Lessons Learned Report

RayGen's Solar Power Plant One

Phase 1 – Project Development to Financial Close

This Project received funding from the Australian Renewable Energy Agency (ARENA) as part of ARENA's Advancing Renewables Program.

Lessons Learnt Report: Cold storage, ice vs water

Project Name: *RayGen's Solar Power Plant – Phase One*

Knowledge Category:	Technical
Knowledge Type:	Technology
Technology Type:	Storage
State/Territory:	Victoria

Key learning

RayGen's cold storage stores thermal energy in the sensible heat of water (between two temperatures), rather than the latent heat of freezing ice. RayGen's investigations showed cold thermal storage without ice was a lower risk, lower complexity and already proven solution. RayGen's cold storage reservoir may be the largest cold storage unit ever deployed globally and relies on principles from pit thermal energy storage (PTES) of solar heat in district energy systems. Ice-based cold storage has never been deployed at this order of magnitude and presents risk. Production of ice required more electricity MWh_e per unit of cold storage MWh_{cold} than equivalent non-ice storage, but offered potential overall round trip efficiency gains. Ice had a higher volumetric efficiency for MWh_{cold} storage, but the lower electrical efficiency reduced the volumetric efficiency of electricity storage MWh_e (ice storage and non-ice storage had similar volumetric efficiency per unit MWh_e).

Implications for future projects

RayGen will implement cold storage via the sensible heat of water (difference of two temperatures) rather than the latent heat of freezing ice.

Knowledge gap

Demonstration that the large-scale cold storage PTES will perform as expected. Implementation of more sophisticated cold storage techniques, e.g.: more than two cold storage temperature bands; suppression of lower cold storage below freezing point. Integration of non-freshwater resources for charging, e.g. brackish water, seawater.

Background

Objectives or project requirements

RayGen has designed Solar Power Plant One (SPP1) for delivery in 2021. The purpose of the product development with a leading utility is for a large-scale, low cost and low risk solar-plus-storage technology for deployment in Australia and internationally.

Process undertaken

RayGen worked with NIRAS to design the thermal storage technology and GHD to validate the engineering design. RayGen visited PTES and ice-slurry suppliers for evaluation of the different approaches, and thanks all parties for their time and support.

Lessons Learnt Report: Grid connection

Project Name: *RayGen's Solar Power Plant – Phase One*

Knowledge Category:	Technical
Knowledge Type:	Network connections
Technology Type:	Storage
State/Territory:	Victoria

Key learning

RayGen was advised to develop a project below 5MVA grid connection to qualify for a standing exemption from generator registration, for a simpler and 'fast-tracked' process. We learned that the exemption was calculated based on the nameplate capacity of all power generation equipment (not the capacity of the grid connection), so we were required to downsize our system more than expected. We learned that we were subject to near identical requirements, including extensive PSSE and PSCAD modelling, as far larger projects (20x larger) in the same region.

The grid connection process has been developed by AEMO and other bodies based upon 'business as usual' principles. The connection process, and in particular the technical requirements of this process are highly refined, and as a result contain limited flexibility. This includes the application of proprietary modelling packages as a mandatory requirement for system implementation. Introduction of a non-standard solution to this process has accordingly drawn extensive technical modelling and simulation requirements, which are seemingly not applied elsewhere in the globe. As a result, Australia has a state of the art modelled grid system, but this same system imposes significant barriers to new technology entrants for grid connection. As the grid connection process is already lengthy and expensive (typically a minimum of 12mths), this further reduces Australia's ability to rapidly transition to implementation of new technologies which can offer substantial gains on traditional systems.

Implications for future projects

RayGen's technology, even at this smaller scale, has been subject to, and successfully met, the grid connection requirements of far larger projects. RayGen anticipates to connect all future projects to the transmission grid.

Knowledge gap

The grid connection process is clear at face value, but in reality the process is underpinned by a quagmire of complex interrelated technical requirements. Despite AEMO's governing ruleset, the true scope of work is largely at the will of LNSPs. This is especially true within the established low-risk sub-5MW project scale that nominally reduces project analysis overheads, where an LNSP can apply whatever rules it sees fit, including the full scope AEMO process if required. Overall the complexity and expense of the grid connection process presents a significant impediment to grid access and nullifies signals from the wholesale market.

Background

Objectives or project requirements

RayGen has been developing a new approach to solar-plus-storage that resolves many of the issues with grid connection, including: long duration storage to reduce congestion and curtailment; naturally synchronous turbines; and fast frequency response.

