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ARCAL Regional Strategic Profile for Latin America and the Caribbean (RSP) 2016-2021

IAEA
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ARCAL
REGIONAL STRATEGIC PROFILE FOR LATIN AMERICA AND THE CARIBBEAN (RSP)
2016–2021

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FOREWORD

This TECDOC presents the Regional Strategic Profile (RSP) for Latin America and the Caribbean for 2016–2021. This key document offers a programmatic reference of major importance for the preparation of project and programme proposals for future technical cooperation (TC) cycles.

The RSP reflects an assessment of the situation in the region made by the States Parties to the Regional Cooperation Agreement for the Promotion of Nuclear Science and Technology in Latin America and the Caribbean (ARCAL). It identifies the most pressing needs that can be addressed through nuclear technology, in the areas of human health, food safety and agriculture, environment, and energy. It also covers radiation technology and radiation protection.

The RSP was prepared by a working group of ARCAL National Coordinators, together with thematic experts from the region, Programme Management Officers and Technical Officers. The group reviewed the previous Profile for the period 2007–2013 to identify lessons learned, and assessed the current situation in the region regarding needs and priorities in the Latin American and Caribbean socioeconomic context.

The new profile is expected to serve as a valuable tool to foster regional cooperation and promote cooperation among countries. As a flagship regional document, it makes visible the region's needs and facilitates the establishment of partnerships with other development community organizations working in the region in complementary fields. The RSP identifies opportunities for cooperation, and for joining forces and creating synergies.

The RSP for 2016–2021 was finalized in 2014, the year in which the ARCAL Regional Agreement turns 30, celebrating three decades of successful implementation of technical cooperation projects and fruitful cooperation between the ARCAL Regional Agreement and the IAEA. It is expected that the RSP will lead to the implementation of effective and efficient regional cooperation mechanisms that will ensure sustainability and relevance as the ARCAL States Parties work with the IAEA to address the development challenges facing the region.

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REGIONAL STRATEGIC PROFILE FOR LATIN AMERICA AND THE CARIBBEAN 2016–2021

1. EXECUTIVE SUMMARY

1.1. BACKGROUND

The International Atomic Energy Agency (IAEA) and the Co-operation Agreement for the Promotion of Nuclear Science and Technology in Latin America and the Caribbean (ARCAL) have worked closely together to prepare a new strategic programme framework to identify and prioritize the region's[1] most pressing problems and needs that could be addressed using nuclear technologies in the period up to 2021.

The new Regional Strategic Profile for Latin America and the Caribbean (RSP) was drawn up on the basis of a sectorial diagnosis 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 and the indicators by which to measure them.

The 39 needs/problems identified were classified into six thematic areas representing the priority areas within the scope of the new RSP: food security, human health, environment, energy, radiation safety and radiation technologies.

At the end of the process, a working document was prepared containing strategic guidance to facilitate the planning of technical cooperation cycles covered under the new RSP. This working document will be updated periodically as progress is made toward achieving the objectives and goals that have been set.

It is anticipated that the new RSP, in addition to serving as a programmatic reference of major importance for the preparation of project and programme proposals both for ARCAL and the IAEA, will help to attract strategic partners, from within the region and outside it, to pursue projects having a larger scope, benefit and impact.

1.2. THEMATIC AREAS

1.2.1. FOOD SECURITY

The Latin America and Caribbean region has some of the largest reserves of land with agricultural potential in the world (700 million hectares), which, together with the region's great biological diversity, makes it a mainstay of global food security. It is expected that by 2050, the region will be meeting more than 60% of the global demand for food. Supporting the agricultural sector's role as a major food supplier requires overcoming critical challenges as regards both increasing production efficiency and preventing the degradation of natural resources. Hence the urgent need to develop technologies to support increased and sustainable

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[1] In this document, 'region' and 'regional' refer to those countries that are States Parties to the ARCAL Agreement.

food production from agriculture, stock-breeding and fishing in the region. Nuclear technologies have demonstrated their effectiveness and can contribute to improving efficiency in fertilization, water use, biological nitrogen fixation, crop and livestock improvement, pest and disease control, and quality control for food products. For this reason, it is anticipated that the implementation of the RSP in the area of food security will help to optimize the efficiency of production systems in the region through projects tied to the six needs/problems identified for this area.

A1. Improvement of practices for the management of agricultural soil and water resources with the appropriate use of agrochemicals, fertilizers, water and microorganisms for biological nitrogen fixation.
A2. Use of technologies for the improvement of animals and plants of recognized economic importance and to support initiatives to improve the yield/production and commercial potential of plants and animals reflecting the region's biodiversity.
A3. Incidence of transboundary diseases in animals, including those with zoonotic repercussions.
A4. Availability of foods of animal (including products derived from aquaculture) and plant origin that meet quality and safety standards.
A5. Damage caused by pests to foods of animal and plant origin.
A6. To support initiatives for the development of aquaculture in the region.

1.2.2. HUMAN HEALTH

In Latin America and the Caribbean, a region with a population of some 580 million inhabitants, roughly 76% of deaths are caused by non-communicable diseases, with cardiovascular diseases being the leading cause of death, followed by malignant neoplasms. By 2030, the number of new cases of malignant neoplasms each year is expected to double, bringing to 1 million the number of deaths annually. It has been estimated that 50–60% of cancer-related deaths could be prevented by applying the available knowledge and technologies. To achieve this would require implementing multiple, complex measures, in addition to timely detection and effective treatment. Nuclear technology has been shown to be a powerful tool in the diagnosis and treatment of these diseases. Nuclear medicine and radiotherapy have evolved significantly in recent decades in most Latin American countries, with advances being made in technological assets, the availability of various radiopharmaceuticals required for diagnosis and treatment, and human resources development. The technical cooperation programme, through ARCAL and IAEA projects, has contributed to these objectives. At the same time, there are still many challenges to be addressed and the RSP serves as an effective instrument for funnelling technical cooperation resources toward the main areas identified as having high priority. Thus, based on a strategic analysis, it has been determined that efforts for the period 2016–2021 should be directed at strengthening national cancer control programmes as a strategy for solving the other needs and problems that have been identified and prioritized in the area of human health:

S1. To improve efficiency and quality in the use of new technologies for the diagnosis and treatment of diseases.
S2. Lack of appropriate technology management systems for planning, incorporation and maintenance of biomedical equipment.
S3. Insufficient nuclear medicine and radiotherapy technicians to meet the growing need arising from the establishment of new centres in the region.

S4. Insufficient human resources in medical physics in imaging services (nuclear medicine and radiology).
S5. Shortage of comprehensive, functional and operational national cancer control plans (NCCP)
S6. Growing childhood obesity in the region and its link to the incidence of non-communicable diseases, caused in part by malnutrition in early infancy.

1.2.3. ENVIRONMENT

Latin America and the Caribbean possess enormous wealth in terms of natural resources, cover 15% of the Earth's surface, account for a third of the world's renewable water resources, and are home to 40% of all plant and animal species and the most diverse flora on the planet. Within the last decade, the region has experienced economic growth which is expected to continue in the near future, accompanied by an improvement in some of the key macro social indicators. In the last 30 years, the population of the region has doubled, over half of it now being concentrated in urban areas, with the attendant concentration of vehicles, industry and other sources of pollution. The trend towards the intensive use of water resources, increased use of agrochemicals, unsuitable production practices and insufficient processing of agricultural, urban and industrial waste have led to contamination of water, soil, plants, food, flora, fauna and air. Sustainable resource use and environmental management require, among other things, techniques for the chemical characterization of various types of samples; this can be done efficiently using nuclear techniques, which explains why they are in high demand among entities involved in environmental management.

These techniques could be used to address the following needs/problems identified in the RSP in the environmental area.

M1. Inadequate management of the region's water resources.
M2. Insufficient evaluation of the impact of pollution from pesticides, persistent organic compounds, heavy metals and other pollutants of anthropogenic and natural origin in water and soil.
M3. Limited knowledge of the main processes affecting coastal areas.
M4. High degree of atmospheric pollution due to trace elements.
M5. Inadequate risk assessment of the environmental and social impact of hydraulic structures.

1.2.4. ENERGY

The Latin America and Caribbean region has over 25 years of experience in the use of nuclear technology for power generation. Installed capacity, in six reactors in three countries, was 4.3 GW in 2012 and will grow to 6.2 GW once two new reactors currently under construction are put into operation. It is estimated that an additional 7 GW of nuclear power capacity will be added to the region's energy mix by 2035. The challenges associated with the construction of new nuclear power plants have been made more difficult by the need to take into account the analysis and evaluation of the extension of the useful life of existing reactors. These factors highlight 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 Latin America and the Caribbean.

In addition, there is in seven countries in the region a total of 17 research reactors, the majority of which are ageing and underused. At the same time, the demand for radioisotope products is growing and is not being met by the existing installations, which is why there are plans to build two new reactors. The main challenges to be addressed through cooperation in the area of energy are identified in the RSP and formulated as six needs/problems:

E1. To improve education and availability of objective and extensive information on nuclear energy.
E2. Absence of integrated appropriate long-term energy development studies in most of the region.
E3. Improved knowledge about the region's uranium potential.
E4. Absence of an established network for the exchange of information and coordination of strategies, from research reactor operators to the radioisotope end user.
E5. Lack of experience in the region in processes to extend the operating lifetime of nuclear power plants.
E6. Shortage of highly qualified staff to manage and operate research reactors.

1.2.5. RADIATION SAFETY

Acceptance in society of the risks associated with radiation is dependent on the net benefit from its multiple applications. Compliance with radiation safety requirements, in accordance with international standards, is an essential requirement for the application of nuclear technologies and ultimately for the implementation of the main priorities set out in the RSP. Substantial progress has been made in the last 15 years as regards the establishment of regulatory programmes and infrastructure in the Latin America region, which has benefited significantly from the efforts by, and the technical cooperation between, the Agency and its Member States.

However, action is required to consolidate the results achieved at the level of international good practices in the field of safety. With this approach, among the needs identified and prioritized in the RSP, the radiation protection of patients and the responsibilities of Governments and regulatory authorities have been defined as priorities, which will help to address the other closely-related needs and problems.

R1. Insufficient application and implementation among end users of principles and requirements concerning radiation protection set out in international safety recommendations for the control of medical exposure in computed tomography, radiotherapy, interventional procedures and digital radiology.
R2. Lack of safeguards in countries of the region to ensure that governments maintain a sustainable national regulatory system for radiation protection and safe transport of radioactive material.
R3. Insufficient management systems in regulatory bodies to ensure compliance with all legislative responsibilities in the countries and recommendations of IAEA standards.
R4. Insufficient coverage by the radiation protection services (individual internal and external monitoring and workplace monitoring) of occupationally exposed workers in the countries. Inadequate implementation of quality systems in technical services and the lack of availability of unified or centralized national records of occupational dose in all countries.
R5. Lack of national strategies and policies for the safe and sustainable management of radioactive waste and improvement in the operational control of waste and disused sources.

R6. Limited capacities in countries for planning, notification and response with regard to radiological emergencies, including the provision of medical care to those affected, systematic analysis of accidents and dissemination of information.

R7. Limitations for calibration at the levels of radiation protection, radiotherapy and radiodiagnostics by secondary standards dosimetry laboratories in the region.

R8. Insufficient application of management systems among end users, including the promotion and implementation of safety culture.

R9. Absence of national strategies for education and training in radiation safety.

R10. Insufficient information and consultation with interested parties and the public concerning possible radiation risks associated with facilities and activities, and processes and decisions of the regulatory body.

1.2.6. RADIATION TECHNOLOGIES

Radiation technologies have found numerous applications in a variety of fields where they can help to improve the quality of life; these include medicine, agriculture, preservation of cultural assets, industry, environment, materials modification, process diagnostics, quality control, sterilization of products and materials, radioisotope production and waste processing, among many others. As the applications of, experience with and confidence in nuclear techniques gradually increase, the use of radiation technologies is on the verge of becoming an important factor in the region's economies. To this end, six needs/problems have been identified in the RSP in the area of radiation technology:

T1. The need to identify, outline and publicize the specific and strategic opportunities and challenges in the region concerning the promotion and use of radiation technologies in priority applications.

T2. The need to increase the competitiveness of regional industries and reduce the environmental impact.

T3. The need to harmonize quality management procedures for the application of radiation technologies in the region.

T4. To improve the quality of industrial goods and services, safety of operation and protection of human life in the region.

T5. To improve the use of the natural, renewable, non-toxic resources of the Latin American and the Caribbean region for sustainable development.

T6. To preserve the rich and vast cultural heritage of Latin America and the Caribbean.

2. PRESENTATION OF THE REGIONAL STRATEGIC PROFILE FOR LATIN AMERICA AND THE CARIBBEAN (RSP) 2016–2021

2.1. INTRODUCTION

The existing Regional Strategic Profile for Latin America and the Caribbean (RSP) covers the period 2007–2013; for this reason it needs to be updated taking into account the level of progress made in achieving its strategic objectives and the prospects for the use of nuclear technology in the region in the next few years.

This new RSP will cover the period from 2016–2021; it will serve as a reference for the promotion and development of cooperation among countries of the region and will facilitate the planning of regional technical cooperation projects, since it will give continuity to the planning undertaken on the basis of the RSP for 2007–2013.

It is important to mention that the 2014–2015 technical cooperation cycle is a transition period that will be used as a bridge between the existing and new RSP. The technical cooperation projects approved for this transition period will focus on needs in thematic areas of the existing RSP that have not been properly met during previous cycles.

The International Atomic Energy Agency (IAEA) and the Co-operation Agreement for the Promotion of Nuclear Science and Technology in Latin America and the Caribbean (ARCAL) have cooperated closely in the preparation of a new, solid regional planning framework aimed at addressing the priority needs and problems of the region within a time frame up to 2021.

In the preparation of the new programmatic framework, account was taken of the important advantages that ARCAL offers, as an intergovernmental agreement, in the development of technical cooperation project proposals, the mobilization of national resources and means to facilitate project implementation, in monitoring and disseminating the results achieved and in evaluating the impact of the projects for the countries of the region.

As a point of departure for the preparation of the new RSP for 2016–2021, consideration was given to the following:

- Evaluation of the results achieved in cooperation cycles during the period 2007–2013;
- The current situation regarding nuclear applications in the region, including new technologies;
- Identification of conceptual and methodological adjustments required to improve the process of elaborating the RSP; and
- Dissemination of the impact and benefits of the technical cooperation projects in the region.

2.2. PROCESS FOR THE PREPARATION OF THE RSP FOR 2016–2021

The process of preparing the RSP for 2016–2021 began at the XII ordinary meeting of the ARCAL Technical Co-ordination Board (ATCB) held in Panama from 23 to 27 May 2011, when a working group was created specifically for this task. Subsequently, at the XIII ordinary meeting of the ATCB, that was held in Chile from 7 to 11 May 2012, agreement was reached on a timetable of activities to be implemented through the Supervision and Coordination Group for the RSP (GSC), which was given the responsibility for the updating work.

In December 2012, the first meeting with experts from the thematic groups for each of the sectors of the RSP was held in Cuba with the objective of evaluating the implementation and results of the regional technical cooperation projects for the period 2007–2013.

Subsequently, from 18 to 22 March 2013, a second meeting of the GSC was held in Costa Rica to analyse the project evaluation reports prepared by the experts in Cuba and to draw up proposed terms of reference for the RSP for 2016–2021 with a respective timeline and agendas for work.

From 13 to 17 May 2013, the thematic groups held a meeting in Vienna, Austria, where the strategic sectorial diagnosis was completed, and the needs or problems were identified with their strategic objectives, impact indicators and prioritization. In the margins of the meeting, the terms of reference for the preparation of the RSP for 2016–2021 were discussed once more and a new final version was drawn up, one notable aspect of which is the plan to prepare indicative programming with respect to the cooperation cycles covered by the new RSP.

From 4 to 8 November 2013, a joint meeting of the GSC and IAEA officers was held to review and align the sectorial reports prepared by the thematic groups of the RSP, and to draw up a complete first draft of the document, which was circulated after the meeting to all Member States of the region and the technical departments of the IAEA for review and comment by the end of January 2014.

From 3 to 7 March 2014, the last meeting of the process was held in Vienna, where the GSC, leading experts of the working groups and IAEA officials prepared the final version of the document taking into consideration the feedback received during the review process, to be submitted for approval to the responsible entities at the IAEA and ARCAL level. During this meeting a working document was prepared with strategic guidance to facilitate the planning of technical cooperation cycles covered under the new RSP for 2016–2021. This document will be updated periodically depending on the progress made in achieving the objectives and goals set.

2.3. OBJECTIVE OF THE REGIONAL STRATEGIC PROFILE

The objective of the RSP for 2016–2021 is to establish a strategic framework for cooperation for the Latin American and Caribbean region on the basis of a descriptive analysis of the most pressing problems and needs[2] in the regional context that can be addressed using nuclear technology.

The framework of cooperation for the RSP 2016–2021 will be a programmatic reference of major importance for the preparation of project and programme proposals for ARCAL as well as the IAEA in terms of the technical cooperation programme for the region.

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[2] For the purpose of formulating needs or problems, it should be noted that:

- a need includes what is wanted and concerns a situation that is not satisfactory or shortcoming;
- a problem is a situation to be resolved.

The new 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 the region, as well as outside it, to develop projects with greater benefit and impact.

It should be noted that the RSP for 2016–2021 provides a dynamic framework, and that, in view of the conditions and needs of the region at a given time, project proposals that have not been covered in this document may be put forward provided that they are in line with the principles, standards and quality criteria of the IAEA's technical cooperation programme.

2.4. SCOPE OF THE RSP 2016–2021

In order to ensure continuity with the existing RSP, the new RSP will include the following priority sectors for the application of nuclear techniques:

1. **Food security:** agriculture, food, animal health.

2. **Human health:** nuclear medicine, radiotherapy, radiodiagnostics, medical physics, radiopharmacy, nutrition.

3. **Terrestrial and marine environment:** atmosphere, water resources, terrestrial environment, marine environment.

4. **Energy:** nuclear energy and research reactors.

5. **Radiation safety:** regulatory infrastructure, protection of patients, the public and the environment, management of radioactive waste and radiological emergency preparedness and response.

6. **Radiation technologies:** radiation processing technologies (gamma, electron and X ray), radiotracers, nucleonic control systems, non-destructive testing and analytical techniques for: treatment of water, emissions and waste; coastal engineering; advanced materials; medicine; characterization and preservation of cultural heritage; industrial processes; natural resources; and inspection technologies

2.5. CONTENT OF THE RSP AND THE METHODOLOGY USED

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

The RSP for 2016–2021 has been drawn up on the basis of a sectorial diagnosis, the identification of priority problems and needs and their respective objectives and indicators, taking into consideration:

- the Millennium Development Goals;
- prioritization between sectors;
- the proposed objectives;
- the desired results to be achieved in the period.

With this objective, a group of regional subject experts was formed that, together with technical officers from the IAEA, carried out an analysis of strengths, weaknesses, opportunities and threats (SWOT), allowing the needs and problems in the region to be identified.

The methodology described in Annex 1 was used to assign priorities within the set of needs/problems identified.

Specific attributes were assigned to these needs/problems relating to their severity, time, extent, relevance and level of difficulty. The resulting values allowed for a quantitative comparison of the needs/problems. In the analysis, account was also taken of the different levels of development of the countries in the region.

The characterization of the need or problem contains the following elements:

- Justification of the need/problem setting out clearly the situation to be addressed. This justification establishes qualitative and quantitative baselines of the situation diagnosed.

- An objective at the strategic level that can be achieved during the period 2016 to 2021 and within the limit of available financial resources, considering that ARCAL and the IAEA technical cooperation programme work on the basis of two-year technical cooperation cycles.

- An indicator for the proposed objective.

2.6. GENERAL RESULTS

A total of 39 needs/problems was identified by the thematic groups. The specific analysis using the methodology applied is set out in each of the sections of the document. The results of this are presented below.

FOOD SECURITY

A1. Improvement of practices for the management of agricultural soil and water resources with the appropriate use of agrochemicals, fertilizers, water and microorganisms for biological nitrogen fixation.

A2. Use of technologies for the improvement of animals and plants of recognized economic importance and to support initiatives to improve the yield/production and commercial potential of plants and animals reflecting the region's biodiversity.

A3. Incidence of transboundary diseases in animals, including those with zoonotic repercussions.

A4. Availability of foods of animal (including products derived from aquaculture) and plant origin that meet quality and safety standards.

A5. Damage caused by pests to foods of animal and plant origin.

A6. To support initiatives for the development of aquaculture in the region.

HUMAN HEALTH

S1. To improve efficiency and quality in the use of new technologies for the diagnosis and treatment of diseases.

S2. Lack of appropriate technology management systems for planning, incorporation and maintenance of biomedical equipment.

S3. Insufficient nuclear medicine and radiotherapy technicians to meet the growing need arising from the establishment of new centres in the region.

S4. Insufficient human resources in medical physics in imaging services (nuclear medicine and radiology).

S5. Shortage of comprehensive, functional and operational national cancer control plans.

S6. Growing childhood obesity in the region and its link to the incidence of non-communicable diseases, caused in part by malnutrition in early infancy.

ENVIRONMENT

M1. Inadequate management of the region's water resources.

M2. Insufficient evaluation of the impact of pollution from pesticides, persistent organic compounds, heavy metals and other pollutants of anthropogenic and natural origin in water and soil.

M3. Limited knowledge of the main processes affecting coastal areas.

M4. High degree of atmospheric pollution due to trace elements.

M5. Inadequate risk assessment of the environmental and social impact of hydraulic structures.

ENERGY

E1. To improve education and availability of objective and extensive information on nuclear energy.

E2. Absence of integrated appropriate long-term energy development studies in most of the region.

E3. To improve knowledge of the region's uranium potential.

E4. Absence of an established network for the exchange of information and coordination of strategies, from research reactor operators to the radioisotope end user.

E5. Lack of experience in the region in processes to extend the operating lifetime of nuclear power plants.

E6. Shortage of highly qualified staff to manage and operate research reactors.

RADIATION SAFETY

R1. Insufficient application and implementation among end users of principles and requirements concerning radiation protection set out in international safety recommendations for the control of medical exposure in computed tomography, radiotherapy, interventional procedures and digital radiology.

R2. Lack of guarantees in countries of the region to ensure that governments maintain a sustainable national regulatory system for radiation protection and safe transport of radioactive material.

R3. Insufficient management systems in regulatory bodies to ensure compliance with all legislative responsibilities in the countries and recommendations of IAEA standards.

R4. Insufficient coverage by the radiation protection services (individual internal and external monitoring and workplace monitoring) of occupationally exposed workers in the countries. Inadequate implementation of quality systems in technical services and the lack of availability of unified or centralized national records of occupational dose in all countries.

R5. Lack of national strategies and policies for the safe and sustainable management of radioactive waste and improvement in the operational control of waste and disused sources.

R6. Limited capacities in countries for planning, notification and response with regard to radiological emergencies, including the provision of medical care to those affected, systematic analysis of accidents and dissemination of information.

R7. Limitations for calibration at the levels of radiation protection, radiotherapy and radiodiagnostics by secondary standards dosimetry laboratories in the region.

R8. Insufficient application of management systems among end users, including the promotion and implementation of safety culture.

R9. Absence of national strategies for education and training in radiation safety.

R10. Insufficient information and consultation with interested parties and the public concerning possible radiation risks associated with facilities and activities, and processes and decisions of the regulatory body.

RADIATION TECHNOLOGY

T1. The need to identify, outline and publicize the specific and strategic opportunities and challenges in the region concerning the promotion and use of radiation technologies in priority applications.

T2. The need to increase the competitiveness of regional industries and reduce the environmental impact.

T3. The need to harmonize quality management procedures for the application of radiation technologies in the region.

T4. To improve the quality of industrial goods and services, safety of operation and protection of human life in the region.

T5. To improve the use of the natural, renewable, non-toxic resources of the Latin American and the Caribbean region for sustainable development.

T6. To preserve the rich and vast cultural heritage of Latin America and the Caribbean.

2.7. STRATEGY FOR THE IMPLEMENTATION OF THE RSP FOR 2016–2021

The RSP for 2016–2021 takes into account the need to establish a strategy for implementation on the basis of the priority needs/problems in each sector.

In order to achieve the long-term results of the RSP, specific objectives and precise indicators will have to be formulated on the basis of updated guidelines facilitating the establishment of goals to be achieved through the technical cooperation programme.

In the strategy for the implementation of the RSP for 2016–2021, consideration will also be given to the need for human resources as well as the availability of financial resources for the period of the RSP.

FOOD SECURITY

3. FOOD SECURITY

3.1. BACKGROUND

The activities for the preparation of the RSP for the period 2016–2021 began with an analysis of the validity of the needs/problems identified in the RSP for the period 2007–2013. This analysis was carried out taking into consideration the results obtained in the projects financed by ARCAL and the IAEA in Latin America and Caribbean based on the reports analysed at the meeting in November 2012 in Varadero, Cuba.

With regard to food security, a number of the characteristics of the SWOT analysis undertaken in the previous RSP still prevail in the region. New opportunities are appearing associated with the great diversity in climate, biology and natural resources (availability of land, water, etc.) in the region; these factors will be reflected in the potential increase in the production of high quality food. The starting point was to determine the needs/problems independently from the application of nuclear techniques; and then, following and analysis of possible solutions, nuclear techniques were found to be tools of considerable value in addressing many of these needs/problems, as will be shown further on.

