediate action in relation to innovation and production.	4.5 The region is characterized as a producer of raw material; new technologies and materials will increase its value.	3.5 The use of advanced materials is necessary for the region's industrial development.	15.5	4.0 Working groups carry out their activities in this field individually, without institutional coordination.	0,88	13.56

TABLE 12. PRIORITIZATION OF THE NEEDS AND PROBLEMS IN THE RADIATION TECHNOLOGY SECTOR (cont.)

P	Need/Problem	Severity	Time	Extent	Relevance	Total grade	Difficulty	R/D	Final grade
7	T5 Increase in industrial competitiveness through the optimization of processes and reduction of environmental impact, using radiation technologies such as radiotracers and sealed radioactive source applications, among others.	3.5 Urgent need to raise the competitiveness of industrial processes with less environmental impact.	4.0 It is important to have advanced technologies to optimize industrial processes.	4.0 Affects the whole region.	3.5 Nuclear and conventional techniques are complementary in process optimization.	15.0	3.0 Lack of dissemination of technologies, infrastructure and human resources training.	1.17	17.50
8	T8 Sustainable processing of the region's renewable non-toxic natural resources (natural polymers) to increase agricultural production and reduce waste and pollution.	3.5 Renewable natural resources need to be recycled to help reduce pollution and improve the competitiveness of the region.	4.0 Need to raise agro-industrial competitiveness with less environmental impact.	3.5 The irradiation of natural polymers is carried out in isolated cases in the region.	3.5 Non-toxic natural polymers can be used in health care, agriculture and industry.	14.5	3.0 Lack of dissemination of technologies, infrastructure and human resources training. Irradiation facilities are limited in the region.	1.17	16.92

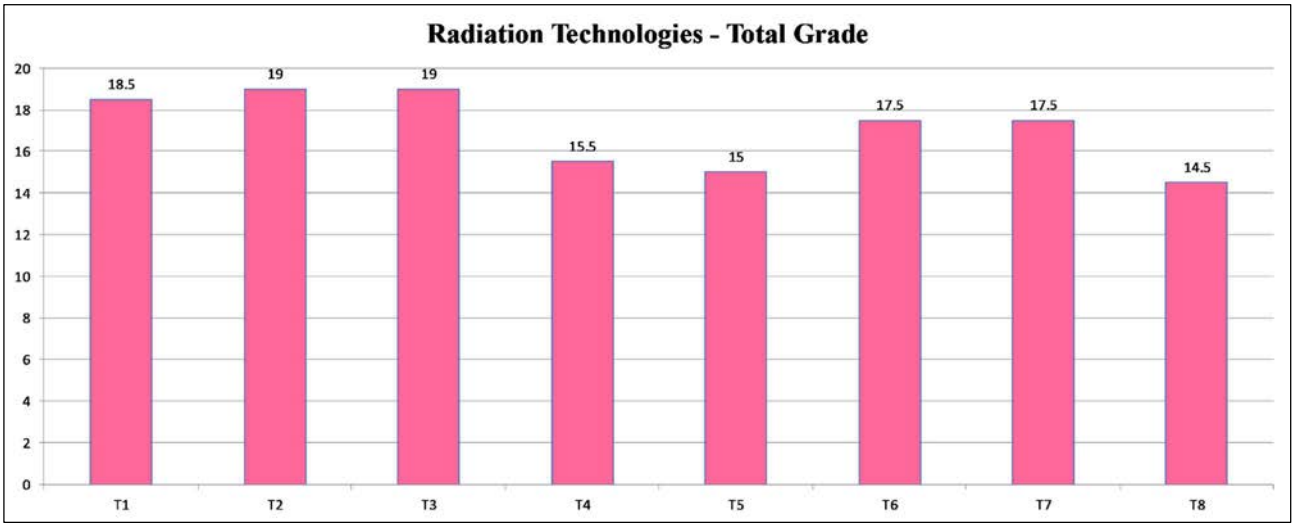

FIG. 6. Needs and problems in Radiation Technologies vs Total Grade

9. GENDER EQUALITY

To reaffirm their commitment to gender equality, in 2019 ATCB and the BAR approved the first ARCAL project not funded by the Agency, entitled 'Establishment of the ARCAL Women in Nuclear (WiN) Chapter'. The overall objective of the project is to contribute to sustainable socioeconomic development in the LAC region by promoting the full and equal participation of women, who make up over half of the region's population [168], in areas related to nuclear science and technology.

