SolarPACES 2022, 28th International Conference on Concentrating Solar Power and Chemical Energy Systems
Emerging and Disruptive Concepts
https://doi.org/10.52825/solarpaces.v1i.687

Published: 28 Mar. 2024

Evaluation of a Small-Scale CSP Plant using POLYPHEM Technology, a Solar Tower Driven Combined GT and ORC with TES

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Abstract. An innovative small-scale CSP tower plant, developed within the European research project POLYPHEM, was technically and economically evaluated and a benchmarking study was carried out including competing solutions to cover electricity demand of two remote locations with no existing access to national grid. First of all, this study shows that the POLYPHEM technology is able to deliver electricity at the target cost for this project. Regarding the cost of electricity per technology, the LCOE of POLYPHEM was higher than the PV+BESS solution, competitive with grid expansion, and significantly lower than diesel generators. Some additional relevant improvements such as the ability of delivering heat and integration of water desalination system, necessary for such a system to expand its competitiveness, were identified towards developing a roadmap to bring small-scale CSP projects to market within another study. In this study, the benchmarking is solely based on electricity production.

Keywords: Solar Tower Technology, Small-Scale CSP, Thermocline Storage, Micro-Gas Turbine, Organic Rankine Cycle

1. Introduction

Decentralized and dispatchable renewable power generation in small scale is a key solution to provide clean heat and electricity, not only but especially for remote locations with no access to wide area synchronous grids. In this domain, energy storage is essential to overcome the intermittency of renewable sources. Among renewable power generation technologies, the thermal energy storage (TES) of Concentrating Solar Power (CSP) technology is currently a feasible and cost-competitive storage solution that can ensure dispatchable delivery of power through sustainable energy resources. Moreover, unlike photovoltaic plants with a battery energy storage system (PV+BESS) or wind energy technologies, CSP can be a direct provider of industrial heat at a range of temperature levels for various applications. It can also be configured as a combined heat and power (CHP) plant and/or a multi-objective plant providing drinking water through desalination.

The POLYPHEM plant is based on Central Receiver Systems (CRS) technology. CRS has a higher optical efficiency (average >60% in small-scale systems) and a higher concentration ratio compared to line focusing collectors that are used in current operating small-scale CSP plants. Although the latter are modular and reliable, they face limitations of concentration ratio (100 suns) and average optical efficiency (<55%) compared to CRS. In addition, previous research projects by CSIRO (Australia), CENER (Spain) and CyI (Cyprus) demonstrated that reducing the size of the heliostats allows significant potential of cost reduction [1]. Therefore, a technology based on small-scale CRS technology can be a feasible solution for small loads and microgrids.

The small-scale CSP systems that are already developed and operated in demonstration plants feature an organic Rankine cycle (ORC), or less commonly a steam Rankine cycle. The integration of a solar receiver into an air Brayton thermodynamic cycle has been envisaged through research projects intended to develop the so-called “Hybrid Solar Gas-Turbine” (HSGT) technology for high efficiency CSP plants from small-scale 230 kW [SOLGATE, EU-FP5, 2001-2003] and 100 kW [SOLHYCO, EU-FP6, 2006-2010] to medium-scale 5 MW [SOLUGAS, FP7 Energy, 2010-2014]. The POLYPHEM technology makes a step forward beyond the state-of-the-art thermodynamic cycles in CSP plants, with an integrated solar combined cycle (ISCC) differing from the conventional ISCC concept and from almost all the HSGT concepts that have been studied in previous works: POLYPHEM is an innovative small-scale and fully integrated solar CSP plant in which the solar energy is integrated in the top cycle and converted at high efficiency by the cascade of two cycles. The project POLYPHEM benefits from the optimization of the combination of two cycles with high TRL each. Another advantage of POLYPHEM is precisely to bridge the two cycles (Gas Turbine (GT) and ORC) using a thermal storage with a high potential of cost reduction (HSGT + ORC + TES), as well as its dispatchability. A detailed description of the POLYPHEM plant has been already published in Ferriere et al. 2019 [2].

To determine the most effective roadmap to bring the POLYPHEM technology to market, a technical and financial benchmarking study with competing technologies to provide electric generation for various locations was conducted. This study investigates the performance of the technology and its place in the future market, identifies the most relevant improvements necessary for such a system and suggests a roadmap to bring small-scale CSP projects to the market.

2. Methodology

The benchmarking study compares POLYPHEM against competing technologies in two locations: a small town in Namibia and a remote mining area in Chile. Since POLYPHEM is aimed at providing electricity in isolated environments, the two common solutions for electricity production in microgrids, solar photovoltaics (PV) with a battery energy storage system (BESS) and diesel generators, have been considered as competing technologies. Additionally, a grid expansion was also considered. Note that the study compares market price of electricity (in case of grid expansion) to cost of electricity generation (in case of PV and POLYPHEM technologies). We assumed in this study, that the owner of the production site (PV or POLYPHEM) is the same as the consumer.

2.1. Definition of Technologies

2.1.1. HSGT plant of POLYPHEM

The reference POLYPHEM configuration considered in this study consists of a solar receiver mounted on a tower, a heliostat field, a solarized micro gas turbine, a recovery heat exchanger, an organic Rankine cycle machine, and an integrated thermal storage tank between the two cycles.