Process undertaken

Initially RayGen had proposed a system that would be limited in export *below 5MVA. However, we were then advised that the <5MVA process applied as a* total sum of the nameplate *(not the maximum permissible export). We then redesigned our system, lowering the system scale, to meet this condition.*
We targeted the <5MVA process as we were advised we could limit the extent of the PSSE/PSCAD modelling and progress more quickly to a grid connection permit. In the end, we were requested to complete extensive PSSE/PSCAD modelling, similar in requirement to a much larger solar farm (e.g. 100MW).
There appeared to be a very limited advantage in time or cost to the <5MVA process, which was unfortunate given to expedite completion we had configured the plant to meet this requirement.

Lessons Learnt Report: Partnership with leading utility

Project Name: *RayGen's Solar Power Plant – Phase One*

Knowledge Category:	Other (Please Specify):
Knowledge Type:	Other (please specify): Commercial
Technology Type:	Storage
State/Territory:	Victoria

Key learning

Co-develop new technologies with the likely customer and begin that dialogue as early as possible. RayGen began outreach to Australian utilities in April 2019, at a very early stage of technology development for the storage. RayGen offered to pay utilities for their participation in an 'agile' design process, and eventually partnered with a leading utility.

This relationship has added extraordinary value. RayGen has made numerous design iterations and re-prioritisations in response to the leading utility's feedback, reducing both the technology risk and the market risk as we progressed towards SPP1. RayGen was able to address key pain points for the market, rather than make uncertain assumptions for what customers might need. The relationship with the leading utility has led to an offtake for SPP1, feasibility studies for larger projects, and increased acumen on the new technology suite of storage.

Implications for future projects

The leading utility is a key partner for this project and later projects. RayGen is seeking market leading partners for expansion into other territories and will leverage experience gained in this project development.

Knowledge gap

N/A

Background

Objectives or project requirements

RayGen has designed Solar Power Plant One (SPP1) for delivery in 2021. The purpose of the product development with the leading utility is for a large-scale, low cost and low risk solar-plus-storage technology for deployment in Australia and internationally.

Process undertaken

RayGen developed a 4-6 month agile design process during the early stages of the solar-plus-storage technology development, working with engineering firm GHD and market leading utility. This process considered multiple different use-cases and configurations for SPP1, ultimately informing the go-to-market strategy for RayGen's technology, and the objectives for SPP1.

Lessons Learnt Report: Funding sources for SPP1

Project Name: *RayGen's Solar Power Plant – Phase One*

Knowledge Category:	Financial
Knowledge Type:	Financial information
Technology Type:	Storage
State/Territory:	Victoria

Key learning

RayGen's AUD 30m capital raise requirement is typically too small for traditional project finance / private equity, and outside of the traditional venture capital (VC) focus on software and biotechnology. RayGen had to go directly to the limited partners (LPs) of the VCs, the corporate strategics. These corporations are typically slower to make a decision than the VC, but offer greater strategic capability and expertise. RayGen also raised finance from individuals and family offices.

Implications for future projects

RayGen's later projects, developed with the support of corporate strategic partners, will be sufficiently large, low risk and high return to attract standard project finance.

Knowledge gap

As RayGen scales in project size, RayGen's projects will need to be progressively lower uncertainty, lower unit cost and higher internal rate of return (IRR). RayGen will deliver this with the support of current and new investors, including key strategic partners.

Background

Objectives or project requirements

RayGen is delivering Solar Power Plant One to demonstrate the full capability of our technology at relevant utility scale with investors and partners who will scale with RayGen to larger projects.

Process undertaken

RayGen began to expand our fundraising network in May 2019, before an investor roadshow through North America and Europe in early 2020. Extensive due diligence has continued throughout most of 2020 and into 2021.

Lessons Learnt Report: Integration with hydrogen electrolysis

Project Name: *RayGen's Solar Power Plant – Phase One*

Knowledge Category:	Technical
Knowledge Type:	Technology
Technology Type:	Storage
State/Territory:	Victoria

Key learning

RayGen's low cost solar-plus-storage can reduce the capex required for large-scale hydrogen electrolysis by 20-25% and re-utilise waste heat generated in the electrolysis/ammonia synthesis process. RayGen's storage can reduce the variability of electricity supplied to the hydrogen electrolysers and ammonia synthesis, improving utilisation, system efficiency and lifetime. The improved utilisation reduces the system capacity required for the same H2 production, thereby reducing the capex required. Excess low grade waste heat from the hydrogen electrolysis and ammonia synthesis can be captured and used in RayGen's storage.

Implications for future projects

RayGen is in discussions with developers of very large scale export projects, for integration of RayGen's solar-plus-storage.

Knowledge gap

Hydrogen electrolysis is at an early stage of development, with many unanswered questions regarding cost, performance, and technology.

Background

Objectives or project requirements

RayGen's mission is to accelerate the transition to renewable energy, with RayGen as the technology provider of choice. RayGen's lowest cost long duration storage is important to resolving the issues of grid renewable electricity, and important to reduce the cost of green hydrogen and ammonia for export.

Process undertaken

Pre-feasibility studies with project developers and technical partners.