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Guidelines for structuring photovoltaic solar energy projects in Colombia, focused on the department of Huila

Lineamientos para estructurar proyectos de energía solar fotovoltaica en Colombia, focalizado en el departamento del Huila

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Abstract

Despite international agreements reached at the United Nations Convention on Climate Change since 2015 concerning the transition to Non-Conventional Renewable Energy Sources (NCRE), Colombia, including the Department of Huila, has lagged behind other South American countries. This study aims to provide comprehensive project management

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guidelines for the development of photovoltaic solar energy projects in Huila and Colombia. The approach incorporates methodological elements from project management frameworks like PMI, PRINCE2, and SCRUM. The methodological design is mixed, involving a documentary analysis of energy demand and supply in Colombia and Huila, consideration of variables essential for photovoltaic solar project development, and integration of the aforementioned project management methodologies. The result is a proposal for methodological hybridization and the establishment of guidelines for structuring photovoltaic solar projects of various types, such as Distributed Generation (GD), Self-Generation and Small-Scale Power Generation (AGPE), Wholesale Power Generation (AGGE), and Large Generators. These guidelines are based on the project life cycle, procedures, activities defined in the proposed methodology, and the legal requirements stipulated in CREG 075 and CREG 174.

Keywords: Electrical Energy; Photovoltaic Solar; Energy Projects; Project Guidelines; Solar Energy.

Resumen

A pesar de los acuerdos internacionales acordados en la Convención de las Naciones Unidad desde el año 2015 sobre el Cambio Climático frente a la transición energética hacia FNCER, Colombia como el departamento del Huila no presentan avances significativos en comparación con otros países suramericanos. En ese sentido, el propósito de este estudio, desde la perspectiva de la gerencia integral de proyectos, consistió en elaborar lineamientos para estructurar proyectos energéticos solares fotovoltaicos en el Huila y Colombia, aprovechando los aportes metodológicos en gestión de proyectos del PMI, PRINCE2 y SCRUM. El diseño metodológico aplicado fue de orden mixto, basado en un análisis documental sobre la demanda y oferta energética de Colombia y el Huila, las variables a tener en cuenta para el desarrollo de proyectos solares fotovoltaicos y las metodologías, mencionadas, de proyectos. Es elaborada una propuesta de hibridación metodológica y se establecen lineamientos para estructurar proyectos de tipo solar fotovoltaico GD, AGPE, AGGE o Gran Generador, con base en el ciclo de vida, procedimientos y actividades presentadas en la metodología propuesta y en los requerimientos legales estipulados en la CREG 075 y CREG 174.

Palabras Clave: Energía eléctrica; Solares fotovoltaicos; Proyectos energéticos; Lineamientos para proyectos; Energía solar.

1. Introduction

Since the 2015 UN Conference on Climate Change, Non-Conventional Renewable Energies (NCREs) have become central to achieving Sustainable Development Goal No. 7, “Affordable and Clean Energy.” Colombia formally embarked on an energy transition path through Law 1715 of 2014, which regulates the integration of non-conventional renewable energies into the National Energy System.

In 2018, Colombia had only three solar parks with a combined electricity generation capacity of 176 MW-year, barely sufficient to meet the energy needs of around 300,000 people. As of 2022, Colombia now boasts seventeen operational solar parks with a combined capacity of 674.5 MW-year, including projects by companies like ENEL-EMGESA and CELSIA. However, this capacity still represents only 6.07% of Colombia’s total national energy consumption, according to the Unit of Mining and Energy Planning’s document titled “Proyección de la Demanda y Consumo Energético en Colombia 2022 – 2035.”

In contrast, as mentioned by Benavides *et al*. (2017), the Huila region is characterized by high solar radiation and abundant sunlight. Furthermore, according to the Institute of Hydrology, Meteorology, and Environmental Studies (2018), the department experiences high temperatures and low precipitation levels, making it one of the regions with the greatest solar potential in the entire country. Despite this potential, it remained largely untapped until 2022, with no large-scale solar energy projects. Only smaller-scale projects, such as Distributed Generators (GD), Small-Scale Self-Generators (AGPE), and Large-Scale Self-Generators (AGGE), are currently in operation.