Although the number of women involved in science and technology has increased significantly in recent years, women continue to be greatly underrepresented in this area. Currently only 30% of the world's researchers are women and, although in the LAC region women constitute 45.1% of all researchers, the figure is significantly lower when it comes to higher hierarchical levels and decision making positions [169]. This situation is known as the 'glass ceiling' or 'scissor effect'.

Nuclear science and technology in the region are no exception to this rule, and this is particularly evident in the context of ARCAL, in which the participation of women continues to be very limited. More than 64% of those involved in ARCAL projects (as counterparts, participants in various types of events, fellows, etc.) are men. Furthermore, the participation of women in certain thematic areas such as energy and radiation technology are remarkably low, standing at around 18%.

The outcomes of the above mentioned project include the creation of a regional ARCAL WiN Chapter, a crucial element in driving progress towards other key targets such as: the launch of regional women's networks in each thematic area; increased visibility of gender-related issues, including the promotion of gender and leadership training in the sector; the consolidation of cooperation between ARCAL and Women in Nuclear Global, an international association of women in the sector with more than 25 years of experience and a presence in 145 countries; and the establishment of a regional observatory for gender in nuclear science and technology, which will facilitate the availability of and access to statistical data relating to the participation of women in these areas. As this project progresses, it is expected that all the technical cooperation projects conducted in the region in the six main thematic areas will continue to consider the gender perspective and support the equal participation of women in the activities covered.

FINAL COMMENTS

The RSP for 2022–2029 establishes a strategic and dynamic framework for cooperation among the countries of Latin America and the Caribbean. The publication presents an analysis of the situation in the region, using as a reference the six thematic areas in which nuclear technology can contribute to meeting needs or solving problems that are common to the countries of the region.

Accordingly, the RSP constitutes a regional programmatic framework for technical cooperation between the countries of the region and the International Atomic Energy Agency, identifying and prioritizing a set of needs and problems in each thematic area to guide the preparation of regional technical cooperation projects during the period covered.

It is important to note, however, that the RSP has been drawn up at the macro level and presents regional objectives. It is therefore necessary to prepare an implementation strategy, identifying mid-term results, targets and performance indicators required to ensure the effectiveness of the regional technical cooperation projects.

Once the RSP has been approved by the BAR, the national coordinator members of the ATCB will meet to prepare the supplementary Guide for the Implementation of the RSP for 2022–2029. This guide will be used to complete the process of prioritizing the needs and problems in line with the methodology outlined in Annex 2022–2029 RSP, allowing for prioritization between sectors. This will help to optimize the use of the budgetary resources allocated to each project and achieve the intended outcomes.

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ANNEX 2022–2029 RSP

PRIORITIZATION METHODOLOGY

A–1. INTRODUCTION

In preparing the Regional Strategic Profile (RSP) for Latin America and the Caribbean, the same prioritization methodology used for the previous RSP was adopted, with various adjustments and updates. This approach has been used over the last 30 years by various public and private institutions, and by various international organizations involved in promotion and development work.

To assign strategic priorities within a set of needs and problems and within various areas of activity, the methodology envisages the use of specific attributes in relation to which a graded scale of values is established for each need/problem so that, at the end of the process, a quantitative comparison can be made.

It is also important to note that any prioritization process involves assigning quantitative values to a qualitative evaluation, which always introduces an element of subjectivity. In this case, the mechanism that has to be adopted to minimize this effect, and at the same time enrich it, is the justification of each need/problem and the justification of each grade assigned to the respective attributes. In addition, when a collective evaluation is made of the problems identified within the framework of the RSP, it is appropriate that there be discussion and debate among the participants until a consensus is achieved and a single value is decided on for each of the grades assigned to each attribute.

Another important aspect of the methodology is choosing the profiles of the people participating in the process. In making this choice, technical training, professional experience and specific knowledge required for the accurate characterization of each problem needs to be taken into consideration.