It should also be pointed out that the subsectors considered in this work are the same as those in the previous RSP, namely:

- Mutation induction and genetic improvements of plants;
- Integrated management of soil, water, plants, fertilizers and environmental protection;
- Integrated management of plant and animal pests;
- Animal production and health;
- Quality foods, free from toxic residues.

3.2. GENERAL ANALYSIS OF THE REGIONAL SITUATION

The world population is now estimated to be in the order of 7021 million, of whom approximately 8–9% live in Latin America and the Caribbean (LAC). Owing to the increasing exodus to urban areas, only 25% of these on average live in rural areas, and this proportion exceeds 43% in the poorest countries [1]; this is why this sector is unquestionably a fundamental source of subsistence and economic progress for millions of people in the region.

In the region, agriculture can be divided into two large groups: smallholders, who are in the majority, use a small fraction of the total farming land with minimal agricultural technology and produce more than 70% of the foods consumed daily by the local population; the major producers, who are mainly engaged in agribusiness in the region.

The Latin America and the Caribbean region occupies 11 % of the global agricultural area (1533.35 million hectares [ha]) [2], and has one of the largest areas in the world that could be used for agricultural purposes (980 million ha); discounting the area currently used, approximately 770 million hectares remain. From this, it can be inferred that the region could increase its agricultural area at least fourfold. This, together with the region’s high level of biological diversity, means that it offers the greatest potential and opportunity for the future development of humankind, at least as far as food production is concerned. The considerable potential for the development of fishing in the region, which has not yet been fully exploited, should be noted. In this regard, the FAO considers that, given that the world population could exceed 9 billion in 2050, food production must grow by more than 70% [3]. Taking into account the potential resources available, it is hoped that Latin America and the Caribbean will guarantee the production to meet more than 60% of the global demand for food. This explains the urgency of developing sustainable farming techniques in the region.

The region also has considerable potential in order to offer the world community new species of agricultural products, since, according to UNEP [4], it has five of the ten megacentres of biodiversity in the world (Brazil, Chile, Mexico, Paraguay and Peru). With regard to agricultural crops, the New World, which is where the region is located, has provided the most diverse crops that today form the basis of the world's food (potato, maize, beans, tomato, yucca, cucurbitaceae, avocado, cacao, garlic chilli, vanilla, etc.). In the area of stockbreeding, Latin America and the Caribbean have large populations of the main species of livestock, across the different subregions, which constitute the economic base for various sectors, in terms of local and regional trade, as well as for large-scale industrial exploitation and the export of derivatives. Owing to the fact that they are indigenous species (as in the case of South American camelids) or were introduced at least 200 years ago by European colonizers (this was the case for cattle, sheep, pigs and buffalo), they have special and select gene pools that have enabled them to adapt to different agro-ecological zones in the region. This is why Latin America and the Caribbean are considered a bulwark of world food security.

In recent decades, the contribution of the agricultural sector to regional GDP has exceeded 8% and in some countries has been greater than 20%. However, from the point of view of economic accounting, the real contribution of the agricultural sector to GDP is viewed more broadly, since, in addition to its share in terms of the primary products it generates, the contribution from its intersectorial links must also be taken into account, in particular its links with the container and packaging, food processing and textile industries, as well as transport and trade services, and the so-called agribusiness. It is estimated that, for every dollar generated in the agricultural sector in the region, an average of three and six dollars are added to the country's economy, the figure being even higher in the relatively more developed countries (Argentina, Brazil, Chile, Mexico and Uruguay). These figures reflect the fact that the agricultural sector is an important driving force for regional progress.

However, positioning agricultural activity as a net provider of food and as a strategic sector for regional development has brought with it negative consequences, such as: progressive degradation of arable land and erosion owing to intensive use and inadequate management, fertilization and irrigation practices; the gradual reduction in the area of natural woodland in order to increase the area available as pasture and for production of industrial crops for export; a loss of biodiversity owing to the substitution of native species crops with crops of high commercial value; pollution by agrochemicals used in pest control during production and in the post-harvest treatment of agricultural products, including losses of foods owing to a high mycotoxin content as a result of poor conservation or storage.

Furthermore, in rural areas the scourges of hunger and malnutrition are present, eroding and concealing the intrinsic value of agricultural and stockbreeding activities. Latin America and the Caribbean mirror the global trend in terms of the poor and malnourished: 80% in rural areas and 20% in urban areas. The highest indicators of poverty and malnutrition in the region are found in the rural areas of the Andean subregion, Mesoamerica, the Caribbean and in the tropical zones of South America [5]. It should be noted that, over the last 10 years, as a result of factors including social policies implemented by governments to reduce poverty, undernutrition in the region decreased from 13.5% to 6.5%; however, there are still approximately 40 million people suffering from undernutrition.

To sum up, although the sector in the region exhibits generally positive results, it also faces a series of important challenges that must be overcome in the coming years to opt for sustainable food development compatible with higher levels of growth and social welfare, combined with conservation and use of biological diversity without harming natural resources. For this development to occur, the condition sine qua non is that regional agricultural activity must increase significantly and in a sustainable manner. Numerous specialists in economic development have identified technological change as the variable which contributes most to economic growth. In Latin America and the Caribbean, 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 in the world, where, over the last 50 years, more than 40% of the rate of increase in the production of foods has been due to the use of nitrogen fertilizers [5].

In summary, the problem of poverty and malnutrition in the region is due to the low fertility or poor quality of the soil, which prevent desired yields from being obtained, and result in the poor quality of foods produced as well as a shortage of sources of employment. It seems that the old adage "poor soils condition poverty", which still prevails to a large extent in many regions of the world (Africa, Asia, among others), continues apply in many areas of the region. In some tropical countries, such as Brazil, where a large part of agriculture is based on soils that are extremely acidic and poor, the use of green revolution technology (use of fertilizers, improved high-yielding varieties, pesticides, and irrigation, etc.), which began in the 60s, made it possible to overcome the aforementioned problems to a large extent, alleviating significantly the problems of hunger and malnutrition and permitting the transformation from importer to exporter of foods. In other poor areas, small farmers produce barely what the soil can give, or, in other words, continue exploiting the nutrients of the soil, which are already low, making this natural resource even poorer or degrading it further, affecting the environment. In these areas, the low use of agricultural inputs (seeds, fertilizers, pesticides) and agricultural machinery is associated with a high economic cost, which cannot be met given the existence of poverty. In these areas, it is essential to seek technological improvements in the efficient use of inputs in order to derive the greatest benefit from their use.

However, technological change in the region is insufficient to respond successfully to global trade liberalization and to exploit the opportunities this offers, assuming as a paradigm sustainable agricultural development founded on increasing production and export of agricultural products without concomitant effects for human health or damage to the environment. These technologies include sustainable management systems, such as direct sowing (zero-tilling) and an integrated crop-livestock farming system that rotates cereal crops with pasture crops; these systems are widespread in Argentina, Brazil and Paraguay, but need to be expanded/adapted for other subregions.

With regard to livestock, the inadequate control of various animal pests, including the New World screwworm (NWS) [6, 7], is well-known in subregions of South America and the Caribbean, and affects not only the yield, but also the quality of meat, milk and leather. The progress made in this regard by the United States, Mexico and Central American countries, which have considerable experience in the successful use of the sterile insect technique as the best technique for eradicating the NWS, should be noted. Panama has a facility for the mass production of sterile NWS and this, together with personnel specialized in this field, could be used as a platform to launch a regional initiative aimed at suppressing and eradicating NWS in the long term in countries of the subregions of the Caribbean and South America.

The absence of technological change, to which nuclear technologies could contribute, can be seen in terms of: genetic improvement of agricultural and livestock species, both traditional and non-traditional; development of good practices in the use and management of soil and water resources; prevention, suppression or eradication of transboundary agricultural and livestock pests; management of health and genetic limitations in the rearing of livestock species and captive aquatic organisms; timely diagnosis of animal diseases; control and monitoring of toxic substances and residues posing a risk to human health in food; and strengthening of networks and capacity for supporting agricultural analytical services.

It should be noted that properly mechanized agricultural areas in the region that account for the agribusiness of countries do not generally produce foods for the direct use of the population, rather food for animals (chickens, cows, pigs, etc.) in developed countries. It is paradoxical that, it is the small producers in the region who produce the largest proportion of staple foods (beans, rice, maize, potato, manioc and sweet potato, etc.) consumed every day by the population. This is why there is great scope in this area for the development and transfer of technology in the context of sustainability.

3.3. SWOT ANALYSIS

3.3.1. STRENGTHS

(1) The existence of local entrepreneurs capable of adopting innovative technologies in the agricultural sector and in aquaculture.

(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) It accounts for a significant percentage of world trade in agricultural and livestock products, such as soya, sugar, coffee, fruit, meat and dairy products.

(4) The region has wide availability of unexploited or underused land to expand agricultural activity.

(5) The region boasts extremely high biodiversity levels and can offer the world community new agricultural and aquaculture products of economic potential with a high nutritional or medicinal value (grains, roots, tubers, fruit, camelids, fish, shellfish, etc.).

(6) Development and implementation of agricultural techniques, such as biological nitrogen fixation, genetic improvement of animals and plants, direct sowing, integrated crop-livestock farming system, and biological control of pests for the sustainable production of food in the region, with the existence of scientific and technological institutions with trained personnel.

(7) The growing increase of national services and subregional agreements for the prevention and control of transboundary pests and diseases, which contribute to the suppression or eradication at subregional level of agricultural pests, (fruit flies) and livestock diseases (foot-and-mouth disease, botulism, rabies, bovine brucellosis, tuberculosis, etc.), including the NWS.

(8) Public policies to promote food security that are being implemented in the region.

(9) The existence of risk management systems: agroclimatic, emerging diseases, food and environmental contaminants.

3.3.2. 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 spread of technologies owing to the frequent leadership changes research programmes and in national health services.

(3) Insufficient participation of the private sector in the initiatives to promote scientific and technological development in the area.

(4) Inadequate coordination among the international organizations associated with food security in the region.

(5) Self-sufficiency has not been achieved in the provision of staple foods in some countries of the region, in particular in the Andean subregion, Central America and the Caribbean.

(6) The inadequate application of international quality standards with regard to food products for domestic consumption and for export is a potential risk to human health, and limits access to markets.

(7) Significant food losses in the post-harvest period owing to the lack of an appropriate infrastructure.

(8) The appearance of new weeds and agricultural and livestock pests/diseases owing to the development of resistance as a result of the irrational use of agrochemicals and medicines, which adds to the contamination of the environment and food by these products.

3.3.3. THREATS

(1) Introduction and expansion of emerging and re-emerging exotic or endemic diseases and pests in the region (for example: fruit fly, highly pathogenic avian influenza, foot-and-mouth disease, rust), which leads to the excessive use of pesticides for their control.

(2) The growing use of products (soil oil, maize, sugar, etc.) in the production of biofuels.

(3) The existence of non-tariff barriers on the region's agricultural products.

(4) Reduction in agricultural productivity due to the effects of global climate change.

3.3.4. OPPORTUNITIES

(1) Development of second-generation biofuels using waste from the harvest of food or industrial crops.

(2) Increase in the international market for agricultural and aquatic products.

(3) Opening for countries to sign agreements for cooperation in the area of science and technology together with local capacity to develop synergistic agreements between the public and private sectors.

3.4. NEEDS/PROBLEMS

This section presents the needs/problems identified in the food security sector with their respective justifications, organized according to the TOTAL GRADE of priority.

A1. <u>Improvement of practices for the management of agricultural soil and water resources with the appropriate use of agrochemicals, fertilizers, water and microorganisms for biological nitrogen fixation.</u>

Justification: The small farmers in the region produce more than 70% of the food for the population, but it is they who suffer from the poor soil quality and limited access to available technology. With the exception of countries in the subtropic and temperate zone of the region, the soil in the vast majority of countries in the Andean and tropical zone (particularly Brazil and Central America) is naturally poor or very poor in nutrients and has toxicity issues as a result of high levels of aluminium, iron and manganese, which leads to very low yields of food products, exacerbating poverty, hunger and undernutrition.

One of the indicators of the level of agricultural technification is based on the effective use of fertilizers. The region consumes only 10.2% of the world's fertilizers [8]. It should be noted that, in virtually all countries of the region, agricultural technology is geared primarily towards industrial or export crops (soya, sugar cane, coffee, fruit and vegetables being some of the main ones) and very little towards food crops (beans, rice, maize, potato, cassava and sweet potato). One regional technology that has a major impact on agriculture is biological nitrogen fixation (BNF) in soya, a typically regional technology used by large producers that enables more than 37 Mt of protein to be produced annually without the use of N fertilizer over an area of 50 million hectares distributed across Brazil, Argentina and Paraguay [9, 10, 11]. This technology is not widely used for basic food crops, such as beans and peas. There is also a clear need to improve nitrogen availability in the poor soils of small farmers through the use of green manure and organic fertilizers. Recently, it has been demonstrated that simply increasing the content of nitrogen in the soil, makes it possible to increase the carbon content of the soil, which helps to mitigate the greenhouse effect. Currently, two technologies for the management of sustainable agricultural systems are becoming more widespread across the region, particularly among large producers of cereal and meat. The first is direct sowing (zero-tilling), which is used in approximately 50 million hectares in Argentina, Brazil and Paraguay. The other technology is an integrated crop-livestock farming system that is fully developed in Argentina and Brazil, whereby growth of cereal crops is rotated every 2 to

3 years with the growth of pasture for the same period of time. These systems have the advantage of not only contributing to sustainable production of foods over large areas, but also of reducing the deterioration of the land, or of rehabilitating it, while also contributing significantly to mitigation of the greenhouse effect and promoting carbon capture in the soil. In view of the above, there is an urgent need to adapt these technologies, and/or develop new techniques for the different agricultural areas of the region.

Nuclear techniques offer the best prospects for this. Use of ^{15}N as a tracer is a fast and economical way of producing recommendations for efficient fertilizer management (dose factors, sources, localization, fractionation and application methods) [11, 12]. The ^{15}N isotope dilution and ^{15}N natural abundance techniques are also extremely useful for evaluating the efficiency of BNF in legume production systems, allowing more efficient varieties and inoculants to be selected [14, 15, 16, 17]. Techniques using ^{13}C will make it possible to evaluate the efficiency of the management systems with regard to carbon capture in the soil and its dynamics over time, with a view to promoting the sustainability of the agricultural system [18]. In the same vein, techniques using ^{137}Cs are valuable tools to quantify soil losses due to erosion or to evaluate the efficiency of production systems in controlling erosion [19]. They are also useful for the efficient use of water in agriculture, which is a concern in the world since agriculture consumes over 70% of fresh water; although the region has large reserves of this resource, it is important to optimize its use. In this regard, techniques based on the use of ^{18}O and ^{2}H isotopes also hold promise for studying the efficiency of the water use of crops. The neutron probe technique, which is already used, enables monitoring of the water content in the soil; and more recently new techniques based on the use of cosmic rays hold promise [20].

The direct beneficiaries will be large and small farmers who will be able to maintain, and/or recover the productive capacity of their land, as well as society in general through the availability of a bigger quantity of foods of nutritional quality, and the reduction in the risk of environmental degradation, which will have a positive impact on food security.

Objective: To improve systems of agricultural production in the countries of the region.

Indicator: Percentage of compliance with the indicators of the proposed objectives.

A2. Use of technologies for the improvement of animals and plants of recognized economic importance and to support initiatives to improve the yield/production and commercial potential of plants and animals reflecting the region's biodiversity

Justification: One way to reduce the food deficit in the region is by obtaining improved varieties of crops that are tolerant/resistant to stress factors and by increasing animal production.

In recent decades, genetic improvement of crops and animals has brought about significant increases in productivity, resistance to diseases and pests, tolerance to drought, adaptation to mechanized harvesting practices and uniformity of grains and fruit. Different methods are recognized for the genetic improvement of plants and animals: a) intraspecific and interspecific hybridization; b) mutation induction; and c) genetic engineering. Each method has its advantages and disadvantages, but it is important to bear in mind that they complement each other. Nuclear techniques are used for animal improvement to: a) control the reproductive cycle (radioimmunoassay techniques to measure the hormonal status of animals) to shorten the period between pregnancies; b) nutritional efficiency using isotopic labelling techniques.

The FAO/IAEA database of mutant varieties shows the huge impact of nuclear technology in crop improvement. There are currently 3218 mutant varieties and the majority of them (>80%) have been developed using nuclear techniques [20]. In the region, limited use is made of this technique, but it holds promise. An example of this is crop improvement: amaranth, “kiwicha” (*Amaranthus caudatus*), an important food source for the indigenous peoples of the Peruvian Andes [21]; the barley variety (*Hordeum vulgare*) ‘Centenario’ produced in 2006 using irradiation techniques for mutation induction is cultivated today in the valleys of the Peruvian Andes with high levels of production.

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

Nuclear energy is extremely important in genetic characterization processes for generating (X-ray) irradiated cell hybrid DNA panels for genetic mapping and/or owing to its use in radioactive labelling processes (^{32}P and ^{33}P) for synthesis of radioactive DNA probes in 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 agro-ecological zones in the region, and 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 genetic selection of superior animals, and appropriate management strategies for these genetic resources.

These measures will therefore create the basis for the use of genetic markers in the assisted reproduction of species of zootechnical interest in the region and for the appropriate use of high genetic merit animals.

These results will facilitate the better use of reproductive biotechnologies, including programmes for artificial insemination and embryo transfer, and improve strategies for the use of forage resources for animal feeding and mitigation of the greenhouse gas effect.

Small and large-scale agricultural producers throughout the region will benefit directly from these technologies, since knowledge and use of the plant and animal germplasm with the genetic characteristics of adaptation and high productivity and quality in a sustainable environment management context helps increase the value of the animals and their subproducts and, consequently, increases the earnings of farmers and the foreign currency revenue of the countries.

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

Indicator: Percentage of compliance with the indicators of the proposed objectives.

A3. Incidence of transboundary diseases in animals, including those with zoonotic repercussions

Justification: The countries of the American continent are separated by approximately 50 000 km of land borders that were put in place basically for geopolitical reasons and do not prevent the movement or spread of diseases and pests. In this regard, the Global Frontiers – Trans-Boundary Animal Diseases initiative (GF-TAD), the outcome of an official agreement between the World Organization for Animal Health (OIE) and the Food and Agriculture Organization of the United Nations (FAO), addresses the challenge of combating animal diseases from a regional and hemispheric perspective [22, 23].

In this connection, various actions are being taken in the region, which, although still isolated, seek to develop and/or improve epidemiological monitoring and control services for emerging transboundary animal diseases of economic importance, such as foot-and-mouth disease, highly pathogenic avian influenza – H5N-1 and spongiform bovine encephalophy – BSE [1,24,25,26,27]. However, a wide technology gap exists between countries in the region, despite the transboundary nature and major relevance of this issue for the regional economy. An outbreak of one of these diseases, would lead to incalculable losses and cause irreversible damage to stockbreeding and economic activity in the entire region due to the economic barriers imposed by countries that import animal products and derivatives.

Laboratories in all countries in the region need to be prepared to provide swift and accurate diagnosis of emerging diseases, using modern and appropriately validated technologies. Nuclear energy is utilized in the development and use of radioactive DNA probes for high-sensitivity processes (such as DNA and RNA blotting) to detect pathogenic agents in field samples, and these should serve as a reference to validate other detection methods involving the analysis of nucleic acids [28]. The use of vaccines and sera that have been inactivated using ionizing radiation (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 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, 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, as regards the prevention and control of emerging diseases. Secondly, livestock farmers will benefit directly, since the control of these diseases maintains their commercial capacity at sustainable levels.

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

Indicator: Increase in the number of official laboratories using harmonized protocols with appropriate interaction with the competent authorities in the country.

A4. Availability of foods of animal (including products derived from aquaculture) and plant origin that meet quality and safety standards

Justification: The growing application of advanced technology to crops and animal products for local consumption and export in the region has contributed to the massive use of various types of inputs, such as pesticides, hormones and antibiotics, the residues of which often pose a risk to human health and compromise trade and the economies of the producing countries. This is a particular problem in connection with coffee, bananas, grapes and other temperate climate fruits, pineapple, citrus fruits as well as cereals (wheat, maize, rice, soya), and products of animal origin, including products derived from aquaculture. Another serious problem in the region is the use of fumigants to resolve plant health problems and overcome quarantine barriers. Many of these fumigants have been banned in the world (e.g. ethylene dibromide) 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. Problems with toxic residues may also be associated with the presence of mycotoxins due to inappropriate management of production, conservation and storage of the foods. There is growing concern about the exposure of consumers to various mycotoxins in these agricultural products, as well as with regard to the need to meet quality standards for international markets.

The frequent rejections of large quantities of foods by international markets owing to problems with levels of residues that pose a risk to health or because of the presence of undesirable pests is affecting the economy of the producer countries and mainly the farmers. This is why it is essential, on the one hand, to rationalize the use of agricultural and livestock inputs, particularly those that present risks to health, and, on the other, to develop and/or adapt integrated methodologies, including analytical methods to control food safety (chemical residues), biological methods to monitor levels of toxic residues in the foods, and to develop or adapt methodologies to replace conventional post-harvest treatment with fumigants. It is important to note that nuclear techniques in conjunction with techniques for chemical analysis and molecular biology are tools that offer the best prospects to resolve the problem of pesticide residues, and that the use of irradiation treatment is a good alternative to replace treatment with fumigants. Irradiation of food products helps to meet sanitary standards and reduce post-harvest losses. To ensure its proper use, networked programmes with standardized methodologies should be implemented in the region.

The main beneficiaries of the programme, in addition to farmers, will be industrial sectors involved in the processing and marketing of agricultural products, as well as consumers, who will have access to better quality products.

These quality control programmes could be part of a rigorous risk analysis programme that would facilitate risk management with the support of certified laboratories. To this end, consideration should be given to the establishment in countries of residue monitoring programmes in the countries with appropriate infrastructure (instrumentation) and strengthened training for human resources.

Objective: To improve the quality and safety of foods.

Indicator: Countries that use validated and accredited techniques in analytical laboratories.

A5. <u>Damage caused by pests to foods of animal and plant origin</u>

Justification: Fruit flies that include the Mediterranean fruit fly (*Ceratitis capitata*) and various species of the genus *Anastrepha* are the pests that cause most damage to the 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, it can sometimes restrict exports of 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 (with a high risk of product contamination) with the establishment of areas of low prevalence or free of pests. In order 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.

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

With regard to the production of foods of animal origin, livestock development is severely hampered in South American countries and on most of the islands of the Caribbean as a result of the myiasis caused by the NWS (*Cochliomyia hominivorax*), which affects livestock production and causes significant commercial losses to the livestock herd estimated at over 450 million head (cattle, horses, pigs, sheep, goats, etc.), as well as 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 on the rise.

In order to reduce losses in the livestock sector and develop production capacity in this area in South America and the Caribbean, specific strategic objectives include: first, maintaining areas free from the NWS in Mexico and Central America and, second, collecting and sharing technical information and building the capacity of national animal health bodies in the use of the sterile insect technique. Lastly, the suppression and long-term eradication of the NWS on the American continent are proposed as a third strategic objective.

In addition, there are several diseases transmitted by vectors that may or may not be endemic to the region but still constitute a significant threat to national and regional economies. African swine fever and bluetongue in Europe are examples of pests that have penetrated non-endemic areas. This is why high priority should be given to the degree of preparation for the early diagnosis of pathogens in animals using advanced diagnostic technologies that can be employed "on the ground", as well as to strategies for the prevention and control of vector-borne diseases.

Objective: To control pests and diseases of animals and plants.

Indicator: The area monitored and where pests and diseases of plants and animals are controlled.

A6. <u>To support initiatives for the development of aquaculture in the region</u>

Justification: There is considerable potential in the region for the development of aquaculture due 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 insufficiently exploited. Aquaculture today is possibly the food production sector that is growing at the fastest rate in the world, and accounts for almost 50% of the world's fisheries products used for food [29]. In Latin America and the Caribbean, the fisheries sector produced 1.76 million tons in 2008 and valued US $7.2 million in 2006, and has been growing twice as fast (18.5%) as the global average rate (8.2%) over the last 30 years. Although this involves the cultivation of approximately 90 more species, 85% of the total production in 2006-2008 was based on only four species (salmon/trout, shrimp, tilapia and mussels) [30,31,32].

However, for the sector to succeed, it is necessary to take actions including appropriate development of structured programmes to control recurrence of disease problems in cultivated species. New biotechnologies are being used to promote health in the sector through the conventional selection for resistance to disease and through 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 soils. Molecular techniques have been used to detect viral diseases in shrimps and to detect bacteria and fungi in fish in various parts of the world. Data from the World Organisation for Animal Health (OIE) indicates that there is a need to develop laboratories with the skills to provide this type of service, and to establish rules for control of transit of these organisms and their products between countries [33].

Given that relatively little is known about the biology of these organisms and their pathogens (compared to terrestrial domestic animals), the fact that the cultivation of various aquatic species of economic importance depends on the collection of 'seed' propagation material in natural populations in the environment, and in view of the genetic deterioration which fish and shellfish can suffer from in 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 (^{32}P and ^{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 monitoring of health and production conditions in their systems, which as yet do not exist in several subregions.

Objective: To contribute to the development of aquaculture in the region.

