

Article

# National Strategy for Framing and Prioritizing Environmental Protection Research and Development Topics

Adi Wolfson <sup>1,\*</sup>, Ofira Ayalon <sup>2</sup> and Daniel Madar <sup>3</sup>

<sup>1</sup> Green Processes Center, Department of Chemical Engineering, Sami Shamoon College of Engineering, Basel/Bialik Sts., Beer-Sheva 8410001, Israel

<sup>2</sup> Samuel Neaman Institute, Technion and Department of Natural Resources & Environmental Management, University of Haifa, Haifa 3498838, Israel; aofira@gmail.com

<sup>3</sup> SP Interface, Rehovot 7630804, Israel; danielm@sp-interface.com

\* Correspondence: adiw@sce.ac.il

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**Abstract:** One of the key methods for implementing the sustainability model in practice includes environmental vision and policy, goal setting, preference areas, and setting environmental research and development (ER&D) priorities. There are different ways to identify and prioritize the R&D of governments or international bodies, yet we have not found a comprehensive study or strategy regarding the framing and prioritization of ER&D at a national level. The aim of the study was to present a methodological approach, principles, and criteria for the prioritization of national ER&D. The study was initiated with a comprehensive literature review, including studies reported by a wide range of entities and countries, followed by the identification of eight principles to select ER&D priorities. Finally, each of the environmental issues was ranked in the frame of every principle, based on a quantitative criterion or criteria, considering global challenges, local needs, and capabilities.

**Keywords:** environmental research and development; sustainability; survey methodology; strategic model

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## 1. Introduction

The extensive impact of the human lifestyle on the state of the natural environment and ecosystem activity has led to the development of policies, models, practical tools, and technologies to reduce the ecological footprint of humanity [1]. The various models seek to address the complexity of human–environment interactions and to balance the needs of both. One of the leading models in this field is the sustainability model, which is defined as nature’s ability to sustain processes and processes’ ability to sustain stability over time taking into account environmental, societal, and economic aspects [2–4]. This means that a balance should be maintained between the ability of nature to continue to sustain the natural systems (life cycles, food chains, etc.) and to support life on earth over time and the development and needs of a particular population (human or otherwise) that depends on these processes. Finally, toward the end of the 20th century and even more so into the 21st century, “climate changes” and “global warming” were marked as being the greatest environmental threats to planet Earth and to humankind, and took a central stage in the environmental struggles. Thus, both the effect of economic activities and growth on environmental externalities and particular on climate change, and vice versa, should be also considered [5,6].

One of the key channels for environmental management in particular and at the state level in general is the promotion of environmental research and development (ER&D) [7,8]. Therefore, investment in ER&D and the implementation of environmental technologies in the world is increasing annually, in terms of both budgets and employees. Moreover, since most human activities affect the environment, ER&D is very extensive and includes many different areas. It is also important to note that the definition of “environmental research” has changed considerably over the years: whereas about 100 years ago it usually belonged to the natural sciences, such as chemistry and biology, and some 40 years ago it focused on research in the fields of ecology and environmental sciences, today it belongs to many and diverse fields of research, including social sciences and engineering. In addition, environmental research is now based on an interdisciplinary approach because of the need to connect the various complex fields to produce solutions.

One of the main issues in the context of ER&D is the investment of countries in R&D budgets and research manpower. This investment addresses local and global needs and challenges, and therefore it is necessary to decide on the priority areas for R&D in the environment and its protection in which the state should invest, to examine the existing research infrastructures as compared with those required in each field, and to define accordingly the investments required to bridge this gap in each area [8]. There are different ways to identify and prioritize the R&D of countries as a whole and R&D in the field of environmental quality and protection in particular. Most frequently, the methodology and principles for deciding on areas are based on existing policies (international, national, etc.) and their derived objectives, comprehensive literature surveys, consultation with experts and stakeholders, and analyses of future needs and challenges [9]. In addition, the determination of priority areas for R&D in countries, and R&D in the field of environment in particular, is based on the definition of appropriate criteria. Thus, there is a need to present a methodology, principles, and criteria for the prioritization of national ER&D. Finally, it is important to ensure that research priorities are not biased by institutional barriers, narrow agendas and interests, or the needs of markets and business opportunities.

Since its inception, the State of Israel has had to deal with complex environmental issues, both because of its unique location between desert and Mediterranean climates, and because of the country’s accelerated development and high population growth relative to OECD countries. In addition, because of geopolitical constraints, the State of Israel is a kind of island in terms of resources, beginning with water and continuing with energy. Therefore, over the past few decades, Israel has invested in several environmental research areas, which it defined as a national objective, and has even become a global leader in R&D and an important player at the global level. One of these areas is related to the domestic water economy, from effluent recovery and desalination technologies to unique technologies for cost-effective irrigation [10]. In addition, R&D in Israel has developed in the field of solar energy [11], as well as in the fields of fuel substitutes and smart transport. Research in the last area, for example, did not actually exist in Israel a decade ago, but today Israel ranks third in the world after the US and China in terms of investment in transportation technology start-ups and in fifth place in the number of companies that have attracted investment since 2010 [12].

## 2. Aims of the Study

The State of Israel wants to continue to develop ER&D and to advance its position in the world in the fields of ER&D and clean technologies. Therefore, during 2017–2018 the Israeli Ministry of Science conducted research to prioritize the ER&D in which the state should invest, to examine existing research infrastructures in the country, as compared to those required in each field, and to define the investments required to bridge the gap in each field. The research addressed the local and global challenges, as well as the research budget and national and international manpower resources.

The study was conducted in three key stages: (1) a comprehensive literature review on methodology, principles, and criteria for selecting priorities in environment and environmental protection research areas; (2) based on the literature review, discussions and consultations were held by the research team with the advisory committee and various researchers and stakeholders, where 18 ER&D topics were identified, out of which a limited group of 3 topics was selected based on the

principles and criteria defined in the first phase; and (3) an analysis of the R&D status in Israel was conducted for the three selected priority topics, including a comparison with selected countries. Within this framework, budgets, manpower, publications, and patents, as well as companies and curricula, were mapped in each field. Finally, recommendations were made for promoting future R&D in Israel in general, and in the three priority areas selected in particular.

