Schweizerische Eidgenossenschaft
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Department of the Environment,
Transport, Energy and Communication DETEC

Swiss Federal Office of Energy SFOE
Energy Research

Final report June 2019

SPACERGY

Space-Energy patterns for smart energy infrastructures, community reciprocities & related governance

SPACERGY

Date: 30 June 2019

Place: Bern

Publisher:
Swiss Federal Office of Energy SFOE
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Summary

SPACERGY builds upon the need of planning authorities to develop new models to implement energy transition strategies in the urban environment departing from the exploitation or reciprocity between the space and energy systems. Several policies are made by each EU nation, but effective and practical tools to guide the urban transformations towards a carbon neutral future, present several challenges. The first is to confront long term changes trying to envision how a specific socio-cultural and transition context can respond to the application of solutions for energy efficiency. Secondly, the engagement of communities in bottom-up approaches mainly includes the sphere of urban planning underestimating the importance of relating spatial transformations with the performances generated in the urban environment. The third challenge regards the tools used for the assessment of the energy performance and the necessity of enlarging the scale in which energy demand is analyzed from the building to the district level. In this context, the project explores the role of mobility, spatial morphologies, infrastructural elements and local community participation in regards to the smart use of local resources and addresses a knowledge gap in relation to interactions and synergies between spatial programming, energy and mobility systems planning and stakeholder involvement necessary to improve models of development and governance of urban transformations.

Based on detailed spatial morphology and energy use modeling SPACERGY develops new toolsets and guidelines necessary to advance the implementation of energy efficient urban districts. New toolsets will be tested in three urban areas under development in the cities of Zurich, Almere, and Bergen, acting as living laboratories for real-time research and action in collaboration with local stakeholders.

The results of this research project support planners and decision makers to facilitate the transition of their communities to a more efficient, livable and thus prosperous urban environment.

Zusammenfassung

SPACERGY gründet auf der Notwendigkeit, dass Planungsbehörden neue Integrationsmodelle für ‘prosumers’ und intelligente Mobilität umsetzen, indem ihre Wechselwirkungen in zukünftigen Urbanisierungsmustern genutzt werden. SPACERGY konzentriert sich auf die Rolle optimierter Mobilität, räumlicher Morphologien, infrastruktureller Elemente und lokaler, gemeinschaftlicher Partizipation in Bezug auf die intelligente Nutzung lokaler Ressourcen. Das Projekt befasst sich mit der Wissenslücke hinsichtlich der Interaktionen und Synergien zwischen räumlicher Funktionsanordnung, Planung der Energie- und Mobilitätssysteme und die Einbeziehung von Interessensgruppen, die für die Verbesserung der Stadtentwicklungsmodelle und die Steuerung urbaner Transformationen wesentlich sind. Auf Basis einer detaillierten Modellierung der räumlichen Morphologie und des Energieverbrauchs wird SPACERGY neue Werkzeuge und Richtlinien entwickeln, die für die weiterführende Umsetzung energieeffizienter Entwicklungsformen notwendig sind. Die neuen Werkzeuge werden in drei urbanen Entwicklungsgebieten in den Städten Zürich, Almere und Bergen getestet und mithilfe von Aktionsforschung in Brescia verifiziert. Diese Städte fungieren als living laboratories für Echtzeitforschung und Aktivitäten in Zusammenarbeit mit lokalen Interessensgruppen. Die Ergebnisse dieses Forschungsprojekts werden Planern und Entscheidungsträgern dabei helfen, die Wandlung ihrer Gemeinden zu einer effizienteren, lebenswerten und damit aufstrebenden städtischen Umgebung zu begünstigen.

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List of abbreviations

CEA	City Energy Analyst
DEIM	District Energy Integration Model
DLWC	District Lake Water Cooling
DOS	Design-Oriented Scenario
ETH	Swiss Federal Institute of Technology, ETH Zürich
EV	Electric Vehicle
FSI	Floor Space Index
GHG	Greenhouse Gas
GIS	Geographic Information Systems
GSI	Ground Space Index
HQ	Hochschulquartier
LL	Living Lab
MATSim	Multi-Agent Transport Simulation
MXI	Mixed Use Index
NMAD	Normalized Mean Absolute Deviation
RC model	Resistance-Capacitance model
USZ	University Hospital Zürich
UZH	University of Zürich

1 Executive Summary

The Transition towards a carbon free society is considered one of the principal challenges of the coming decades for cities and metropolitan regions. This transition marks the shift from the fossil fuel era to an era where a new energy mix is dominated by renewables energy production. Urbanized areas, which account for substantial portion of energy demand, are already gradually becoming spatial structures for production, storage and exchange of energy. However, to realize Energy Sensitive Cities cannot just pass by a technological challenge but needs to include considerations on consequences in values and uses for the communities, to support decision makers in the development and support of a long-term vision. In this context, the main scope of the research is to explore, within the “new Transition”, the reciprocal relationship between urban planning and the development-application of energy strategies to reduce demand, produce and re-use energy, based on the maximum exploitation of energy potentials provided by urban environments.

In this context the project investigates how to implement and use decision making tools that allow for the integration of spatial and energy dimension in urban development projects. Firstly, it explores the use of Living Lab approach and develops a design oriented scenario method to envision and evaluate possible futures taking in account the spatial and the energy transition components, as well as internal and external drivers of pressure. Secondly, quantitative tools are discussed and tested to perform the assessment of future energy demand enlarging the computational scale from the building to the district level. Finally, a District Energy Integration Model (DEIM) is developed by coupling four different modules for the synergic assessment of energy demand for the building and the mobility sector at the scale of a district.

In the first phase of the project relevant data on the case studies have been collected and analyzed, looking at the three focus areas of Floriade (Almere, the Netherlands), Mindemyren (Bergen, Norway) and Hochschulquartier (Zurich, Switzerland) and their spatial contexts. On one hand, land use characteristics, and goals set for urban areas aiming towards a sustainable transformation, deal with physical and system proprieties in terms of energy transition strategies. On the other hand, national policies delineate priorities to achieve an energy balance between use and supply, to comply with targets set. Within this context, a reflection on the practice of integration of spatial and energy based planning is introduced and analyzed according to its different components. Two integrated frameworks are employed in this phase. The selection of three case studies is based on determinant factors defined by the Living Lab environment (Veeckman et al., 2013). Context research, Co-creation and Evaluation are defined as pillars of the project activities defined by a Living Lab approach. On the gathered information a description of the status quo Energy context, Urban transition and District space is given by using a transition practice based approach (Faller, 2014).

The knowledge base developed has been further used for building scenarios for the three case studies. Scenarios are instruments that allow the critical exploration of alternative models or urban transformations, but can also support decision makers in developing new future pathways. However, these are often used in the field of energy planning only to compare the energy performance of different possible solutions, underestimating physical and local spatial components that can guide design processes. In order to bridge this gap and promote a synergetic integration between spatial and energy system planning, a new type of scenario is needed for the construction of common, so-called "desirable futures". To meet this demand within energy transition processes and support coordination of design, research and planning towards an energy-sensitive approach, in the SPACERGY project such a method is being developed. The hybrid Design-Oriented Scenario (DOS) method allows to define common visions within a multi-actor Living Lab (LL) approach. The DOS method, tested in the three case studies, combines descriptive, explorative and normative components. It aims to help decision makers in complex multi-actor processes by setting common objectives, sharing and creating a multidisciplinary common ground, and exploring alternative spatial and energy performative visions.

Within the first analytical phase, the main goal was to identify social, political and economic components to determine potential trajectories to develop energy concepts in the different study areas. The exploration of energy-spatial strategies to guide robust design choices and processes of implementation requires the creation of a solid and common knowledge basis. Therefore, workshops with stakeholders and experts have allowed the creation of Internal and External Scenarios. Three Workshops took place in the cities of Almere (the Netherlands), Bergen (Norway) and Zurich (Switzerland) between September and October 2016, involving the SPACERGY academic partners (TU Delft, HIB Bergen, ETH Zurich), together with most relevant local stakeholders (energy experts, administrators, technicians, etc.) for each of these locations. The main aim of these workshops was to discuss external trends and to determine design oriented scenarios for the development areas.

The second part of the project focuses on collection of knowledge and development of tools for the assessment of building energy demand and mobility energy demand at the district scale. The role of urban form and energy related attributes are also discussed. Although morphological factors are considered fundamental because influence energy demand and the potential for consumption, temporal storage, matching of supply and demand, and integration of production, they are frequently overlooked in the design process. This holds in particular for the neighborhood scale. As a consequence, a multi-scale approach for cooperation of different urban patterns and their relative energy performance in a synergic urban system is difficult to address. Therefore, quantitative parameters to analyze morphological attributes of the building environment are discussed and used to describe the Zurich baseline scenario. Space Syntax and ENVI-met tools are used to address the spatial dimensions of building geometry and street network.

Moreover, a dynamic energy demand model for the *Hochschulquartier* was developed in order to analyze the demands of the area. The work was carried out in the City Energy Analyst (CEA), a computational framework for the analysis and optimization of energy systems in neighborhoods and city districts. CEA comprises a collection of physical models for the simulation of energy demands and supply in the area of study as well as statistical databases containing building properties for typical archetypal buildings as well as operating parameters and schedules. The results for two different models are presented and discussed. The first one is the Status Quo, that is, the area at the time of publication of the new Masterplan for the area, 2014. The necessary information about 3D geometry, materials, occupancy and mechanical components was obtained from GIS data, owner information and the archetype database. Data on energy-relevant retrofits for the main building components was scarce and thus estimated. The second model present corresponds to the SPACERGY Baseline scenario, which is roughly based on the 2014 Masterplan for the area.

The results show that the demand for heating per square meter in the Baseline is significantly reduced due to the construction of highly-insulated buildings, but the demands per square meter for electricity and cooling increase with increased usable floor space. University Hospital and ETH Zürich are the largest consumers for both the Status Quo and Baseline scenario due to their large built areas and highly energy-intensive functions. The University of Zurich's demands are much lower, but increase in the Baseline scenario due to its increased usable floor space in this scenario. Other buildings in the area hosting complementary functions such as residential, gym, and restaurants have a comparatively much smaller impact on the demands in the area. Due to the increase in energy efficiency in the buildings in the area and the introduction of low emission cooling infrastructure, the overall performance of the area in the Baseline scenario is better than in the Status Quo. Nevertheless, 2000 Watt Society targets are not met, and hence further proposals need to be made to reduce the operating emissions and primary energy demand of the area in order to meet this goal.

A model for testing out the relationship between the spatial structure of the mobility network and energy usage for transport is built up for Bergen and Zürich. First, a Space Syntax map was made for Bergen and Zurich, and this map was used to carry out various Space Syntax analyses. Geographic Information Systems (GIS) are used as a platform to correlate the results of four different spatial parameters with one another. The following four spatial measurements are used:

- Through-movement potentials on a city-wide scale
- Through-movement potentials on the neighborhood scale
- To-movement potentials on a city-wide scale
- To-movement potentials on the neighborhood scale

In addition, we also conducted analyses on the building-street relationship (the urban microscale tools). The aim was to reveal to what extent the degree of permeability and visibility of adjacent buildings towards streets affect energy usage for transport. After finishing the spatial model, the data for energy usage for car traffic for the present context for the mobility network were correlated with the results from the spatial analyses. MATSim was used to get the data for energy usage for transport. Here, we gained data on average speed and origin and destination travel for Zürich and for Bergen. GIS was used as a platform to correlate all the data with one another.

