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Water, Energy and Food Nexus: A Project Evaluation Model

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Abstract: The connections between universal rights to water supply, energy security, and food supply stand out as a challenge that requires project evaluation models that can capture the complex dynamics and interdependencies of these resources. This study proposes the elaboration of a nexus evaluation model (NEM) for projects related to the water–energy–food nexus (WEFN) from the perspective of sustainability, Industry 4.0, and the Sustainable Development Goals (SDGs). The model considers the three dimensions of sustainability—economic, environmental, and social; the three structuring factors of Industry 4.0—physical, biological, and digital; and the 17 SDGs proposed by the United Nations. A Design Science Research (DSR) approach was adopted in which the design and development of the model, and demonstration and evaluation phases, were supported by a group of experts. The model was applied to three different projects focused on sustainable technological innovation in energy and agriculture, with the results presented in the RGB color scale represented numerically as a number from 0 to 255. The results demonstrated that, in the relationship between nexus and sustainability, the projects presented scores between 162 and 217 for the environmental dimension, between 158 and 202 for the economic dimension and between 170 and 212 for the social dimension. In the nexus and Industry 4.0 relationship, the projects obtained scores ranging from 9 to 94 in the biological factor, from 13 to 141 in the digital factor, and from 13 to 141 in the physical factor. In the nexus and SDG relationship, scores ranged from 214 to 244 for water, from 195 to 255 for energy, and from 30 to 255 for food. These results from the model were consistent with the reality of the projects being evaluated, demonstrating a greater alignment of the projects with the dimensions of sustainability and the SDGs than with the factors of Industry 4.0. The proposal of the model contributes to broaden the understanding of how projects related to the nexus can be evaluated considering multiple contemporary dimensions.

Keywords: water–energy–food nexus (WEFN); sustainability; Industry 4.0

Citation: Neto, R.d.C.S.; Bohner, J.P.; Birch, R.S.; Junges, I.; Mussi, C.C.; Soares, S.V.; Dutra, A.R.d.A.; Salgueirinho Osório de Andrade Guerra, J.B. Water, Energy and Food Nexus: A Project Evaluation Model. *Water* **2024**, *16*, 2235. https://doi.org/10.3390/w16162235

Academic Editor: Elias Dimitriou

Received: 30 June 2024
Revised: 22 July 2024
Accepted: 26 July 2024
Published: 8 August 2024

1. Introduction

The growing global demand for resources, such as water, energy, and food, which are fundamental to life and associated with the human development index, imposes a great challenge on managers in terms of the results to be achieved in their work and the expected returns for their investors. The need of nations throughout the world for natural resources capable of feeding their people and providing them with comfort and security is historic. The postmodern world, with its need for food production, demands greater amounts of water and energy [1–3]. The global demand for additional agricultural land is expected to increase by approximately 50% by 2050 [4]. In this scenario, the water–energy–food nexus has received global attention, especially when considering the need for interdependence of these resources in the development of environmental, social, and economic sustainability [5].

In this sphere of production, that is so diverse and demanding of natural resources, it is possible to observe a convergence in the search for strategic data on the use and acquisition of such resources [3]. Media and commerce have become increasingly digital, while industry and agricultural systems are increasingly automated and, consequently, also digitized. Therefore, governments, managers, and researchers, who have the capacity to process and manipulate large amounts of data, will be better able to manage the allocation of resources, especially natural resources [3,6].

However, the technologies that are developing in the context of the so-called fourth industrial revolution, Industry 4.0, do not appear to be compatible with the generation of jobs and income opportunities for the Earth's current population of almost 8 billion inhabitants. In many countries, workers are not prepared for these advanced technologies which, for instance, in turn can have impacts on more efficient and cleaner production of food [7,8]. Another challenge emerging from Industry 4.0 comes from the diversity of machines active in machine–machine interactions with the aim of minimizing, and even dispensing with, direct human control in production processes. This revolution stands out for the integration of biological, digital, and physical elements, enabling a new paradigm in the formation of value in the production chains of today's society [9].

Some countries can produce most of the food they consume and also have the capacity to export it to other countries, making it an important commercial activity in their economies [10]. Other countries import natural resources, usually out of necessity due to having incompatible geographical and climatic characteristics that limit the production of food on a scale capable of supplying their internal markets, thus, impacting negatively on their own food security [11]. To this end, there are indicators, such as the Water Footprint Assessment, which make it possible to record and track the amount of water that these traded products consumed during their production process within their respective source country [12]. In this sense, the availability of water to produce food is driving an important movement by foreign countries towards the purchase of large tracts of arable land [13]. This recognition of the interconnected nature of water, energy, and food resources has resulted in a growing push to change approaches towards the management of these resources [14]. Managers face the challenge of aligning their actions with integrated sustainability demands while balancing the environmental, economic, and social aspects [15].

Managers have also been increasingly pressured to verify that their institutions are aligned with the Sustainable Development Goals (SDGs) as defined by the United Nations. Compliance with the SDGs has become an indicator for companies listed on the world's major stock exchanges, influencing not only corporate practices, but also the perception of value in the financial market [16,17]. Previous research has demonstrated the importance of using indicators that consider the SDGs [18–22]. Results globally show substantial progress is made in both the private production and public initiative sectors when evaluating their projects, and their differing realities, with indicators aligned to the SDGs. These surveys highlight the success that SDG-aligned projects can attain, especially in the areas of water supply, ecosystems, and natural resource infrastructure in cities, and sustainability of national priorities, together with a greater number of people benefiting from them.

When considering the water–energy–food nexus, Al-Saidi and Elagib (2017) [23] highlight the absence of a consistent view on the meaning of integration within it. They add that the nexus has been successful in changing policy debates, but that there is a lack of prioritization of issues, denoting the importance of governance in the debate on the topic. Similarly, Sarkodie and Owusu (2020) [5] point out that the nexus is expanding rapidly because of its political implications, but there is a lack of a common conceptual framework for this relationship. According to these authors, heterogeneous results have been observed, which makes the development and evaluation of a conceptual framework even more challenging, since the effect of the nexus on environmental sustainability depends on several socioeconomic factors that require attention.

Investigating the processes and projects that involve the nexus requires the consideration of variables that make up the current world, and that consider the complexity and complementarity nature of the production process throughout its chain from start to finish [24]. D'Amore et al. (2022) [6] highlight the need to adopt a multi-stakeholder approach and the important role played by artificial intelligence and other digital technologies to address the nexus challenge. Researchers argue that the gap between research and policy-making can be bridged by combining scientific data and policy needs with inclusive tools that are technically feasible for the sustainable utilization of resources.

Given this complexity and the need for models that holistically address the water–energy–food nexus (WEFN), the central research question of this study is the following: how can projects within the WEFN be evaluated from the perspective of sustainability, Industry 4.0, and the SDGs? Therefore, to answer this question, the goal of this study is to develop a project evaluation model related to this WEFN that is integrated with aspects of sustainability, Industry 4.0, and the SDGs. It is worth noting that, in this study, projects are defined as strategic plans that involve the elements of the WEFN generating impacts on society. Examples include projects for the implementation of energy efficiency technologies and structuring of municipal master plans, and in the areas of food, implementation of basic sanitation treatment plants, and reuse of industrial waste, among others.

The concept behind the evaluation model proposed here is based on the combination of knowledge from the science of the WEFN, which is structured around the integration of three resources of sustainability supported by the Triple Bottom Line (TBL, i.e., environmental, economic, and social) and from Industry 4.0, which can be recognized by the composition of biological, digital, and physical factors. The model affords a visual representation of this based on the assumptions that a project manager is able to define. From this, it is possible to identify the results of the project in terms of the WEFN resources linked to the three dimensions of sustainability, Industry 4.0, and the SDGs.

In this study, a Design Science Research (DSR) methodology was adopted for the creation and validation of a WEFN evaluation model (nexus evaluation model: NEM) whose functionalities are based on a combination of color theory and the method of Cartesian axes [25]. In the case of the proposed NEM, color is used as a functional visual indicator to convey information [26]. In this way, when collecting together a series of information as expressed by individual assigned colors, a new illustration is created and readily visualized from this compilation of colors. In this study, Descartes' Cartesian axes were used to integrate WEFN resources into the dimensions of sustainability and Industry 4.0, as well as the SDGs. The proposed NEM is innovative in creatively using colors and the Cartesian planes to facilitate the visualization of the results of initiatives and projects based on the nexus; it offers a clear and holistic picture of the reality being studied. The incorporation of Industry 4.0 elements contributes to improving the efficiency and sustainability of projects, especially those based on emerging technologies. The multidimensional and technological integration differentiates this approach, allowing the identification of synergies and trade-offs between the nexus resources and the multiple dimensions and variables being analyzed. The synthesis of readily visualized color graphics and numerical data resulting from the NEM enables professionals from different areas to build and interpret a complete picture of a WEFN action, and thus make better-informed decisions. In consequence, the NEM brings the academic and corporate worlds closer together, as well as guiding actions to optimize results.

The following section presents more details of the methodology used to develop the NEM. The results of the study are presented in Section 3 followed by a structured discussion that considers the phases foreseen by the DSR. Finally, the limitations of the research and suggestions for future studies are examined in Section 4.

2. Methodology

Following the fundamentals of DSR, the approach focused on the development of knowledge and support for the solution of organizational problems through the construction and application of innovative artifacts [27,28]. Systems, methods, applications, models, and instantiations are considered artifacts [27,29]. Conceptually, a design research artifact can be any designed object in which a research contribution is embedded in the design [30]. In the case of this study, the artifact comprised a NEM for the purpose of evaluating projects related to the WEFN and was based on three instantiations of the model.

Models are abstractions and representations that support the understanding of a problem and its solution. Instantiations demonstrate that the model can be implemented while providing a clear understanding of its structure and the purpose for which it was built [27]. Therefore, the proposed NEM considers both the complementarity and complexity of the nexus' features. It integrates a set of elements that allows the evaluation of the dynamics of these resources from the perspective of critical and emerging aspects that influence sustainability and technological development in today's society. In order to demonstrate the model, three instantiations are proposed. These instantiations refer to the application of the model in three projects that incorporate nexus elements in their design. The selected projects are focused on sustainable technologies for energy and agriculture, addressing specific challenges and opportunities within the Brazilian context.

By understanding design as both a process and artifact and recognizing that the process comprises a set of activities developed in the construction of an artifact, the framework proposed by Peffers et al. (2007) [30] was followed for the purpose of creating the NEM in this study. The phases of the DSR process used are shown in Table 1 together with the participants.

Table 1. Phases of the DSR and participants for the developing the NEM.

Phase	Definition	Participants
(1) Identification and motivation of the problem	Definition of the specific research problem and justification for the search for a solution.	Researchers
(2) Definition of the objectives for a solution	Definition of the goals of a solution based on the problem.	Researchers
(3) NEM design and development	Determination of the functionality, architecture, and creation of the NEM.	Researcher and Experts
(4) NEM demonstration	Demonstration of the use of the NEM on one or more WEFN case studies.	Researcher and Experts
(5) NEM Assessment	Evaluation of the effectiveness of the NEM	Researcher and Experts
(6) Communication of the research	Communication to researchers and other relevant audiences.	Researchers

Note: Source: Adapted from [30].

The phases of the DSR process were conducted by researchers in conjunction with industry professionals who were experienced experts in the themes involved in the problem and potential solutions. Phases 1 and 2 of the research were based on developing knowledge from an extensive literature review, as well as the practical expertise in nexus-related projects in Brazil processed by two of the authors of this study. This knowledge enabled the study to identify the problem and justify the value of a solution from both theoretical and practical perspectives.

The problem was contextualized within the WEFN, highlighting the specific challenges and general opportunities that can be applied in different contexts. The literature review included theories and models to support the identification of the problem. Meetings were held among the researchers to map the problem in detail, considering the practical contributions and literature review. Using this knowledge, the state of the problem and gaps to be filled enabled the objectives for a solution be defined. The objectives of the solution were defined based on criteria of technical feasibility; economic, social, and environmental impact; alignment with the SDGs; and the integration of emerging Industry 4.0 technologies.

Based on the outcome of these objectives, the design and development of the NEM began in Phase 3 which involved developing a set of decisions, including how the evaluation indicators would be defined, collected, and measured, and how the evaluation results would be presented. One of the premises was that the indicators would be designed in a flexible way, allowing users of the model to adapt them according to their specific interests, needs, and contexts. Decisions related to data collection and analysis involved the definition of techniques and instruments to obtain information from the projects and analyze them. In this case, the premise was that the collection and analysis techniques should be standardized to ensure the consistency and comparability of the data obtained from different projects. Decisions were also made about which data sources would be used, such as primary data collected directly from the projects through interviews, questionnaires, and observations, and secondary data obtained from existing databases and documents related to the projects. The presentation of the results from the NEM was planned to be clear and accessible, facilitating interpretation and decision-making by project managers and other stakeholders.

In DSR, the researcher acts as a constructor and/or evaluator of the artifact [28]. In the case of this study, construction of the NEM artifact was assisted by three senior engineers operating currently as research and development experts for a large organization in the Brazilian national electricity sector and who were also experienced in projects related to the WEFN. This interaction in support of the model construction was carried out through open interviews, brainstorming, and interactive learning sessions [31]. The interviews and brainstorming sessions provided insights into the applicability of the indicators and the feasibility of the proposed methodologies. The interactive learning sessions contributed to adapting the model to the operational and technical realities of projects involving the nexus, ensuring that it was not only theoretical but also practice-oriented.