Indicator: The number of techniques used in aquaculture activities in the region within the framework of regional technical cooperation.

3.5. PRIORITIZATION OF THE NEEDS/PROBLEMS

The prioritization of the needs/problems in the sector is shown in Table 1.

Table 1. Prioritization of the needs/problems in the food security sector.

	NEED/PROBLEM	SEVERITY	TIME	EXTENT	RELEVANCE	TOTAL GRADE	DIFFICULTY	R/D	FINAL GRADE
A1	Improvement of practices for the management of agricultural soil and water resources with the appropriate use of agrochemicals, fertilizers, water and microorganisms for biological nitrogen fixation.	4.00 The agricultural soils of the region are very poor in nutrients and are subject to degradation because of inappropriate management.	3.88 In view of the global demand for foods, there is an urgent need to develop sustainable agricultural systems to increase production and control the degradation of land.	4.38 It affects the entire region with different degrees of magnitude in the subregions.	4.00 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 the land degradation and monitor the process of rehabilitation.	**16.25**	2.75 There are methodologies already developed, but their use is limited owing to the small number of functional laboratories.	**1.45**	**23.64**
A2	Use of technologies for the improvement of animals and plants of recognized economic importance and to support initiatives to improve the yield and commercial potential of plants and animals reflecting the region's biodiversity.	4.00 The region has to respond to the challenge of increasing the production of food without impacting on the environment (increase the unit yields of animals and plants).	3.50 The processes to improve plants and animals are relatively slow, and this is why immediate action is required to achieve effective results.	4.13 This extends throughout the region, with each subregion presenting its own peculiarities (variety of species, animals and plants).	3.88 In addition to the nuclear methods of mutation induction, the nuclear component also forms part of an extensive chain of complex biotechnological processes.	**15.50**	2.75 Efforts are required to characterize the germplasm of native plants and animals. The process of improving varieties is, in general, overdue.	**1.41**	**21.84**
	Incidence of	4.00 Diseases are	3.75 There is a need to	4.00 Present throughout	3.38 The nuclear component	**15.13**	3.50 Requires	**0.96**	**14.58**

A3	transboundary diseases in animals, including those with zoonotic repercussions.	emerging and are transboundary in nature with the potential to inflict serious damage on the economy and public health.	maintain a state of constant vigilance to coordinate rapid and effective responses during epidemics.	the region and transboundary in nature.	forms part of an extensive chain of complex biotechnological processes.		optimization of techniques and integration among the competent authorities of countries for effective action in the event of an epidemic situation.		
A4	Availability of foods of animal (including products derived from aquaculture) and plant origin that meet quality and safety standards.	3.50 In addition to permanent risks to human health, the economic losses due to contamination of foods have a serious effect on the region.	3.63 Installed capacity to monitor food contaminants is required owing to the unpredictability of the problem, as well as installed capacity for post-harvest treatment.	3.38 It affects almost all countries.	3.75 The existing nuclear techniques are key in the processes to detect contaminants and eliminate pests in transported products.	**14.25**	2.50 Limited degree of implementation of active and standardized laboratories in the region.	**1.50**	**21.38**
A5	Damage caused by pests to foods of animal and plant origin.	3.13 Loss of economic value of products of animal and plant origin with significant effects on national and regional economies.	2.88 Accidental import by humans or the natural mobility of the pest may cause an increase and/or unexpected appearance in pests	3.75 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, and has been applied successfully in countries of the American hemisphere	**14.13**	3.75 Requires specialized training and coordination of a high number of (technical and business) institutions.	**1.17**	**16.48**

A6	To support initiatives for the development of aquaculture in the region.	2.88 Aquatic species are abundant in the region and are still not appropriately exploited.	3.00 Increase in productivity, genetic deterioration and severity of epidemics caused by infectious diseases require urgent action.	3.13 This has a regional dimension in relation to the sea as well as water basins with peculiarities in each subregion (variety of aquifer species).	3.00 The nuclear component forms part of an extensive chain of complex biotechnological processes.	**12.00**	3.00 Requires specialized training and coordination of a high number of (technical and business) institutions.	**1.00**	**12.00**

HUMAN HEALTH

4. HUMAN HEALTH

4.1. BACKGROUND

The "Regional Strategic Profile for Latin America and the Caribbean (RSP) 2007–2013" was drawn up within the framework of the ARCAL-IAEA Strategic Alliance and identified, from the regional perspective, the priority needs in the human health sector associated with the use of nuclear technology. These priority needs were the main focus of the goals and objectives of the projects approved and implemented during this period.

In order to ascertain the current status of the situation in the region in the light of progress made in the projects implemented and new needs linked to technological developments in the medical applications of ionizing radiation, a working group was established to draw up this document.

The group includes experts in the areas of medical physics, radiotherapy, medical imaging (nuclear and radiological medicine) and food safety, as well as in the planning and implementation of ARCAL-IAEA projects.

Material used for the preparation of the RSP 2016–2013 was: the RSP 2007–2013, the achievements of the projects implemented, documents providing a macro view of the situation in the region published recently by specialized international organizations and documents on working methods within the framework of the ARCAL projects.

4.2. GENERAL ANALYSIS OF THE REGIONAL SITUATION

The general health situation in the region was analysed by the Pan American Health Organization (PAHO) in the 2012 publication "Health in the Americas" [34]. According to the conclusions of this document, the total population of the Region of the Americas increased from 886 to 935 million between 2005 and 2010; if that trend continues, it is estimated that, by 2020, the population of the continent will increase to 1027 million, which is equivalent to 13.4% of the world population.

According to "Health in the Americas" the general mortality rate in the region continued to decrease (from 6.9 to 6.4 per 1000 inhabitants) between 2005 and 2010, while the global fertility rate fell from 2.3 to 2.1 children per woman over the same period. PAHO considers that, although these trends are a reflection of the main public health successes achieved over the last century, ageing will lead to an increase in chronic diseases and disabilities.

From the epidemiological point of view, all the countries of the region are going through different phases of epidemiological transition. At the regional level, data for the 2007–2009 triennium indicate that 76.4% of deaths were due to non-communicable diseases, 12.5% to communicable diseases, and 11.1% to external causes, with variations between countries.

Cardiovascular diseases (CVD) are the leading cause of death among chronic non-communicable diseases (CNCDs). Hypertension is one of the risk factors for this and other chronic diseases. Premature deaths from CVD are more common among men than women and occur at the time of life when productivity is at its highest and the economic and social impact is greater. Between 2000 and 2007, mortality from CVDs fell 19% in the region (from 207.8 to 167.9 per 100 000 inhabitants [rates adjusted in 2007]) with behaviour differentiated by subregion: in North America, the decrease was 25% (from 192.3 to 144.2) and in the non-Latin Caribbean, 14% (from 296.4 to 254.9). In Latin America, the decrease was also 14% between 2000 and 2009 (from 229.9 to 191.4 per 100 000 inhabitants). Although the reductions observed in North America and Latin America were linear and statistically significant, the decrease in the non-Latin Caribbean was statistically significant, but non-linear [34].

Malignant neoplasms as a whole are the second cause of death in the countries of the Americas. The main cancers among men in Latin America and the Caribbean are prostate, lung, colorectal and stomach cancer; and among women, they are: breast, cervical cancer, colorectal and lung cancer [35]. The incidence of malignant neoplasms depends on complex interactions between biological and genetic factors, lifestyles and other social determinants such as poverty, education, employment, accommodation, transport, contamination and nutrition. In the Americas, mortality as a result of malignant tumours is declining. Between 2000 and 2007, age-adjusted mortality rates per 100 000 inhabitants fell 8% (from 131.3 in 2000 to 121.3 in 2007). However, there are significant variations between different subregions and countries. Recent profiles of the cancer situation in the different countries of the region have recently been published. Using available knowledge and technology, it is estimated that between 50% of 60% of cancer deaths can be prevented. To achieve this, multiple actions must be taken at the regulatory level, and lifestyle changes made throughout the life course. In this regard, early detection and effective treatment are essential to improve the quality of life of cancer patients [34].

At the regional level, a rapid and undesirable change is taking place in the eating habits of broad sectors of the population, especially those with lower levels of income and education [34]. 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 [36, 37]. 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. Furthermore, it is predicted that these figures will increase rapidly to reach 289 million in 2015 (39% of the total population). ARCAL has helped to provide evidence of the links between micronutrient deficiencies, chronic low-level inflammation and obesity risk factors associated with non-communicable diseases in school-age children[3]. According to Globocan project reports 2008 [35], cancer constitutes a growing burden for all countries in the Latin American and Caribbean region; it is estimated that by 2030, the number of new cases will double every year, resulting in approximately 1.7 million new cases and 1 million deaths annually. A significant number of cases could be preventable (with changes in diet and lifestyle, and through immunization strategies); another percentage could be detected early with appropriate programmes and techniques; for another percentage, the health systems should be prepared to improve patient treatment and care, improving survival rates and quality of life. For appropriate cancer control, recommendations have been made at the international level to establish national cancer control programmes (NCCP) that address different components, with actions at different levels for prevention, early detection, treatment and palliative care. Information from monitoring systems and research is an essential element

[3] Project RLA/6/059: Implementation and Evaluation of Intervention Programmes to Prevent and Control Childhood Obesity in Latin America (ARCAL XCI).

of any NCCP, and from the IAEA's point of view, it is necessary to have regional data and information on the results of the application of radiation medicine. In addition, the IAEA has agreements with WHO and the International Agency for Research on Cancer (IARC) with a view to strengthening cancer control from a comprehensive perspective.

One of the ARCAL projects recently implemented with the participation of 16 countries of the region, RLA/6/063, provided important information on the actual situation in Latin America with regard to the development of technology and human resources in nuclear medicine. The final report of this project [38] indicates that nuclear medicine has developed significantly in the region in recent decades. In particular, the majority of countries already had gamma cameras and SPECT systems in 2009, however concentration varies (the average number of units per million inhabitants is 2.2 and varies from 0.5 to 10.0); however, during the period 2009–2012, a significant increase was identified in installed PET units, which rose from 56 to 161, with the majority PET-CT units. There are also 32 cyclotrons in 9 of the countries with PET-CT units.

Moreover, the report highlights that, in the majority of countries in Latin America, the various radiopharmaceuticals required for diagnosis and treatment of heart diseases and malignant neoplasms are available.

The situation across the region in terms of the production of radioisotopes and radiopharmaceuticals continues to be very heterogeneous. Countries such as Argentina, Brazil, Mexico and Peru have research reactors allowing national production of radionuclides for the preparation of radiopharmaceuticals for use in diagnosis and treatment. Only 4 countries in the region: Argentina, Brazil, Cuba and Mexico, produce $^{99}Mo/^{99m}Tc$ generators, the others have to 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 IAEA Operational Guidance on Hospital Radiopharmacy. All radiopharmaceuticals for treatment are imported, with the exception ^{131}I, which is produced in Argentina and Brazil.

There are approximately 1560 nuclear physicians in the region; the number per gamma camera varies between 0.5 and 2.5, while the number of technicians per gamma camera varies between 0.5 and 3.5 with an average of 1.5. However, there is a marked shortage of medical physicists and radiochemists in nuclear medicine services.

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 supraradical surgery, achieving higher rates of anatomical and functional preservation of organs and improving the quality of life of the cancer patient. Radiotherapy is also becoming more relevant in the treatment of non-cancerous lesions, such as benign tumours or neurological diseases.

In this area, the IAEA's Directory of Radiotherapy Centres (DIRAC) database [38] reflects a significant increase in technical infrastructure and in its level in the region. A review by PAHO of the information in DIRAC shows that, between 2005 and 2013, the proportion of linear accelerators in relation to the total number of high-energy radiotherapy units increased from 42% to 63% per million inhabitants. In the field of human resources, the analysis concludes that, over the same period, the number of radiation oncologists increased from

1.6 to 2.2 per million inhabitants, and the number of medical physicists from 0.7 to 1.1 per million inhabitants. However, these figures are lower than those of industrialized countries, where there are currently 8.1 high-energy units per million inhabitants (compared to 2.2 in Latin America), 93% of which are linear accelerators, and 4.5 medical physicists per million inhabitants. It should be noted that this gap is tending to narrow with the launch, in various countries of the region, of Master's programmes in medical physics [39]; however, there is a need to strengthen the clinical and imaging component of these programmes to improve the performance of new graduates in the hospital setting.

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, in particular, 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 (especially computerized tomography) and, in turn, leads to a marked increase in the collective radiation dose.

Radiology equipment is associated with high costs in terms of procurement, operation and maintenance. One of the problems identified by WHO is the lack of national policies for health technologies in almost 70% of low-income countries to guide the planning, evaluation, procurement and management of medical equipment, including for medical imaging [40]. The implementation of such policies would have a positive impact on purchase, proper installation, preventive maintenance, rational use and quality assurance of the technology, as well as on the safety and efficiency of procedures.

4.3. SWOT ANALYSIS

4.3.1. STRENGTHS

(1) Capacities for the assessment of nutritional problems in children using isotope techniques have been established in 18 countries of the region as a result of ARCAL and national projects.

(2) Available installed capacity in the area of highly complex nuclear medicine has increased in the region and is sufficient to meet demand in the majority of countries. Four countries have infrastructure that meets international quality requirements to produce radionuclides and radiopharmaceuticals with the capacity to export to other countries of the region.

(3) There has been a rapid development of installed capacity of imaging and radiotherapy services with a high technological standard in the region.

(4) National standards in the majority of countries in the region address aspects related to quality in the provision of health services. In some, regulations are specific for the quality of radiotherapy, nuclear medicine and radiology services, including association with medical physicists and systematic quality control for equipment and procedures.

(5) Existing inter-institutional, national and international agreements have been strengthened, resulting in better regional integration. There are national and regional professional societies in the various different disciplines in the health sector and functional scientific and strategic support networks.

(6) Regional capacity has been strengthened for the conduct of quality audits in radiotherapy and nuclear medicine, as well as radiology evaluations. A large number of centres and human resources could benefit from these projects.

(7) Various virtual training programmes, in particular in the nuclear medicine sector, are being implemented in the region.

(8) Studies of reference dose levels in radiology have been evaluated in various countries.

(9) Some countries of the region have postgraduate programmes for training specialized human resources in all areas of interest: radiotherapy, radiology, nuclear medicine, medical physics and radiopharmacy.

(10) In the region there are 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 and regional scientific events are held periodically for refresher training, sharing of experience and ongoing education.

(11) The majority of countries in the region speak the same language, which facilitates exchanges and ongoing training.

4.3.2. WEAKNESSES

(1) Shortage of radiotherapy and nuclear medicine technicians in some countries of the region leads to the redeployment of human resources from other sectors (radiology technicians or nurses), affecting the quality of the service provided.

(2) The significance of nutrition in the first years of life and its effect on health and development has assumed importance in the global health agenda, but there is little knowledge of the contribution that nuclear and isotope techniques can make in the evaluation of national programmes on nutrition.

(3) Very little information in the region on the link between nutrition in the first years of life, healthy growth in babies and young children and the risk of contracting non-communicable diseases later on.

(4) Limited knowledge of the benefits of using isotope techniques to study the relationship between food and growth of children in early infancy, and improvement of lifestyles for the prevention of non-communicable diseases.

(5) Despite clear improvement in the coverage of health services in the regions, there are still areas in some countries with limited access to diagnostic and therapeutic procedures employing radiation.

(6) Limited knowledge among referring physicians and administrators of health institutes of the specificity and benefits of complex nuclear techniques in diagnostic and therapeutic procedures.

(7) Although medical specialists and medical physicists have become more highly valued, human resources trained in the region are still migrating to more attractive labour markets, particularly from countries with limited resources.

(8) Poor management of technological resources (national inventory, repair budget, record of prolonged outages and duration of obsolescence).

(9) Shortage of reliable official information in the ministries of health of countries concerning installed technological capacity and human resources, as well as requirements to meet the needs of the population.

(10) Shortage of medical physicists in nuclear medicine and radiology services.

(11) Unevenness in the structure and application of regulations in force.

(12) Delays in diagnosis owing to a shortage of specialists.

(13) Deficient mechanisms for monitoring, by the health authorities, of quality assurance programmes in institutions providing health services.

(14) Shortage in some countries of operational and funded national cancer control programmes (NCCP).

(15) Limitations in follow-up of radiotherapy patients and in the research capacity to establish results indicators (no correlation with epidemiology teams).

(16) Continued use of adult image acquisition protocols in paediatric patients, which results in children receiving unnecessary radiation doses.

(17) Limited access of potential beneficiaries to the projects is limited because national and project coordinators do not disseminate the information.

(18) Heterogeneous level of development among potential beneficiaries of regional cooperation, which makes it difficult to establish an effective standard for training programmes.

4.3.3. THREATS

(1) Economic and working conditions that prevent families from feeding their children properly in early infancy.

(2) Decrease in investment in health as a percentage of Gross Domestic Product (GDP), which undermines the continuity of programmes and improvement in the quality of health care.

(3) Lack of administrative and governmental continuity causes instability in the smooth running of projects.

(4) Influence of donor organizations and the media in the reallocation of resources, which leads to changes in priorities previously identified.

(5) Speculative overpricing by providers of equipment and inputs, in terms of sale as well as maintenance.

(6) Migration of specialized human capital to other sectors or other regions.

4.3.4. OPPORTUNITIES

(1) Cooperation among international organizations (UNICEF, PAHO, WHO) to address the issue of nutrition in early infancy and its influence on the epidemiology of problems affecting the population.

(2) Growing awareness among different medical specialists of the advantages of nuclear techniques for diagnosis, treatment and research.

(3) A number of medical specialities are using new diagnostic and therapeutic procedures for the management of pathologies prevalent in the region.

(4) Recognition by health authorities of chronic non-communicable diseases (cancer, cardiovascular disease, diabetes, etc.) as an important public health issue.

(5) National professional societies in the region can participate in legislative processes and the development of public policies relating to the health sector.

(6) Technical cooperation involving international organizations and professional societies in the area of training, and the availability of quality protocols and guidelines.

(7) The possibility of evaluating existing resources and needs of countries, using international databases, such as DIRAC.

(8) The possibility of improving the performance of nuclear medicine, radiology and radiotherapy services through quality audits organized by international organizations.

(9) In the majority of countries, information and communications technologies are sufficiently developed for use in virtual and distance learning activities.

4.4. NEEDS/PROBLEMS

This section presents the results of the analysis undertaken on the basis of the SWOT analysis, identifying the needs/problems of the sector, their justification, objective and indicator.

The needs/problems are set out in terms of the TOTAL GRADE of priority, in accordance with the prioritization table in section V (Prioritization of needs/problems).

S1. To improve efficiency and quality in the use of new technologies for the diagnosis and treatment of diseases.

Justification: The region is incorporating new technologies at an accelerated rate and technology in the area of radiation medicine is evolving rapidly. In order to obtain maximum benefit from these new technologies, professionals and technical staff must be appropriately trained. The migration of specialized staff to other sectors and regions remains a threat.

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

Indicator: The percentage, in each country, of radiotherapy and nuclear medicine services with complex technologies, and human resources properly trained in their appropriate use.

S2. Lack of appropriate technology management systems for planning, incorporation and maintenance of biomedical equipment

Justification: The regional capacities for the evaluation, incorporation and management of technologies are either very weak or non-existent. This means that: the technologies procured are not always appropriate for local conditions, there is an inefficient geographical distribution of technologies, no provision is made for lifecycle-associated costs (including maintenance and depreciation), technology is underutilized, and that there are shortcomings in the monitoring and evaluation of new technologies. Although institutions responsible for evaluation and management of health technologies at country level already exist in the region (Argentina, Cuba, Mexico, Uruguay and Brazil) and processes are implemented, the need still remains in the majority of countries.

Objective: To contribute to the organization and establishment of technology management systems for planning, incorporation and maintenance of biomedical equipment.

Indicator: The number of countries with a national system for the management of biomedical technology based on IAEA recommendations.

S3. Insufficient nuclear medicine and radiotherapy technicians to meet the growing need arising from the establishment of new centres in the region

Justification: The IAEA and ARCAL have made significant efforts to train technical radiotherapy and nuclear medicine staff through regional training courses and internships that have been used primarily by the staff currently linked to the services. However, countries face difficulties in meeting their needs in terms of appropriately trained human resources for new services, and this has not been reflected in the development of sustainable training programmes in all countries. It is necessary to find mechanisms to provide training at the highest level for technical staff in the field of radiotherapy and nuclear medicine in the skills required. In nuclear medicine, regional cooperation has progressed with virtual training, which should be strengthened and broadened for radiotherapy.

Objective: To increase the availability of radiotherapy and nuclear medicine technicians, supporting existing training programmes and encouraging the development of new ones.

Indicator: A 30% increase in radiotherapy and nuclear medicine technicians available in the region by 2021.

S4. Insufficient human resources in medical physics in imaging services (nuclear medicine and radiology)

Justification: The region has noticeably improved its capacity to train medical physicists at the level recommended by international organizations. However, because of requirements and needs in radiotherapy, the majority of trained medical physicists joined this sector, having not been exposed to the nuclear medicine and radiology sectors. The new Basic Safety Standards (BSS) [41] (approved by the governing bodies of 8 intergovernmental organizations) require medical physicists to support all medical practices because of the complexity of the procedures used. This situation is exacerbated by the increase in advanced technologies incorporated in imaging services in the region.

Objective: To strengthen the imaging component of Master's programmes in medical physics in the region.

Indicator: The percentage of Master's programmes in medical physics that provide specialist professionals for advanced nuclear medicine and radiology services for the development of their quality assurance programmes.

S5. Shortage of comprehensive, functional and operational national cancer control plans (NCCP)

Justification: In order to ensure appropriate cancer control, recommendations have been made at the international level concerning the establishment of NCCPs that address different components and include action at different levels regarding prevention, early detection, diagnosis, treatment and palliative care. These NCCPs should also base their actions on information from surveillance, control and research systems. From the IAEA's point of view, there is a need for information on the disease burden at the national and regional level, as well as information on the impact of the Organization's inventions in radiation medicine in order to develop and evaluate strategies to address the problem at the regional level.

Objective: To help to ensure that the NCCPs address coverage in an effective manner and ensure the quality of radiation medicine.

Indicator: The number of countries that have implemented and/or improved NCCPs as a result of cooperation with the IAEA; that have structured mechanisms to obtain, in a systematic manner, up-to-date information on functioning and operation, as well as on population coverage in terms of infrastructure and properly trained human resources in the centres, the quality of services and survival rates associated with the use of radiation medicine.

S6. Growing childhood obesity in the region and its link to the incidence of non-communicable diseases, caused in part by malnutrition in early infancy.

Justification: It is estimated [34] 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. Furthermore, it is predicted that these figures will increase rapidly to reach 289 million in 2015 (39% of the total population). It is recognized that obesity is a determinant in the incidence of non-communicable diseases among the population, such as cardiovascular disease, diabetes and cancer.

Appropriate nutrition during pregnancy and the first years of life is essential for the healthy growth of the child, his or her mental health and resistance to infection. The IAEA supports the use of stable isotope techniques for the appropriate evaluation of public health interventions, including the promotion of breastfeeding, micronutrient supplementation programmes, a healthy diet and more physical activity in order to prevent and control the double burden of malnutrition and non-communicable diseases.

Measurement of the changes in the body composition of children is important in order to evaluate the quality of growth in the first years of life. There is currently very little information as to what constitutes a “healthy” body composition at different ages and on the changes in body composition as children grow and mature. The IAEA supports the use of nuclear techniques to measure the proportion of fat-free mass and body mass, and to evaluate small changes in body composition.

Objective: To create the conditions for preparation, with the use of isotope techniques, of body composition reference curves for each country of the region for use in the development of public policies to fight child malnutrition.

Indicator: The number of countries that use their specific body composition reference curves in national policies and programmes concerning child nutrition.

4.5. PRIORITIZATION OF THE NEEDS/PROBLEMS

The prioritization of the needs/problems in the sector is shown in Table 2.

