<u>Future City Design under extreme weather conditions</u>

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Introduction

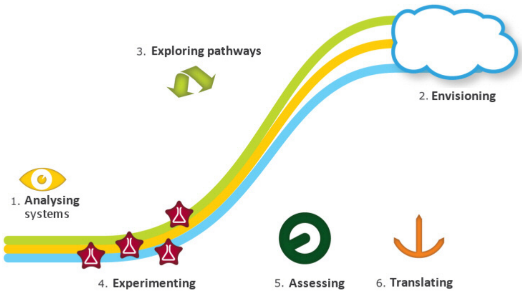
Extreme climatic conditions resulting in heavy winters and hot summers are becoming more prominent due to climate change and global warming [reference]. Cities pressured by these extreme weather conditions are increasingly constrained in meeting their energy demands and form a challenging environment to create a sustainable city in all sectors.

Objective

To create a *sustainable* and *resilient* future energy system of a city bound by extreme climatological conditions, exploiting as much as possible the locally available (renewable) energy resources and the local environmental features.

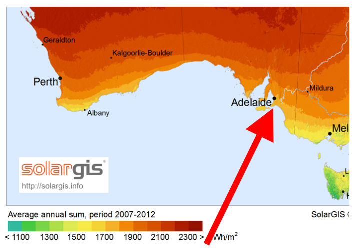
Methodology

Transition theory is employed, as illustrated in the figure right. A future city design is envisioned based on the current status of the considered city. Back casting is then utilized to transition the current city structure to the future city design through retrofitting



City Profiles

Two cities are the scope of the study: Adelaide, South Australia and Hirosaki, Japan. The choice of cities is motivated by *climate*, *available resources* and *potential of improvement*. The characteristics and motivation of each city are given in the table below.

City	*Adelaide*	*Hirosaki*
Average yearly solar irradiation		
Max avg Temp. Min avg Temp.	29-30 degrees 7-8 degrees	15 degrees 5 degrees
RES	Solar – Wind - Biomass	Wind – Geothermal - Biomass
Population	1,203,200	183,473
Climate	Hot Mediterranean climate - mild winters with moderate rainfall and hot, dry summers	Mild humid summer and cold winters with heavy snowfall
Characteristics	- summer heat waves: >10 consecutive days >35 degrees - water usage restrictions - low household insulation standard - Stand-alone 1 floor houses – spread out living - car culture – barely public transport - peak cooling demand - Only major city in the state - 75% of population - access to the sea	- heavy accumulated snowfall winter: 2.4 m - low household insulation standard - compact residential living - peak heating demand - second biggest city in the region - land locked

Future city design

Although climatologically different, the basic future structure of both cities can be set up similarly. The urban areas will be designed based on a meshed network divided into zones of an equivalent of 50 to 250 households as seen on the figure below. The electrical network will follow the boundaries of the mesh and feeds to all residences in the urban area. Central generation plants can be installed outside the city centers feeding into the meshed network. A districting heating or cooling network will be installed following the streets. For Hirosaki this hot water distribution network can double for road heating and snow smelting during winter.

The district thermal network can be fed in from several sides, both centrally through waste heat of central generation plants as well as distributed through local waste heat generation. Each zone will be operated by the distribution system operator as a smart energy grid employing centrally controlled demand side to shave peak load and control household appliances. The buildings and households will be insulated appropriately to reduce end consumer demand further. Each zone will have a small scale CHP unit installed ranging from 100 kW to 500 kW, which feeds its electricity to the households in the zone as well as to the central meshed network. The waste heat will used to feed into the district heating system or in the district cooling system using small scale absorption chillers. Additionally ground heat and cooling pumps are installed in each household in the respective cities. The small commercial consumers will be integrated into the system similarly to the residential consumers. Large commercial and industrial consumers will have onsite CHP or CHPC generation both electricity and heat or cooling can be used locally as well as fed into the central system.The transportation sector will be transformed changing to hybrid electric vehicles as well as battery electric vehicles. The batteries of cars can be charged using excess electricity generation at night by CHP units, central generation as well as rooftop PV where applicable. A public transport scheme will be put into place using hydrogen fuelled busses. The hydrogen is generated in a hydrolysis plant outside of the city fuelled by excess generation at night.

Adelaide	Hirosaki
- smart energy grid meshed network with demand side management - house insulation - small scale CHP with absorption chillers CHPC in each zone - district cooling system - CHPC for industrial players and hospitals connected to the network - roof top PV and solar hot water exploiting large surface areas - waste incineration and biomass for cogeneration of heat to cooling an electricity -installation of large scale solar desalination plant and rain water storage tanks in each building to elevate water restrictions - hydrolysis plant for hydrogen generation - installation of central wind farm park outside city to feed in on central network	- smart energy grid meshed network with demand side management - house insulation - small scale CHP in each zone - district heating system also for road heating - CHP for industrial players and hospitals connected to the network - low exergy heat source through geothermal generation outside city center to feed in on district heating network - waste incineration and biomass for cogeneration of heat to cooling an electricity - installation of central wind farm park outside city to feed in on central network - hydrolysis plant for hydrogen generation

Transition pathway

The current situation of both cities is analysed and their future design is envisioned. Now the transition pathways and timeline to achieve the change have to be checked. The proposed pathway is to make distribution and transmission system operators in each city area key for the implementation and roll out of the smart energy network since they will provide the energy as well as own the local CHP generation units. The district thermal systems together with the electricity network will be owned and operated by them. The local government will be supporting the roll out through incentives under the form of tax reductions, subsidies for building insulation and local generation and feed-in tariffs for consumers as well as subsidies to roll out the smart network to the DSO and TSOs.

Conclusion

The cities considered are constraint in terms of their future design through climatic extremities. Nevertheless, a general meshed zone approach can be used to create a future smart and resilient network with different resources using transition theory. In terms of sustainability, the future city designs increase efficient use of locally available energy resources such as wind and geothermal as well as cogeneration. The energy demand is decreased through building insulation and smart network demand side management. In terms of resilience, the meshed network structure with multiple sources provides flexibility and smart usage of the generation sources.

References

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