Managers from the same organization were also consulted, especially those responsible for the environmental and legal areas within the organization itself. These managers mainly contributed to the definition of how the project data would be collected and how the results of the evaluation would be presented. This interaction highlighted the importance of reports being graphically visual while being numerically accurate and having a clear description. In addition, when addressing topics involving any subjectivity, it was established that an evaluation instrument (i.e., a questionnaire) should contain an open field to include a justification for answers to closed questions (see Section 3.3).

All collaborative activities were documented and the collected feedback was incorporated iteratively into the design and development of the NEM. Finally, in this early phase of the design and development of the model, it was also essential for researchers to search for and understand all theories that could be applied to the solution.

Demonstration of the NEM in Phase 4 was carried out by a single researcher with experience in research, development, and innovation management. The NEM was applied to three Brazilian WEFN-based projects designated as Project 1, Project 2, and Project 3, as detailed in Section 3.4. Although these projects were concerned with different perspectives, they involved sustainable technological innovations for energy and agriculture. At the time of this activity, Project 1 had not been implemented, while Projects 2 and 3 had already been completed. The researcher working on this NEM demonstration phase was also involved in these projects at various levels and was able to fully access the documentation relating to them. Therefore, the data were collected through participant observation and documentary research, which allowed the applicability of the NEM to be validated and for its performance to be assessed in the context of real projects based on the WEFN.

Finally, in Phase 5, the NEM was trialed by a group of three experts (designated as E1, E2, and E3) who worked on the projects being evaluated by it. Ten open questions were used to seek their opinion of the NEM's effectiveness in carrying out the evaluation process. The first nine questions were related to the results obtained from the NEM, while the last question sought the opinion of experts regarding the potential use of the NEM for other applications. The responses included those of three experts from the energy sector who work in research and development associated with the evaluation, elaboration, implementation, and management of projects. This group of experts brought together backgrounds that include mechanical engineering, electrical power production, and economic sciences, with additional backgrounds in areas such as renewable energy and project management. All had a rich history of innovative contributions in their fields, extensive experience applied in corporate environments, and track records of leading projects that have received international recognition and global certifications. Figure 1 illustrates the DSR process employed in this research for the construction of the NEM.

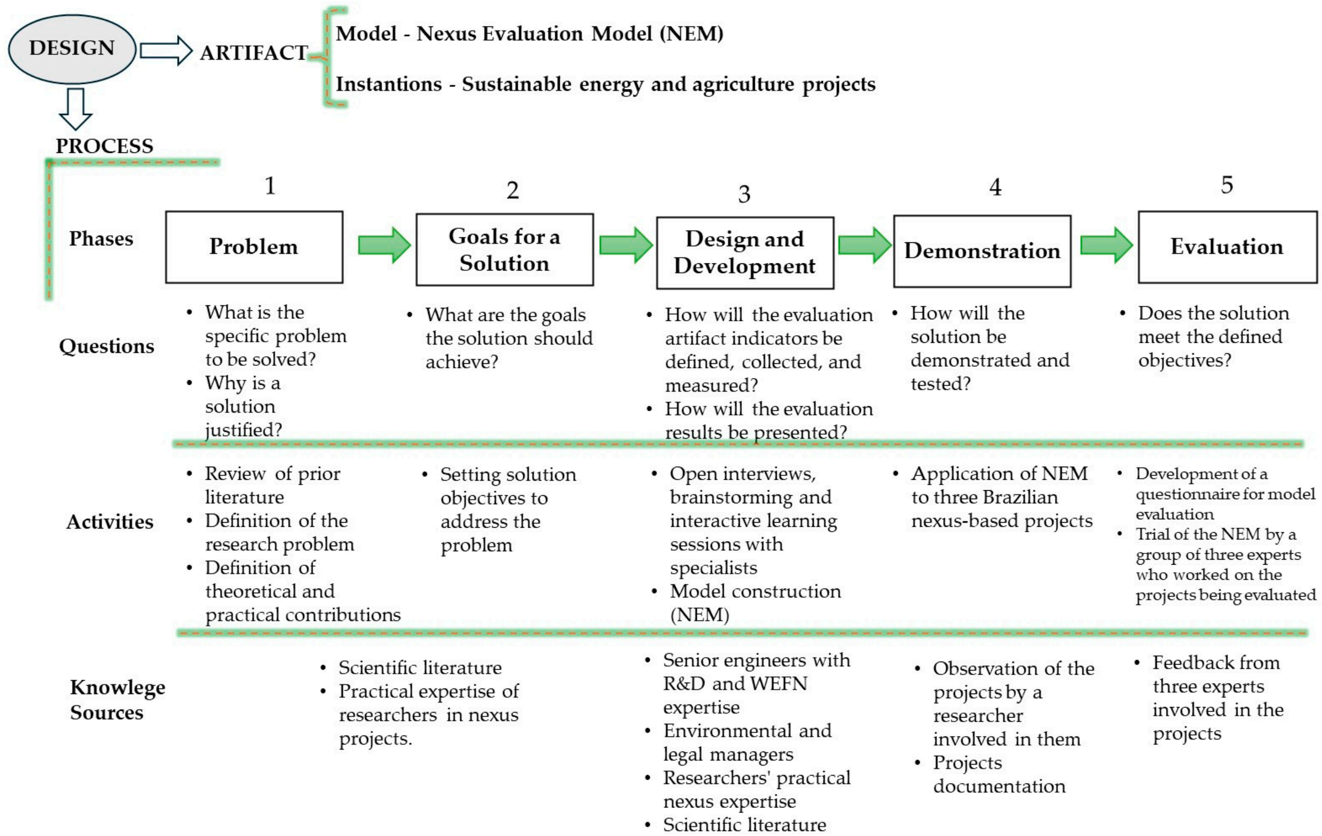

Figure 1. DSR process applied to the construction of the NEM. Note: Source: Prepared by the authors (2024).

Finally, in addition to empirical evidence, the principles and criteria of quality in the DSR as proposed by Hevner et al. (2004) [27] were applied, namely, design as an artifact (verifying that the created NEM fulfilled its function as a useful artifact), relevance of the problem (assessing the relevance and importance of the problem addressed by the NEM), design evaluation (inspecting NEM effectiveness through expert feedback), research contributions (identifying the theoretical and practical contributions of the research), and research rigor and communication of research (assessing the clarity and effectiveness of the communication of the results and the methodologies employed).

3. Results: NEM—Process of Development, Demonstration, and Evaluation

This section is structured according to the phases of the DSR [30], comprising the results of the design study, development, and demonstration phases of the NEM (Sections 3.1–3.4), as well as providing a discussion of the results in the evaluation phase (Section 3.5).

3.1. Identification and Motivation of the Problem

This research addressed the challenge of integrating sustainability into the process of evaluating projects related to the WEFN in its social, economic, and environmental aspects, as well as the technological factors, especially the biological, digital, and physical factors, of Industry 4.0. This gap becomes critical as sustainability becomes an imperative in the scientific, corporate, and social environments. In addition, Industry 4.0, characterized by its ability to transform production processes through technology, significantly influences projects related to the WEFN, thus demanding the integration of its characteristics into management models. This challenge is exacerbated by the need to align practices with the SDGs that are necessary to maintain competitiveness and social responsibility in the global marketplace. The motivation to investigate this problem stems from the scarcity of models that can guide the evaluation and optimization of nexus-related projects, considering both the technological advances of Industry 4.0 and the imperatives of sustainability.

3.2. Defining the Objectives for a Solution

The solution involved the creation of an NEM within the WEFN from the perspective of sustainability, Industry 4.0, and the SDGs. More specifically, the following objectives adopted for the creation of the NEM are outlined as follows:

Technological integration—Incorporating Industry 4.0 capabilities to optimize the management of the WEFN. The solution should enable an interaction between the biological, digital and physical dimensions and the nexus, facilitating more efficient and sustainable production processes.

Multidimensional sustainability—Ensure that the model contemplates sustainability criteria in the environmental, economic and social dimensions.

Alignment with the SDGs—Ensure that the model contributes to the achievement of the SDGs. Each aspect of the project should be evaluated for its ability to address specifically the SDGs, serving as a tool for the implementation of policies and projects aligned with these global goals.

Practicality and usability—Develop a tool that is not only theoretically robust, but also practical and easy to use by managers and decision-makers. The NEM should offer clear and intuitive interfaces for project evaluation, with easily interpretable indicators and metrics.

Adaptability and scalability—Ensuring that the model is flexible enough to adapt to different projects, deployed or not, and applicable to both small and large initiatives.

3.3. Model Design and Development

This phase involved determining the functionalities of the NEM, its architecture, and its effective creation, based on the knowledge of theories that can be applied in the solution. Based on the assumption of the relevance of sustainability, Industry 4.0, and the SDGs in projects related to the WEFN, the next step was to think about how to structure the logic of the relationship between this body of knowledge and the WEFN in a project evaluation context. A logical structure of the design for the NEM and its development is presented in Figure 2.

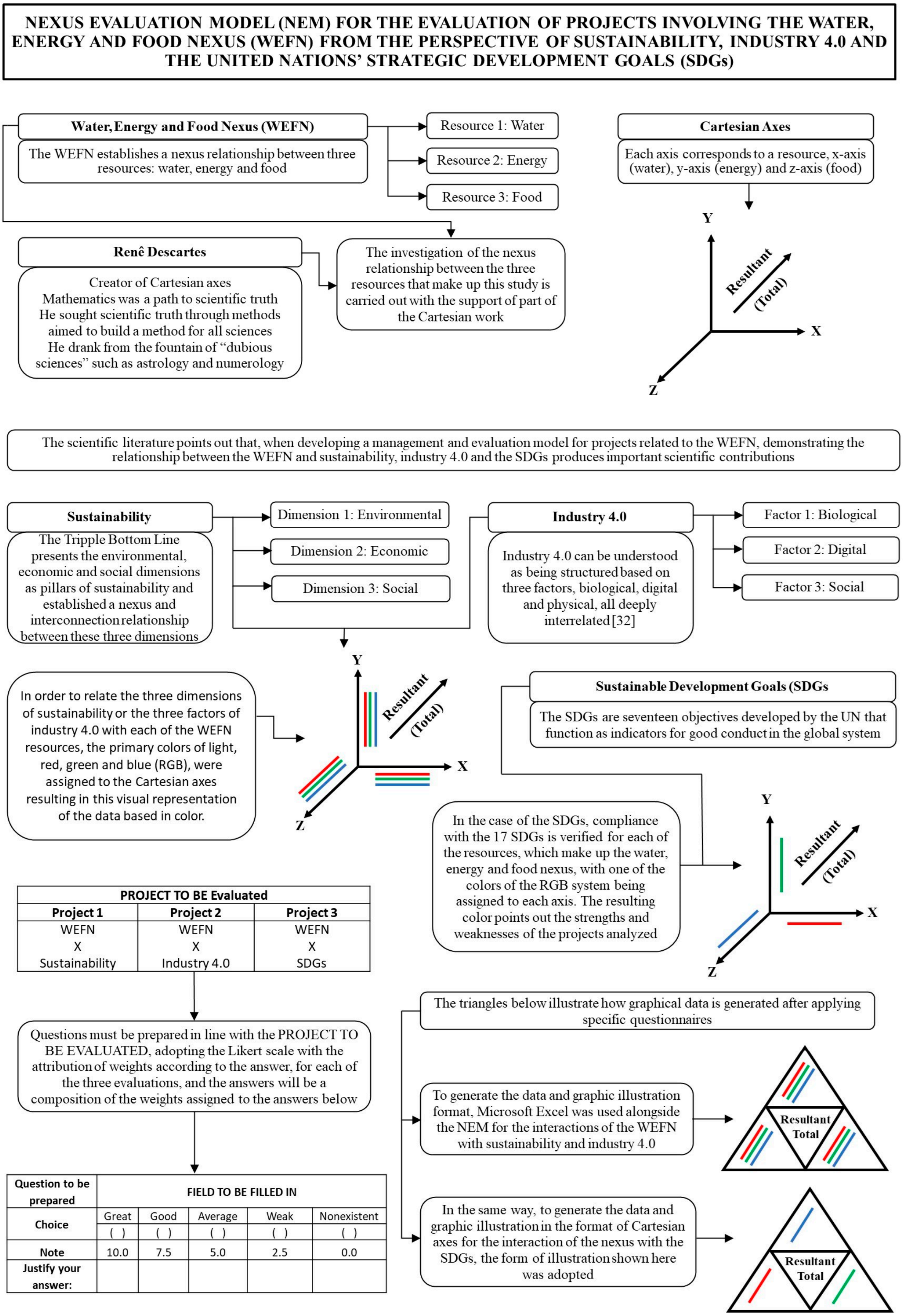

Figure 2. NEM—Design and development. Source: Prepared by the authors from the website Lucid.app/lucidchart (2024) [32].

Considering that the WEFN is structured with three resources, sustainability with three dimensions, Industry 4.0 with three factors, and the SDGs with 17 goals, it was necessary to consider carefully the types of visualization that could be used in the NEM to represent its results clearly and concisely. For this purpose, the principles of color theory, along with mathematical and geometric concepts inspired by the Cartesian method of Descartes (2005) [25], were adopted. This methodology highlights the progression of thought from intuition to deduction, an approach analogous to mathematical reasoning. The NEM presented here applies this logic, performing a detailed analysis of different segments of a project, which facilitates a holistic understanding of the project through the synthesis of information that resembles clear and objective indicators for decision-making.

