Synergy Grids

A. Smart Grids and Synergy Grids

This short paper is intended to provide a rationale and starting point for an exploration of a concept we call Synergy Grids. This concept is based on an extension of a relatively well-known concept called Smart Grids, which is currently the focus of much intensive study in many countries. In order to understand our idea of Synergy Grids, we must first review the major ideas and features behind the Smart Grid concept.

B. Smart grids

A Smart Grid is an electric power network that links generators and users of electric power in a new way, by adding intelligent electronic controls and software to the system.

The smart grid can collect the optimal amount of information necessary for customers, distributors and generators to change their human and equipment behavior in a way that reduces system demands and costs, increases energy efficiency, optimally allocates and matches demand and resources to meet that demand, and increases the reliability of the grid.

The social and technical benefits of a smart grid are reduced greenhouse gas and other emissions, lower costs, increased reliability, greater security and flexibility to accommodate new energy technologies, including renewable, intermittent and distributed sources. The issue of GHG emissions is key in driving climate change, and the focus on electrical production goes to the heart of the issue, since commercial buildings in developed countries use the majority of all electrical output, and most electricity is generated in very inefficient thermal power plants.

Components of a **Smart Grid** may be defined to include:

- Electrical distribution networks;
- Energy generation sources including:
  - Traditional fossil-fuel or nuclear power generating stations;
  - Large renewable power supply sources, such as wind, solar thermal or wave power;
  - District or local renewable energy sources, including wind, solar and bio-mass combined heat and power (CHP);;
  - Small intermittent power supply sources to and from individual homes and buildings;
- Network software that optimizes power demand and supply and provides diagnosis of actual or incipient problems with the line or with equipment;
- Power use controllers that are linked to individual appliances or equipment, and that have the ability to shave peak power demands by signaling linked equipment to turn itself off for a period of time, or to reduce its power requirements;

The scale of application of most Smart Grid projects is somewhat undefined, but it appears that most project developers are looking at regional or sub-regional areas; e.g. large areas with many thousands of customers.