This article presents the first stage of the research conducted in Israel, which is focused mainly on the methodology, principles, and criteria for prioritization of R&D activity areas in the field of the environment and its protection at the national level with regard to infrastructure and manpower. The study output is a systematic compilation of the current literature in the field, allowing the execution of an in-depth and structured process to determine the R&D issues that are preferred in the field of environmental protection in other countries.

### **3. Review of Worldwide Methodologies, Principles, and Criteria for Determining Priorities for R&D and ER&D**

The determination of priority areas for the R&D of countries in general, and for R&D in the field of environment in particular, was based primarily on a comprehensive literature survey. As part of this study, the literature review included several studies and reports from a wide range of organizations: international organizations (such as the UN), unions of countries (the EU, for example), governments, industry organizations, non-governmental organizations, and more. The review addresses the methodology and principles we identified that were employed to conduct the research and the criteria used to select the priority areas for research.

#### *3.1. The United Nations (UN)*

The United Nations Environment Program [13] defined the methodology for identifying the major issues for environmental research. The methodology includes four key steps: (1) a review of the relevant literature; (2) brainstorming among a broad-based group of experts; (3) multiple consultations with experts and affiliates (smaller groups than above); and (4) surveys conducted by individual experts and affiliates by email, phone, or regular mail.

In addition, the fourth evaluation report on the issue of climate change of the IPCC-Intergovernmental Panel on Climate Change of 2007 [14] contains four principles for evaluating the environmental policy tools that are reported in the literature, which can also be used to select environmental research priority areas: (1) environmental effectiveness: does the policy fit the expected environmental goal or realize positive environmental results? (2) cost-benefit: can the policy achieve its objectives with minimum costs to society? (3) distribution considerations: these include the policy distributive implications, which include dimensions such as fairness and justice, although there are also other implications; and (4) institutional practicality: will the policy tool be considered legitimate, accepted, adopted, and applied?

The United Nations Environment Program Periodic Global Environmental Reviews [11] also address priorities. It is noted that, in order to conduct an Integrated Environmental Assessment (IEA), it is essential to identify a list of key environmental issues and then classify them into a number of manageable issues. The desired outcome is a comprehensive but flexible list. The United Nations Environment Program also notes that often, even after a process for identifying areas and environmental issues, the list is too long to be included in a national analysis process, given the constraints of time and human and financial resources. Therefore, it is necessary to rank the priorities for both the areas and the specific issues. Finally, the program identifies several challenges related to this prioritization, including: (1) a problem in selecting the criteria for ranking priorities, such as high cost, significant risk, public awareness, and political attention; (2) identifying the context of/approach to the priorities outlined in official policy statements; (3) the identity of the affinity holders who select the priorities and the legitimacy of their representation; (4) the number of issues that can be included in the National Assessment Report; and (5) the process used to agree on the priority issues.

### 3.2. European Union (EU)

The EU's guide to "Strategy for Research and Innovation—Smart Specialization" [15] presented a detailed methodology for research in this area. The strategy's approach is focused on demonstration and implementation, which are done in combination with academia, industry, and civil society, and form a solid foundation for achieving the goals. The work sought to address all the complex socio-economic challenges facing Europe in the 21st century. Therefore, it was decided to invest more in research in the fields of innovation and entrepreneurship, and to develop an integrative strategy and approach to innovation that would maximize the potential for research and innovation of Europe as a whole and of each country and region in particular. It has also been decided that the main route to achieving these goals is to invest wisely in areas where Europe has smart expertise. The work defines that the process of selecting the priority areas for research should be based on qualitative and quantitative information and the definition of key criteria for choosing the priority areas.

The work also presented principles for research and innovation strategy: (1) choice and critical mass: selection of a limited number of priorities based on local strengths and international expertise, including concentration of budgeting sources to ensure more effective management; (2) relative advantage: mobility of talent through the science and technology connection and through business capabilities and needs; (3) connecting and clusters creation: the development of clusters at an international level; and (4) collaborative leadership: a smart innovation system based on private–public partnership.

In addition, the work also presented criteria for selecting priorities for R&D to ensure that the following principles are achieved: (1) the presence of capabilities and assets (such as unique personnel and technologies) in each proposed area, and if possible, a quantitative analysis of both capabilities and assets; (2) the potential for diversification of domains; (3) the critical mass or critical potential in the domain; and (4) the region's position at the international level. These criteria should be applied by decision makers to select priorities while focusing on strengths and relative advantages and also on the identification of new opportunities. In addition, the work indicates that the method of presenting priorities is important. For example, if the topic is too general, such as "Green Energy", it will be difficult to pinpoint its strengths and relative advantage. Therefore, the issues should be focused. Moreover, one must be careful not to be attracted to areas just because they have a strong lobby or emulate another area where successes have already been recorded.

### 3.3. Organization for Economic Cooperation and Development (OECD)

The methodology for selecting the OECD ER&D priority areas was based on technology forecasts resulting from workshops attended by hundreds of thousands of technology forecasting experts, during which key technologies emerged that should be explored and for which policies have to be set [16]. The OECD's work in this field summarizes the proceedings of several expert workshops conducted by the governments of Canada, Finland, Germany, England, Russia, and the EU.

### 3.4. The Davos World Economic Forum (WEF)

A report of the WEF on "Innovation for the Earth—Harnessing Technology Breakthroughs for People and Earth" [17] sought to explore the extent to which technology can produce revolutionary solutions to the climate change problem. The report noted that the Fourth Industrial Revolution (4IR), the beginning of which we are witnessing, presents unprecedented opportunities to solve the climate problem. The report lists technologies that can improve the sustainability of the planet, especially in the context of climate change, alongside game-changers, where combinations of 4IR technologies may radically change different domains. It also includes recommendations for the promotion of the field by businesses, investors, governments, and research organizations, including: (1) investment in R&D in these areas to harness them for the benefit of solving the problems of climate change, (2) the establishment of cross-sectoral programs (environment, computers, materials engineering, etc.) to promote the mentioned game-changers, and (3) the introduction of the field of sustainability into the curricula of computer science, material engineering, etc.