In the case of the RSP, it is important to highlight the strategic nature of the document, which is based on the identification of regional needs and problems and is to be used to develop a strategic alliance between ARCAL and other institutional partners, including the IAEA. This alliance can only be achieved through a strategic planning process that allows for an appropriate identification and characterization of each need/problem.

Another aspect relevant to the preparation of the RSP is the need to consider the various levels of development of each country in the region, when considering the six sectors selected: food security, human health, environment, energy, radiation safety and radiation technology.

A–2. ATTRIBUTES FOR PRIORITIZATION

Five attributes were adopted for the evaluation of the needs and problems, considering the strategic nature of the RSP. These are presented in Table A–1. below:

TABLE A–1. ATTRIBUTES FOR THE EVALUATION OF NEEDS AND PROBLEMS

Attribute	Description
Severity (seriousness)	This is a measure of the degree of severity of the need/problem, considering the negative impact of not addressing it.
Time	This relates to the level of urgency of addressing the need/problem, its likelihood of worsening and future consequences.
Extent	This determines the degree of regional impact of the need/problem, taking into account, for example, the number of countries affected.
Relevance of/for nuclear techniques	On the one hand, this measures to what extent nuclear applications can contribute to addressing/solving the need/problem. On the other hand, it takes account of the extent to which solving the problem has relevance for nuclear applications.
Level of Difficulty	This measures the degree of difficulty of implementing the solution to the need/problem identified, which can be related to infrastructure, resources, technology, legislation, intergovernmental commitments, etc.

A–3. SCORING FOR PRIORITIZATION AND JUSTIFICATION

To prioritize needs and problems by sector, prioritization grades are used for the attributes SERIOUSNESS, TIME, EXTENT and RELEVANCE. These grades range from 1 to 5, as shown in Table A–2.

TABLE A.–2. PRIORITIZATION GRADES FOR THE ATTRIBUTES

Grade	Meaning
1	Very low
2	Low
3	Medium
4	High
5	Very high

The prioritization grade assigned to each attribute has to be justified and entered in a table. Subsequently, these values are added together to obtain the TOTAL value, which corresponds to the prioritization score for the need/problem. This operation needs to be performed for each of the sectors under consideration.

Below is Table A–3., which presents the needs and problems and attributes. Once the need/problem has been described, the grade assigned to each attribute is entered in each cell along with the respective justification, and the sum of these grades is entered in the TOTAL column.

TABLE A–3. PRIORITIZATION WITHIN A SECTOR
Sector and/or subsector, where appropriate:

Attributes Need/problem	Seriousness	Time	Extent	Relevance	Total
1) Description	Grade: 1 to 5 Justification (text)	Grade: 1 to 5 Justification (text)	Grade: 1 to 5 Justification (text)	Grade: 1 to 5 Justification (text)	Sum:
2) Description	Grade: 1 to 5 Justification (text)	Grade: 1 to 5 Justification (text)	Grade: 1 to 5 Justification (text)	Grade: 1 to 5 Justification (text)	Sum:

The TOTAL value corresponds to the priority score for the need/problem within the sector and can range from 4 to 20 points.

One important aspect that needs to be considered when evaluating the TOTAL is that the values in this column cannot be the same for two or more needs and problems. If this situation arises, adjustments need to be made to the grades assigned to the attributes, including by using decimal places (0.25; 0.5; 0.75) if necessary.

The TOTAL score establishes how the set of needs and problems in the sector have to be prioritized.

Another attribute that is evaluated is the degree of DIFFICULTY in resolving the need/problem. This is done by adding a column to the attributes table presented above (Table A–3.), as shown in Table A–4.

TABLE A.4. PRIORITIZATION IN THE SECTOR, INCLUDING THE DIFFICULTY ATTRIBUTE
Sector and/or subsector, where appropriate:

Attributes Need/problem	Seriousness	Time	Extent	Relevance	Total	Difficulty
1) Description	Grade: 1 to 5 Justification (text)	Grade: 1 to 5 Justification (text)	Grade: 1 to 5 Justification (text)	Grade: 1 to 5 Justification (text)	Sum:	Grade: 1 to 5 Justification (text)
2) Description	Grade: 1 to 5 Justification (text)	Grade: 1 to 5 Justification (text)	Grade: 1 to 5 Justification (text)	Grade: 1 to 5 Justification (text)	Sum:	Grade: 1 to 5 Justification (text)

Also, in this case, the range of values to evaluate the degree of DIFFICULTY is from 1 to 5, as set out in Table A–2.

