TOWARDS AN ENERGY-AUTONOMOUS CAMPUS

"Blueprint for a distributed, renewables-based interconnected energy system"

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Background and context

South Africa's endowment with world-class solar and wind resources, combined with recent strong cost decreases for solar and wind technologies, makes renewable power generation now a cost-competitive new-build option in the country, and will be one building block in South Africa's journey towards a more diversified energy mix.

However, for the successful deployment of renewable and clean energy technologies on a large scale, significant research is required on technology level, and from an energy-system integration perspective. New cross-cutting technologies, such as energy storage, power-to-gas/-liquids, demand-side management and grid-related information technologies to manage bi-directional power flows are required to enable the stable operations of an energy system with a large share of renewables.

The CSIR Energy Centre's research will be brought to direct application on the CSIR's campuses across the country.

Renewable energy technologies is fairly new to South Africa and, although, the country has done very well in introducing the technology at utility scale, there is still very little progress in the embedded generation/small-scale domain. It is also important to note that the introduction of renewable energy generation is foreign to the South African electricity grid (at all levels), and some development work is already being done to address high- and medium- voltage networks. Of particular interest is the low-voltage network as very little progress is evident in this category. Some key questions remain in this sector, e.g. how should low-voltage networks of the future be planned to cater for embedded generation, how will the current networks respond to large volumes of embedded generation, what should be the control methodologies to be applied, what are the operation and maintenance philosophies to effectively manage this, and many more questions. A real-world energy-autonomous campus with a mix of renewable energy technologies (solar PV, wind and biomass/biogas) will assist in creating a platform to address the abovementioned questions.

Purpose of the project

The aim of the project is to create an Energy-Autonomous Campus by supplying energy from the three primary energy sources: solar, wind and biogas from biogenic waste. The power generators will be combined with electricity and heat storage, integration of electric and hydrogen-driven vehicles, power-to-liquid and power-to-gas processes, demand-side management and energy-efficiency measures. The other CSIR campuses across the country will gradually become part of the programme where, in the long-term, supply and demand will virtually be balanced across all CSIR campuses, which will form a Virtual Power Plant.

This project will stand as a real-world research platform for designing and operating a primarily renewables-based energy system at the lowest possible cost in R/kWh. This platform will be used to demonstrate in a real-world setting of significant size (> 10 MW total installed capacity) how a future energy system that is based on fluctuating and dispatchable renewables can be designed and operated in the most cost-efficient manner.

The research platform will attempt to address specific questions relating to grid-integration, optimal energy mix, energy tariff regimes, possible trading of energy between CSIR campuses and other potential customers who require green energy (using wheeling arrangements). The project will also address the demand-side component of the energy equation by identifying,

developing and implementing energy efficiency and load-management initiatives.

It will also at the same time allow technology demonstrators and technology development in different renewable energy and associated technologies, different control/management philosophies, the functioning of a smart grid and its impact on the main electrical network.

The project will be led by the Energy Centre with support from Facilities Management, and in close collaboration with other relevant CSIR research and support units. It is also envisaged that Eskom will collaborate with the CSIR with this initiative, as the utility has research questions relating to management of an electricity network/system with a significant component of renewables. Eskom will benefit greatly from the technology knowledge-base to be developed and can improve the understanding of the changing utility model where consumers can become producers of energy, i.e. the development of "prosumers".

The aim is to have a fully-functional, integrated, energy-autonomous plant by 2020 with all components at the CSIR Pretoria campus as mentioned above.

Project objectives

Development and establishment/construction of renewable energy plant(s)/

source(s) to supply the CSIR campus and to provide a platform for research regarding different technologies, management and control methodologies and its impact on the main grid.

The research questions will range from technology choices and grid integration to the changes in the regulatory framework and pricing mechanism. This will provide critical input to the energy policy direction to be decided on by the South African government.

A fully functional energy-autonomous system will be implemented on the campus by 2020, although some components thereof will be completed in phases prior to this milestone.

Measures of success are:

- A high percentage of annual energy demand on the campus is provided from renewable energy sources at low costs.
- Technology demonstrators have successfully been implemented.
- Commercialisation with involvement of South African industries has been stimulated.
- A numbers of research questions regarding distributed renewables-based energy systems are answered.

- CSIR Energy Centre has built capacity to advise the renewable energy fraternity (incl. government) regarding least-cost design and deployment of energy systems, and best practices and technology options to be considered for the future.

Business case

The business case for the project is as follows:

- To demonstrate in a real-world setting of significant size (> 10 MW total installed capacity) how a future energy system that is based on fluctuating and dispatchable renewables can be designed and operated in the most cost-efficient manner.
- This will at the same time be a commercially run and operated research platform to allow technology demonstrators and technology development on top of that platform.
- To supply the CSIR energy demand across all CSIR campuses in South Africa from renewable energy sources (wind, solar, biomass/-gas) and, by doing so, creating a Virtual Power Plant across the campuses that is built on distributed renewables, including energy efficiency, dispatchable loads, energy storage, and more early-stage developments, such as power-to-gas and power-to-liquids.
- In order to cater for an increasing share of renewables in the energy supply system of the future, a platform needs to be created to allow for/facilitate the evaluation of the real-world impact of renewable energy technologies on the main grid (Eskom and/or the municipality). This ranges from questions relating to the optimal mix of renewables to the behaviour of the grid as a result of the implementation of renewable energy. This real-world platform can be used for a number of future, yet-to-be-identified studies by industry (suppliers of technology, project developers, funders, etc.), academia and government, as it will be a unique facility on the continent. This will place the CSIR Energy Centre in the advantageous position of providing a platform for numerous studies, earning revenue either through research to be conducted on behalf of the industry, or sharing/leasing a portion of the platform for the introduction of supplier-specific technology to be evaluated.
- Funding for the Energy-Autonomous Campus programme will be secured by the CSIR Energy Centre.
- All assets of the Energy-Autonomous Campus programme will be in the asset base of the Energy Centre for the duration of the implementation of the programme.
- Once the entire programme is finalized, the assets in their entirety can be moved into a separate CSIR department/unit that is solely responsible for operating the CSIR energy system (CSIR's own energy-utility function).
- The energy generated from the renewable plants will be fed into the CSIR campus electrical grid, which is managed by the Facilities Management (FM). FM therefore receives electricity from the City of Tshwane (CoT) and from the Energy Centre (EC). Regardless of what the underlying cost of power generation is (which is a function of the technology deployed), the Energy Centre will charge Facilities Management an energy charge below that of the City of Tshwane's energy charge applicable at the time. The Energy Centre will pay rent to Facilities Management for the use of land and roof space and will, furthermore, pay a fee for the operations and maintenance of the assets.

Scope definition

The aim is to supply energy to the CSIR campus from the following three primary energy sources; i.e. solar, wind and biogas over the 5- to 8-year horizon. This project will also integrate electric vehicles, demand-side management and energy-efficiency measures to ensure a balanced approach. A "state-of-the-art" control/management system will be employed to ensure optimal dispatch of the appropriate resource (supply- and/or demand-side) and that all the different actual operation modes are properly recorded for analysis.

The project will exclude any fossil-fueled generation options.

Deliverables

The main objective of the programme is to design, build and operate a CSIR energy utility that will be capable of securely supplying the campus' energy needs from renewable energy sources at competitive cost. This objective entails:

- Install approximately 8 MW of PV on all rooftops of the CSIR buildings at the Pretoria campus and another few 100kW on rooftops at other CSIR sites across South Africa.
- Install approximately 3MW of wind turbines on the CSIR Pretoria campus.
- Install approximately 5MWel of biogas-fired gas engines, where biogas is produced through anaerobic digestion from municipal waste; the biogas will be stored onsite for the gas engines to be able to provide the flexibility that is required to balance wind/PV supply.
- Conduct an energy efficiency audit across all CSIR facilities (current demand: 30 GWh of electricity per year) and implement energy efficiency measures.
- Identify dispatchable/non-essential loads that can be utilised as a demand-side part of the system operations.
- Model and simulate the entire CSIR Virtual Power Plant across all campuses to optimise mix of renewables and dispatch regimes.
- Identify need for energy storage in the form of batteries and heat storage and implement technologies.

- Operate the system as a commercially run Virtual Power Plant.
- Use the operational system as a platform to demonstrate technologies that are further away from commercialisation (e.g. large-scale electrolyses, subsequent power-to-gas and power-to-liquids processes).
- Connect electricity and transport sector by integrating electric vehicles into the CSIR car fleet and by establishing a hydrogen fuel station on campus for later integration of hydrogen-driven vehicles; in the long-term, establish a fuel station with carbon-neutral, own-produced synthetic diesel and petrol to supply to conventional CSIR car fleet (CO_2 + electricity from renewables + H_2O --> carbon-neutral synthetic fuels).
- The end-result will be an energy-autonomous campus supplied by renewable energy and integrated with the electricity grid of the municipality and/or Eskom. This will result in reduced energy consumption from the grid (materializing in significant savings) and could potentially facilitate feeding (and selling) excess energy into the grid and provide a real-world platform for research initiatives.

Assumptions, constraints, dependencies and success criteria

The following assumptions are made:

- Funding will be available for the entire project.
- Provision will be made for escalation of unforeseen costs.
- The CSIR strategy includes active participation in the renewable energy sphere.
- Acquisition of suitably qualified human personnel.
- Suitable service providers will be contracted to deliver on the different components of the project.
- Support from the CSIR units identified to assist with the project (i.e. Facilities, Management Services and Procurement).

Risks

A separate risk management plan for the programme will be developed and approved by the Programme Steering Committee (PSC). It may entail, but is not limited to, the following:

- Programme funding is not approved, or reduced, resulting in a change of scope.
- Delays in execution as a result of external factors (e.g. permitting).
- No successful bidders for the different components of the project.
- Inability to find suitably qualified personnel to ensure proper execution of the project.
- Lack of necessary skills and resources to provide the necessary support from other CSIR departments (e.g. Facilities, Management Services and Procurement).
- Lack of, or reduced support from, external partners.
- Health and Safety risk during construction and operations.
- Human resources (loss of resources and how continuity is managed, human capital development).
- Unknown.

Conclusion

As stated in the beginning, some key questions remain in this sector, such as how should low-voltage networks of the future be planned to cater for embedded generation, how will the current networks respond to large volumes of embedded generation, what should be the control methodologies to be applied, what are the operation and maintenance philosophies required to effectively manage this, and many more.

It is hoped that a real-world energy-autonomous campus with a mix of renewable energy technologies (solar PV, wind and biomass/biogas) will assist in creating a platform to address the abovementioned questions.