### 3.5. The United States (US)

The US Environmental Protection Agency's (EPA) strategic plan for 2014–2018 [18] presents an outline for protecting public health and the environment in every community in America. The outline includes a methodology for evaluating a program based on some of the criteria included in the EPA Environmental Report [19]. These criteria help the tracking of trends in the state of the environment and the environmental impacts on human health. They were designed to provide information within the EPA for planning, prioritization, and decision-making processes, as well as to provide information to the public on the state of the environment. According to this methodology, there are over 80 criteria that help answer 23 questions that are critical to the EPA's mission to protect environmental and public health. These questions may indicate important environmental trends but are not necessarily questions that the EPA can answer comprehensively. The questions were developed in consultation with other scientists and experts from across the agency, where questions and criteria can be changed over time to reflect changes in EPA priorities. After a question has been developed, the EPA also determines which criteria are appropriate to help answer it and what data are available for developing these criteria. In addition, some criteria can help answer more than one question.

The Scientific Branch at the US EPA has also established guidelines for designing and stabilizing environmental research programs [20]: (1) public health protection and sustainability promotion, (2) science quality and transparency, (3) achieving a broad impact, (4) innovation, (5) information on decisions and actions, (6) seeking collaboration, and (7) support for high-performance teams.

The US Department of Energy's Environmental Management Program also stated that the most important step in setting priorities for effective research is that of identifying, defining, and selecting criteria to determine priority areas [20]. By its definition, the first step should be to identify the factors that should be considered for setting priorities, and the proposed method is to develop "bottom-up" criteria; that is, affiliates were asked to review a preliminary list of criteria and recommend changes or additions. The basis for developing this list was a comprehensive list of previously developed assessment criteria, as shown in Figure 1.

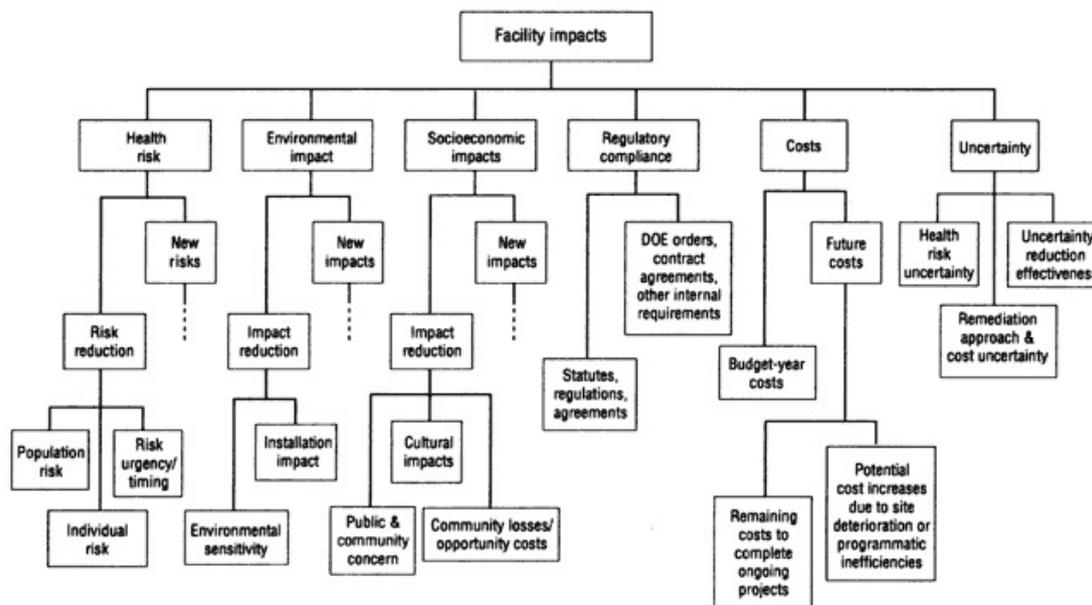


Figure 1. Criteria for examining R&D priorities [20].

The program of the US Energy Department of Environmental Management states that, to ensure an effective selection of criteria, the process should involve [20]: (1) a national panel of affiliates, (2) focus groups that can identify the problems to be considered when setting priorities, (3) dedicated specific stakeholder groups that can help ensure that the specific considerations are properly

integrated into the priority set, and (4) a panel of reviewers who can assess the information and help identify analytical gaps or inadequate information.

It was also found important to consider two characteristics: (1) the criteria should be quantified and ranked according to the importance and value of each criterion and regardless of the place where the activity takes place; and (2) risk and regulation considerations must be taken into account.

### *3.6. Sweden—Council for Research in Environmental Sciences and Agriculture and Spatial Planning*

The Swedish Council for Research in Environmental Sciences and Agriculture and Spatial Planning proposed a national strategy for environmental research for 2011–2016 [21], together with prioritized environmental research areas. The work was based on a survey and analysis of strategies and research in the field of the environment, conducted in the country by 2011. The methodology for identifying priority areas was based on national policy regarding the environment and agriculture in several stages: (1) survey and consultation with the various research partners, (2) review of reports and examination and assessment of environmental studies in various specific fields conducted in Sweden in the last decade, and (3) an analysis of investments in environmental research concerning a number of key questions. Finally, the mapping in this study was performed by analyzing the funding of research on various environmental issues by national entities as compared with funding in other countries.

### *3.7. Norway—Ministry of Environment Protection and Climate*

The Ministry of Environmental Protection and Climate of Norway has set priorities for environmental research for 2016–2021 [22] based on the overall goals and environmental objectives set by the Norwegian government. Further, the ministry has established guidelines for environmental research in the country, which serve as principles for selecting areas for R&D: (1) the study will be in accordance with Norway's environmental objectives, which are set in the budget of the Ministry of the Environment and Climate and in the definition of other political platforms; (2) the research in the field of the environment must be in cooperation with the European Community and other countries. It is important to encourage research in European settings and to consider the implementation of European environmental regulation; (3) it is of high importance for research to be able to develop and implement Norwegian environmental policy in order to meet national objectives and international commitments, (4) the research products should be distributed effectively to the general public and the various administrative systems, and (5) methods for monitoring and collecting information in the field of the environment, as well as digital systems for the use and sharing of environmental information and knowledge between research groups and various entities, must be developed.