This research study aims to propose guidelines for managing photovoltaic solar energy projects in both the local context of Huila and the broader Colombian context. It employs a hybrid methodological approach that draws from project management methodologies such as PMI, PRINCE2, and SCRUM. The study also considers critical factors such as climatological, geographical, and sociocultural variables influencing project locations and aligns with Colombian regulations related to energy projects.

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Table 1. Characteristics of Project Management Methodologies	
PMI	The Project Management Institute (PMI), as presented in the seventh edition of the PMBOK®, offers a comprehensive foundation that includes standards, guidelines, and norms for project management. This framework is applicable across various industries, locations, project sizes, and delivery approaches.
PRINCE2	The Controlled Environment Projects methodology incorporates principles of best practices for the efficient management of projects. It employs a hierarchical management structure to define the roles of the project team and their respective responsibilities. Moreover, PRINCE2 addresses critical topics essential for the effective application of the methodology and prescribes processes with specific activities that must be executed throughout the project's lifecycle.
SCRUM	The Scrum Body of Knowledge Guide (SBOK Guide) is a methodology designed for the agile development of portfolios, programs, or projects of any nature. It is characterized by its mastery of principles that guide project management within an agile framework. These principles are supported by thematic pillars that underpin the philosophy of agile project management. Additionally, the SBOK Guide outlines processes and the associated activities necessary to conduct project management according to this methodology.

Source: Authors' own elaboration based on concepts from the PMBOK® Seventh Edition (2021), PRINCE2 Fifth Edition (2009), and SCRUM SBOK Guide Third Edition (2017).

Table 2. Components of Photovoltaic Solar Systems

Components	Function
Solar Panels	They capture solar energy through photovoltaic cells.
Accumulator/Battery	Store electricity generated during periods of limited sunlight.
Load Controller	Manages the energy stored in the battery.
Inverter	Convert energy from Direct Current (DC) to Alternating Current (AC).
Bidirectional Meter	Calculate energy consumption.

Source: Authors' own elaboration based on concepts from the Solarama (2021).

2. Theoretical Framework

2.1. Project, Guidelines, and Methodologies

The Project Management Institute (PMI), (2021) defines a project as a "temporary effort undertaken to create a unique product, service, or result" (p. 251). Projects consist of phases and stages designed to achieve specific objectives, interconnected to reach the overall project goal. Various methodologies and guidelines have been developed globally to systematize and standardize project phases, stages, and steps, simplifying planning and ensuring adherence to initial objectives. Three prominent methodologies used in project management are PMI, PRINCE2, and SCRUM (Table 1).

2.2 Solar Energy Systems, Types, and Components

Photovoltaic solar energy projects have seen significant growth due to society's transition to cleaner energy sources. These projects primarily involve five key components (Table 2).

There are three types of projects based on generation capacity and energy supply:

- **Self-contained standalone systems,** independent of the regional electrical grid.
- **Hybrid systems,** generating energy primarily for self-supply but also feeding surplus energy into the grid.
- **Solar parks or solar farms,** designed for large-scale energy generation and grid distribution.

The environmental variables under consideration remain consistent, regardless of the project's type or size. However, technical and legal requirements differ based on the project's capacity and purpose. Therefore, the initial step involves defining the project's size and purpose, which subsequently guides the analysis of the environmental variables

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Table 3. Types of Photovoltaic Solar Projects by Generation Capacity	
Type	**Capacity Range**
Small-Scale Self-Generator	0,1 a 1 MW
Large-Scale Self-Generator	1 a 5 MW
Large Generators	5 o más MW
Source: Authors' own elaboration based on concepts from the CREG 030 of 2018 and CREG 174 of 2021.	

within the context. Following this, technical and legal aspects are addressed, with adjustments made according to the project's purpose and size.

Within the realm of environmental variables, experts in the field have stressed the importance of an optimal correlation of three variables, irrespective of the project's size. These findings are documented in the 2017 'Atlas of Solar Radiation, Ultraviolet, and Ozone in Colombia,' published by IDEAM and UPME. These variables are as follows:

1. Solar Radiation Intensity (kWh/m^2).
2. Average Hours of Sunlight per Day (hSd).
3. Average Number of Days per Month with Sunshine.

Regarding the legal aspects, conditions and requirements indeed vary depending on the project's size and purpose. Resolution CREG 030 of 2018 and Resolution CREG 174 of 2021 regulate and offer a step-by-step guide for compliance with the requirements according to the intended purpose of the project. In Colombia, energy projects are categorized into three types based on their generation capacity (Table 3).