In addition to the Cartesian axes, the fundamentals of color science were incorporated into the model, adopting an interdisciplinary perspective that explores both physical and physiological aspects [26]. From a physical point of view, colors are perceived as manifestations of light reflected by objects and not as intrinsic properties of objects. Primary colors (red, yellow, and blue) are fundamental in the formation of the entire visible spectrum through their unique combinations [26,33,34]. In the digital context, the red, green, and blue (RGB) system of colors, as used in electronic devices, operates by the additive synthesis of these colors, resulting in white light when all three are combined equally [26,35]. Thus, in computer systems, the RGB colors are used, which, like the primary colors, make up all the other colors.

From a physiological point of view, color is studied through the relationship between vision and the brain [26,33]. The theories of Young-Helmholtz and Retinex (1964) [36–38], for example, explain how the three types of cones on the retina (red, green, and blue) detect different wavelengths, allowing for accurate color reproduction in devices such as monitors and televisions. This discovery was essential for the development of the RGB system in visual technologies [26,36–38]. In addition, we consider variations in color perception, including conditions such as color blindness, and phenomena such as color illusions, to deepen our understanding of the complexities of color perception [26,39,40].

D'arcy W. Thompson argues that biological forms are controlled more by the laws of physics than by evolution [41], and the laws of physics, in turn, use mathematical laws as a language to express themselves. The proposed NEM adopts physical laws for the composition of colors and uses mathematics to explain how this same composition can express the result of each resource of the analyzed nexus in the face of the interaction made with sustainability, Industry 4.0, and the SDGs. In addition, the model uses the mathematical and geometric logic of the Cartesian axes, associating them with the features of the WEFN.

Using the Cartesian axes and the RGB color system, the sequence of the WEFN components was combined with the sustainability (environmental, economic, and social) and Industry 4.0 (biological, digital, and physical) components in the model, as well as the 17 SDGs. Thus, the X-axis is associated with water, the Y-axis with energy, and the Z-axis with food.

As sustainability and Industry 4.0 are structured using three components, the three additive primary colors were adopted to represent them. In the case of sustainability, the color Red is associated with the environmental dimension, the color Green with the economic dimension, and the color Blue with the social dimension. The combinations were structured in the sequence of the Cartesian axes X, Y, and Z, and for each axis there is a resultant, as illustrated in Table 2. It should be noted that the "questions" in each of the axes in Table 2 correspond to information from the projects that will be evaluated regarding the interaction of the resource that the axis represents with each of the dimensions of sustainability.

Similarly, in the case of Industry 4.0, the color Red is associated with the biological factor, the color Green with the digital factor, and the color Blue with the physical factor, as shown in Table 3.

Table 2. WEFN and Sustainability—Questions making up the X, Y, and Z axes with color pointing.

X-Axis Composition (Water)			Y-Axis Composition (Energy)			Z-Axis Composition (Food)		
Sustainability			Sustainability			Sustainability		
Environmental	Economical	Social	Environmental	Economical	Social	Environmental	Economical	Social
Question X 01	Question X 11	Question X 21	Question Y 01	Question Y 11	Question Y 21	Question Z 01	Question Z 11	Question Z 21
Question X 02	Question X 12	Question X 22	Question Y 02	Question Y 12	Question Y 22	Question Z 02	Question Z 12	Question Z 22
Question X 03	Question X 13	Question X 23	Question Y 03	Question Y 13	Question Y 23	Question Z 03	Question Z 13	Question Z 23
Question X 04	Question X 14	Question X 24	Question Y 04	Question Y 14	Question Y 24	Question Z 04	Question Z 14	Question Z 24
Question X 05	Question X 15	Question X 25	Question Y 05	Question Y 15	Question Y 25	Question Z 05	Question Z 15	Question Z 25
Resultant X with color to be composed from the combination of the percentage of the three colors above			Resultant Y with color to be composed from the combination of the percentage of the above three colors			Resultant Z with color to be composed from the combination of the percentage of the above three colors		
Resulting in a color to be composited from the combination of the three axes								

Note: Source: Prepared by the authors (2023). Note: The red, green and blue colors are intended to differentiate data related to environmental, economic, and social dimensions.

Table 3. WEFN and Industry 4.0—Questions that make up the X, Y and Z axes with color pointing.

X-Axis Composition (Water)			Y-Axis Composition (Energy)			Z-Axis Composition (Food)		
Industry 4.0			Industry 4.0			Industry 4.0		
Biological	Digital	Physical	Biological	Digital	Physical	Biological	Digital	Physical
Question X 01	Question X 11	Question X 21	Question Y 01	Question Y 11	Question Y 21	Question Z 01	Question Z 11	Question Z 21
Question X 02	Question X 12	Question X 22	Question Y 02	Question Y 12	Question Y 22	Question Z 02	Question Z 12	Question Z 22
Question X 03	Question X 13	Question X 23	Question Y 03	Question Y 13	Question Y 23	Question Z 03	Question Z 13	Question Z 23
Question X 04	Question X 14	Question X 24	Question Y 04	Question Y 14	Question Y 24	Question Z 04	Question Z 14	Question Z 24
Question X 05	Question X 15	Question X 25	Question Y 05	Question Y 15	Question Y 25	Question Z 05	Question Z 15	Question Z 25
Resultant X with color to be composed from the combination of the percentage of the three colors above			Resultant Y with color to be composed from the combination of the percentage of the above three colors			Resultant Z with color to be composed from the combination of the percentage of the above three colors		
Resulting in a color to be composited from the combination of the three axes								

Note: Source: Prepared by the authors (2023). Note: Red represents the biological factor, Green denotes the digital factor, and Blue symbolizes the physical factor.

In the case of the SDGs, each Cartesian axis of the WEFN was represented by a specific color of the RGB system, varying its intensity from weakest to strongest, according to the information of the project under evaluation in relation to the 17 SDGs. The resulting axis is the composition of these three colors, remembering that it is expected to result in the color white. Table 4 illustrates the relationship between WEFN and SDGs.

These X, Y, and Z axes of the Cartesian coordinate system can be considered components of a vector possessing intensity and direction as defined by the information from the project being evaluated and generated by the questions in Tables 2–4. Structuring how to capture this information in a project was key to the design and development of the NEM. For this purpose, a structured evaluation questionnaire (see Table 5) comprising both closed and open mixed questions [42] was incorporated into the model. For each question, an opinion on its theme was requested using a Likert scale and a means to justify the chosen option. This justification aimed to demonstrate the respondent's understanding of the theme in each answer made and, through this, an understanding of the respondent's answers was developed. In filling in the questionnaire, the field "justify your answer" opens a range of judgments from readers who may disagree with the arguments made and formulate different opinions knowing the respondent's beliefs and reasons supporting their response [25].

The structure of each question is illustrated in Table 5. The NEM proposes that the completion should be made by specialist(s) in nexus-based projects and the data collected can be obtained by one or more respondents.

Table 4. WEFN and SDG—Questions that make up the X, Y, and Z axes with color pointing.

Composition of the X-Axis of the SDG (Water)	Composition of the Y-Axis of the SDG (Energy)	Composition of the Z-Axis of the SDG (Food)
Question X 01	Question Y 01	Question Z 01
Question X 02	Question Y 02	Question Z 02
Question X 03	Question Y 03	Question Z 03
Question X 04	Question Y 04	Question Z 04
Question X 05	Question Y 05	Question Z 05
Question X 06	Question Y 06	Question Z 06
Question X 07	Question Y 07	Question Z 07
Question X 08	Question Y 08	Question Z 08
Question X 09	Question Y 09	Question Z 09
Question X 10	Question Y 10	Question Z 10
Question X 11	Question Y 11	Question Z 11
Question X 12	Question Y 12	Question Z 12
Question X 13	Question Y 13	Question Z 13
Question X 14	Question Y 14	Question Z 14
Question X 15	Question Y 15	Question Z 15
Question X 16	Question Y 16	Question Z 16
Question X 17	Question Y 17	Question Z 17
Resulting in a color to be composited from the combination of the three axes		

Note: Source: Prepared by the authors (2023).

Table 5. Structure of questions and scoring grades for the NEM.

Question to Be Elaborated	Field to Be Filled in				
Choice	Excellent	Good	Average/Regular	Weak	Nonexistent/Null
	(. . .)	(. . .)	(. . .)	(. . .)	(. . .)
Note	10.0	7.5	5.0	2.5	0.0
Justify your answer:					

Note: Source: Prepared by the authors (2023).

The construction of the questions involving WEFN and sustainability and WEFN and Industry 4.0 may vary. The selection criteria for these questions present elements of subjectivity and multiple interpretations to the motivating biases of the selected questions, as well as their answers. In the case of the SDGs, as they are already defined by the United Nations, the possibility of variation between issues is more restricted.

A grade is assigned to the answer given to each question and the final result varies according to the answers obtained for the proposed questions. The measurement of each question is obtained in association with the weighted average that makes up the result of each axis. The composition of the sum of the answers to Questions X01 to X25 (sustainability and Industry 4.0) will define the resulting color of the X axis. Similarly, the composition of Questions Y01 to Y25, and Z01 to Z25, will define the colors of the Y and Z axes, which have their own resultants.

As for the SDGs, the composition of the sum of questions X01 to X17 results in the color red, varying its intensity, according to the answers received. Similarly, for the composition of the Y and Z axes, the composition of Questions Y01 to Y17 results in the color green, and Questions Z01 to Z17 result in the color blue, respectively, with the intensity of their colors varying according to the answers received.

The resultant output from the NEM is a graphical illustration resulting from a representative of the set of answers to the questions about the project being evaluated. This result may be expressed mathematically as an organized table of data or graphically as a vector, by means of the Cartesian axes. However, for the purpose of this study, Microsoft Excel version 2019 was used to express the result in the form of graphical illustrations, where triangles are used to represent each of the simulated relationships. Each triangle represents a Cartesian axis, and a central triangle represents the resultant vector.

Figure 3a,c present graphically the format of presentation of the results for the evaluations of WEFN and Sustainability and WEFN and Industry 4.0, where it is possible to visualize the results in three axes that have colors determined by the answers to the questions composed from the result of the composition of the RGB color system. In the case of WEFN and SDGs, each axis is represented by a color, as illustrated in Figure 3b,d. Figure 3a is equivalent to Figure 3c, just as Figure 3b is equivalent to Figure 3d.

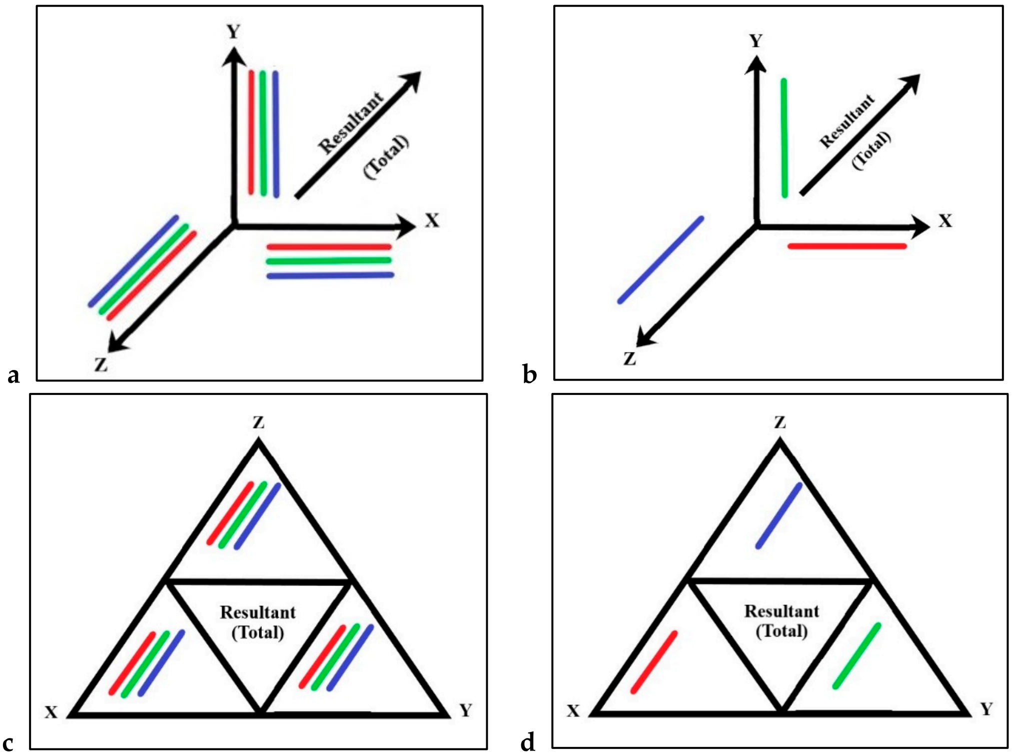

Figure 3. (**a**) Cartesian axes X, Y, and Z with illustration of the RGB colors, applicable to the WEFN and Sustainability and the WEFN and Industry 4.0. (**b**) Cartesian X, Y, and Z axes with RGB color illustration, applicable for WEFN and SDG. (**c**) Equilateral triangle X, Y, and Z with illustration of RGB colors, applicable for WEFN and Sustainability and WEFN and Industry 4.0. (**d**) Equilateral triangle X, Y, and Z with light-color illustration, applicable for WEFN and SDG. Source: Prepared by the authors (2023).