The POLYPHEM plant can operate under several different operating strategies: it can either follow a demand curve or it can operate at maximum capacity while simultaneously charging the storage. The latter will be considered for this work to evaluate POLYPHEM’s full generation potential. As seen in **Figure 1**, the micro gas turbine (μGT) operates at full load while the stratified storage is being charged. As an increasing amount of excess heat cannot be stored, this is instead delivered to the ORC. This is due to a slowly reducing temperature difference between bottom and top of the thermocline tank as it is being charged. The power generation from the daytime ramp-up of the ORC is then compounded with the µGT generation. As soon as the storage is fully charged, the ORC operates at full capacity and POLYPHEM can deliver more than 75kW of electricity.

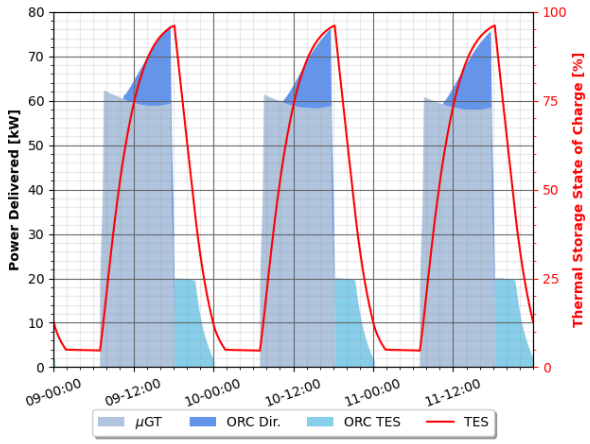

Figure 1. Summer POLYPHEM power delivery profile in Antofagasta, Chile [Nov. 9 – 11]

Techno-Economic Assumptions

According to previous studies [3], the plant lifetime is taken as 30 years and the annual operational costs (OPEX) were taken as 2% of initial installation cost (CAPEX). The remoteness of the locations when estimating maintenance cost is not considered. The production cost figures, shown in **Table 1**, were determined within the project and are assumed to be the benchmark investment cost. The production costs were converted from Euro to U.S. Dollar with an assumed conversion rate of 1.00€ = 1.10$ in order to compare against other technologies. Real interest rates assumed for this study are 2.5% for Chile and 7.5% for Namibia.

Table 1. Overview of cost based on production cost estimated in the POLYPHEM project based on information from project partners

Component	Production Cost [$]	Size - Capacity
Solar Field	96 $/m^2	1920-2100 m^2
Solar Receiver	499.4 $/kW$_{th}$	534.6 kW$_{th}$
Solar Tower	687.5 $/m	40 m
Solarized micro–Gas Turbine	1683 $/kW$_{el}$	76.5 kW$_{el}$
Heat exchanger	349.25 $/m^2	126 m^2
Organic Rankine Cycle	1980 $/kW$_{el}$	22 kW$_{el}$
Thermal Energy Storage	41.25 $/kWh	1600 kWh
Plant Controls	55 000 $	-
Balance of Plant	37 400$	-
Contingencies	10% of Hybrid Solar Cycle (Top & Bottom)	

2.1.2. PV + BESS

Photovoltaics (PV) combined with a Battery Energy Storage System (BESS) is a popular solution for remote electrification. Since PV power production is constrained by actual solar irradiation, the technology is often paired with batteries for off-hour production. Battery system technology has significantly improved in performance and environmental friendliness over the last years, transitioning from lead-acid batteries to lithium-ion storage solutions. However, the possible future impact of resource scarcities on the implementation of batteries needs to be better understood in the coming years.

Techno-Economic Assumptions

The generation of the PV+BESS per location was determined using Fraunhofer ISE's inhouse dynamic system simulation tool ColSimCSP. The PV is assumed to be fixed axis and the installed cost of the PV is assumed to be country dependent. The PV module used is a PV STP330-24 [330 W_p, monocrystalline panel] and the PV inverter used is the Renergy RS-5000 [240V]. The installed cost assumptions of the PV system in **Table 2** were revised using the unitary method. The PV maintenance costs are assumed to be 42 \$/year/kW_{AC} installed and 1955 \$/year/system [4]. The remoteness of the locations when estimating maintenance cost is not considered.

Table 2. PV installation costs [5]

Location	1.2 DC-AC Ratio	1.8 DC-AC Ratio
Chile	1047 \$/kW_{AC}	1570.5 \$/kW_{AC}
Namibia*	1148 \$/kW_{AC}	1722 \$/kW_{AC}

**Note: South Africa PV costs were assumed for Namibia.*

Table 3. BESS system installation costs [6]

Location	Battery Type	Cost Assumption	Lifetime
Chile	Lead-Acid (Flooded)	147 \$/kWh	9 yrs.
Namibia*	Lithium-Ion (LFP)	578 \$/kWh	13 yrs.

