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Relation between Urban energy systems - analysis of smart metering district heating system of Kaposvár and sustainability

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Abstract:
Sustainability is a "wicked" subject – which most people automatically relate to energy. But it's more. Locally – here specially for the area of district heating – it has many relationships within several areas. The present thesis will shed some light how the 17 SDGs are related to a local district heating company, the local sugar factory, public transportation and the local grid. To use wood chips for a district heating system seems very common but using a waste product such as methane gas (or something close to it) and convert it into better Compressed Natural Gas (CNG) instead of creating only energy out of it, is a local novum. Sustainable urbanization is a term which is filled with meaning and some aspects of that are described within this essay.
Key Word*: energy, district heating, sustainability, smart meter infrastructure, 17 SDGs*

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I. Introduction

Energy, especially renewable energy is often seen as a synonym for sustainability. When asking average people, if (renewable) energy is related to sustainability, most probably a high percentage would say "Yes" (Gill Owen and Judith Ward). To help and support cities which plan for sustainability, companies and organizations have created a wide variety of networks and benchmark systems that collect, measure and rank sustainability in order to help cities to develop and apply practical strategies, tool and methodologies or provide a venue to share best practices and lessons learned around sustainability. One of this are Smart Meters – but that is not the only relation between district heating and sustainability, but most probably the most obvious one. According to the 17 SDGs defined by the United Nations, the subject of sustainability shows more than the obvious relations. "It's a wicked subject" (Prof. Dr. Sándor Kerekes Febr. 2020). The smart meter enables energy savings and integration of renewable energy resources and is a component on its own. If we, as a society, decide and act, the smart meter can become a sustainable, circular product that can help to build an integral and sustainable solution for the end consumer and the utility.

In addition, however, local conditions and the requirements and support from the European Union play a role that should not be underestimated. In its Autumn 2019 forecast for the global economy, the International Monetary Fund maintains its approach of classifying Poland and Hungary as emerging markets. Following approval by the European Parliament, Hungary will receive around 20.5 billion euros from the EU's structural funds in the funding period 2014 to 2020 (IHK Aachen 2020). It is precisely these funds that have a considerable local impact, which in turn contributes to the issue of sustainability. This influence is described in the present essay and attempts to calculate or prove initial effects.

II. Definitions and references

Sustainability

A brief explanation of the original meaning and definition of sustainability can be found on the Wikipedia (Wikipedia 2020a): "Sustainability is the ability to exist constantly. In the 21st century, it refers generally to the capacity for the biosphere and human civilization to coexist. It is also defined as the process of people maintaining change in a homeostasis balanced environment, in which the exploitation of resources, the direction of investments, the orientation of technological development and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations."

Important for PhD students would also be the relation towards journals: "Sustainability" — is a monthly peer-reviewed, open access, scientific journal that is published by MDPI (MDPI 2020). But this relation shall not be further described or researched for the present work.

According to the United Nations Millennium Declaration sustainable development consists of three domains: economics, environment, and social sustainability. This definition is also used by the World Commission on Environment and Development reports on the eight Millennium Development Goals and later

on the 17 Sustainable Development Goals (SDGs). More recently cultural sustainability was added to the Circles of Sustainability. James Paul specified culture as the fourth domain of sustainable development.

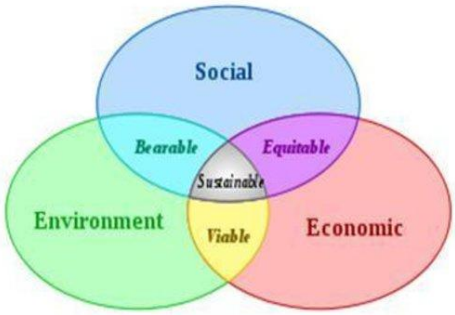

Figure 1-Three dimensions of sustainable development (Source: IUCN, 2006)

There are other definitions as well – Lucas Seghezzo for example refers to five dimensions of sustainability: "Sustainability could be better understood in terms of 'Place', 'Permanence', and 'Persons'. Place contains the three dimensions of space, Permanence is the fourth dimension of time, and the Persons category represents a fifth, human dimension. The five-dimensional sustainability framework is arguably more inclusive, plural, and useful to outline specific policies towards sustainability." Sustainability could be better understood in terms of 'Place', 'Permanence', and 'Persons'. Place contains the three dimensions of space, Permanence is the fourth dimension of time, and the Persons category represents a fifth, human dimension. The five-dimensional sustainability framework is arguably more inclusive, plural, and useful to outline specific policies towards sustainability. (Seghezzo 2009)

Within this work, the definition by the United Nations and it's 17 SDGs will be used as those are widely known and many companies and organizations already also report according to the 17 SDGs (SAP SE 2020).