The total priority grade (TPG) is used to prioritize the needs and problems within one sector — i.e., the priority (P) is ranked as 1, 2, 3, etc., according to the score obtained for the corresponding total grade.

If two needs/priorities are awarded the same grade, it is recommended that the assessment of the attributes be repeated to look for factors that allow the score to be adjusted, so as establish which one of them will be presented as the priority. Another option is to use the final priority grade as described below.

A–4. Quadrant graph

In analysing the data obtained, there are four possibilities which are defined relative to the values of the RELEVANCE and DIFFICULTY attributes:

1. HIGH RELEVANCE and LOW DIFFICULTY;

   This corresponds to the first category of priorities and includes the needs and problems that need to be chosen first.

2. HIGH RELEVANCE and HIGH DIFFICULTY;

   This corresponds to the second category of priorities.

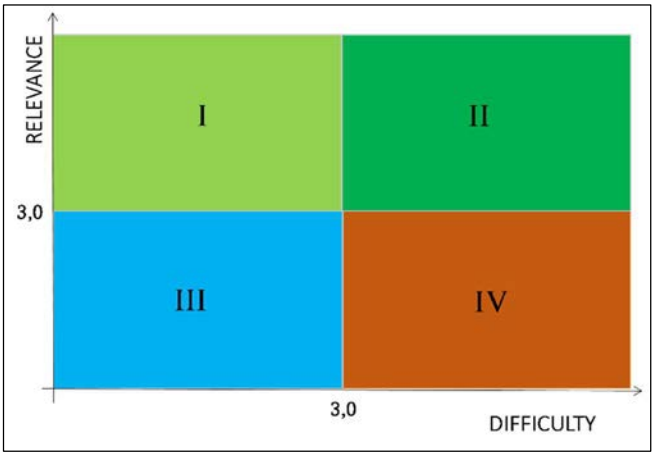
3. LOW RELEVANCE and LOW DIFFICULTY;

   This third category includes needs and problems that are of relatively low importance, but which may still be chosen because of their low level of difficulty to implement.

4. LOW RELEVANCE and HIGH DIFFICULTY;

   This fourth category includes the last set of needs and problems which can, in principle, be eliminated and which need to only be considered subject to specific interests or special situations.

These four possibilities can be represented in a quadrant graph where DIFFICULTY is placed on the X axis and RELEVANCE on the Y axis, as shown in graph A–1. below:



Graph A–1. Quadrant graph of RELEVANCE vs DIFFICULTY

As we can see in this graph, the quadrants correspond to the following categories:

- Quadrant I — HIGH RELEVANCE and LOW DIFFICULTY
- Quadrant II — HIGH RELEVANCE and HIGH DIFFICULTY
- Quadrant III — LOW RELEVANCE and LOW DIFFICULTY
- Quadrant IV — LOW RELEVANCE and HIGH DIFFICULTY

A–5. FINAL PRIORITY GRADE (FPG)

Once the data has been analysed in terms of the RELEVANCE and DIFFICULTY of the needs and problems, the next step is to determine the Final Priority Grade (FPG).

This is achieved as depicted in equation (1) where the TOTAL is the sum of all the attributes: SEVERITY, TIME, EXTENT AND RELEVANCE for each need/problem in each sector, and the RELEVANCE/DIFFICULTY quotient is an adjustment factor, so that the final priority grade may be greater than, equal to or less than the TOTAL value.

$$FPG = TOTAL\ X\ \frac{RELEVANCE}{DIFFICULTY} \qquad (1)$$

Using the final priority grade values obtained, an order of priority can be established for the needs and problems, per quadrant, between all the sectors.

It needs to be emphasized that the prioritization methodology is a support tool that provides decision makers with a basis for quantitative comparison of the needs and problems, although this is not necessarily the only consideration that may be considered when prioritizing a set of needs and problems.

Thus, at this stage of preparing the 2022–2029 RSP, the quadrant graph was not used for the purposes of prioritization of sectors; this will be done during the next stage of work, which will focus on the preparation of the Guide for the Implementation of the RSP.