3. Methodology

The study follows an exploratory-descriptive mixed research approach, involving a statistical analysis of the current state of electricity supply and demand in Colombia and the evolution of the national and regional energy matrix in the context of solar energy integration.

Semi-structured interviews were conducted with key industry stakeholders, including the Deputy Distribution Manager of ELECTROHUILA, the Operator of the Huila Network Company, and a co-founder of a photovoltaic energy company. These interviews provided insights into the regional energy outlook.

A documentary review encompassed articles, theses, and research on photovoltaic solar projects, their components, and technological equipment, along with the identification of climatological and geographical variables. The guidelines for photovoltaic solar projects were developed through a descriptive analysis and the integration of project management methodologies (PMI, PRINCE2, and SCRUM). These guidelines also cover legal requirements according to Colombian regulations for large-scale energy projects integrated into the National Interconnected System (SIN) (Figure 1).

The integration of the three project methodologies into a hybrid model required a structural analysis of the content of these bodies of knowledge. The most significant difference among them lies in the project development approach they adopt. For example, in a predictive approach like PRINCE2, a robust initial planning is required to guide the project throughout its lifecycle. In contrast, the adaptive approach inherent to SCRUM is much more flexible, relying on constant feedback and generally not requiring such detailed initial planning.

However, despite the differences mentioned earlier, it was observed that in all three bodies of knowledge, even if the development approach varies between methodologies, there is a repetition of key elements for project management, such as quality control, project progress control, change management, and risk management. This repetition opened the

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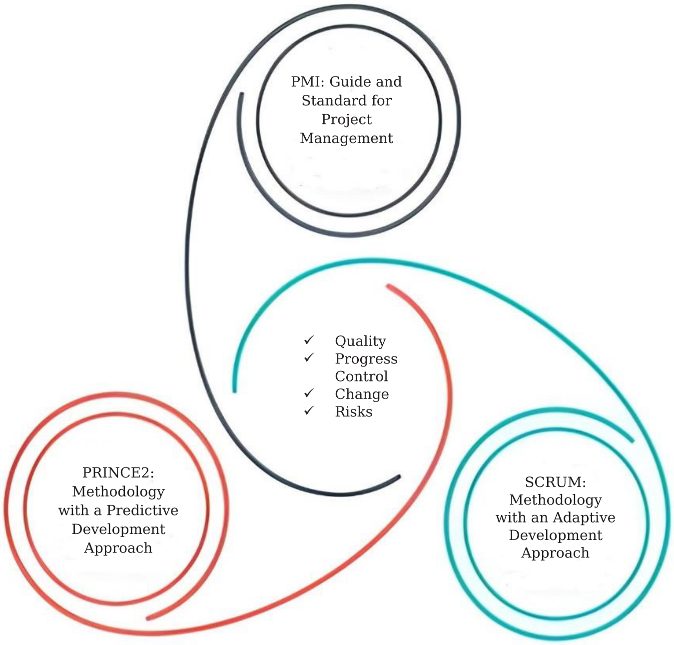
Figure 1. Key Common Elements of PMI, PRINCE2, and SCRUM”



Source: Authors’ own elaboration based on concepts from the PMBOK® Seventh Edition (2021), PRINCE2 Fifth Edition (2009), and SCRUM SBOK Guide Third Edition (2017).

possibility of integrating a hybrid model that could incorporate the best concepts from each methodology.

4. Results

4.1. Evolution of Solar Energy in Colombia and Huila Department

From 2018 to 2022 in Colombia, Non-Conventional Renewable Energies (NCREs) have increased their share within the national energy matrix, rising from approximately 1% to 6% whit diferents proyects in the national territory. Wind energy and solar energyare the most popular Non-Conventional Renewable Energies (NCREs) in the country (Graph 1).

In the case of solar energy, three large-scale projects have been developed in the departments of Cesar, Santander, and Valle del Cauca. These solar parks, connected to the National Interconnected System (SIN), have a combined installed capacity of 176 MW-year. However, traditional sources such as hydroelectric power continue to predominate, accounting for 63.4%, while fossil energy sources (oil, gas, and coal) constitute 30.6% of the energy mix (Table 4).

