# Optimal sizing and selection of Microgrid energy sources and storage based on the lowest NPC for a pre-defined load profile

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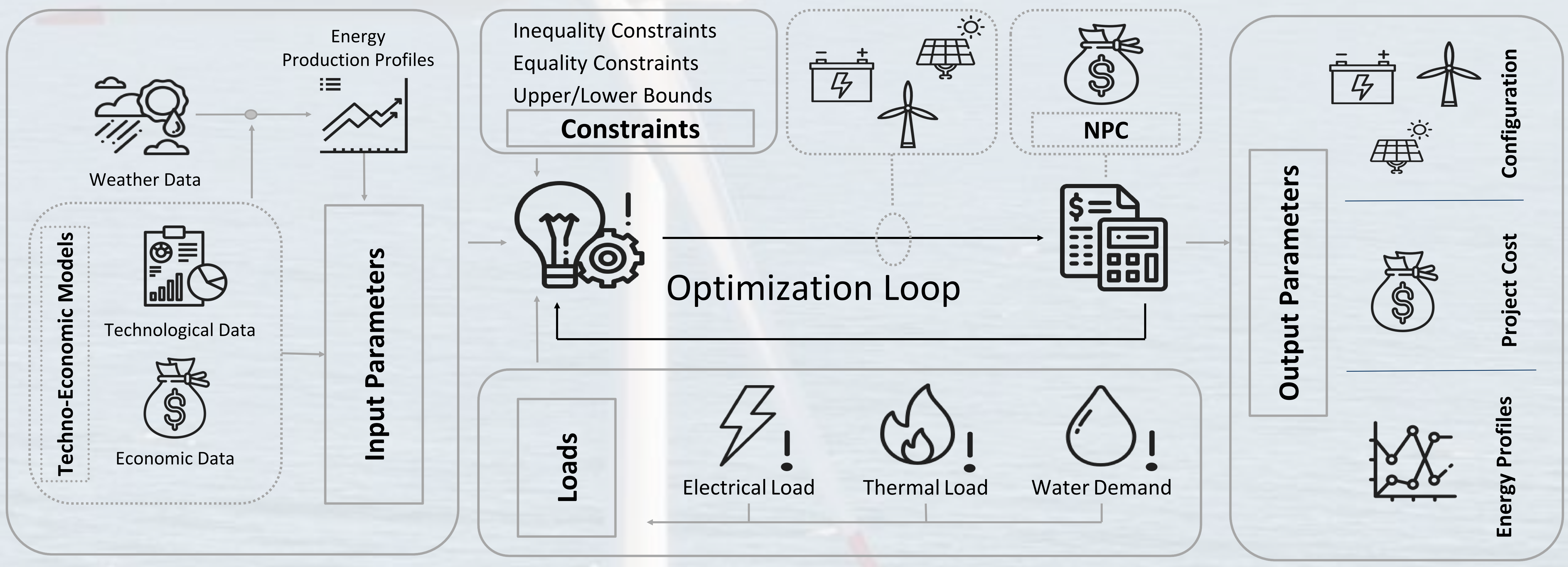
## Abstract

A methodology was developed with the aim of designing an optimal energy production and storage configuration, characterised by the lowest net-present-cost, that meets a predefined load profile. In different contexts, microgrids may be required to respond to varied load profiles, which may be combination of electricity, heat and even fresh water demands (electric, thermal and water loads, respectively). To satisfy the specified load profile, an optimization loop compares a vast array of energy production and storage technologies (electrical and thermal) included in the ever-developing database of techno-economic models, to find the most suitable configuration.

Weather data, economical data and technological data are input parameters of the optimization process. The algorithm considers multiple combinations of user selected power generation technologies from a database which can be easily expanded and updated at discretion. The optimization algorithm also considers user specified constraints, through upper and lower bounds, to easily force, prohibit or limit the usage of any technology (e.g. existing energy grids). Within the optimization loop, all possible solutions to satisfy the load profiles with the considered technologies are computed and compared in terms of overall net-present-costs.

## Flowchart of the Optimization Process




## Techno-Economic Models

The energy production and storage technologies are modelled using a range of parameters relevant for the techno-economic assessment. This enables the calculation of the net present cost of each individual micro-grid configuration, together with the energy production estimation from weather data.

