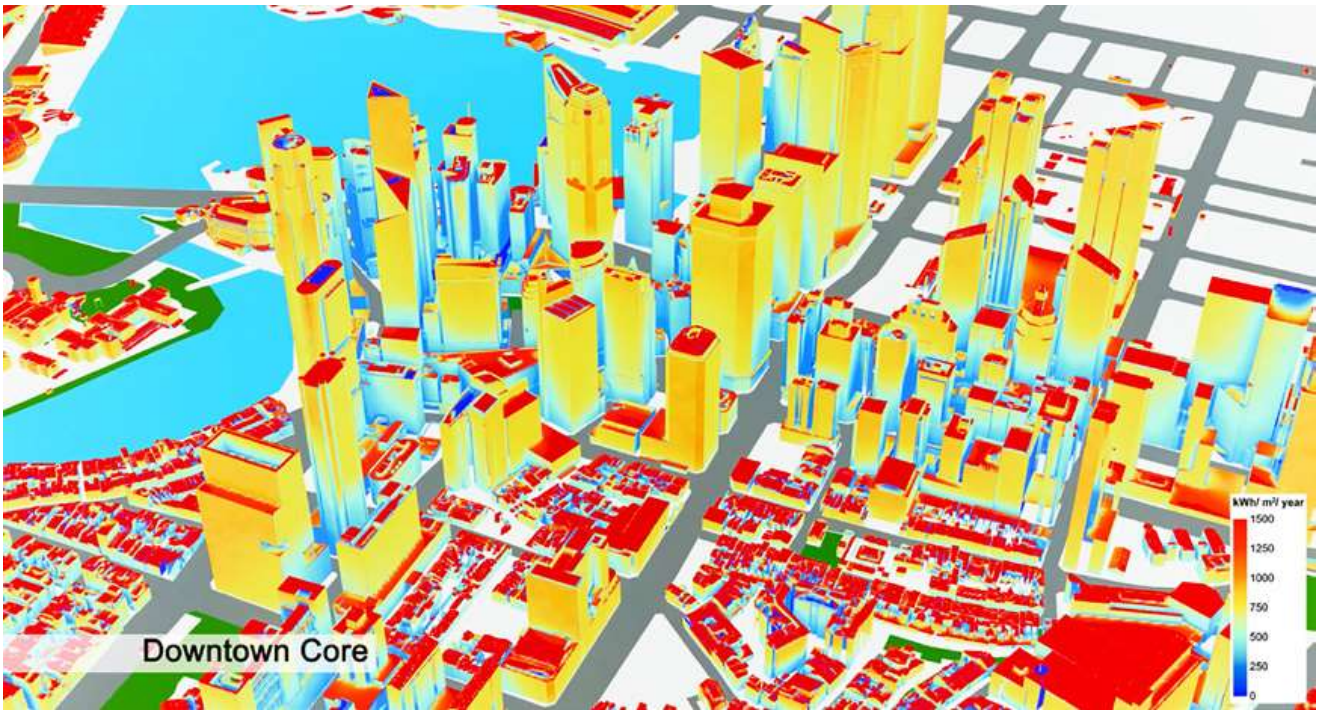
More Solar Power for Singapore

Dr Thomas REINDL



Visualisation of the annual solar energy reaching the different building surfaces in downtown Singapore (CBD, Chinatown, Boat Quay, Marine Bay areas). Red colour means highest insolation values, hence very suitable for solar PV deployment. The methodology to derive this solar potential assessment was jointly developed by SERIS, NUS SDE and the Singapore Land Authority as part of the "Update of the PV Roadmap for Singapore" project.

Singapore is determined to "go green" and add more renewable energies to its electricity generation mix. This is manifested in Singapore's submission of its enhanced Nationally Determined Contribution (NDC) and Long-Term Low-Emissions Development Strategy (LEDS) under the United Nations Framework Convention on Climate Change (UNFCCC) on 31 March 2020.

Being land constrained and "disadvantaged" in the availability of its renewable energy resources — there is insufficient constant wind around the equator for wind power, there are no major river streams or elevations for hydropower, and there is only little space for biomass — the only economically viable option for Singapore is solar energy. Apart from a few applications for using solar thermal heat, the (by far) largest potential lies in the direct conversion of solar energy into electricity using the photovoltaic (PV) effect in solar cells.