In the case of the RGB system, the intensity of each of the three colors is expressed digitally using a numbered scale from 0 to 255. It is from the combination of these colors that a final resulting color is obtained. The most accurate way to know colors through the RGB system is using the numbered scale from 0 to 255 for each color. The representation of colors may vary according to the medium in which the information is being conveyed, with the technical characteristics of the media, among others, being a factor. Figures 4 and 5 illustrate the logic implemented in the NEM when summing the answers to the questions that make up the composition of the final colors. Weights were assigned to the answers of the questionnaire and to the RGB system, as follows: “0” represents “Non-existent/Null” and “black” in the RGB system; “0.25” for a “Weak” response is assigned “64” in the RGB system; “0.5” for an “Average/Regular” response is assigned “128” in the RGB system;

"0.75" for a "Good" answer is assigned "191" in the RGB system; and "1.0" for an "Excellent" response is assigned "255" in the RGB system. White represents the perfect balance of the three RGB colors.

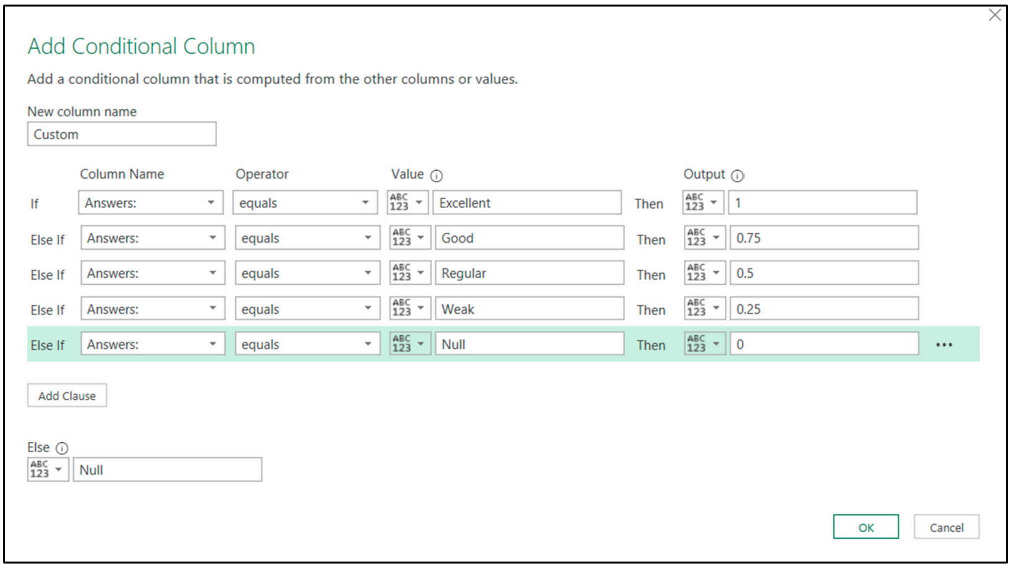

Figure 4. Weights assigned to the questionnaire responses during the formation of the final colors emerging from the summation of the colors. Source: Prepared by the authors (2024).

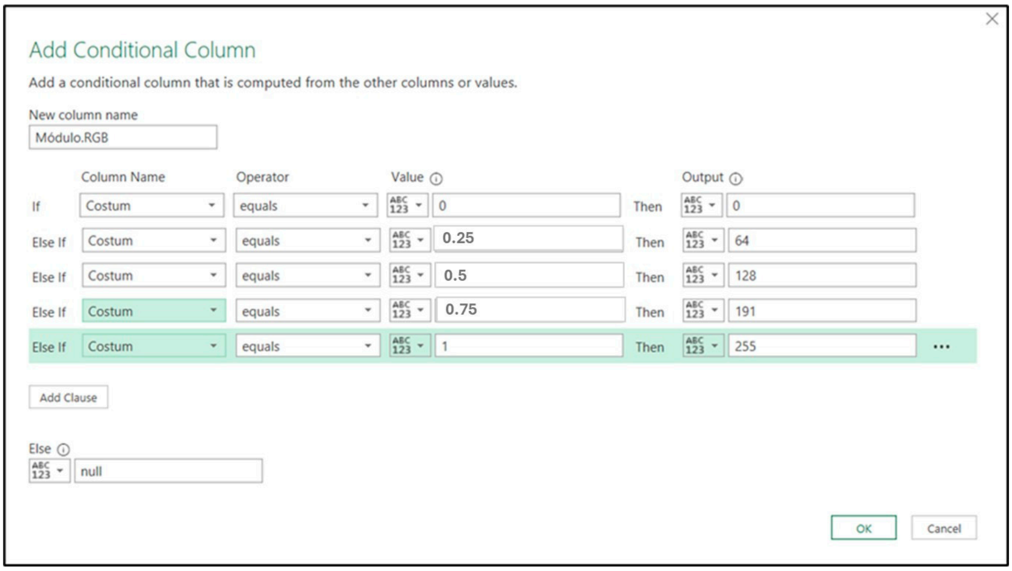

Figure 5. RGB values assigned to the responses in the formation of the resulting colors during the summation process. Source: Prepared by the authors (2024).

For the demonstration of the model, as presented in the following section, a set of questions related to WEFN and Sustainability, WEFN and Industry 4.0, and WEFN and SDG was elaborated and is listed in Appendix A. For the application of the questionnaire, the questions were implemented in Google Forms and the answers were integrated into an Excel spreadsheet.

3.4. Demonstration of the Model

Once the model had been developed, this phase of the DSR involved demonstrating its use to evaluate one or more WEFN case studies. In this case, the NEM was applied to three different projects, but with all having traces of the WEFN in their conception:

Project 1—Photovoltaic solar plants integrated with beef cattle farms: this project proposed a business model between the energy and agricultural sectors, through the installation of photovoltaic solar plants on beef cattle farms. The photovoltaic roofs capture rainwater to mix with the cattle manure underneath, where the resulting mixture is conducted to a bio-digester.

Project 2—Efficient House: refers to a single-family housing project designed within the scope of the National Program for the Conservation of Electric Energy. Inaugurated in March 2006, in its conception it sought to be a showcase of concepts and technologies so that researchers, professionals in the field of civil construction, and the community in general could adopt in their projects the concepts that best suited their needs. Having won several national and international awards, this project is now a reference in the sector.

Project 3—Biogas project: aimed to generate electricity from pig manure in the city of Itapiranga, located in the extreme west of Santa Catarina in the Uruguay River basin, and bordering Rio Grande do Sul (RS) and Argentina. On the one hand, Itapiranga and Santa Catarina stand out economically for their pig breeding; on the other hand, it is as a result of this production that animal waste has polluted the Uruguay River basin. This is the largest biogas R&D project in Brazil when considering the number of bio-digestion solutions investigated and associated with the size of the project, and because it contains a gas pipeline system having a length of more than eleven kilometers and an associated supervisory system.

The instruments developed for project data collection, as recommended by the model (Section 3.3), are shown in Appendix A. For this study, questions compatible with the analyzed projects were elaborated in order to compare the results of the application of the NEM in different projects. The same set of questions was applied to all three projects being analyzed in order to capture the differences between them, and thus demonstrate the functionality of the model. With this it was possible to show, through the graphic illustrations of each project, how each project is presented according to the characteristics evaluated either by the resulting color or the numerical data.

From the answers obtained, the results were calculated for the three simulated situations for each project: WEFN and Sustainability, WEFN and Industry 4.0, and WEFN and SDGs. Although the results of the evaluations were computed and analyzed for each project individually, they are presented together here, allowing a better graphical and numerical comparison to be made between the projects.

3.4.1. WEFN and Sustainability Evaluation

The graphic and numerical illustrations resulting from the evaluations of the three projects regarding the WEFN and dimensions of sustainability are presented in Figure 6 and Table 6.

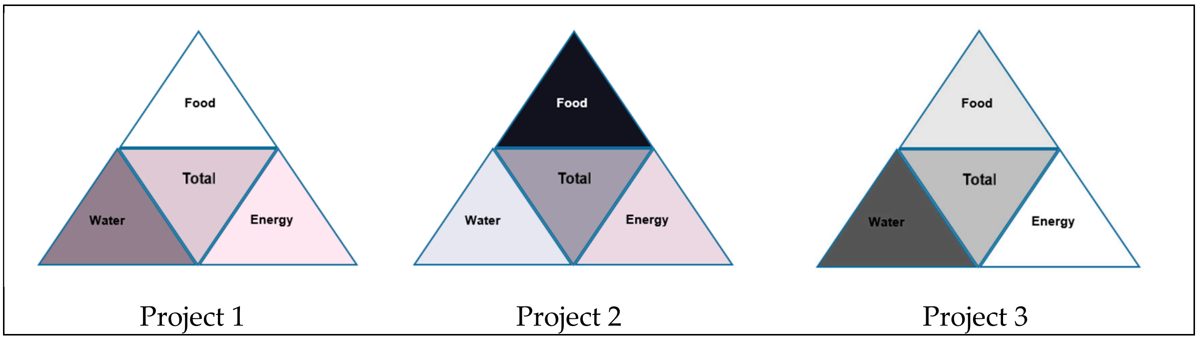

Figure 6. Comparison between the simulated projects for WEFN and Sustainability. Source: Prepared by the authors (2024).

Table 6. Comparison between the simulated projects for WEFN and Sustainability.

Projects	WEFN	RED (Dim. Environmental)	GREEN (Dim. Economic)	BLUE (Dim. Social)
Project 1	Water	140	128	140
	Energy	255	223	242
	Food	255	255	255
	Resultant (Total)	217	202	212
Project 2	Water	230	230	242
	Energy	230	217	229
	Food	26	26	38
	Resultant (Total)	162	158	170
Project 3	Water	89	89	89
	Energy	255	255	255
	Food	230	230	230
	Resultant (Total)	191	191	191

Note: Source: Prepared by the authors (2024). Note: The red, green and blue colors are intended to differentiate data related to environmental, economic, and social dimensions.

For Project 1, shown graphically in Figure 6, it is possible to observe that the food resource was the one that presented the best performance because it was represented by the white color, the energy resource was the second best and presented a pinkish color, while the water resource presented the worst performance in this project. The numerical analysis in Table 6 shows that the three values of the food resource in the composition of the sustainability dimensions, on the RGB scale, were 255, which results in the color white at its maximum intensity. It is important to remember that the understanding of better or worse will depend on the context of the analysis. For example, if managers or researchers seek to implement a project in a place where they need to emphasize their environmental actions aimed at water resources, then this will be evaluated specifically to see, for example, whether Red 140, equivalent to the environmental dimension of sustainability, meets the expectations of local actions. In this way, the model helps to guide actions that institutions such as companies, universities, and governments must take so that even greater gains can be achieved.

In the case of the results of Project 2, it is possible to observe in Figure 6 that the food resource was the one with the worst performance, as it was represented by the color black. The water resource showed the best performance, being closely followed by the energy resource. In the case of these last two resources, graphically there may be some doubt, and it should be noted that water is closer to the white color than energy. In this case, the observer has the means to clarify the performance of the project being evaluated by examining both the graphic illustration and the numerical table. In doing this, it can be seen that the water and energy resources presented the same value for the environmental dimension, 230, and for the economic and social dimensions, while they presented values of 230 and 242 for water and values of 217 and 229 for energy.

The results of the evaluation of Project 3 (see Figure 6) show that the energy resource was the one that presented the best performance, as it was represented by the light white color, symbolizing the balanced mixture of red, green, and blue colors. The food resource was the second best and presented a light gray color, while the water resource presented the worst performance. In the numerical illustration (see Table 6), it can be seen that the three resources present different values, but when examined individually, present the same values for all three dimensions of sustainability. It was found that the result of the energy resource was excellent, that of the food resource was very good, and that of the water resource was weak. It must be emphasized that the NEM applied the same set of questions to all projects and, in the case of Project 3, this was not through rainwater harvesting or water reuse being a project concept. Therefore, despite the important contribution of this Itapiranga Biogas Project, and its predecessor, Alto Uruguay Project, in the preservation of the Uruguay River, the result of the water resource was weak.

It can be demonstrated that the model also allows a comparative analysis to be carried out between the three projects. Thus, considering the WEFN and Sustainability evaluation, we can identify that, graphically (Figure 6) for the water resource, there are no white or black triangles whose interpretation is more direct, referring to the presence, or absence, of all colors, represented by the dimensions of sustainability. For this analysis, the numerical data (Table 6) show that Project 2 presents the best result. This result is in line with the fact that the Efficient House was designed with the rational use of water in mind. In cases of visual proximity such as this, it is important to refer to the numerical data to gain more a more in-depth analysis.

In the case of energy, Project 3 presented the best results. The result of Project 1 was also very good, and a similar situation was observed for Project 2 which, despite having presented the worst performance for this resource, also presented good numerical results. The good scores of the three projects for the analyzed resource are in line with the fact that they were projects implemented, or that are being implemented, by a reputable company in the national electricity sector.

From the analysis of the food resource, it can be seen that Project 1 presented the best result, while Project 2 had the worst. These results are in line with the projects analyzed, as Project 1 refers to an animal protein production project and, to integrate the energy and livestock sectors, it adopts important animal welfare practices for the production of animal products. In the case of Project 2, it is noted that, at the time of its installation, animal protein production systems were not thought of for the Efficient House. Project 3 was classed as the second-best project for the food resource as, being a project to generate energy from pig manure, pigs are seen as important source of food.

Observing the triangle graphics in Figure 6 and referring to the total placed in the center triangle, it can be seen that Project 1 presented the best performance, being composed of the results 217, 202, and 212 for the dimensions of sustainability, as shown in Table 6. Project 3 received the second-best evaluation, consisting of the results 191, 191, and 191. Project 2 was in third position, consisting of the results 162, 158, and 170. These results illustrate the potential of the NEM, as it allows managers and researchers to compare projects based on the WEFN from the perspective of sustainability, and thus evaluate and manage more efficiently the important resources necessary for life.