### *3.8. Denmark—Ministry of Research and Information Technologies*

The Ministry of Research and Information Technologies in Denmark has conducted research in the field of environmental quality and energy [23], which included basic, strategic, and applied studies. The research also addressed the criteria for selecting research priority areas: (1) relevance to the impact on society and research development, (2) reasonableness, (3) quality and originality, and (4) special strengths.

### *3.9. Australia*

Unlike the process taking place in Sweden, Norway, and Denmark, and in the absence of strategic R&D policy and criteria for prioritizing R&D, the Australian Chief Scientist has prioritized research investment based on the research of models similar to those used in the US, UK, and EU [24]. The approach adopted by the Australian Chief Scientist, based on studies conducted in other countries, was first to identify areas that have demonstrated extensive and high-quality activity and those that deal with national issues. Later, competitive domains at the international level were also examined. Further, some principles for selecting the domains were established: (1) identification of

the major challenges facing communities, (2) identification of broad preferred areas, (3) the degree of funding of basic research required to ensure the continuity and succession of new ideas within or outside the priority domains, and (4) the execution of regular priority reviews, e.g., in the US the process is conducted every two years.

In order to streamline Australia's research effort with its competitive advantages, a methodology for identifying challenges was developed, which included the following steps: (1) the agreement of the Science Council community; (2) identification of practical challenges: the Chief Scientist together with the National Science, Technology and Research Committee (NSTRC) will consult with workgroups of experts from industry, the government, and research organizations to identify practical challenges that are suitable for research in any priority area; (3) the declaration of priority areas and the appropriate practical challenges; and (4) evaluation of the research activities.

### 3.10. World Health Organization (WHO)

The WHO conducted a study during 2008–2013 on “Research Priorities in the Environment, Agriculture, Infectious Diseases and Poverty” [8]. Naturally, the research topics that are relevant to organization are predefined and delimited and are focused on the domain of health, but it is important to present this paper because of the methodology used. The methodology consisted of four steps: (1) identification of key research gaps to define the scope of work; (2) assessment and adjustment of scientific information in relevant areas to increase the understanding of the relations and synergies between environmental, agricultural, and infectious diseases, with a special emphasis on poverty-related infectious diseases. The process also involved consultation with various affiliates from governments and local and international health and environmental organizations; (3) the performance of an extensive literature survey and consultation with experts, and (4) the definition of research priority areas based on prioritization criteria developed by the research team.

## 4. Methodology

As noted, a thorough literature survey conducted as part of the study examined the methodology for selecting preferred R&D topics in general, and ER&D topics in particular. However, in the various studies reviewed, the methodology was usually presented in a general way, and no works were found that detail the method(s) for selecting the preferred areas.

Policy development and governance in the field of environment must be knowledge-based. Thus, the environmental authorities must have information and knowledge on the current and expected state of the environment and develop appropriate tools and policy instruments. The purpose of a methodology for prioritizing ER&D topics is to provide guidance on priority areas and critical research gaps based on the evaluation and analysis of scientific information on local and global environmental research activities and challenges. An additional purpose is to identify priorities based on expected outcomes. It will result in an overview of the state of the ER&D and identifying what action needs to be taken and which investments should be made.

We offer a conceptual methodology for determining preferred research and development topics in the field of environmental science and technology that can be implemented in any country following these steps:

1. An international updated review of ER&D policies, principles, criteria, objectives, research topics, and budgets allocated to ER&D in different countries.
2. A national review of ER&D policies, principles, criteria, objectives, research topics, and budgets in the country.
3. Definition of national principles for framing ER&D.
4. Definition of national criteria for framing ER&D. In this context, it is important to ensure that the criteria fit the needs of future R&D in that country and are not necessarily dependent on the current research fields and those selected in other countries in the world.

5. Selection of a number of priority areas for ER&D by the research team and in consultation with experts and based on the surveys conducted in Steps 1 and 2 and the principles set out in Step 3.
6. Selection of a limited number of priority areas for ER&D based on the criteria set out in Step 4. These areas will be studied in-depth as follows:
  - A. Mapping of knowledge centers in national academia and industry: mapping among government agencies, academia, and industrial companies that deal with the field of environment as part of the nature of their business, as well as those that are required to engage in ER&D because of regulatory pressure.
  - B. Analysis of R&D status in each of the priority areas to be selected (research, knowledge, and infrastructure) for ER&D as compared to that of selected countries. The review will be conducted by using databases and reports of the OECD, UN, EU, and companies, using bibliometric indices (publications and citations) and various databases. The analysis will be performed using:
    - A presentation of comparative metrics that reflect R&D activity in a country versus countries with similar characteristics. Examples of metrics include national and private investment in ER&D, number of companies, number of researchers, number of patents, number of publications, and number of employees, both absolute and relative to the GDP or to the number of residents.
    - Identification of gaps and relative advantages in ER&D and technologies in the country in relation to the world.
  - C. Analysis of future infrastructure and manpower needs for ER&D and economy needs: mapping will be done by surveying academic institutions, government offices, and industrial companies dealing with the environment and by using databases.
  - D. Recommendations for promoting future ER&D issues.

## 5. Principles for framing ER&D

In order to define more precise and specific directions for ER&D, and to upgrade decision making, strategic planning, and policy, there is a need to define simple and practicable principles for framing ER&D priorities. These principles should take into account the effects of each topic on the individual and on society in general, at the local and global levels, and in the short and long terms, and also consider the cost-effectiveness of the topic and the ability to implement it.

Based on the literature survey mentioned above, as well as on the literature survey on the environmental challenges facing humanity and the place of research and development in addressing these challenges, the present study proposes eight principles that can be used to select ER&D priorities:

1. Impact on human society—while focusing on the degree of impact on public health. Both the magnitude and extent of the impact must be considered.
2. Impact on ecosystems and how they work—the degree of the impact on biodiversity, the marine environment, the desert environment, and more. Both the magnitude and extent of the impact must be considered.
3. Achieving a broad impact—areas that may solve more than one environmental problem, for example, in climate change as well as in air pollution areas. Who are the end consumers of the field: the broad public, industry, academia, etc.?
4. Research innovation—to what extent is the field scientifically groundbreaking and does it raise new research questions?
5. Technological innovation—is the research a technological breakthrough to answer old questions? Is the technology at the forefront of this area?