Before venturing into the large-scale deployment of solar power, the following three research questions would need to be answered:

- Where should solar panels be installed within a densely built-up city like Singapore?
- Are there any impacts on the national electric power grid from the highly variable output of solar PV systems?
- Will the cost of generating solar electricity be more compared to staying with conventional power generation?

To answer these three questions, the Solar Energy Research Institute of Singapore (SERIS) at NUS led a consortium of institutes and departments from both NUS and the Nanyang Technological University (NTU) to update the Solar PV Roadmap for Singapore. The previous roadmap which was published in 2014, was also prepared by SERIS. During the project, the team developed a unique set of capabilities using latest research approaches.

Where should solar panels be installed?

For question 1, the team designed and implemented a very detailed, yet computationally efficient assessment process of the solar potential of 132,000 individual buildings in Singapore, using a high-resolution 3D city model that was made available by the Singapore Land Authority (SLA). This included both roof-top areas as well as facades for building-integrated PV (BIPV). The team also assessed other potential deployment options, such as Floating Solar (on reservoirs and near-shore) and moveable structures (for temporary use of land or over-building existing infrastructures). Under the accelerated (ACC) scenario, Singapore could see a solar deployment of 2.5 GW_p by 2030 and 5 GW_p by 2050.

It was also highlighted in the report that Singapore should expand its research into high-efficiency solar cell technologies (both single-junction silicon solar cells and tandem solar cells) in order to maximise the limited amount of space available and increase the annual energy yield.

Impacts on the national electric power grid

For question 2, the team employed the latest power system simulation techniques to assess the impact of the variable and highly distributed generation of solar power on the Singapore grid. The possible impacts could be aggravated by the tropical weather conditions in Singapore with frequent fluctuations in cloud cover.

In close collaboration with the Power System Operations Division at the Energy Market Authority (EMA) and Singapore Power, the assessment covered four distinct areas: demand profile and ramp rate impact, distribution network impact, inertia and reserve requirements, and the protection system. The assessment found that there were no critical concerns foreseen for the national power grid until 2030. However, for 2050, there was a need to further review and ensure grid resilience, particularly for strong reductions in solar power output during extreme weather events (i.e. sudden island-wide thunderstorms).

To overcome such challenges, suitable mitigation measures such as solar forecasting, flexible conventional generation, energy storage systems and demand-side management, should be considered.

Cost of generating solar electricity

For question 3, the team developed a comprehensive set of tools, databases and forward-looking input parameters for assessing and projecting the "levelised cost of electricity" (LCOE) for solar PV in Singapore. This is important as solar power has to compete in the open electricity market with conventional power generation, and the future value of the generated solar electricity is a critical factor for the economic viability of a planned PV investment.

The outcome is a merit order list, ranking the various deployment options by their LCOE. In 2020, the lowest generation costs for PV in Singapore are calculated to be SGD 0.065/kWh for large-scale ground-mounted installations, SGD 0.076/kWh for MW-scale rooftop systems, and SGD 0.097/kWh for large-scale floating PV installations on reservoirs. By 2030, the lowest generation costs are expected to be in the range of SGD 0.042-0.056/kWh, and by 2050 in the range of SGD 0.038-0.045/kWh. This compares to recent Uniform Singapore Energy Prices (USEP), equivalent to the electricity wholesale price, in the range of SGD 0.08-0.11/kWh (prior to the extremely low oil prices of end of April 2020).

With this work, the team confirmed the feasibility of the Singapore government's target of at least 2 GW_p of solar PV by 2030, and substantiated it with technology, research and policy recommendations. The skills developed through this PV Roadmap project are readily available and can also be employed to other megacities or countries that want to assess their long-term solar energy potential and derive the necessary technical, economic and policy steps that would be required to implement the plans in a sustainable way.

The team also assessed other potential deployment options, such as Floating Solar on reservoirs and near-shore. Image shows the 1 MW_p Floating PV testbed on Tengeh Reservoir in Singapore. (Photo: SERIS)