By 2022, there are 17 solar parks interconnected to the National Interconnected System (SIN) located in the departments of Cesar, Santander, Sucre, Tolima, and Valle del Cauca. These parks have a cumulative energy generation capacity of 674.5 MW Graph 2.

In the Huila Department, the energy matrix is primarily based on hydraulic sources from the Betania and El Quimbo hydroelectric dams and Small Hydroelectric Power Plants (PCH) in the municipalities of Garzón and Iquira. The integration of NCREs into the departmental energy matrix has only recently been considered. The construction of solar projects connected to the SIN in Huila is anticipated in the coming years, including projects by ECOPETROL with a total generation capacity of 25 MW and, a 10 MW solar farm by ELECTROHUILA, and a 230 MW solar park by a foreign company in the Tatacoa Desert, indicating a shift towards solar energy in the region.

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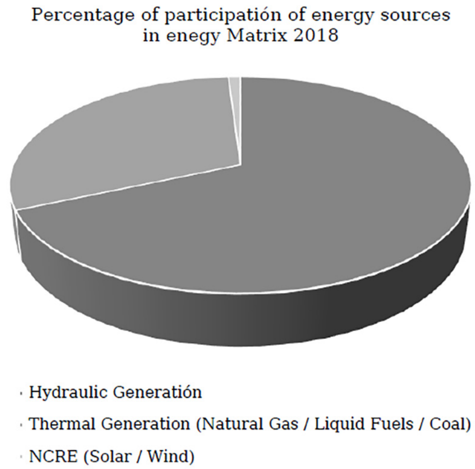
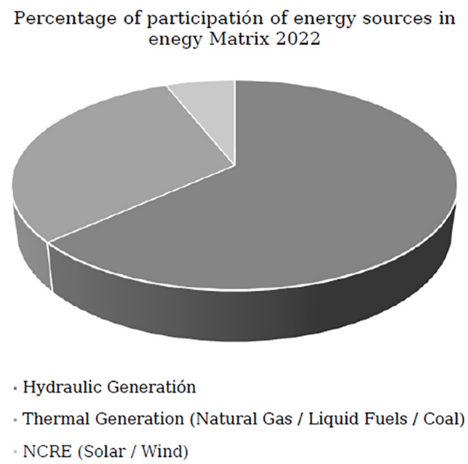
Graph 1. Evolution of the Colombian Energy Matrix 2018 – 2022





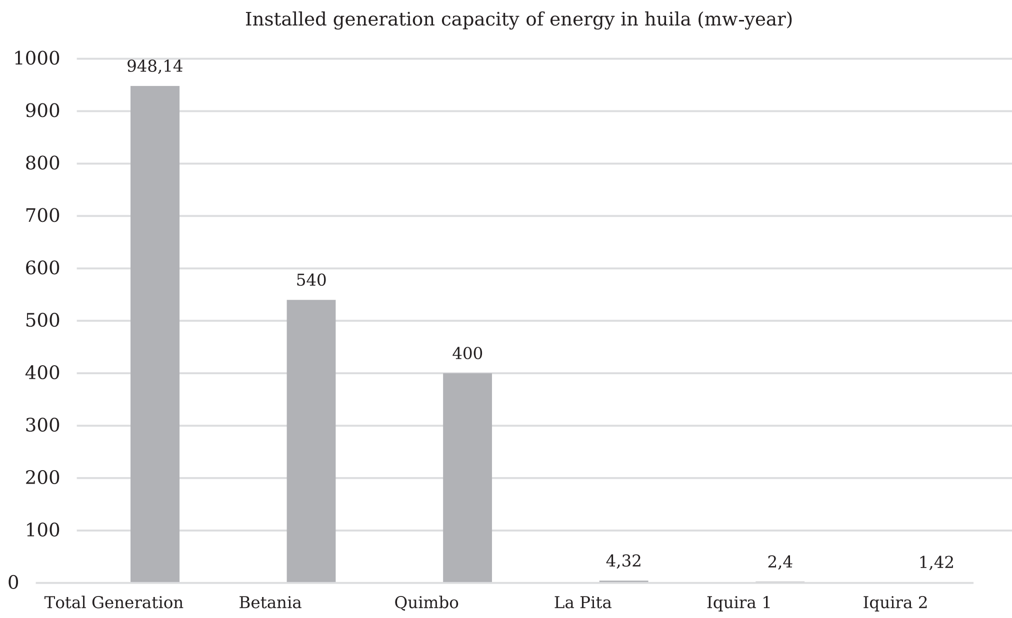
Source: Authors' own elaboration based on concepts from the Planas Marti & Cárdenas (2019).