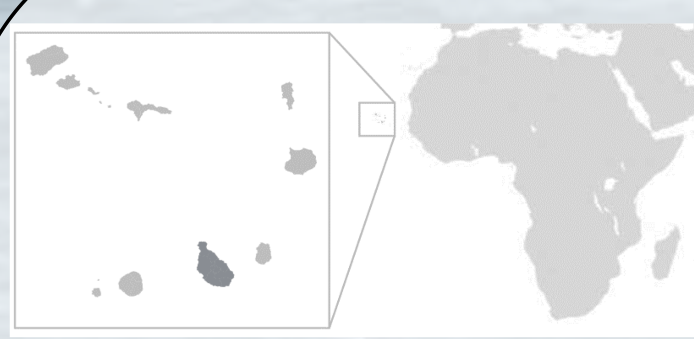
| | Power Generation (Wind Turbines, PV Solar, Concentrated Solar Power, Electrical Grid) | Storage Systems (Lead-acid, Lithium-ion, Vanadium redox flow, Hydrogen, Molten Salt) |
|---|---|---|
| Technical Parameters | • Power curves<br>• Thermal Efficiency [%]<br>• Electrical Efficiency [%]<br>• Derating Factor<br>• Land use [m²/kW] | • Round-trip Efficiency [%]<br>• Lifetime [nº cycles]<br>• Land use [m²/kWh]<br>• Depth of Discharge [%] |
| Economic Parameters | • CAPEX [€/kW]<br>• OPEX [€/kW/a]<br>• Discount rate [%]<br>• Energy price [€/kWh] | • CAPEX [€/kWh]<br>• OPEX [€/kWh/a]<br>• Discount rate [%] |

## Optimization Loop

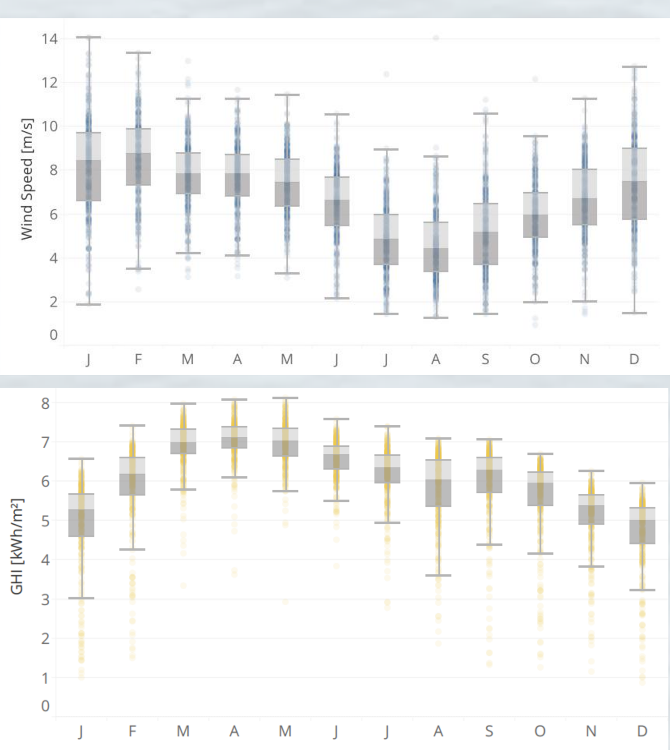
The optimization loop aims to obtain the micro-grid configuration with lowest LCOE/LCOW (Levelised Cost of Water) capable of satisfying the pre-defined load profiles. For this purpose, the algorithm relies on the energy production profiles to generate configurations that satisfy predefined load profiles at every time-step. The economic data is subsequently used to compute the NPC of each individual configuration. This linear optimization problem is finally solved using the Dual-Simplex Algorithm.

The tool is configurable with inequality and equality constraints and upper and lower bounds to easily force, prohibit or limit the usage of any technology (e.g. existing electrical grids). Both load and weather data availability define the accuracy of the optimization loop, which is by default running with one-year data.