GLOSSARY

3D simulation. Also known as 3D planning (3D radiation treatment planning (3D-RTP)), is the latest system for 3D treatment planning, with definition of the planning treatment volume (PTV) and precise dose distribution calculations.

Atherosclerotic artery disease. A disease in which plaque builds up inside the arteries. Arteries are blood vessels that carry oxygen-rich blood to the heart and other parts of the body. The plaque is made up of fats, cholesterol, calcium, and other substances found in blood. Over time, the plaque hardens and narrows the arteries, limiting the flow of oxygen-rich blood to organs and other parts of the body.

Authorization. The granting by a regulatory body or other governmental body of written permission for an operator to perform specified activities.

Brachytherapy. Radiation therapy in which the radiation source is placed near the surface of the body or into a natural cavity.

Calibration. A set of operations establishing, under specified conditions, the relationship between the values of a magnitude indicated by a measurement system or instrument, or the values represented by a measurement taken or a reference material, and the corresponding values established by the standards.

Cardiotoxicity. A quantitative or qualitative alteration in the heart owing to drugs and other substances toxic to this organ. It can evolve into heart failure or arrhythmia.

Cerebrovascular diseases. These are usually defined generically as ictus since they include cerebral infarctions, strokes and other medical conditions. Cerebrovascular disease can be ischaemic, when due to decreased blood supply to the brain, or haemorrhagic (brain haemorrhage), when due to the presence of blood in the cerebral ventricles or in the subarachnoid space. Cardiovascular disease or Cerebrovascular disease (CVD) are the second most common cause of death and the primary cause of disability. Women are more likely to have a cerebrovascular disorder.

Cobalt unit. Used for the radiation treatment of cancer patients. An item of equipment that uses gamma radiation from a cobalt-60 source inside it.

Contamination. Radioactive substances on surfaces, or within solids, liquids, or gases (including the human body), where their presence is unintended or undesirable, or the process giving rise to their presence in such places.

Cyclotron. An item of equipment in which a particle beam is placed in a constant high-frequency electric field and a perpendicular static magnetic field causing acceleration of the particles. It was invented in 1929 by Ernest Lawrence.

Disposal. The emplacement of waste in an appropriate facility without the intention of retrieval.

Disused source. A radioactive source that is no longer used and is not intended to be used in the practice for which an authorization was granted.

Dosimeter. A device that responds to radiation in a reproducible and quantifiable way, which can be used to measure absorbed dose in a given system.

Dosimetry. Measurement of absorbed dose using dosimeters.

Echocardiography. A safe, non-invasive ultrasound procedure that uses sound waves to obtain a detailed image of the heart. Echocardiographic studies are carried out to define cardiac anatomy.

Emergency plan. A description of the objectives, policy, and basic concepts of emergency response operations, and of the structure, capacities and responsibilities inherent to a systematic, coordinated and effective response.

Emergency preparedness. The capacity to take measures that will effectively mitigate the consequences of an emergency in terms of human health and safety, quality of life, property, and the environment.

Emergency response. The performance of actions to mitigate the consequences of an emergency in terms of human health and safety, quality of life, property, and the environment.

First responders. The first members of an emergency service to respond at the site of an emergency.

Food irradiation. Process of exposing food to ionizing radiation to improve its safety and quality.

Gamma camera or SPECT. A computerized machine that detects the radiation emitted by patients who have taken radiopharmaceuticals. Types of gamma camera: a) planar, producing single-slice images; b) SPECT, revolving around the patient, creating images from multiple angles.

Gamma radiation or gamma rays (γ). A type of electromagnetic radiation and therefore comprises photons and is usually produced by radioactive elements or by subatomic processes such as the annihilation of a positron–electron pair. It is also generated in violent astrophysical phenomena.

Good practices. Combination of operational and quality procedures aimed at ensuring that products or processes are systematically carried out according to their specifications.

Hypercholesterolemia. (High blood cholesterol) The presence of elevated cholesterol levels in the blood. It cannot be considered a pathology, but rather a metabolic imbalance that can be secondary to many diseases and can also contribute to many forms of disease, especially coronary artery disease. It is closely linked to the term hyperlipidaemia (elevated lipid levels) and hyperlipoproteinemia (elevated lipoprotein levels).