Table 2. Prioritization of the needs/problems in the human health sector

	NEED/PROBLEM	SEVERITY	TIME	EXTENT	RELEVANCE	TOTAL GRADE	DIFFICULTY	R/D	FINAL GRADE
S1	To improve efficiency and quality in the use of new technologies for the diagnosis and treatment of diseases.	4.2 Significant investment for the purchase of technology in the region with limited human resource capacities for its optimum use.	4.2 The equipment is in the countries and is being underused.	4.2 Common problem in the majority of the countries.	4.6 It concerns the transfer of nuclear technology to the service for the diagnosis and treatment of diseases.	**17.2**	2.8 It concerns, primarily, the training of human resources and use of the capacity that already exists in the region.	**1.64**	**28.21**
S2	Lack of appropriate technology management systems for planning, incorporation and maintenance of biomedical equipment.	4.2 The expensive technology is procured without sufficient justification and without an estimate of maintenance costs or the availability of the human resources required.	4.1 Rapid advancements in technology, backlogs, prolonged equipment outages.	4.2 Frequent in the region.	4.6 It has a direct effect on the timely and effective treatment of patients with the techniques.	**17.1**	2.8 Political will and the rotation of decision makers has an influence.	**1.64**	**28.04**
S3	Insufficient nuclear medicine and radiotherapy technicians to meet the growing need arising from the establishment of new centres in the region.	4.4 In many countries there are no training programmes; untrained staff perform the procedures.	4.0 An immediate solution is required to assure the quality of procedures.	4.0 Many countries do not have training programmes, and where such programmes exist, the increase in the number of centres is exacerbating the problem.	4.4 Essential for the safe quality use of nuclear technology.	**16.8**	3.0 Actions that require commitment from national institutions and authorities.	**1.47**	**24.70**

S4	Insufficient human resources in medical physics in imaging services (nuclear medicine and radiology).	4.0 The involvement of medical physicists is required to assure the quality of complex services.	4.0 Patients are given care that does not comply with international requirements for quality.	4.0 Common problem in the region.	4.5 It concerns the use of nuclear techniques recognized for the diagnosis and treatment of disease.	**16.5**	3.0 The regulatory authorities should monitor compliance with the requirement; the need for strategies to strengthen postgraduate programmes in these areas.	**1.50**	**24.75**
S5	Shortage of comprehensive, functional and operational national cancer control plans (NCCP)	3.6 This has a relevant effect on the integrated approach to the cancer issue.	3.6 The urgent need for governmental action on this subject is recognized.	3.6 It covers a large part of the region.	2.0 Political decisions and administrative actions to resolve the problem are paramount.	12.8	3.8 The rotation of decision makers in governmental organizations and limited allocation of resources has an influence on the solution.	**0.53**	6.78

S6	Growing childhood obesity in the region and its link to the incidence of non-communicable diseases, caused in part by malnutrition in early infancy.	3.2 Serious, but there are other actions to identify solutions.	3.2 Multi-sectorial long-term solutions are required that can be initiated as soon as possible.	3.8 It is a growing problem in the region.	1.4 Nuclear techniques constitute one of several options to address the problem, but they are the validation standard for other techniques.	**11.6**	3.4 A high degree of commitment is required from governments for implementation on a national scale.	**0.41**	**4.76**

ENVIRONMENT

5. ENVIRONMENT

5.1. BACKGROUND

As for the previous RSP, the objective of this document is to describe the environmental conditions in the Latin American and Caribbean region (LAC) and to identify areas for improvement through international cooperation. The focus of considering the three elements of the environment: land, water and air as an integrated whole, has been retained.

The RSP for 2016–2021 was prepared by reviewing the RSP for 2007–2013, environmental literature and the development trends outlined in reports by other organizations, as well as the information provided by members of the group. Projects developed within the framework of ARCAL and the IAEA via thematic planning and the cooperation programme in Member States also served as a reference for the applicability of nuclear technology to environmental issues.

5.2. GENERAL ANALYSIS OF THE REGIONAL SITUATION

The Latin American and Caribbean region occupies 15% of the planet's surface, has a great topographic and climatic diversity, reflected in a great variety of ecosystems from tropical forests to Andean high plateaux, and major socio-political, cultural and economic differences. Many of the world's ecologically richest eco-regions are in this region, such as the second largest coral reef in the world off the coast of Belize. Land used for agriculture (excluding pasture) occupies 19% of the region's total area and contributes 10% of the countries' GDP; a substantial proportion of the population (30-40%) is involved in this activity [42]. According to recent data, the population of Latin America and the Caribbean increased by 295 million (51%) between 1970–2009, and reached 581.4 million according to 2012 data from the World Bank, increasing the pressure on space for human dwellings. This same source indicates that approximately 53% of the population live in urban areas. According to the United Nations "Millennium Development Goals Report 2013" [44], the proportion of the population living in slums fell from 29% (2000) to 24% (2012), achieving access to improved water sources, sanitation facilities, durable housing and a sufficient living area. According to this report, the proportion of people living on less than $1.25 a day fell from 12% (1990) to 6% (2010). According to the OECD/ECLAC "Latin America Economic Outlook 2013" [45], the economic outlook for Latin America remains relatively positive, but is subject to uncertainty and volatility because of the external context. After almost a decade of continued expansion, interrupted only in 2009, the most recent forecasts indicate that regional GDP will increase by 3.2% in 2012 and 4% in 2013, which signifies a slowdown, while inflation is expected to fall. In the short term, this scenario presupposes an acceptable performance vis à vis the global situation and continued economic stability in the region. In the ECLAC report "Economic Survey of Latin America and the Caribbean 2013", it is also estimated that GDP in Latin America and the Caribbean in 2013 will be 3%, which is similar to 2012 [46].

The Latin American and Caribbean region comprises four subregions [47]:

1) The Andean subregion (Bolivia, Colombia, Ecuador, Peru and Venezuela): Covers an area of 4.7 million km^2, comprising 25% of the region, with 2.3 million km^2 of forest, which is 35% of the region's total;

2) The Caribbean subregion (Anguilla, Antigua and Barbuda, Netherlands Antilles, Bahamas, Barbados, Cayman Islands, Cuba, Dominica, Grenada, Guadeloupe, Haiti, Jamaica, Martinique, Montserrat, Puerto Rico, Dominican Republic, Saint Vincent and the Grenadines, Saint Martin, Saint Lucia, Saint Kitts and Nevis, Trinidad and Tobago, Turks and Caicos, British Virgin Islands and United States Virgin Islands): The islands are a wide variety of sizes from Anguilla at 91 km^2 to Cuba at 110 860 km^2, and have a broad diversity of marine coastal habitats (coral reefs, seagrass meadows, mangrove swamps, marshes and rocky coasts);

3) The Central American subregion (Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama) and Mexico has an area of 2.5 million km^2 and is the bridge between North and South America. It has a broad biodiversity, extensive mountain chains and mangrove swamps, and 8000 km of coast;

4) The Southern Cone subregion (Argentina, Brazil, Chile, Paraguay and Uruguay): has an area of 12.6 million km^2, a highly varied topography and 6.2 million km^2 of forest. It has the lowest population density in the region and the highest rate of urbanization.

Latin America and the Caribbean have one third of the world's renewable water resources, which should ideally meet the demand of its population, which comprises 8–9% of the world population. It has tropical and subtropical ecosystems producing a significant volume of water; hence it has 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 rivers and tributaries. The region has the largest pluvial system in the world, the Amazon, with 7.5 million km^2 and which, 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 [48]. 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 [4]. 96% of the fresh water is carried by rivers to the Atlantic Ocean and only 4% to the Pacific Ocean.

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

Demand for water has increased as a result of demographic growth (particularly in urban areas), expansion of industrial activity and demand for irrigation [4]. Water resources in Latin America are also intensively used as a source of energy in hydroelectric and geothermal power generation. Water as a source of electricity generation makes a very significant contribution to national and regional development, and hydroelectric power in the region has a potential amounting to 22% of world output; the region has the potential to produce 582 033 MW per year, but only 139 688 MW (approximately 24%) are being used [48,4,49]. Currently, hydropower sources produce between 64% and 70% (~153 000 MW) of the energy consumed [50]. Despite offering all the benefits associated with the generation of 'clean' energy and being available via regional and interregional interconnections, it also causes environmental problems.

Argentina, Brazil, Paraguay, Uruguay and Venezuela have major hydraulic structures, including the largest in the world, namely: the Itaipú hydroelectric power plant between Paraguay and Brazil and the Guri hydroelectric power plant in Venezuela.

Since 2003, consumption of agrochemicals in the region has risen significantly by around 30%. In 2004, 14% of the world total was sold and, in 2005, 17% [51], and at least 5% growth is anticipated over the coming years [52].

Countries of the region are facing a series of problems related to pesticide residues in food for local consumption and export, though the latter tends to be given greater importance since, in these cases, the hold-up of products in importing countries' ports of entry causes losses in exports and/or markets. Residues in products for local consumption can affect public health, and in several countries, the percentage of samples containing levels exceeding the legal limits has been found to be high [48, 53].

The excessive use of fertilizers, irrigation practices and the intensive use of natural resources are causing changes in the soil, such as nitrification, salinization and depletion of nutrients, with desertification, the most extreme manifestation of this, affecting about 30% of the region's total area [4].

Mining, even on a small scale, is an important source of soil and water contamination in the region. Heavy metal contamination is a particular problem for Andean countries, where the majority of mining sites are to be found; although no complete inventory of these sites exists, examples include Bolivia (antimony, tin, gold), Brazil (mercury), Chile (arsenic, copper), Ecuador (arsenic, cadmium zinc, copper, mercury), Mexico (arsenic, lead), Peru (arsenic, cadmium, zinc, copper) and Uruguay (lead) [54].

Latin America and the Caribbean has more than 10% of the world's oil reserves, accounts for approximately 14% of production and only 8.3% of global consumption. Oil extraction has a high environmental cost, ranging from the irreversible transformation of terrestrial and marine ecosystems from which it is extracted to the serious effects of spills [55, 56]. These problems are aggravated when economic conditions in the producer countries do not allow for the use of advanced technologies that are less risky and have less impact.

Urban and population growth and rural migration to cities have caused an explosive increase in the urban population, and environmental management is one of the major threats. The increase in energy consumption, energy generation, the lack of technology to control emissions and transport are the main causes of air pollution in urban areas. Combustion processes produce a complex mix of pollutants that include primary emissions (particulate matter, lead) as well as those coming from atmospheric transformations (ozone, sulphates), which cause an increase in air pollution, deterioration of air quality and health problems [4]. Rural areas are also exposed to emissions of anthropogenic and natural origin that are produced locally as well as transported over a large distance.

The problems associated with air pollution in urban areas vary considerably and are influenced by a number of factors. For example, vehicular combustion processes are less efficient at higher altitude, which has a significant influence on the problems of atmospheric pollution in many cities of the region, such as Arequipa, Bogota, Mexico City and Quito [4].

The serious consequences of the exposure to high levels of air pollution were demonstrated in the middle of the twentieth century when various cities in Europe and America experienced serious episodes of contamination. This led to the development of legislation on air pollution and action to reduce it in many regions.

In Latin America, air pollution causes 2.3 million cases of chronic respiratory disease in children and 100 000 cases of chronic bronchitis in adults every year [49]. Furthermore, 35 000 deaths every year are attributed to air pollution; however, according to a 2005 report by the Pan American Centre for Sanitary Engineering and Environmental Sciences (CEPIS), the actual figure may be much higher, which is a public health concern [4].

The World Health Organization [49] 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. Between 50% and 75% of the population in certain parts of Latin America are still using solid fuels for cooking, and their exposure may be much higher than the ambient (outside) level for highly polluted cities.

Many cities in Latin America have a high population density, a large number of vehicles and heavy industry. These latter two emit — among other pollutants — high levels of particulate matter that cause a deterioration in air quality, respiratory problems, an impairment of quality of life, and affect the economy through absence from work and lower productivity. In addition to the increase in the number of cars, consideration should be given to other factors that influence emissions, such as the age of vehicles, inadequate maintenance, the lack of technology to control emissions and the type and quality of fuel.

There are other activities apart from transport that contribute to atmospheric pollution. The main ones include electricity generation, production of goods and services, food preparation, water treatment, use of various consumer products and the management and distribution of fuel.

In general, throughout the region, the management of solid and liquid urban and industrial waste is of poor quality. The amount of rubbish generated per person has increased. In Latin America, some 424 thousand tons of rubbish is produced every day, less than 35% of which is taken to sanitary landfills [55]. The majority of the waste is deposited in open rubbish dumps or partially controlled landfills, with no protection for the environment or prior treatment [56]. Solid municipal 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, contamination of soils, water, air and flora and fauna, and disasters, such as flooding [56]. There is very little, or no, information regarding the presence of pollutants, such as hormones, antibiotics, natural radioactive emissions and additives; their effect on the population and the environment is not evaluated.

The main causes of soil degradation are indiscriminate logging, overgrazing, expansion of agricultural areas and fires. Deforestation is one of the factors with the greatest impact on the erosion of land and one of the greatest challenges for the region. The region has 40% of the plant and animal species in the world, and is believed to have the greatest diversity of flora in the world; however, habitat destruction is causing many species to become extinct [57].

Between 2000 and 2005, the annual rate of loss of vegetation was 0.50%, almost three times more than the annual global rate of 0.18% [54,57]. This rapid loss of tropical forests threatens biodiversity.

The Latin America coastal zone is 64 000 km long and covers an area of 16 million km^2. For many countries, such as the island nations of the Caribbean, Costa Rica and Panama, this territory accounts for more than 50% of the total area under the national jurisdiction. Intensive fishing and commercial overexploitation of valuable species are endangering production systems in the Central Caribbean.

The tons of nutrients spilled on the coasts are associated with the development of red tides, also known as harmful algal blooms (HAB). One of the most significant manifestations of HAB is the production of toxins by certain species of algae, which may build up in seafood products and constitute a health risk for consumers. The effects in humans range from passing discomfort to long-term debilitating diseases and even death from poisoning syndromes.

Harmful algal blooms have a wide range of negative economic impacts that include: the cost of routine programmes to monitor shellfish and other resources affected; temporary or permanent stoppage of the harvesting of fish and shellfish; reduction in sales of sea food; death of wild and farmed fish, shellfish, submerged aquatic vegetation and coral reefs; the effect on tourism and associated business, and the need to provide medical treatment to the exposed population. The expansion of HAB over recent decades has been significant, and the losses incurred by the extensive shellfish, fish or mariculture industries often exceed 5–10 million dollars per event.

The quantity of CO_2 produced from human activity and emitted to the atmosphere has been increasing gradually since the beginning of the industrial revolution in the 19th century, and has accelerated rapidly in recent decades. The concentration of this gas in the atmosphere has increased from ~ 270 ppm in the second half of the 19th century to 316 ppm in 1958 and reached 400 ppm in 2013. The consequence of the rapid increase in this greenhouse gas is a change in temperature and significant climatic disturbances. The most direct and important impacts include the increase in sea temperature, the rise in sea level and ocean acidification. This last effect is due to the increase in CO_2 captured in the oceans and the resulting decrease in pH. Although the global impact of these changes has yet to be evaluated, it is known that coral reefs have great biodiversity and are highly sensitive to these changes. The deterioration in coastal zones and reefs also has an impact on tourist activities in the region. In addition to coral, molluscs and other edible species are highly sensitive to the change in ocean acidity, which might have an impact on marine resources.

The cryosphere in Latin America, which comprises the high Andean glaciers and three areas of ice in southern South America, may be seriously affected by global warming [50]. The retreat of glaciers and the decrease in water availability is currently one of the major concerns for Andean countries, where 95% of the world’s tropical glaciers are found [4]. These countries provide 10% of the planet’s water, which comes mainly from high-Andean and glacial systems [4].

There are a large number of wetlands in continental or coastal environments in the region that depend on groundwater, surface water and/or precipitation. The wetlands provide services, including water supply, production of food resources and raw materials, hydrological regulation and water purification. The main factors that induce change in the services provided by wetlands are water extraction, organic farming, changes in land use, pollution and climate change.

5.3. SWOT ANALYSIS

5.3.1. STRENGTHS

(1) Existence of regional reference centres for the management of some environmental aspects (for example, water, pests, dangerous waste) that promote synergy in different areas, providing logistical technical support for the transfer of technology through horizontal cooperation among countries of the region, promoting access to database information, and also acting as training centres.

(2) Existence of international conventions and protocols on environment issues, to which countries in the region are party, including the Basel Convention, the Stockholm Convention, the Regional Seas Programme and the Environment Ministers Forum, among others.

(3) Existence of laboratories with equipment and trained personnel for the quantification of radiotracers and pollutants in environmental samples. There are laboratories that use environmental and activation radiotracer techniques, nuclear analytical techniques such as alpha and gamma spectrometry, liquid scintillation, NAA, IRMS, ICP-MS and non-nuclear analytical techniques, such as XRF and PIXE/RBS. There are laboratories with quality control systems in place, which is essential for the mutual recognition of analytical results achieved, and some of these laboratories have ISO/IEC 17025 accreditation.

(4) Some countries of the region have experience of and standardized protocols for the application of nuclear techniques in certain environmental areas, as well as a history of collaboration between groups carrying out research on environmental issues and nuclear techniques.

(5) Complementarity of the techniques. The availability of various complementary nuclear and non-nuclear techniques enables environmental issues to be tackled in a comprehensive manner, facilitating more complete characterization of the samples for analysis.

5.3.2. WEAKNESSES

(1) Lack of continuity in policies applied and in efforts made, especially from the government sector. Compared with social problems such as hunger, lack of potable water or communicable diseases, environmental issues tend to be regarded as secondary, even though, in many cases, they contribute to the existence of these problems. In addition, there are shortcomings in: networks for long-term monitoring, harmonized legislation and policies, political will as well as intra- and interregional control structures.

(2) Lack of interaction between environmental protection institutions and those that could provide support for studies using nuclear applications. The relationship

between the institutional sector and scientific institutions is very limited, leading to insufficient knowledge of the potential and advantages of nuclear techniques. For improved diagnosis and monitoring of environmental issues and mitigation strategies, better communication is needed between the scientific sectors.

(3) Lack of knowledge of environmental problems in the region. There is scant scientific information that could serve as a basis for understanding the environmental problems affecting the region and their impacts. Many efforts tend to address the symptoms of the problems rather than identifying their causes and ways of mitigating the effects.

(4) Lack of or failure to comply with environmental quality standards. There is a lack of data to substantiate the need to monitor pollution problems and to establish proper environmental quality standards. Even where these do exist, no great effort is made ensure compliance with them.

(5) Little interaction between agencies of the United Nations system and/or regional entities on topics related to environmental protection.

(6) Limited promotion of the scope for use of nuclear techniques. The characteristics of nuclear techniques make them an ideal, and often the only, tool to support environmental monitoring and toxicology studies, but their potential is often restricted to the academic field; there is therefore a need to raise awareness among the general public and government departments responsible for environmental management.

(7) Insufficient personnel trained in the application of nuclear techniques in environmental areas. Although the region has existing capacity in the area of nuclear techniques, in many cases it is insufficient to cope with the magnitude of the task, or the staff need specific training in the application of the technique to environmental studies.

(8) Disparity in the use of techniques, as well as in the quality of analytical results generated within the region.

5.3.3. THREATS

(1) Lack of commitment on the part of governments and institutions to the sustainability of environmental projects. In order to solve environmental problems, long-term efforts are needed, which are not dependent on any political changes that could affect the region.

(2) Negative social perception and lack of understanding of nuclear techniques. The peaceful uses of atomic energy and applications of nuclear techniques should be better publicized not only among the public but also in government circles.

(3) Lack of stability in terms of qualified staff. Efforts should be made to ensure that qualified staff stay in their fields of work.

(4) Inadequate budgetary provision for the effective maintenance and ongoing modernization of the equipment of the facilities and/or laboratories.

5.3.4. OPPORTUNITIES

(1) Existence of programmes of United Nations agencies and international institutions interested in environmental issues.

(2) Identification of critical problems that affect the environmental situation in the region.

(3) Increasing demand from the population to resolve various environmental issues common to all the countries in the area: this awareness, together with the capacity available, make this the right time to promote the adoption/consolidation of comprehensive environmental management plans, control emissions of pollutants and ensure the appropriate characterization of different environmental compartments.

(4) Nuclear techniques are part of the array of techniques demanded by the institutions responsible for environmental management.

These techniques are used in the following activity groups linked to environmental issues:

- Diagnosis and basic studies of the environmental situation in the region;
- National, regional and global programmes and monitoring networks;
- Remediation of environmental problems.

5.4. NEEDS/PROBLEMS

This section presents the results of the analysis undertaken on the basis of the SWOT analysis, with identification of the needs/problems in the sector, their justification, objective and indicator.

The needs/problems are given as a function of the TOTAL GRADE of priority, in accordance with the prioritization table under section V (Prioritization of needs/problems).

M1. <u>Inadequate management of the region's water resources</u>

Justification: Latin America and the Caribbean has one third of the world's renewable water resources, which should, ideally, meet the demand of 9% of the world population. However, availability varies greatly in the region, leading in some cases to a marked water deficit.

The intensive exploitation of water resources causes problems, such as: falling water tables, pollution and loss of biodiversity.

Objective: To achieve the comprehensive management of water resources in the region, to ensure their availability and maintain their quality.

Indicator: The number of water management plans developed and implemented.

M2. Insufficient evaluation of the impact of pollution from pesticides, persistent organic compounds, heavy metals and other pollutants of anthropogenic and natural origin in water and soil

Justification: A significant proportion of the region's soils are polluted with heavy metals and various polluting compounds are present in water, soils, flora and fauna. Moreover, only 5% of the region's urban and industrial waste water receives any type of treatment and only 35% of solid waste is managed using sanitary landfills, causing pollution of soils and water sources and affecting human and animal health.

17% of the world total of pesticides and over 10% of the world total of fertilizers in the world are sold in the region. Countries in the region are faced with problems related to pesticides in food for local consumption and export, exceeding the legal limits in many cases. There is not enough information and/or analytical capacity to determine the pollutants and their impact on human health, flora and fauna.

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

Indicator: The number of diagnostic reports on pollutants in soil and water using nuclear techniques as inputs for drawing up legislation.

M3. Limited knowledge of the main processes affecting coastal areas with the resulting negative impact on habitat.

Justification: Overexploitation of marine resources, increased marine aquaculture, increased harmful algal bloom, changes linked to climate change (ocean acidification and rising sea level), transport of pollutants in water bodies and altered nutrient cycles, increase in tourism and maritime transport, and beach and coastal erosion are causing a loss of biodiversity and habitat as well as a significant deterioration in the coastal area of the region, undermining the development of countries in the area.

Objective: To develop comprehensive information, including through the use of nuclear techniques that facilitate the sustainable management of coastal resources and preserve the coasts.

Indicator: The number of countries that generate comprehensive information of use for the management of coastal areas.

M4. High degree of atmospheric pollution due to trace elements.

Justification: 75% of the region's population lives in cities. The majority of these have serious atmospheric pollution problems. Rural areas are also exposed to anthropogenic and natural emissions. In all cases, the sources of the emissions may be local, regional or transboundary. High levels of particulate matter in the air have been associated with different ailments, and constitute a risk to human health. Chemical characterization not only provides information on the concentration of various elements in the atmospheric particulate matter, but also identifies the sources.

Objective: To help to improve the management of air quality using nuclear analytical techniques (NAT) for the chemical characterization of particulate matter in monitoring studies.

Indicator: The number of cities with studies of the chemical characterization of particulate matter in the atmosphere, in particular using NAT.

M5. <u>Inadequate risk assessment of the environmental and social impact of hydraulic structures.</u>

Justification: Hydroelectric power in the region accounts for 22% of world output, producing between 64% and 70% of the energy consumed. Large hydraulic structures have a major impact on the environment and make the downstream populations highly vulnerable. For example, changes in the flow regime of the rivers, rising water table levels and the possibility of flooding. Inadequate assessment of the hydrological and hydrogeological risk in hydraulic structures and the lack of systematic monitoring of sedimentation in the region's artificial water bodies justify the characterization of the interrelation of surface water and groundwater in order to evaluate these effects in a systematic manner and to ensure better levels of structural and functional safety in hydraulic structures.

Objective: To improve dam surveillance programmes through the incorporation of nuclear techniques in the routine activities of the operators.

Indicator: The percentage of dams in each country that have incorporated nuclear techniques in their routine monitoring programmes.

5.5. PRIORITIZATION OF THE NEEDS/PROBLEMS

The prioritization of the needs/problems in the sector is shown in Table 3.

