Energy and Utilities Infrastructure: Can All be in One?

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Abstract

In today's developed society it is fully expected that every household is provided with general utility products such as heating, lighting, water supply, communication, and waste removal. Provision of these utility products requires large and complex physical, economic and social structures that interact and are interdependent. Furthermore, we underline that each distinct utility product (communication, transportation, water, etc.) provided to our households incurs similar material and embodied energy expenses. But are such structures and their respective expenses really necessary? Or could energy (and other resources) be saved by reducing redundant utility infrastructures, while still maintaining services to the households? Conventional approaches to improved utility provision focus on better management models with optimization, enhanced handling, and increased efficiency in organisations. This paper, on the other hand, presents a novel and radical idea to address this complex problem, by moving from the management level to the scientific & technological level. The paper challenges the need for distinct utility infrastructures for household utility products provision. In particular, the paper discusses the emerging scientific and technological options for using a single energy-provision infrastructure, which would potentially deliver the full set of household utility services.

I. Introduction

In today's society it is fully expected that every household is provided with general utility products such as heating, lighting, water supply, communication, and waste removal. Provision of these utility products requires large and complex physical, economic and social structures that interact and are interdependent. For instance, in order to supply gas and electricity to households, enormous expenses are made for gas, oil and metal prospecting, metal and plastic pipe production, pipeline and electricity station building, and finally distribution network construction, upon which electricity-to-heat/light conversion devices are used in homes for heating and lighting.

Each step of the (very incomplete) process discussed above consumes energy, produces environmental pollutants, and depletes non-renewable natural resources. Furthermore, we underline that each distinct utility product (communication, transportation, water, etc.) provided to our households incurs similar material and embodied energy expenses. Figure 1 below represents the current situation of multiple infrastructure based product provision. But are such structures and their respective expenses really necessary? Could the provision of the products that we as consumers demand be provided in a radically different way through the uptake of new and emerging scientific and technological advances, removing reliance on, and the need to maintain, multiple, duplicated, wasteful, aging infrastructure systems?

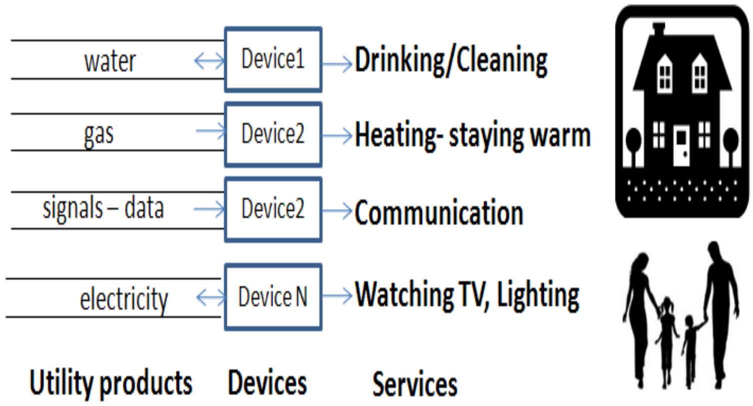

Figure 1: Current Situation

Conventional approaches to improved utility provision focus on better management models with optimization, enhanced handling, and increased efficiency in organisations. The utility companies are looking for ways to reduce the cost and improve efficiency of providing services to customers. Recent studies (Engelken et al., 1999), (Shaw et al., 2004), (Isbell and Lee, 2006) propose to achieve this by merging different aspects of companies' operations. The majority of work in the literature uses the word "merge" in terms of changing managements structures by merging utility companies (i.e., company marriage) (Engelken et al., 1999), merging information systems, (Shaw et al., 2004), or merging work groups in different utility companies into a single division (Isbell and Lee, 2006).

