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Review of the Energy transition assessment methods in touristic municipalities

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Abstract. Initiatives have been launched by the EU to address climate change, including those aimed at islands and municipalities. Analysing the impact of the energy transition through modelling is essential for the strategic decision-making process to move forward to the ET. The new energy model requires municipalities to be key drivers, although their needs are very specific and depend on external factors such as their own governance. In the case of municipalities located on tourist islands, the need for tools and support for the creation of energy and sustainable transition plans is even more evident. Currently, methods and models have been developed for energy planning or for the assessment of different energy scenarios, but there is no model that integrates a multidimensional approach at the municipal level, enhances the decisions of policymakers, integrates a knowledge base specifically focused on islands and monitors the progress of local measures through energy indicators. This paper reviews the state of existing decision-making models and energy tools, specifically those aimed at islands and policymakers, and identifies the gaps to generate added value to facilitate the path to ET for island tourist municipalities and monitor their progress.

Key Words

Energy Transition, Energy Planning, Municipal Sustainability Plans, Monitoring tool, Renewable Energy

1. Introduction

The European Union (EU) is swiftly tackling one of the biggest challenges facing the world: climate change. To this end, the EU intends to accelerate the process towards Energy Transition (ET) by setting ambitious objectives such as decarbonisation of the electricity system by 2030 or carbon neutrality by 2050.

In 2019, the EU launched the 'Clean Energy for All Europeans' energy regulation [1] in favour of clean energy and the reduction of fossil fuels. This package of measures aims to prioritise energy efficiency, increase renewable energies and present new opportunities to decarbonise the whole EU economy. In addition, it seeks to create synergies between the different member countries, resulting in a legislative balanced impact at all levels: EU, national and local. The most revolutionary point of this package is not the measures towards the 2030 targets, but achieving long-term climate neutrality by 2050. The visualisation and planning of these 2050 targets greatly affect all governance processes and schemes, and cities are collaboratively developing cross-cutting roadmaps that affect all areas and sectors of society [2]. Considering that cities account for 2/3 of all energy use worldwide, energy and infrastructure decisions must be long-lasting and have a long-term impact on emissions reduction [3].

Another highlight of the package is the introduction of the citizen as a key actor in ET. Citizens will take on the role of prosumers [4], bringing flexibility to the electricity grid and ultimately becoming a stakeholder that deals with societal challenges. However, in order for citizens to benefit from the opportunities offered by the EU, and to be able to act effectively against climate change, Public Authorities have an important role to play [5]. Local governance is important for encouraging behaviour change among individual residents and industries, raising the visibility of initiatives and offering guidance and support to communities. In this regard, the EU has promoted and supported the creation of the Covenant of Mayors for Climate and Energy [6] to develop transversal roadmaps and highlight the power of local and regional authorities to support the energy transition.

On the one hand, the Covenant of Mayors promotes the creation of a Sustainable Energy and Climate Action Plan (SECAP) to define a set of actions to achieve climate change mitigation and adaptation objectives. This facilitates the achievement of the objectives set by the EU, however, the definition of a SECAP requires the creation of an ecosystem involving all citizens, businesses, political authorities and other funding bodies. This calls for the creation of urban governance, in which all stakeholders must be involved in public decision-making [7]. However, the Covenant of Mayors initiative also involves follow-up and monitoring to achieve the objectives. This is done through reports in which all stakeholders must participate, yet in recent years there has been a notable lack of commitment to this monitoring task [8].

On the other hand, the EU is taking a special interest in helping islands to define their paths towards energy sustainability and decarbonisation. Due to their location, they are more vulnerable to climate change and ecologically more fragile [9]. Rising sea levels or changing rainfall patterns negatively affect their economy. To cope with this challenge, measures are proposed to reduce emissions and to engage in climate change adaptation and mitigation policies. With regard to the latter point, EU initiatives have been set up to help islands to define their Energy Transition Agendas and encourage and attract other stakeholders to join these strategies [10, 11]. Thus, it appears the Manual for the Energy Transition on how to tackle transition on EU islands [12]. The challenge of addressing climate change is even greater for tourist islands, whose energy patterns vary seasonally.