Interventional radiology. Interventional radiology allows surgical procedures to be performed by means of needles, guides, and catheters through the skin or inside vessels, with a high degree of success and no need to perform surgical procedures.

Irradiation. Process of exposing a material to ionizing radiation.

Irradiation facility. Establishment where irradiation treatment is carried out. There are different types of irradiation facility, depending on the type of irradiator, the radiation source, the convey or system, and the operating mode. The irradiation facility consists of an irradiator, shipment and receipt bays, storage areas for irradiated and non-irradiated products, a conveyor system, safety systems and

infrastructure for personnel and services of the facility, including record control.

Irradiator. Set of equipment and housing in which the product is exposed to ionizing radiation. The irradiator ensures safe and reliable irradiation treatment and comprises the radiation source and related mechanisms, together with the conveyor, safety devices and biological shielding.

Linear accelerator. A medical linear accelerator (LINAC) forms high-energy X rays or electrons to match the shape of a tumour and destroy cancer cells without affecting the surrounding normal tissue.

Management system. A set of interrelated and interacting elements (system) for establishing policies and objectives and enabling the objectives to be achieved in an efficient and effective manner.

Molybdenum-99/metastable technetium-99 (99Mo/99mTc) technetium generator. A device using which the radioisotope technetium-99m (Tc-99m) can be extracted from the radioactive decay of molybdenum-99 (Mo-99). Technetium-99m is employed in the production of radiopharmaceuticals used in nuclear medicine for diagnostic purposes and represents the vast majority of all diagnostic tests of this type.

Nanomedicine. Medical application of nanotechnology. Nanomedicine ranges from medical applications of nanomaterials and biological devices to nanoelectronic biosensors and even possible future applications of molecular nanotechnology such as biological machines. One of the current problems facing nanomedicine is the understanding of the toxicity and environmental impact of nanoscale materials (materials whose structure is on the nanometre scale, i.e., billionths of a metre).

Naturally occurring radioactive material (NORM). Radioactive material containing no significant amounts of radionuclides other than naturally occurring radionuclides.

Neoplasm. Abnormal mass of tissue that appears when cells multiply more than they have to or do not die when they have to. Neoplasms can be benign (non-cancerous) or malignant (cancerous). Benign masses sometimes grow a lot but do not spread and do not invade nearby tissues or other parts of the body. Malignant masses often spread or invade nearby tissues and may also spread to other parts of the body through the blood and lymphatic system. Also known as neoplasia or tumours.

Non-communicable diseases. Non-communicable or chronic diseases are long-lasting conditions that usually progress slowly. They include cardiovascular diseases (e.g., myocardial infarctions or strokes), cancer, chronic respiratory diseases (e.g., chronic obstructive pulmonary disease or asthma) and diabetes.

Nuclear cardiology. Nuclear cardiology studies use non-invasive techniques to assess myocardial blood flow, assess the pumping function of the heart, and visualize the size and location of a heart attack. Myocardial perfusion imaging is the most widely used nuclear cardiology technique.

Nuclear or radiological emergency. An emergency in which there is, or is perceived to be, a hazard due to: a) the energy resulting from a nuclear chain reaction or from the decay of the products of a chain reaction; or b) radiation exposure.

Oligometastatic disease. A type of metastasis in which cancer cells from the original (primary) tumour move through the body and form a small number of new tumours (metastatic tumours) in one or two other parts of the body.

Orphan source. A radioactive source which is not under regulatory control, either because it has never been under regulatory control or because it has been abandoned, lost, misplaced, stolen or otherwise transferred without proper authorization.

PET, PET–CT, Positron emission tomography (PET). An imaging test that evaluates the metabolism of the structures analysed, bones, muscles, brain, lungs, liver, and other organs. Currently, most PET scans are performed on devices synchronized with CT scanners that allow the metabolic and anatomical images obtained using the two techniques respectively to be combined, hence the acronym PET–CT.

PET–MRI. A hybrid imaging technology that incorporates positron emission tomography imaging with magnetic resonance imaging (MRI).

Phytosanitary treatment. Any official procedure aimed at preventing the introduction or spread of quarantine pests or limiting the economic repercussions of regulated non-quarantine pests.