This paper presents a novel and radical idea to address this complex problem, by moving from the management level to the scientific & technological level. The paper challenges the need for multiple distinct utility infrastructures for household utility products provision. In particular, the paper discusses the emerging scientific and technological options for using a single energy-provision infrastructure, which would potentially deliver the full set of household utility services, as shown in Figure 2 below. This paper poses a challenge "Can a single utility product ("the one") supply all the services that the end users need and/or want?". For instance, it proposes to consider such questions as "What are the implications of using dehumidifier technology to 'transform' electricity to water?", "Can electricity be used for transportation?", "Can the end-user have devices that 'transform' electricity to water via local sewage and rainwater recycling?", "Can we use water pipes as communication medium". This perspective leads to removal of the need of high level (interim) merges. With the "all-in-one" concept there is no need to deliver multiple utility products, instead, one utility product, and associated infrastructure, is sufficient for delivery of all required domestic services.

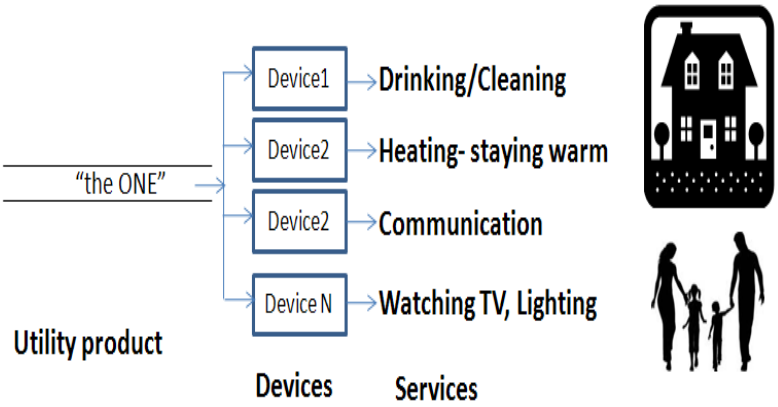

Fig 2: All in One Concept

The remainder of this paper is concerned with consideration of the current state-of-the-art and emerging scientific and technological discoveries and theories that potentially enables the vision of the all-in-one infrastructure, whereby all domestic services would be supplied via a single energy focused infrastructure. Such dramatic reduction in infrastructure provision will inevitably lead to many-fold reduction in energy consumption for building, maintenance, and resourcing of utility products and multiple infrastructure.

II. Towards the "All-in-One" Vision

Though the notion of "all-in-one" (i.e., provision of all services via a single infrastructure) is completely new, there is some evidence that while extremely adventurous, this goal could ultimately be an achievable one. This is based on the observation that some elements of provision of several services through a single utility product have already been either undertaken, or, at least, discussed in literature. Thus, for instance, the concepts of Combined Heat & Power (CHP) or Combined Cooling Heating Power (CCHP) (Wu and Wang, 2006), which are defined as the combined production of electrical and thermal energy from the same primary energy source, have existed for many years (Kavvadias et al., 2010). Below we review this evidence in more detail.

Natural Gas and Hydrogen:

Today natural gas is one of the principle sources of energy, while hydrogen is being widely discussed as a possible main future energy carrier (US DoE, 2011). Both natural gas and hydrogen can directly satisfy lighting, heating and food preparation needs. They can also provide energy for other home appliances via distributed generation (Pepermans et al., 2005), in other words, by transformation of gas into electricity via electric generation units placed with the end-user. Existing gas distribution infrastructure is already being equipped with the means for data transmission (Oommen 2010), while experimental results indicate feasibility of using the pipeline itself as a communication medium (Erickson et al., 2005). Gas can also be used to locally incinerate non-organic solid waste, while existing supply can be supplemented by biogas or hydrogen obtained locally via processing of organic waste (Cheng and Logan, 2007), (Boggs et al., 2009).

Fuel Cells:

Another promising technology is that of the fuel cells (Adachi et al., 2009) and millions have already been invested in their development (Williams et al., 2004). Furthermore, a by-product of the reaction within a fuel-cell is water which can be used for consumption and hygiene needs.

