reviewed paper

Smart Energy Supply Conception for the Urban Development Area of Aspern Seestadt (Vienna)

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1 ABSTRACT

The paper describes the Smart Energy Supply Conception for the northern part of the urban development area aspern Seestadt in Vienna. It illustrates concrete options and potentials by different scenarios for the actual implementation of a future innovative energy system. The final conception was elaborated in the framework of a research project (Transform+)[1] in cooperation with local key stakeholders and experts in the field of planning and energy research, public administration, including Vienna´s energy supply company and the responsible development agency.

With the transformation of the former airfield of Aspern, the city of Vienna aims for a new quality in urban development, providing a new urban area with major central functions which is supposed to stimulate neighbouring quarters as much as the way urban development is being done in general. One of the main priorities in this context is the strive for high quality of life for future residents, combined with the important aspect of affordability. The masterplan foresees the development of a multifunctional area with a mix of residential, office, scientific, research and educational uses. By 2030, the area of aspern Seestadt (223 ha) shall be developed for 26,000 residents and offer 23,000 jobs.

The masterplan for aspern Seestadt as well as the activities and measures set by the development agency Wien 3420 Aspern Development AG have been guided by the vision of an ecological, resource-friendly and climate neutral city from the beginning. This aim is also in accordance with the ‘Smart City Framework Strategy of Vienna’ passed in 2014[2] after the start of the implementation of aspern Seestadt (first phase).

Within the context of the project Transform+, different options for a smart energy supply have been elaborated for the second implementation phase of urban development, named aspern Seestadt North. Here, in an area designed for 7,000 new apartments and 14,000 jobs, it was the main challenge to take the step from research on innovative future energy systems to a complete roll-out in an urban area to be developed in near future. In order to estimate future energy consumption (heating, cooling, electricity) and different options of energy supply and local renewable energy production, several ‘smart city’ scenarios were elaborated and compared against a ‘business as usual’ scenario.

An important component in all ‘smart city’ scenarios is the share of renewable energy, for which a quantitative target has been defined in the Smart City Framework Strategy for the city of Vienna (50% until 2050). To contribute to Vienna´s Smart City aims, aspern Seestadt North should strive to gain a high share of its energy from locally available renewable energy sources and also offer high flexibility to make use of additional sources (e.g. from potential future waste heat) in a later phase of implementation. In addition, total energy consumption and according CO_2 emissions were critical factors for defining the final energy system configuration of the ‘smart city’ scenarios.

As result, the elaborated ‘smart city’ scenarios show considerable potential for reducing energy consumption and significantly higher shares of renewable energy use compared to the ‘business as usual’ scenario, and therefore greatly reduced overall CO_2 emissions. By implementing the ‘smart city’ scenarios, total energy consumption could be reduced by 39% against technical standards as in the ‘busines as usual’ scenario. Due to a higher use of local renewable energy supply the best ‘smart city’ scenario shows an overall CO_2 emission reduction potential of up to 75%. Through the intensive cooperation process of the research team and the key stakeholders responsible for the development of the area, the Smart Energy Supply Conception laid a solid foundation for the relization of innovative future energy systems in aspern Seestadt.

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[1] The project was funded by the Austrian Climate and Energy Fund (KLIEN) within the research program “Smart Cities – FIT for SET”. Project website: www.transform-plus.at

[2] MA18 (Department for urban planning), 2014 (https://smartcity.wien.gv.at/site/files/2014/09/SmartCityWien_FrameworkStrategy_english_doublepage.pdf)

2 URBAN DEVELOPMENT CONTEXT

Until 2030, 223 ha of land will be developed providing space to some 26,000 people plus about 23,000 workplaces. The Masterplan for aspern Seestadt foresees the development of a multifunctional district with a mix of residential, office, scientific, research and educational uses. A lake of 5 ha will be at the centre and give the new city district its characteristic name. Green – and public spaces, the proximity to the Natural re¬serve Donau-Auen and high quality urban infrastructures should guarantee high quality of life in this newly built part of Vienna.

The area of aspern Seestadt is located in the north-eastern fringe of Vienna in close proximity to two old village centres of Aspern and Eßling, with the vast factory area of Opel Austria GmbH on its southern side, and the railway Vienna-Marchegg-Bratislava enclosing the development area in the North.