As the results from these aggregations for Zurich and Bergen show, the spatial structure of urban space and the degree of building-street interface affect energy usage for transport. High local integration and short urban blocks, combined with buildings with active frontages allowing for interaction with the streets, contribute to a high degree of 'walkability' in streets. Areas with high integration on the main routes running through the locally highly integrated neighbourhoods yield for an efficient public transport system on the integrated main routes network. In Bergen as well in Zürich, some of these streets have tram, busses or light rail lines on them.

The private car in particular is a major contributor to energy usage for transport. If the to-movement potentials on a local scale are well-integrated with the high-scale through-movement network, private car usage is reduced. Walking and cycling seem to become a natural choice for shorter, local trips. In addition, these streets need to be constituted and have a high degree of inter-visibility from adjacent buildings. As indicated by Jacobs (2000) and Gehl (2011), this urban microscale aspect contributes to a natural surveillance mechanism and makes walking attractive as a local transportation mode. When combined with an equally well-integrated, diverse public transport system, local trips can then extend to car-free regional trips, too, reducing energy usage further. As we have seen in the energy usage equation, longer and therefore more high-velocity car trips consume exponentially more energy.

Neighbourhoods with high values on all the four spatial measurements on the street network tend to have short urban blocks. In line with Jacobs, short urban blocks enhance walking as a transportation mode. Walking and cycling is the mobility means with the lowest energy consumption for transport. Therefore, the first task is to explain what kind of spatial features enhance these kinds of transport.

So far, the studies of Bergen and Zurich have shown that short urban blocks (or a fine-grained urban mobility network within a short metrical distance), integrated main routes running through neighbourhoods with short urban blocks, constituted and inter-visible streets from adjacent buildings are complex necessary conditions for enhancing sustainable transport means in terms of facilitating public transport and a high degree of walkability. All these parameters need to be present at the same time for making neighbourhoods attractive for walking. Moreover, neighbourhoods with these spatial features tend to transform themselves naturally to highly urban areas with high building density and high degree of land use diversity (Ye and van Nes 2014).

Highly integrated main routes connecting various neighbourhoods with one another supports a public transport network. Urban areas with low values on the angular choice with a low metrical radius and buildings turned away from streets generate private car dependency, low density urban sprawl into the countryside and mono-functional areas. This again contributes to complex travel routes between work, shopping, leisure activities and home.

Finally, an integration between tools previously described is attempted in two stages of integration by coupling different models. Methods for partial integration separately addressed mobility and building related energy assessment.

Regarding building energy demand a computational approach has been developed. It allows quantitative analysis of building energy demand on a district scale, including interdependent factors such as local air temperature, relative humidity and wind speed, diversity in building geometry and materials as well as user behaviors. The method, which links the microclimate model ENVI-met and the district-scale energy simulation tool City Energy Analyst, has been applied on a Masterplan for a district development in Zurich, and Almere, in order to analyze the energy performance of the proposed design and define guidelines for improvement.

Focusing on mobility and transport, which account for 25% of energy usage in cities, a second approach asks, what are the factors of urban form and networks that affect patterns of movement and choice of transport mode in relation to energy usage? Using a quantitative analysis of spatial elements influencing mobility choices with Space Syntax, we demonstrate how spatial configuration and degree of walkability relate to energy usage for mobility. By correlating the spatial analysis data with energy consumption data obtained from measured traffic data, findings show that street segments with both a high level of local and global integration tend to exhibit lower amounts of energy usage for car traffic. This suggests that cities with highly integrated streets advance walkability and choice for sustainable means of transport (i.e. cycling and public transport) which then reduces energy usage.

A complete integration model for assessing energy demand jointly for the building and the mobility sector on a district scale is finally developed and tested. The District Energy Integration Model (DEIM) was used in order to estimate energy demand for space cooling in the Baseline Masterplan of the Hochschulquartier in Zurich and for other three scenarios developed in WP3. The results allow for an overall quantitative comparison between scenarios and serve to understand more in detail the complex interdependent relationships between buildings and street network transformations, and the overall district energy performance. The four modules employed consist of available simulation models, ENVI-met, City Energy Analyst (CEA), Space Syntax and MATSim, which have been coupled in a workflow.

The results of the mobility analyses show that the lowest amount of car traffic is seen in the Synergy scenario, and with that the amount of energy used for car traffic (21.2 TWh). This is, however, higher than the Status Quo (18.6 TWh). The highest energy consumption by cars (23.7 TWh) occurs in the Baseline scenario. Most car and bicycle traffic seems to follow streets with high through-movement potential on the city scale, whereas most pedestrian traffic seems to follow the shortest path to the central railway station in the northwest of the study area. On the local scale (R=500), there are some considerable improvements in through-movement potential between Hochschulquartier and the east bank of the historic city centre. However, the values do not increase in the masterplan area itself, with exception of the Synergy scenario. Here, the newly introduced promenade sees a distinct increase in local through-movement potential.

In all scenarios, the amount of walking is higher than the Status Quo. The differences between the scenarios themselves are marginal. The highest amount of walked distance occurs in the Super Urban scenario. Interestingly, the amount of distance driven by cars is not lower as a consequence.

Regarding building energy demand, heating for space conditioning, domestic hot water and processes is the primary contributor to the demands of all scenarios (31–37 GWh/yr), however due to the large share of functions with high demands for processes, lighting and appliances, the demand for electricity is similarly significant (31–35 GWh/yr). As expected, the energy demands are highest for the Health Campus scenario, mainly due to the increased demand domestic hot water and process heating, cooling and electricity. The demands are lowest for the Synergy and Super Urban scenarios due to the increase in residential buildings in these scenarios, which lead to an overall decrease in process energy and space cooling demands.

The average space heating demand for all scenarios is around 40 kWh/m^2/yr, whereas the space cooling demand ranges from around 12 kWh/m^2/yr for the Synergy scenario to 18 kWh/m^2/yr for the Health Campus scenario. Regarding process cooling, the minimum is also encountered in the Synergy scenario (10 kWh/m^2/yr) while the highest demand is also found in the Health Campus scenario (18 kWh/m^2/yr). The domestic hot water demand is also highest for the Health Campus scenario (26 kWh/m^2/yr), while the other scenarios range from 17-20 kWh/m^2/yr.

A key assumption in the definition of the SPACERGY scenarios was that the introduction of residential buildings in the Synergy and Super Urban scenarios would lead to peak shaving and a more balanced load throughout the day. However, while the peaks were indeed lower in these two scenarios with respect to the baseline, the load balancing effect was largest in the Health Campus scenario. This is due to hospital buildings not only have night time occupancy, but also have demands for domestic hot water and process heating during off-peak times.

When accounting for the effects of urban microclimate on the hottest day of the year, there was a noticeable dip in the peak demand for all scenarios, with a decrease in the peak power required ranging from 5% for the Synergy scenario to 7% for the Health Campus scenario. However, due to the higher nighttime temperatures the cooling demand during these off peak hours and hence there was an overall increase in the cooling demand on the hottest day of the year of 4% for the Baseline scenario to 6% for the Health Campus scenario. The effect of occupant models on the predicted demands of the area was also analyzed by comparing the standard CEA deterministic occupant model with a new model using the MATSim population as a basis. The results showed that the predicted peak power for space heating was barely changed by the choice of occupant model (< 5%), however the peak power for appliances and lighting as well as for space cooling varied by an average of 15% when changing the occupant model.

The SPACERGY scenarios also contemplated the development of a free cooling network distributing cold water from nearby Lake Zurich for all scenarios as well as an increase in photovoltaic panel and batteries in two further scenarios. The systems were modelled in CEA and their environmental and economic feasibility was verified by comparing to the standard alternative (i.e., vapor compression chillers and electricity from the grid). In every scenario, the best solution in terms of minimizing CO_2 emissions and primary energy always includes the installation of a district cooling network for the area. Given the high construction costs, however, the cost-optimal solution in each scenario involves the use of decentralized vapor compression chillers for cooling. In terms of electricity, for those scenarios where photovoltaic technologies were assessed, the installation of PV panels proved to lower CO_2 emissions and primary energy, whereas a cost-optimal PV solution was found that would also lead to the lowest costs, including with respect to foregoing PV technologies altogether. The installation of batteries was generally unprofitable for most buildings given the large demands of the building functions hosted in the area, such that the self-consumption of photovoltaic electricity was generally high even without batteries.

The application of the DOS method has showed its capacity to support complex multi-actor processes of spatial-energy transformation by helping in setting common transition objectives, sharing and creating a multidisciplinary common ground, and exploring alternative spatial and energy performative visions in a participatory workshop setting. In the scenario method elaboration phase and its application in the Almere, Bergen and Zurich Living Labs, visions were considered a fundamental contribution for the body of information and knowledge developed, while being consistent in terms of description regarding the relations between the energy impact factors and processes. The modeling framework developed allowed the computation of energy demand based on the principal types of factors which shape building and mobility performance such as urban form, design, systems and behaviors. Moreover, the multi-domain simulation framework constitutes an attempt to tackle the major limitations of the single computational methods which have been discussed in the previous reports describing the partial coupling methods. Through the application of partial integration models on each of the Living Labs, the transferability of the proposed framework developed for the Zurich case study was demonstrated.

2 Introduction

Energy demand in cities is globally growing, while of all human activities the burning of fossil fuels for energy is also the leading contributor to GHG emissions worldwide. The rising energy demand is strongly related to (changed) lifestyles (with a significant role for mobility and the built environment) that involve increasing levels of comfort and use of space. While fossil fuels will be quite difficult to replace for many applications (fertilizer, medicine, plastics, etc.), renewable energy systems offer a viable, carbon-free and often locally available alternative that many countries are beginning to transition towards (Jong, 1996). This (almost) globally initiated transition towards renewables is to a rising amount starting to influence the use of space, including cityscape and natural landscape. Within this context, in the last decade these trends have made the topic of energy generation and consumption reappear in the agenda of spatial planning (Schubert 2014), with a stronger focus on reciprocity of 'clean energy production' and an energy system that can become gradually dominated by renewable resources, while being smart and more integrated and interconnected to use(rs). Additionally, ICTs have become a ubiquitous part of everyday life. ICTs will have an integral role to play in developing more sustainable and resilient patterns and in particular matches of consumption and production. Of all the areas in which ICTs contribute to sustainable development, technologies coming from the user-centric field of sustainable Human Computer interaction (HCI) could potentially be used to buttress sustainable behaviors. Within this, and the coming energy transition, the inclusion of Distributed Energy Generation (DEG) at a local scale and with included HCI based feedback loops will be of rising importance (Pepermans et al. 2005). DEG means that bilateral energy trading becomes possible with the use of local resources, (temporal) storage and exchange facilities and alternative network geometries (Timmeren et al., 2012).

Within the perspective of alternative network geometries and the context of reciprocities of cities and their surrounding area (hinterlands) towards regional sustainable metabolisms, urban environments can not only act as energy consumers, but as spatial structures useful for the production, storage and exchange of energy (prosumers). One of the resulting and urgent challenges is a proper energy infrastructure which ensures a proportionate penetration of renewable energy, and a new 'grid functionality' (including spatial lay-out and functional use for building and mobility related), including all the necessary spatial, economic, logistical and social components (Alanne and Saari, 2005) able to support the idea of the Inclusive and Energy Sensitive City (the city as generator). The design and integration of a new energy system into the city environment must begin to tackle a variety of issues and resolve critical aspects regarding interdependency between the city, its underlying (infra)structures and end-users. Recent research (e.g. Schlueter et al. 2015) has pointed out how different urban forms and programs can have direct implications in the way we consume and produce energy in the built environment. This holds even stronger when one includes mobility (Silvester et al., 2013). The strong ties of patterns of consumption and related infrastructure represents a series of opportunities to study how different urban morphologies either benefits or constrains the performance of energy and mobility infrastructures. As urban form shapes the demand of energy and mobility in an area, modes of transportation (public, private, electric vehicles, trams etc.) and the penetration of DEG (including for instance roof top area for harvesting solar potential, temporary storage in parked EVs, etc.) it is urgent to evaluate the interaction among these variables in early stages of urban (re)development. In this context, new models of governance and urban development considering the integration of urban and energy planning approaches are extremely important to facilitate a transition to a more efficient, inclusive and livable urban environment.