Urban energy systems - analysis of smart metering district heating system of Kaposvár

Challenged by climate change and coupled with the need to secure sustainable economic growth and social cohesion, Europe must achieve a genuine energy revolution to reverse present-day unsustainable trends and live up to the ambitious policy expectations. Toward this direction, district heating (and cooling) systems need to be more efficient, intelligent and cheaper. "Contrary to electricity smart meter data analysis, little research regarding district heat (smart) meter data has been published" (Tureczek et al. 2019).

When it comes to the climate-neutral buildings in inner cities and highly densely populated conurbations, one inevitably ends up with the topic "green district heating." Heat pumps or other CO2-low individual heating solutions are already pushed to their limits. Heating networks, on the other hand, provide further possibilities, for example to use renewable heat and industrial collected waste heat from various sources and transport it to the consumer. But there are additional issues to be solved: Currently, the generation of district heating mainly consists of coal and gas. To integrate climate-friendly heat sources, the district heating network operators face a major challenge. This is because many of these "green sources" are at lower temperature levels and require a lowering of the network temperatures for an economic heat integration. This lowering cannot be done at will. It is limited by the needs of industrial consumers and the state of refurbishment of the building in the grid area. This means that the decarbonization of district heating is largely dependent on the local conditions - and each transformation path of an existing network is a very individual business.

Relation towards the 17 SDGs

As sustainability is very broadly defined, the relationship will be more specified towards the 17 Sustainable Development Goals (SDGs). In September 2015, the General Assembly adopted the 2030 Agenda for Sustainable Development that includes 17 Sustainable Development Goals (SDGs). Building on the principle of "leaving no one behind", the new Agenda emphasizes a holistic approach to achieving sustainable development for all.

Figure 2: 17 SDGs, Source: https://www.un.org/development/desa/disabilities/envision2030.html

III. SDG 7: Affordable and Clean Energy

While the term "electricity" can be found eight times within the 2019 report "Special edition: progress towards the Sustainable Development Goals" (United Nations: Economic and Social Council 2019), the term "district heating" is not mentioned at all and pure "heating" on in relation with transportation of energy. The SDG 7 defines the following targets by 2030 (United Nations 2020a):

- Ensure universal access to affordable, reliable and modern energy services
- Increase substantially the share of renewable energy in the global energy mix
- Double the global rate of improvement in energy efficiency
- Enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology
- Expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States, and land-locked developing countries, in accordance with their respective programmes of support

So, if not even Secretary-General of the United nations refers to district heating systems as part of urban energy systems and several other authors (for example Bonjour et all 2010) refer to it only as "cooking and heating" – how could that be related? Luckily newer research performed on electricity also starts to include co-generation or even pure district heating systems (for example Pamela Jagger et all 2019). One finding is: "Most existing coal power plant infrastructure could transition at a relatively low cost to burning biomass pellets. Switching from coal to biomass pellets using existing infrastructure alleviates the financial burden of financing new infrastructure projects and has gained significant attention in the USA, Europe and China. Eastern European countries maintain large production and consumption shares of forest bioenergy for district heating and cogeneration. In particular, wood chips overtook natural gas in Lithuania as primary district heating fuels in 2017" (Pamela Jagger, Robert Bailis, Ahmad Dermawan, Noah Kittner, Ryan McCord 2019)

The Kaposvár district heating company already started several years ago a new 10 MW wood chips-fired boiler. The planned and extrapolated simulation shows the following distribution of sources as soon as the wood chips-fired boiler starts operating:

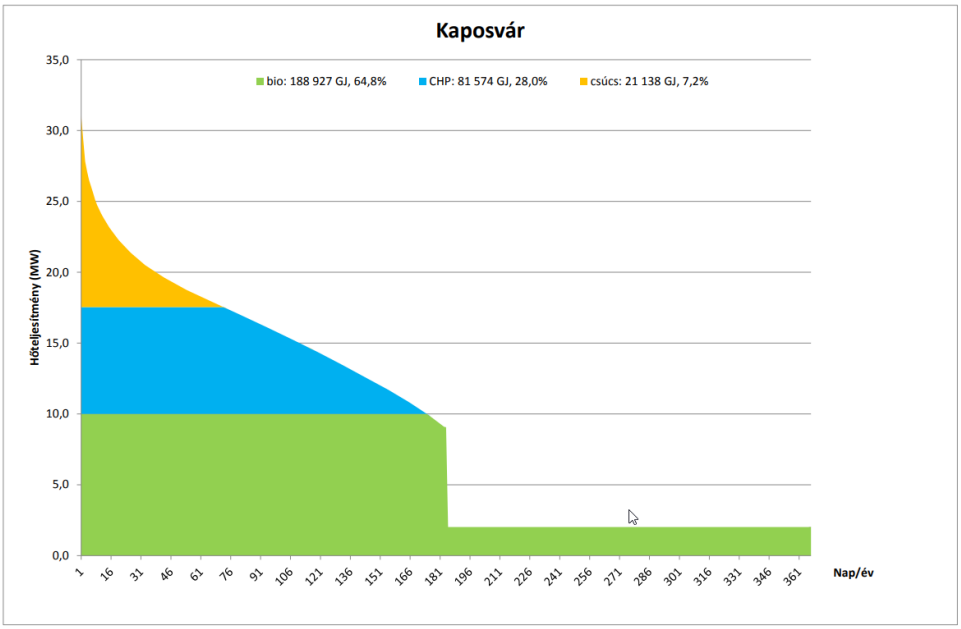

Figure 3: District heating system, Kaposvár (Source: https://ec.europa.eu/energy/sites/ener/files/documents/Art%2014_1%20ReportHungary%20annex%202en.pdf)

Within the planned detailed research, a data-driven approach shall be used to partition district heating users into separate clusters such that users in the same cluster possess similar consumption pattern. Because of the unavailability of high-resolution, hourly or sub-hourly meter data before the installation of smart meters, the literature on energy analytics in district heating is still in its infancy.

The proposed methods for this research will include the use of the K-means algorithm to segment consumption groups based on consumption intensity and representative patterns according to their consumption. Another idea is also to examine the correlation between energy intensity and the characteristics of buildings and occupants, load profiles of households and their consumption behavior change over. Calendar context has an impact not only on the patterns but also on the consumption intensity and user behaviors. District heating is robust with a delay of at least two hours. Due to climate change, the weather has become very dynamic. The forecasts, on the other hand, are quite accurate – so the research will contribute to developing a system for adapting to climate change – which closes the relation towards the SDG number 7.

IV. SDG 9: Industry, Innovation and Infrastructure

"Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation" (United Nations 2020b) – that's the subtitle on the progress and info report for the Sustainable Development Goal number 9. Within the reports for 2018 and 2019, mainly manufacturing industry is the target and the reported indicator. Within the earlier reports, 2017 and 2016, the indicator 9.1 "Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all" (United Nations 2016) finds also reference. To get the relationship towards the initial research question regarding urban energy systems, some local conditions have to be illustrated.

The Kaposvár district heating company has a local partnership with the sugar factory: the "waste product methane gas" of the sugar factory is converted into biogas, better Compressed Natural Gas (CNG), and made available to the local infrastructure. The buses of the transport company partly run with CNG, which is provided by the district heating factory. The CNG is also used to generate district heating and electricity - but is obtained from the "waste product" of the sugar factory. Local infrastructure is provided for the benefit of all and also to promote Objective 9 of the SDGs. In a broader sense - because there is a corresponding need due to the multiple use of the CNG, further funding was also provided by the European Union. Investment of HUF 5.627 billion under the project "Completion of 40 Compact Sites for CNG Buses with the Identification Number IKOP-3.2.0-15-2016-00002", co-financed by the European Union and co-financed by the European Regional Development Fund is realized. ("80 SZÁZALÉKOS KÉSZÜLTSÉGBEN A CSERI ÚTI BUSZTELEPHELY" 2020)

The sugar factory could probably also generate the CNG and produce electricity for own purpose – for environmental benefits it is more efficient to fuel busses directly with the CNG instead of converting the CNG

into electricity and use electrical busses. So locally the environmental effect seems to be related to urban energy systems. Such local effects are not fully researched so far.

Another aspect of this goal is the research to be conducted itself as well - in 2014, investments in research and development stood at 1.7 per cent of global GDP, up from 1.5 per cent in 2000 (United Nations 2016). Worldwide, there were 1,098 researchers per million inhabitants in 2014, ranging from 63 in the least developed countries to 3,500 in Europe and Northern America. Innovation and the creation of new and more sustainable industries are spurred by investments in research and development. Global expenditure on research was 2.4 per cent of GDP for developed regions, 1.2 per cent for developing regions, and below 0.3 per cent for the least developed countries and landlocked developing countries. According to the International Monetary Fund, Hungary is still seen as a developing country (Wikipedia 2020b). Investing in research and development contributes to goal number 9 of the 17 SDGs.