Housing uses are foreseen mostly in the south- and north-eastern part of aspern Seestadt (yellow), with a projected development of 4,600 residential units south of the lake and 7,500 residential units in the northern part of the lake. Since October 2013, aspern Seestadt is connected by subway to the public transport network. Two subway stations – one in the North and one in the centre of aspern Seestadt – are connecting the new city district to the rest of Vienna. The extension of the subway line U2 prior to the settling in of the first residents was conceivesd as an engine of urban development and stimulate the use of public transport.

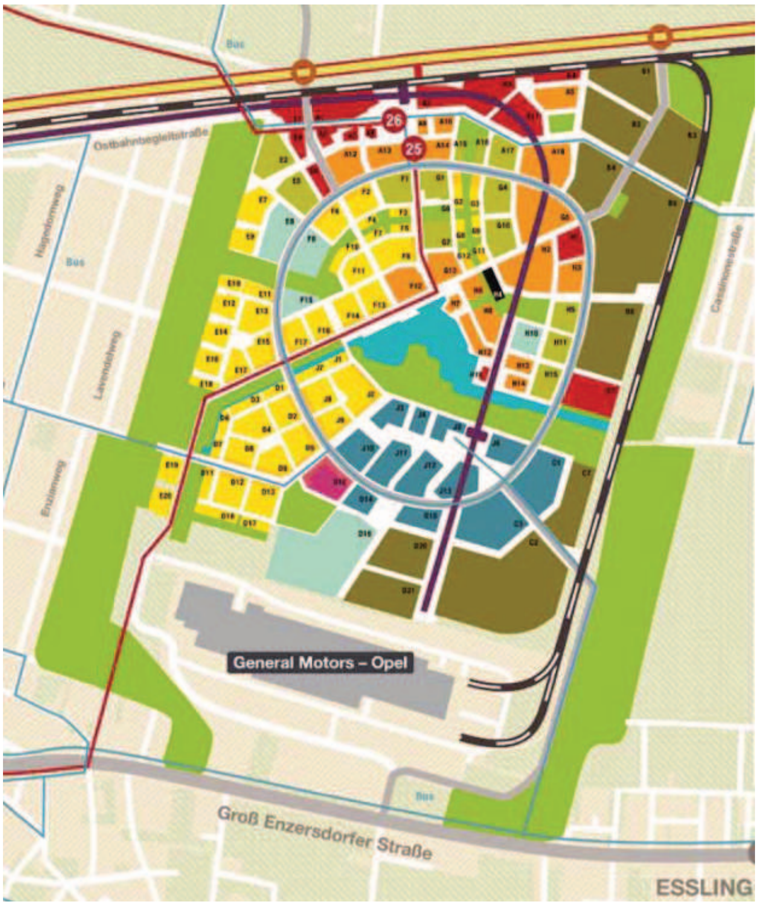

Fig. 1: Area map aspern – Donaustadt, Source: aspern+ citylab (2010): Vision + Wirklichkeit. Die Instrumente des Städtebaus. Ein citylab-Report von aspern Die Seestadt Wiens.

Within the context of the projects TRANSFORM[3] and Transform+ a new tool, named **'Implementation Plan'**, has been developed for new construction or transformation of districts into low energy districts. This tool was applied at aspern Seestadt North, to elaborate short to medium feasible possibilities for future energy systems.

[3] TRANSFORM – Transformation agenda for low carbon cities (http://urbantransform.eu/) was a European FP 7 research project in which the city of Vienna took part as a project partner together with the cities of Amsterdam, Copenhagen, Genoa, Hamburg and Lyon, together with industrial and research partners such as the ÖIR.

Although the city of Vienna has a lot of experience in the fields of urban construction and transport planning, it lacks holistic planning procedures and methods for innovative, resource-friendly energy supply and energy system planning – combining spatial planning and energy system planning. The Implementation Plan developed in the course of Transform+ triggered the development of new planning procedures and methods for aspern Seestadt North.