The transition processes involved in the implementation of infrastructural systems “have a strong spatial (and in particular urban) dimension in which not just technical, but also social processes are reflected” (Schubert 2014). SPACERGY focuses on the role of optimized mobility, spatial morphologies and infrastructural elements, while adding local community participation in regards to the smart use, storage and exchange of local resources. It addresses a knowledge gap in relation to interactions and synergies between spatial programming, energy and mobility systems, and to models of governance to support the transition towards a more Energy Sensitive City.

2.1 Goals

The main objective of this research project was to develop smart toolsets and guidelines necessary to advance the development of smart energy strategies to promote inclusive, intelligent, and integrated infrastructures that improve the sustainability and resilience of energy provision in (existing) urban environments. A key aspect was the development of an integration model for assessing energy demand jointly for the building and the mobility sector on a district scale. The goals of the project were as follows:

1. Develop scenarios for transition to energy sensitive urban development for each case study.
2. Generate a framework for spatial urban morphology modeling and assessment.
3. Generate model for dynamic building simulation at the district level to assess the quality and quantity of the demand of energy services per scenario.
4. Generate model of energy provision for mobility and predict mobility energy demand patterns based on agent-based model.
5. Develop a partial model to integrate spatial urban morphology modeling and building energy demand modeling for each scenario.
6. Develop a partial model to integrate spatial urban morphology modeling and mobility energy demand patterns.
7. Develop an integrated model for spatial urban morphology, building energy demand and mobility energy demand.
8. Simulate the operation of energy supply systems according to plausible scenarios of energy demand and size optimal configurations of energy infrastructure per scenario.

9. Develop collaborative framework for new forms of distributed governance and reveal the existing planning and decision-making system in the areas of study.

3 Approach and methodology

The first part of the research consisted on setting-up a baseline scenario for each living lab where all relevant parameters at social, economic, and environmental levels influencing the spatial morphology, infrastructure and governance models of each area are identified. In parallel, a theoretical framework was built in order to analyze typical patterns of urbanization and operational modes in the context of smart energy systems strategies (WP2). In conjunction with interviews to main stakeholders, these patterns helped to outline "narrative" scenarios that address the uncertainty of potential trajectories of development for every study area (WP3).

These formed the basis of three parallel research 'lines' (WP4, 5 and 6) where energy related to buildings and mobility and spatial morphology simulation models were developed. For the sake of simplicity, a specific Living Lab and related scenarios were used to develop each model.

In a next iteration (WP7) a partial model of two times two WP-focuses (4+5; and 4+6) were combined and each transferred jointly with stakeholders to the Zurich living. Both research lines will lead to respectively building-morphology and mobility-morphology energy models that will be validated in respectively Almere and Bergen.

In the next iteration (WP8) these were integrated into an energy infrastructure for buildings and mobility at neighborhood scale in the Zurich living lab. Again, in workshop feedback sessions, new synergies between the communities in the Living Lab and the research teams form the basis of a framework for the definition of innovative and flexible guidelines able to tackle fast changes and short transitions in urban developments (WP9).

The definition of an integrated model for energy demand assessment has been developed by identifying the relevant factors that contribute to determine the performance level of a district and by including these in a modeling workflow.

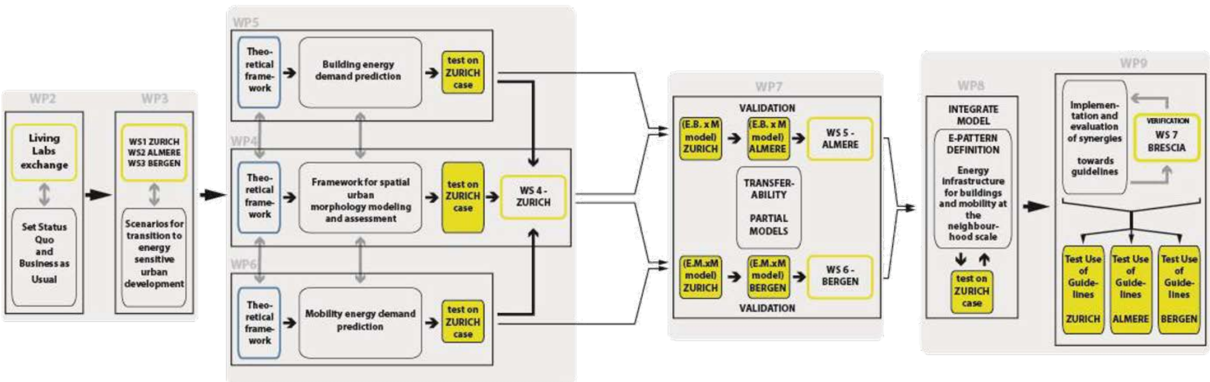


Figure 1 SPACERGY methodological scheme.

4 Results

4.1 WP2: Knowledge management and data collection

The energy transition of cities and urban districts depends upon multiple intrinsic and extrinsic variables as well as processes. In order to achieve a successful transition towards a carbon neutral society, integration of spatial and energy-based planning needs to be developed in a coherent process along the different scales and dimensions that the urban transformation involves. However, the coordination of spatial and energy-based planning requires a solid base of knowledge and information on the area of focus (in this case districts), urban and national context. On one hand, land use characteristics, and goals set for urban areas aiming towards a sustainable transformation, deal with physical and system proprieties in terms of energy transition strategies. On the other hand, national policies delineate priorities to achieve an energy balance between use and supply, to comply with targets set. Within this context, a reflection on the practice of integration of spatial and energy-based planning is introduced and analyzed according to its different components.

Therefore, the main goal of the first phase of the SPACERGY project has been to collect relevant data on the case studies, looking at the three focus areas of Floriade (Almere, the Netherlands), Mindemyren (Bergen, Norway) and Hochschulquartier (Zurich, Switzerland) and their spatial contexts. To identify the benefits and the challenges that this working frame can bring to the research and development process, also the definition, methodological setup and benefits of using a Living Lab approach are discussed.

The energy policy and planning context are also described for each of the cases, at both the national and local (city) context. This description highlights the typical differences with respect to the energy transition-based approaches at stake, that have to be taken into account in this research project.

Two integrated frameworks are employed in this work-package. The selection of three case studies is based on determinant factors defined by the Living Lab environment (Veeckman et al., 2013). Context research, Co-creation and Evaluation are defined as pillars of the project activities defined by a Living Lab approach. On the gathered information a description of the status quo Energy context, Urban transition and District space is given by using a transition practice-based approach (Faller, 2014).

The results show that national goals to preceding in a long-term energy transition have in Norway, the Netherlands and Switzerland different drivers and related challenges. However, some common elements can be found in the definition of targets such as the reduction of carbon emissions. National policy in the Norwegian and Dutch case are more orientated towards a shift from policies of energy demand reduction to new concepts of sustainable production. At the opposite in the Swiss context a larger attention is found on addressing energy reduction of consumption.

At the city level the process of energy transition is challenged by the expected population growth in different urbanization models in the three cities of Almere, Bergen and Zurich. Attention at people behaviors and the engagement of citizens and companies is promoted in particular in the first two cases with a significant focus on innovation. Only the city of Zurich employs a clear target of energy consumption pro-capita.

Moreover, the spatial dimension of transition is partially discussed in all the three cities. However, only Zurich makes a clear attempt to regulate integration between spatial and energy planning through a proper normative instrument.

Finally, at the district scale despite the different land use program, the three districts challenge the same spatial need of increasing the building density and include energy measures in coherence with the national and city goals. The spatial dimension of energy transition requires therefore further discussion and will be addressed in the following work-packages.

4.2 WP3: Scenario development

Scenario tools are recurrently used in urban planning and design in circumstances where it is important to take a long-term view of techno-social developments and related strategies. It is frequently used when there are a limited number of key factors influencing appropriate strategies, and a high level of uncertainty about such influences (van Timmeren et al., 2011). Scenarios build plausible views of different possible futures for relevant actors based on clustering of certain key social, spatial and environmental influences and drivers of change. The result is a limited number of logically consistent, yet different scenarios that can be considered alongside each other (Ibid).

Although in recent years, scenario planning and scenario modeling have become more common (Schoemaker, 2004; Mehaffy, 2015), particularly in support of visioning processes (Lemp et all, 2008; Bartholomew 2005), a Living Lab Approach implies the necessity of far-reaching interdisciplinary integration and active participation of the different actors. The process of envisioning possibilities for an energy transition should be developed by creating joint discussions in the communities and by including all relevant public stakeholders as well as citizens and users (Valeska Sager-Klaub, 2016). Moreover, in complex trajectories that build upon innovation, like the process of urban development and transformation towards low carbon urban energy systems, technical expertise is also required. Scenario methods should thus function as processual tool, supporting development processes with multiple actors, and multi-disciplinary focuses. The benefits in this way would concern both the actors, who are informed regarding strategic options regarding (positive) future pathways, and designers and decision makers who can evaluate the robustness of different strategies. Therefore, what is needed, is a scenario-based method that allows to set common objectives and explore alternative future pathways, while helping the construction of a shared, so-called "desirable visions".

4.2.1 Methodology

In the SPACERGY project, the selection of the type of scenario is based on the main objective: the building of a conceptual and methodological toolset to guide the design and urban development (including its technical systems) in the Living labs to achieve a successful energy transition. Although DOS are identified as useful approaches to guide the process of design and identification of visions in the specific context of urban transformations, these are often developed as a designed research product, without the involvement of all relevant stakeholders. In particular, concerning the field of energy planning and design, DOS have been associated with the visualization of energy footprint at larger scales, as explorative instruments, and for informing planning strategies. Therefore, in the context of Energy Transition towards a carbon free society, as Sager-Klauß (2016) states: “to start a process of energy transition in small and medium sized communities, guiding principles based on energy should be integrated in the urban development concept on a broad basis”, while the process of envisioning should be developed by creating joint discussions with these communities and by including all relevant actors. Within this context, the main question thus became: What type of scenario model is needed in the Living Lab approach and how should this DOS approach be adapted for use in all LLs?

The central scopes of a scenarios building method intended as a tool for co-creation are recognized to be the following in a Living Lab environment:

- to collect knowledge by multi-disciplinary experts and actors and to understand drivers which influence the urban development (DESCRIPTIVE);
- to explore possible internal energy-spatial integrated development (EXPLORATIVE);
- to understand how to achieve national and urban objectives set for the energy-spatial transformation (NORMATIVE).