3.4.2. WEFN and Industry 4.0 Evaluation

Similar to the previous section, the WEFN and Industry 4.0 evaluation in the NEM provides the graphics shown Figure 7 and the numerical representation shown in Table 7.

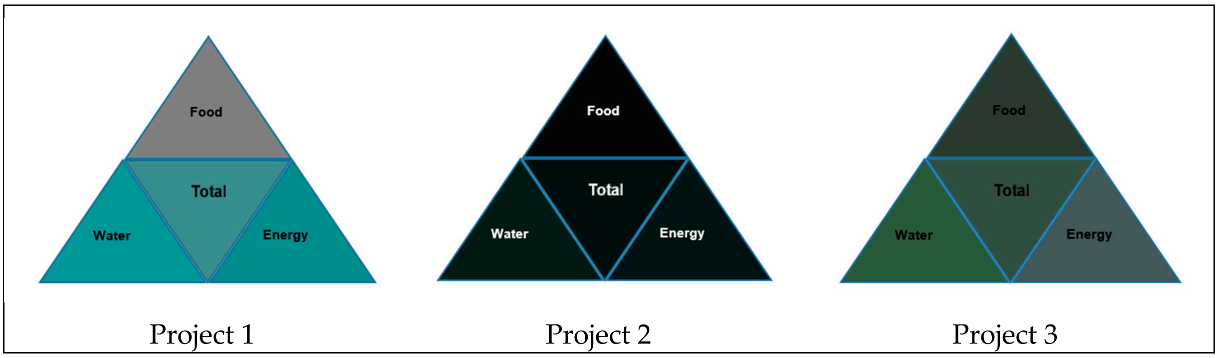

Figure 7. Comparison between the simulated projects for WEFN and Industry 4.0. Source: Prepared by the authors (2024).

Table 7. Comparison between simulated projects for WEFN and Industry 4.0.

Projects	**WEFN**	**RED (Biological Factor)**	**GREEN (Digital Factor)**	**BLUE (Physical Factor)**
Project 1	Water	77	153	153
	Energy	77	141	141
	Food	128	128	128
	Resultant (Total)	94	141	141
Project 2	Water	13	32	26
	Energy	0	26	26
	Food	13	13	13
	Resultant (Total)	9	24	22
Project 3	Water	64	90	64
	Energy	77	90	90
	Food	51	64	51
	Resultant (Total)	64	81	68

Note: Source: Prepared by the authors (2024). Note: Red represents the biological factor, Green denotes the digital factor, and Blue symbolizes the physical factor.

In the case of Project 1, from the graphics in Figure 7 it can be seen that the water resource obtained the clearest result, demonstrating that it is the resource with the greatest balance among those evaluated. However, the energy resource in his illustration was much closer to the result presented by the water resource than to the result of the food resource, which was the worst result in this evaluation. Numerically (Table 7), the food resource presented a perfect balance between the three factors, registering 128 for all of them; however, its color became dark gray because on the RGB scale, 128 represents the half intensity between the purely black (0) and purely white (255) results. It can be seen too that Project 1 was conceived with much more focus on sustainability than on Industry 4.0. Again, this is shown graphically in Figure 6 as the colors are closer to white. Additionally, in the case of the numerical representation (Table 7), the RGB axes values are significantly higher for the resources of water, energy, and food in the Project 1 WEFN and Sustainability evaluation rather than in the Project 1 WEFN and Industry 4.0 evaluation.

In the evaluation of Project 2 for WEFN and Industry 4.0, it was observed that the three resources are very close to the absolute black color (see Figure 7), which demonstrates that the Efficient House project practically had nothing in its conception that was being questioned for this theme. Looking at the numerical values in Table 7, it is possible to see that water was the resource that did best in this evaluation, as it had the best values for the three factors of Industry 4.0, i.e., 13, 32, and 26, respectively, although it was tied with the food resource in the biological factor and with the energy resource in the physical one.

The graphic illustration for Project 3 shown in Figure 7 may raise doubts about its interpretation because the color tones are similar, which requires further investigation of colors and their RGB compositions. In this case, the numerical table presents the colors and their scores in a stratified manner, allowing for an accurate evaluation. Considering Table 7, it can be seen that Project 3 presented the best score for the energy resource, which obtained the best evaluations for the three factors of Industry 4.0. The water resource was the second best, because in this case its three component factors of Industry 4.0 had higher evaluations than the food resource.

The comparative analysis of the three projects evaluated shows that, in the case of Industry 4.0, Project 2 presented the worst results for all resources. Project 3 had the second-worst result, while Project 1 showed the best results for all resources, as shown in Figure 7.

3.4.3. WEFN and SDG Evaluation

In the WEFN and SDG evaluation, it can be observed that the graphic and numerical illustrations are different from the previous evaluations presented against sustainability and Industry 4.0. This is due to the fact that the WEFN and SDG evaluation crosses data between the three resources, water, energy, and food, with the 17 SDGs, where the rates of service of the projects for each of the SDGs are evaluated separately for each resource. In this evaluation, each of the three features is composed of only one color, varying only the intensity of the color, whose scale goes from 0 to 255. So, the higher the feature score, the closer it will get to the pure red, green, or blue color, with the sum of these resulting in pure white. Figure 8 and Table 8 present graphically and numerically, respectively, the results of the evaluation of the three projects regarding WEFN and SDG.

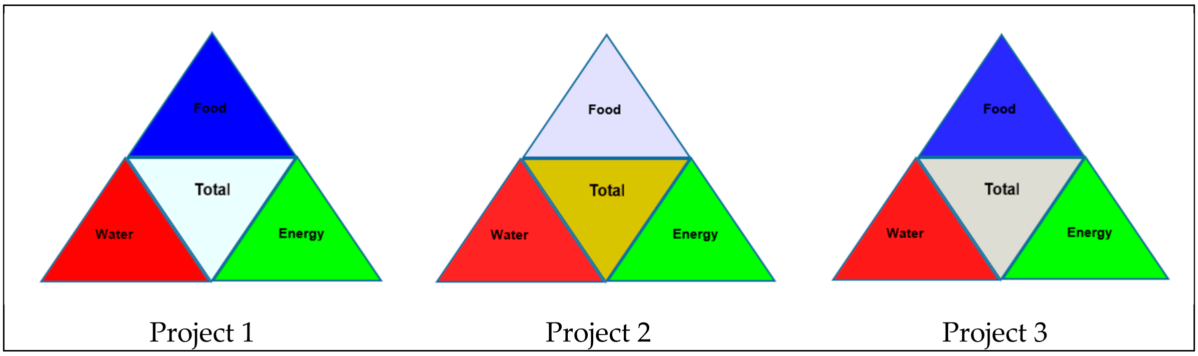

Figure 8. Comparison between the simulated projects for WEFN and SDG. Source: Prepared by the authors (2024).

Table 8. Comparison between the simulated projects for WEFN and SDG.

Projects	WEFN	RED (Water)	GREEN (Energy)	BLUE (Food)	Resultant (Total)
Project 1	Water	255	11	11	244
	Energy	0	255	0	255
	Food	0	0	255	255
Project 2	Water	255	41	41	214
	Energy	60	255	60	195
	Food	225	225	255	30
Project 3	Water	255	34	34	221
	Energy	34	255	34	221
	Food	45	45	255	210

Note: Source: Prepared by the authors (2024). Note: The colors red, green, and blue respectively represent issues related to water, energy, and food.

It can be seen, both graphically and numerically, that the evaluation of Project 1 WEFN and SDG presented an excellent result since two resources, energy and food, reached the maximum score, 255, in the RGB scale and the third resource, water, approached this number by reaching 244, as illustrated in the resultant (Total) column shown in Table 8.

Although Project 1 excelled, as demonstrated by the well-defined colors in Figure 8, the same cannot be observed for Project 2, where it can be seen that the water resource is the one that comes closest to its pure color (corresponding to the template), followed by the energy resource, which presented a performance from average to good. In the case of the food resource, it is observed that the project presented a poor performance for the WEFN and SDG evaluation, and this can be seen by the blue color, which is shown in a weaker less-intense color. From the numerical data in Table 8, it is possible to confirm what was observed graphically, since the water resource presented a resultant score of 214 while the energy resource presented 195. The poor performance of the food resource can be observed by the result presented in the value of 30.

In the case of Project 3, the Figure 8 graphic illustrates this project presented good results because the three colors of the triangles that represent each of the WEFN features are relatively strong. This can be confirmed by the result of the sum of the three features, as the composition of the three colors resulted in the light gray color. Again, as shown by the numerical data in Table 8, the three resources of the WEFN presented high values, registering 221 for water and energy resources, and 210 for food resources.

Comparing the three projects with regard to WEFN and SDGs, Project 1 had the best results for the three resources as seen by the intense colors in the red, green, and blue triangles (axes), and, above all, by the white color of the resulting (total). Project 2 presented the worst results for WEFN and SDGs, while Project 3 presented intermediate results.

These results illustrate another potential of the NEM, as it allows managers and researchers to compare projects based on the WEFN from the perspective of the SDGs. This is important since a demonstration of compliance with the SDGs is required, especially in the case of large companies listed on stock exchanges or those that establish business relationships with listed companies. In the graphical analysis (Figure 8), the main doubts regarding the project classifications may exist regarding the water and energy resources of Projects 2 and 3. In this case, the numerical analysis shown in Table 8 is recommended. The food resource presents a visually striking difference for the three projects.

3.5. Evaluation of NEM

The validation and legitimization of the NEM as a tool to support the identified WEFN should occur in accordance with the ontological or epistemological view adopted, and comply with the scientific perspective as well as the practical perspective [43,44]. Thus, to support this analysis, both perspectives are considered to ensure the relevance, efficacy, and applicability of the NEM.

From a practical perspective, results from the application of the NEM to real projects by experts in the demonstration phase, who were also part of the teams of the projects being evaluated, gave evidence about the degree or capacity of the NEM to describe and represent correctly and accurately the status of the projects being evaluated [45]. The results of the application of the NEM to the three projects, in general, were more positive regarding the WEFN and Sustainability relationship (environmental, economic, and social) than the WEFN and Industry 4.0 relationship (biological, digital, and physical). This difference in results signals, firstly, that the projects meet the dimensions of sustainability more satisfactorily than the structuring factors of Industry 4.0. The experts demonstrated in their answers that these results were in line with the reality of the evaluated projects. For example, the following statement shows how one of the three experts, designated as E1, refers to this when dealing with the WEFN and Sustainability result for Project 3 (Biogas):

> "Here, too, the results of the assessment are consistent with expectations, since the direct impacts involve energy generation and production of animal protein for human food purposes. With regard to water, it must be considered that the full operation of the system, once installed, has the consequence of not discharging effluents into streams, preserving and even recovering environments that were previously contaminated." (E1)

Similarly, in relation to Project 2 (Efficient House), the experts agreed among themselves with the results regarding sustainability as shown in the following illustrative testimonies:

> "As for Project 2 and sustainability, I agree with the water and energy indexes, but as for food, I believe that with all the technologies used in the house, it would

> be very possible to create hydroponic gardens and even raise animal protein, especially insects, in an urban environment." (E1)

> "The result of the proposed project is aligned with what is expected empirically, since food development is not part of the scope, being, at most, a side effect. For the Water and Energy items, the result is representative of what has been put in place and built." (E2)

These testimonies show that the application of the model not only reflects the real results of the project, but also denotes the potential of the model to present possibilities for improvements in terms of aligning the WEFN with the dimensions of sustainability. Although the food resource was not part of the scope of Project 2, as expert E2 says; the results presented by the model make expert E1 reflect on the possibility and gains of incorporating this resource into the project. Regarding the relationship between WEFN and Industry 4.0, experts also denote the coherence of the results presented in the demonstration of the application of the model with the reality of the projects. This is illustrated by these comments from E2 regarding projects 2 and 3, respectively:

> "The result is within the expected limits, since the Efficient House, from its conception to the present moment, did not take into account aspects related to Industry 4.0." (E2)

> "Compared to the scores in the scope of Sustainability and SDGs, here again the result was below the midpoint of evaluation because it is yet another project that was not conceived, planned and developed considering the aspects of Industry 4.0." (E2)

The less-favorable results of the evaluation of the projects regarding the relationship between WEFN and Industry 4.0 are coherent, considering that the factors of Industry 4.0 were not in the design of the projects. It must be considered that the results are more favorable to sustainability than to Industry 4.0, and are in line with the very nature of the WEFN that emerged at the Bonn Conference [46], in the search for more sustainable management solutions and the projects that were evaluated were structured in the logic of the WEFN. However, in some of the projects evaluated, experts already understand that Industry 4.0 factors could have been considered, as referred to by Expert E3 regarding Project 3:

> "The Itapiranga project, as we discussed previously, is very useful, profitable, has a timely marketing appeal, and is part of the model of socio-environmental improvement of Brazil's energy matrix. However, I think it could be more disruptive, advancing not only with current technologies, but also allowing us to anticipate the probability of new technologies." (E3)

In other cases, it is observed that even in the "eyes" of the experts themselves, the relationship between the elements of the WEFN and the factors of Industry 4.0 became difficult to see in practice, as shown in this extract from Expert E1's report regarding Project 1:

> "As for the digital factor, I can't see a relationship between water and food and the digital factor." (E1)

Although they are specialists with extensive experience in evaluating projects that bring together the three resources, this difficulty may be related to the nature of the WEFN, which has sustainability at its core and not Industry 4.0. Considering that Industry 4.0 is increasingly present in contemporary times, the possibility of this evaluation perspective being incorporated in the model is promising in the management of projects related to the WEFN. In general, experts also agree with the positive results of the WEFN and SDG evaluations and reinforce that this is due to the fact that the WEFN resources are implicit in the SDGs. Expert E2 states this in relation to Project 1:

> "Due to the fact that the elements analyzed were directly anticipated in the SDGs, the result of the project was of high value in its aspects." And also, regarding Project 3: "The result shows the adherence of the project to the SDGs, quite close to a condition of perfect equilibrium in high scores. As expected empirically when pre-analyzing the project." (E2)

Similarly, Expert E3 reinforces this perspective when addressing the results of the evaluation of Project 1:

> "The project, as we had previously discussed, is very useful and innovative, as it involves in the same project, the interactions of water, energy and food, water and energy as vectors for the food result, which clearly refers to the SDGs". (E3)

Another point considered that appears in the evaluation of the model carried out by the experts, that can be attributed to a limitation of the model, is the fact that it is not available in software with a user-friendly interface, but through an evaluation made in Excel. This fact implies the visualization of the results of the evaluation, since the answers that generated the graphs are presented separately, which may cause some difficulty for the specialists.