As an important framework condition of the planning process, the 'Smart City Framework Strategy of Vienna' (municipal council resolution 2014) has become an important new basis for a future sustainable development of Vienna from an overall perspective. This strategy constitutes the long-term objectives of Vienna concerning climate change and energy. Most important for the developmen of aspern Seestadt are the following objectives:

- overall goal: 80% reduction of CO_2 emissions per capita till 2050 (1990 reference), at least 35% till 2030
- energy efficiency to reduce energy consumption per capita by 40% in 2050 (2005 reference)
- 50% gross energy consumption coming from renewable 2050, 20% already in 2030
- 2,000 Watt steady power supply per capita, 1 ton CO_2 per capita
- zero energy standard for new buildings from 2018/2020

These quantitative targets were considered when elaborating the alternative 'smart city' scenarios for the future development of the area. Another, very important framework condition is the fact that nearly 80% of the housing development will be built under the economic and technical standards of social housing, which means – in the case of Vienna – a modern, low to middle income urban development of high building quality but with very limited construction costs.

In the project Transform+, a so called 'energy group aspern Seestadt' was formed, consisting of the Wien 3420 aspern development AG, Wien Energie (the city´s energy company), MA 18 (urban development and planning), MA 20 (energy planning), ETA environmental management GmbH, ÖIR (Austrian Institute of Regional Studies and Spatial Planning) and the AIT (Austrian Institute of Technology). The group discussed and defined the scenarios, focusing on mid-term, concrete measures for implementation, comprising the (energy) system architecture, costs and financing and calculation of emissions. Legal and organizational aspects and barriers for implementation also were discussed and recommendations for the development partners elaborated. Thus the Transform+ energy group aspern Seestadt developed scenarios as a foundation for the energy supply planning at aspern Seestadt North.

The implementation of these ideas already will start in 2016. An important actor for this implementation is "Wien 3420 Aspern Development AG" (subsequently named 'Wien 3420'), which was founded to develop and to promote aspern Seestadt as fully equipped, mixed-use urban development. The company owns the land and cooperates closely with the city administration. Acting as comprehensive developer, 'Wien 3420' draws up planning and design concepts, defines planning guidelines and offers consultancy for individual projects development, and subsequently sells off or leases property. In this comprehensive developer role, it is therefore responsible also for the realization of the Implementation Plan´s energy concept, together with the city administration and relevant energy companies.

3 DEVELOPING A SMART ENERGY SUPPLY CONCEPTION FOR ASPERN SEESTADT

At the beginning of Transform+, Wien 3420 aspern development AG faced the challenge to submit a feasible and realistic energy supply concept for the entire Seestadt North area as an input for the Environmental Impact Assessment (EIA). At the same time this concept was supposed to determine a long-term development vision, which considers adjustment possibilities to future technical solutions (already today).

For the northern part of aspern Seestadt there is currently only a master plan outlining the different building areas and the planned timeline for construction, which will start in 2016 and last until 2028. It is very likely that during this rather long period of time framework conditions, energy markets and financial constraints will change drastically. But it is hard to predict how and when. This makes it difficult to design a robust and resilient energy system for aspern Seestadt North.

However, to continue with the development process, Wien 3420 needed to apply for the environmental impact statement (EIS) already in the beginning of 2016, which will after approval, determine the baseline parameters for the energy supply for aspern Seestadt North. That means on the one hand that there is a need for an energy supply concept, which can be implemented parallel to the starting construction phase beginning in 2016. But on the other hand there is also a need for a longer term ‘smart city vision’, taking into account future obligations and opportunities.

In order to meet these challenges, the Transform+ energy group developed a foundation for this energy supply concept (business as usual, named ‘BAU’ scenario) as well as three Smart City scenarios which build on and refine the basic structural assumptions taken in the ‘BAU’ scenario.

3.1 Future energy demand levels as a basis for Smart City suppy conception

In a first step, two demand levels – named ‘BAU’ and ‘efficiency’– were developed in order to estimate the future energy demand (heating, cooling, electricity). These demand levels focused on assumptions concer¬ning the thermal quality of the building envelope, the use of hot water as well as on energy efficiency in terms of electricity use (energy efficiency of devices and user behavior).