Radiation dose. Radiation dose or absorbed dose is the concentration of energy deposited in tissue as a result of exposure to ionizing radiation. N.B. In this case, it refers to the energy absorbed by human tissue.

Radiation protection. Protection of people against the exposure to ionizing radiation, or exposure due to radioactive material and the means to achieve this.

Radiation protection programme Systemic arrangements that are aimed at providing adequate consideration of radiation protection measures

Radiation risk. The detrimental health effects of exposure to radiation (including the likelihood of such effects occurring) and any other safety related risk (including the environment) that might arise as a direct consequence of (a) exposure to radiation (b) presence of radioactive material or its release into the environment (c) a loss of control over a nuclear reactor core, nuclear chain reaction, radioactive source or any other source of radiation

Radiation safety. The achievement of proper operating conditions, prevention of accidents and mitigation of accident consequences, resulting in protection of workers, the public and the environment from undue radiation risks

Radioactive waste. Radioactive material in gaseous, liquid or solid form for which no further use is foreseen by the Contracting Party or by a natural or legal person whose decision is accepted by the Contracting Party, and which is controlled as radioactive waste by a regulatory body under the legislative and regulatory framework of the Contracting Party

Radioactive waste management. All administrative and operational activities involved in the handling, pre-treatment, treatment, conditioning, transport, storage and disposal of radioactive waste.

Radionuclide. Radioactive isotope of an element (for example, 137Cs or cobalt–60 (60Co)).

Radiopharmaceuticals. Radioisotopes attached to biological molecules that can act on specific organs, tissues, or cells of the human body. These radioactive drugs are used in the diagnosis and, increasingly, in the treatment of diseases.

Radiosurgery. A radiotherapeutical medical procedure in which fine beams of radiation, generated in megavoltage units (cyclotron, Gamma Knife and linear accelerator (LINAC)), through multiple convergent and conformed fields that allow high doses of irradiation to be administered locally with precision, are focused on a specific anatomical area or structure, avoiding the administration of toxic doses to adjacent tissues.

Regulatory authority. One or more authorities designated by the government of a State as having legal authority for conducting the regulatory process, including issuing authorizations.

Regulatory body. An authority or a system of authorities designated by the government of a State as having legal authority for conducting the regulatory process, including issuing authorizations, and thereby regulating the nuclear, radiation, radioactive waste and transport safety.

Regulatory control. Any form of control or regulation applied to facilities and activities by a regulatory body for reasons relating to nuclear safety and radiation protection or to nuclear security.

Safety assessment. Assessment of all aspects of a practice that are relevant to protection and safety; for an authorized facility, this includes siting, design and operation of the facility.

Safety culture. The assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, protection and safety issues receive the attention warranted by their significance.

Soft tissue sarcoma. Rare malignant tumours that originate in tissues such as muscles and fat. The vast majority grow and develop in the limbs, but they can affect any part of the body, from the head and neck to the torso and internal organs. More than 50 types of tumour are categorized as ‘soft tissue sarcoma’; they can appear anywhere in the body, although 60% of cases affect the lower and upper limbs.

Theranostics. Involves the integration of nanosciences that combine diagnostic and therapeutic applications to form a single agent (called a radiopharmaceutical or radioligand). This allows diagnosis, administration of medications, and treatment response follow-up to occur at the same time.