Table 3. Prioritization of the needs/problems of the environment sector

	NEED/ PROBLEM	SEVERITY	TIME	EXTENT	RELEVANCE	TOTAL GRADE	DIFFICULTY	R/D	FINAL GRADE
M1	Inadequate management of the region's water resources.	4.5 A third of the world's renewable water resources are to be found in Latin America and the Caribbean. Overexploitation of limited water resources causes problems such as: lowering of water tables, marine intrusion and capture of highly mineralized groundwater.	4.5 The problems become irreversible, and must therefore be prevented before they arise. Demand for water in the region has increased by 76% between 1990 and 2004 as a result of demographic growth, expansion of industrial activity and high demand for irrigation. In addition, deforestation affects the balance of the water cycle.	5.0 In all countries water resources are used without sufficient knowledge of their availability and quality.	**4.0** Mass and laser spectrometry (^{18}O, ^{2}H and ^{3}H), currently available in the region gives valuable information on the origin, age and interrelation of types of water, recharge, and validation of flow and circulation models. These techniques could be complemented with additional techniques that measure ^{14}C and noble gases.	**18.0**	2.0 Average While the generation of information and the proposal concerning management plans are feasible, their adoption by water managers and inclusion in management plans depend on external factors.	**2.0**	**36.0**
M2	Insufficient evaluation of the impact of pollution from pesticides, persistent organic compounds, heavy metals and other pollutants of anthropogenic	4.5 A significant percentage of the region's soils are polluted with heavy metals; these and other pollutants are present in water, soil, flora and fauna. Only a very small percentage of waste water and solid waste is treated. Pesticides and	4.0 The problem has existed for some decades and is rapidly becoming worse.	5.0 For all countries in the region.	4.0 Some countries have capacities and experts in: i) nuclear techniques to determine pollutants in soil and water; ii) use of environmental isotopes to determine the origin of nutrients in the water; iii) application of radioisotopes to validate	**17.5**	3.0 The region does not have sufficient access to advanced technology and/or human resources to quantify these pollutants, and has few laboratories that area accredited or have adequate	**1.3**	**22.75**

	and natural origin in water and soil.	fertilizers are used extensively and inappropriately. There is not enough information and/or analytical capacity.			pollutant analysis methods.		quality assurance and control systems.		
M3	Limited knowledge of the main processes affecting coastal areas with the resulting negative impact on habitat.	4.5 Phenomena and activities such as overexploitation of marine resources, increased anthropic activities that affect the sea and coasts, increased harmful algal bloom, changes linked to climate change, the transport of pollutants in water bodies, and erosion of beaches and coasts lead to losses of biodiversity and habitat as well as significant deterioration in the coastal area.	4.5 Degradation of the coastal area is increasing rapidly and urgent action is therefore essential to improve understanding of the phenomena and generate information to solve the problems.	4.5 With the exception of Paraguay and Bolivia, all countries in the region have coastal areas affected by this phenomenon.	3.5 Isotopic and nuclear techniques have been shown to be very useful in studying the various problems associated with the deterioration of coastal areas. The use of environmental radiotracers, stable isotopes and nuclear analytical techniques are techniques that are available or accessible to different countries of the region.	**17.0**	4.0 The complexity of the processes to be studied requires elaborate research designs, the use of different complementary techniques and a high level of cooperation between institutions.	**0.9**	**15.3**
M4	High degree of atmospheric pollution due to trace elements.	4.0 75% of the region's population lives in cities. The majority of these have serious atmospheric pollution problems. Rural areas are also exposed to	4.0 The deterioration in air quality and its impact on health are becoming more severe and there is a need for reliable information to	4.0 The pollution goes beyond national borders, and is becoming a problem at the regional level. All countries have rural and urban areas	4.0 Nuclear analytical techniques are extremely beneficial tools for the chemical characterization of particulate matter in the atmosphere, providing reliable	**16.0**	3.0 Although efforts have been made in the region to use different nuclear analytical techniques, their	**1.3**	**20.8**

		anthropogenic and natural emissions.	monitor problems associated with pollution and to establish appropriate standards.	affected by air pollution, which causes millions of cases of chronic respiratory disease in children and hundreds of thousands of cases of acute bronchitis in adults per year.	information on pollutant levels that is particularly beneficial in identifying their sources, establishing seasonal or spatial trends, transport phenomena, and identifying elements associated with the occurrence of disease.		systematic use and implementation are uneven. Furthermore, the quality of the results achieved varies, which limits their use in comprehensive analyses at the regional level.		
M5	Inadequate risk assessment of the environmental and social impact of hydraulic structures.	3.0 Large hydraulic structures have a great impact on the environment.	3.5 The vulnerability of the population downstream of dams continues to grow.	3.5 There are hydraulic structures in all countries of the region.	3.0 Isotopic techniques can supply useful information on the average lifetime of reservoirs and on the scale of leaks, and should therefore be included in routine monitoring programmes of these hydraulic structures.	**13.0**	3.0 The use of environmental tracers to evaluate dam yield may require the installation of expensive observation networks in some hydrogeologic settings.	**1.0**	**13.0**

ENERGY

6. ENERGY

6.1. BACKGROUND

In carrying out this work, the energy group divided the sector into two subsectors:

- Nuclear energy
- Research reactors.

In developing the RSP for 2016–2021, the following were taken into account: the RSP for 2007–2013, the results obtained in the projects implemented since the 2009–2011 cycle, and the results expected in the projects proposed up to 2013.

Those elements and factors in each subsector which constitute part of a platform for the undertaking of new growth and progress initiatives were identified as strengths. Aspects related to qualitative and quantitative shortcomings from which each subsector currently suffers were identified as weaknesses. Those current or foreseeable conditions which could be made use of either because they harmonize with growth and progress prospects or because they trigger such prospects were identified as opportunities. Conditions which could impede or retard such growth and progress prospects were identified as threats.

6.2. ANALYSIS OF THE REGIONAL SITUATION

a. Summary of the current situation with regard to nuclear energy in the region

The region of Latin America and the Caribbean region comprises 45 countries in an area covering 20.4 million km^2. The population was a little over 590 million as of 2010 and is growing at a rate of 1.1% per year. In 2010, the gross domestic product of the region was US $3262 thousand million at 2005 prices. The annual per capita income (2010) was US $5583 (at 2005 prices). The life expectancy at birth is 74 years. The literacy rate among the population of 15 and above was 91.4% in 2010 [58].

Primary energy demand in 2010 was 586 million tonnes of oil equivalent (toe), and it is estimated that this figure will increase by 26% by 2020 and 46% by 2030 [59].

Known oil reserves in the region have risen to around 247 491 million barrels (bbl), which is 18% of global reserves. The main oil producers are Brazil, Mexico and Venezuela. Oil production in the region exceeded 3500 million barrels in 2009, which is 12% of world production. Latin America and the Caribbean have 8% of the world's refining capacity [60].

With regard to natural gas, the region has 8591 Gm^3 of known reserves, which is 4% of global reserves. Argentina, Brazil, Mexico, Trinidad and Tobago and Venezuela have traditionally been the region's main gas producers. In 2009, 262 Gm^3 of this fuel was produced, which is 9% of world production [60].

The region has 42 427 million tonnes of known carbon reserves, which is 5% of global reserves. In 2009, production was 97 million tonnes (1% of global production), with Colombia the largest producer in the region [60].

Electricity generation capacity in the region rose to 292.7 GW in 2009. 51% of this comes from hydroelectric plants, 46% from thermal power plants, 2% from nuclear power and 1%

from renewables [60]. In 2009, consumption of electricity in Latin America and the Caribbean was 1276 TW·h, which was 6% of global consumption [61]. With regard to CO_2 emissions, total global greenhouse gas emissions in 2007 were 28 962 Mt CO_2. In Latin America and the Caribbean, the per capita emissions were 2.63 tonnes CO_2/hab. Even though the values of CO_2 emissions per inhabitant are lower in Latin America and the Caribbean than in industrialized countries, the average annual growth rate is 2.6% [60].

It is estimated [59] that gross electricity generation capacity additions between 2012 and 2035 in Latin America and the Caribbean will reach 269 GW, a figure similar to installed capacity in 2009. 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 (PV), 16 GW from bioenergy, 7 GW from nuclear, 3 GW from concentrated solar power plants and 2 GW from geothermal plants.

It is estimated that, in a scenario where current policies are maintained, electricity consumption in the region will grow on average by 2.7% [59].

It is forecast that the region's population will rise to around 720 million by 2030, which poses an enormous challenge in terms of the establishment of the necessary conditions to meet the welfare requirements of such a population size.

Total primary energy consumption would rise to 1483.23 Mtoe in 2030. Accordingly, electricity consumption would rise to 2621 TW·h, which would be double the current level or more. As regards CO_2 emissions, scenarios predict figures of 2680 Mt CO_2.

The IAEA estimates that installed capacity will increase from 344 GW in 2012, to 1000 GW in 2030 in a low-growth scenario and to 1359 GW in 2030 in a high-growth scenario, which confirms the need to expand current capacity by between 66% and 75% over the next 18 years [62].

Latin America has over 25 years' experience in the generation of electricity. Installed nuclear capacity rose to 4.3 GW in 2012 [62], distributed among six units in three countries. Electricity generation from nuclear means increased in these countries in 2010 to 26.2 TW·h. In Argentina, the share of nuclear power is the highest, contributing 4.7% of electricity generated [63]. In Mexico, the share of nuclear power is 3.9% [64] and in Brazil 3.1% [65]. Two new reactors with a capacity of 1937 MW are under construction in the region.

Despite the negative impact of the Fukushima accident on investment in the nuclear field, signs of a beginning in the development of plans for nuclear plant projects are appearing. In the region, countries with nuclear plants are expanding their nuclear generation capacities or are planning to do so.

Some countries that decided not to include the nuclear option in their energy matrices because of the Fukushima accident may review their position between 2016 and 2021.

The decisions taken in connection with the United Nations Framework Convention on Climate Change (UNFCCC), derived from the new climate regime to be adopted in 2015 for implementation from 2020, should strengthen the commitments of all countries through mitigation and reduction of greenhouse gases (GHG).

The nuclear power reactors in the region are coming to the end of their planned lifetime and an analysis and evaluation of a lifetime extension should therefore be undertaken.

These factors highlight 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 Latin America and the Caribbean.

b. 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% uranium enriched is at an advanced stage of conversion to low enriched uranium (see Table 4).

The range of applications these reactors can be used for depends on the power level or neutron flux. In general terms, reactors under 250 kW may be categorized as low power and those over 2 MW as high power.

Seven countries in the Latin American and Caribbean region have experimental nuclear reactors of various types and power levels, as shown in Table 4.

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), Buenos Aires
	RA-3	*Pool*	10 000	19.7	266	CNEA, Ezeiza Buenos Aires
	RA-4	*Pool*	0.001	19.8	16	University of Rosario
	RA-6	*Pool*	500	19.75	180	CNEA, San Carlos de Bariloche
	RA-8	*Pool*	0.01–0.1	1.8-4.3	0	CNEA, Pilcaniyeu, Rio Negro
BRAZIL	*ARGONAUT*	*Pool*	0.5 – 5	19.9	Not available	Nuclear Engineering Institute (IEN) – National Nuclear Energy Commission (CNEN), Rio de Janeiro
	IEA-R1	*Pool*	2000–5000	19.9	256	Nuclear and Energy Research Institute (IPEN-CNEN), São Paulo
	MB-01	*Pool*	0.1	4.3	Not available	IPEN-CNEN, São Paulo
	IPR-R1	*Pool*	250	*Triga* 19.9	Not available	Nuclear Technology Development Centre (CDTN)-CNEN, Belo Horizonte
CHILE	*RECH-1*	*Pool*	5000	19.75	96	Chilean Nuclear Energy Commission (CCHEN)- La Reina-Santiago
	RECH-2	*Pool*	10 000–15 000	19.75	0	CCHEN-Lo Aguirre-Santiago
COLOMBIA	*IAN-R1*	*Pool*	100	*Triga* 19.9	0	Colombian Institute of Geology and Mining (INGEOMINAS), Bogota
JAMAICA	*SLOWPOKE*	*Pool*	20	90 *(in the process of conversion to LEU)*	Not available	International Centre for Environmental and Nuclear Sciences (ICENS), Kingston
MEXICO	*TRIGA*	*Pool*	1000–2000	*Triga* 19.9	60	National Nuclear Research Institute (ININ), Mexico City
PERU	*RP 0*	*Pool*	0.001	19.75	96	Peruvian Institute of Nuclear Energy (IPEN)- Headquarters, Lima
	RP 10	*Pool*	10 000	19.75	30	IPEN-Huarangal, Lima

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

For more than 60 years, experimental reactors have been centres of production and innovation for nuclear science and technology [66,67]. 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 and 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 IAEA – as well as in a bilateral format. A couple of projects have also been implemented within the framework of ARCAL.

At the bilateral level, the collaboration between Argentina and Peru on the design and construction of the RP 0 and RP 10 reactors stands out.

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

With regard to 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, (NUR, 1MW, 1989), Egypt (ETR-2, 22MW, 1997) and Australia (OPAL, 20 MW, 2006).

The construction of two new reactors in Argentina and Brazil is planned.

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

Within the framework of the IAEA, from 2001 to date, 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 mutual cooperation could be achieved in order to improve standard practice and provide mutual assistance in these tasks.

As regards documentation and quality assurance, joint cooperation in implementing the modifications to safety guides 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. The possibility exists to develop and manufacture parts using experience acquired in the region, where Argentina, Brazil, Chile, Colombia, Mexico and Peru have formed a reliable instrumentation and control group.

There is capacity in the region 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 (BNCT, NR, PGNAA); critical combination as regards the arrangement of irradiated fuel elements, management of reactor lifecycle; calculation validation tools.

The results of the project RLA/0/037 and ARCAL Project CXIX [68] show that one of the main uses of research reactors is for the production of radioisotopes. The radioisotopes produced in nuclear reactors are, in order of volume in the region, ^{99}Mo, followed by ^{131}I, ^{192}Ir, ^{177}Lu, ^{153}Sm, ^{90}Y, ^{125}I and ^{32}P. Regional demand for radioisotopes produced in nuclear reactors was estimated to be 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%.

Regional demand is estimated to exceed US$ 28 million in 2017, with a 7% increase in fission-produced ^{99}Mo for generator production according to trends observed between 2010 and 2012. It is anticipated that consumption of the rest of the radioisotopes would remain stable up to 2017.

Regional production supplies 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 [68].

In the years to come, Canada, which is one of the major suppliers of fission-produced molybdenum to the region, is planning to shut down the nuclear reactor that produces the radioisotopes. However, during the period of the RSP for 2016–2021, it is expected that two reactors will come online in countries of the region, which will cover the shortage in the region.

6.3. SWOT ANALYSIS

A strategic analysis of the region’s profile is given below in the form of a summarized list of the strengths, weaknesses, opportunities and threats identified in the sector.

6.3.1. STRENGTHS

(1) The existence of uranium resources, technological and professional capacities in certain nuclear reactor technologies and in the nuclear fuel cycle.

(2) Operating experience in certain types of nuclear power plant which could be shared.

(3) Existence of training centres for specialists in the nuclear field.

(4) Development of energy technologies, in particular concerning innovative nuclear reactors and the fuel cycle (CAREM, nuclear fuel fabrication).

(5) Existence of a high level of electrification and joint construction projects in the region.

(6) Joint collaboration between institutions with research reactors.

(7) There are 13 research reactors in 7 countries of the region, some of which have the capacity to produce radioisotopes and to be extended to other applications.

(8) High design, construction, operation and maintenance capacity for research reactors and design and fabrication of fuel.

(9) Existence of targeted knowledge in energy planning groups in the region for the implementation of comprehensive studies of sustainable energy development.

6.3.2. WEAKNESSES

(1) Limited knowledge in the majority of countries of the region about the potential of their uranium resources.

(2) Disparities in energy, social and economic development indices among countries of the region, which hampers integration.

(3) Large land area and existence of geographical barriers, which hampers integration.

(4) Weak statistical database structures and analytical tools for energy planning.

(5) Insufficient public education and information on the uses, benefits and risks of nuclear energy, to promote favourable public opinion.

(6) Financial limitations as regards large investments.

(7) Insufficient budget for management and maintenance of research reactors.

(8) Research reactors, which require modernization.

(9) Lack of knowledge at the social level and, in many cases, among potential users, of the uses of research reactors.

(10) Insufficient incentives to attract and maintain the highly qualified human resources required in research reactors.

(11) Underutilization of research reactors.

(12) Absence of integrated appropriate long-term energy studies in some countries of the region.

(13) Different levels of knowledge regarding development of a nuclear power programme.

(14) Reactors in the region are coming to the end of their operating lifetime.

6.3.3. THREATS

(1) Unfavourable public opinion owing to a negative perception of the risks associated with the use of nuclear energy.

(2) Difficulty in resolving the issue of waste disposal in the region in the long term.

(3) Competence of international commercial enterprises providing radioisotopes (RI) and radiopharmaceuticals (RF).

(4) Restrictions on and resistance to transport of radioactive material.

6.3.4. OPPORTUNITIES

(1) Growing demand for electricity, which has led to the activation of nuclear power programmes in various countries (Argentina, Brazil, Chile and Mexico).

(2) Existence for the region of international cooperation entities and organizations: IAEA, OLADE, CIEMAT, ECLAC, CIER, etc.

(3) Increase in fossil fuel prices and high CO_2 emissions work in favour of the nuclear option.

(4) Reactivation of nuclear programmes (Argentina, Brazil), which opens up possibilities for the training and development of human resources in the nuclear field.

(5) Demand exists in the region for RI and RF, which could be met to a large extent by the region's research reactors.

(6) The possibility for countries that do not have research reactors to use and benefit from them. There is potential demand from interested parties in the State and private sectors for advanced services and technologies that could be met by research reactors.

(7) The trend towards diversification of the energy matrix with a view to improving security of the energy supply.

(8) The political strategy of countries to implement programmes for electricity for all.

(9) Existence of guidance and documentation to direct a country towards analysis and implementation of a nuclear programme.

6.4. NEEDS/PROBLEMS

This section presents the results of the analysis undertaken on the basis of the SWOT analysis, with the identification and justification of the needs/problems of the sector.

The needs/problems are given as a function of the TOTAL GRADE of priority, in accordance with the prioritization table under section V (Prioritization of needs/problems).

E1. <u>To improve education and availability of objective and extensive information on nuclear energy.</u>

Justification: The nuclear option as an energy alternative is being discredited owing to the arguments of lack of safety, uncontrolled emissions of harmful radiation, or the dangers of long-lived radioactive waste.

It is therefore necessary to conduct honest, transparent and objective information programmes with goals differentiated by sector, that are gradually introduced to the public to increase understanding of nuclear energy on the basis of an objective and timely analysis.

The inclusion of information on requirements for the development of a nuclear power programme aimed at sectors involved in analysis, decision-making and implementation is very important.

Objective: To foster a better understanding among the public on the use, benefits and complexities of a nuclear power programme.

In this objective for this period, priority will be given to the target audience: decision-makers. This is the sector that will decide whether or not to undertake an analysis of the nuclear option in the energy mix of the countries in the region.

Indicator: The number of countries that have carried out training activities

E2. <u>Absence of integrated long-term compehensive studies of energy development in most of the region.</u>

Justification: According to studies undertaken by international organizations, the forecast growth in energy demand in Latin America is estimated to range from 2.8% and 5.0% per year. However, the studies were not undertaken by countries of the region, which introduces a certain degree of uncertainty.

For this reason, more detailed studies are needed using comprehensive models to analyse energy supply and demand to develop national, subregional and regional scenarios based on assumptions concerning existing energy resources, fuel prices, economic growth, population growth, structure of the energy system and environmental impact. In particular, efforts should be made to determine the role that nuclear energy could play in the development strategies of countries of the region.

Many countries of the region lack statistical data and mechanisms for collection, limiting their capacity for studies on energy planning that allow for better definition and understanding of possible present and future scenarios.

Strengthening of analytical capacity involves:

- Expanding and improving analytical tools and databases relating to energy and the environment;
- Incorporating sustainable development energy indicators for the evaluation of statistical energy data;
- Developing possible energy supply and demand scenarios for the medium and long term;
- Elaborating national energy profiles for sustainable development;
- Elaborating an integrated energy profile for Latin America within the framework of sustainable development.

Objective: To develop national and/or regional energy plans for sustainable development.

This objective involves strengthening analytical capacity, including through: expanding and improving analytical tools, statistical programmes and databases relating to energy and the environment; incorporating sustainable development energy indicators for evaluation of statistical energy data; developing possible energy supply and demand scenarios for the medium and long term; elaborating national energy profiles for sustainable development; elaborating an integrated energy profile for Latin America within a framework of sustainable development.

The result of this would be more detailed studies that use integrated models to analyse energy supply and demand in order to develop national, subregional and regional scenarios based on assumptions concerning existing energy resources, fuel prices, economic growth, population growth, structure of the energy system and environmental impact. In particular, efforts should be made to determine the role that nuclear energy could play in development strategies of countries of the region.

Indicator: The number of countries that develop integrated long-term energy plans.

E3. <u>To improve knowledge of the region's uranium potential.</u>

Justification: Political decisions on the stages of the fuel cycle are a necessary part of the nuclear power option. In particular, it is planned to increase the number of nuclear power reactors in the region, and fuel consumption in the future will therefore increase. Capacities for nuclear fuel fabrication and design exist in the region.

One element that affects the achievement of an assured supply of fuel is the need to ascertain the uranium potential in the region, not only in the countries with nuclear plants. The baseline for uranium evaluation in the region has not been established. Knowledge of this potential is important from the moment the possibility of using the nuclear option is considered and analysed.

Objective: To obtain information on the region's uranium potential from the baseline to the evaluation of regional resources.

In view of the anticipated growth in the use of nuclear energy, it is necessary to have knowledge of the uranium potential across the whole region. Efforts to support projects to ascertain potential that has already been studied, determine current status and to support planned studies to deepen this knowledge are important to achieve this objective.

Indicator: The number of countries with an evaluation of uranium resources.

E4. <u>Absence of an established network for the exchange of information and coordination of strategies, from research reactor operators to the radioisotope end user.</u>

Justification: Most of the region's research reactors have been in operation for many years and require some degree of modernization. Furthermore, many are underutilized, even though the demand for RI exists.

Efforts have been made in the region to exchange experience among different actors involved in the safe operation of research reactors and their use for the production of 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 all the actors involved 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 would 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 for 2006–2021.

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

In order to achieve this objective, efforts should be made to establish a network facilitating the exchange of information and coordination of strategies from research reactor operators to the radioisotope end user, which would 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 for 2006–2021.

Indicator: The number of countries participating in the network.

E5. <u>Lack of experience in the region in processes to extend the operating lifetime of nuclear power plants.</u>

Justification: The majority of the reactors in the region are coming to the end of their operating lifetime, and the political will for extension has been expressed. The region does not have practical experience in these processes, and this is why it is important to acquire the necessary experience and ensure that it is shared among teams from the countries requiring it.

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

In the period under consideration, the exchange of experience among personnel responsible for extending the lifetime of the reactors, and support for these processes from experience accumulated at the IAEA constitute the essence of this objective.

Indicator: The percentage of key personnel with training in lifetime extension processes.

E6. <u>Shortage of highly qualified staff to manage and operate research reactors.</u>

Justification: Highly qualified personnel work at the region’s experimental reactors. However, these human resources need to be renewed to ensure preservation of knowledge as a new generation takes over operations. Training of human resources for experimental reactors takes at least three years.

There are plans to build two new nuclear reactors. The growing demand for RI and RF could, to a large extent, be met by the region itself.

Objective: To provide the research reactors in the region with highly qualified staff.

Support, from a perspective of regional cooperation, for clearly identified national plans to ensure that research reactors have qualified staff, will make an important contribution to achievement of the objective identified.

Indicator: The percentage of research reactors where all staff are trained.

6.5. PRIORITIZATION OF THE NEEDS/PROBLEMS

The prioritization of the needs/problems in the sector is shown in Table 5.

Table 5. Prioritization of needs/problems in the energy sector

	NEED/PROBLEM	SEVERITY	TIME	EXTENT	RELEVANCE	TOTAL GRADE	R/D	DIFFICULTY	FINAL GRADE
E1	To improve education and availability of objective and extensive information on nuclear energy.	4.5 High social and political importance.	4.0 Urgently required before starting a nuclear programme.	5.0 All countries potentially involved should address this matter.	5.0 High for the development of nuclear power programmes.	**18.5**	1.67	**3.0** Average. Achieving it requires political will.	**31.0**
E2	Absence of integrated long-term comprehensive studies of energy development in most of the region.	4.5 Development of scenarios is important as a starting point for integrated energy planning.	4.5 Urgent for definition of energy development policies.	4.0 The majority of countries in the region.	4.0 Important for the diversification of the energy mix including the nuclear option.	**17.0**	1.33	**3.0** Average, its achievement depends on the decisions of the authorities in the country.	**23.0**
E3	To improve knowledge of the region's uranium potential.	3.0 The results are required to ensure the security of fuel supply in the medium to long term.	3.5 The results are required in the medium to long term.	4.0 Knowledge of the resource should be improved in many countries of the region.	4.5 Very high for nuclear programmes in the region.	**15.0**	1.12	**4.0** High political will and significant resources are required.	**17.0**
E4	Absence of an established network for the exchange of information and	3.0 Important to meet the region's needs in terms of radioisotopes and	3.0 A solution to this problem is required in the short to	4.0 Countries with experimental reactors and countries that use	4.5 Of high relevance for programmes concerning the application of	**14.5**	1.5	**3.0** Average, it requires the coordination of strategies of many	**22.0**

	coordination of strategies, from research reactor operators to the radioisotope end user.	for the efficient use of facilities.	medium term.	radioisotopes.	nuclear techniques.			elements in the chain of production distribution, transport and users.	
E5	Lack of experience in the region in processes to extend the operating lifetime of nuclear power plants.	4.0 The reactors in operation are coming to the end of their lifetime.	4.0 High, is required for decision-making.	2.0 For the three countries that have nuclear power plants.	4.0 Important for the continued operation of nuclear power plants.	**14.0**	1.6	**2.5** Average – low given the facilities that the authorities bring to the process and the fact that experience exists in other regions.	**22.5**
E6	Shortage of highly qualified staff to manage and operate research reactors.	3.5 Average to high, important for the operation of research reactors.	3.0 The results are required for the medium term.	3.5 For the countries with research reactors.	3.5 Of average – high relevance for programmes concerning the application of nuclear techniques.	**13.5**	1.17	**3.0** Average this requires not only staff preparation, but also budgetary incentives for the facilities.	**16.0**

RADIATION SAFETY

7. RADIATION SAFETY

7.1. BACKGROUND

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 ionizing radiation.

The IAEA, in accordance with Article III of its Statute, is authorized to establish standards of safety for protection of health and minimization of danger associated with the application of ionizing radiation to life and property, and to provide for the application of these standards. IAEA standards cover nuclear safety, radiation safety, safe transport of radioactive material and radioactive waste management.

The Fundamental Safety Principles [69] stipulate that States should 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 of regulation, authorization, control and sanction, as well as to ensure compliance with international commitments laid down in international agreements, arrangements, protocols or conventions. States should also have the necessary arrangements in place so that, if needed, a capacity for intervention and mitigation in the event of accidents exists.

In the area of radiation safety, the Regional Strategic Profile (RSP) for the period 2007–2013 used as a reference point information provided by the IAEA, such as expert missions, reports from evaluation missions, (RaSSIA, ORPAS, EPREV and others), information from international meetings and congresses, country reports presented or regional coordination meetings, Radiation and Waste Safety Infrastructure Profiles (RaWaSIP), Country Programme Frameworks (CPFs) for the technical cooperation programme, surveys and other sources of information.