Therefore, a new type of DOS is developed and framed as a hybrid DOS. For its methodological definition a framework merges in different phases characteristics of descriptive, explorative and normative scenario models in the procedural structure. Furthermore, the procedure inserts employment of techniques and activities which facilitate the interaction between scientific partners/researchers and expert in different fields, together with municipality administrators as well as engineers. The scenario method itself is structured in three main phases involving the following activities:

- **Preparation**: i) Actors, energy policy, energy objectives and key drivers of change are identified, highlighting the role of planning instruments and main challenges and constrains for urban transformation. ii) A scenario matrix is developed taking in account the main factors of uncertainty.
- **Workshop**: i) The scenario matrix is discussed and validated in a workshop setting. ii) The participants divided in four heterogeneous groups describe and discuss four external and internal visions according to the assigned matrix.

  External scenarios are driven by factors beyond the control of the key actors as macro-economic and political drivers of change that can influence policies and the implementation of planning strategies. Internal scenarios on the contrary are framed around local drivers that may guide the related spatial and energy design of the urban areas under study.
- **Evaluation and implementation**: The multidisciplinary research team assesses the outcomes, with qualitative and quantitative techniques. i) A first evaluation is performed by the stakeholders through the comparison between internal and external scenarios (when possible) in order to discuss the robustness of the principles used for the energy transition. ii) A second type of quantitative assessment performed only for one case study is carried out and described in work package 8. In that later stage resulting design scenarios for the Zurich case will be assessed on their energy performance with an integrated simulation model.

This report focuses on the application and the consequences of the developed DOS in the three Living Labs. The diversity of geographical, cultural and political contexts required minor variations in the employment of the method described before.

4.2.2 Results

External and internal scenarios have been developed, discussed and evaluated by key actors in three Living Labs, by following a hybrid Design Oriented Scenarios method.

In the Almere case, the scenario that emerged as the more resilient one as to responding to external pressures, is the Scenario D. This scenario shows to be potential successful for the implementation of an energy efficient district, while it can be characterized by a green overall image and collective energy solutions. The spatial configuration merges dense building clusters and a large area dedicated to vegetation and food production. The green identity of the district could raise the interest of certain types of households, looking for a quieter, greener living environment, while at the same time being well connected to Amsterdam by direct access to the highway and relative fast public transportation. Moreover, the sharing of investment costs and the mix of sources for energy supply might allow the creation of an energy self-sufficient neighborhood, reducing the energy bill for its inhabitants.

In the Bergen Living Lab the internal Scenario A is evaluated as the one that can bring a successful energy efficient development for the Mindemyren area. This scenario promotes an integrated transport model with a separated monofunctional and compact design of the district. The separation of use and the large surface dedicated to open spaces allows the allocation of potential climate adaptive strategies to be included easily. Moreover, the fast connections to the city centre and the high accessibility support the attractiveness of the district for both families and businesses.

For the Zurich Living Lab the deductive construction of the four scenarios highlights the connections between the cooperation of land use types and the availability of space for energy production. Where the integration of functions balances the energy demand, this also potentially decreases the competition for space. Furthermore, the introduction of microclimatic measures needs some more elaboration in the construction of a knowledge basis, since there seems to be little awareness among the participants about the benefits from an energy perspective. Regarding mobility, a numerical model should distinguish between internal and external mobility connections, both regarding mode of transport and calculation of the numbers of trips. The Super Urban scenario is identified as a so-called desirable one since it balances multifunctional use and optimization of energy and mobility related aspects. The high political sensitivity regarding the area, the request to discuss possible futures in a small setting and unusual framework in this context were the key elements that led to limited participation of the invited actors in the workshops. For this reason, additional efforts were made to include more stakeholders in the evaluation. This was achieved, and the evaluation of the visions developed during the workshop by experts, through a methodology of interviews could complement the hybrid DOS method.

4.2.3 Conclusions

The application of the DOS method has showed its capacity to support complex multi-actor processes of spatial-energy transformation by helping in setting common transition objectives, sharing and creating a multidisciplinary common ground, and exploring alternative spatial and energy performative visions in a participatory workshop setting. In the scenario method elaboration phase and its application in the Almere, Bergen and Zurich Living Labs, visions were considered a fundamental contribution for the body of information and knowledge developed, while being consistent in terms of description regarding the relations between the energy impact factors and processes.

Moreover, the evaluation of the scenario robustness based on external drivers, contributes to create awareness amongst decision makers regarding the interdependency between the external, national and global drivers of change on the one hand and the internal development processes, design principles and mobility models on the other. The DOS method has shown good results as a descriptive and exploratory tool. However, further studies need to deal with the normative goal of the method that in fact was not completely addressed during the workshop activities.

4.3 WP4: Spatial urban morphology model

Urban form significantly affects both direct and indirect energy demand and is often an underestimated factor of urban development (Güneralp et al., 2016). Concerning the mobility sectors, the relation between urban form and energy demand has been recognized in several studies, while the wider relationship between urban form and energy demand and, to a lesser extent, supply is less clear. However, new data are emerging which demonstrate a complex but significant relationship. The study ‘Global typology of urban energy use’ on 274 cities found that distribution of economic activity, transport costs, geographical factors and urban form explain around 37% of urban energy use (Creutzig et al., 2015). According to Güneralp et all (2016), the development of Global Scenarios of future urbanization and the energy implications of different urban futures shows that factors such as Urban density will significantly determine building energy use in the next 50. Additionally, this study highlights that the savings in energy use can substantially increase from compact urban development. Factors such as density and mixed use can for example reduce the costs and improve the efficiency because they enable the adoption of efficient heating and cooling networks. On the other hand, the same characteristics could lead to effects such as urban heat island and reduce the potential for renewable production with wind and solar technologies.

To reduce the urban energy demand, Vendevyvere & Stremke (2012) identify urban morphology and building design as the pre-eminent ‘passive design’ variables. However, the role of the urban texture in the total energy consumption varies considerably (between 10% and 80%) according to different estimations (Ratti et al., 2005; Salat, 2009).

With a few exceptions, most literature that discusses impacts of form on energy performance generally focuses on two scales of analysis (that of the city and that of the building), neglecting the neighborhood scale-level and the metropolitan or urban-regional (van Timmeren, 2006; Timmeren & Henriquez, 2013) and the interrelated effects between these scale-levels. At the city scale a conspicuous number of scientific researches have been exploring the impacts of density and compactness of urban patterns in relation with the energy demand for mobility and resulting greenhouse gas emissions (Oliveira, 2016). At the building scale, three main groups of researches can be recognized. The first investigates various frameworks for the classification of built form from an energy perspective. The second focuses on the development of models to value the energy use of buildings. A third, finally, analyses the potential for improvement in buildings. An intermediate scale of analysis starts to be addressed in a limited number of researches in the last few years, with the focus on models and tools to estimate energy consumption (Osmond, 2010; Bonhomme et al. 2010, van Timmeren, 2012), and related considerations on the set of parameters (Ratti et al., 2005; van Timmeren, 2006) or metrics (Salat, 2009) to explore the energy consumption. However, from a morphological perspective a limited number of variables are investigated at the neighborhood scale.

Urban planning and design can benefit from a morphological approach (Marcus & Colding, 2011), however there is a gap in the knowledge field regarding the explanation and description of morphological phenomena to define guidelines for the production of urban forms (Oliveira et al, 2014). Furthermore, the relationship between research on urban morphology and mainstream urban planning and design practice is marginal, because of limited communication between the two activities.

Although morphological factors are considered fundamental because influence energy demand and the potential for consumption, temporal storage, matching of supply and demand, and integration of production, they are frequently overlooked in the design process. This holds in particular for the neighborhood scale. As a consequence, a multi-scale approach for cooperation of different urban patterns and their relative energy performance in a synergic urban system is difficult to address. The main reasons for these gaps can be found in a fragmentation of knowledge on the combined analysis of the energy and spatial potentials according to the triple role of cities, and in methods for the implementation in the design process. Based on the assumption that, in the process of urban transformations, an integrated spatial-energy design approach can yield tremendous benefits for cities in terms of livability and energy efficiency, this work-package has the main objective of identifying parameters that can be used to analyze the related energy characteristics of urban form at the district scale. Parameters are classified in different categories and methods are defined for their calculation in order to analyze the case study of Zurich:

4.3.1 Degree of building density & building form

The Spacematrix method does two things at the same time; quantifying the density parameters FSI (floor space index) and GSI (ground space index) at the same time and to quantify various morphological forms of the buildings in a neighborhood. The categories of building density are classified into low-rise, mid-rise, or high-rise depending on the number of floors. The categories of building type are separated into point-type, stripe-type, or block-type depending on the building's form. The entire built environment can thus be divided into nine categories: 1) low-rise point type, 2) low-rise strip type, 3) low-rise block type, 4) mid-rise point type, 5) mid-rise strip type, 6) mid-rise block type, 7) high-rise point type, 8) high-rise strip type, and 9) high-rise block type. Figure 1.3 shows a simple illustration how types of building volumes in relation to their plots are placed in a 'Spacematrix scheme'.

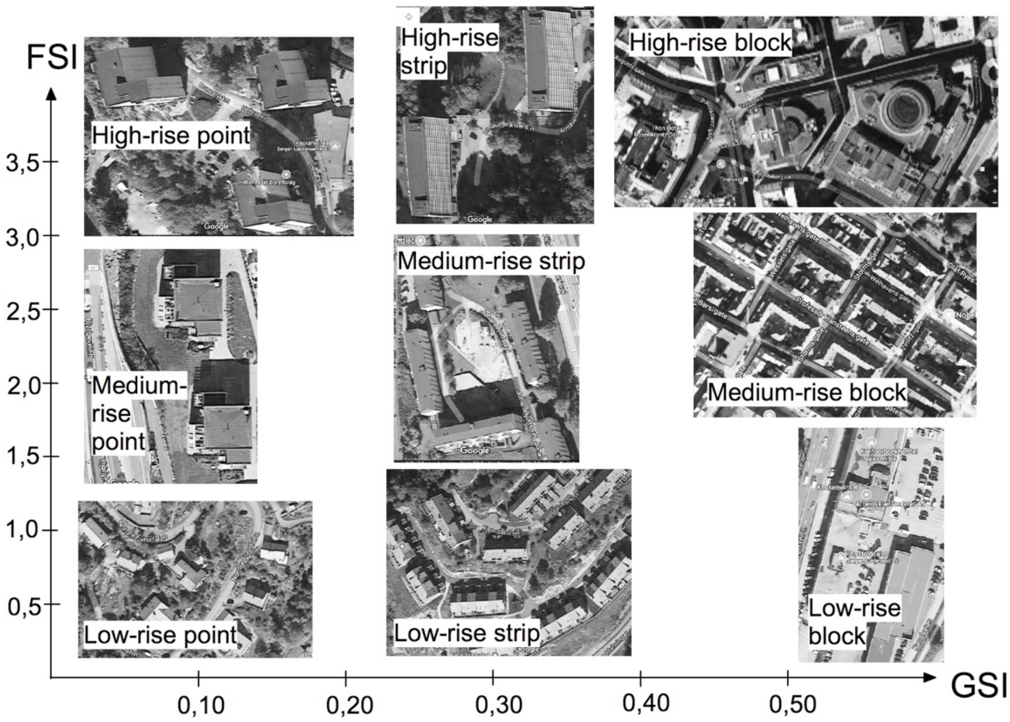


Figure 2 The Spacematrix diagram with examples from Bergen and Oslo in Norway (source: Google Earth).

Most of these building types can be found in every large town or city. Figure 2 shows a dispersal of Google Earth images from Bergen. Even though the population density is low in Norway, most categories could be found in Bergen. For illustration, a well working example on a high-rise urban block is taken from Oslo city centre. The use of GIS makes it easy to aggregate FSI and GSI with one another. Good basic shape files with information on built up plots and the number of floors for each building is a necessary condition for doing so.