The above highlights the challenge for municipalities and local regions to lead the transformation process towards a more sustainable energy context with the support of local energy transition experts. This need is even more evident when it concerns tourist islands with large population shifts. To this end, assessing the consequences of the energy transition through modelling involving policymakers is essential for strategic decision-making, but it is also important to monitor progress towards the objectives.

2. Particularities of tourist islands in ET

The EU has a wide variety of islands which, despite their common characteristics, vary greatly in terms of electricity grids, geographical specificities, local population, tourism and other aspects, all of which affect the stability of the energy grid and create energy planning challenges [13]. In this regard, the EU is taking a special focus on the islands, as they offer specific opportunities very well suited for modern energy planning, both in terms of the potential for energy efficiency, renewables and innovative solutions, as well as the creation of a broad and strong community-driven transition process. The Clean Energy for EU islands or the Smart Island initiatives are tangible proof of it.

Facing the necessity of developing a SECAP, island communities present important differences and difficulties compared to mainland communities. Factors such as small size, remoteness, high environmental impact and climate vulnerability make islands susceptible to external factors and therefore more vulnerable to climate change. However, although the costs of grid connections are high, islands offer opportunities for energy autonomy that are rarely available in mainland communities [14], i.e. they enjoy a high natural potential for renewable energy sources that can be harnessed to lead decarbonisation. Despite having access to renewable energy sources, such as wind and wave power, many of them rely on costly fossil fuel imports for their energy supply. A further point that affects all island communities is that political decisions are essential when it comes to investing funds to establish sustainable scenarios.

In particular, tourist islands are facing crucial energy challenges such as limited space for the implementation of Renewable Energy Sources (RES), weak connections of energy grids with the mainland, architectural restrictions in cultural heritage areas, touristic flow variations and protected areas (e.g. nature, environmental parks, etc), that makes the process towards ET even more complicated. All these issues should be considered in the clean solutions presented to communities, addressing all parameters potentially affecting their SECAP.

Revitalising the economy of tourist islands with a green approach and accelerating the ET requires the active involvement of stakeholders and, crucially, policymakers in setting the agenda and defining ET solutions. To this end, methods and approaches to energy assessment and planning have been developed over time to facilitate the path towards ET.

3. Review of assessment methods and tools for ET

Energy planning is an essential technique for achieving the EU objectives, but it also has two other main goals: to provide guidance and material for the debate on future energy systems and to support policymakers in the development of short- and long-term energy strategies [15]. Several authors have studied the use of energy models to aid policy decision-making, and the classification of energy models dates back to the 1990s [16]. Since then, considerable revisions and modifications have been made up to date, resulting in a large number of energy models classified according to criteria such as purpose, analytical approach, mathematical approach, geographical coverage, time horizon, etc [17]. This section will review some of these classifications by addressing the methods that are considered to be of interest for islands, policymakers and overall for the ET. In addition, it will also identify some models in which the methods have been applied.

A. Governance approaches

A governance approach is considered as a method that directly addresses policymakers in order to advise their mandate towards the ET. These approaches are easily understood by policymakers and all related stakeholders in ET and provide valuable information for climate policy decisions.

In this regard, and directly addressed to the islands, the EU Clean Energy Islands Secretariat offers a range of support materials and a wide database of good practices that allow for synergies between the islands themselves. Among the studies carried out, the *Methodological Handbook* was created to advise islands on how to move towards ET [12]. This handbook is a methodology-driven guide to steer projects in any of their stages towards the ET and initiate, restart and boost the decarbonisation of islands. The methodology focuses mainly on three actions or phases:

- *Explore.* This phase aims to initiate the islands' path towards TE by creating a Clean Energy Transition Agenda (CETA). Firstly, it aims to create a baseline scenario, and to start defining possible alternatives to achieve the objectives set. To this end, it provides the islands with templates and technical assistance in energy system analysis, stakeholder mapping and transition governance. In addition, it has also created an easily accessible and user-friendly self-assessment tool, which allows the monitoring of actions.

- *Shape.* The second phase is focused on identifying the specific actions required to achieve the CETA. To this end, templates and information are provided as guidance to identify the technologies needed, and conduct a feasibility study of the project and the business and financial model. Easy support tools for the business model, such as the CANVAS method or the SWOT analysis, are also provided.
- *Act.* This phase focuses on implementing the plan, establishing contacts with stakeholders and securing the necessary funding.