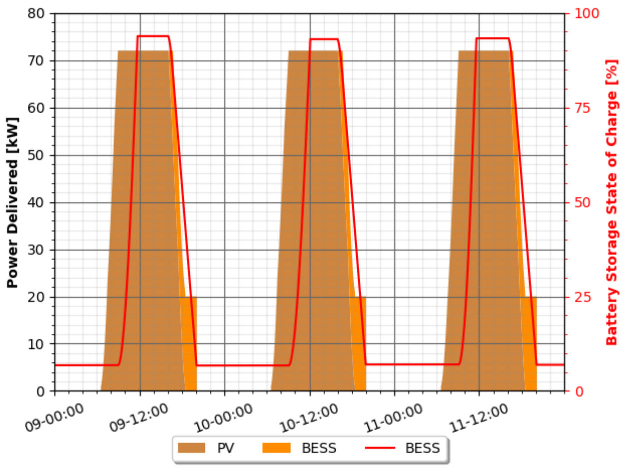

Figure 2. Summer PV+BESS generation profile in Antofagasta, Chile

As seen in **Figure 2,** during the summer months in Chile, a PV+BESS system that has a PV sizing of 132/72 $kW_{DC/AC}$ and 100 kWh of Lithium-Ion battery storage is fully charged and then fully discharges in the evening. The PV-BESS system was sized and optimized per location so that its annual yield and night-time BESS generation is equivalent to the POLYPHEM system.

Two types of commonly found batteries were considered with assumptions shown in **Table 3**. Even though the lead-acid battery is significantly cheaper, the depth of discharge and energy density of the lead-acid battery are lower than the lithium-ion battery. While battery replacement was considered, degradation of the battery was not.

In **Figure 3**, the LCOE sensitivity of the two BESS technologies are compared with an equivalent interest rate of 7.5%. The two figures illustrate that even though the Lithium-Ion BESS system is more expensive, its longer lifetime, infrequency to be replaced and higher efficiency can be more cost effective when looking at the same PV price.

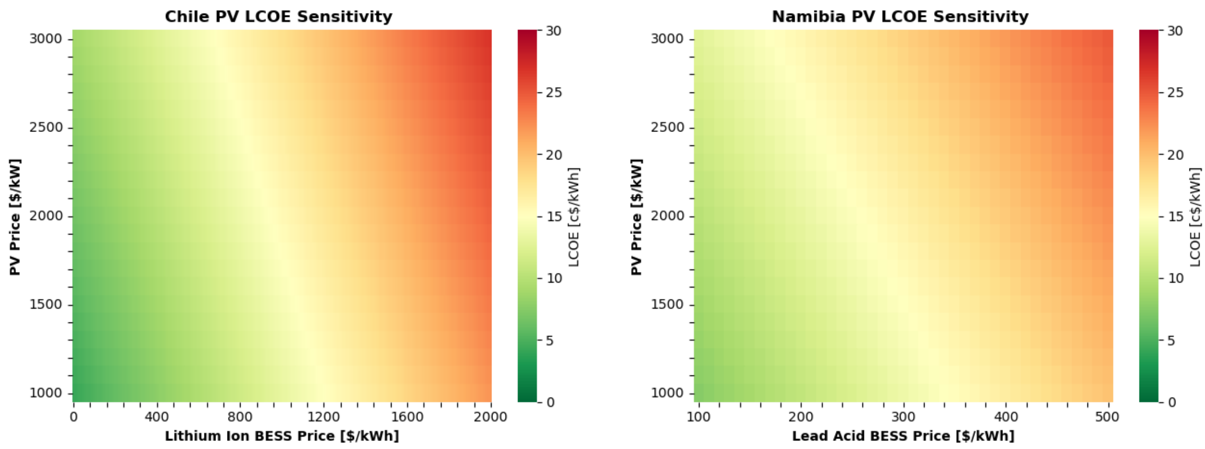

Figure 3. PV+BESS pricing sensitivity with a 7.5% interest rate

2.1.3. Diesel generator

Diesel generators are a very common form of remote electric generation with the ability to have constant power generation independent of the weather conditions. However, the system is entirely reliant on fossil fuels, which introduce many other problems. Diesel needs to be delivered regularly, its price fluctuates, and repairs can become very expensive. Most importantly, the environmental impact from diesel generators needs to be considered where large quantities of diesel are required for annual operation. Another critical factor is that in many countries fossil fuel generation is gradually being phased out, so a diesel generator should not be assumed as a long-term viable solution.

Techno-Economic Assumptions

The Generac 80 kW Diesel Generator is assumed to consume 23.8 liters per hour. The generator is assumed to cost 563 $/kW, have an operation cost of 2000 $/year, and have a lifetime of 15 000 operational hours [4]. It is assumed that 1 liter of diesel emits 2.62 kg of CO_2 [7] and that the cost of diesel varies by country. Cost of Diesel per Country are considered to be 0.65 $/l for Chile and 0.74 $/l Namibia (2016) [8].

