Lessons from the European island territory decarbonization: the role of flexibility to ensure a high renewable integration

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Overview

The achievement of sustainability goals to tackle climate change is nowadays a major challenge in many different sectors for energy transition. In such a context, the increase in the share of renewable energy sources in the production mix appears to be a valid solution. Indeed, these technologies can ensure energy production at low (or null) carbon emissions and the current decrease of power generation costs is making renewable energy more and more attractive for public and private investors. This price drop is relevant especially when dealing with solar and wind energy, that represent today competitive renewable energy sources. However, this increase of renewable energy share in the power generation mix to achieve national and international targets of greenhouse gases emissions reduction comes with important consequences, especially for the electricity grid that has to increase its flexibility to assure the quality and reliability of supply. This requirement can be much more relevant when dealing with islands, as they have limited (or no) interconnections to the continent and thus have to rely more on flexibility options to ensure the secure and cost-efficient operation of their energy system. To ensure the decarbonization of islands, a reliable power system for the long-term should be designed. At this aim a proper energy plan should be assessed, defining the type of technologies to install or remove, their capacities and location over time still considering constraints of different nature, such as technological, environmental, social and political ones. This can be made by considering different evolution scenarios showing possible future pathways of the energy system. This approach would allow decision-makers to evaluate possible trajectories that ensure the increase of the share of renewable energy sources and a better management of their resources. In this context, the development of innovative solutions are studied to integrate vast amounts of renewables in islands. As part of this subject, a long-term prospective study is carried out to explore decarbonization pathways that ensure grid flexibility of two European islands, namely Procida in Italy and Hinnøya in Norway. The TIMES models developed attempt to integrate flexibility options. Particular emphasis is given to the study of the use of electric storage technologies, given their potential key role for islands grid flexibility

Methods

This long-term decarbonization is carried out through the implementation of TIMES models, a methodological corpus developed within the Energy Technology Systems Analysis Program (ETSAP) from the International Energy Agency. This bottom-up energy system model is a mathematical tool that can be used to support long-term strategic planning in the face of uncertainties related to future events that is based on the definition of possible future trajectories, or scenarios, that are compared to evaluate contrasted possible future outcomes. Scenarios can be used to prove that a desirable future is attainable or to explore possible evolutions when adopting different strategies. Based on a technology-rich representation of systems, different scenario can be explored through the definition of energy supply and demand curves, the set of possible technologies and a policy setting, on the time horizon (here 2050). To increase the flexibility of the electricity grid when massive renewables are integrated in the system, storage technologies are considered (including long-term storage) and, in accordance with national contexts that promote the decarbonization of the transportation sector, electric vehicles are considered and analysed in this study.

Results

Long-term prospective modelling allows to evaluate the best configuration of the energy system in terms of amount of technology capacities to install or withdraw, the best location and at the best moment in time for installation in order to satisfy technical, economical and environmental constraints and optimise the costs related to such a development at the same time. Therefore, it is a powerful tool for decision-makers dealing with energy planning.
For example, in the context of Procida, a Italian island, when the investments in new supply technologies tend to maximise the use of photovoltaics, as the maximum amount of installations per year is always attained, public and tertiary installations are preferred in the first years of the horizon, since their investment cost is lower with respect to residential ones due to economies of scale. However, it is relevant to notice that in the cases in which investments on storage technologies are allowed the optimal choice for PVs investments changes. In this case, investments on photovoltaics installed on public buildings are preferred, as a larger amount is installed at the first years of the horizon. Focusing on storage systems, investments are only made for batteries and in particular the ones for public and residential applications. Long-term storage technologies are instead not taken into account despite their lower