Ultimately, this methodology guides policymakers on how to develop a CETA. Furthermore, it is a support guide to define actions and provides simple tools that policymakers can use, but it does not provide technical information on future scenarios or relevant data that could reflect the impact of the actions. It is a very disaggregated methodology, i.e. it provides many accessible documents but is not integrated into a single platform. A similar methodology was developed under the *RenewIslands* initiative [18] and was envisaged as a complement to an energy planning system. More technical models that can support policymakers are discussed below.

B. Modelling approaches

To define the impact of actions implemented in a SECAP, modelling models are provided. Among the different modelling methods, two main types can be distinguished: simulation and optimisation. The main difference between these two methods is that simulation allows a system to be represented and its performance to be estimated under certain conditions, while optimisation minimises or maximises an objective function subject to constraints [19].

In the case of *simulation modelling*, there are several scenarios that can be given as a solution. The most relevant options and recommendations are presented to policymakers in order to choose the most appropriate scenario. Simulation models are typically fast and detailed in their ability to compare different future options. Furthermore, it can be used to obtain the future implications of some current choices or, to find out what possibilities exist to reach a set goal in the future.

As for the *optimisation modelling*, this is a computational process prior to policy decisions. Mathematically, most optimisation models use the linear programming (LP) approach, which aims to maximise or minimise a function given a set of constraints. It is also possible to use mixed integer linear programming (MILP) or even for an optimisation model to be non-linear. On the other hand, heuristic optimisation models can also be used, which differ from traditional optimisation models in that the optimum solution is not necessarily found [17]. Experts analyse the data and politicians receive the information from them. The process is complex: models are slow and detailed in describing current systems, but in theory, they are well suited for forecasting in order to prescribe the optimal future on the basis of the built-in assumptions.

Both models are advisable for energy planning, but simulation modelling allows more variables to be included in the analysis and gives a more qualitative result of the scenario.

C. Decision Making Methods

The models described below provide more than one solution (not pure optimisation models) and also mobilise the knowledge and experience of policymakers and stakeholders to consider the various risks and uncertainties of implementation and their consequences. For this reason, it has been called the decision-making method, as it allows to obtain an analysis of the different scenarios generated, highlighting the value of the authority's decision, an important approach to dealing with ET at the municipal level.

- Multiple Criteria Decision Analysis

This method, also called "Multiple Criteria Decision Making (MCDM)", is a method of measuring, scaling, weighting and aggregating criteria to obtain a relative final result that fulfils a set of objectives. It is mainly used to support decisions in complex problems where several criteria have to be considered in order to reach a satisfactory solution.

In the last decade, its use has increased in studies related to climate change mitigation and adaptation, mainly due to the increase of experts involved in the climate area and in modelling activities [20]. In addition, the multi-criteria approach is having a major impact in the EU due to the need for sustainable development, not only sustainability and its implications for the environment are intertwined with decarbonisation and climate change mitigation, but also have an impact on different sectors of the economy. This approach can help in various phases of decision-making, such as modelling preferences or designing interactive solution procedures.

MCDM methodology is implemented by various techniques such as WSM, WPM, PROMETHEE, ELECTRE or TOPSIS, although AHP is the most popular method [21]. In particular, the Analytic Hierarchy Process (AHP) method can help policymakers obtain the best strategy for a given issue [22], following a simple procedure that consists of ranking the problem, assigning weights to the evaluation criteria (weighting) and finally obtaining a final overall relative score for each alternative.

Therefore, it can be observed that these methods help better understand the inherent characteristics of the decision problem, involve stakeholders in decision making and encourage and facilitate commitment. It is a method for analysing a scenario in a realistic way, although it is not as objective as optimisation models.

- Multi-objective (MO) analyses

Multi-objective (MO) analysis is another methodology used to illustrate the trade-off between parameters and help select a compromise solution. This method is less typical in energy planning, and, unlike linear optimisation models, these models require newer heuristics to find solutions, such as evolutionary or genetic algorithms [23].