Table 4. Solar Parks Connected to the National Interconnected System (SIN) in Colombia by 2019

Project Name	Capacity (MW)	Location (Region)
El Paso	86,2	Cesar
Celsia Chicamocha Solar	80	Santander
Celsia Solar Yumbo	9,8	Valle del Cauca

Source: Authors' own elaboration based on concepts from the ENEL-EMGESA 2021, CELSIA 2021.

Graph 2. Electric Power Generation Capacity in the Huila Department



Source: Authors' own elaboration based on concepts from the ELECTROHUILA 2020 and ENEL Group 2021.

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Table 5. Influential Climatological and Geological Variables in Solar Projects

Climatological Variables	Geological Variables
Intensity of Solar Radiation (kWh/m^2) Average Hours of Sunlight per Day (hSd) Average Number of Days per Month with Sunshine Altitude and latitude Cloudiness in the area Zenith Angle Presence of aerosols in the atmosphere Rainfall and presence of water vapor Presence of shadows	Bearing capacity of the soil Soil types Soil formation angle Presence of objects in the area. Accessibility and quality of roadways.

Source: Authors' own elaboration based on concepts from the Benavides Et Al (2017), Barrera y Castilla (2018) and Peña 2016.

4.2. Influential Technical Variables in Photovoltaic Solar Projects

Through documentary review, it was identified that the success of solar projects depends on certain climatological and geological variables that influence the energy efficiency that can be obtained from them. Therefore, these variables should be considered in advance during the project location analysis (Table 5).

4.3. Proposed Hybrid Project Management Methodology

The main purpose of the hybrid methodology is to structure an step by step complemented by the three methodologies analyzed and according to the analysis and study carried out; it is determined that in general, the aspects influenced by all three methodologies include the initial and ongoing justification of project viability; adaptability to the project's context and needs based on its size, complexity, importance, capacity, and specific risk level; the identification, evaluation, and engagement of influential stakeholders for project success; management based on iterations or phases throughout the project's lifecycle for better control and feedback on the project's status; planning and quality assurance of deliverables; initial and ongoing risk exposure assessment; continuous management and adaptation to change; ongoing monitoring and control of progress; and the formation of a committed and organized project team with clearly defined roles and responsibilities; The similarities and differences are explained in abbreviated form in Figure 2 and Table 6.

On the other hand, the differential characteristics mentioned in points 1, 2, and 3 emphasize that a significant contrast found is the project development approach, as it directly affects project planning, the scope of objectives, deliverables, and the resources required to carry out scheduled activities. For example, SCRUM, as it lacks complete clarity from the project's outset regarding the scope of the deliverables to be generated, requires the iterative application of its five events during each Sprint to ensure that the product is developed according to stakeholder expectations. In contrast, PRINCE2 requires clear upfront knowledge of the project's objectives and deliverables to plan how tasks should be carried out and what resources are needed for it.

Regarding the perception of the project's value, each methodology adopts a different perspective on what should be prioritized to achieve the objective. For SCRUM, it gives the highest priority to the specific needs of the customer regarding the product. PRINCE2 focuses on the results through the fulfillment of quality requirements established at the beginning for the products. In contrast, PMBOK® focuses on the benefits that will be generated by the project, where the products are merely the means by which the project's value is obtained.

Despite these disparities, it is possible to design an integration between the methodologies that adapts to photovoltaic solar energy generation projects within

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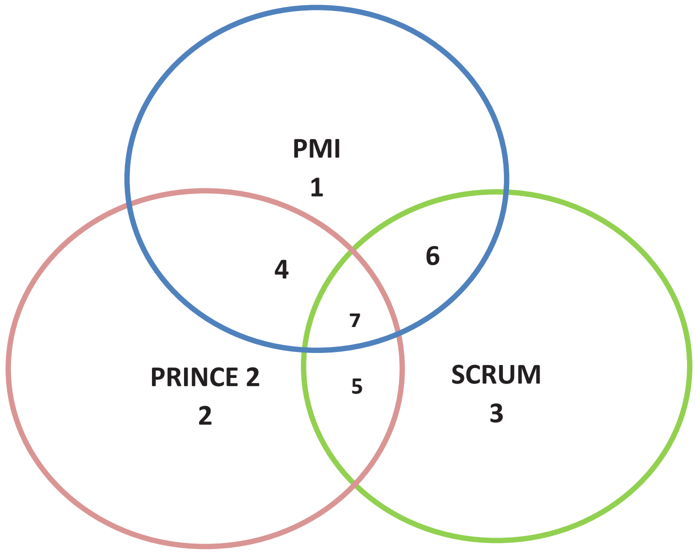
Figure 2. Venn Diagram of the Similarities and Differences between PMI, PRINCE2, and SCRUM