price per unit of energy. This is probably due to the large conversion losses related to these processes (the efficiency of a charge/discharge cycle is only 37.5%), that makes these technologies energetically not convenient in a context in which local sources electricity production is already quite limited. The introduction of renewable energy sources comes with the decarbonization of the energy mix of the island.
As the only possible supply solutions are the photovoltaics and imports, whose processes are not directly (i.e. not taking into account life cycle assessment considerations) related to emissions, the electricity supply mix of Procida is already entirely decarbonized. However, important prospective for decarbonization concern the demand side. It can therefore be relevant to evaluate the possible decarbonization levels that can be reached with the different photovoltaics deployment scenarios considered for the analysis. At a first sight, the results obtained for the renewables share in final consumptions and the imports seem to suggest that the use of storage technologies does not significantly foster the increase of renewables.
However, a closer look at the results can show the benefits of these devices on the energy system of the island. At a system level, one of the main advantages is the grid congestion relief at peak hours. Indeed, the results show that the use of batteries allows to decrease the electricity imports at peak hours, when the grid is more subjected to congestion problems. However, the results could probably be more significative if requirements related to grid congestion relief are integrated in the model or in cases of larger renewables penetration, as in this case a larger amount of energy produced by photovoltaics could be shifted from high production hours (midday) to no production hours (especially in the evening, when the peak of demand occurs).
Moreover, care should be noticed that a better estimation of the seasonal consumptions share, that takes into account the load increase in summer, could result in a higher deployment of storage technologies, as a higher electricity production is possible during this season. Another advantage is related to the possibilities of self-consumption. Considering public buildings, that are the ones in which the most important investments on batteries are made in the model, the results show that the use of batteries enables to decrease the electricity imports up to about 55%. This implies important economic advantages for the users, as well as advantages for grid congestion relief and grid flexibility, especially at peak hours, as the grid has to manage a lower amount of electricity flows (the improvements noticed at system level are probably mostly due to the public sector).

Conclusions

This study is developed under a H2020 project, GIFT - Geographical Islands FlexibiliTy, as part of the European innovative projects developed to meet the sustainability goals for the energy sector. The achievement of the objectives proposed for this project will allow to decarbonize the energy mix and to increase the share of renewable energy sources in European islands. As part of the project, long-term prospective modelling will contribute to the realisation of energy transition. The results will enable municipalities to consider different regulatory policies to achieve the energy transition of the territory. Moreover, as Hinnøya and Procida are representative of completely different European contexts, the results obtained in this study will not be limited to these two demonstration sites, but other islands could benefit from the analysis.
The first results obtained with this model configuration allow to draw several conclusions. First of all, the results obtained considering different realistic renewables' integration scenarios show that promoting the use of photovoltaics in the island could lead to important improvements both in terms of costs, energy independence of the users (and thus of the island itself) and grid congestion relief. Improvements could be detected even in cases of low renewables deployment, suggesting that the energy system could benefit from the policies supporting local energy production. However, the results also showed that in the long-term the use of photovoltaics alone is not enough to cope with the increase of electricity consumptions. Additional solutions should then be considered, such as policies supporting energy efficiency. This analysis also attempted to evaluate the potential benefits coming from the use of the flexibility solutions integrated in the model. Concerning storage solutions, the results showed that the use of these devices is strictly related to the amount of renewable energy integrated in the energy system, as the investments in these devices increase with the share of photovoltaics. From the economical point of view, investing in storage solutions seems not to lead to particular advantages, as the total system cost remains quite the same. As in the case of low renewables' integration in the system this technology is not taken into account by the model solution, the results may also suggest that there exists a lower limit over which this technology becomes competitive. The only investments on storage solutions concern electricity batteries, probably due to the fact that seasonal storages present high energy losses that make their deployment inconvenient in an energy system with scarce possibilities of local production. Nevertheless, these technologies result a valid solution when considering the energy system as a whole. Indeed, improvements with regard to grid congestion relief and self-consumptions can be observed even when limited investments in these devices are made.
In conclusion, the analysis showed that ensuring the decarbonization of the island is possible, but for this scope other solutions are needed (e.g. efficiency, storage technologies or other flexibility solutions when high shares of renewables are included in the power system).