4.3.2 Degree of land use diversity

Recently, van der Hoek made a triangle matrix where it is possible to quantify degree of mono-functionality versus multi-functionality. The method is named the Mixed Use Index (MXI). Urban areas with only one function, such as either dwellings, working places (industrial areas or offices parks) or amenities (leisure activities such as sports, shopping, etc.) are defined to be mono-functional. Urban areas are bi-functional where two of these three functions are present and they are multi-functional when all three functions are present (van der Hoek 2009). The original MXI model measured the percentage of housing, working space, and amenities occupying urban blocks. The function “housing” included various residential dwellings, such as apartments, condominiums, and townhouses. The function “working” encompassed offices, factories, and laboratories. The function “amenities” covered commercial facilities such as shopping centers, schools, and universities in addition to leisure facilities such as sporting arenas, cinemas, concert halls, and museums. Hereby, the MXI is defined as: MXI = (%Housing / %Working / %Amenities).

4.3.3 Degree of inter-accessibility of the mobility network

Hillier develops an argumentation by properties of space. He distinguishes accordingly between extrinsic and intrinsic properties of space. Extrinsic properties determine how spatial units relate to one another. In this respect, we conceive configurative laws of space. If we intend to understand settlements in terms of these laws they are regarded as sets of spaces. Primarily topological issues become relevant as volume, texture and size are not taken into consideration. When regarded in purely extrinsic terms spaces are shape free. It is solely their inter-relational aspects or structure that is at issue. Every space has one or more functions either in terms of occupation or with regard to movement (Hillier, 1999e, p. 1). Extrinsic properties of space determine both built form and its possible function.

While extrinsic properties of space consist of invisible, structural relationships, intrinsic properties are visible, such as shape, size, volume, and texture of physical objects or built mass. Intrinsic properties present themselves mostly through geometrical properties. They account for the articulation of social meaning via built form (Hillier, 1999e, p. 1). We have many words for describing the intrinsic properties of space. Words like “a narrow street, a large square, a massive building etc.” make it possible to describe the artefacts of a city.

Space syntax focuses on extrinsic properties of space. The method calculates how each street is related to all others in terms of the total number of direction changes and the degree of angular deviation. In SPACERGY we used the following measurements: Through-movement potentials and To-movement potentials.

The following through movement potential measurements were used:

- Local angular integration with a high metrical radius: “Choice R5000 metric” - show how each street is connected to its vicinity in terms of a high metrical radius. Here in this case (with a geo-referenced axial map) it is 5 km. Shows how integrated a street segment is in a large metrical radius. Highlights the potential through-movement routes running through or around urban neighbourhoods.
- Local angular integration with a low metrical radius: “Topological Choice R500 metric” - show how each street is connected to its vicinity in terms of a low metrical radius. Here in this case (with a geo-referenced axial map) it is 500 meters. Shows how integrated a street segment is in a short metrical radius. Highlights the potential through-movement routes inside pedestrian based local centers.
- Local segment integration with a high metrical radius: “Integration R5000 metric” - show how each street is connected to its vicinity in terms of a high metrical radius. Here in this case (with a geo-referenced axial map) it is 5 km. Shows how integrated a street segment is in a large metrical radius. Highlights the potential to-movement routes for various local big centers in a city.
- Local segment integration with a low metrical radius: “Integration R500 metric” - show how each street is connected to its vicinity in terms of a low metrical radius. Here in this case (with

a geo-referenced axial map) it is 500 meters. Shows how integrated a street segment is in a short metrical radius. Highlights the potential to-movement routes to pedestrian based local centers.

- Angular step depth from one or several street segments “Angular Step Depth” – shows how all street segments are connected from one particular segment in terms of angular deviation. The red lines show the streets with the highest integration values, while the blue ones shows the most segregated ones. In SPACERGY we did the angular step depth analyses from all the tram stops with purpose to identify the degree of orientability from these stops to their vicinity.

4.4 WP5: Building energy demand prediction

4.4.1 Methodology

Dynamic energy demand models for the Zürich and Almere living labs were developed in order to analyze the demands for each scenario. The work was carried out in the City Energy Analyst (CEA), a computational framework for the analysis and optimization of energy systems in neighborhoods and city districts. CEA comprises a collection of physical models for the simulation of energy demands and supply in the area of study as well as statistical databases containing building properties for typical archetypal buildings as well as operating parameters and schedules.

The CEA demand model involves the calculation of all energy flows (heating, cooling, electricity) from the building meter (i.e., from the district-scale utility) to the end user. Figure 3 shows the full chain of the energy demand model in CEA. The calculation takes place in the following order: first the heat gains (due to solar radiation Φ_{sol}, due to occupant presence Φ_{occ} and due to lighting and appliances $\Phi_{app/lig}$) as well as transmission losses through the envelope (Φ_T) and through the ventilation (Φ_{ve}) are calculated at the room / end user level, then the demands for hot water (Φ_{ww}), space heating (Φ_{hs}) and cooling (Φ_{cs}) are calculated given the aforementioned boundary conditions. Finally, distribution losses for each of these thermal demands as well as auxiliary electricity needs to operate building systems such as fans and pumps are calculated, which provide the final, building-level demand for heating, cooling and electricity from the utility.

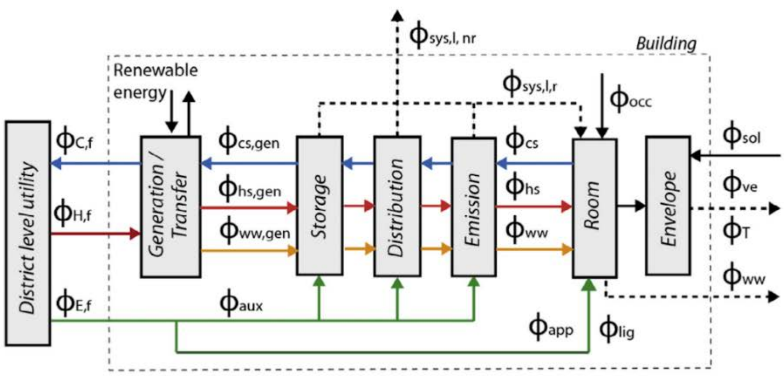


Figure 3 Simplified heating chain showing the subsystems and heat flows of the heating, cooling, and electricity supply chains in the buildings as well as solar and internal gains and ventilation and transmission losses (Fonseca & Schlueter, 2015).

CEA includes deterministic schedules for 18 building functions (such as single- and multi-family residential, once, school, etc.), which mainly arise from SIA standard 2024 (SIA Merkblatt 2024, 2006).

At the beginning of the simulation for each building, yearly schedules of occupant presence and associated indoor comfort parameters, as well as schedules of electricity and hot water consumption are calculated. In addition to this deterministic model, CEA includes the option of using the occupant presence model of Page et al. (Page, Robinson, Morel, & Scartezzini, 2008) as an alternative occupant modeling option in the tool. In this model, each occupant's presence is modeled as a two-state Markov process in which transition probabilities between the states “absence” and “presence” are calculated at each hour of the year for each user in the area.

Once the schedules for the year have been defined, the energy of each building can be calculated. The end use demands for lighting, appliances, processes, refrigeration, data centers and domestic hot water are simply calculated through the aforementioned schedules and user inputs for demands per unit of floor area (e.g. W/m^2 of electricity for lighting or appliances) or per person (e.g., liters of water per person per day, or liters of ventilation per person per second). The thermal loads in a building are strongly dependent on the heat gains from solar irradiation as well as the internal gains from occupant activities, electrical demands, etc. Therefore, only after all of the previously-discussed modules can the thermal loads in the building finally be calculated.

The CEA thermal loads model is based on a simplified resistance-capacitance model as described in ISO (ISO 13790, 2008) and SIA standards (SIA Merkblatt 2044, 2011). The CEA model is an adaptation of the simple hourly method described in SIA 2044 (SIA Merkblatt 2044, 2011). Each building in the area is represented by a single thermal zone, meaning that the building interior is assumed to be well-mixed with no effects of partitions, occupant distribution within the building or localized temperature differences. The building material properties, solar and internal gains are then represented as resistances and capacitances in an electrical circuit, as shown in Figure 4. In this system is composed of four nodes representing the outdoor air (which is at temperature θ_e), the indoor air (which is at temperature θ_a), a surface node (which is at temperature θ_c), and a node in the building's thermal mass (which is at temperature θ_m). These nodes are connected by resistances representing building materials and systems, whose heat transfer coefficients are shown and described in the figure. The solar gains and the internal gains in the building are distributed among the three indoor nodes. The building also has an effective mass area and an internal heat capacity, which represents the thermal inertia in the building thermal mass.

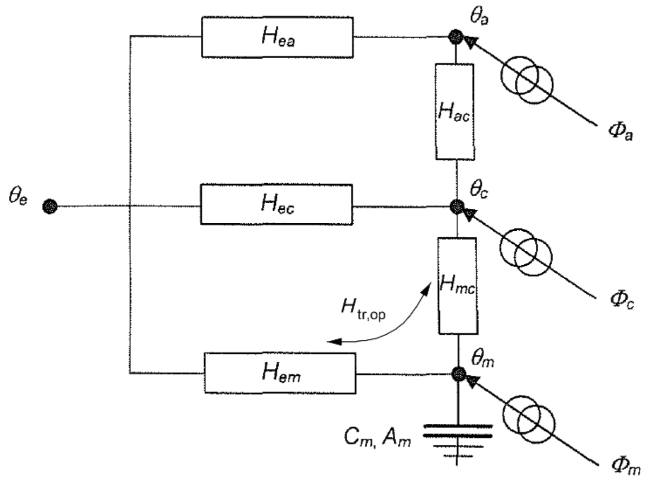


Figure 4 Resistance-capacitance (RC) model used in CEA (adapted from (SIA Merkblatt 2044, 2011)). θ_e,θ_a,θ_c,and θ_m are the temperatures of the exterior air, indoor air, surface node, and building thermal mass, respectively. H_{ea} is the air heat flow coefficient of the ventilation systems, whereas H_{ec} and H_{em} are the transmission heat coefficients lightweight and heavyweight building materials, respectively, and the heat transfer coefficients between the air and surface node, and between the surface node and the thermal mass are H_{ac} and H_{mc}, respectively. The internal and solar gains in the air, surface and thermal mass nodes are Φ_a, Φ_c and Φ_m, respectively. Finally, C_m and A_m are the internal heat capacity and effective mass area of the building.

Finally, given the sensible and latent loads of the occupied spaces of the building, the losses during distribution of heating and cooling to the room and from the emission systems providing them can be calculated. Auxiliary electricity demands for operating the pumps and fans required by these systems are calculated.

4.4.2 Results

The results for two different models are presented and discussed. The first one is the Status Quo, that is, the area at the time of publication of the new Masterplan for the area, 2014. The necessary information about 3D geometry, materials, occupancy and mechanical components was obtained from GIS data, owner information and the archetype database. Data on energy-relevant retrofits for the main building components was scarce and thus estimated. The second model present corresponds to the SPACERGY Baseline scenario, which is roughly based on the 2014 Masterplan for the area.