- Fuzzy Cognitive Maps (FCMs)

FCM is a semi-quantitative or quasi-quantitative modelling technique, consists of fuzzy structures similar to neural networks and are often used as a powerful tool for modelling complex systems, such as climate change mitigation policies. There are several studies on climate change issues related to policy-making and the consequent generation of different scenarios [20]. This is due to their high flexibility, low dependence on data availability and the fact that they are based on human experience and knowledge. This approach facilitates policymaking, brings policymakers and experts closer together, and thus increases trustworthiness between them. The aim of this approach, beyond avoiding the quantitative models needed to optimise, evaluate and select policies to help achieve the desired energy transition objectives, is to complement quantitative methodologies by linking them to qualitative, experience-based models.

There are studies involved in climate policy development using this approach [20, 24]. They show the methodology used: using quantitative models, a number of policy pathways are defined to achieve objectives. The objective of the FCMs will be to help select the optimal policies, through expert knowledge and experience on the feasibility and applicability of different sets of policies.

- Cost-Benefit Analysis (CBA)

Cost-Benefit Analysis (CBA) is considered an analytical method that can be used in the decision-making process of energy projects to evaluate design alternatives from a social point of view. The procedure is as follows: first, the items under consideration are converted into costs and benefits, then, to account for the variation in costs and benefits over time, a discount rate is applied, which converts the amounts into an estimated net present value (NPV) that provides a fair basis for the time value of money. Finally, the benefit-cost ratio (BCR) is calculated [25]. However, in this criterion, the weighting of non-fungible values applies a subjective value and therefore generates a fair degree of uncertainty in the results. Furthermore, the efficiency outcome of the CBA is considered a valuable input for public spending decisions, which is why this tool is mainly used by policymakers (mostly governments) [26].

D. ET Assessment tools

Through the above approaches and models, the aim is to involve policymakers and stakeholders in energy modelling processes and to improve the understanding and assessment of uncertainty. Even more, these approaches can be integrated together, resulting in models in which energy, climate economics and decision support frameworks all contribute key drivers, creating a composition that fits together and should be considered in climate policymaking [17, 20]. These models have been applied as tools for ET policy on climate change. Below are discussed some of these models which are of particular interest to this research work and which are used by a large number of users.

The *EnergyPLAN* software is a simulation model that allows the evaluation of different future energy system alternatives by testing different energy mixes. The model has been in continuous expansion since its development and approximately 16 versions have been created. It is intended for use by experts in the field but can be downloaded free of charge, and training can last from a few days to months (depending on the type of analysis). The main objective of the tool is to assist in the design of national or regional energy planning strategies by simulating the entire energy system [27]. This model has a very wide scale of geographical coverage: from the European level to the scale of cities and municipalities and even small islands. It has been used to analyse the integration of strategies, as well as the optimal mix of renewable sources or integrated energy systems and local markets [28]. This tool was also deployed after following the application of the methodology for energy assessment of the PRISMI project on the island of Malta [29]. After its application, it became clear that political decisions are essential when investing funds to establish sustainable scenarios. Therefore, the creation of a tool where political decisions are taken into account in the development of energy transition plans would facilitate the path towards achieving the set targets. However, the use of powerful tools such as EnergyPLAN and their combination with other ones that provide the variable of political decisions can be a viable solution.

Another powerful tool used for scenario simulation in all sectors is *LEAP* (Long Term Energy Alternatives Planning), usually used to analyse national energy-systems [28]. LEAP can be used to estimate climate impacts, estimate different scenarios associated with air-pollution health impacts, explore mitigation scenarios addressed to policy analysts to reduce air pollutants or greenhouse gases (GHG) and characterize national emissions of greenhouse gases and pollutants. Through this tool, interesting economic analyses can be obtained for experts, which can later be beneficial if the proposed measures are implemented. However, it is mainly focused on the emission of pollutant gases from different sources, which at the national level works very well, but at the city and municipal level, it has shortcomings [30]. LEAP does not currently support optimisation modelling, although this capability is currently being developed. However, an extension LEAP-IBC (Integrated Benefits Calculator), which allows energy planning and greenhouse gas mitigation assessments for 25 years, has also been implemented in this tool. In addition, this extension was proposed as part of a guide for the development of climate change mitigation policies and was used for the development of the national plan to reduce short-lived climate pollutants in Ghana [31]. It is therefore a useful tool for quantifying the impact of the various schemes already in place but requires an elaborate database on the study site and a mid-level of knowledge from users.