It was suggested by the experts that the creation of specific software based on the proposed NEM would be useful in order to disseminate the science of the WEFN without requiring the need for an in-depth knowledge of Excel. This will allow managers and researchers to achieve better performance in their projects under elaboration, or in restructuring, as well as in the evaluation of the acquisition of companies in *brownfield* processes, whether in meeting the dimensions of sustainability or in the factors that structure Industry 4.0. In the case of organizations listed on stock exchanges, which must annually fill out questionnaires aimed at meeting the SDGs, the experts pointed out that this solution can be an instrument to help managers.

4. Discussion

The NEM developed in this study presents an important solution in which the practicality and usability of a software with clear and intuitive interfaces for project evaluation, with easily interpretable indicators and metrics, enables the use of a tool that is not only theoretically robust, but is also practical and easy to use by managers and decision-makers. In addition, the NEM provides a readily understood visual and numerical representation of a WEFN-related project's alignment with sustainability, Industry 4.0, and the SDGs, making it simple to interrogate and effectively justify the generated results. It is, in the view of experts, a solution with adaptability and scalability, capable of ensuring that the NEM is flexible enough to adapt to different projects and different scopes. The experts also highlight the potential it presents for international organizations such as banks in their evaluation of risk in financing the execution of such projects. Thus, they highlight the potential of the NEM to evaluate not only those projects executed already, but also projects that have not yet been implemented. This is relevant, as the model can indicate potential areas for improvement of a project prior to implementation. This was indicated by Expert E2's testimony when considering the relationship between WEFN and SDGs in Project 1 which, at the time of carrying out this study, had not been implemented:

> ". . . the result of the project was of high value in its aspects. Taking this result by itself, the project presents itself as having high potential for execution, with a great expected return in the analyzed scope". (E2)

These perceptions from the experts on the practical uses of the proposed NEM are in line with those of the authors of this study. From a purely scientific perspective, the validity of the NEM is robust considering the quality criteria established from the DSR approach [27], i.e., design as an artifact; problem relevance; design evaluation; research contributions; research rigor; design as a search; and communication of research. The complexity of projects involving the WEFN requires innovative solutions that can assess the multiple dimensions involved. The NEM was conceived as an innovative artifact, integrating within the assessment the dynamics and interdependence of the WEFN's critical resources with sustainability criteria, and considering the imperatives of Industry 4.0, as well as the SDGs. Similar research using models or a set of indicators, especially related to the SDGs, has been shown to arrive at feasible analyses of national projects, especially those aligned with the UN's global agenda and with the priorities of populations that have less access to natural resources [20,22].

The NEM is designed with functionalities to be flexible, useful, and financially viable. Its ability to generate graphic and numerical illustrations by means of the RGB system and Cartesian axes is a distinctive feature that increases its usefulness and applicability, allowing visualization of the impact in each area. This result was achieved through an exploratory and iterative design process involving experimentation and continuous refinement of this solution to meet the requirements of the problem [20,27] from the exploration of supporting theoretical foundations and including the participation and feedback of experts. Adaptations to the NEM were necessary throughout the design and development process. For example, the need for changes in the format of graphical representation of the results was aimed, in this case, towards a greater scalability based on easily accessible technologies. The development of the NEM was based on the integration of theoretical foundations that supported the content of the elements and their interactions regarding the functionalities offered.

The alignment of the method that was finally adopted, combined with the thoroughness in its application, as well as the input from the experts whose experience and participation in projects related to the WEFN, gave greater rigor, credibility, and legitimacy to the research that led to the final NEM. Its validity and effectiveness were confirmed by demonstrating the interactions and impacts between the different dimensions evaluated in a manner consistent with the reality of the projects being evaluated. In particular, the experts highlighted the innovative visualization approach that facilitates the interpretation of complex data. However, the same experts also pointed out that the development of specific dedicated software would avoid the necessity to become familiar with the more general Excel 2019 software.

The NEM offers a means to contribute effectively to WEFN research by expanding the understanding about how related projects can be evaluated by considering multiple contemporary dimensions studied by today's leading scientists in sustainability, innovation, and global issues. Establishing links between the WEFN and the dimensions of sustainability, Industry 4.0, and the SDGs brings together indicators capable of identifying gaps, objectives, and/or future development demands. Therefore, the proposed NEM is aligned with the demand for evaluation models that incorporate the three features of the nexus, i.e., practicability, measurability, and clarity, and the implementation roadmap that contributes to integrative governance [23].

Competitions and synergies can be evaluated through the results of the interactions "WEFN and Sustainability" and "WEFN and Industry 4.0" + "WEFN and SDGs". Taking into account that the model is integrated and evaluates the dimensions of sustainability, SDGs, and Industry 4.0 in the context of the nexus, positive and/or negative impacts may occur. For example, an action on a certain SDG can lead to a positive or negative impact on another SDG. As Sarkodie et al. (2020) [5] point out, although fossil fuel energy technologies compete with water capture and consumption, some renewable energies compete with food for land use, which requires cost and benefit policy estimations.

Situations of synergies and trade-offs can be reflected visually in the alignment or misalignment of the colors resulting from the proposed NEM which, in turn, reflects the performance of a project. For example, the results of the evaluation of Project 3 present several synergies, mainly in the transformation of waste into renewable energy and biofertilizers, contributing to environmental, economic, and social sustainability. The evaluation of this project also highlights trade-offs. For example, when considering SDG 6 (Clean water and sanitation), the project contributes to the sustainable management of drinking water and sanitation by treating pig waste and reducing the pollution of water resources. On the other hand, when considering SDG 12 (Sustainable consumption and production), the project has an average evaluation with regard to the responsible use of antibiotics in animals. The application of animal welfare techniques to reduce the use of antibiotics was not considered, which negatively impacts responsible consumption and production patterns.

These results illustrate how the possibilities of interactions between the different components of the model can influence, both positively and negatively, the overall performance of the project, allowing an integrated analysis of the various variables involved. This contributes to nexus-based projects being evaluated holistically and aligned with the global agendas of clean and inclusive technologies, avoiding the generation of contradictory indicators.

This research study contributes an innovative and intuitive proposal that involves dimensions studied by today's leading scientists related to sustainability, innovation, and global issues. In addition, the practical contributions the NEM can make are evidenced in its ability to influence strategic and operational decisions in organizations that seek to integrate sustainability and technological innovation into their projects. When WEFN-based project managers have access to a stratified analysis of their analyzed projects, more precise actions are enabled so that the projects to be implemented are able to achieve greater reach in meeting the initial objectives. In addition, by applying the NEM, they can identify unforeseen gaps that are capable of enhancing projects and their social impact in the areas of sustainability and Industry 4.0.

The proposed NEM goes beyond the issue of economic and financial metrics and starts with a holistic and sensitive view of the purposes and interests of humanity, including the local issues indicated in the projects and their surroundings. To this end, it uses an analytical approach that can be easily applied by managers, and also those involved in the planning, implementation, and evaluation of projects.

5. Conclusions

The main limitation of the research is that the study was confined to the activities and support of a single state-owned company. Thus, the construction of the NEM, its application, and its evaluation were narrowed to the view of professionals who are part of the same organization. This does not invalidate the results of the research, but it does limit it in terms of the findings and context studied. It does not compromise the analytical generalization for similar cases of state/government projects, nor for universities and public science and research institutions. However, the proposed model needs further studies for replication in projects led by private enterprises and institutions. This is due to the fact that the expected results and timelines required by the private sector are, preferably, in the short and medium term and involve market interests. This is unlike government projects, which focus on the medium and long term and where the greatest concern is more towards the impact on the social aspects of a project.

Thus, in order to improve the proposed model, future research can explore its application in different geographical contexts and industrial sectors to validate its effectiveness and adaptability. It is suggested that future research should expand the scope of the study in two directions: firstly, to continue in the public sector and, secondly, to extend it to other productive sectors that aim at the socioeconomic development of the territories being studied. Another research approach is to include segments of the private sector that work with strategic development projects, both independently and in public/private partnerships.

Currently, a technical limitation of the NEM is the requirement for operator expertise in the use of Excel in relation to its application with equivalent functionality. Although the solution adopted has proven to be capable of validating the research proposition, future studies could propose the development of a specific software application for easier operationalization of the NEM and to incorporates different formats of graphic illustrations, leaving it up to the user to choose the one most aligned with their preference. Another feature that could be incorporated into the NEM is a sound system in the presentation of the results of the evaluation of the projects. Just as the numerical table allows colorblind people who do not distinguish colors to locate themselves in the results presented, blind people, as well as users in general, would be able to hear the sound of the projects, enabling a broader sensory experience of the projects being evaluated.

Since this study identified several gaps regarding the alignment of the projects evaluated to Industry 4.0, additional studies can investigate how the integration of emerging technologies, such as artificial intelligence and the Internet of Things, can further optimize the results of nexus-based projects. In addition, future research may focus on developing more detailed metrics for each of the 17 SDGs, considering synergies and trade-offs in projects involving the nexus. The proposed model allows for analyses of projects related to the WEFN, considering sustainability, Industry 4.0, and the SDGs, leading to broad awareness of the connections between universal rights to water supply, energy security, and food supply. Future studies may use the logic of the proposed artifact for evaluations of projects of other natures, in addition to those related to the WEFN.

Author Contributions: R.d.C.S.N. and J.P.B. were responsible for the conceptualization of the article. The methodology was developed by I.J., C.C.M., R.d.C.S.N. and A.R.d.A.D. performed the validation of the methodology and the investigation (data collection). S.V.S. was responsible for the formal analysis of the data. R.S.B. worked on the review and editing in English. J.B.S.O.d.A.G. was the project coordinator. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Data is contained within the article.

Acknowledgments: We gratefully acknowledge the contributions of several institutions in the successful completion of this study. The research was carried out by the Centre for Sustainable Development (Greens) in collaboration with the Graduate Program in Administration at the University of Southern Santa Catarina (Unisul) as part of the Greens 10 × 10 project. We also extend our appreciation to the Fundação de Amparo à Pesquisa e Inovação do Estado de Santa Catarina (FAPESC), Ânima Institute (AI), Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), and the National Council for Scientific and Technological Development (CNPq) for their invaluable support and assistance throughout the research process.

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A. Questions Applied in the Proposed Assessment Model

This appendix presents the questions applied in the evaluation model proposed for the three simulations, (1) Nexus and Sustainability, (2) Nexus and Industry 4.0, and (3) Nexus and SDGs, and for the three different projects simulated in this research. The questions are the same and the results presented vary.

Appendix A.1. Evaluation Model—Nexus and Sustainability

Table A1. Questions regarding the ***X*-axis (Water)** and the **Environmental** dimension of **Sustainability**.

Question X01	How does the project classify, in terms of **water** resources, in terms of the **environmental** dimension of **Sustainability** in relation to rainwater harvesting?
Question X02	How does the project classify, in terms of **water** resources, in terms of the **environmental** dimension of **Sustainability** in relation to the water reuse system?
Question X03	How does the project classify itself, regarding the **water** resource, in terms of the **environmental** dimension of **Sustainability** in relation to the presence of water consumption control mechanisms?
Question X04	How does the project classify, in terms of **water** resources, in terms of the **environmental** dimension of **Sustainability** in relation to waste treatment?
Question X05	How does the project classify, in terms of **water** resources, in terms of the **environmental** dimension of **Sustainability** in relation to its water self-sufficiency?

Table A2. Questions regarding the **X axis (Water)** and the **Economic** dimension of **Sustainability**.

Question X11	How does the project classify, in terms of **water** resources, in terms of the **economic** dimension of **Sustainability** in relation to rainwater harvesting?
Question X12	How does the project classify, in terms of **water** resources, in terms of the **economic** dimension of **Sustainability** in relation to the treatment of water for reuse?
Question X13	How does the project classify, with regard to the **water** resource, in terms of the **economic** dimension of **Sustainability** in relation to the presence of water consumption control mechanisms?
Question X14	How does the project classify, in terms of water resources, in terms of the **economic** dimension of **Sustainability** in relation to waste treatment?
Question X15	How does the project classify, in terms of **water** resources, in terms of the **economic** dimension of **Sustainability** in relation to its water self-sufficiency?

Table A3. Questions regarding the **X axis (Water)** and the **Social** dimension of **Sustainability**.