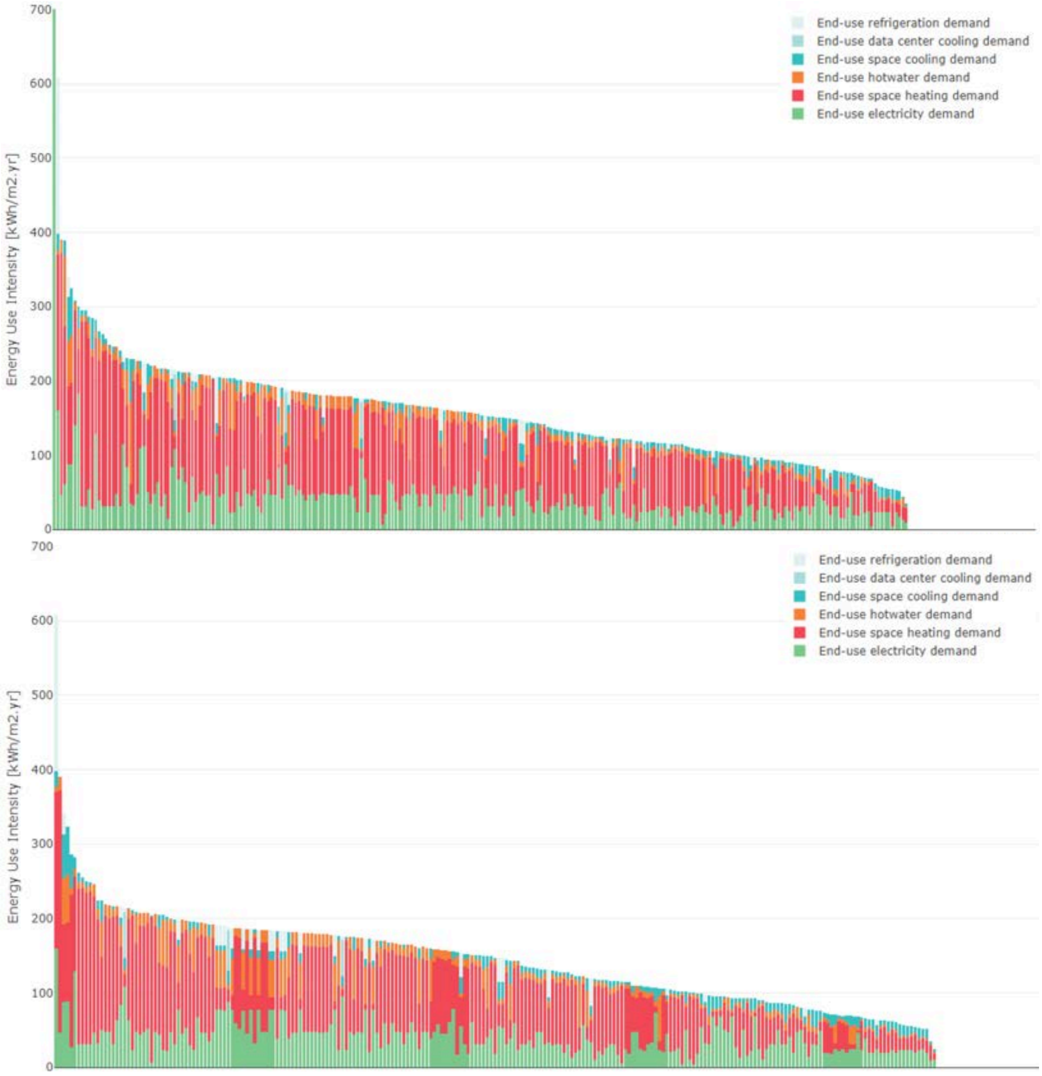


Figure 5 Energy use intensity (kWh/m^2-yr) for space heating and cooling, domestic hot water and electricity for each building in the Status Quo (top) and Baseline scenario (bottom).

The results show that the demand for heating per square meter in the Baseline is significantly reduced due to the construction of highly-insulated buildings, but the demands per square meter for electricity and cooling increase with increased usable floor space. The University Hospital and ETH Zürich are the largest consumers for both the Status Quo and Baseline scenario due to their large built areas and highly energy-intensive functions. The University of Zurich's demands are much lower, but increase in the Baseline scenario due to its increased usable floor space in this scenario. Other buildings in the area hosting complementary functions such as residential, gym, and restaurants have a comparatively much smaller impact on the demands in the area.

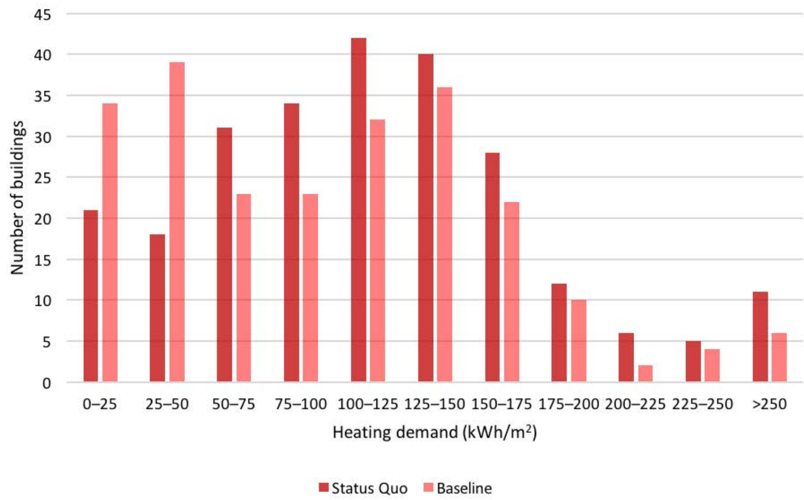


Figure 6 Frequency of space heating demands in the area for the Status Quo and Baseline scenario.

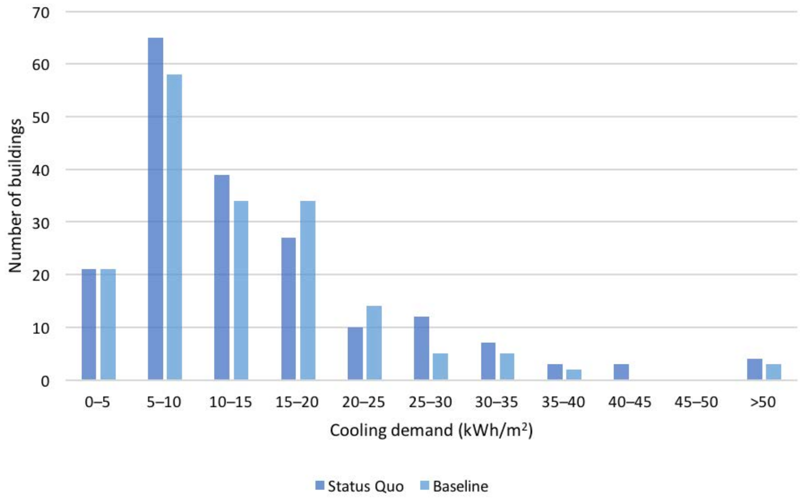


Figure 7 Frequency of space heating demands in the area for the Status Quo and Baseline scenario.

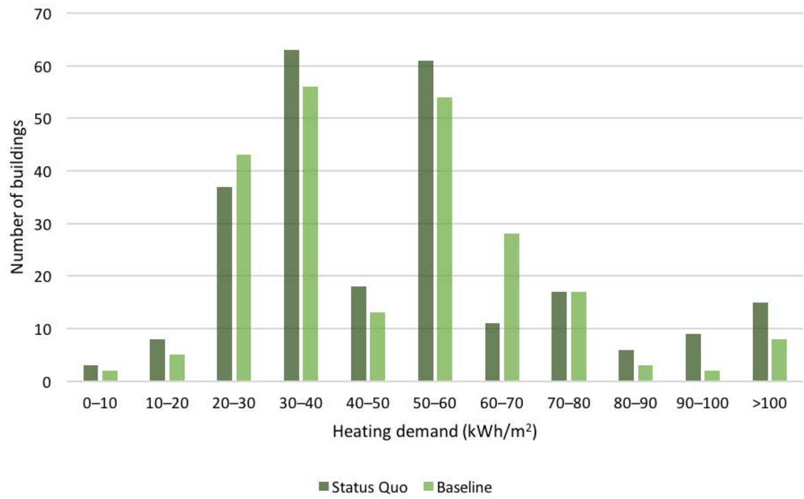


Figure 8 Frequency of electricity demands in the area for the Status Quo and Baseline scenario

Due to the increase in energy efficiency in the buildings in the area and the introduction of low emission cooling infrastructure, the overall performance of the area in the Baseline scenario is better than in the

Status Quo. Nevertheless, 2000 Watt Society targets are not met, and hence further proposals need to be made to reduce the operating emissions and primary energy demand of the area in order to meet this goal.

4.5 WP6: Mobility energy demand prediction

4.5.1 Methodology

Multi Agent Transport Simulation MATSim is a microscopic simulation environment that is able to cope with macroscopic level assignments. Discrete agents and their simplified interactions are simulated based on day plans on a node-link network with specific configuration parameters. After the simulation, the realized plans are scored according to scoring parameters and a new plan is constructed by modifying a selected plan with innovation strategies. This allows MATSim to target both large scale effects and also show impacts of small scale changes on the whole system.

Looking at the current mode share in the Hochschulquartier, public transit and walking are the predominant modes of access to the district. With three campus-centered institutions, many pedestrians concentrate on the roads and sidewalks. MATSim, however, focuses on car and public transit systems. With the multimodal contribution, comparable to a plugin, walk and bike modes got introduced.

A scenario in MATSim consists of at least the following core parts:

- Config – Configuration file with all relevant input settings
- Network – Links between Nodes with attributes
- Population – Individual agents with day plans and attributes

4.5.1.1. Network

To incorporate pedestrians and cyclists, a base decision had to be taken: How to implement the walk capabilities into the network? On the one hand, each road could be considered walkable and thus all the links could be extended with the walk attribute in the allowed modes. On the other hand, there are roads that have limitations in crossing possibilities and also pedestrian/cyclist paths, that are not contained in the network, as they did not serve any purpose in simulating cars.

As a mixed approach, the following has been pursued:

- Inside Hochschulquartier, bigger arterial roads have separated sidewalks with designated pedestrian crossings, all other existing roads have been made walkable by adding walk and bike to the allowed modes. Pedestrian and bike paths previously nonexistent have been added. Additionally, as facilities have only one access link, the inside of certain buildings have been modelled so entrances and exits are used in the right way.
- Outside Hochschulquartier, the existing network, with the exception of motorways, has been made walkable by adding walk and bike to the allowed modes of all car links.
- Between Hochschulquartier and Zurich main station as well as Zurich Stadelhofen, the two main access points to national and suburban rail traffic, special care was taken to ensure realistic access to the station facilities.

4.5.1.2. Population

The populations file contains all agents with their attributes and different day plans. Attributes include age, sex, car availability, driving license, season ticket availability and potentially more. For the day plans, the first and last activity (usually home) need to be the same. In between, a chain of activities and legs can be defined with variable degree of freedom.

First the plan was to enrich the plans of existing agents that attend activities in the Hochschulquartier with enrollment data presented below. This would have allowed to keep the whole scenario and have the relevant part of it in more detail. The Zurich scenario is, however, purely synthetic and the facilities are aggregated on a hectare raster according to their type of activity. This meant that no differentiation could be made between buildings.

On the assumption, that there will be no substantial changes outside of the Hochschulquartier regarding settlement and infrastructure, only agents working and studying within the Hochschulquartier were taken into consideration for the generation of the Population. All other agents were completely removed from the scenario. Residents to the district were not considered in in the composition of the agent segments as their contribution to transportation factors is negligible in this example.

Table 1 provides an overview of the different agent segments, magnitudes and input data sources.