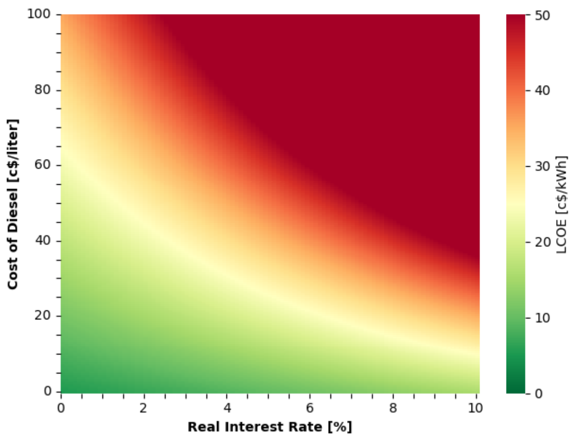

Figure **4.** LCOE sensitivity - Diesel pricing and real interest rate

As seen in

, the combination of real interest rate and the cost of diesel has a great impact on the LCOE, easiest seen by the competitive LCOE price of 25 c$/kWh (depicted as bright yellow in the color coding). If no real interest rate is assumed, then the price of diesel can be as high as 60 c$ per liter of diesel to achieve 25 c$/kWh, while a 10% real interest rate would require the diesel price to fall 87.5% to achieve the same LCOE. Additionally, only the real interest rate is considered for the LCOE while more complex diesel price behaviors such as diesel price fluctuations or inflation are not considered.

2.1.4. Grid Extension

One “simple” solution to bring electricity to an un-electrified region is to connect it to the main grid. While this approach is usually technically feasible, it is not always practical. Often, the costs outweigh the benefits to connect areas that are remote and sparsely populated. Additionally, the terrain (mountains, ocean, etc.) can make it very difficult or expensive to connect certain areas. Lastly, the main grid in many countries can be unreliable and is powered by traditional fossil fuels, so in some circumstances an extension would only cause further exasperation on the grid and increase pollution.

Techno-Economic Assumptions

The cost to extend the grid is assumed to be 15 500 $/km, maintenance cost is 310 $/year/kilometer, and that the lifetime of the system is 50 years [4]. For the locations in Chile and Namibia, the site for installment is considered to be located 30 km away from the power grid [9]. The cost of electricity per country are considered to be 16.1 c$/kWh for Chile and 12.3 c$/kWh for Namibia [10].

In **Figure 5**, the extension cost, and the extension distance are important factors when determining rural electrification. As previously seen, the economic impact of the real interest rate is a decisive factor. If a grid extension cost of 15 500 $/km is assumed with fixed grid power price of 15 c$/kWh, the 5% difference in real interest rate reduces the distance by nearly 55% for a target LCOE of 25c$/kWh, or from 35 kilometers to 20 kilometers. It continues to play a critical role but when inflation is considered and the annual price of electricity increases year by year, the lifetime cost of electricity increases approximately 50-60% according to simulations.

2.2. Techno-economic benchmarking

In a preceding study, a techno-economic optimization for POLYPHEM was performed for several locations. This optimization determined which POLYPHEM configuration (size of components etc.) would generate electricity at the lowest cost, quantified by the primary benchmarking indicator i.e. the levelized cost of electricity (LCOE). As described in the following equation (1) (source: [11]), the LCOE is calculated by the sum of the costs divided by the discounted energy production of the power plant over the lifetime.

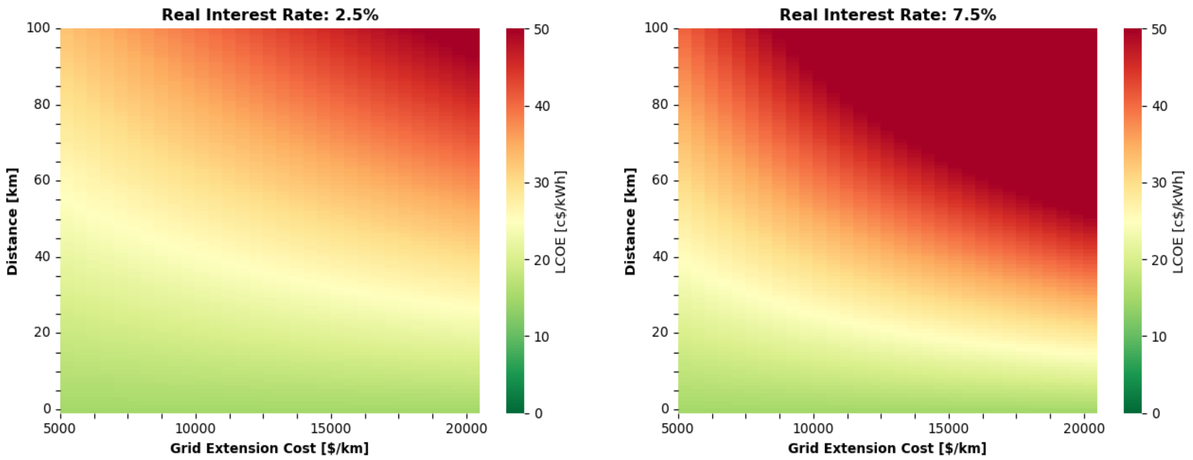

Figure 5. LCOE sensitivity – Grid extension with a grid power price of 15 c$/kWh

$$LCOE = \frac{I_0 + \sum_{t=1}^{n} \frac{A_t + F_t}{(1+i)^t}}{\sum_{t=1}^{n} \frac{M_{t,el}}{(1+i)^t}} \tag{1}$$

where I_0 corresponds to the initial capital expenditure, A_t refers to the annual operational costs, F_t refers to the annual fuel or electricity purchased in year t, $M_{t,el}$ is the electricity generated (kWh) by the plant in year t, i is the interest rate, t is the operational year, and n is the lifetime of the plant in years. Real interest rates assumed for this study are 2.5% for Chile and 7.5% for Namibia. Since economic scenarios change, different real interest rates were considered for each location to further demonstrate pricing sensitivity. As illustrated by the compared interest rates in **Figure 6**, increasing or decreasing the real interest rates can have a significant impact on the system economics. Therefore, when determining potential deployment locations for POLYPHEM, the financial environment of the location must be carefully considered. Additionally, it is assumed that these real interest rates include inflation which consequentially impact the cost of fuel and electricity.