Source: Authors' own elaboration based on concepts from the PMBOK® Seventh Edition (2021), PRINCE2 Fifth Edition (2009), and SCRUM SBOK Guide Third Edition (2017).

Table 6. Interrelation of Project Methodologies PMI, PRINCE2, and SCRUM

Climatological Variables	Geological Variables
1. PMI	The value of the project lies in the benefits that will be generated. Phases of the project's life cycle.
2. PRINCE2	Predictive development approach. The project's value in terms of product quality. Lessons learned from previous projects. Exception management.
3. SCRUM	Adaptive development approach. The project's value in meeting customer needs. Time box for the events that make up each management phase.
Interrelation of Methodologies	Similarities
4. PMI - PRINCE2	Adapt the project according to the specific needs of its environment.
5. PRINCE2 – SCRUM	Project justification. Phase-based or iterative management. Business case.
6. PMI – SCRUM	N/A
7. PMI, PRINCE2 - SCRUM	Project stakeholders. Training for the project team. Quality planning and assurance. Risk assessment and control. Change management and adaptation. Project progress control. Roles and responsibilities of project members.

Source: Authors' own elaboration based on concepts from the PMBOK® Seventh Edition (2021), PRINCE2 Fifth Edition (2009), and SCRUM SBOK Guide Third Edition (2017).

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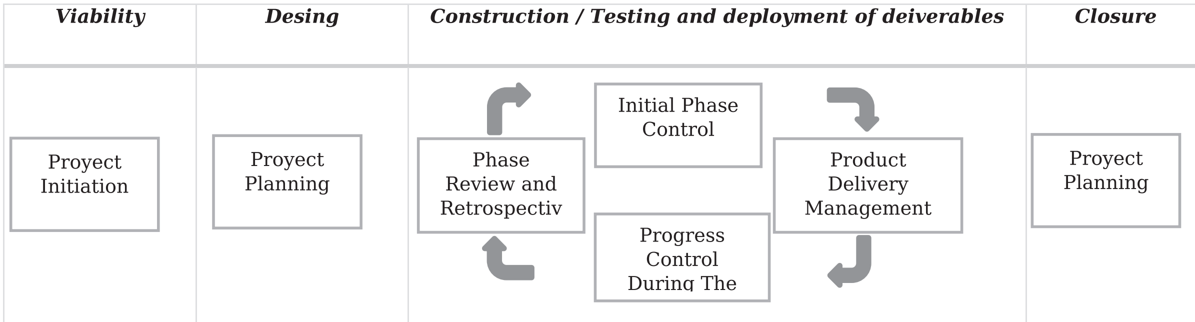
Figure 3. Project Lifecycle of the Hybrid Model



Source: Authors' own elaboration based on concepts from the PMBOK® Seventh Edition (2021), PRINCE2 Fifth Edition (2009), and SCRUM SBOK Guide Third Edition (2017).

a hybrid model. This hybrid approach is based on a predictive development focus with periodic or multiple deliveries of the products that make up the energy generation system (depending on how the management phases are established). However, it also incorporates certain aspects of the adaptive approach to provide greater flexibility and agility in relation to quality, progress, change, and risk.

Solar projects worldwide have managed to standardize detailed and fully defined initial planning for some common elements and processes, such as project scope, very approximate estimates of actual times and costs, and specific personnel and technology resources. Therefore, a waterfall development approach like PRINCE2 is better suited to managing these types of projects. Even though SCRUM is an evolutionary approach, it has some interesting characteristics that can enhance the management of the predictive approach.

Based on the information presented earlier, the initiative was taken to create a hybrid methodology proposal composed of the most significant contributions from these project methodologies to meet the needs of photovoltaic solar energy projects. This proposal describes the principles, thematic axes, process groups, activities, and the project's lifecycle.