V. SDG 11: Sustainable Cities and Communities

Mainly two sub-goals are related to smart district heating:

- By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries
- Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning

This mainly consists of providing a framework for combating global warming worldwide with the key objective of limiting the rise in global temperature to below 2ºC. In that sense, cities will need to improve its efficiency in resource consumption and use of urban services. A smart city is an urban development vision that integrates connectivity between infrastructures, facilities and citizens by means of data-driven solutions to manage needs of urban areas. The main objective of smart cities is the use of information and communication technology (ICT) to improve quality of life of citizens and to provide real-time response to challenges (Wikipedia, S. Cities 2020). In comparison with individual systems on each building or apartment, DHC systems have several advantages that permit the creation of cost-effective solutions to develop urban areas, thus minimizing carbon emissions. A key barrier to wider deployment is poor strategic planning for heating and cooling infrastructure. In 2017, as a result of the Energy Efficiency Directive (Article 14) EU member states are required to submit national to the European Commission a comprehensive assessment of the potential for the application of high efficiency co-generation and efficient district heating and cooling.

In conurbations, heating networks have a key role to play in managing the heat turnaround, because decentralized renewable heat solutions are helping to improve technical, structural and spatial limits. District heating is not only a cost-efficient solution, but also because of the high energy density and the need to supply the portfolio infrastructure versus property solutions, advantageous.

In 2005, in Kaposvár, the integration of isolated and/or island networks into a single network was completed. The unified network is provided by the Main Needle, which is located on the site of the boiler at Béke-Füredi. A significant step forward was the extension of the network towards the city center, thus supplying heat to 5 public institutions through the district heating network. By 2019, the network was further expanded to include consumers in the southern part of the city, as well as stadium and school consumers connected to the former Gym Hall network. With that the foundation is provided to move into smart consumers and smart grids.

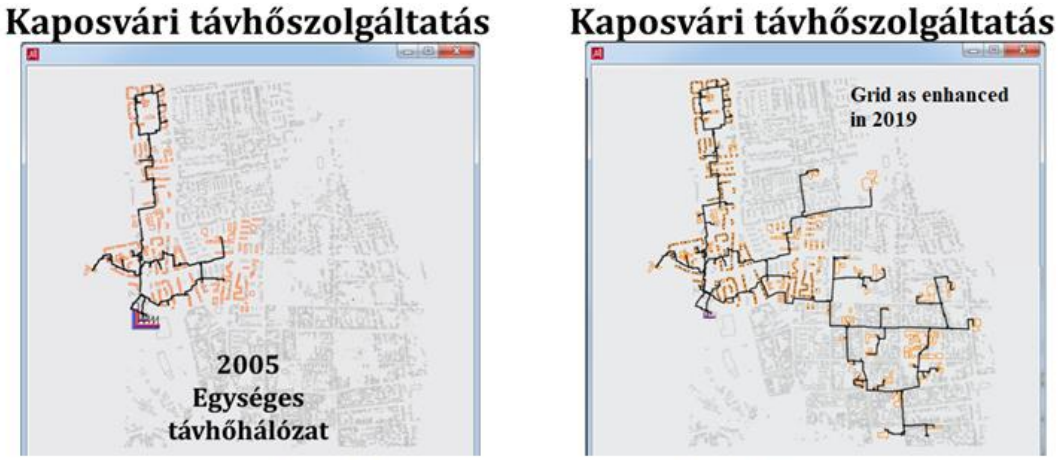

Figure 4: Grind enhancement between 2005 and 2019

"District heating systems connect energy sources and energy users. District heating can provide affordable energy to consumers by using low-cost energy sources, such as surplus heat and waste." (Gebremedhin 2012) With the expansion of the network, more inhabitants will have access to a sustainable and cost-effective heat supply. This directly correlates with the SDG 11 as shown above.