Question X21	How does the project classify, in terms of **water** resources, in terms of the **social** dimension of **Sustainability** in relation to rainwater harvesting?
Question X22	How does the project classify, in terms of **water** resources, in terms of the **social** dimension of **Sustainability** in relation to the treatment of water for reuse?
Question X23	How does the project classify, in relation to the **water** resource, in terms of the **social** dimension of **Sustainability** in relation to the presence of water consumption control mechanisms?
Question X24	How does the project classify, in terms of **water** resources, in terms of the **social** dimension of **Sustainability** in relation to waste treatment?
Question X25	How does the project classify, in terms of **water** resources, in terms of the **social** dimension of **Sustainability** in relation to its water self-sufficiency?

Table A4. Questions regarding the **Y axis (Energy)** and the **Environmental** dimension of **Sustainability**.

Question Y01	How does the project classify, in terms of **energy** resources, in terms of the **environmental** dimension of **Sustainability** in relation to the generation of energy considered clean?
Question Y02	How does the project classify, in terms of **energy** resources, in terms of the **environmental** dimension of **Sustainability** in relation to the generation of energy considered renewable?
Question Y03	How does the project classify, in terms of **energy** resources, in terms of the **environmental** dimension of **Sustainability** in relation to its self-sufficiency in energy generation?
Question Y04	How does the project classify, in terms of **energy** resources, in terms of the **environmental** dimension of **Sustainability** in relation to distributed energy generation?
Question Y05	How does the project classify, in terms of **energy** resources, the **environmental** dimension of **Sustainability** in relation to the use of national technology?

Table A5. Questions regarding the **Y axis (Energy)** and the **Economic** dimension of **Sustainability**.

Question Y11	How does the project classify, in terms of **energy** resources, in terms of the **economic** dimension of **Sustainability** in relation to the generation of energy considered clean?
Question Y12	How does the project classify, in terms of **energy** resources, in terms of the **economic** dimension of **Sustainability** in relation to the generation of energy considered renewable?
Question Y13	How does the project classify, in terms of **energy** resources, in terms of the **economic** dimension of **Sustainability** in relation to its self-sufficiency in energy generation?
Question Y14	How does the project classify, in terms of **energy** resources, in terms of the **economic** dimension of **Sustainability** in relation to distributed energy generation?
Question Y15	How does the project classify, in terms of **energy** resources, in terms of the **economic** dimension of **Sustainability** in relation to the use of national technology?

Table A6. Questions regarding the **Y axis (Energy)** and the **Social** dimension of **Sustainability**.

Question Y21	How does the project classify, in terms of **energy** resources, in terms of the **social** dimension of **Sustainability** in relation to the generation of energy considered clean?
Question Y22	How does the project classify, in terms of **energy** resources, in terms of the **social** dimension of **Sustainability** in relation to the generation of energy considered renewable?
Question Y23	How does the project classify, in terms of **energy** resources, in terms of the **social** dimension of **Sustainability** in relation to its self-sufficiency in energy generation?
Question Y24	How does the project classify, in terms of **energy** resources, in terms of the **social** dimension of **Sustainability** in relation to distributed energy generation?
Question Y25	How does the project classify, in terms of **energy** resources, the **social** dimension of **Sustainability** in relation to the use of national technology?

Table A7. Questions regarding the **Z axis (Food)** and the **Environmental** dimension of **Sustainability**.

Question Z01	How does the project rank in terms of **the food** resource and the **environmental** dimension of **Sustainability** in relation to food production in general?
Question Z02	How does the project classify, in terms of **food resources**, in terms of the **environmental** dimension of **Sustainability** in relation to the production of food that is of animal origin?
Question Z03	How does the project rank in terms of **the food** resource and the **environmental** dimension of **Sustainability** in relation to local food security?
Question Z04	How does the project classify, in terms of **food resources**, in terms of the **environmental** dimension of **Sustainability** in relation to the reduction in the use of pesticides and/or antibiotics?
Question Z05	How does the project classify, in terms of **food** resources, the **environmental** dimension of **Sustainability** in relation to the use of national technology?

Table A8. Questions regarding the **Z axis (Food)** and the **Economic** dimension of **Sustainability**.

Question Z11	How does the project rank in terms of **the food** resource in terms of the **economic** dimension of **Sustainability** in relation to food production in general?
Question Z12	How does the project classify, in terms of **the food** resource, in terms of the **economic** dimension of **Sustainability** in relation to the production of food that is of animal origin?
Question Z13	How does the project rank in terms of **food** resources in terms of the **economic** dimension of **Sustainability** in relation to local food security?
Question Z14	How does the project classify, in terms of **food** resources, in terms of the **economic** dimension of **Sustainability** in relation to the reduction in the use of pesticides and/or antibiotics?
Question Z15	How does the project classify, in terms of **food** resources, in terms of the **economic** dimension of **Sustainability** in relation to the use of national technology?

Table A9. Questions regarding the **Z axis (Food)** and the **Social** dimension of **Sustainability**.

Question Z21	How does the project classify, in terms of **food** resources, in terms of the **social** dimension of **Sustainability** in relation to food production in general?
Question Z22	How does the project classify, in terms of **food** resources, in terms of the **social** dimension of **Sustainability** in relation to the production of food that is of animal origin?
Question Z23	How does the project rank in terms of **food** resources and the **social** dimension of **Sustainability** in relation to local food security?
Question Z24	How does the project classify, in terms of **food** resources, in terms of the **social** dimension of **Sustainability** in relation to the reduction in the use of pesticides and/or antibiotics?
Question Z25	How does the project classify, in terms of **food** resources, in terms of the **social** dimension of **Sustainability** in relation to the use of national technology?

Appendix A.2. Evaluation Model—Nexus and Industry 4.0

Table A10. Questions regarding the **X axis (Water)** and the **Biological** factor of **Industry 4.0**.

Question X01	How does the project classify, with regard to the **water** resource, regarding the **biological** factor of **Industry 4.0** in relation to the use of computer simulation for real-time data analysis, whether for rainwater harvesting or for water reuse?
Question X02	How the project is classified, with regard to the **water** resource, regarding the **biological** factor of **Industry 4.0** in relation to the use of the Internet of Things (IoT), connecting physical objects, machines, vehicles and machines through embedded electronic devices, and thus allowing the collection and exchange of information in a fast and controlled manner, as programmable mechanisms for controlling water consumption and waste treatment?
Question X03	How does the project classify, in terms of **water** resources, the **biological** factor of **Industry 4.0** in relation to the use of robotics, through robots/monitoring and evaluation systems, as well as additive manufacturing, also known as 3D printing?
Question X04	How does the project classify, in terms of **water** resources, in terms of the **biological** factor of **Industry 4.0** in relation to system integration, enabling harmony between all systems involved in the project, cybersecurity, and in relation to the concept of cloud *computing*?
Question X05	How does the project classify, in terms of **water** resources, the **biological** factor of **Industry 4.0** in relation to the reduction in the use of pesticides and/or antibiotics?

Table A11. Questions regarding the ***X*-axis (Water)** and the **Digital** factor of **Industry 4.0**.

Question X11	How does the project classify, with regard to the **water** resource, regarding the **digital** factor of **Industry 4.0** in relation to the use of computer simulation for real-time data analysis, whether for rainwater harvesting or for water reuse?
Question X12	How does the project classify, with regard to **the water** resource, regarding the **digital** factor of **Industry 4.0** in relation to the use of the Internet of Things (IoT), connecting physical objects, machines, vehicles and machines through embedded electronic devices, and thus allowing the collection and exchange of information in a fast and controlled way, as programmable mechanisms for controlling water consumption and waste treatment?
Question X13	How does the project classify, in terms of the **water** resource, in terms of the **digital** factor of **Industry 4.0** in relation to the use of robotics, through robots/monitoring and evaluation systems, as well as additive manufacturing, also known as 3D printing?
Question X14	How does the project classify, in terms of **water** resources, in terms of the **digital** factor of **Industry 4.0** in relation to systems integration, enabling harmony between all systems involved in the project, cybersecurity, and in relation to the concept of cloud *computing*?
Question X15	How does the project classify, in terms of **water** resources, in terms of the **digital** factor of **Industry 4.0** in relation to the reduction in the use of pesticides and/or antibiotics?

Table A12. Questions regarding the **X axis (Water)** and the **Physical** factor of **Industry 4.0**.

Question X21	How does the project classify, with regard to the **water** resource, regarding the **physical** factor of **Industry 4.0** in relation to the use of computer simulation for real-time data analysis, whether for rainwater harvesting or for water reuse?
Question X22	How does the project classify, with regard to the **water** resource, regarding the **physical** factor of **Industry 4.0** in relation to the use of the Internet of Things (IoT), connecting physical objects, machines, vehicles and machines through embedded electronic devices, and thus allowing the collection and exchange of information in a fast and controlled manner, as programmable mechanisms for controlling water consumption and waste treatment?
Question X23	How does the project classify, in terms of **water** resources, the **physical** factor of **Industry 4.0** in relation to the use of robotics, through robots/monitoring and evaluation systems, as well as additive manufacturing, also known as 3D printing?
Question X24	How does the project classify, in terms of **water** resources, in terms of the **physical** factor of **Industry 4.0** in relation to the integration of systems, enabling harmony between all the systems involved in the project, cybersecurity, and in relation to the concept of cloud *computing*?
Question X25	How does the project classify, in terms of **water** resources, the **physical** factor of **Industry 4.0** in relation to the reduction in the use of pesticides and/or antibiotics?

Table A13. Questions regarding the **Y-axis (Energy)** and the **Biological** factor of **Industry 4.0**.

Question Y01	How does the project classify, in terms of the **energy** resource, the **biological** factor of **Industry 4.0** in relation to the use of computer simulation for real-time data analysis, whether for rainwater harvesting or water reuse?
Question Y02	How does the project classify, in terms of the **energy** resource, in terms of the **biological** factor of **Industry 4.0** in relation to the use of the Internet of Things (IoT), connecting physical objects, machines, vehicles and machines through embedded electronic devices, and thus allowing the collection and exchange of information in a fast and controlled manner, as programmable mechanisms for controlling water consumption and waste treatment?
Question Y03	How does the project classify, in terms of the **energy** resource, in terms of the **biological** factor of **Industry 4.0** in relation to the use of robotics, through robots/monitoring and evaluation systems, as well as additive manufacturing, also known as 3D printing?
Question Y04	How does the project classify, in terms of the **energy** resource, in terms of the **biological** factor of **Industry 4.0** in relation to the integration of systems, enabling harmony between all the systems involved in the project, cybersecurity, and in relation to the concept of cloud *computing*?
Question Y05	How does the project classify, in terms of **energy** resources, the **biological** factor of **Industry 4.0** in relation to the reduction in the use of pesticides and/or antibiotics?

Table A14. Questions regarding ***Y*-axis (Energy)** and the **Digital** factor of **Industry 4.0**.

Question Y11	How does the project classify, in terms of **the energy** resource, in terms of the **digital** factor of **Industry 4.0** in relation to the use of computer simulation for real-time data analysis, whether for rainwater harvesting or water reuse?
Question Y12	How does the project classify itself, in terms of **the energy** resource, in terms of the **digital** factor of **Industry 4.0** in relation to the use of the Internet of Things (IoT), connecting physical objects, machines, vehicles and machines through embedded electronic devices, and thus allowing the collection and exchange of information in a fast and controlled way, as programmable mechanisms for controlling water consumption and waste treatment?
Question Y13	How does the project classify, in terms of **energy** resources, the **digital** factor of **Industry 4.0** in relation to the use of robotics, through robots/monitoring and evaluation systems, as well as additive manufacturing, also known as 3D printing?
Question Y14	How does the project classify, in terms of **energy** resources, in terms of the **digital** factor of **Industry 4.0** in relation to systems integration, enabling harmony between all systems involved in the project, cybersecurity, and in relation to the concept of cloud *computing*?
Question Y15	How does the project classify, in terms of **energy** resources, the **digital** factor of **Industry 4.0** in relation to the reduction in the use of pesticides and/or antibiotics?

Table A15. Questions regarding the **Y-axis (Energy)** and the **Physical** factor of **Industry 4.0**.

Question Y21	How does the project classify, in terms of the **energy** resource, the **physical** factor of **Industry 4.0** in relation to the use of computer simulation for real-time data analysis, whether for rainwater harvesting or water reuse?
Question Y22	How does the project classify itself, in terms of the **energy** resource, in terms of the **physical** factor of **Industry 4.0** in relation to the use of the Internet of Things (IoT), connecting physical objects, machines, vehicles and machines through embedded electronic devices, and thus allowing the collection and exchange of information in a fast and controlled manner, as programmable mechanisms for controlling water consumption and waste treatment?
Question Y23	How does the project classify, in terms of the **energy** resource, in terms of the **physical** factor of **Industry 4.0** in relation to the use of robotics, through robots/monitoring and evaluation systems, as well as additive manufacturing, also known as 3D printing?
Question Y24	How is the project classified, in terms of **energy** resources, in terms of the **physical** factor of **Industry 4.0** in relation to system integration, enabling harmony between all systems involved in the project, cybersecurity, and in relation to the concept of cloud *computing*?
Question Y25	How does the project classify, in terms of **energy** resources, the **physical** factor of **Industry 4.0** in relation to the reduction in the use of pesticides and/or antibiotics?

Table A16. Questions regarding the **Z axis (Food)** and the **Biological** factor of **Industry 4.0**.

