Has a 100% renewable power system a lower environmental impact than one using diesel generators as backup?

AtLAST is the first ground-based telescope planned to be fueled mostly by renewable energy sources (RES). Photovoltaics (PV), batteries and a hydrogen system are to supply power for its off-grid operations in contrast to today's telescopes, mostly run on fossil fuels.

In techno-economic system sizing, we find systems with 95% RES cheaper than their 100% counterparts: Diesel backup evades PV curtailment and oversizing (Fig. 2).

By adding a Life Cycle Assessment (LCA), we aim to find a system with both low environmental impacts and costs.

Comparative **life cycle assessment** of renewable-based energy systems to power a **telescope**

What we did

We optimized power systems that could power the ~1MW$_e$ power demand of AtLAST with the GAMS-based *highRES-AtLAST* model [2]. Six scenarios with all possible combinations of PV, LFP batteries, hydrogen systems (Alkaline electrolyzer, compressed gas storage and PEM fuel cell), and diesel generators were optimized for lowest costs, see Fig. 2. Technology and cost developments assumed for 2030, potential building year of the telescope [1].

These component sizes were then included in a LCA. The functional unit was set to supply 7.7GWh$_e$ annually as per the telescope's estimated demand curve [1] over a lifetime of 25 years. See system boundary in Fig. 1. With Simapro, we calculated climate change, water use and metal resource use.

What we found

Both scenarios with PV, energy storage and diesel backup (PDB, PDBH) had lower climate change (CC) impact than the 100% RES systems with either batteries or batteries and hydrogen (PB, PBH), see Fig. 3.

- There is an optimum in CC impact below a RES share of 100%.
- Resource use of metals in 95% scenarios is also lower than in 100% ones.
- Water use of PV panel cleaning is higher than that for hydrogen system.

Outlook

We will further

1. integrate the climate change impact datasets for the individual components into *highres-AtLAST*, to create a multi-objective optimization that can minimize low CC impact next to low costs of the system;
2. broaden the investigation by including more storage options such as NMC batteries and liquid, metal hydride hydrogen storage.

Sources

[1] Viole et al. (under review): A renewable power system for an off-grid sustainable telescope fueled by solar power, batteries and green hydrogen. https://arxiv.org/abs/2212.03823

[2] https://github.com/highRES-model/highRES-AtLAST

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Fig. 1: Foreground system of the life cycle assessment, **system boundary** set as thick black line. Background system includes production of components and transport thereof to the power system.
The **50-m single dish** telescope is not part of this LCA's scope.

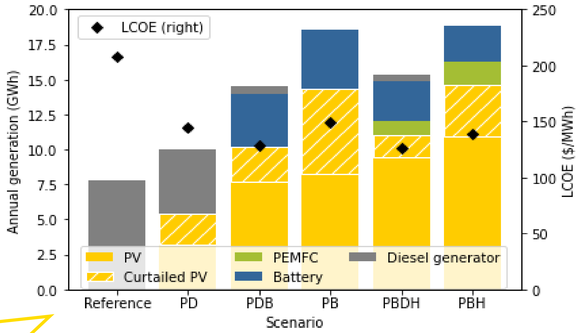

Fig. 2: Results of techno-economic optimization. **95% RES** systems (PDB, PDBH) have **lower levelized costs of electricity** (LCOE) than those with 100% RES.

Scenarios

Reference: Diesel Generators
PD: PV & Diesel
PDB: PV, Diesel, LFP Batteries
PB: PV & Batteries
PDBH: PV, Diesel, Batteries, Hydrogen Storage
PDBH: PV, Batteries, Hydrogen

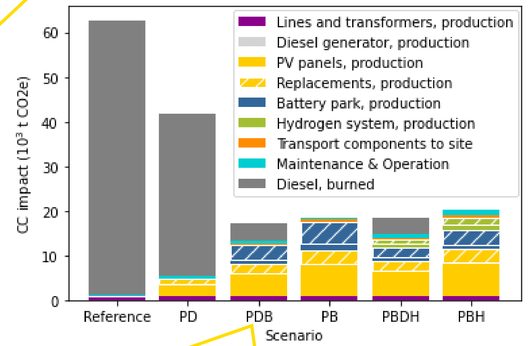

Fig. 3: Climate change impact of the six compared systems in 10^3 t CO_2 equivalents, calculated for the functional unit set as supplying the AtLAST's power demand for 25 years. Systems with **100% RES** have slightly **higher CC impact** than those employing diesel for 5% of the supply.

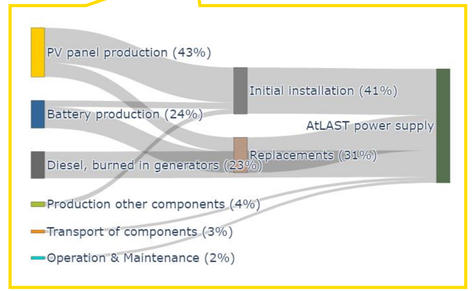

Fig. 4: In depth climate change impact of PDB (PV, Diesel & Batteries) system over lifetime of 25 years. Initial installation mostly made up by PV panel production's impact, replacements mostly impacted by LFP battery production.

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