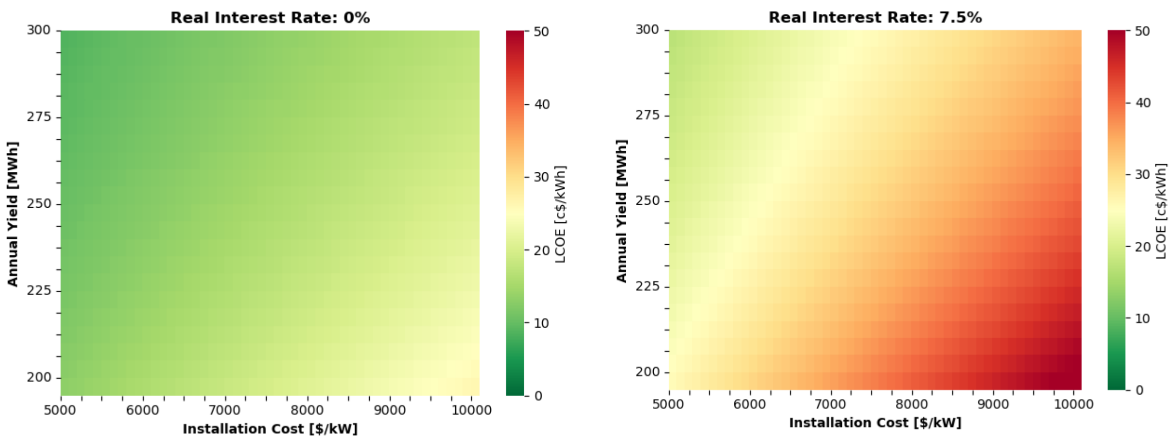

Figure 6. Effect of real interest rates on the POLYPHEM LCOE price

To compare different technologies with different production profile, the optimized total annual POLYPHEM generation for each location, as well as the same storage duration are assumed to be the requirement for other competing technologies as well and used to size the competing technologies accordingly. Furthermore, the grid connection capacity of POLYPHEM was considered for the other technologies as well.

2.3. Site Selection and Deployment

Considering the requirements for POLYPHEM to be effective and successful, potential deployment locations must meet baseline requirements. The first requirement is that a location needs to have a number of sufficiently sunny days with a high value of direct normal irradiation (DNI). The second key requirement is that the location can fully utilize the POLYPHEM technology, or in other words, be a remote area that does not have an existing grid connection.

With these requirements two potential locations have been considered for evaluation that are briefly described in **Table 4**, the regions surrounding Antofagasta in Chile and Keetmanshoop in Namibia. Each location represents a unique deployment opportunity for the POLYPHEM project. Antofagasta is a fast-growing Chilean mining city near the Atacama Desert with a very high annual DNI. Keetmanshoop is a small, rural town within Namibia. In the sections below, a short case study evaluates the potential for a POLYPHEM plant deployed in these two regions as well as how it performs against the other microgrid technologies.

Table 4. Overview of potential deployment locations

Comparison Factor	Antofagasta, Chile	Keetmanshoop, Namibia
Population (approx.)	350 000	21 000
Annual GHI [kWh/m²]	2792	2236
Annual DNI [kWh/m²]	3829	2500
Accessibility	Port Nearby, Close to Coast	Accessible by multiple highways
Quality of Power Available from Grid	Moderate to High	Insufficient

3. Case study A: Antofagasta, Chile

The optimized POLYPHEM configuration for this location produces an annual electricity yield of 270.6 MWh with an aperture area of 1920 m². To produce the same amount, a 72 kW_{AC} / 132 kW_{DC} of installed PV with a 100-kWh Li-Ion BESS system is required. As seen in **Figure 7** and **Figure 8**, the monthly generation profiles of the two technologies and the share of nighttime generation for POLYPHEM and PV+BESS of 10.2% and 10.3% respectively, are very similar thus able to cover the same demand profile and are comparable.

When costs are considered, the initial installation cost of POLYPHEM ($917 561) compared to the PV+BESS system ($228 676) is 4 times greater and the POLYPHEM lifetime operational expenses are approximately 4.2 times greater. As a result, POLYPHEM's LCOE of 22.98 c$/kWh is 3.4 times higher than the calculated LCOE of 6.79 c$/kWh of the PV+BESS system. As demonstrated in **Figure 9** and **Figure 10**, in order for the two technologies to reach a similar LCOE, the POLYPHEM would be required to reduce its installation and maintenance costs and/or increase the efficiency of the plant.

Of the technologies considered, the diesel generator is the most expensive solution due to the high cost and consumption of diesel. As seen in **Figure 11**, average cost of diesel would have to stay below 30 c$/liter for the diesel generator be more affordable than POLYPHEM. Alternatively, only in certain scenarios could a grid expansion be justified as seen from the sensitivity analysis shown in **Figure 12**. Only if the new location is less than 20 kilometers away and the grid power price is maintained below 16 c$/kWh, grid extension would be a more attractive solution.