TRNSYS is an open source, modularly structured transient system simulation software that simulates the power and heat sectors of an energy system [28]. It has been commercially available since 1975, and to date there are 18 versions. It is a tool that allows the transient simulation of many plant configurations, which can be modelled from its database and system components. Another important feature is that it has an extensive meteorological database. There are a large number of building applications for modelling electrical and heating systems, but one application of interest is the simulation of renewable systems on the island of Gran Canaria [32]. In the latter case, in order to understand the dynamic behaviour of the system, an integrated TRNSYS-Matlab model was performed and an optimisation was carried out to identify the best system in terms of RES exploitation. The results obtained were positive and could be of interest to policymakers and their stakeholders, so this tool is designed to be adapted to small and isolated islands and their specific needs, in various locations and at multiple scales. However, the need to enter the island's energy demand data and the use and handling of the tool make it difficult to replicate, unless experts are familiar with its use.

Finally, another tool that is not as widely used but of interest for this article is *H2RES*, a planning tool for island energy systems. This tool is specifically designed to increase RES integration in island systems operating as stand-alone systems. In addition, it is also used as a planning tool for individual energy systems [28]. The H2RES model is designed as a support for ADEG/ RenewIslands methodology [33]. The main problem is that H2RES is not yet sold to external users, but is provided to internal users to complete their research. In addition, the training period required to use the tool is up to two months for experts only. It is therefore a tailor-made tool for island systems, but its technically difficult use and understand, as well as the fact that it is not available to everyone makes its implementation quite limited.

4. Gaps and Knowledge Areas to Be Addressed

A review of existing methods and approaches reveals the heterogeneity of energy models as well as their classifications. The use of the corresponding energy tools requires specific technical competencies for the proper evaluation of such (often complex) interdisciplinary studies. This not only represents a key barrier to the comprehensibility of a particular study, but also hinders its comparability.

These existing gaps in energy planning models lead to the creation and adoption of additional frameworks to support climate policies. These frameworks should include models and tools that, in addition to including and involving policymakers and stakeholders, allow them to increase their knowledge and expertise by participating in the process and see and understanding the risks of the strategies adopted.

The two main challenges in using tools for such assessments are therefore the severe lack of available data in many of the target countries, and in particular, on islands, and the lack of sufficient capacity in local organisations to make use of such tools.

Therefore, there is no tool that integrates different models or approaches aimed primarily at policymakers to elaborate and monitor their plan towards ET, is freely accessible, integrates an island-specific database, allows the visualisation of future scenarios behind strategies and, in addition, incorporates the decisions of policymakers into its criteria. This highlights the need and value of creating an innovative tool that homogenises a multidimensional approach at the national level, focuses on municipal needs, defines a wide range of up-to-date indicators and, in addition, allows for monitoring of actions at the municipal level. Focusing on the municipal level, through established good practices and plans, makes it possible to specify areas of action and to analyse the progress of local measures within the specific context of each municipality.

5. Conclusions

In a nutshell, the creation of a CETA or SECAP is therefore necessary to achieve the objectives set by the EU. The islands are currently one of the great challenges facing the EU. On the one hand, their energy potential stands out, but their vulnerability and energy instability hinder the transition to climate change. Currently, there are limited tools aimed at islands to support them in the energy transition, although the existing tools offer guidance to policymakers, they are very generic guidelines that can give ideas on how to set up the plan, but they do not really provide solutions. On the other hand, there are other tools based on analysis and decision models that are broader in coverage, although they can also be used on islands. However, they do not integrate island-specific data, are not user-friendly for policymakers (they need technical expertise), do not allow monitoring of plans towards ET, and only provide quantifiable scenarios or results in the face of different strategies. Therefore, there is a clear need for a new model for monitoring the energy transition based on electrification strategies at the island municipal level, which considers existing strategies and the potential for action, as well as the value added by policymakers through a multi-criteria decision algorithm that provides qualitative analysis.

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