Based on the needs identified in the RSP, the IAEA 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.

7.2. GENERAL ANALYSIS OF THE REGIONAL SITUATION

In May 2013, regional experts met with technical officers and project management officers with a view to updating the RSP in force with plans for 2016–2023. In order to assess the situation in the region, information in the IAEA's "Radiation Information Management System (RASIMS)" database was used, as well as technical advice provided by technical officers from the IAEA with responsibility in different areas.

From this analysis, it was concluded that significant progress has been made in the Latin American region in establishing regulatory infrastructures and programmes over the last 15 years. This has been a result of the efforts of and technical cooperation between the IAEA and its Member States. However, decisive action is required by all parties to consolidate the results achieved as international good practice in the safety area.

Mention must be made of the importance of political commitment and government understanding in order to move towards a better level of organization and develop effective and sustainable regulatory infrastructures.

It should also be noted that the new IAEA safety standards, General Safety Requirements (GSR Part 1, Part 3 and Part 5) [70, 71, 72] with their new structure and content, reflect clearly the responsibilities of governments and regulatory bodies in the development and application of regulatory infrastructures and systems. The IAEA should therefore encourage the governments of Member States to put in practice the safety requirements set out in the IAEA standards in order to ensure the establishment, at last, of efficient and sustainable regulatory infrastructures.

The updating of the evaluation of the current situation in the area of radiation safety in the countries of the Latin American region shows the following:

- The evaluation recognizes the achievements of previous regional projects in implementing all aspects associated with the creation and/or improvement of radiation safety infrastructure. However, the evaluation also recognizes that there are still important elements that need to be addressed to ensure that the regulatory bodies are actually independent, have sufficient scientific knowledge and are free from political influence, and the existence of an appropriate national structure and effective, updated and sustainable regulations that guarantee the safety of radiation sources.

- Existing legislation and regulations are not always compatible with international regulations and, in some cases, do not facilitate the proper application by the regulatory body of guidelines for control in the area of radiation safety.

- With regard to human resources, there is a high rotation of regulatory staff and a lack of new people although the people working in the area are ageing; this leads to a loss of institutional memory and shortcomings concerning the regulatory process for inspection and control. This situation also affects end users and technical services in the area of radiation protection.

- The presence of orphan sources in material to be recycled continues to be observed, albeit less frequently, which could cause radiological emergencies, and this is why the measures necessary for detection and timely safety action must be taken.

- Not all occupationally exposed workers receive the individual monitoring required under international recommendations and national regulations; the problem is worse for individual internal monitoring. The dosimetry calibration laboratories are not sufficient to meet the region's needs.

- Single national registers of all occupational doses are not available in all countries of the region.

- In the majority of countries in the region, no action has been taken to identify existing exposure scenarios associated with industries that involve NORM (naturally occurring radioactive material) and to assess their impact.

Furthermore, an effective regulatory framework to address this area has not been developed.

- Although planning, reporting and coordination in the region to respond to emergencies, including with respect to the provision of medical care to those affected, systematic analysis of accidents and dissemination of information have improved, they remain insufficient.

- There is a continued lack in the region of national strategies and policies for the management of radioactive waste, and there are deficiencies in the application of the concepts of exemption, declassification and clearance.

- The majority of regulatory bodies do not have the human and financial resources to fulfil all their designated responsibilities under applicable regulations and legislation.

- There is a clear shortage of management systems of regulatory authorities that are in line with the competencies assigned under the legal framework.

- Safety culture in the area of radiation safety is not properly promoted or implemented.

- It is noted that the governments of some Member States in the region still do not have an exhaustive knowledge of the role of the regulatory body, and this could adversely affect the sustainability of the national radiation safety system.

- Documented experience and information on the infrastructure for the safe transport of radioactive material is not available in the majority of countries, and problems associated with the denial of shipments of radioactive material arise.

- There is a shortage of national strategies for education and training in radiation safety.

- Information on possible radiological risks associated with facilities and activities and on processes and decisions of the regulatory body, and its dissemination to interested parties and the public, is insufficient.

- There is insufficient training on programmes for optimization of radiation protection in all practices, particularly in medicine, with emphasis on new technologies (digital techniques — multislice computed tomography — hybrid systems SPECT - PET/CT).

- There is also insufficient training for medical and paramedical staff in radiological protection programmes for treatment of children and pregnant women in specialities with greater radiation risk, such as radiotherapy and interventional procedures.

- The majority of the research reactors in the region have been operating for decades, and the challenge is whether to engage in an effective lifetime extension or to begin decommissioning and closure. Furthermore, the regulatory control of these facilities requires improvement, in particular as regards the establishment and implementation of the statutory inspection programme.

7.3. SWOT ANALYSIS

7.3.1. STRENGTHS

(1) A cultural identity and language that facilitate exchange of experience, information and professional support, helping to bring countries to the same level in various areas relating to safety.

(2) Existence of professionals trained in all fields of safety with experience that can collaborate within a bilateral framework.

(3) In almost all countries, legislative and regulatory frameworks and systems for authorization and inspection have been established and are operational.

(4) Recognition by countries of the need for authorized centralized storage facilities for radioactive waste and disused radioactive sources.

(5) Existence of organizations for conventional emergency management that can assist in the event of radiation emergencies.

(6) Skill and preparation levels of the regulatory authorities have increased.

(7) Use of the benefits of international conventions concerning emergencies and knowledge of other safety conventions.

(8) Existence of national inventories of radioactive sources from Category 1 to Category 3, radioactive waste and disused radioactive sources.

(9) Countries have identified the main problems they face in the area of radiation safety.

(10) Legislation in the majority of countries of the region sets out basic responsibilities concerning planning, preparation for and response to radiation emergencies.

(11) Existence of a shared vision to resolve radiation safety issues.

(12) Clearer vision on the part of countries as regards their development needs with respect to regulation and control infrastructure.

(13) Greater awareness of the radiation risk from medical exposure.

(14) Existence of an extensive private sector working with sources and interested in optimization of occupational radiation protection.

(15) Existence of basic technical services to determine occupational exposure and aspects of radiation measurement during environmental releases and emergency response.

7.3.2. WEAKNESSES

(1) High rotation rate of trained professionals, particularly within regulatory bodies.

(2) Some regulatory bodies have limited capacity in terms of infrastructure and trained human resources to meet their responsibilities under national legislation.

(3) Regulatory bodies do not have the financial resources necessary to fulfil all their designated legislative responsibilities.

(4) Low pay and incentive to work in regulatory bodies, which leads to the ageing of the human resources specialized in the field of radiation safety and a lack staff renewal. Lack of knowledge management necessary to maintain an institutional memory on radiation safety issues.

(5) Coexistence of more than one regulatory body in some countries. Lack of officially established cooperation and coordination between different national authorities.

(6) Lack of actual independence of the regulatory body in some countries where the regulators are also operators of some practices that need to be regulated.

(7) In some cases, regulations in the area of radiation safety are lacking or not up-to-date.

(8) In many countries, regulatory frameworks do not cover all activities and practices (particularly practices associated with lower radiation risk and new technologies). Limited application of safety evaluation requirements. Insufficient coverage of regulatory control in diagnostic radiology.

(9) Insufficient utilization of computer systems for the recording of sources.

(10) In many countries, records of sources are not used to organize appropriately and in a graded approach the work of the regulatory bodies.

(11) Absent or weak enforcement systems or failure to decide on their use.

(12) In a large number of regulatory bodies, no efforts are made to establish, implement, evaluate and improve continuously management systems, including: records, authorization, implementation of standards, inspections information and cooperation.

(13) Many countries do not require implementation of management systems in facilities and regulated activities.

(14) Absence, or limited dissemination, of formal programmes for the development and promotion of a safety culture among users and regulators.

(15) Implementation and control of radiation protection programmes, and their optimization in facilities and activities remain weak, as do efforts to introduce concepts relating to safety culture.

(16) Lack of documented experience and information on the infrastructure for the safe transport of radioactive material. Problems associated with denials of shipment and failure to nominate national contact points.

(17) Countries' dependence on the support, resources and programmes of international organizations, especially the IAEA, for training and procurement of equipment.

(18) Coverage of external personal dosimetry is not sufficient to encompass all workers and all types of radiation to be measured. Difficulties concerning beta and neutron dosimetry.

(19) Laboratories providing internal dosimetry services are insufficient in number or unevenly distributed geographically, which makes it difficult to provide broad coverage for all the exposed workers who require it.

(20) Limited services and equipment available to monitor the workplace (measurement of radiation beams and contamination of surfaces).

(21) The services of the dosimetry calibration laboratories in the region are limited in terms of levels of radiation protection and the need to calibrate the equipment for workplace monitoring.

(22) Quality systems in technical support services are not fully implemented.

(23) Lack of harmonization concerning processes and criteria for authorization/approval/verification of the competence of technical services at the national and regional level.

(24) The absence of unified national records for occupational dose in the majority of countries.

(25) Lack of clarity with respect to the meaning, need and scope of national policies and strategies pertaining to radioactive waste management, which makes safe and sustainable implementation in this area difficult.

(26) Lack of information on the existence of NORM and identification of exposure scenarios that exist in the countries.

(27) Lack of clarity with respect to the regulation and practical application of the concepts of exemption, declassification and clearance.

(28) Weaknesses in the timely detection and control of materials to be recycled to monitor the possible presence of radioactive material in consumer products.

(29) There is no notification system with regulated coordination for all organizations which must be involved in emergency response.

(30) Shortcomings in the evaluation of threats in the majority of countries for planning in response to radiological and nuclear emergencies.

(31) The regulatory frameworks in the majority of countries do not set out clear requirements for education and training in radiation safety for different categories of staff and types of practice.

(32) Absence of national strategies for education and training in radiation safety.

(33) Failure to become State parties to the Conventions on Nuclear Safety, on Early Notification of a Nuclear Accident, and on Assistance in Case of a Nuclear Accident or Radiological Emergency.

(34) Insufficient information and consultation with interested parties and the public concerning possible radiation risks associated with facilities and activities, and processes and decisions of the regulatory body.

(35) Failure to disseminate internally the knowledge acquired during specific courses provided by international organizations.

7.3.3. THREATS

(1) 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.

(2) Economic difficulties in countries in connection with the improvement or upgrading of infrastructure, owing to insufficient allocation of resources.

(3) Weak governmental commitment to support, strengthen and establish infrastructure and regulatory programmes concerning radiation safety.

(4) Lack of multiplier effect with respect to knowledge acquired at specific courses provided by international organizations.

(5) Lack of awareness-raising on radiation protection issues among professionals working with ionizing radiation and the general public.

(6) Limited use by countries of evaluation tools developed by the IAEA, such as SARIS (Self-Assessment of Regulatory Infrastructure for Safety) to assess the efficacy of regulatory programmes and monitoring systems to measure the effectiveness of technical cooperation in various areas relating to safety, such as RASIMS.

(7) Weak systematic action of the IAEA with governments of countries to raise awareness of the importance of safety aspects and regulatory infrastructure to control risks and radiation sources.

(8) Little attention paid by governments to strengthening the capacity of regulatory bodies for control in some areas of medical practice.

(9) There are some countries of the region that have not signed the Early Notification and Assistance Conventions and safety conventions.

(10) The region is essentially dependent on external financing for the development of capacities to respond to nuclear and radiological emergencies.

(11) Health-care resources in the region to treat those injured in emergency situations are not properly identified.

(12) The region does not have enough experts to advise on the medical response in the event of nuclear and radiological emergencies.

(13) No systematic analysis has been performed of the accidents that have occurred in the region, nor are all accidents officially reported.

7.3.4. OPPORTUNITIES

(1) Possibilities to access specialized international (IAEA, PAHO) and bilateral cooperation aimed at supporting the development of radiation safety infrastructures in countries.

(2) Existing capacity in countries of the region for training of trainers and production of multiplier effects.

(3) Interest in some countries of the region in nuclear power generation.

(4) Existence of international conventions on safety and emergency response.

(5) Existence of regional projects and plans of action that help to find solutions to the problems.

(6) Existence in the region of a group of experts and access to services (LBDNET) to respond to radiological emergencies.

(7) Existence of two regional training centres for the provision of postgraduate courses in radiation protection recognized by the IAEA.

(8) Availability of training packages developed by the IAEA allowing standardization of the information imparted in training.

(9) Access to expertise, normative documents, procedures and outputs developed through the Ibero-American Forum of Radiological and Nuclear Regulatory Agencies.

(10) Availability of updated IAEA international standards concerning radiation safety.

(11) Existence of a comprehensive package of national standards that can service as a reference for countries developing their national legislation.

(12) Availability of tools (software) that serve as a basis for the preparation of personnel and other activities in the area of radiation safety.

(13) Availability of guidance for establishing requirements in terms of qualification and recognition of different categories of workers and practices associated with the area of radiation safety.

(14) Availability in the region of qualified experts to meet needs in terms of knowledge and guidance in the field of radiation safety.

(15) Existence of services for evaluating the radiation safety infrastructure and the legislative and regulatory framework (IRRS, EPREV, ORPAS, etc.)

(16) Existence of international programmes for the conditioning and repatriation of disused radioactive sources.

(17) Existence of a database that reflects the current radiation safety situation of countries of the region (RASIMS).

(18) Open and ongoing exchange of professional experience, training, regulatory documents, etc. in the area of nuclear and radiation safety through networks (REPROLAM, etc.).

(19) Existence of essential technical services to support radiation safety infrastructure.

(20) Existence of professional societies associated with areas of radiation safety.

(21) Public opinion in favour of the protection of the public and the environment.

(22) Large number of training programmes implemented and provided by the IAEA.

7.4. NEEDS/PROBLEMS

This section presents the results of the analysis undertaken on the basis of the SWOT analysis, with identification of the needs/problems in the sector, their justification, objective and indicator.

The needs/problems are given as a function of the TOTAL GRADE of priority, in accordance with the prioritization table under section V (Prioritization of needs/problems).

R1. Insufficient application and implementation among end users of principles and requirements concerning radiation protection set out in international safety recommendations for the control of medical exposure in digital radiology, computed tomography, interventional procedures and radiotherapy.

Justification: In view of the universality and magnitude of medical exposure of the population, and the fact that compliance with internationally recommended radiation protection requirements [71], in particular concerning application of the principle of justification and optimization programmes, is not required by respective regulatory authorities in the nuclear and health areas, all parties involved must strive to increase the radiation protection of patients and the public. In addition, a lack of awareness of radiological risk and of a safety culture in medical practice, that lead to the unnecessary exposure of patients and, on occasions, of medical staff, have been identified.

Objective: To raise the level of compliance with radiation protection requirements with regard to medical exposure, with particular emphasis on digital radiology, computed tomography, interventional procedures and radiotherapy.

Indicator: The number of countries to have documented that they have increased the degree of implementation of RASIMS performance indicators associated with optimization of medical exposure in digital radiology, computed tomography, interventional procedures and radiotherapy (elements 3, 6, 8 and 12 TSA3).

R2. Lack of guarantees in countries of the region to ensure that governments maintain a sustainable national regulatory system for radiation protection and safe transport of radioactive material.

Justification: The vast majority of Member States in the region have a legally established regulatory body. However, this does not guarantee in all cases the existence of a sustainable national regulatory system for radiation protection that provides the regulatory body with sufficient resources to fulfil 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. The majority of countries have limited human and financial resources to fulfil all their designated responsibilities under the legal framework. In some cases, workers are poorly paid and lack motivation; the tenure of staff of regulatory bodies is not always guaranteed, which puts at risk institutional memory and knowledge management.

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: The number of countries to have documented that they have increased the degree of implementation of RASIMS performance indicators associated with a legal and budgetary framework and human resources enabling them to ensure the stability and sustainability of the regulatory programme for radiation safety and the safe transport of radioactive material (elements 1, 2, 3, and 4 TSA1).

R3. Insufficient management systems in regulatory bodies to ensure compliance with all legislative responsibilities in the countries and recommendations of IAEA standards.

Justification: The majority of regulatory authorities face limitations in terms of their action and do not cover all activities and practices, in particular in diagnostic radiology. Justification: The majority of regulatory authorities face limitations in terms of their action and do not cover all activities and practices, in particular in diagnostic radiology. Management systems are not established in regulatory bodies in many countries. Furthermore, there is no requirement to implement these management systems in connection with facilities and activities. Implementation and control of radiation protection programmes and their optimization remain weak. Procedures for authorization and inspection have not been formalized, enforcement systems are non-existent, weak, or no decision has been taken on their use. Insufficient use is made of computer systems for recording sources. Their use is limited in terms of organization of the work of the regulatory body, and implementation of a phased approach. There is not always harmonious coexistence of more than one regulatory authority, compromising effective independence is undermined in some countries where regulators are operators of activities that are also regulated. There is still a lack of officially established coordination and cooperation between different national authorities. Regulations are lacking or not in line with recent international recommendations in the area of radiation safety. Poor enforcement of safety assessment requirements.

Objective: To consolidate the work of the regulatory bodies on the basis of an established management system that facilitates fulfilment of the responsibilities under national legislation and recommendations of IAEA standards.

Indicator: The number of countries to have documented that they have increased the degree of implementation of RASIMS performance indicators associated with the processes, procedures, records and reports of the management systems in accordance with the performance indicators set out in the IAEA standards: GSR Part 1 and GSR Part 3 [70, 71] (elements 8, 9, 11, 12 and 14 TSA1).

R4. <u>Insufficient coverage by the radiation protection services (individual internal and external monitoring and workplace monitoring) of occupationally exposed workers in the countries. Inadequate implementation of quality systems in technical services and the lack of availability of unified or centralized national records of occupational dose in all countries.</u>

Justification: Although the number of technical services for external dosimetry has increased in the region, there is still a lack of coverage, particularly concerning neutron and beta dosimetry. Because of a lack of internal dosimetry services in the majority of 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 contamination of surfaces in workplaces remain limited. Quality systems in these services have not been implemented in all countries and technical competence has not been recognized by the body concerned. The majority of countries do not have centralized national records of occupational dose and therefore do not have information on levels of exposure associated with different practices; actions for optimization are not promoted.

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 monitoring of the workplace).

To establish and keep updated national records of occupational dose in countries of the region.

Indicator: The number of countries to have documented that they have increased the implementation of RASIMS performance indicators associated with individual monitoring, external exposure, internal contamination, workplace monitoring, and that they have established national records of the doses received by workers (RASIMS: elements 2, 3 and 4 TSA2).

R5. <u>Lack of national strategies and policies for the safe and sustainable management of radioactive waste and improvement in the safe management of waste and disused sources.</u>

Justification: In the majority of countries there are no national strategies and policies approved by the government for the safe and sustainable management of radioactive waste, including the conditioning and safe storage of radioactive waste and disused radioactive sources, and for the use of the tools of declassification and clearance. In countries of the region there are metal recycling industries where orphan sources have appeared, or may do so, and if such sources are not detected and properly managed they may result in exposure of the public and industrial workers, and costly economic losses. In most of the countries of the region, no action has been taken to identify existing exposure scenarios (for example NORM) and to evaluate their radiological impact with a view to taking the appropriate regulatory measures. In the majority of countries, no solutions have been identified for the final disposal of radioactive waste and disused radioactive sources.

Objective: The establishment and implementation, by governments, of national policies and strategies to guarantee the safe and sustainable management of radioactive waste. The implementation of actions to increase the safety of radioactive waste and existing disused sources and improve capacity for detection and safe management of orphan sources.

Indicator: The number of countries in the region with national policies established by the government for the safe and sustainable management of radioactive waste; with licensed storage facilities for radioactive waste and systems for the security and physical protection of orphan sources (RASIMS: elements 7 and 8 TSA4 and element 10 TSA1).

R6. Limited capacities in countries for planning, notification and response with regard to radiological emergencies, including the provision of medical care to those affected, systematic analysis of accidents and dissemination of information.

Justification: There are capacities in the region (plans, procedures, first responders) that can be strengthened and used in the event of an emergency situation, and which, if appropriately coordinated through official mechanisms (e.g. RANET), could be made available to the country concerned. In most countries, shortcomings have been identified in the evaluation of threats for planning and response to radiological and nuclear emergencies, taking into account aspects associated with mitigation of the potential consequences of the emergency itself and the response. Health-care resources in the region for those injured in emergency situations are not properly identified, and there are not enough experts to provide guidance on the medical response in the event of nuclear and radiological emergencies. Although actions have been taken to improve the knowledge and infrastructure of the first responders, they need to be strengthened further in the majority of countries. No systematic analysis has been performed of the accidents that have occurred in the region. A number of countries of the region are still not party to conventions on radiological and nuclear emergencies.

Objective: To increase capacities for planning, recording and responding to emergencies, including the provision of medical care to those affected, systematic analysis of accidents and dissemination of information.

Indicator: The number of countries to have documented that they have increased the degree of implementation of RASIMS performance indicators associated with basic responsibilities: identification, notification and activation, and elements associated with infrastructure in order to respond to radiological and nuclear emergencies (elements 1, 4 and 14 of TSA5)

R7. Limitations for calibration at the level of radiation protection, radiotherapy and radiodiagnostics by secondary standards dosimetry laboratories (SSDL) in the region.

Justification: Services for the calibration and verification of equipment in the secondary standards dosimetry laboratories in the region are not sufficient to meet the needs of the end users in terms of levels of radiation protection, radiotherapy and radiodiagnostics with photon radiation. This is mainly due to the obsolescence of the equipment and the shortage of trained technical staff. In addition, problems often arise at customs concerning the transfer of equipment between countries.

Objective: To identify real needs for calibration in the region, the existing problems, actual possibilities for providing these services as well as proposed solutions for the short and medium term to ensure the updating and coverage of the dosimetry calibration services required in the region for calibration of equipment or dosimeters in areas including external radiotherapy, brachytherapy, radiology, nuclear medicine and radiation protection.

Indicator: Document with a full diagnosis of the situation in the region and proposed solutions, which will serve as an input for the national authorities, national organizations responsible for the secondary standards dosimetry laboratories and the IAEA in the identification of strategies and solutions.

R8. Insufficient application of management systems among end users, including the promotion and implementation of a safety culture.

Justification In most countries of the region, a shortage of management programmes for implementation of radiation protection programmes in facilities has been identified. No specific actions have been determined for the development and promotion of a safety culture among end users of the different activities, which could increase the potential for radiological accidents and incidents.

Objective: To establish and implement management systems in facilities in countries of the region and to promote the development of the safety culture concept.

Indicator: The number of countries to have documented that they have increased the degree of implementation of RASIMS performance indicators associated with the implementation of management systems and a safety culture in facilities (element 6 TSA2).

R9. Absence of national strategies for education and training in radiation safety.

Justification: In the majority of countries there is an absence of sustained national strategies for education and training in radiation safety for all practices and places of work at the basic and postgraduate levels. There is a shortage of human and financial resources for the establishment of sustainable national education and training programmes in occupational radiation protection for facilities and activities, in particular in medical practice.

Objective: To develop and implement national strategies for education and training in radiation safety and optimization of radiation protection in all practices (with emphasis on medical practice) and the regulatory body.

Indicator: The number of countries to have documented that they have increased the degree of implementation of RASIMS performance indicators associated with the design and implementation of the national strategy for education and training in radiation safety (elements 4, 5, 6 and 7 TSA6).

R10. <u>Insufficient information and consultation with interested parties and the public concerning possible radiation risks associated with facilities and activities, and processes and decisions of the regulatory body.</u>

Justification: Information and consultation with interested parties and the public regarding possible radiation risks associated with radiation activities and facilities are not sufficiently developed in the majority of countries despite being recognized in the Fundamental Safety Principles [69] and IAEA Safety Requirements [70, 71, 72].

Objective: To raise public awareness of the radiation risks associated with the facilities and activities and encourage the involvement of interested parties in the processes and decisions of the regulatory body.

Indicator: The number of countries to have documented that they have increased the degree of implementation of RASIMS performance indicators associated with national mechanisms to provide for the participation of interested parties and public knowledge regarding the radiation risks associated with the facilities and activities and the processes and decisions of the regulatory body (element 13 TSA1).

7.5. PRIORITIZATION OF THE NEEDS/PROBLEMS

The prioritization of the needs/problems in the sector is shown in Table 6.

Table 6. Prioritization of the needs/problems in the radiation safety sector.