Electricity:

Electricity is a highly flexible source of energy, which can easily be transformed into other forms such as heat or mechanical energy. The infrastructure to supply electricity is relatively cheap compared to infrastructure of other utility products and is, arguably, less disruptive to the urban environment. Although, the cost of electricity per kWh is currently higher than the cost of natural gas it may change in the future when the gas reserves are exhausted and the electrical power generation becomes cheaper, for instance, due to advances in controlling and harnessing fusion. Given such virtually limitless, cheap, non-polluting electricity, the technology already exists to recycle rain and wastewater into potable water making water supply and sewer systems largely redundant, although significant quality assurance and reliability challenges exist. It can also be used to charge batteries or produce hydrogen fuel (e.g. via water electrolysis) for personal and goods transportation vehicles. Power cables can also be used for some communication needs, covering a wide range of frequencies and applications including broadband.

Water Distribution Networks:

There have been studies on harvesting power from existing water distribution networks without running volumes to waste (Guoliang and Kenichi, 2010). Even though it is possible to produce milliwatts under normal distribution conditions, more work on theory and technology is needed.

Transportation:

Transportation was the common method of distribution of utility products in the past. Even today, in some countries, trucks are used to distribute LPG tubes and drinking water as well as collection of solid waste. Presently these vehicles are fossil-fuel consumers, as present-day battery technologies are limited. However, already now the main trend in future car manufacturing is based on provision of various types of batteries. Thus, it is realistically feasible that all future transpiration will be battery-based. Moreover, such battery developments may also create the opportunity of satisfying long-term household energy demands using batteries. This may result in the need of supplying or recharging batteries by transportation.

Information and Communication Technologies:

Today, we are witnessing enhanced information and communication technologies substituting transportation needs through working from home, on-line shopping, and teleconferencing. The social media, such as Facebook, MySpace, Windows Live Space is largely substituting traditional face-to-face socialising activities. Online social care media, online health diagnostics and well-being media reduce the physical demand on social care infrastructures. Furthermore, enhanced communication initiatives, such as personal fabrication (Gershenfeld, 2005), show that data communication can provide a lot more than simply connecting people and communities. For instance, prototypes of food printers, which take raw food materials and mix/prepare and deposit these in accordance with the electronic blueprint to produce a customised menu items, with tweaked taste and texture already introduce a complete change in the way food could be prepared at homes (Periard et al., 2007). Not being limited to food printing, personal fabrication could potentially revolutionise the complete industrial production and distribution fabric of our society, making mass production industries both redundant and obsolete (Economist, 2011).

Waste:

One of the critical points in supplying all services from one utility product lies in the fact of reducing the number of utilities to be distributed by using products that already exist at the end point, such as waste (solid/liquid waste) or naturally distributed products (solar light, rain, wind, air, etc.). It is now widely recognized that `waste` materials can and should be thought as a resource. Energy harvesting using waste is valuable not only due to energy production, but also due to the waste reduction (Judd and Judd, 2006). Production of electrical energy and various types of calorific fuels such as methanol, methane and H_2 from organic liquid wastes is possible through application of anaerobic digestion processes, dark fermentation, microbial fuel cells and microbial electrolysis cells. It has been recently demonstrated that sustainable production of hydrogen, the cleanest combustible gas, is possible from any type of biodegradable organic matter (Cheng and Logan, 2007). However these technologies only currently exist as prototypes at a centralised scale, still requiring extensive waste collection infrastructure and redistribution infrastructure for the useful by-product of waste digestion / reduction.

In summary, there is a solid scientific and technological evidence of possibilities to provide *multiple services from fewer utility products* than currently supplied. However, the current state of research is far from enabling us to obtain *all services from only one utility product* and there appear to be conflicting and competing scientific and technological routes that could be followed. The All-in-One project (All-in-One, 2011) aims to explore the possibilities that will enable realisation of this single utility vision for all services provision and pose challenges to scientific and technological research and development to make this vision achievable.

III. Conclusion

Provision of utility products to end users requires large and complex physical, economic and social structures that interact and are interdependent. Conventional approaches to improved utility provision focus on better management models with optimization, enhanced handling, and increased efficiency in organisations. This paper presents a radical idea to move this problem from the management level to the scientific & technological level by challenging the need for distinct utility infrastructures for household utility products provision.

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