In comparison to the demand at ‘BAU’ level, the ‘efficiency’ level set higher demands concerning the con¬sumption side, defined as a basis for the ‘Smart City’ scenarios (see following chapter) – relating to the objective of a ‘2,000 Watt society’ according to the Smart City Framework Strategy of Vienna). Regarding the future energy demand, the set ‘efficiency’ levels for the ‘Smart City’ scenarios includes a more innova¬tive and resource- efficient building development with higher standards for building envelopes (better quality of the thermal hull) and a much higher awareness in terms of energy consumption by tenants and working population (through good quality electric devices and energy saving user behavior, e.g. by lower room temperatures during the heating season, energy saving use of electricity etc.).

Thus, two consumption side based levels of energy demand formed the basis for the elaboration of alternative ‘Smart City’ energy systems for aspern Seestadt North:

- the demand level of ‘business as usual’ (BAU) includes building standards according to legal require¬ments as of 2020 (nearly zero energy buildings), in the BAU scenario this level is combined with an energy supply that meets the predefined standards by the city´s energy authority.
- the ‘efficiency’ demand level as a basis for the ‘Smart City’ scenarios assumes the construction of buildings with a higher thermal quality and a more efficient use of energy, in the Smart City Scenarios this level is combined with a more innovative heat supply concept.

The following estimations on energy demand describe the demand for the entire area of aspern Seestadt North, except the construction sites at the eastern edge, which are desigated for industrial usages (where no closer details on industrial branches and their future energy uses are available yet).

[GWh per year]	Business as usual demand level	Efficiency demand level	Potential for demand reduction
Heat demand (space heating and hot water)	91	56	-38%
Electricity demand	61	36	-41%
Total energy demand (heat and electricity)	152	92	-39%

Table 1: Estimations on energy demand for aspern Seestadt North – business as usual level versus efficiency level, Source: T+ Energy group aspern Seestadt

When comparing the ’business as usual’ with the ‘efficiency’ demand level, the potential overall energy saving (on consumption side) amounts to approximately 39%. Thus, a reduction in energy demand (without cooling) from 152 GWh/ year (’business as usual’ level) to 92 GWh/ year (‘efficiency’ level) seems possible (see table 1).

3.2 Alternative ‘Smart City’ scenarios concerning the future heat supply

As part of the Implementation Plan, different conceptions for the future heat supply at aspern Seestadt North were discussed. In general, the aspern Seestadt energy group recommended a local low-temperature grid as basic infrastructure. It allows a more flexible use of many different – and partly still unknown – local renewable energy sources and can balance energy generation and energy consumption spatially and temporally to some extent.

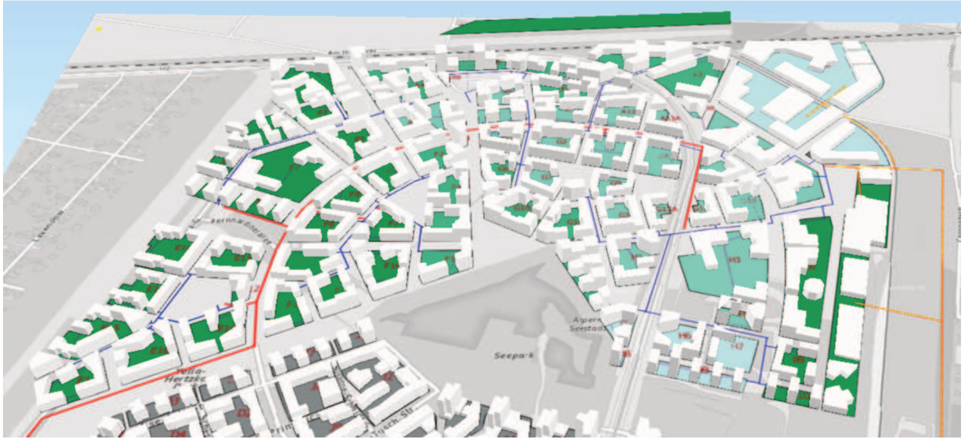

Fig. 2: Exemplary Building Construction of Aspern Nord (including pipes of district heating and gas supply), Source: AIT in Transform+ Deliverable 3.4 – Implementation Plan aspern Seestadt, December 2015

In terms of the conception of the heat supply, a business as usual scenario and three different options for Smart City scenarios were compiled.