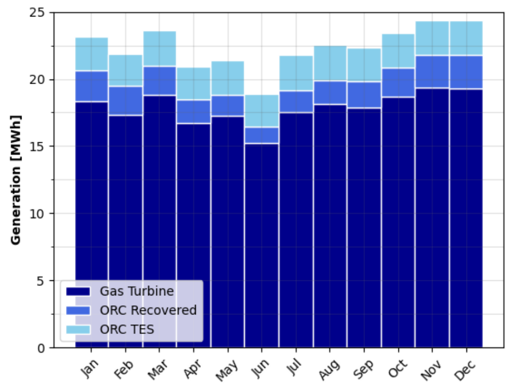

Figure 7. Chile – POLYPHEM monthly generation profile

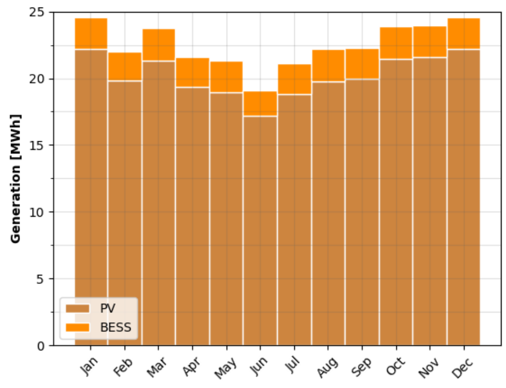

Figure 8. Chile – PV+BESS monthly generation profile

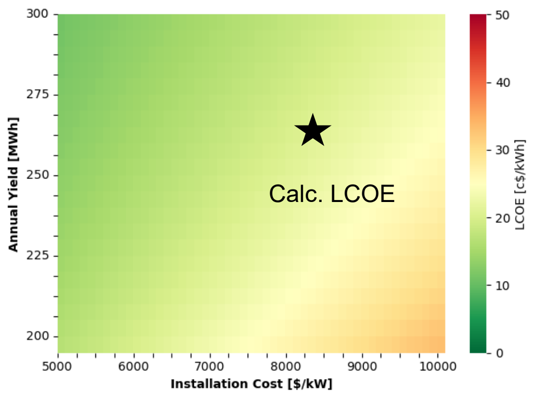

Figure 9. Chile – POLYPHEM cost sensitivity analysis

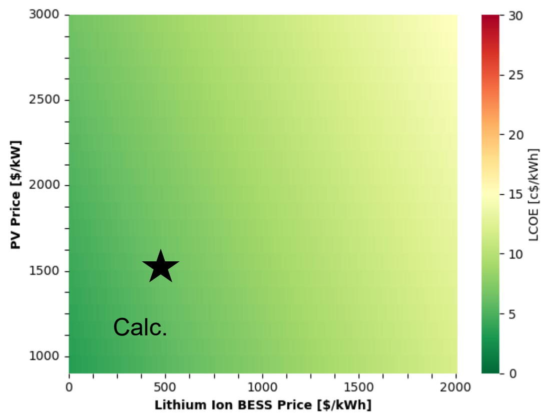

Figure 10. Chile – PV+BESS cost sensitivity analysis

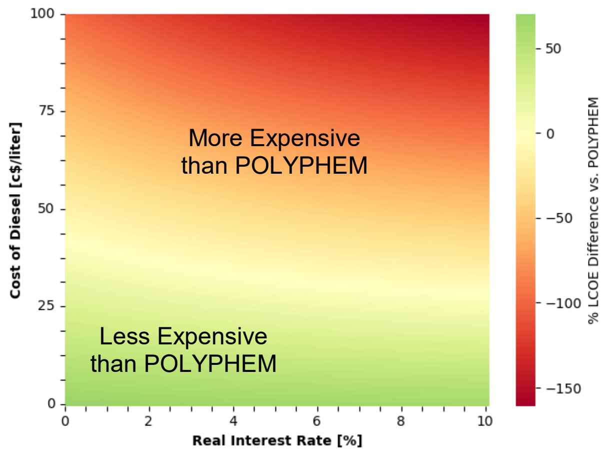

Figure 11. Chile – Diesel generator cost sensitivity analysis

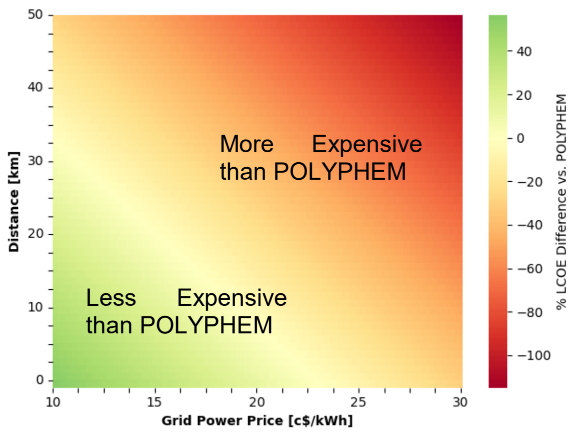

Figure 12. Chile – Grid extension cost sensitivity analysis

4. Case study B: Keetmanshoop, Namibia

When the different technologies are evaluated, a similar outcome emerges when comparing the results as in the case of the Antofagasta region. The optimized POLYPHEM configuration produces annually an electricity yield with 261.9 MWh with a slightly larger aperture area of 2100 m². To produce an equivalent amount, a 77.5 kW_{AC} / 137.5 kW_{DC} of installed PV with a 275 kWh Lead-Acid BESS system is required. Similar to Case A, the monthly generation profiles of the two technologies match to a comparable extent with the share of nighttime generation for POLYPHEM and PV+BESS of 9.6% and 10.0% respectively.