6. Need for research—the degree of the added value of the field. Are there knowledge gaps? What are the knowledge gaps, and do they need research, or would regulation and enforcement suffice?
7. Addressing local needs unique to the country. Does the field address the unique problems of the country that are not addressed in the world?
8. Addressing global challenges—global impact and global importance: the extent to which the domain is on the list of domains that are defined as being of high importance in the world.

## 6. Criteria for Choosing Preferred Topics for ER&D

For each of the principles presented above, a literature survey and individual research were conducted to determine a quantitative criterion or criteria that will allow us to rank each of the environmental issues, while considering global challenges and local needs and capabilities. The different criteria have been quantified into a grade table that will be used to provide a score for each selected domain in the expanded domain list. As each principle deals with different dates and is quantified by different values, e.g., impact on human health or number of publications, there is a need to put all the grades into a comparative scale that will allow us to sum all the principles together. Table 1 summarizes the conversion of each grade to a score between 1 and 6 for each of the eight selected principles. In the final stage, the score given to each field will be summarized, giving equal weight to each principle [25], and the areas that will receive, in aggregate, the highest score, based on the eight principles and all the criteria, will be selected for the completion of the study, i.e., an in-depth examination of the field in terms of R&D activity—infrastructure and manpower in the industry and academia. Below is an example of criteria suggested in this study.

**Table 1.** Final score for each principle.

Score	Principle 1 Impact on Human Society	Principle 2 Impact on Ecosystems	Principle 3 Broad Influence	Principle 4 Research Innovation	Principle 5 Technological Innovation % of Patents	Principle 6 Need for Research	Principle 7 Local Needs	Principle 8 Global Needs
1	A < 4	B < 17	C < 7	D < 100 Projects	E < 12%	F = 1	G < 2.5	H = 1
2	4 < A < 7	17 < B < 34	7 < C < 10	100 < D < 500 Projects	12% < E < 23%	F = 2	2.5 < G < 5	H = 2 or 3
3	7 < A < 10	34 < B < 51	10 < C < 13	D > 500 Projects	23% < E < 34%	F = 3	5 < G < 7.5	H = 4 or 5
4	10 < A < 13	51 < B < 78	13 < C < 16	1% < X < 10% of the budget	34% < E < 45%	F = 4	7.5 < G < 10	H = 6 or 7
5	13 < A < 16	78 < B < 85	16 < C < 19	10% < X < 20% of the budget	45% < E < 56%	F = 5	10 < G < 12.5	H = 8 or 9
6	A > 16	B > 85	C > 19	X > 20% of the budget	E > 56%	F = 6	G > 12.5	H > 9

### 6.1. Principle 1: Impact on Human Society

The state of the environment and its quality have a direct and indirect impact, in the short and long term, locally and globally, on human society. This impact is manifested in a variety of aspects, for example, in the context of socio-environmental justice and economic development. However, the main impact is on human health. Exposure to various pollutants in the home, work, and public spaces that originate in air, soil, water sources, waste, food, and various products can lead to a wide range of illnesses, from respiratory illnesses to cancer, and even death. Finally, there are quite a few environmental factors that affect health, and often exposure to several different pollutants can even have a synergistic effect.

The main environmental issues affecting health are as follows.

1. **Air quality:** exposure to various air pollutants, even at low concentrations, is associated with a wide range of adverse health outcomes in the general population, especially in sensitive populations, such as children, pregnant women, and the sick. Adverse health outcomes of air pollution include respiratory illnesses, such as asthma and chronic diseases, cardiovascular diseases, certain types of cancer, adverse effects on the nervous system development, adverse birth outcomes, type 2 diabetes, obesity, and cognitive defects.
2. **Chemical substances in drinking water:** exposure to chemical contaminants in drinking water can cause a variety of adverse health effects in humans, including cancer, adverse effects on the nervous system development, and adverse effects on the reproductive system and birth outcomes. Desalinated water also has an impact on health, mainly because the desalination process removes essential minerals such as magnesium and iodine from the water.
3. **Effluent water:** the main potential hazard to public health arising from the use of effluent water for agricultural irrigation is the transfer of pathogens (disease-causing agents) into agricultural crops as a result of irrigation with improperly treated effluents. Given the threat of antibiotic resistance to global health, there is growing concern over the possible role of wastewater treatment plants in the proliferation of resistant genes and antibiotic-resistant bacteria. There is also evidence that crops irrigated with effluent may contain drug leftovers and new contaminants.
4. **Pesticides:** pesticides are mixtures of substances used in agriculture and in urban environments to protect plants and animals from pests and diseases, kill weeds, and protect humans from pests and diseases carried by vectors. Acute exposure to high doses of certain pesticides, whether under professional or poisoning conditions, can cause serious health effects, including neurological effects and death.
5. **Climate change:** climate change can pose a real threat to public health. Extreme heat causes death from cardiovascular and respiratory diseases, and an extreme increase in the number of hot days can lead to an increase in the premature birth rate. In addition, high temperatures raise the levels of ozone and other pollutants in the air, and an increased frequency of dust storms can increase the risk of respiratory illnesses. Extreme weather events and natural disasters such as floods can lead to an increased risk of water-borne diseases. High temperatures can damage sanitation conditions and increase the risk of food spoilage due to bacterial or fungal proliferation. In addition, climate change, as well as the increased use of pesticides to combat pests, is expected to affect the incidence of diseases borne by vectors such as insects.
6. **Planning:** accelerated development processes, such as industrialization and urbanization, cause an increase in air pollution and population density and have a potential impact on public health.