3.2.1 The 'business as usual' scenario as a basis for the EIS

In the 'BAU' scenario, energy used for space heating and hot water together should not cause emissions exceeding 150 g CO2 per kWh. This limit had been set by the city´s energy authority. Based on this requirement, a so-called 'minimum scenario' was developed by Wien Energie (the municipal utility) under the assumption that the company Wien Energie should be able to provide the proposed energy supply as soon as 2016.

The scenario proposes 3 local heat grids for the supply of the heat demand according to 'BAU' demand level:

- Heat grid east (65°C forward temperature), supplied by a natural gas powered heating plant
- Heat grid west (65°C forward temperature), supplied by the municipal district heating grid
- optionally a groundwater heat grid north (12°C forward temperature), supplied by ground water and combined with heat pumps.

The following figure illustrates the overall concept for the heat supply system in aspern Seestadt North according to the 'BAU' scenario, as proposed in the Environmental Impact Statement (EIS). Due to the (probable) partially high temperature requirement by industial users, the 'business as usual' scenario assumes a connection to the gas network for the industrial area in the East, which can be used for a heating plant as well.

As potential optional extension of the 'BAU' scenario, the heat grid north can be supplemented by ground water heat pumps for space heating and hot water supply (submitted as optional in the EIS), but realization is depending on its economic feasibility and it is therefore not considered in the 'BAU' scenario results (see table 2, below). The size will depend on the expected minimum of usable geothermal energy from the ground water stream in the area. Furthermore, the installation of photovoltaic appliances in the entire area is foreseen (and included in the 'BAU' scenario), but relization is not necessarily covered by Wien Energie.

The BAU scenario would cause CO_2 emissions of 132 g per kWh (for space heating and hot water provisi-on), but only as an overall average for the whole area. Parts of the area, e.g. the natural-gas supplied heat grid east, exceed the limit of 150g per kWh by far[4]

[4] A full supply of aspern Seestadt North with heat from the municipal district heating network was economically not feasible from Wien Energie's point of view at the time of the project. This has been explained mainly by the need for a connection from the south-western corner (aspern Seestadt South) to the existing main supply pipeline, while construction for aspern Seestadt North starts in the North-east. This would cause the need for pre-financing of a main district heat supply pipeline from the South-west to the North-east.

Fig. 3: Heat supply conception aspern Seestadt North, business as usual scenario, Source: Transform+ Deliverable 3.4 – Implementation Plan aspern Seestadt, December 2015

3.2.2 Three ‘Smart City’ scenarios

The ’Smart City’ scenarios were elaborated by the “aspern Seestadt energy group”, combining knowledge from experts in energy and urban planning, authorities, the development agency and the energy supplier.

The conception of ’Smart City’ scenarios is an attempt to come up with innovative and ambitious design options for the energy supply for aspern Seestadt North. It is based on the long-term aim of Vienna – as stated in its Smart City Framework Strategy 2014 – to follow the idea of a ‘2,000 Watt society’ (which equals 17,500 kWh primary energy consumption per capita for the whole energy demand) and to lower CO_2 emissions to maximum of 1t per person.

Furthermore, the goal is to cover as much of the energy demand as technically feasible from renewable sources. This is only possible if the energy demand from residents and businesses can be considerably re¬duced. Therefore, the ‘Smart City’ scenarios are based on the lower ‘efficency’ level energy demand (heat and electricity) of 92 GWh annually, compared to 152 GWh at the ‘BAU’ level.

Based on this lower energy demand the proposed ‘Smart City’ energy supply concept should be able

- to use local renewable energy sources to a high extent (mainly solar energy, ground water and local waste heat sources of different temperature levels);
- to be flexible enough to cope with the large uncertainty of future usable waste heat in the area (future industrial uses are still unknown and therefore also the amount and temperature levels of available waste heat);
- to allow a stepwise development of the energy supply network parallel to the ongoing urban develop¬ment of the area, allowing for the use of growing knowledge, technological innovations and the use of available waste heat;
- to provide considerably lower specific CO_2 emissions than the ‘BAU’ scenario in order to show the range of feasible reduction.