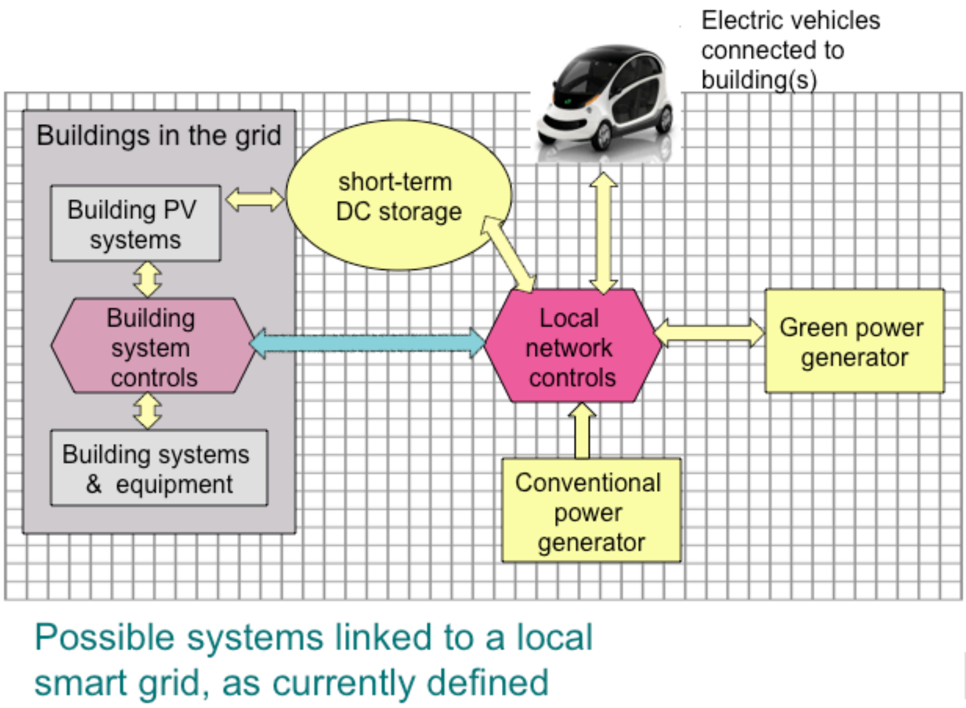

Figure 1: conceptual diagram a Smart Grid

Potential Smart Grid benefits for utilities

- Avoidance or minimisation of power blackouts or disruptions because of network resiliency (similar to internet);
- Inducing consumers to use power more efficiently with respect to sources and peak periods;
- Reduction of peak loads
- From the two factors above, reduced greenhouse gas emissions
- Stability of consumption
- Maintenance of a high level of power quality through the ability of identifying sources and characteristics of distributed power sources in the grid;
- Fraud detection and prevention

Benefits for building operators and owners

Assuming that building systems and equipment have interfaces with an external smart grid network, benefits also occur at the building level. Such gains could be:

- Real-time load and supply adjustment according to power generation situation;
- Real-time information on the source of electric power (green or conventional) that allow building operators to use sources with reduced or no GHG emissions, and also to take advantage of shifting electricity rates, optimize the scheduling and performance of building and tenant systems (including electric cars), and to optimize the way that occupants use the building.
- Performance data from the grid can also form the basis of emissions trading;

- An ability to export power that may be generated on site by, for example, PV arrays or regenerative power captured from elevator braking;
- Higher level of power quality for critical IT systems;
- Smaller sized building technical facilities that mean savings in investment and operation cost.
- Performance data from the grid on GHG reductions can also form the basis of emissions trading;
- Use of building “operation flows” such as waste water to produce energy
- Use of building functions as a variable in energy consumption, for instance anticipated or delayed cooling or ventilation
- Predictive systems can be linked to the grid
- Use of energy storage capabilities built in the building such as:
    - Building thermal inertia or thermal storage
    - Built in batteries or power storage
    - Sprinkler water tanks as thermal storage.

Broader extensions of the concept:

Malta depends entirely on foreign fuel oil for the production of its electricity and a substantial portion of the electrical output is used for the desalination of more than half of its water supply. Malta is therefore developing a smart grid to cover both electrical and water supply systems across the island. 250,000 interactive meters will monitor electricity and water usage in real time, set variable rates and reward customers who consume less energy and water.

C. Synergy grids

Smart grids R&D has been focused on the optimization of electric power. One of the fundamental aspects of the concept is the optimization of supply and demand, through control and storage systems. If we develop the Smart Grid idea at a local scale, we may be able to deal with a wider range of issues and more in depth;

There are many other neighborhood-scale systems that could benefit from optimization. This would provide an appropriate framework for developing strategies for neighborhood infill and renovation programs that must reach very high levels of performance. Such an integrated approach at a local scale might more logically be called a Synergy Grid.

Some of the neighborhood-scale (zone) systems that could benefit from optimization of supply and demand include:

- Buildings with a deficit or surplus of thermal energy;
- Buildings with a deficit or surplus of domestic hot water;
- Buildings with a deficit or surplus of grey water;
- Buildings with a deficit or surplus of DC power;
- Buildings with a deficit or surplus of parking spaces;
- Owners of private electric vehicles with a deficit or surplus of DC power;

Each of these urban sub-systems could benefit from appropriate storage systems, controls and algorithms for optimization of supply and demand, and distribution networks.

A **Synergy Grid**, as we define it, would go beyond the current definition of Smart Grids to include the following elements within a small urban neighborhood (here referred to as a Zone for convenience).

1. The Smart Grid proposals we have seen are silent on the topic of **space heating or cooling,** and the possibility of **thermal generation** in the zone (GSHP, CHP or bio-mass), as well as **thermal storage** in the zone to serve such thermal sources. This is especially logical in the context of some buildings producing a heat surplus (captured through heat-recovery ventilation systems), while others could benefit economically from zone-supplied heat.