After researching the information related to the topic and conducting the necessary fieldwork within the framework of the research, it was determined that no project methodology is exclusively used for structuring and developing photovoltaic solar energy projects. Therefore, based on the main characteristics and particularities of these projects, the structure and content of the three project management methodologies, SCRUM, PRINCE2, and PMI, were evaluated. This evaluation aimed to propose a hybrid methodology that extracts the most relevant and applicable aspects for these projects, thus creating a new model that addresses the specific needs of such projects.

The basic foundations (principles, thematic axes, process groups, activities, and the project lifecycle) of a hybrid methodology for managing photovoltaic solar projects with a hybrid development approach were designed. This hybrid approach is based, in part, on the predictive analysis of PRINCE2, which involves robust initial planning and estimation of scope, schedules, costs, and resource needs in a project plan. On the other hand, it incorporates the adaptive approach of SCRUM, adapting project execution based on constant iteration of management phases to provide greater flexibility and agility in terms of quality, progress, change, and risk during construction (Figure 3).

The proposed design of the project lifecycle for this hybrid methodology adopts the phases described in the PMBOK. It starts with a linear model where the activities in the feasibility and design phase are carried out sequentially. Subsequently, in the construction and deliverable deployment phase, the processes of initial phase control, product delivery management, progress control during the phase, phase review, and retrospective are carried out iteratively in

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each of the established management phases. This can be done either with a specific uniform time period for each phase (e.g., one month) or with varying times for each phase based on the expected deliverables and the work required for their construction. Finally, in the closing phase, the linear model is resumed during the execution of the activities related to the complete project delivery, marking its conclusion.

In the feasibility phase, which comprises the project initiation process, the first step is to ensure, through the initial Business Case, that the scope, objectives, and expected results can be achieved. The other activities involve identifying all influential stakeholders, whether their roles are central or not in project planning and execution, and gathering all the necessary documentation to formally authorize the project's commencement.

The standardization of various elements in the initial planning of photovoltaic solar energy projects makes it a case where the predictive approach of the PRINCE2 methodology allows for early and reasonably accurate estimations of costs and budgets, time and schedules, deliverables and their quality requirements, procurement/acquisition requirements, initial risk identification and management, and the establishment of progress control strategy/strategies.

The construction and deliverable deployment phases draw inspiration from the Deming or PDCA cycle, in which, through continuous iteration of its processes during each project management phase, it adapts the rigor employed in the SCRUM methodology regarding quality, risks, and change to have better control over project execution.

The initial phase control process begins with a general project retrospective through the analysis and update of the Business Case and the Project Plan, ensuring that there are no progress deviations outside the established cost and time tolerances for each phase and that the project remains viable overall. This process involves activities related to change management, the Stakeholder matrix, and risk register.

The product delivery management and progress control during the phase processes involve the most operational activities throughout the project life cycle. In these processes, the team manager is responsible for constructing the deliverables of the accepted work package for the phase. The quality strategy is put into practice, and the status of both the work package and the phase itself is closely monitored through Daily Standup meetings.

In the phase review and retrospective process, an element of SCRUM related to prioritizing rejected deliverables at the end of the phase is adapted. In this case, the products that did not fully meet the requirements in one phase are prioritized for the next phase, opting to continue the project execution according to the corresponding schedule adjustments. If necessary, authorization for an exception plan is considered in case the permissible change limits for that management phase are exceeded.

4.4. Guidelines for Structuring Photovoltaic Solar Energy Projects in Colombia

Based on the analysis and interpretation of the information, guidelines were established to guide those interested in structuring photovoltaic solar projects of the Self-Generator (GD), Small-Scale Self-Generator (AGPE), Large-Scale Self-Generator (AGGE), or Large Generator types. These guidelines are based on the life cycle, procedures, and activities presented in the proposed methodology and the legal requirements stipulated in CREG 075 and CREG 174 (Table 7).

Starting from the Initial Phase Control process, the project's construction begins, which will be developed and controlled throughout the selected project management stages. Each management period consists of four (4) processes that must be performed iteratively until all project deliverables have been successfully delivered.

Depending on whether the project is GD, AGPE, AGGE, or a Large Generator, a decision is made regarding how to incorporate changes. For large generators, due to their broader scope, it may be necessary to use the rigorous process used in PRINCE2.