The three listed ‘Smart City’ scenarios give a short overview on the possible contributions and influencing components. The three scenarios build on each other in stepwise improvement: the higher the proportion of renewable energy sources, the more reduction of CO_2 emissions can be achieved. Where, scenarios 1 and 2 solely use locally available renewable energy potentials, scenario 3 additionally considers the use of biomass.

- 'Smart City' scenario 1, based on 'BAU' system scenario, combines a groundwater heating network for office buildings (in the north of the area) with medium deep probes (as a support for the domestic hot water production).
- Smart City scenario 2, combines Smart City scenario 1 with solarthermal heat from appliances installed at the roofs in the industrial area (about 50% of roof surfaces) and with PV-installations for the electricity need of heat pumps (used for increasing the heat level from probes and the groundwater net¬work, about 30% of roof surfaces).
- Smart City scenario 3, combines Smart City scenario 2 with a biomass heat plant for covering the baseload of heat demand (instead of the natural gas fired heat plant).

3.3 Smart City scenarios – results relating to Smart City objectives

The three Smart City scenarios show the potential of significant energy savings (due to consumption side measures) as well as a considerable higher proportion of renewable energy – this twofold approach allows for a substantial reduction in CO_2 emissions.The following tables on results only refer to energy demand for heat, including energy for heating and (residential) hot water provision.

Energy demand for heat supply	Business as usual BAU scenario	Smart City scenario 1	Smart City scenario 2	Smart City scenario 3
Energy demand (GWh/a)	91	72	72	72
Necessary power for heat supply (MW)	72	55	55	55
CO_2-factor (g CO_2/kWh)	132	117	88	43
t CO_2/a	11,973	8,560	6,320	3,070

Table 2: Reduction of total heat demand, power and CO2 emissions of Smart City scenarios versus business as usual scenario (heating concepts aspern Seestadt North), Source: T+ Energy group aspern Seestadt

The analysis of the different development scenarios of aspern Seestadt North show, that a reduction of the specific CO_2 emission values from 132 g/kWh ('business as usual' scenario) to 43 g/kWh (Smart City scenario 3) can be achieved (scenario 3 including the groundwater heating network for office buildings, medium deep probes, solar thermal heat from the industrial area, electricity from PV for heat pumps and biomass base load), if a resource-friendly conception on the production side is applied. The Smart City scenario 2, using solely local renewable energy, still achieves a reduction of its specific CO_2 emission values to 88 g/kWh.

Total CO_2 emissions can be reduced by the combination of consumption (demand level) and production side (heat supply concept) measures from nearly 12,000 tons CO_2 to about 3,000 tons CO_2,:

in % compared to BAU scenario (heat supply)	Smart City scenario option 1	Smart City scenario option 2	Smart City scenario option 3
Energy demand (GWh/a)	-20.7	-20.7	-20.7
Necessary power for heat supply (MW)	-23.0	-23.0	-23.0
CO_2-factor (g CO_2/kWh)	-11.4	-33.3	-67.4
t CO_2/a	-28.5	-47.2	-74.4

Table 3: Reduction potential of heat demand, power and CO2 emissions of Smart City scenarios versus business as usual scenario in % (heating concepts aspern Seestadt North), Source: T+ Energy group aspern Seestadt

In relative numbers, the heat demand decreases in all 'Smart City' scenarios according to the 'effficiency' demand level as a basis of Smart City scenarios (-21%). The best Smart City scenario option shows a reduction of nearly -75% of CO_2 emissions when compared to the 'BAU' scenario, scenario 2 (using only local renewable energy) achieves a reduction of about -47% of CO_2 emissions.

4 CONCLUSIONS

The cooperative elaboration and testing of alternative energy system concepts, carried out by an interdiscipli¬nary working group ('Transform+ energy group') has proven to be a best practice example. This group, consisting of representatives from the development company, the city urban planning and energy planning departments, the city owned energy supply company and research institutions such as ÖIR and AIT, was established with the aim to develop a technically and economically feasible energy concept for aspern Seestadt North.

As a main input for the so called ‘Implementation Plan’, a thorough analysis of all relevant energy supply options including the local potential for renewable energy and aiming at maximum CO2 savings, is an essential step for the realization of urban energy systems which contribute substantially to the achievement of climate and energy targets.