   On the **cooling** side, some building operators may find it more economical to draw on a chilled thermal source supplied from the zone. We therefore see a need for **thermal mid-term storage** of thermal generation sources and a re-distribution system of low-temperature heating systems of buildings in the zone that have thermal deficits. As with AC and DC power, **optimization controls and software** are essential to optimize such a system.

2. Many modern buildings make provision for **rainwater capture** and grey water use, but some (e.g. highrise) have relatively minimal opportunities for rainwater capture, while low-rise buildings can produce large amounts. There is therefore logic in exploring a **zone-wide greywater and redistribution system** for all buildings in the zone. Such a system would filter and treat grey and black-water within the zone before storage. Again, optimization controls and software are essential to optimize such a system.

3. A similar case can be made for a zone-wide system for **solid waste storage and recycling** for all buildings in the zone.

4. In large zones, **a local transport system** should be considered, as has been provided in Masdar. This would be designed to operate in conjunction with central vehicle parking for all buildings in the zone, with capacity calculated and controlled according different peak time usage patterns of different occupancy types (e.g. peak use for office and retail during the day, residential at night).

5. The role of **DC power** is dealt with in some Smart Grid proposals, but usually in relation to power contributions by regional renewable energy sources and with respect to plug-in electric vehicles. The possibility of **DC power as a parallel system in a smart grid** is one that should be investigated further, in view of the possible use of DC for power storage, lighting and equipment. The usual disadvantage of DC is a high rate of power loss over distance, but that problem has been minimized in new high-voltage systems, and in any case would not apply to a local smart grid system.

   Sources of DC power include that produced from CHP, PV, wind power, bio-mass or other renewable source on site or in buildings in the zone (remember that some buildings are better oriented, or have configurations better suited for solar).). Providing this at the zone level, as well as in member buildings, would ensure diversity of supply.

6. As in Smart Grid systems, DC power should be provided for **vehicle re-charging** in the zone.

7. The **storage of DC power** would have to be an important feature of a Synergy Grid, to store power generated in the zone, and to store off-peak power from outside sources, for redistribution to other buildings in the zone with a deficit. Of course, as in Smart Grid projects, excess DC power could be converted to AC and exported back to the grid.

8. We also propose to explore the installation of **DC power systems in commercial buildings** in the zone, operating in parallel with conventional AC systems to directly provide power to low-voltage DC equipment. This reflects the greater availability of DC power sources and also the increasing prevalence of DC-powered systems in buildings, such as electronic light

ballasts and computer equipment. Such an approach would greatly reduce AC-DC conversion losses. A major Japanese company is reportedly ready to produce a parallel AC/DC distribution system for buildings. Such parallel systems would represent a major shift in systems thinking, and would also require that parallel lines of electronic equipment be developed.

All of these systems will require optimization algorithms and systems, and a new form of zone management to be successful.

