Sustainable Development of a Residential Demand Response System

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The Brundtland commission defined in 1987 sustainable development as:
"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

It contains within it two key concepts: the concept of needs, in particular the essential needs of the world's poor, to which overriding priority should be given; and the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs. As a consequence, we talk about three dimensions of sustainable development: environmental sustainability, economic sustainability, and social sustainability, the "triple-bottom-line". A single-minded focus on economic sustainability can succeed in the short-run; however, in the long-run sustainability requires all three dimensions to be satisfied simultaneously. Economic sustainability has always been present when developing software systems and to some extent development of software systems has focused on social sustainability when constructing system architectures that are attractive to work with and contributes to making the everyday life for its customer easier. Environmental sustainability though has rarely been part of the vision and requirements elicitation for software systems. Climate change and the focus on reducing CO_2 emissions have changed this. The European Strategic Energy Technology Plan (SET-PLAN) states that:

"*In the longer term, new generations of technologies have to be developed through breakthroughs in research if we are to meet the greater ambition of reducing our greenhouse gas emissions by 60-80% by 2050"*

Development of smart grid systems is part of the development of the new generation of technologies required for a sustainable energy system. The European SET-PLAN sets up the goal of an expansion of the wind power capacity and introduction of commercially ready large-scale solar PV. With wind power and solar PV power we get intermittent power generation in the power grid, i.e. power generation that varies in time depending on the wind and the sun. Intermittent power generation introduces new requirements on load balancing as power production and power consumption have to be balanced in the power grid. Hydropower from the Nordic countries will most likely not be able to cover the required needs for balance power from a large scale European expansion of intermittent power generation. A complement to hydropower as balance power would be gas fueled power generation with large emissions of CO_2 or large-scale energy storage with high cost. Another more environmentally friendly and lower cost solution would be to adapt the consumption to the intermittent power production as part of demand side management. "Active House" is a building concept developed by a large collaboration of actors from the automation and power industry and research institutes in Sweden targeting sustainable development of a city's energy system. ABB is one of these actors, developing a residential demand response system interlinking the utility- and the home level. The building is called an "Active House" since it has active interaction between the home and the utility resulting in residential demand response. The active interaction aims at reducing CO_2 emissions through customer-controlled changes in power consumption pattern as a response to the availability of power produced from renewables. The triple bottom line of sustainability has constituted the guiding principle for the development of the residential demand response system: social sustainability is crucial as changing consumption patterns has to be socially acceptable; economic sustainability means that the targeted solution has to be economically attractive to the involved stakeholders; and environmental sustainability must be ensured in the way that the developed technology should result in lowered CO_2 emissions from the power consumption. As smart grids deals with system of systems, the starting point was the development of a deployment architecture where the building stones were the systems involved in the sustainable development, e.g. the utility's demand response management system and the city's sustainable development follow up system. System functionality gaps were identified that needed to be closed in order to fulfill the sustainability requirements. One example of such a gap closure is the utility's demand response system that was designed to communicate a 24h forecast of an hourly CO_2 intensity signal and an hourly price/tariff signal to the home automation system. Consumers using the forecast of the hourly CO_2 and price/tariff signal can decide the balance between economical and environmental impact by configuring the home automation system to either run loads during low CO_2 intensity hours, e.g. when large amounts of wind power are available in the grid, or in low-cost hours. To understand what system functionality in the home automation system has the highest value from the environmental sustainability perspective, an analysis was done of the CO_2 impact of the different load shift and reduction functionalities. Interesting conclusions could be drawn, e.g. for the Swedish power system shifting white goods electricity consumption has very limited impact on CO_2 emissions, as we have the highest CO_2 intensity during night due to imported power, while turning of stand-by loads at night and when leaving home has a significant impact. In this way, the team worked with the development on the system of systems level down to the development on the software level while focusing on reduced CO_2 emissions of the power consumption. The work started in the autumn 2010 and is ongoing with the first planned apartment installation in autumn 2012.

About the speaker:

Pia Stoll received her Licentiate degree from Mälardalen University, Sweden in 2009 and is currently pursuing a PhD in the field of Industrial Ecology at the Royal Institute of Technology (KTH) as an industrial PhD student. Her PhD focus is sustainable development of software systems for Smart Grids. She joined ABB Corporate Research in 2000 where she is working as principal scientist with research related to software development and software architecture for industrial software systems.

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