LIST OF ABBREVIATIONS

^{131}I	iodine–131
^{137}Cs	caesium–137
^{15}N	nitrogen–15
^{32}P	phosphorus–32
^{33}P	phosphorus–33
^{60}Co	cobalt–60
ALHSUD	Latin American Association of Underground Hydrology for Development
ARCAL	Spanish acronym for Co-operation Agreement for the Promotion of Nuclear Science and Technology in Latin America and the Caribbean
ATCB	ARCAL Technical Coordination Board
BAR	Board of ARCAL Representatives
BNF	biological nitrogen fixation
CBCT	cone-beam computed tomography
CBD	Convention on Biological Diversity
CCHEN	Spanish acronym for Chilean Nuclear Energy Commission
CDTN	Spanish acronym for Nuclear Technology Development Centre
CH_4	Methane
CLEW	climate, land, energy and water
CNEA	Spanish acronym for National Atomic Energy Commission, Argentina
CNEN	Portuguese acronym for National Nuclear Energy Commission, Brazil
CO_2	Carbon Dioxide
CODEX Alimentarius	Food standards established by the UN through the FAO and WHO
CTA	cellulose triacetate
DIRAC	Directory of Radiotherapy Centres
DNA	deoxyribonucleic acid
ECLAC	Economic Commission for Latin America and the Caribbean
EduTA	Education and Training Appraisal
EPREV	Emergency Preparedness Review
EPRIMS	Emergency Preparedness and Response Information Management System
ESCAP	Economic and Social Commission for Asia and the Pacific
FAO	Food and Agriculture Organization of the United Nations
GDP	gross domestic product
GHG	greenhouse gas
GSG	General Safety Guide
GSR	General Safety Requirements
GW	gigawatt
IAEA	International Atomic Energy Agency
IAEA-TECDOC	IAEA Technical Document

ICENS	Spanish acronym for International Centre for Environmental and Nuclear Sciences
IEC	International Electrotechnical Commission
IEN	Spanish acronym for Nuclear Engineering Institute
ILO	International Labour Organization
INGEOMINAS	Colombian Institute of Geology and Mining
ININ	National Institute for Nuclear Research, Mexico
IPEN	Peruvian Institute of Nuclear Energy, Peru
IPEN	Portuguese acronym for Nuclear Energy and Research Institute
IRENA	International Renewable Energy Agency
IRRS	Integrated Regulatory Review Service
ISO	International Organization for Standardization
IWRN	Inter-American Water Resources Network
kW	kilowatt
LAC	Latin America and the Caribbean
LBDNet	Latin American Biological Dosimetry Network
MAED	Model for Analysis of Energy Demand
MESSAGE	Model for Energy Supply Strategy Alternatives and their General Environmental Impact
M&E Group	Monitoring and Evaluation Group
MRI	magnetic resonance imaging
Mt	million tonnes
Mtoe	million tonnes of oil equivalent
MW	megawatt
N_2O	Nitrous oxide
NAT	nuclear analytical technique
NCS	nucleonic control system
NDT	non-destructive testing
NORM	naturally occurring radioactive material
NWS	New World Screwworm
OECD	Organization for Economic Co-operation and Development
OIE	World Organization for Animal Health, formerly the Office International des Epizooties
ORPAS	Occupational Radiation Protection Appraisal Service
PACT	Programme of Action for Cancer Therapy
PAHO	Pan American Health Organization
PET	positron emission tomography
PET–CT	positron emission tomography–computed tomography
PET–MRI	positron emission tomography coupled with magnetic resonance imaging
PMMA	polymethyl methacrylate
QA	quality assurance

QUAADRIL	Quality Assurance Audit for Diagnostic Radiology Improvement and Learning
QUANUM	Quality Assurance in Nuclear Medicine
QUATRO	Quality Assurance Team for Radiation Oncology
QC	quality control
RACAL	Spanish acronym for Network for the Analysis of Environmental Quality in Latin America
RALACA	Spanish abbreviation for Latin American and Caribbean Analytical Network
RASIMS	Radiation Safety Information Management System
REMARCO	Spanish abbreviation for Marine-Coastal Research Network
REPROLAM	Spanish abbreviation for Network for the Optimization of Occupational Radiation Protection in Latin America
RNA	Ribonucleic acid
RP	radiation processing
RPO	radiation protection officer
RSP	Regional Strategic Profile
SDG	United Nations Sustainable Development Goal
SIDS	Small Island Developing States
SIT	sterile insect technique
SMR	Small Modular Reactor
SPECT	single photon emission computed tomography
SPECT–CT	single photon emission computed tomography coupled with computed tomography
SWOT	strengths, weaknesses, opportunities, threats
T	Radiotracers
TOs	Technical officers
ToR	Terms of reference
TSA	Thematic Safety Area
TW·h	terawatt-hour
UN	United Nations
UNCCD	United Nations Convention to Combat Desertification
UNDESA	United Nations Department of Economic and Social Affairs
UNECA	United Nations Economic Commission for Africa
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations Children’s Fund
WHO	World Health Organization
WMO	World Meteorological Organization
WiN	Women in Nuclear

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