This is especially true for the ambitious targets set by the Smart City Framework Strategy of Vienna (2,000 Watt society until 2050, 1 t CO_2 per person): In terms of the quantitative targets for renewable energy, the Smart City Framework Strategy aims at a share of 50% (mainly locally available) until 2050. In order to achieve these targets overall, urban quarters will have to be transformed by using a appropriate strategies to their starting situation and development perspectives: Existing quarters need ambitious transformation concepts, while new urban developments will have to achieve best results, surpassing the overall targets for the city.

Following the experiences from Transform+, there should be similar working processes and considerations for all other development districts, including the elaboration of alternative scenarios for energy systems and detailed calculations for costs and benefits relating to the CO_2 objectives of the Smart City Framework Strategy. The following conclusions summarize the results and seem also relevant for the energy system development in other urban districts:

- The commitment of the city of Vienna to become a ‘smart city’ and the general targets defined in the re¬cently adopted Smart City Framework Strategy are a most relevant guidance for the development com¬pany, Wien 3420. However, this high-level framework strategy is not enough to secure high smart city standards to be implemented, since Wien 3420 has to consider a number of different, often conflicting objectives and requirements. This is also true for Wien Energie, the city´s energy company. A differentiated set of targets, taking into account the variation of given urban structures and functions of urban quarters is necessary, but still missing (quantified, not only the CO_2 factors). Together with a clear backing from cities’ authorities for implementation processes, well-defined administrative responsibili¬ties and an ongoing monitoring process, the urban transformation towards smart city objectives should take up momentum.
- A tailor made, area-focused and integrated planning approach for the construction of new or the refur¬bishment of existing buildings, including energy supply, (local) energy production, urban planning and development is needed. For new urban development districts, it is also necessary to coordinate compre¬hensive energy supply concepts (reaching beyond the supply for single buildings or building blocks) and the use of district heating (at lower temperature levels), waste energy and groundwater resources in larger area context.
- Integrated planning and agreements between involved stakeholders are of major importance in order to achieve higher liability of planning when developing new urban quarters with respect to energy and climate protection targets. For this challenge, specific requirements and guidelines, planning security and financing matters represent core issues. In any case, investment costs shall be compared with achievable long-term savings (life-cycle cost-analysis):
    - Investors on all sides need clear, area-specific frameworks for decision making and implementation. A number of legal conditions are forming barriers for the development of efficient and economically feasible energy systems: The hampered use of own electricity production across building sites, the lack of contractual agreements between urban planning and energy system development, heat tariff regulations which prevent differentiation between areas in the city.
    - To overcome these barriers it seems necessary to establish an urban, area-specific process providing
        - alternatives for integrated energy systems,
        - a choice of a preferred alternative,
        - a competition between providers (infrastructures and operation),

        - a selection of the best provider by the city and a related concession for a reasonable time span (e.g. 25 years),
        - an obligation by the investors and end-users to comply with the energy system in the specified area.
    - Based on such an approach, energy service providers for larger areas will be enabled to present an approach for the effective organization of a local area energy system, balancing varying financial benefits and losses within the overall system in a given area.
- In the high urban density of aspern Seestadt, the energy demand exceeds the supply potential of local renewable energy by far. This will be the case in many other densely built urban areas, therefore, the city of Vienna will not be able to supply its energy demand by local renewable energy only. Complementing local efforts, an approach of a common energy region (matching demand and supply) should be considered in Eastern Austria, forming a larger energy supply area together with regions Lower Austria and Burgenland. Such an approach was recently chosen by the 'Northern Germany' region (Hamburg and Schleswig-Holstein) in the model project 'NEW 4.0'.
- To achieve the Smart City objectives, a change of the population's energy consumption behavior is essential. Therefore, it is necessary to develop and implement support measures for changing energy consumption awareness and behaviour in addition to technical measures.

The development of a greenfield area of the size of aspern Seestadt into an attractive urban neighbourhood is a challenging task. It requires high quality planning, openness for technical and social innovation and a strong and committed management, especially with regard to the broad variety of stakeholders and the timeline of over 20 years of development.

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