	NEED/PROBLEM	SEVERITY	TIME	EXTENT	RELEVANCE	TOTAL GRADE	DIFFICULTY	R/D	FINAL GRADE
R1	Insufficient application and implementation among end users of principles and requirements concerning radiation protection set out in international safety recommendations for the control of medical exposure in digital radiology, computed tomography, interventional procedures and radiotherapy.	4.5 It seriously affects the protection of the patient, the public and workers.	4.5 It is advisable that these requirements are implemented as soon as possible.	5.0 This is a problem in most of the countries of the region.	5.0 It is essential for the protection of patients, workers and the public.	**19.0**	4.5 It is linked to the wide application and number of practices in each country and the need for experienced regulatory bodies to comply with requirements.	**1.11**	**21.09**
R2	Lack of guarantees in countries of the region to ensure that governments maintain a sustainable national regulatory system for radiation protection and safe transport of radioactive material.	4.5 It affects the establishment of the national regulatory framework and effective compliance concerning the responsibilities of the regulatory body.	5.0 It is advisable that these guarantees are put in place as soon as possible.	4.0 This is a problem for a large group of countries in the region.	4.5 It is vital for the establishment and application of a regulatory framework in line with international standards for the protection of workers, the public and the environment.	**18.0**	4.5 It is linked to the political will of governments to establish an effective framework and regulatory infrastructure to ensure the protection of workers, the public and the environment.	**1.00**	**18.00**
R3	Insufficient management systems in regulatory bodies	4.5 It affects the regulatory control	4.0 It is to be recommended that	4.0 This is a problem for a group of	4.5 It is vital for the establishment and	**17.0**	4.0 It is linked to the political will of the	**1.13**	**19.21**

	to ensure compliance with all legislative responsibilities in the countries and recommendations of IAEA standards.	of sustained and effective compliance with radiation protection requirements concerning workers, the public and the environment.	these criteria be implemented as soon as possible.	countries in the region.	application of a regulatory framework in line with international standards for the protection of workers, the public and the environment.		regulatory bodies to comply with the requirements set out in the legislation in force and lack of support of senior government authorities for implementation of these actions.		
R4	Insufficient coverage by the radiation protection services (individual internal and external monitoring and workplace monitoring) of occupationally exposed workers in the countries. Inadequate implementation of quality systems in technical services and the lack of availability of unified or centralized national records of occupational dose in all countries.	3.5 This limits the monitoring of the level of safety of workers and facilities, and hampers appropriate control by the regulatory body.	3.5 It is advisable that these requirements are implemented as soon as possible.	4.0 This is a problem for the majority of countries of the region.	4.0 It is crucial for occupational radiation protection.	**15.0**	3.0 It involves established services and techniques for which quality systems are required. Regulatory bodies are needed for their practical implementation.	**1.34**	**20.1**
R5	Lack of national strategies and policies for the safe and sustainable management of radioactive waste and improvement of the safe management of waste and disused sources.	3.5 It affects the establishment of responsibilities, the regulatory framework and the financial mechanisms to ensure the sustainable	3.5 It is advisable that these requirements are implemented as soon as possible.	4.5 This is a problem for the majority of countries of the region.	3.5 Implementation will ensure the safety and sustainability of the management of radioactive waste and disused radioactive sources, and	**15.0**	4.0 It is linked to the political will of the governments to establish an effective legal framework and the infrastructure necessary to ensure the safe and sustainable	**0.88**	**13.20**

		management of radioactive waste, protection of the public and the environment.			ultimately, protection of the public and the environment.		management of radioactive waste.		
R6	Limited capacities in countries for planning, notification and response with regard to radiological emergencies, including the provision of medical care to those affected, systematic analysis of accidents and dissemination of information.	3.5 No capacity exists in some countries.	3.0 It should be undertaken relatively soon given its serious nature. A plan of action needs to be drawn up.	4.0 This is a problem for a large group of countries in the region.	3.5 Coordination will increase the level of protection of the personnel affected and the public.	**14.0**	3.5 It is mainly linked to coordination to make use of installed capacities and training in some areas, such as medical care.	**1.00**	**14.00**
R7	Limitations for calibration at the levels of radiation protection, radiotherapy and radiodiagnostics by secondary standards dosimetry laboratories in the region.	3.0 It affects the quality and objectivity of the radiation protection of workers, patients and the environment.	3.0 It should be undertaken relatively soon given its serious nature.	3.5 This is a problem for a large group of countries in the region.	4.0 It is important for the protection of occupationally exposed workers and crucial for the protection of patients and the public involved with it.	**13.5**	4.0 It is linked to investment in expensive laboratories, equipment and trained personnel in the region: It has been shown that this activity has not been sustained in some countries where these laboratories have been established.	**1.00**	**13.5**
R8	Insufficient application of management systems among end users, including the	3.0 Failure to apply these concepts has an adverse effect on	3.0 It should be undertaken in the medium term in	4.0 This is a problem for the majority of countries of the	3.5 Implementation will increase the sustainability of	**13.5**	4.0 It is linked to the political will of the regulatory authorities	**0.88**	**11.88**

	promotion and implementation of a safety culture.	the structure, effectiveness, scope and continuity of the regulatory authority.	view of the complexity of the problem.	region.	regulatory control, and, ultimately the protection of workers, the public and the environment.		to ensure compliance with the requirements set down in the legislation in force and international standards (IAEA).		
R9	Absence of national strategies for education and training in radiation safety.	3.0 It compromises the sustainability of the radiation protection infrastructure.	3.0 A solution needs to be found soon to ensure the availability of trained staff in the near future.	3.5 This is a problem for a large group of countries in the region.	3.5 Considerable, in order to have trained professionals and technicians in post and ensure effective continuity of radiation safety	**13.0**	3.0 Coordination is necessary to benefit from established and available national and regional services and capacities.	**1.17**	**15.21**
R10	Insufficient information and consultation with interested parties and the public regarding possible radiation risks associated with facilities and activities, and processes and decisions of the regulatory body.	2.5 This is a safety requirement that has not been implemented widely in the region due to the low national priority attached to this subject.	3.0 It should be undertaken in the medium term given the complexity of the problem and the fact that this is an increasingly important subject for the public.	3.5 This is a problem for a large group of countries in the region.	3.0 Implementation will increase transparency and credibility in the regulatory programme.	**12.0**	3.5 It is linked to the political will of the regulatory authorities to ensure compliance with the requirements set down in the legislation in force and international standards, and to respond to the increasing demand for information from the public.	**0.86**	**10.32**

RADIATION TECHNOLOGY

8. RADIATION TECHNOLOGY

8.1. BACKGROUND

The activities began with a review of the validity of the needs/problems set out in the previous RSP covering the period 2007–2013. This analysis also considered the results being achieved in projects financed by ARCAL/IAEA in Latin America and the Caribbean based on the reports analysed at the meeting in held November 2012, in Havana, Cuba.

The needs of the region were identified in the areas of: water (treatment), the environment (treatment of emissions and waste), coastal engineering, advanced materials, medicine, cultural heritage (characterization and preservation), industrial processes, natural resources and inspection technologies, taking into account the use of the following nuclear techniques:

- Radiation processing technology (gamma, electrons and X-rays)
- Radiotracers
- Nucleonic control systems
- Non-destructive testing;
- Analytical techniques

An analysis of strengths, weaknesses, opportunities and threats was undertaken for each area and, finally, the needs identified were characterized and prioritized in accordance with the methodology identified for this purpose, taking into account the following: severity, time, extent, relevance and difficulty.

Application of radiation technology

The use of radiation technology to improve quality of life has several 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 [73–87]. 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 Co-60), 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 (wires, cables, tyres, semiconductors, foam, films, tubes, etc.), colouring gemstones, preservation of cultural objects, archives, disinfection and conservation of books and preservation of the environment (treatment of industrial waste water, combustion gases and sludge) [77–89].

Short-lived *radiotracers (T)*, such as: Na-22, Tc-99m, I-131, Br-82, La-140, etc., are used for diagnosis in industrial processes, including troubleshooting, underground leaks, residence time, and 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. The cost/benefit ratio is greater than 30 and provides for better product quality, productivity, safety and process availability. [74–79, 88–91].

Nucleonic control systems (NCS): There are different 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 (Am-Be, Cf-252). These systems use radiation sources such as Am-241, Cs-137 and X-ray or neutron generators coupled with detectors that provide the signal used for process control [73, 77–82, 83–87].

Analytical techniques (L): Nuclear analytical techniques can be used for laboratory analysis; they can also be configured for on-line analysis for process control. The most important analytical techniques are neutron activation analysis, X-ray fluorescence, prompt gamma neutron activation analysis and particle-induced X-ray emission [76, 80, 83, 87].

Non-destructive testing (NDT): This 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 with gamma rays and X-rays welding defects in pipework and tanks [92-106]. Computed tomography and neutrography are also important. Non-nuclear techniques include ultrasound, induced current, liquid penetrant and magnetic particle testing, etc.

8.2. ANALYSIS OF THE REGIONAL SITUATION

The Latin American and Caribbean region comprises 45 countries in an area covering 20.4 million km^2. The population was 581.4 million in 2012, and is growing at a rate of 1.2% per year. The gross domestic product (GDP) of the region was US $5344 thousand million in 2012. This year the annual per capita income was US $8981. The life expectancy at birth was 74 years in 2011. Primary enrolment has reached 107% [107–108].

It is forecast that the region's population will increase to approximately 902 million in 2050 [109–110].

Figure 1 shows the growth of GDP and figure 2 shows industrial growth in different regions of the world.

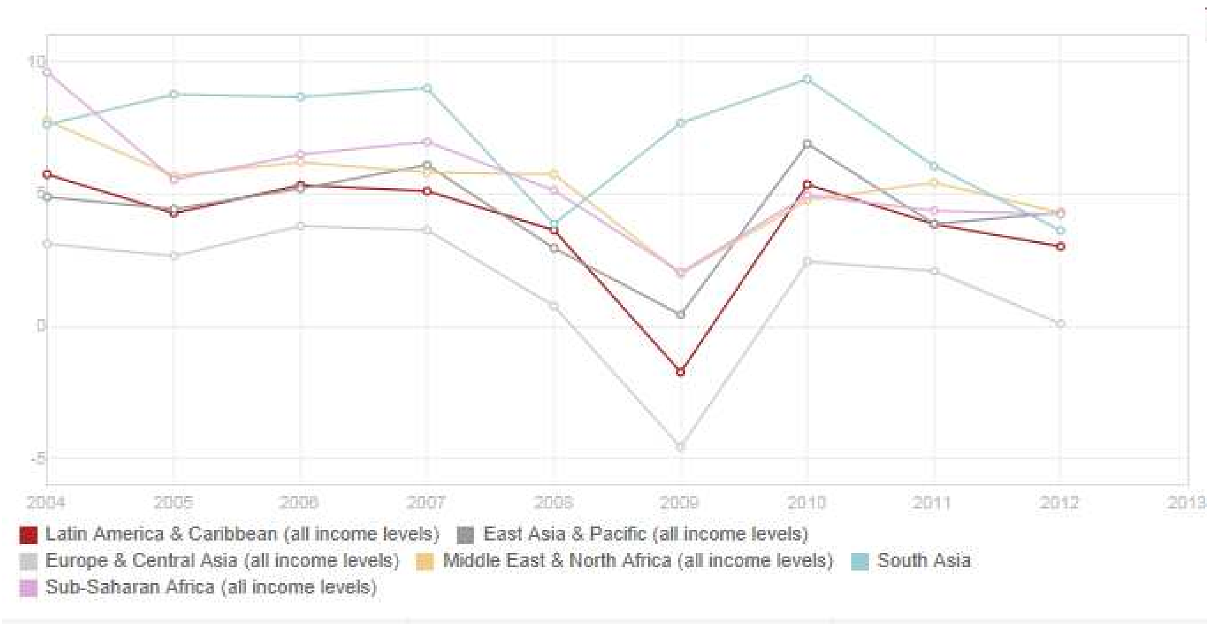

Fig. 1. Annual GDP growth by region of the world[4].

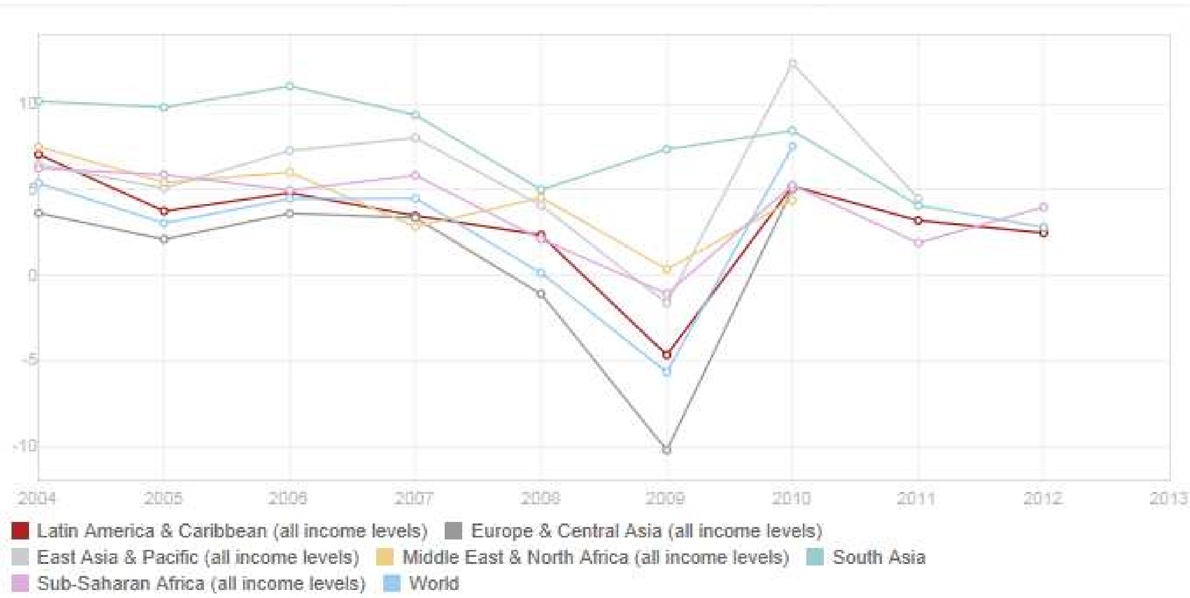

Fig. 2. Industrial growth by region of the world[5].

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[4] 3 Prepared on the basis of the data available in: The World Bank: Dataset name: World Development Indicators: Size of the economy (http://wdi.worldbank.org/table/1.1)

[5] 4 Prepared on the basis of the data available in: The World Bank: Dataset name: World Bank national accounts data, and OECD National Accounts data files (http://data.worldbank.org/indicator/NV.IND.TOTL.KD.ZG/countries/ZJ-Z7-Z4-ZQ-8S-ZG-iW?display=graph)

Table 7. Percentage of the population employed in industry in 2011.

Country	%	Country	%	Country	%
Argentina	23.8	Ecuador	17.7	Panama	18.6
Bolivia	20.6	El Salvador	21.2	Paraguay	17.8
Brazil	21.9	Guatemala	23.8	Peru	17.0
Chile	23.1	Honduras	19.0	Uruguay	21.5
Colombia	20.6	Mexico	25.2	Venezuela	21.9
Costa Rica	19.8	Nicaragua	16.5		

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

The following tables present the situation in the countries of Latin America in terms of the use of radiation technologies. Table 8 shows the situation of the countries with regard to the use of radiotracers in: diagnosis of industrial production and processes; radiotracers in the environment, in oil fields, in sediment transport; nucleonic control systems in industrial quality control, exploration of mineral resources and the environment. Table 9 presents the situation with regard to non-destructive testing by country; Table 10 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 8. 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		
Venezuela	X	X		

Table 9. Use of non-destructive testing in countries of the region.

Country	Partial development	Advanced
Argentina		X
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	
Venezuela		X

Table 10. 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, reserch and development	Red Perspex, Amber Perspex, Gammachromic	Fricke, Alanine, Dichromate	Yes	No
	Private Co-60 plant. Current activity 1070 kCi	Service	Red Perspex, Amber Perspex, Gammachromic	Dichromate /CNEA	No	No
Brazil	3 private Co-60 plants (CBE/Embrarad). Current activity 6000 kCi	Service and development	Red Perspex		Yes	Yes (Private)
	01 10 MeV electron accelerator CBE/Embrarad	Service				
	Co-60 plant, IPEN. Current activity 400 kCi	Service, research and development	Radiochromic, Red Perspex, Amber Perspex	Fricke, Alanine	Yes	No
	12 private electron accelerators from 0.3 a 10 MeV	Service	Alanine, CTA	Alanine	Yes	
	2 electron acclerators, IPEN (1.5 MeV – 37.5 mA and 70mA)	Service, reserch and development	CTA		Yes	
	1 Gamma cell activity: < 5 kCi, IPEN	Service and development	Red Perxpex, Amber Perspex Gammachromic, GEX B3	Alanine	Yes	No
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, reserch and development	Red Perspex, Amber Perspex	Fricke, Ceric/Cerous	Yes	Non-certified quality system
Dominican Republic	Electrom Beam Sure Beam 10/15 (Fenwall)	Service	GEX B3	NPL	Yes	ISO 13485 and ISO 11137

	Electron Beam Integrated model (Fenwall)	Service	GEX B3	NPL	Yes	ISO 13485 and ISO 11137
Ecuador	Co-60 plant, capacity 1.5 kCi. Current activity < 4 kCi	Research and service	No	No	No	No
	5 - 10 MeV accelerator	Research and service	PVC	Radiochromic; calorimetric	No	No
	Gammacell JL SHEPHERD 109 Initial activity of 11 kCi. Current activity 0.7 kCi	Investigation	Fricke	No	No	No
El Salvador	JS 7500 plant. 1974 - accident 1991 - 18 kCi	Closed	No	No	No	No
Mexico	Plant Co JS 6500. Current 800 kCi, (ININ)	Service	Red Perspex	Alanine / NIST	No	ISO9001: 2008
	Gammacell 125 Ci, (ININ)	Research and service	Red Perspex	No		ISO9001: 2008
	Transelektro LGI-01 3247, (ININ)	Research and service	Red Perspex	No		ISO 9001: 2008
	VickRad 3Ci, (ININ)	Research and service	Red Perspex	No		ISO 9001: 2008
	UNAM 100 kCi	Research and service	No information	No information	No information	No information
	Sterigenix 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
	Self-shielded horizontal Cs-137, SAGARPA Tuxtla Gutz (closed)	Service	No information	No information	No	No information
Peru	Gammacell 220 Excel 220 IPEN 11.4 kCi	Service	Ethanol chlorobenzene, Fricke	Fricke	No	No
	Multi-use Co-60 plant PIMU 18.7 kCi	Service	Ethanol chlorobenzene, GEX FILM	Fricke	No	No

	Gamma Beam 127 Nordion. Current 11 kCi SENASA	Flies and service	Gafchromic; Fricke	Fricke	No	No
	Shepherd & Associates Mod 109-68 5.2 kCi	Flies	Gafchromic; Fricke	Fricke	No	No
	Shepherd & Asociates Mod 109-68 4.4 kCi	Flies	Gafchromic; Fricke	Fricke	No	No
	Cs-137 9.6 kCi	Flies		Fricke	No	No
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				
Venezuela	IR 216 irradiator PEGAMMA Co - 60 design 1000 kCi. Current 85 kCi	Service	Red Perspex, Fricke	No	No	No

The applications of radiation technologies are continuing to grow and are developing 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 the cultural heritage, the environment and protecting coasts from erosion.

With the increase in experience and confidence in the technology, 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 group identified the following areas in which the use of radiation technologies could be beneficial.

Water (treatment):

- Treatment of water for reuse or discharge (RP);
- Treatment of sludge (RP);
- Optimization of water treatment processes (T);
- Measurement of precipitation (T);
- Areas of protection for hydrographic basins (T).

Environment (treatment of emissions and waste):

- Treatment of gaseous effluents (RP);
- Discharge from industries (T);
- Sediment transport (T).

Coastal engineering:

  - Protecting coasts from erosion (T, NCS);
  - Ports and dredging work, optimization and administration (T, NCS).

Advanced materials:

- Polymer modification and treatment (RP);
- Processing of advanced materials (RP);
- Measurement of wear using thin layer proton activation (T).

Medicine:

- Sterilization of medical products (RP);
- Sanitization of recipients (RP);
- Hydrogels (cosmetics, medicines, etc.) (RP);
- Irradiation of blood (RP);
- Irradiation of biological tissues (human and animal) (RP);
- Production of radioisotopes for medicine and industry (RP).

Cultural heritage (characterization and preservation):

- Preservation of historic objects (RP);
- Disinfection of archives, documents, paintings (RP);
- Authentication and characterization of objects (L);
- Preservation of objects (T, RP);
- Analysis of objects (NDT).

Industrial processes:

- Optimization of processes (T);
- Quality control (NCS);
- Modification and improvement of products (RT).

Natural resources:

- Food:
  - Quarantine treatment and preservation using irradiation (RP);

  - Quality control (NCS);
  - Development of packaging using natural polymers (RP):
  - Optimization of processes (T).
- Agriculture:
  - Sterilization of soils (RP);
  - Plant growth promoters (using natural polymers) (RP);
  - Super water absorbers (using natural polymers) (RP);
  - Biocides (using natural polymers) (RP);
  - Soil erosion studies (T);
  - Studies of fertilizer and pollutant transfer (T);
  - Sanitization of animal feed (RP);
  - Sanitization of agricultural products – flowers, wood, tobacco, seeds, etc. (RP).
- Mining (T, L, NCS):
  - Exploration (NCS);
  - Processing (T, NCS).

Inspection technologies (NDT):

- Metals, welding, pipework, energy plants, oil and gas, aerospace industry, etc.;
- Concrete, roads, bridges, buildings, etc.;
- In-service inspection of power plants, in particular nuclear power plants;
- Harmonization of training and certification of operators;
- Digital training of operators.

8.3. SWOT ANALYSIS

8.3.1. STRENGTHS

Water (RP, T)

(1) Water is a strategic and limited public resource in all countries.

(2) Simple and accessible technologies.

(3) No waste generated.

(4) Helps to clean waste water for its discharge or subsequent use.

(5) Helps to increase the availability and quality of potable water.

(6) Non-nuclear tracer techniques are often more expensive and technically more difficult to apply.

(7) Existing experience in various countries of the region.

(8) Capacity to improve the efficiency of existing water treatment facilities.

Environment (RP, NCS)

(9) Common interest across the region to protect the environment.

(10) Efficient and effective technologies.

(11) Treatment of combustion gases with electron beams is the only technology that can eliminate effectively all pollutants simultaneously, without generating waste.

(12) Groups for radiotracers and nucleonic control systems and equipment currently exist in the majority of countries.

Coastal engineering (T, NCS)

(13) Coastal management is important for the region.

(14) Accessible and validated technology.

(15) Already exists in some countries.

(16) Very high cost-benefit ratio.

(17) Need to protect the environment.

Advanced materials (RP)

(18) Common interest across the region to add considerable value to materials.

(19) Energy efficient and environmentally friendly processes.

(20) Improvements in quality and safety.

(21) Affordable (in some cases, cheaper than the alternatives).

(22) Infrastructure established in the region.

Medicine (RP)

(23) Well-established and available technology.

(24) Strong commercial demand for sterilization of medical instruments and irradiation of blood.

(25) Accessible and simple technology.

(26) No waste generated.

(27) Technology is free of additives and at ambient temperature.

(28) The technology is usually accepted by the general public.

(29) The technology is more efficient and competitive than non-nuclear technologies (once the facility has been established).

Cultural heritage (RT, L, NDT)

(30) Latin America has a very rich cultural heritage, which spans the entire region.

(31) At least four countries have and use applicable technologies.

(32) Existing infrastructure.

(33) Some countries are already working with UNESCO.

(34) Experience in the IAEA (model projects and knowledge).

(35) Accessible technologies.

(36) Simple and effective technologies.

(37) No waste generated.

Industrial processes and production (T, NCS, L)

(38) It is in the common interest to improve the efficiency of production processes.

(39) Tools available for all industries.

(40) Currently, in some countries of the region, radiotracer techniques and nucleonic process control systems are already used in some activities.

(41) Improvement in the quality of the products and continuing quality control of the products.

(42) Very high cost-benefit ratio.

(43) Improvement in the competitiveness of the industry.

(44) Existing institutes and businesses capable of providing the technology.

(45) Accessible technology.

Natural resources (RP, T, NCS)

(46) The region is rich in natural resources (agriculture, marine products, minerals, hydrocarbons).

(47) Simple and accessible technologies.

(48) No waste generated.

(49) Some hydrogels are already being produced and used in the region.

(50) The materials used could be waste from another process and the final product becomes a product with great value added.

(51) There are already reference products on the market (IAEA projects in Asia).

Inspection technologies (NDT, NCS)

(52) Common interest in certified products.

(53) Improvement in product quality.

(54) Improvement in the safety of operation and protecting human life.

(55) Accessible technology.

(56) High cost-benefit ratio.

(57) The simplicity of the technology.

(58) Various projects have already been implemented in this field.

(59) Existing network of service providers and end users of the technology.

(60) Advanced countries can facilitate regional cooperation.

8.3.2. WEAKNESSES

Water (RP, T)

(1) Development of technology for radiation treatment is still in its infancy.

(2) Potential actors have limited information about the technologies.

(3) Few facilities to demonstrate the technology.

Environment (RP, NCS)

(4) Capital investment for new radiation processing facilities is high.

(5) There are no providers of systems ready for use.

(6) Few facilities to demonstrate the technology.

Coastal engineering (T, NCS)

(7) Limited availability of radiotracers.

(8) Public concern.

(9) Very strict regulations.

Advanced materials (RP)

(10) More qualified staff are required.

(11) Development of naturally clean products.

(12) Few companies report the use of these technologies.

Medicine (RP)

(13) Some countries do not have appropriate irradiation facilities.

(14) There is a need to improve compliance in the region with international standards in force.

(15) In some cases, investment required for a new irradiation facility is greater than for the application of non-nuclear techniques.

Cultural heritage (RT, L, NDT)

(16) Incomplete reference figures on the use of the technologies in the region.

(17) Lack of experience and knowledge regarding the appropriate use of the technologies.

(18) Lack of institutional networks between custodians and the technology operators.