Table 1 Agent segments, magnitudes and input data sources

Agent segment	Magnitude	Input source
ETH students	15’000	Enrollment data
UZH students	15’000	Enrollment data
ETH employees	5’000	Internal phone registry
UZH employees	5’000	Internal phone registry
USZ employees	1’000	Executive report

Both ETH and UZH provided enrollment data for each student. It contains home information or where handing-over to third parties is not allowed, the Heimatort, the swiss quasi-equivalent to place of origin. Furthermore, it contains all lectures, seminars and exercises the student is enrolled in. As courses can be parallel, a priority list was assumed, and a linear day plan was constructed for each student. For the home facility, the information on the home location was used. Where home location lay outside of the perimeter, agents were distributed in the same way the perimeter-insiders were distributed.

Both ETH and UZH could not provide exact data on employee presence. They referred to phone book data which states the office location and phone number for each individual employee. Based on this data, standard deviations were used to determine the start of the day and working hours with a lunchbreak in between.

University hospital pointed to the staff section of their executive report. The number of employees for a regular weekday was estimated based on the total number and the number of full-time equivalents. These employees were assigned a normally distributed start and end time for both their morning and afternoon shifts with a one-hour lunchbreak, the same way the employees of ETH und UZH were handled. Earlier starting and later end hours were account for with bigger standard deviations in the distributions.

A hospital, compared to a regular institution or company. has also night shifts. An inquiry was made on how many employees work in the night hours. Agents with night shift schedule were then incorporated into the population.

Patients were excluded from the calculations, as information was not provided. Considering the size of the hospital, the numbers are probably significant and should thus be considered in an iteration to the scenarios.

4.5.1.3. Facilities

Facilities are the constructs where agents can conduct their activities. The activity options can have a capacity or be bound to opening times. A facility has always a single access link in the network. In the existing scenario, facilities were aggregated based on their function on a hectare raster. This meant, that the singular buildings were not distinguishable.

- Inside *Hochschulquartier*, a facility was placed by hand at the location of every major building. Smaller buildings with little occupancy and spatial vicinity were clustered. For transportation, this generalization is negligible. Additionally, important lunch establishments inside the district got their own facility to model lunch behavior.
- Outside *Hochschulquartier*, facilities were placed automatically at the center of the swiss Zip-code districts, obtained from state data. This has implications on transportation and mode share patterns. This trade off had to be made, as generating a synthetic population and their homes for these very specific user segments would have made the task far too complex.
- The other campuses (ETH Hönggerberg, UZH Irchel and UZH Oerlikon) are represented by a single facility. This is acceptable, as focus lies on the *Hochschulquartier* and small spatial variance at the destination point does not influence transportation patterns.

4.5.2 Results

Due to many challenges within the MATSim framework, transport planning analysis of the scenarios is still in process and measures will be tested for the final report.

4.6 WP7: Partial energy model development

4.6.1 Urban morphology and energy demand from buildings

4.6.1.1. Methodology

In order to simulate the microclimate effects in the area and the energy demands of its buildings, ENVI-met 4.0 and City Energy Analyst (CEA), respectively, are used in this study. These software tools have been described in detail in previous work packages and hence are only discussed here insofar as relevant to their integration.

The aim of the coupling method is to model the energy demand of a number of buildings on a district scale level, by taking into account the various factors that are co-responsible for the energy performance: microclimate environment, locus and topographic context, building geometry and materials, energy systems as well as user behaviour. Common input for the two software packages are the spatial characteristics of buildings and the macro atmospheric data from a weather station.

Moreover, for the coupling approach types of employed spatial units have been taken in account. In the first place the two models differ in their spatial components. In ENVI-met, building entities are composed of a number of 3D cells or alternatively of meshes for the building facades and ground surfaces. Differently in CEA, buildings are single entities with 3D characteristics which emerge from a process of extrusion from a polygon area. Complex 3D geometries however are not supported and articulated building shapes imposes to split the overall geometrical entity according to the diverse heights. In order to establish a connection between the microclimate data and the CEA model linking steps that aggregate the data for the CEA spatial units are introduced, using a GIS tool.

Differently from previous studies (Yang, Zhao, Bruse, & Meng, 2012; Dorer, et al., 2013) where the linking units are defined as vertical and horizontal planes (exterior walls, roof and ground floor), here the unit is the building 3D shape, which allows to consider the building entity as an absolute mediator between inside and outside conditions.

The method to convert ENVI-met output into CEA input consists of three main phases. In the first phase, the spatial model for the selected case study is built in ENVI-met 4.0 and simulations are performed using the simple forcing method using weather data for the selected days. Secondly, output data for air temperature, wind speed and relative humidity are exported and aggregated in a 3D buffer around single buildings in a GIS platform. In the third phase, the aggregated data are imported in the CEA software and used as boundary climatic conditions for the calculation of the energy demand for each building in the simulation domain.

The method has been applied to assess the building energy demand in the Zurich and Almere case study.

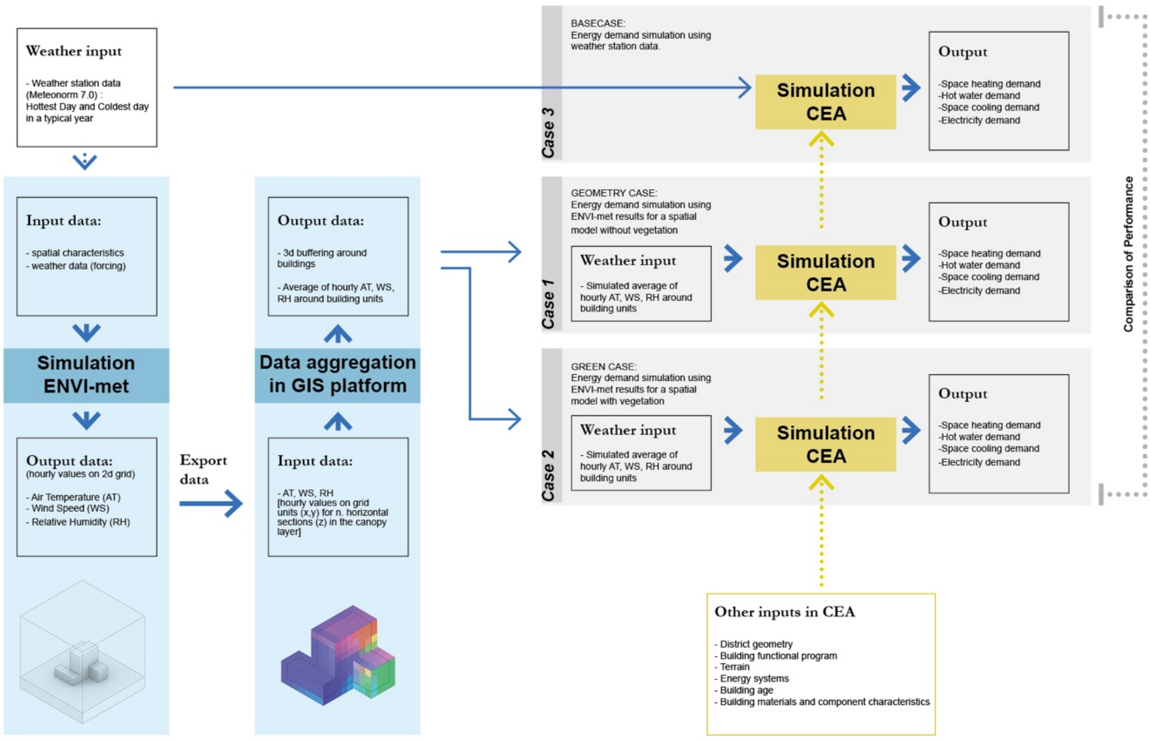


Figure 9 Methodological scheme for Zurich case

4.6.1.2. Results of Zurich case

From the results some general conclusions can be drawn. First, from a microclimate perspective, an evident atmospheric urban heat island phenomenon is observed in the area. Compared to the measured data from the weather station, local temperatures are higher during the night and wind speed is mitigated for the two days analyzed. The consideration of these local climatic patterns in energy demand calculation leads to a general increased building cooling demand on the hottest day, representing the cooling season, and a lower building heating load during the coldest day, representing the heating season. The difference in impact for the buildings taken into consideration likely depends on the level of envelope insulation and air tightness, position and geometrical characteristics of different buildings.

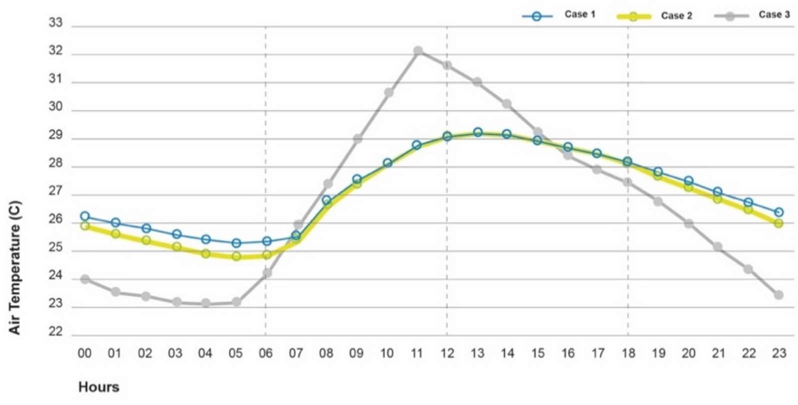


Figure 10a Comparison of the meteorological air temperature from weather station (Case 3) and average air temperature around the buildings in Case 1 and 2 (resulting from ENVI-met) for the hottest day in a typical year.

Figure 11a Comparison of the meteorological wind speed from weather station (Case 3) and average wind speed around the buildings in Case 1 and 2 (resulting from ENVI-met) for the hottest day in a typical year.

Figure 12a Comparison of the meteorological relative humidity from weather station (Case 3) and average relative humidity around the buildings in Case 1 and 2 (resulting from ENVI-met) for the hottest day in a typical year.

Due to the general low wind speed and its little variation in the area, heat transfer by wind convection on building envelopes has likely an almost insignificant impact on energy load variation during the hottest day. Therefore, we argue that on this day, air temperature and relative humidity variations are the main responsible microclimate factors for the deviations in building energy demand. Previous studies also found that air temperature change is the main factor that affects energy load variation (Sailor & Muñoz, 1997; Fung, Lam, Hung, Pang, & Lee, 2006).