VI. SDG 12: Responsible Consumption and Production

Since sustainable consumption and production aims at "doing more and better with less," net welfare gains from economic activities can increase by reducing resource use, degradation and pollution along the whole life cycle, while increasing quality of life (United Nations 2020c). There also needs to be significant focus on operating on supply chain, involving everyone from producer to final consumer. This includes educating consumers on sustainable consumption and lifestyles, providing them with adequate information through standards and labels and engaging in sustainable public procurement. With respect to SDG 12, the International Chamber of Commerce argues that smart grids and meters, cloud computing, and reduced energy consumption of Information and communications technology (ICT) have a positive impact on reducing consumption. (Antonio García Zaballos, Enrique Iglesias, Alejandro Adamowicz) Customers often seek simple, integrated solutions which do not require them to be experts. Companies who can provide simple solutions that truly focus on customer needs by effectively leveraging their expertise across the full energy value chain will have a strong competitive advantage. While the Kaposvár district heating company has already started to use smart meters within the households, the research to be conducted will also help to get a better understanding of customers for district heating. It will allow the company to determine actual hourly consumption and use forecasts to adjust production according to expected demand. District heating, unlike electricity, does not react immediately, but with a delay of about two hours, so that the forecasting and forecasting tools have to be used differently here. The Termis software is currently being introduced with smart meters, which provides possibilities to lower or rather optimize the grids temperature. The purpose of temperature optimization is to minimize the total production and distribution costs over a certain period of time in a district heating system by means of reducing the average temperature level in the system. This also allows to meet the demand at peak periods in a more economical way while also securing defined minimum supply temperatures. The Kaposvár district heating company already aims on responsible consumption and production – while the research to be conducted will help with providing consumption patterns and analyzing the correlation between energy intensity and the characteristics of buildings.

VII. Summary and Conclusion

The use of fossil fuels has accelerated economic development. However, the consequences of this have led to serious environmental problems and calls to de-carbonize future energy use to mitigate climate change. The United Nations 17 Sustainable Development Goals set out targets for a range of targets to be achieved by 2030 to ensure peace and prosperity for people and the planet. Energy plays a critical role – probably much more than the present thesis has shown, as the planned research focuses specially on district heating as one aspect. Nevertheless, the relation between energy and the 17 SDGs is broad:

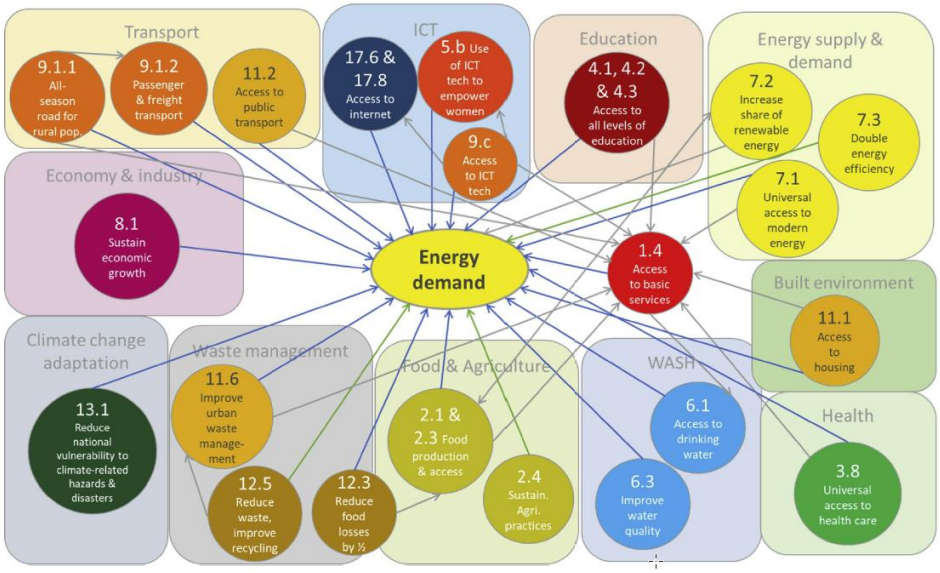

Figure 4: examples of the relationship between energy and other SDGs (Santika et al. 2019).

To evaluate every aspect and every relation would go beyond the limitations of a study. Therefore, some were picked and elaborated to show that even a rather minor and simple subject such as heating is, has a significant influence and impact of the 17 SDGs.

The planned research will consist of several parts contributing to several questions regarding the reason and the use of smart meters in a district heating system. The aim is to focus on local needs and take a scientific, methodological approach to local problem-solving. The district heating system of Kaposvár will be explored and used as example to perform an economic and (customer) service research. With the analyses and the results, the heating plant has access to more information and could easier explore strategic suggestions. This can indirectly contribute to the efficiency of district heating, the reduction of environmental load and higher consumer satisfaction.

VIII. List of Figures

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