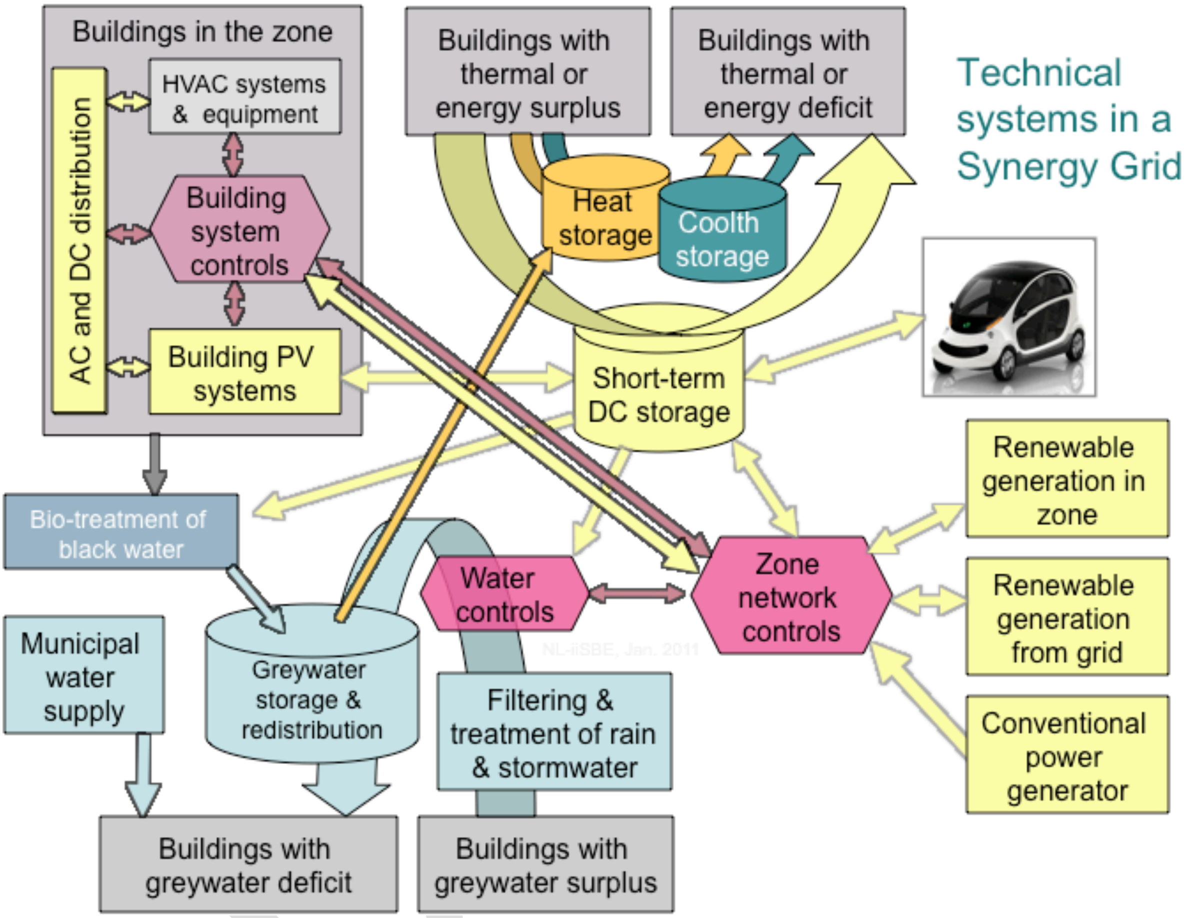

Figure 2: example of possible Synergy Grid

D. Research required

1 Costs and benefits v. scale of implementation for PV, solar thermal, thermal storage, DC storage;

2 Technical issues in parallel AC-DC distribution systems;

3 Preliminary estimates of energy, emissions, water and cost performance gains that can be made in a synergy zone relative to a building- by-building and occupancy-by-occupancy approach;

4 Developing control and allocation strategies for potable, grey, storm and black water;

5 Regulatory issues related to DC power and greywater use;

6 Issues related to management structure, occupant input needed for operations and likely occupant behaviour;

7 Operating cost and income models;

8 Identify case studies that approximate at least some of the concepts being studied, and study aspects that were successful and others that were not;

9 Special issues related to new v. existing neighborhoods;

10 Special implementation issues in existing neighborhoods – linking technical systems to existing buildings;

E. Anticipated benefits

We have already outlined the benefits that are awaited from the introduction of Smart Grids. We see Synergy Grids as adding additional energy and environmental benefits from the integration of other systems, beyond what is currently planned. Perhaps most important are gains in resiliency, efficiency and quality of service. More detailed theoretical and practical work is needed to test this hypothesis.

Nils Larsson and Frank Hovorka
iiSBE, January, 2011