## Exemplary Results



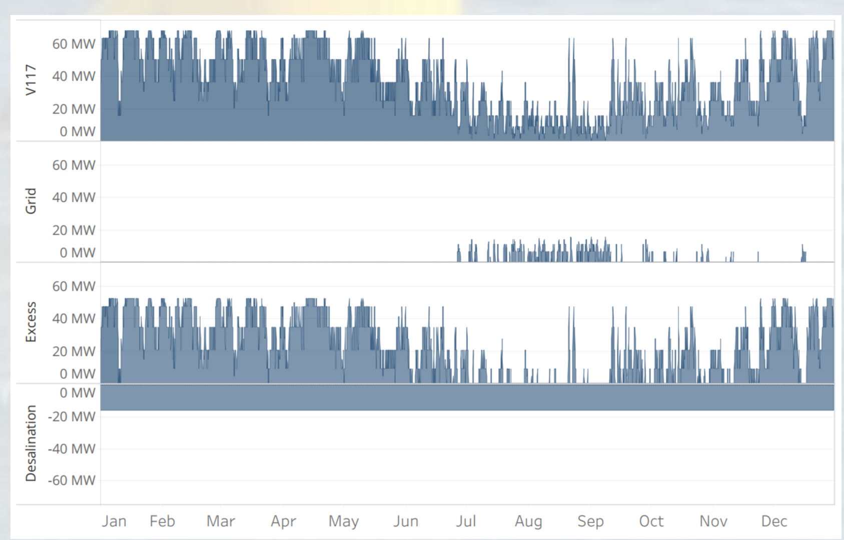
Weather Data



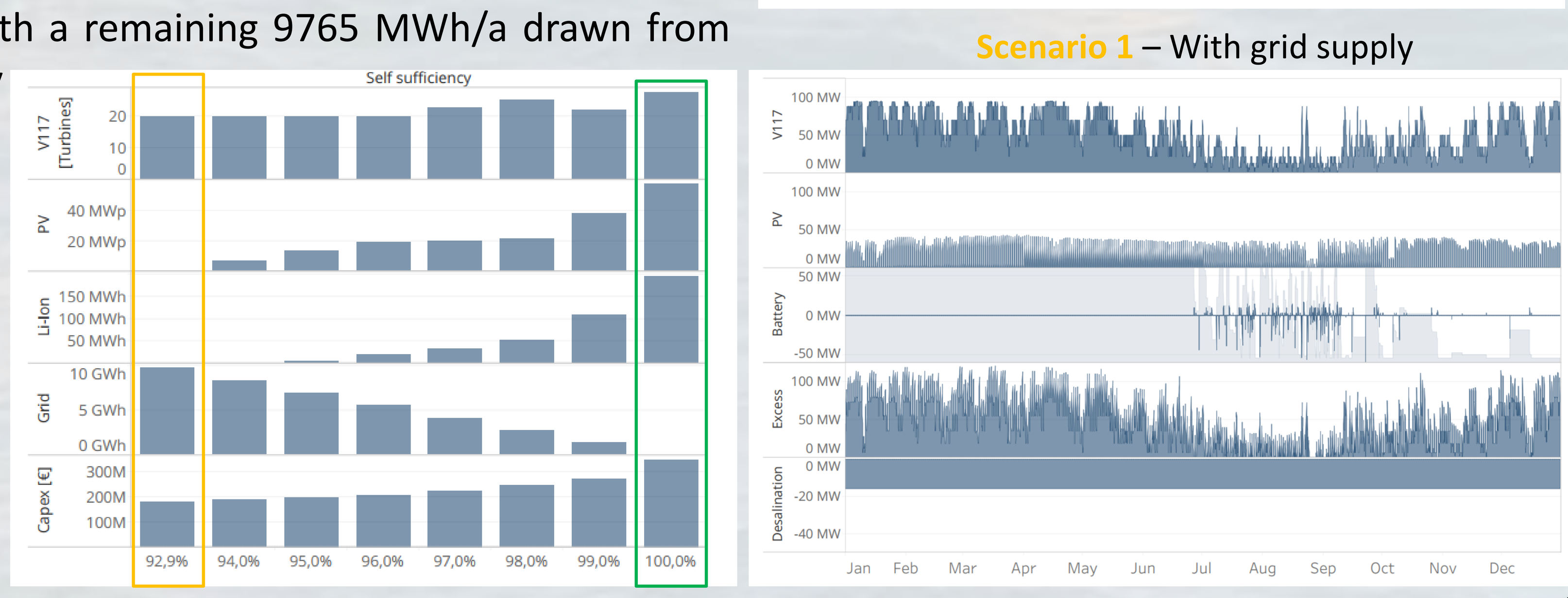
The developed optimization tool was used to carve out the best solution to supply the Cape Verdean island of Santiago with fresh water produced with desalination plants. In this specific case, the optimization tool is fed with a water demand profile. After selecting and sizing an adequate desalination technology (Reverse Osmosis 80m³/d), the optimization tool translates the water demand profile into the resulting electrical load profile (15.8MW continuous load). With such electric load, two optimization scenarios were setup, Scenario 1: with grid supply, assuming an electricity price 0.3€/kWh, and Scenario 2: without grid supply, or simply put - model constraint to 100% self-sufficiency.

The results showed that for Scenario 1, the lowest LCOW was achieved with a configuration consisting of 20 wind turbines of the type V117 using the existing grid as backup, this setup guaranteed the project a self-sufficiency of 93%, with a remaining 9765 MWh/a drawn from the grid. For Scenario 2, in order to obtain an entirely self-sufficient production, the lowest LCOW configuration increases the number of V117 to 28 and adds a photovoltaic power plant contributing an installed power of roughly 58 $MW_p$. The chosen battery unit in this solution is based on a Lithium-ion storage with a capacity of 197 MWh. Assuming a discount rate of 12%, Scenario 1 has an LCOW of 1.78€/m³ while Scenario 2 requirement for self-sufficiency increases the LCOW to 2.57€/m³.

Energy Profiles



Scenario 1 – With grid supply



Scenario 2 – Without grid supply