(19) Limited knowledge of the technology among custodians.

Industrial processes and production (T, NCS, L)

(20) Limited availability of radiotracers.

(21) Restrictive regulation.

Natural resources (RP, T, NCS)

(22) Demonstration of the technology will take time.

(23) Groups need to be established for a long time for the development of capacity (sustainability).

(24) Early stage of development in the region.

(25) The need to standardize certain processes and products (for commercial use).

Inspection technologies (NDT, NCS)

(26) Certification of staff training is not harmonized.

8.3.3. THREATS

Water (RP, T)

(1) Public acceptance of the radiation treatment of water is low.

(2) Compliance with laws and regulations concerning treatment of waste water and sludge is weak.

Environment (RP, NCS)

(3) Other alternatives are available for the reduction of specific pollutants, but is only limited to one.

Coastal engineering (T, NCS)

(4) The existence of alternative technologies (with lower yield but fewer regulations).

Advanced materials (RP)

(5) Competition from alternative technologies.

Medicine (RP)

(6) There are non-nuclear techniques for sterilization processes that may be cheaper.

Cultural heritage (RT, L, NDT)

(7) Perception of risk among possible end users regarding the benefits of the technology.

(8) Other non-nuclear techniques are available (but may not be the most effective).

Industrial processes and production (T, NCS, L)

(9) Perception of risk among possible end users regarding the benefits of the technology.

(10) Authorizations from different national authorities are required.

Natural resources (RP, T, NCS)

(11) Perception of risk among possible end users regarding the benefits of the technology.

(12) Facilities that use the technology must be licensed.

(13) Authorizations from different national authorities are required.

Inspection technologies (NDT, NCS)

(14) Increase in the cost of disposal.

(15) Increasingly restrictive regulations.

8.3.4. OPPORTUNITIES

Water (RP, T)

(1) The increase in waste water from human and industrial activities should be addressed, and is one of the main challenges for the region.

(2) Regional need to improve the quality and availability of water resources.

(3) Helps to reduce waste and clean up the environment.

Environment (RP, NCS)

(4) Industrialization increases the release of pollutants and this is why there is a growing demand for technologies to reduce them.

Coastal engineering (T, NCS)

(5) Better understanding of the effects of climate change on the costs increases the need for 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 generates a need to develop, improve and manage port infrastructure.

(9) Better coastal management has indirect effects on tourism.

Advanced materials (RP)

(10) Existing facilities can be used for the development of advanced materials tailored to the specific needs of countries.

(11) Development of new advanced materials for new applications (for example, production of hydrogels, fuel cells).

Medicine (RP)

(12) Countries of the region are updating their irradiation facilities.

(13) Irradiation of medical implements is necessary and there is a large demand for this.

(14) The technology is respectful of the environment.

Cultural heritage (RT, L, NDT)

(15) Involvement of government public service institutions (archives, research).

(16) Opportunities to establish links and cooperate with Portugal, France and the United States (countries that already use this technology).

(17) High potential of visibility.

(18) Expansion of the tourist industry.

Industrial processes and production (T, NCS, L)

(19) Industrial development requires increased use of technologies.

(20) To combat climate change.

Natural resources (RP, T, NCS)

(21) The primary and secondary sectors are very important in the region. Considerable potential exists to use natural polymers for the processing of raw materials in industrial products.

(22) Economic incentive to use the technology.

(23) Respectful of the environment (could transform waste into a product).

(24) Potential association with the FAO.

(25) Marketing potential through the Southern Common Market (MERCOSUR) and the North American Free Trade Agreement (NAFTA).

(26) Some countries have made progress while others have shown potential interest in the technologies.

(27) The IAEA has an interest in the development and use of radiation technology for the mining industry.

Inspection technologies (NDT, NCS)

(28) The need to introduce advanced technologies.

8.4. NEEDS/PROBLEMS

This section presents the results of the analysis undertaken on the basis of the SWOT analysis, with identification of the needs/problems in the sector, their justification, objective and indicator.

The needs/problems are set out in terms of the TOTAL GRADE of priority, in accordance with the prioritization table in section V (Prioritization of needs/problems).

T1. <u>The need to identify, outline and publicize the specific and strategic opportunities and challenges in the region concerning the promotion and use of radiation technology in priority applications.</u>

Justification: A clear baseline concerning the specific and strategic opportunities and challenges in the region is essential for the future development and application of radiation technologies in the region itself. Furthermore, dissemination and promotion of information concerning how these technologies can be used in different fields are important not only for the development of the technologies but also in order to meet needs associated with cultural heritage, natural resources, industrial processes and production, and inspection processes. The preparation of a regional reference plan would make it possible to update the status of the use of radiation technologies in the region, identify opportunities and propose a plan of action that is disseminated and implemented by interested parties in order to identify the impact of the ARCAL programme at the end of the cycle.

Objective: To prepare a regional reference plan with interested parties on the use of radiation technologies, which identifies opportunities, benefits, prospects, challenges and needs in terms of human resources training in the region, as well as the main strategies to be implemented in order to expand these applications.

Indicator: Availability of a regional reference plan to identify opportunities for radiation technologies in Latin America and the Caribbean.

T2. <u>The need to increase the competitiveness of regional industries and reduce the environmental impact.</u>

Justification: Regional industries, such as mining, the processing, production and food and agriculture industries, face a number of problems, including relatively low competitiveness, the impact of their activities on the environment, the poor quality of finished products, inefficient energy consumption and scarcity of strategic minerals. For example, radioactive tracers and nucleonic control systems can help to tackle the abovementioned problems, and minimize their impact, from their origin through to their elimination.

Objective: To improve the competitiveness and quality of the products of regional industries (natural resources, foods and products), reducing environmental impact, through the use of radiation technologies in accordance with international practice.

Indicator: The number of countries and institutions/industries in the region that use radiation technologies in industrial processes.

T3. <u>The need to harmonize quality management procedures for the application of radiation technologies in the region.</u>

Justification: Harmonization of quality management procedures (QC/QA) is essential to correct and reduce deficiencies and commercial barriers in the region within the context of international trade.

Objective: To establish harmonized procedures for quality control, quality assurance and quality management concerning the application of radiation technologies in the region.

Indicator: The number of countries implementing harmonized procedures for the application of radiation technologies in accordance with international standards.

T4. <u>To improve the quality of industrial goods and services, safety of operation and protection of human life in the region.</u>

Justification: Radiation technologies (NCS, NDT, T, RP) play an important role in general quality control programmes and are essential in order to improve the safety of infrastructures and structures and the competitiveness of regional industries within the international normative framework.

Objective: To develop the use of advanced technologies and improve harmonization of methodologies and training of staff in accordance with certification standards and regimes, such as the new 2012 ISO 9712 standard on NDT.

Indicator: The number of countries that have established methodologies and an established structure for the training of staff, in accordance with the new 2012 ISO 9712 for NDT and the certification of processes using radiation technologies.

T5. <u>To improve the use of the natural, renewable, non-toxic resources of the Latin American and the Caribbean region for sustainable development.</u>

Justification: Radiation technologies can contribute in an efficient, simple and affordable manner to promoting the use of the region's natural, renewable and non-toxic resources. These technologies can be utilized for the preparation of products derived from or based on natural polymers or wastes that could be used in areas, including health care (dressings), agricultural applications, food conservation, cosmetics, water purification or environmental remediation.

Objective: To improve radiation processing of the region's natural, renewable, and non-toxic resources (natural polymers) to increase agricultural production, reduce waste and contamination and improve health care, helping to clean up the environment and promote other sustainable development solutions.

Indicator: The number of products developed in the region using radiation processing.

T6. <u>To characterize and preserve the rich and vast cultural heritage of Latin America and the Caribbean.</u>

Justification: Radiation technologies can contribute in a simple, effective and affordable manner to the characterization, conservation and restoration of cultural goods (paintings, documents, artefacts, objects, etc.) throughout the region. The technologies already exist in the region, as does the infrastructure, and there are successful cases that could be used as a reference for the region.

Objective: To increase the use of irradiation treatment, analytical techniques and non-destructive testing to help to preserve the rich and vast cultural heritage of Latin America and the Caribbean.

Indicator: The number of countries that use radiation technologies to preserve the cultural heritage in accordance with international good practice.

8.5. PRIORITIZATION OF THE NEEDS/PROBLEMS

The prioritization of the needs/problems in the sector is shown in Table 11.

Table 11. Prioritization of the needs/problems in the radiation technology sector

No.	NEED/PROBLEM	SEVERITY	TIME	EXTENT	RELEVANCE	TOTAL GRADE	DIFFICULTY	R/D	FINAL GRADE
T1	The need to identify, outline and publicize the specific and strategic opportunities and challenges in the region concerning the promotion and use of radiation technology in priority applications.	4.88 There is no regional reference plan for the promotion and use of radiation technologies.	4.69 To contribute to the economic development of the region and reduce environmental impact.	4.81 It affects the whole region; very few techniques are being used. Gamma irradiation is most widely used in the region.	5.0 The use of radiation technologies can help to increase the competitiveness of industry in the region, improve quality of life, care of the environment and conservation of the region's cultural heritage.	**19.38**	2.38 Various applications of radiation technologies are not well known in the region.	**2.10**	**40.70**
T2	The need to increase the competitiveness of regional industries and reduce the environmental impact.	4.50 There is an urgent need to increase the competitiveness of industrial processes and reduce the environmental impact.	4.44 There is a need to increase the competitiveness of industry in the region and improve product quality.	4.81 It affects the whole region; very few techniques are being used. Gamma irradiation is most widely used in the region.	4.75 To contribute to the economic development of the region and reduce environmental impact.	**18.50**	2.0 Various applications of radiation technologies are not well known in the region.	**2.38**	**44.03**
T3	The need to harmonize quality management procedures for the application of radiation technologies in the region.	4.56 It is necessary to harmonize procedures and reduce trade barriers in the region.	4.31 To contribute the economic development of the region.	4.63	4.56	**18.06**	2.19 Need for greater dissemination and joint meetings to harmonize procedures for the irradiation of products in	**2.08**	**37.57**

							accordance with international standards.		
T4	To improve the quality of industrial goods and services, safety of operation and protection of human life in the region.	4.31 There is no standardized procedure for the training of personnel in the region.	4.31 Where qualified personnel exist, the efficiency and benefits of the use of radiation technology will be improved.	4.81 It affects the whole region; the procedures for the training of personnel need to be standardized.	4.50 Where qualified personnel exist, the efficiency and benefits of the use of radiation technology will be improved.	**17.93**	2.00 There is a need to disseminate more widely the new standard for the training of personnel in the region.	**2.25**	**40.34**
T5	To improve the use of the natural, renewable, non-toxic resources of the Latin America and Caribbean region for sustainable development.	4.31 There is an urgent need to use renewable natural resources, such as non-toxic natural polymers to help to reduce contamination and improve the competitiveness of the region.	3.81 Advanced technologies are necessary for the profitable use of radiation processing of natural polymers.	4.94 Radiation processing of natural polymers is used in isolated cases in the region.	4.38 Non-toxic natural polymers can be used in health care, agriculture and industry.	**17.44**	2.44 Lack of dissemination of the technologies, infrastructure training of human resources.	**1.80**	**31.39**
T6	To characterize and preserve the rich and vast cultural heritage of Latin America and the Caribbean.	3.88 The cultural heritage of the region has been lost due to the lack of advanced techniques for	4.0 It is important to have advanced and non-destructive technologies.	4.69 In isolated cases in the region, some radiation technologies are used for characterization or preservation.	4.38 It is important to preserve the rich and vast cultural heritage of the region at a competitive cost.	**16.95**	2.56 Lack of dissemination of the technologies, infrastructure and training of human resources.	**1.71**	**28.99**

		characterization, preservation and conservation.							

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ANNEX 1. RSP 2016-2021. PRIORITIZATION METHODOLOGY

I.1. INTRODUCTION

In preparing the Regional Strategic Profile (RSP) for Latin America and the Caribbean for 2016–2021, a methodology was used for assigning priorities within a set of needs/problems of a strategic nature identified within different thematic areas. This methodology envisages the adoption of specific attributes for which a graded scale of values is established for each need/problem, and which, at the end of the process, allows a quantitative comparison among them.

For this, a group of regional experts was established; the experts were selected on the basis of their professional experience, as well as their technical knowledge and knowledge of the situation in each thematic area in Latin America and the Caribbean. They worked with representatives of the Supervision and Coordination Group and IAEA officials to properly characterize each need/problem; participants engaged in a process of discussion and debate until a consensus was achieved and a single value was determined for each of the grades assigned to each attribute.

It must be highlighted that this type of prioritization process considers the need to assign quantitative values to a qualitative evaluation, which always introduces a subjective component in the process. In order to be objective and minimize potential effects in the evaluation, consideration was given to including a justification of each need/problem as well as of each grade assigned to the respective attributes.

Another aspect relevant considered concerns the various levels of development of each country in the region, in particular when considering the six thematic sectors chosen for the preparation of the Profile: food security, human health, environment, energy, radiation safety and radiation technology. food security, human health, environment, energy, radiation safety and radiation technology.

I.2. ATTRIBUTES FOR PRIORITIZATION

Five attributes were adopted for the evaluation of needs/problems, taking into account the strategic nature of the RSP. These are set out in Table A.1.

Table A.1. Attributes for the evaluation of needs/problems

SEVERITY	This is a measure of the degree of severity of the need/problem, taking into account the negative impact of not addressing it.
TIME	This is related to the degree of urgency in 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**	Two components are evaluated: • The extent to which nuclear applications can contribute to addressing/solving the

	need/problem. • It is considered that the solution to the problem is also of 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.

I.3. SCORING FOR PRIORITIZATION AND JUSTIFICATION

To prioritize needs/problems by sector, prioritization grades are used for the attributes SEVERITY, TIME, EXTENT and RELEVANCE. These grades range from 1 to 5, in accordance with the information shown in Table A.2.

Table A.2. Prioritization grades for the attributes.

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

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

Below is Table A.3, which shows the needs/problems and attributes. Once the need/problem has been described, the grades assigned for each attribute are entered in each cell along with its justification, and the sum of these grades is entered in the TOTAL column.

Table A.3. Prioritization in the sector.

Sector:

Attributes NEED/PROBLEM	SEVERITY	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 scoring for the need/problem within the sector and can range from 4 to 20 points.

One important aspect that must be taken into account when evaluating the TOTAL is that the values in the field cannot be the same for two or more needs/problems. If this situation arises, adjustments must be made to the grades assigned to the attributes, including by using decimal places if necessary.

The TOTAL score establishes the prioritization for the set of needs/problems in the sector.

Another attribute that is evaluated is the degree of DIFFICULTY in solving the need/problem. This is done by adding a column to the attributes table presented above, 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	SEVERITY	TIME	EXTENT	RELEVANCE	TOTAL	DIFFICULTY
1)	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)	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 shown in Table A.2.

I.4. QUADRANT GRAPH

In analysing the date obtained, there are four possibilities that are defined relative to the values of the RELEVANCE and DIFFICULTY attributes.

I. HIGH RELEVANCE and LOW DIFFICULTY

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

II. HIGH RELEVANCE and HIGH DIFFICULTY

This corresponds to the second category of priorities.

III. LOW RELEVANCE and LOW DIFFICULTY

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

IV. LOW RELEVANCE and HIGH DIFFICULTY

This fourth category includes the last set of needs/problems which can, in principle, be eliminated and which should 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. Figure A.1 shows a quadrant graph of RELEVANCE and DIFFICULTY, which shows these four possibilities:

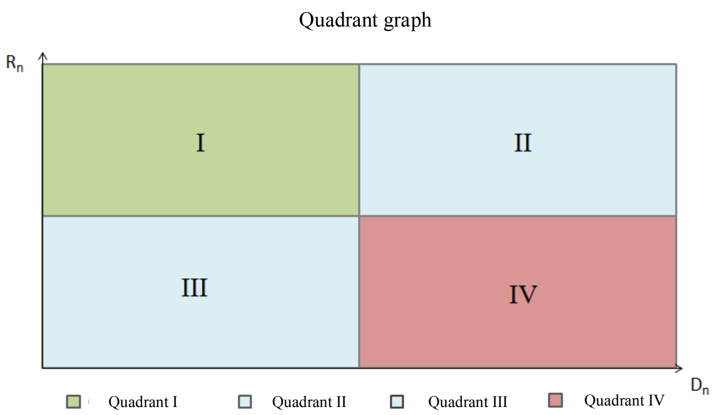

Figure A.1. Quadrant graph of RELEVANCE and DIFFICULTY

I.5. FINAL PRIORITY GRADE (FPG)

Once the data has been analysed in terms of the RELEVANCE and DIFFICULTY of the needs/problems, the next step is to determine the final priority grade (FPG).

This is calculated using the values obtained from the following formulae:

$$\text{Total priority grade (TPG)} = \text{Severity (S)} + \text{Time (T)} + \text{Extent (E)} + \text{Relevance (R)}$$

$$\text{Final priority grade (FPG)} = \text{Total Priority Grade (TPG)} \times \frac{R}{\text{Difficulty (D)}}$$

Where the total priority grade represents the sum of the attributes: Severity, Time, Extent and Relevance for each need/problem in each thematic 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.

Using the final priority grade values obtained, it is possible to establish an order of priority for the needs/problems, by quadrant, for each one of the sectors.

Finally, it is important to mention that the prioritization methodology is a support tool that provides decision-makers with a basis for a quantitative comparison of needs/problems, although this is not necessarily the only consideration that may be taken into account when prioritizing a set of needs/problems. The application of the quadrant graph for prioritization will be dealt with in a guide concerning the implementation strategy for the RSP 2016–2011, which will be drawn up on the basis of the information contained in this document.

GLOSSARY

ARCAL:	Co-operation Agreement for the Promotion of Nuclear Science and Technology in Latin America and the Caribbean
ATCB:	ARCAL Technical Coordination Board
BSE:	Bovine spongiform encephalopathy
BSS:	Basic Safety Standards
CEPIS:	Pan American Centre for Sanitary Engineering and Environmental Sciences
CIEMAT:	Research Centre for Energy, Environment and Technology
CIER:	Regional Energy Integration Commission
CNCD:	Chronic Noncommunicable Diseases
CO_2:	Carbon dioxide
CVD:	Cardiovascular diseases
DBO_5:	five-day biochemical oxygen demand
DDT:	dichlorodiphenyltrichloroethane
DIRAC:	Directory of Radiotherapy Centres of the IAEA
DNA:	Deoxyribonucleic acid
ECLAC:	Economic Commission for Latin America and the Caribbean
FAO:	Food and Agriculture Organization of the United Nations
GDP:	Gross domestic product
GEF:	Global Environment Facility
GF-TAD:	Global Frontiers – Trans-Boundary Animal Diseases initiative
GHG:	greenhouse gases
GLADA:	Global Assessment of Land Degradation and Improvement
ha:	hectare
HAB:	harmful algal bloom
HCB:	hexachlorobenzene
H5N-1:	avian influenza
IAEA:	International Atomic Energy Agency
IARC:	International Agency for Research on Cancer
ICP-MS:	inductively coupled plasma mass spectrometry
IFA:	International Fertilizer Industry Association
I-131:	Iodine 131
IRMS:	isotope ratio mass spectrometry
ISO/IEC:	International Organization for Standardization/International Electrotechnical Commission
L:	analytical techniques
LAC:	Latin America and the Caribbean
Mo99/Tc99m:	Molybdenum-99/metastable Technetium-99
NAA:	neutron activation analysis
NAEL:	Environment Laboratories Monaco (Monaco and Seiberdorf) of the Department of Nuclear Sciences and Applications, IAEA
NAFA:	Division of Nuclear Techniques in Food and Agriculture, IAEA
NAPC:	Division of Physical and Chemical Sciences (IAEA) of the Department of Nuclear Sciences and Applications, IAEA
NATs:	Nuclear analytical techniques
NCCP:	National Cancer Control Programme

NCS:	nucleonic control systems
NDT:	non-destructive test
NEFW:	Division of Nuclear Fuel Cycle and Waste Technology, Department of Nuclear Energy IAEA
NENP:	Division of Nuclear Power, Department of Nuclear Energy, IAEA
NEPES:	Division of Nuclear Power Engineering, Department of Nuclear Energy, IAEA
NORM:	naturally occurring radioactive material
NPP:	nuclear power plants
NSIEC:	Incident and Emergency Centre, Department of Nuclear Safety and Security, IAEA
NSNI:	Division of Nuclear Installation Safety, Department of Nuclear Safety and Security, IAEA
NSRW:	Division of Radiation, Transport and Waste Safety, Department of Nuclear Safety and Security, IAEA
NWS:	New World screwworm
OECD:	Organisation for Economic Co-operation and Development
OLADE:	Latin American Energy Organization
PAHO:	Pan American Health Organization
PET:	Positron emission tomography
PET-CT:	Positron emission tomography – computed tomography
POCs:	Persistent organic compounds
PIXE:	proton-induced X-ray emssion spectrometry
PIXE/RBS:	proton-induced X-ray emssion spectrometry/Rutherford backscattering
PM10:	particulate matter up to 10µm in diameter
PM2.5:	particulate matter up to 2.5µm in diameter
PR:	radiation processing technologies
RNA:	Ribonucleic acid
RF:	radiopharmaceuticals
RI:	radioisotopes
RSP:	Regional Strategic Profile for Latin America and the Caribbean
SCBD:	Secretariat of the Convention on Biological Diversity
SPECT:	single photon emission computed tomography
SWOT:	Strengths, weaknesses, opportunities, threats
T:	radiotracers
TCLA:	Division for Latin America, Department of Technical Cooperation (IAEA)
TENORM:	Technologically-Enhanced, Naturally-Occurring Radioactive Materials
UN-DESA:	United Nations Department of Economic and Social Affairs
UNEP:	United Nations Environment Programme
UNFCCC:	United Nations Framework Convention on Climate Change
UNFPA:	United Nations Population Fund
UNICEF:	United Nations Children's Fund
WHO:	World Health Organization
XRD:	X-ray diffraction
XRF:	X-ray fluorescence

DEFINITIONS

Regulatory authority:	Authority or authorities designated or otherwise recognized by a government for the purpose of regulation in the area of protection and safety.
Authorization:	The granting, by a regulatory body or other government organ, of written permission for an operating entity to conduct specific activities.
Calibration:	Measurement or adjustment of an instrument, component or system to make sure that its accuracy or response is acceptable.
Contamination:	The presence of radioactive substances on surfaces or within solids, liquids or gases (including the human body), where their presence is neither intentional nor desirable, or a process that causes the presence of radioactive substances in those places.
Regulatory control:	Any form of control or regulation that a regulatory body applies to facilities or activities for reasons associated with radiation protection or the safety and security of radioactive sources.
Safety culture:	A set of characteristics and attitudes of organizations and persons that establishes, as an absolute priority, the need to give issues associated with protection and safety the importance they deserve.
Radioactive waste:	Materials, whatever their physical form, that result from practices or interventions, and for which no further use is identified i) that contain or are contaminated by radioactive substances and have an activity or activity concentration higher than the legal limits, and ii) exposure to which is not excluded from the standards.
Final disposal:	The placement of waste in an appropriate facility without any intention of recovery.
Nuclear or radiological emergency:	An emergency in which danger due to: a) energy from a nuclear chain reaction or disintegration of the products of a chain reaction; or b) exposure to radiation, exists, or is considered to exist.

Safety evaluation:	An evaluation of all aspects of a practice that are related to protection and safety; in the case of an authorized facility, it includes selection of the location, design and operation of the facility.
Disused source:	A radioactive source that is no longer used or is not intended to be used in the practice for which it was authorized.
Orphan source:	A radioactive source that is not subject to regulatory control, possibly because it has never been subject to such control or because it was abandoned, lost, mislaid, stolen or transferred without the appropriate authorization.
Radioactive waste management:	A set of administrative and operational activities concerning the handling, previous treatment, processing, conditioning, storage and final disposal of radioactive waste.
Naturally occurring radioactive material (NORM):	Radioactive material that does not contain significant quantities of radionuclides different to natural radionuclides.
Regulatory body:	An authority or set of authorities to which the government of a State entrusts legal powers to implement regulatory processes, including the granting of authorizations, and thus to regulate nuclear and radiation safety, radioactive waste and transport.
Emergency plan:	A description of the objectives, policy and basic concepts of operations to respond to an emergency, and of the structure, capacities and responsibilities inherent in a systematic, coordinated and effective response.
Emergency preparation:	The capacity to adopt measures that will mitigate effectively the consequences of an emergency in terms of human health and safety, quality of life, goods and the environment.
First responders:	The first members of an emergency service to respond to an emergency where it occurs.
Radiation protection programme:	Structured arrangements aimed at facilitating appropriate consideration of radiation protection measures.

Radiation protection:	Protection of persons against the effects of exposure to ionizing radiation and means to achieve this.
Emergency response:	The application of measures to mitigate the consequences of an emergency in terms of human health and safety, quality of life, goods and the environment.
Radiation risk:	The harmful health effects of exposure to radiation (including the possibility of such effects occurring).
Radiation safety:	The establishment of appropriate operating conditions, prevention of accidents or mitigation of their consequences, resulting in the protection of workers, the public and the environment from excessive dangers caused by radiation.
Management system:	A set of interrelated and interacting elements (system) aimed at establishing policies and objectives and at ensuring that these objectives are achieved in an effective and efficient manner.

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