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Table 7. Guidelines for Structuring Photovoltaic Solar Energy Projects

Process	Components
Project Initiation	Determine the project's location. Prepare the Initial Project Business Case. Create the project plan. Prepare Additional Project Documentation. Upload the documentation to the single window found on the UPME website. After uploading the documents, proceed with the procedures stipulated in resolutions CREG 075 and 174, depending on the project's generation capacity. Make corrections and adjustments to the project documentation issued by the Network Operator or UPME, as applicable. Resubmit the documents within the specified deadlines (depending on the project type) and wait for a response and approval. Appoint the Project Board. Define and detail the roles and responsibilities of the Team Manager and select the Project Manager. Design the Training Plan based on the specific needs of the team. Prepare the Project Charter.
Project Planning	Develop Estimated Plans for Each Management Phase. Plan Work Packages for Each Phase. Prepare Quality Management Strategy. Develop Acquisition Management Plan. Prepare Project Progress Control Strategy. Prepare Risk Management and Change Adaptation Strategy.
Initial Phase Control	Conduct the planning meeting for the next phase. Plan and Incorporate Approved Changes from the Next Phase. Update the Business Case. Update the Stakeholder Matrix. Update the project plan. Update the risk register and the risk response action strategy. Authorize the work package for the phase.
Product Delivery Management	Accept a work package for the phase. Create the phase's deliverables or products. Verify compliance with product quality requirements. Deliver the completed work package.
Progress Control During the Phase	Review the status of the work package. Review the Phase Status.
Phase Review and Retrospective	Hold the phase review meeting. Verify compliance with the quality requirements of the deliverables. Accept or reject the products. Conduct the phase retrospective meeting.
Project Handover and Closure	Perform a final check to ensure compliance with product requirements. Deliver all products. Notify the OR in all cases and additionally the UPME if it is a large-scale generation project about the project's completion. The OR and UPME will proceed to conduct technical and visual inspections within the specified deadlines. Hold a final feedback and project retrospective meeting. Authorize the Formal Project Closure.

Source: Authors' own elaboration based on concepts from the PMBOK® Seventh Edition (2021), PRINCE2 Fifth Edition (2009), and SCRUM SBOK Guide Third Edition (2017).

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Otherwise, the change request method proposed in SCRUM is recommended.

5. Conclusions

The guidelines for structuring and executing photovoltaic solar projects were established based on the technical variables identified in the documentary review, the interrelation of project management methodologies through a hybrid proposal that adopts and integrates elements of the predictive development approach of PRINCE2 and the agile approach of SCRUM, as well as the legal requirements of Colombian regulations for the development of these types of projects.

Through this proposal, it is expected to encourage the generation of new solar projects in Colombia, especially in the Huila department, the region in which the study was conducted. Unfortunately, this region has not yet ventured into large-scale energy projects that contribute to the energy transition, despite its great solar potential. In addition to the above, a limitation encountered in the study's development was the scarcity of other research and government documents related to solar energy in Huila, to the extent that no study related to the solar energy potential in the region was found.

To initiate the energy transition in the Department of Huila, ELECTROHUILA has proposed a strategy to establish alliances with the Government of Huila and the Ministry of Mines and Energy (MINMINAS) to develop self-generation solar projects for remote rural populations that are not currently connected to the National Interconnected System (SIN) and lack access to electricity. Additionally, they plan to develop new large-scale projects that will attract the attention of investors to promote the industrial development of the department.

However, for this energy transition to be truly effective, it also requires the participation of the academic and productive sectors throughout Huila. Therefore, it is recommended:

- Promote actions to standardize and disseminate the regulations, procedures, and processes required by different national ministries and entities for the structuring, development, and implementation of projects based on Non-Conventional Renewable Energies (FNCER).
- Encourage the Government of Huila and municipal authorities to establish public policies and campaigns aimed at the population of the Department, domestic investors, and Huila-based companies, to stimulate the development of solar energy projects and other FNCER.
- Encourage higher education institutions in the Department to create new study programs or enhance existing ones related to solar energy, photovoltaic solar projects, and the development of FNCER in general. Also, motivate students to conduct new research for the Department on these topics related to FNCER.

6. Conflict of interest

The authors declare no conflict of interest.

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