POLYPHEM's LCOE of 37.37 c$/kWh is 3.3 times greater than the calculated LCOE of 11.15 c$/kWh for PV (see **Figure 13** and **Figure 14**). The 60% increase with respect to the Antofagasta LCOE can be attributed to three reasons: a 3% decrease in annual yield, a 9% increase in solar field size, but the greatest impact was the increase of real interest rate to 7.5%. A real interest rate of 2.5% would result in an LCOE of 24.2 c$/kWh, close to the LCOE achieved for Antofagasta.

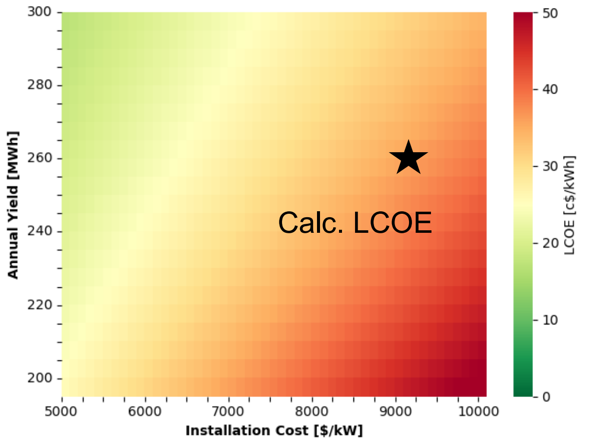

Figure 13. Namibia – POLYPHEM cost sensitivity analysis

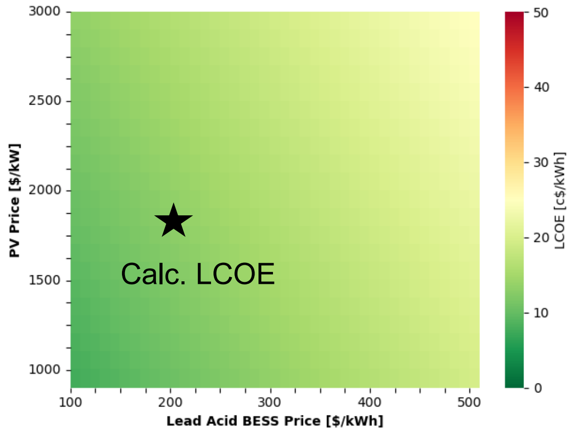

Figure 14. Namibia – PV+BESS cost sensitivity analysis

At 74 c$/liter, the cost of diesel makes the diesel generator the most expensive solution. As seen in **Figure 15**, with real interest rate maintained at 7.5%, the cost of diesel would have to fall below 40 c$/liter to be competitive with POLYPHEM while it would produce nearly 6126 tons of CO_2 emissions over the 30-year period. Even if there was an unlikely scenario where an interest rate of 0% was assumed, the cost of diesel would have to decrease by 35% to be competitive with POLYPHEM. The cost of grid expansion, however, is competitive with POLYPHEM. Assuming a grid power price of 12.3 c$/kWh, POLYPHEM would be more economically competitive if the installation was more than 40 kilometers away. In order for POLYPHEM to be competitive at a 30-kilometer distance, the Namibian power price would have to be higher than 18.8c$/kWh (see **Figure 16**). The competitiveness of the grid extension is due to two main reasons: first the relatively low cost of electricity and, second, the high interest rate of POLYPHEM. If either of these factors were to increase or decrease respectively, POLYPHEM would become the more affordable solution.