The Health and Environment Report in Israel 2017 [26] indicated the relative impacts of each of the areas on public health. According to the report and the global assessments conducted by the WHO and other organizations, the major environmental risk factors include the following: (1) air pollution from particulate matter—the overall impact of environmental and intra-structural air pollution is estimated at 7 million premature deaths worldwide each year, more than 10% of global deaths. Exposure to environmental air pollution contributes to the increasing global burden of chronic obstructive pulmonary disease and other respiratory and cardiovascular diseases; (2) the global burden of morbidity in 2004 due to lead exposure (in water sources, soil, or various products) was 143,000 deaths, as well as 600,000 new cases of children with mental disabilities each year; and (3) additional environmental exposure to materials such as mercury, arsenic, and pesticides also contributes to the global burden of morbidity.

A data analysis of six European countries published in 2014 shows that about 3–7% of the annual burden of morbidity in these countries was related to risk factors, mainly environmental tobacco smoke, fine particulate pollution, and transport, noise, and radon pollution. Exposure to chemicals that affect the endocrine system and pesticides belonging to the organic phosphorus group also contribute to the burden of global morbidity. Moreover, according to the WHO estimations in 2014, in 2030 there will be 38,000 deaths of elderly people due to exposure to heat, 48,000 deaths because

of gastrointestinal diseases or food or water contaminated with bacteria or fungi, 60,000 deaths caused by malaria, and 95,000 deaths because of malnutrition in children.

Based on these data, the relevant health aspects were graded as summarized in Table 2.

**Table 2.** Impact on human society—health.

Aspect	Grade
Air quality	6
Water quality	4
Chemicals in agriculture/effluent	4
Climate change	3

The scoring of the various ER&D areas according to Principle 1 was done based on their impact on each of the aspects listed in Table 1, in an absolute, not relative, manner. For example, R&D, such as that related to smart transport, will affect both air quality and climate change, and therefore its grade is  $6 + 3 = 9$ . At the same time, different areas can indirectly impact health, in which case they are rated at only half the original grade. For example, air quality is indirectly influenced by environmental information and communication technologies, and therefore, this R&D area received a grade of 3 rather than 6 points.

The final score for each R&D area according to Principle 1 was obtained after summarizing the score and according to the key summarized in Table 1, where the higher the score (A), the greater the need for research in this field.

## 6.2. Principle 2: Impact on Ecosystems and Their Functioning

The state of the environment and its quality have a direct and indirect impact in both the short and long term, locally and globally, on ecosystems and their activities. Many factors influence the activity of ecosystems, from water and air quality to biodiversity. One of the indices related to the relative impact of each of the environmental factors on the viability of ecosystems is the Environmental Performance Index [27] presented by Yale and Columbia Universities in collaboration with the World Economic Forum and the European Commission's Joint Research Center.

The Environmental Performance Index (EPI) is a comparative analytical tool for policy makers, which is updated twice a year. The data are based on 9 categories with 19 performance indices, which are derived from many and varied databases (Table 3). The EPI consists of two main objectives of the same weight (50%): health and the environment and the viability of ecosystems. Each objective consists of a number of issue categories with a total value of 100%, and each category consists of a number of indicators with a total value of 100%, where each has a relative weight referring to its effect (Table 3).

Based on these data, the relative impact of each index on the viability of ecosystems can be determined. However, because air quality also affects the viability of ecosystems but appears only under the objective of health and environment, it was decided to add to the grading the relevant index under this category: exposure to nitrogen oxides (NOXs), because the indices of partial air pollution and pollution from particles are less relevant to ecosystems.

**Table 3.** Various indices used to determine the Environmental Performance Index.

Objective	Issue Category	Indicator
	Environmental health (50%)	
•	Health impacts (33%)	• Environmental risk exposure (100%)
		• Household air quality (30%)
•	Air quality (33%)	• Air pollution—average exposure to PM <sub>2.5</sub> (30%)
		• Air pollution—PM <sub>2.5</sub> exceedance (30%)
		• Air pollution—average exposure to NO <sub>2</sub> (10%)
•	Water and sanitation (33%)	• Unsafe sanitation (50%)
		• Drinking water quality (50%)
	Ecosystem vitality (50%)	

• Water resources (25%)	• Wastewater treatment (100%)
• Agriculture (10%)	• Nitrogen use efficiency (75%)
• Forests (10%)	• Nitrogen balance (25%)
• Fisheries (5%)	• Change in forest cover (100%)
	• Fish stocks (100%)
	• Terrestrial protected areas (National biome weights) (20%)
• Biodiversity and habitat (25%)	• Terrestrial protected areas (global biome weights) (20%)
	• Marine protected areas (20%)
	• Species protection (national) (20%)
	• Species protection (global) (20%)
• Climate and energy (25%)	• Trend in carbon intensity (75%)
	• Trend in CO <sub>2</sub> emissions per kWh (25%)

Based on the various metrics used to determine the EPI and their relative value (in percentage), the rates of environmental impacts on ecosystems were graded as summarized in Table 4.

**Table 4.** Impact on ecosystems and their functioning.

Aspect	Grade
Water resources	23
Greenhouse gas emissions	17
NO <sub>x</sub> s exposure (air quality)	9
Conservation of species diversity	9
Agriculture	9
Forests	9
Conservation of terrestrial land	9
Greenhouse gas emissions from energy production	6
Conservation of aquatic environment	4.5
Fisheries	4.5

The scoring of various ER&D areas in accordance with Principle 2 is done based on their impact on each of the above-mentioned areas in an absolute and not relative manner. The final scoring of each R&D area in accordance with Principle 2 was obtained by summarizing the scoring and according to the key summarized in Table 1, where the higher the score (B), the greater the need for research in this field.

### 6.3. Principle 3: Broad Influence

Any process, whether natural or manmade, uses materials and energy, affecting the quality of the environment, and it is even affected by it. The analysis of this principle was based on three major stakeholders or affiliates: the public, industry, and academia.

The scoring of the impact of the various environmental issues on the general public, of the ability of the government to influence each field, and of the impact of industry in each field was done in consultation with experts in the field. Importantly, in the case of the impact on the general public, not only health impacts (which are outlined in Principle 1) were included, but also broader issues, such as the impact of climate change on infrastructures and the impact of public transportation on the aspects not only of air pollution but also of planning, suburbanization, loss of time, accidents, etc. The rankings of the various R&D areas by the experts were on the scale of 1–6, where 1 refers to the lowest impact of the domain on the general public and the least influence of government or industry on the domain, and 6 refers to the highest impact of the domain on the general public and the greatest influence of the government or industry in the field. For example, R&D on mitigation has a high impact on the public and therefore receives the maximum grade on the scale, 6. In addition, state and industry activities have a high impact on mitigation, and therefore they also receive the maximum grade.