Question Z01	How does the project classify, with regard to the **food** resource, regarding the **biological** factor of **Industry 4.0** in relation to the use of computer simulation for real-time data analysis, whether for rainwater harvesting or for water reuse?
Question Z02	How does the project classify, with regard to the **food** resource, regarding the **biological** factor of **Industry 4.0** in relation to the use of the Internet of Things (IoT), connecting physical objects, machines, vehicles and machines through embedded electronic devices, and thus allowing the collection and exchange of information in a fast and controlled manner, as programmable mechanisms for controlling water consumption and waste treatment?
Question Z03	How does the project classify, in terms of **food** resources, the **biological** factor of **Industry 4.0** in relation to the use of robotics, through robots/monitoring and evaluation systems, as well as additive manufacturing, also known as 3D printing?
Question Z04	How does the project classify itself, in terms of **food** resources, in terms of the **biological** factor of **Industry 4.0** in relation to system integration, enabling harmony between all systems involved in the project, cybersecurity, and in relation to the concept of cloud *computing*?
Question Z05	How does the project classify, in terms of **food** resources, the **biological** factor of **Industry 4.0** in relation to the reduction in the use of pesticides and/or antibiotics?

Table A17. Questions regarding the **Z axis (Food)** and the **Digital** factor of **Industry 4.0**.

Question Z11	How does the project classify, with regard to **the food** resource, regarding the **digital** factor of **Industry 4.0** in relation to the use of computer simulation for real-time data analysis, whether for rainwater harvesting or water reuse?
Question Z12	How does the project classify, with regard to **the food** resource, regarding the **digital** factor of **Industry 4.0** in relation to the use of the Internet of Things (IoT), connecting physical objects, machines, vehicles and machines through embedded electronic devices, and thus allowing the collection and exchange of information in a fast and controlled way, as programmable mechanisms for controlling water consumption and waste treatment?
Question Z13	How does the project classify, in terms of **food** resources, the **digital** factor of **Industry 4.0** in relation to the use of robotics, through robots/monitoring and evaluation systems, as well as additive manufacturing, also known as 3D printing?
Question Z14	How does the project classify, in terms of **food resources**, in terms of the **digital** factor of **Industry 4.0** in relation to systems integration, enabling harmony between all systems involved in the project, cybersecurity, and in relation to the concept of cloud *computing*?
Question Z15	How does the project classify, in terms of **food** resources, the **digital** factor of **Industry 4.0** in relation to the reduction in the use of pesticides and/or antibiotics?

Table A18. Questions regarding the **Z axis (Food)** and the **Physical** factor of **Industry 4.0**.

Question Z21	How does the project classify, with regard to **the food** resource, regarding the **physical** factor of **Industry 4.0** in relation to the use of computer simulation for real-time data analysis, whether for rainwater harvesting or for water reuse?
Question Z22	How does the project classify, with regard to the **food** resource, regarding the **physical** factor of **Industry 4.0** in relation to the use of the Internet of Things (IoT), connecting physical objects, machines, vehicles and machines through embedded electronic devices, and thus allowing the collection and exchange of information in a fast and controlled way, as programmable mechanisms for controlling water consumption and waste treatment?
Question Z23	How does the project classify, in terms of the **food** resource, in terms of the **physical** factor of **Industry 4.0** in relation to the use of robotics, through robots/monitoring and evaluation systems, as well as additive manufacturing, also known as 3D printing?
Question Z24	How does the project classify, in terms of **food** resources, in terms of the **physical** factor of **Industry 4.0** in relation to system integration, enabling harmony between all systems involved in the project, cybersecurity, and in relation to the concept of cloud *computing*?
Question Z25	How does the project classify, in terms of **food** resources, the **physical** factor of **Industry 4.0** in relation to the reduction in the use of pesticides and/or antibiotics?

Appendix A.3. Evaluation Model—Nexus and SDG

Table A19. Questions regarding the **X axis (Water)** and compliance with the **SDGs**.

Question X01	How does the project rank in terms of **water** resources in terms of meeting **SDG 1** on the eradication of poverty in all forms and in all places?
Question X02	How does the project rank, in terms of **water** resources, in terms of meeting **SDG 2** regarding zero hunger and sustainable agriculture, eradicating hunger, achieving food security, improving nutrition and promoting sustainable agriculture?
Question X03	How does the project rank, in terms of **water** resources, in terms of meeting **SDG 3** regarding health and well-being, ensuring access to quality health and promoting well-being for all at all ages?
Question X04	How does the project rank, in terms of **water** resources, in terms of meeting **SDG 4** regarding quality education, ensuring access to inclusive, quality and equitable education, and promoting lifelong learning opportunities for all?
Question X05	How does the project rank, in terms of **water** resources, in terms of meeting **SDG 5** regarding gender equality, achieving gender equality and empowering all women and girls?
Question X06	How does the project rank, in terms of **water** resources, in terms of meeting **SDG 6** regarding drinking water and sanitation, ensuring the availability and sustainable management of drinking water and sanitation for all?
Question X07	How does the project rank, in terms of **water** resources, in terms of meeting **SDG 7** regarding clean and affordable energy, ensuring access to reliable, sustainable and modern energy sources for all?
Question X08	How does the project rank, in terms of **water** resources, in terms of meeting **SDG 8** regarding decent work and economic growth, promoting inclusive and sustainable economic growth, full and productive employment and decent work for all?
Question X09	How does the project rank, in terms of **water** resources, in terms of meeting **SDG 9** regarding industry, innovation and infrastructure, building resilient infrastructure, promoting inclusive and sustainable industrialization and fostering innovation?
Question X10	How does the project rank, in terms of **water** resources, in terms of meeting **SDG 10** regarding the reduction of inequalities within and between countries?
Question X11	How does the project rank, in terms of **water** resources, in terms of meeting **SDG 11** regarding sustainable cities and communities, making cities and communities more inclusive, safe, resilient and sustainable?
Question X12	How does the project rank, in terms of **water** resources, in terms of meeting **SDG 12** regarding responsible consumption and production, ensuring sustainable consumption and production patterns?
Question X13	How does the project rank, in terms of **water** resources, in terms of meeting **SDG 13** regarding action against global climate change, adoption of urgent measures to combat climate change and its impacts?
Question X14	How does the project rank, in terms of **water** resources, in terms of meeting **SDG 14** regarding life below water, conservation and sustainable use of the oceans, seas and marine resources for sustainable development?
Question X15	How does the project rank, in terms of **water** resources, in terms of meeting **SDG 15** regarding life on land, protection, restoration and promotion of the sustainable use of terrestrial ecosystems, sustainable management of forests, combating desertification, halting and reversing soil degradation and halting biodiversity loss?
Question X16	How does the project rank in terms of **water** resources, meeting **SDG 16** on peace, justice and strong institutions, promoting peaceful and inclusive societies for sustainable development, providing access to justice for all, and building effective, accountable and inclusive institutions at all levels?
Question X17	How does the project rank, in terms of **water** resources, in terms of meeting **SDG 17** regarding partnerships and means of implementation, strengthening the means of implementation and revitalizing the global partnership for sustainable development?

Table A20. Questions regarding the Y axis (**Energy**) and compliance with the **SDGs**.

Question Y01	How does the project rank, in terms of **energy** resources, in terms of meeting **SDG 1** regarding the eradication of poverty in all forms and in all places?
Question Y02	How does the project rank in terms of **energy** resources, in terms of meeting **SDG 2** regarding zero hunger and sustainable agriculture, eradicating hunger, achieving food security, improving nutrition and promoting sustainable agriculture?
Question Y03	How does the project rank, in terms of **energy** resources, in terms of meeting **SDG 3** regarding health and well-being, ensuring access to quality health and promoting well-being for all at all ages?
Question Y04	How does the project rank, in terms of **energy** resources, in terms of meeting **SDG 4** regarding quality education, ensuring access to inclusive, quality and equitable education, and promoting lifelong learning opportunities for all?
Question Y05	How does the project rank, in terms of **energy** resources, in terms of meeting **SDG 5** regarding gender equality, achieving gender equality and empowering all women and girls?
Question Y06	How does the project rank, in terms of **energy** resources, in terms of meeting **SDG 6** regarding safe drinking water and sanitation, ensuring the availability and sustainable management of drinking water and sanitation for all?
Question Y07	How does the project rank, in terms of **energy** resources, in terms of meeting **SDG 7** regarding clean and affordable energy, ensuring access to reliable, sustainable and modern energy sources for all?
Question Y08	How does the project rank, in terms of **energy** resources, in terms of meeting **SDG 8** regarding decent work and economic growth, promoting inclusive and sustainable economic growth, full and productive employment, and decent work for all?
Question Y09	How does the project rank, in terms of **energy** resources, in terms of meeting **SDG 9** regarding industry, innovation and infrastructure, building resilient infrastructure, promoting inclusive and sustainable industrialization and fostering innovation?
Question Y10	How does the project rank, in terms of **energy** resources, in terms of meeting **SDG 10** regarding the reduction of inequalities within and between countries?
Question Y11	How does the project rank, in terms of **energy** resources, in terms of meeting **SDG 11** regarding sustainable cities and communities, making cities and communities more inclusive, safe, resilient and sustainable?
Question Y12	How does the project rank, in terms of **energy** resources, in terms of meeting **SDG 12** regarding responsible consumption and production, ensuring sustainable consumption and production patterns?
Question Y13	How does the project rank, in terms of **energy** resources, in terms of meeting **SDG 13** regarding action against global climate change, adoption of urgent measures to combat climate change and its impacts?
Question Y14	How does the project rank, in terms of **energy** resources, in terms of meeting **SDG 14** regarding life below water, conservation and sustainable use of the oceans, seas and marine resources for sustainable development?
Question Y15	How does the project rank, in terms of **energy** resources, in terms of meeting **SDG 15** regarding life on land, protection, restoration and promotion of the sustainable use of terrestrial ecosystems, sustainable management of forests, combating desertification, halting and reversing land degradation and halting the loss of biodiversity?
Question Y16	How does the project rank, in terms of **energy** resources, in terms of meeting **SDG 16** regarding peace, justice and strong institutions, promoting peaceful and inclusive societies for sustainable development, providing access to justice for all, and building effective, accountable and inclusive institutions at all levels?
Question Y17	How does the project rank, in terms of **energy** resources, in terms of meeting **SDG 17** regarding partnerships and means of implementation, strengthening the means of implementation and revitalizing the global partnership for sustainable development?

Table A21. Questions regarding the Z axis (**Food**) and compliance with the **SDGs**.

Question Z01	How does the project rank, in terms of **food** resources, in terms of meeting **SDG 1** regarding the eradication of poverty in all forms and in all places?
Question Z02	How does the project rank, in terms of **food** resources, in terms of meeting **SDG 2** regarding zero hunger and sustainable agriculture, eradicating hunger, achieving food security, improving nutrition and promoting sustainable agriculture?
Question Z03	How does the project rank, in terms of **food** resources, in terms of meeting **SDG 3** regarding health and well-being, ensuring access to quality health and promoting well-being for all at all ages?
Question Z04	How does the project rank, in terms of **food** resources, in terms of meeting **SDG 4** regarding quality education, ensuring access to inclusive, quality and equitable education, and promoting lifelong learning opportunities for all?
Question Z05	How does the project rank, in terms of **food** resources, in terms of meeting **SDG 5** regarding gender equality, achieving gender equality and empowering all women and girls?
Question Z06	How does the project rank, in terms of **food** resources, in terms of meeting **SDG 6** regarding safe drinking water and sanitation, ensuring the availability and sustainable management of drinking water and sanitation for all?
Question Z07	How does the project rank, in terms of **food** resources, in terms of meeting **SDG 7** regarding clean and affordable energy, ensuring access to reliable, sustainable and modern energy sources for all?
Question Z08	How does the project rank, in terms of **food** resources, in terms of meeting **SDG 8** regarding decent work and economic growth, promoting inclusive and sustainable economic growth, full and productive employment, and decent work for all?
Question Z09	How does the project rank, in terms of **food** resources, in terms of meeting **SDG 9** regarding industry, innovation and infrastructure, building resilient infrastructure, promoting inclusive and sustainable industrialization, and fostering innovation?
Question Z10	How does the project rank, in terms of **food** resources, in terms of meeting **SDG 10** regarding the reduction of inequalities within and between countries?
Question Z11	How does the project rank, in terms of **food** resources, in terms of meeting **SDG 11** regarding sustainable cities and communities, making cities and communities more inclusive, safe, resilient and sustainable?
Question Z12	How does the project rank, in terms of **food** resources, in terms of meeting **SDG 12** regarding responsible consumption and production, ensuring sustainable consumption and production patterns?
Question Z13	How does the project rank, in terms of **food** resources, in terms of meeting **SDG 13** regarding action against global climate change, adoption of urgent measures to combat climate change and its impacts?
Question Z14	How does the project rank, in terms of **food** resources, in terms of meeting **SDG 14** regarding life in water, conservation and sustainable use of the oceans, seas and marine resources for sustainable development?
Question Z15	How does the project rank, in terms of **food** resources, in terms of meeting **SDG 15** regarding life on land, protection, restoration and promotion of the sustainable use of terrestrial ecosystems, sustainable management of forests, combating desertification, halting and reversing land degradation and halting biodiversity loss?
Question Z16	How does the project rank, in terms of **food** resources, in terms of meeting **SDG 16** regarding peace, justice and strong institutions, promoting peaceful and inclusive societies for sustainable development, providing access to justice for all, and building effective, accountable and inclusive institutions at all levels?
Question Z17	How does the project rank, with regard to **food** resources, in terms of meeting **SDG 17** regarding partnerships and means of implementation, strengthening the means of implementation and revitalizing the global partnership for sustainable development?

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