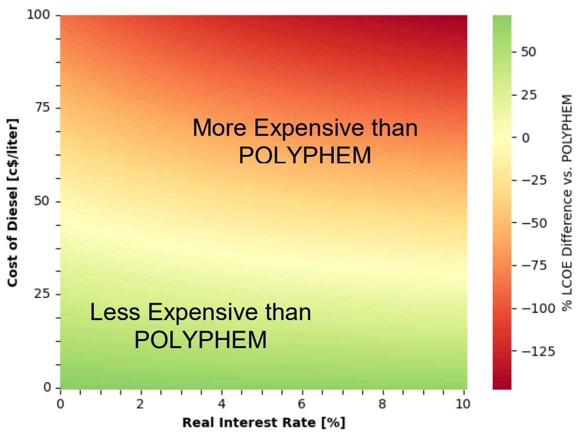

Figure 15. Namibia – Diesel generator cost sensitivity analysis

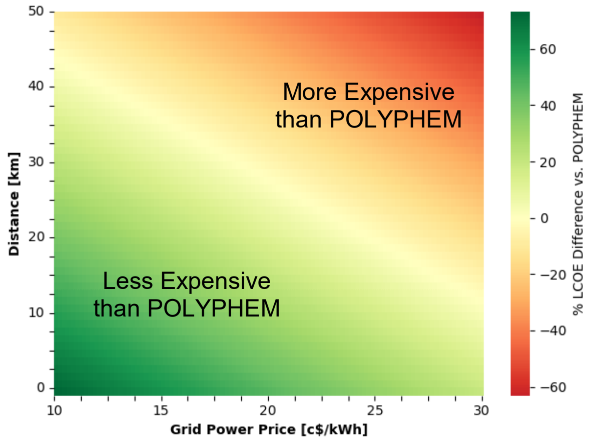

Figure 16. Namibia – Grid extension cost sensitivity analysis

5. Conclusion and Discussion

Four different solutions, POLYPHEM, PV+BESS, a diesel generator and a grid extension, were evaluated for two remote locations in Chile and Namibia. These locations, either surrounding a desert city in South America or a rural town in Southern Africa, represent unique cases where the POLYPHEM technology may be deployed. According to these results, the other three technologies were configured to best be compared with POLYPHEM. The PV systems were optimized to match both the annual generation and the nighttime generation of POLYPHEM using two different BESS technologies, lead-acid (flooded) and Lithium Ion (LFP).

This study shows that the POLYPHEM technology is able to deliver electricity at the target cost of the Polyphem research project. When comparing to other technologies, the LCOE of POLYPHEM was higher than the PV+BESS solution, competitive with grid expansion, and significantly lower than the diesel generators. As demonstrated when comparing POLYPHEM to a grid expansion in the two different locations, the interest rates assumed for the technology had a significant effect. For areas with a high interest rate and low electricity purchase price, as assumed for Namibia, the cost-competitiveness of grid expansion should be considered.

The installation cost (CAPEX) of POLYPHEM is significantly higher than the CAPEX of the other technologies, being two to four times greater than for the other technologies considered. The high installation costs can be justified when compared against the overall lifetime costs of grid expansion or a diesel generator which include the purchased electricity and fuel. However, these high capital costs further reduce POLYPHEM's financial competitiveness when high interest rates are considered.

The relatively lower LCOE of the PV+BESS technology can be largely attributed to the low CAPEX, resulting from large economy of scale with increased demand and advancements made in the technology.

These above-mentioned observations are from the specific benchmarking scenario where POLYPHEM is evaluated for solely electricity generation. In the locations where the attractiveness of POLYPHEM is not as much of PV, there are multiple aspects that can overall improve its competitiveness.

First, the configuration of the POLYPHEM system should be re-evaluated. One example is to enlarge the micro-gas turbine from 76.5 to 100 kW, an upgrade that would require minimal cost. By doing so, not only will the daytime generation increase, but the overall heat recovery potential, bottom cycle utilization, and thermal storage capacity would also increase.

Second, to repurpose the POLYPHEM bottom cycle as a combined heat and power cycle, instead of solely on electric generation. While the 4-6 % thermal to electric conversion efficiency of the ORC can be lucrative during nighttime electricity demands, selling or utilizing the heat in other areas such as industrial heat, thermal desalination, or district heating could reduce or compensate the economic benefit of a PV+BESS alternative. Alternatively, an ORC system with a higher turbine inlet temperature can significantly improve the conversion efficiency of the bottom cycle.

Last, economic realities are not fixed and can quickly change. This study did not take into account rising inflation, market volatility, and other economic factors that affect these competing technologies in different ways. One strong opportunity that POLYPHEM presents is to be a renewable technology that can be completely sourced within the E.U. and is independent of rare materials sourced otherwise. By doing so, further risks such as offshore manufacturing, international supply chain issues, and the increased demand for rare materials can be avoided, which may be faced using e.g. BESS.

Table 5. Techno-economic comparison of POLYPHEM vs. competing technologies

Comparison Factor	POLYPHEM	PV+BESS	Diesel Generator	Grid Expansion
Generation Dependency	Solar Irradiation	Solar Irradiation	Fossil Fuel	Pre-Existing Infrastructure
Sensitive to Fuel/Market Pricing	No	No	Very	Very
Lifetime	30 Years	PV: 25 yr. BESS: 9 - 13 yr.	15 000 hours	50 Years
Carbon Emissions	None	None	6000+ Tons CO_2/yr.	Grid Dependent
Environmental Impact	Low	Low	High	Moderate

It must be noted that the POLYPHEM technology aiming at small-scale energy supply at remote sites without grid connection is not comparable with large multi-MW CSP plants, which have much higher capacity factors and much lower LCOEs. Finally, **Table 5** provides an overview of additional comparison factors beyond the LCOE for the four solutions considered.

Data availability statement

Part of the data supporting the results of this article, as well as the project public reports can be accessed via the website of the project under https://www.polyphem-project.eu/.

Competing interests

The authors declare that they have no competing interests.

Author contributions

Conceptualization, S. Rohani. N. Chandler, T. Fluri; Funding acquisition, T. Fluri, P. Schöttl; Methodology, S. Rohani, N. Chandler; Project administration, S. Rohani, T. Fluri; Software, S. Rohani, N, Chandler, M. Ferreres, P. Schöttl; Supervision, S. Rohani; Visualization, N. Chandler; Writing – original draft, N. Chandler, S. Rohani; Writing – review and editing, S. Rohani, P. Schöttl.

Funding

The “Polyphem” research project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 764048.

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