The impact of the academy on the various environmental fields was graded according to the number of publications in the field, from 2014 to 2019, as reflected in a Google Scholar search. Though Google Search was selected, there are also other specialized databases, such as Scopus or Web of

Science, which can be used for this purpose, and the grade can be also given based on some databases together. Grading in this category was performed according to the key summarized in Table 5.

**Table 5.** Impact of the academy on the various environmental fields.

Number of Publications	Grade
Up to 280,000	1
Up to 560,000	2
Up to 840,000	3
Up to 1,120,000	4
Up to 1,400,000	5
Over 1,400,000	6

The final score of each R&D field in accordance with Principle 3 was obtained by applying the same weighting of the R&D impact in the field on the public and the impact of the administration, industry, and academia on R&D in this area, and according to the key summarized in Table 2, where the higher the score (c), the greater the need for research in this field.

#### 6.4. Principle 4: Research Innovation

Innovation, which deals essentially with finding new solutions to existing or new needs and challenges, is one of the main attributes of academic research. Within this project, research innovation was measured based on the number of projects funded in each topic under the European Horizon 2020 R&D budget. According to this index, the more projects funded, the higher the grade. The Horizon 2020 budget was chosen for scoring because it is the most extensive R&D funding program in the world in terms of both topics and budget. In addition, information is available for this program, and the use of information from one R&D funding program allows uniformity in scoring across various subjects.

The Horizon 2020 program has a budget of ~EUR 80 billion for 2014–2020 [3]. The budget breakdown, in percent, as part of the total budget is shown in Table 6.

**Table 6.** Environmental research areas that are budgeted by Horizon 2020.

Major Areas	Sub-Areas
<ul style="list-style-type: none"> <li>Scientific excellence: 31.73%</li> </ul>	<ul style="list-style-type: none"> <li>The European Research Council: 17%</li> <li>Future and developing technologies 3.5%</li> <li>Marie Skłodowska-Curie Actions 8%</li> <li>European research infrastructures 3.23%</li> </ul>
<ul style="list-style-type: none"> <li>Industrial leadership: 22.09%</li> </ul>	<ul style="list-style-type: none"> <li>Enabling leadership and industrial technologies 17.6%</li> <li>Access to venture capital 3.69%</li> <li>Innovation in SMEs 0.8%</li> </ul>
<ul style="list-style-type: none"> <li>Social challenges: 38.53%</li> </ul>	<ul style="list-style-type: none"> <li>Health, demographic changes, and quality of life (including the influence of climate change) 9.7%</li> <li>Food security, sustainable agriculture and forestry, aquatic environment, inland water, bio-economics (including the influence of climate change) 5%</li> <li>Safe, clean, and efficient energy 7.7%</li> <li>Smart, green, and integrated transportation 8.23%</li> <li>Climate change, streamlining environmental resources and raw materials 4%</li> <li>Europe in a changing world 1.7%</li> <li>Safe society—maintaining Europe’s security and freedom and that of its citizens (including coping with the risks of climate change, ICT) 2.2%</li> </ul>
<ul style="list-style-type: none"> <li>Science with and for society 0.6%</li> </ul>	
<ul style="list-style-type: none"> <li>Distributing excellence and expanding participation 1.06%</li> </ul>	

- 
- European Institute of Innovation and Technology 3.52%
- 
- Joint Research Center (JRC) direct actions, not including nuclear fusion and fission 2.47%
- 
- Nuclear fusion and fission: 2.1%
- 

An analysis of the budget shows that about 60% of it refers to sustainable development and about 35% to climate change, with considerable overlap between the two, obviously. It is important to note that, although it is impossible to break down the program's budget by keywords, they can be used to segment the projects. This segmentation allows one to obtain the number of sponsored projects related to the selected search words [28]. It is also important to note that there is a limit to searching the program's research database and that searching with relevant keywords can only be done in the name of the project and its objectives, and it is impossible to search the abstract or the full report of the project. Therefore, the scoring concerns both the segmentation of all Horizon 2020 projects by keywords (a total of 16,935 projects) and the percentage of the budget allocated to each topic. The final score of each R&D field in accordance with Principle 4, based on the relative impact in relation to the number of projects and the scope of budgeting, was obtained according to the key summarized in Table 1.

#### 6.5. Principle 5: Technological Innovation

Technological innovation is the process in which abstract ideas are turned into technologies embedded in economics and society. Innovation can be addressed in several aspects, including technological improvement that is characterized by little research and considerable development, technological change that does not result from an improvement in an existing product and requires more research, or a technological revolution that requires more intense research. At the same time, it is difficult to rate the degree of innovation by general areas. Therefore, to rank innovation in the environmental context within this study, the scope of patents registered in each domain in the world rankings from 2005 to 2014 was used [29].

The scoring of the various ER&D areas in accordance with Principle 5 is based on the proportion (in percent) of patents registered in each field of the total of patents registered in all the fields together. The final score of each R&D field in accordance with Principle 5 was obtained according to the key summarized in Table 2, where the higher the score (E), the greater the need for research in this field.

#### 6.6. Principle 6: Need for Research

The need for research is usually a subjective matter, based on various and varied motivations. However, as part of this principle, the question whether the various environmental issues require extensive and in-depth research and whether these issues should receive a high grade, or whether the knowledge in the field is already well founded and the promotion of the issue requires mainly regulation and enforcement and whether these subjects should therefore be given a relatively low grade was examined.

Scoring of the various ER&D areas in accordance with Principle 6 was based on weighing the score received from 20 experts in the field from the academy, R&D authorities, and governmental departments and agencies, who were asked to score each and every R&D field on a scale from 1 to 6. The higher the score (F), the greater the need for research in this field.

