COMPARATIVE SCENARIOS IN ISLANDED SYSTEMS: ENERGY SUPPLY-STORAGE SIZING PROBLEM APPLIED TO ELECTRICITY AND MOBILITY

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Overview

This paper brings insights into the energy transition policy making process in islands while solving the capacity sizing problem and the investment allocation issue. The framework raises the general problem of the electricity management in remote electrical grids to continuously reach the balance between production and consumption, to operate with sufficient reserve margins to guarantee grid stability and to insure returns on capital high enough to attract investors. The case study is Yeu Island, a French territory located in the Atlantic Ocean, of 23 km^2, 5,000 regular inhabitants and up to 40,000 inhabitants during the summer.

Yeu Islands has good energy renewable potential, such as wind, solar and wave, as well as biomass if sustainably managed. Yeu Island currently exploits a limited share of its solar potential and has ambitious projects for further deploying energy renewables. However, the industrial development of projects on the island faces constraints related to urban planning, touristic and fishing activities, along with conditions for the conservation of *Natura 2000* sites.

Yeu Island is interconnected to the mainland grid network through distribution submarine cables. Energy consumption scenarios for 2030 show an increase in the power demand by 30%, and peak demand well above the current interconnection capacity. Policy makers are about to consider two options, on the supply side the implementation of renewable energies, and on the demand side the management of energy consumption through smart grids and hydrogen storage means.

This research builds a methodology which integrates island specific constraints to build energy transition scenarios in support to public choices. Scenarios combine complex technologies at different maturity levels (TRL between 3 and 9) with demand management solutions, which are as common as house insulation, or complex such as two-way electrical vehicle storage. These options are costly to plan, implement, operate and maintain, despite positive effects in terms of employment, innovation and growth. The investment allocation programme is a trade-off between costs and expected benefits from supply and demand investments, priority being given to demand peak shaving projects. Next on project efficiency comes the local energy production, based on wind, solar, wave and biomass.

The island being interconnected with the mainland guarantees the equilibrium of power supply and demand, which eliminates the risk of power plants overcapacity and reserve margins provision. While reversely acting the power cable connections, any production excess on the island could be sold on the market, this business model being successfully experienced in Scotland (Orkney Islands) and Denmark (Bornholm Island).

The project aims at simulating the island power system such as to obtain the level of energy independency degree that optimally meets the constraints of urban planning standards and money scarcity. It highlights the benefits of grid interconnection in terms of energy and investment capital saving. Projections will be compared to one completely remote energy case where grid stability and supply security would have significantly high costs composed of large fixed costs and non technical losses from ready-to-operate power plants.

The paper is organized as follows. Section 1 introduces the problem and makes an overview of energy choices in different islands worldwide. Section 2 describes the energy scenarios boundaries and sets maximum installed capacity options for each technology, under local social and political constraints. Section 3 details the economic model used to simulate the equilibrium between supply and demand for power and mobility. Section 4 depicts the model results and gives orders of magnitude of investments required. Section 5 assesses the policy implications and put in balance costs and benefits from a social-wide perspective. Section 6 concludes that one of the market pull instruments in support to renewables and storage, hydrogen and wave in particular, could be the State involvement in infrastructure building, as the necessary investment in the energy transition to a low carbon economy.

Methods

An optimization model is built to minimize the short-run system cost to operate and generate the power under economic constraint of hourly supply and demand equilibrium, and technical constraints of plants operation, wind speed, solar irradiance, tide cycles, biomass potential and distribution grid capacity. The model is dynamic with 8,760 time slices and simulates the local market hour-by-hour over one year. The model results are extrapolated to the entire technical lifetime of technologies such as to reproduce the investors business model. The economics of all energy projects are assessed by calculating the Net Present Value of benefits and the Levelised Cost of Energy. The supply aggregates the power generated by local energy projects (wind, solar, wave, biomass), the interconnection to the inland and the hydrogen storage while discharging (power-to-power; power-to-mobility). The demand includes the aggregated power consumption from residential and tertiary sectors, from the local industry and electrical vehicles, and from the hydrogen production to fuel fishing vessels and the bus fleet. Calibration is based on projections to 2030 of the power demand and of the territory renewable energy potential.

Results

Three main scenarios are selected and depicted.

- First scenario focusses on investments in demand side measures, such as energy saving projects and smart grids with storage and communication techniques and devices. This allows reducing the demand by at least 25% and to shave the peak by 10%.
- The second scenario combines investments in demand side management with renewable energy projects. Several cases are tested such as to select the best economic combination of energy projects, based on their investment cost and usage rate. In general, small remote areas have low profusion effect (smoothing effect), and limited uncorrelation degree of intermittent energy resources. This increases the risk to curtail the power in surplus. Yeu Island being grid interconnected to the mainland, the risk of curtailment could partly be eliminated. The power in excess generated on the island could be sold on the market provided that the distribution cable capacity is large enough to transport the power. Scenario sizing becomes an exercise of how much local supply is necessary to match the demand such that any excess could be sold via submarine cables.
- The third case builds an energy independency scenario in order to draw the costly and complex grid system specific to remote islands. Results estimate the financial cost and depict the infrastructure required to balance continuously supply and demand. This case highlights the complexity of the system when the energy mix is composed for 90% of intermittent energy resources, which leads to overcapacity while removing the interconnection to the inland. The curtailment rate is high for each energy project, which affects the profitability of investments and the maintenance operations while frequently shutting down the power plants.

Conclusions

Energy scenarios resulting from the optimization exercise list the energy flows from local potential resources, storage means and mainland supply, and give orders of magnitude of the costs and expected benefits. Technological options recommended by scenarios are the first step into the policy decision process. Options are next ordered by economic importance, in terms of employment and growth effects, by political value of the energy independency degree, and social acceptability in terms of standards protection of the local economy and natural sites. Weights of the decision criteria will be calibrated based on Yeu Island regulatory and policy makers, on the civil society opinion and national provisions on energy transition. Each scenario reveals different regulatory requirements since different operators act on the power market each with conflicting market strategies. New regulatory provisions should be drawn in terms of tariffs, grid codes, technology curtailment order, project selection and market operation.

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