#### 6.7. Principle 7: Addressing Local Needs

The State of Israel is a small and very crowded country. These facts mean that the state has relatively few natural resources (land, water, minerals, etc.) to provide for the entire population and also that the potential for pollution per area is high (waste, air pollution, etc.). However, while Israel's list of environmental challenges is more or less clear and includes air pollution from transportation and industry, damage to open areas and biodiversity, desertification, damage to the marine

environment, water scarcity for nature, and treatment of domestic and industrial waste, the ranking of these challenges is not trivial.

In this study, it was decided to rank the issues in Israel according to accepted environmental indicators and in comparison, with OECD countries or countries worldwide. Basically, the ranking is based on Israel's position in relation to OECD countries [30]. Such a rating will help determine which issues the State of Israel needs to improve in relation to the OECD, and on which issues Israel is doing well on. To calculate all the indices on a single comparative scale from 0 to 1, the ratio between Israel's position and that of the total measured countries was calculated (not every index contains data for all OECD countries). Further, because the impact on the environment can be positive, that is, the higher the value, the lower the environmental impact, in the case of negative impact the value was calculated according to one minus the ratio. Thus, the higher the value, the greater the impact on the environment, and therefore more research is needed. For example, in 2014, for average greenhouse gas emissions per capita (kg/cap), Israel was ranked 18 out of 33 countries, i.e., the resulting value is  $18/33 = 0.55$ . However, since the effect is negative, the final grade is  $1 - 0.55 = 0.45$ .

Scoring of the various ER&D areas in accordance with Principle 7 was based on the relative impact of each field. Yet, as the scoring is based solely on comparison with other countries, the score of each issue will be adjusted by adding extra 0.1–0.5 points based on the comparative advantage of Israel's research on each issue. This added score will be done in consultation with experts in the field, identified in Principle 6. The rankings of the various ER&D issues by the experts will be on the scale of 0–0.5, in intervals of 0.1, where 0 refers to the lowest comparative advantage of Israel, and 0.5 refers to the highest comparative advantage of Israel. For example, ER&D on wastewater treatment or irrigation, which is one of the most powerful research activities in Israel, will receive the maximum grade on the scale, 0.5. At last, the final score of each R&D area in accordance with this principle was obtained by summing the relevant score for each field of the various comparative indices examined, and according to the key summarized in Table 1.

#### *6.8. Principle 8: Addressing Global Challenges*

To determine priority areas for environmental research in response to global challenges, the priority areas identified by different entities and countries, in accordance with the literature survey, were added together. Since some of the issues, such as biodiversity conservation or air quality, did not emerge as an issue in themselves but as part of other subjects, these issues were considered only once for each country.

Scoring of the various ER&D areas in accordance with Principle 8 was done by summing all the countries/entities that chose each area as their R&D priority area, and the final score was given according to the key summarized in Table 1. A higher score (G) suggests that more entities/states are involved in R&D in the given field, that is, there is a greater need in the world for research in the field.

## **7. Conclusions**

Facing global challenges, most notably the climate crisis, the decline in biodiversity and population growth, together with the increase in quality of life, the research in the field of the quality of the environment and its protection has evolved in recent years. In addition, more research entities and funds consider ER&D to be of great importance, and as a result, it is allocated more budgets, and more policy studies are conducted to identify the areas of ER&D on which they should focus.

There are different ways to identify and prioritize the R&D of states in general and in the field of environmental quality and protection in particular. Usually, the methodology and principles for setting the domains are based on existing policies (international, national, etc.) and their derived objectives, on a comprehensive literature survey, on consultation with experts and stakeholders, and on an analysis of future needs and challenges based on multiple criteria.

As part of this study, a comprehensive review of the methodology, principles, and criteria for selecting priority areas for environmental quality and protection was conducted in the first phase.

The review included studies reported by a wide range of entities and countries. The findings of the surveys showed that the methodology for selecting priority areas for the R&D of countries in general and in the field of environmental protection in particular is based on the following steps:

1. Definition of key policies, principles, and research gaps. There are two main approaches:
  - To rely on existing national policies, defined by the government or the Ministry of the Environment/Government Agency for Environmental Protection and backed by budgeting, which dictates key areas of interest.
  - To rely on international policy, mainly on a survey of leading global fields of interest and their adaptation to local research and needs.
2. Extensive literature review and expert opinion to determine a broad list of relevant research areas, in terms of both local and international importance and of existing economic and research capabilities (manpower, infrastructure, etc.), to conduct the research successfully.
3. Definition of the final priority areas based on principles and criteria that consider future needs and challenges and focus on the strengths and relative advantage, but also allow new opportunities to be identified.

It should be mentioned that although ER&D drew significant attention over the last decade, and many countries have invested in the field, we did not identify many studies at the national level, and the studies we identified did not supply comprehensive and detailed methodologies. Thus, we based our methodology also on studies of different entities and used studies that examined the prioritization of relevant topics such as public health, among others. In addition, the literature review did not yield enough selection principles and criteria, so these were further developed based on consultation with experts and stakeholders.

The study defined eight principles according to which research priorities are selected: impact on human society, impact on ecosystems and how they operate, achieving a broad impact, research innovation, technological innovation, need for research, addressing local needs, and addressing global challenges. For each principle, a criterion or criteria were determined to enable the quantification of the impact of each field of research on the advancement of each principle, so that finally, it would be possible to score each area of ER&D according to the different criteria and narrow down the research priority areas.

The current methodology has also some weaknesses. First, the balance between local concerns, needs, research abilities, and funds and global ones should be further optimized. In addition, the sensitivity of the methodology should be applied better to broad issues, rather than very specific ones, e.g., carbon capture and storage instead of mitigation of greenhouse gases, due to a lack of data. Therefore, the methodology should be better refined and adjusted. Finally, the grading of the different issues based on each principle should be a mix of local and global environmental databases and review of local and international experts in the field.

These limitations can be improved by further research, in order to optimize the data mining for priorities selection, the decision-making process, and the grading of each topic in each principle. In addition, the criteria that were chosen for each principle can be further shaped and tuned, based on application of the methodology to various countries. At last, the use of different methods to improve the performance and productivity of the criteria while assigning different weights to each principle could also be further examined.

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