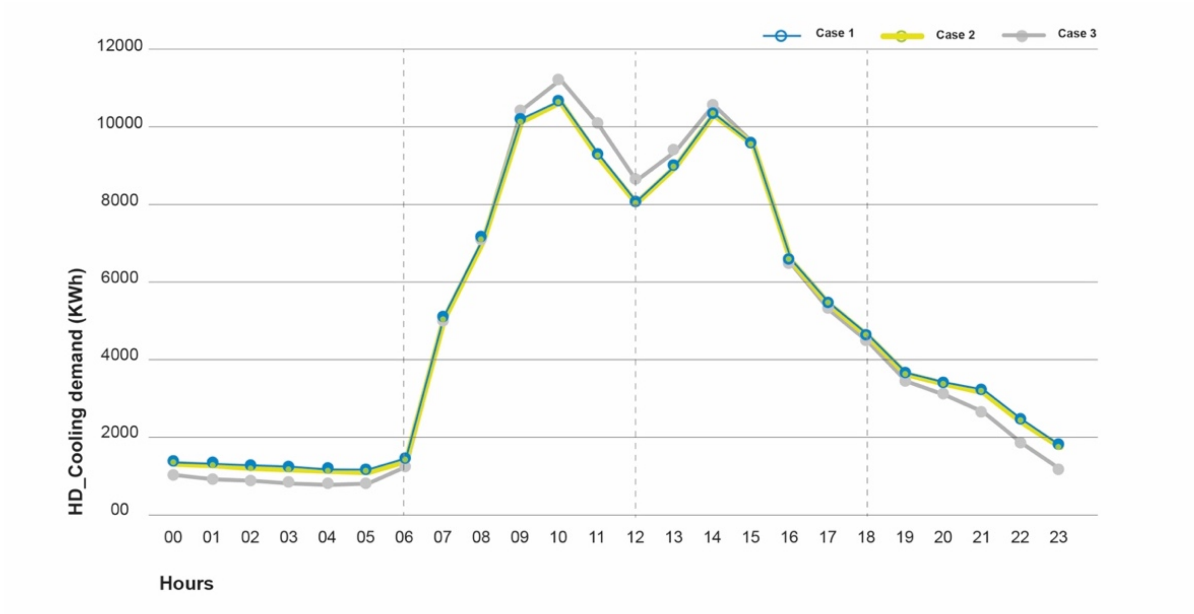


Figure 13a Comparison of hourly cooling load for the three cases on the hottest day in a typical year.

Green areas and vegetation around buildings clearly affect the space cooling demand as a consequence of the cooling effect by evapotranspiration on air temperature in the night hours. However, it is an important factor also in winter days since it contributes to lower space heating demand. The reason could be found in the capacity of vegetation to lower wind speed (in the coldest day) and resulting heat losses thought the building envelopes.

A sensitivity study is conducted to understand the individual impact of parameters used in the coupled modeling on variation of energy loads. Different variables are found to be statistically significant predictors. Occupied hours, average envelope U-value, and Floor Space Index have an impact on the variation in both heating and cooling demand when microclimate boundary conditions are used in CEA. In particular, the density of the building surrounding calculated with radii of 50 and 100 meters appear to be an important factor that mediates between form and microclimatic processes.

Table 3. Regression analysis

			Unstd. Coeff.		Std.Coeff.		
Model	**R square**	**Variables**	**B**	**Std. Error**	**Beta**	**t**	**Sig.**
Heating_HeC3_WMnoV	0.410	(Constant)	-.762	1.595		-.478	.635
		occupied hours	-.181	.042	-.522	-4.350	.000
		avg. U-value	-1.376	.520	-.316	-2.648	.011
		FSI_50	-.584	.258	-.473	-2.266	.029
		~~FSI_100~~	~~.739~~	~~.384~~	~~.402~~	~~1.923~~	~~.061~~
HeC3_WMwV	0.330	(Constant)	-7.481	3.413		-2.192	.034

		occupied hours	-.453	.114	-.515	-3.978	.000
		FSI_50	1.066	.398	.340	2.681	.010
		~~Green_area_100~~	~~.000~~	~~.000~~	~~.255~~	~~1.962~~	~~.056~~
Cooling_CoC3_WMnoV	0.715	(Constant)	-10.95	7.034		-1.557	.127
		occupied hours	1.544	.183	.714	8.449	.000
		Avg. U-value	11.784	2.315	.434	5.090	.000
		~~Surface exposed~~	~~.000~~	~~.000~~	~~.160~~	~~1.721~~	~~.093~~
		FSI_50	3.893	1.249	.505	3.118	.003
		FSI_100	-6.716	1.798	-.586	-3.735	.001
CoC3_WMwV	0.673	(Constant)	-15.39	7.967		-1.933	.060
		occupied hours	1.638	.207	.715	7.912	.000
		Avg. U-value	10.527	2.622	.366	4.014	.000
		Surface exposed	.001	.000	.228	2.297	.027
		FSI_50	3.547	1.414	.435	2.508	.016
		FSI_100	-6.513	2.037	-.537	-3.198	.003

4.6.1.3. Results of Almere case

The same method applied in the Zurich case study was used to simulate the energy demand of the planned energy-neutral residential area in Almere, Netherlands, on an extremely hot day. The project for the Floriade district was developed with the initial purpose of hosting the International Horticultural Expo in 2022. However, the new city neighborhood has been designed to accommodate 660 new residential units after the event and become an example for sustainable and livable urban areas. Surrounded by a lake and conceptually structured on an orthogonal grid, the site design is shaped by the 'arboretum', a green structure composed by 3000 plant species. Only the new street network and buildings are modelled in the first scenario, while green areas and trees are included in the second scenario.

The simulation results of the two scenarios were compared with the measured data from the weather station in Lelystad. The hourly patterns for the variables of air temperature, wind speed and relative humidity are analyzed at the scale of the district. In the extreme hot day under analysis, a significant variation in average air temperature around the 260 buildings is observed. While the meteorological station reaches a maximum temperature of 34°C, local temperatures at the Floriade rise to 35°C in scenario 1 (without vegetation) and to 37°C in scenario 2 (with vegetation). Air temperatures in the early hours of the day (until 10 am) and in the late afternoon (after 8 pm) are similar for the two Floriade scenarios and the rural weather data. Conversely, during day time, local Floriade air temperatures are significantly higher than rural ones with a maximum difference of 3.4°C and 1.6°C for the scenarios with and without vegetation, respectively. The simulation results strongly indicate that the presence of vegetation in the district contributes to increasing air temperatures during the central hours of the day. These results are in contrast with previous findings regarding the cooling effect of greenery in urban areas.

However, a second comparison in shows a significant decrease in wind speed, which drops from a maximum of 4 m/s in the rural measurement to 1.7 m/s in the scenario without vegetation and further decreases when vegetation is taken into consideration. Finally, data of local relative humidity are found to be higher along the entire day except for the hours between 3 and 5 pm.

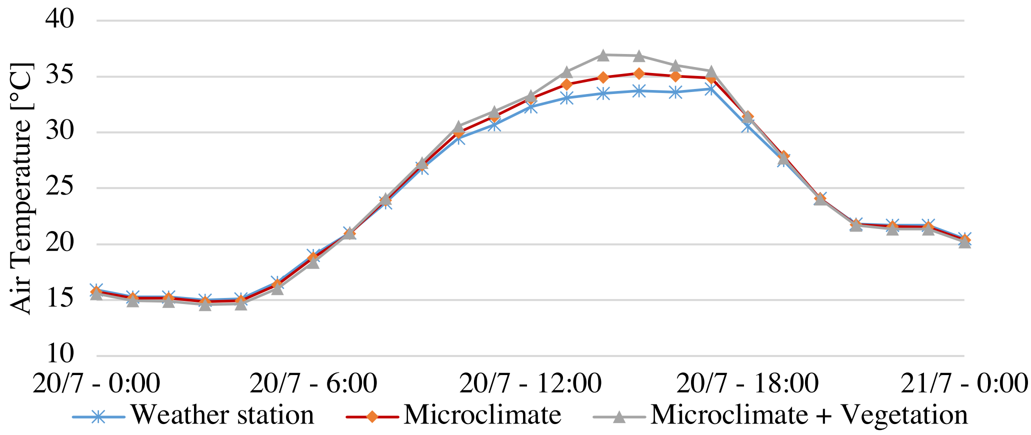


Figure 10b. Average air temperature for all buildings in the area for both microclimate scenarios compared to the measured air temperature from the weather station in Lelystad.

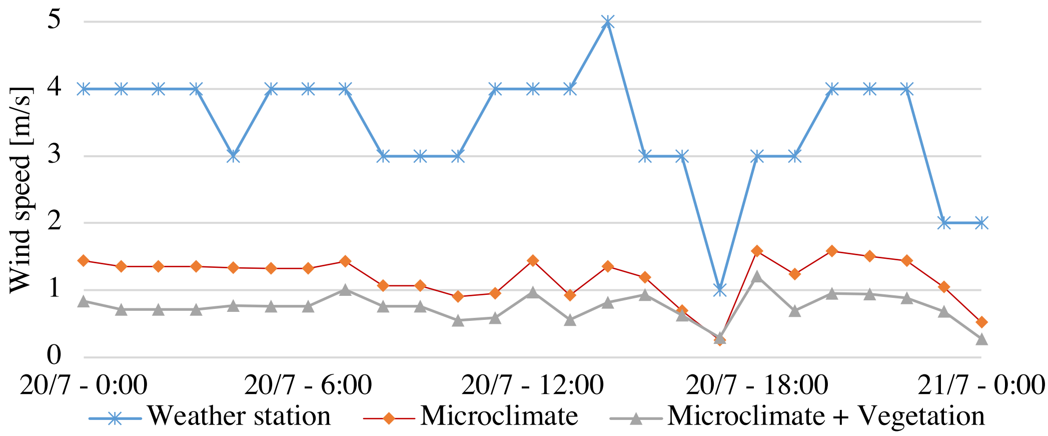


Figure 11 b. Average wind speed for all buildings in the area for both microclimate scenarios compared to the measured air temperature from the weather station in Lelystad.

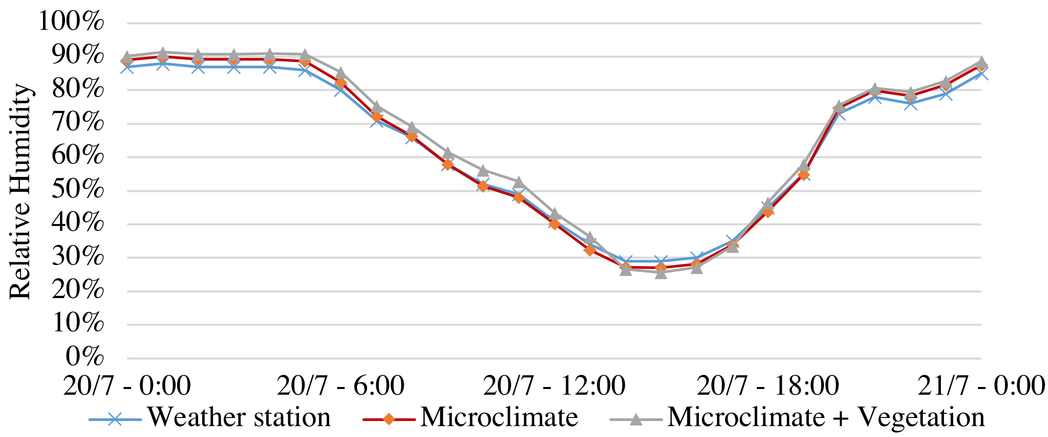


Figure 12b. Average relative humidity for all buildings in the area for both microclimate scenarios compared to the measured air temperature from the weather station in Lelystad.

The Urban Heat Island phenomenon that emerges from the simulation results is characterized by higher temperatures in the urban district compared to the rural area during the daytime. This type of pattern has been observed for both Floriade scenarios and average temperatures result to be even higher when the green structure is modelled. This finding appears to be in contrast with previous studies that support urban vegetation as an important strategy to mitigate the UHI effect (Shishegar, 2014; Oliveira, Andrade, & Vaz, 2011).

However, in literature the cooling effect of green areas and trees is observed mainly in tropical and arid urban environments (Wong & Yu, 2012; Chen, Wang & Yuan, 2012, Chow & Roth, 2006) with relatively low wind speeds or when methods that do not consider wind velocity in the modeling are employed Chun & Guldmann, 2018). In the specific case of Floriade, the combination of a low building density, high ambient wind speed and the presence of a (cooling) lake upwind gives rise to the hypothesis of a relation between the decrease in wind velocity caused by the vegetation and the type of Urban Heat Island observed.

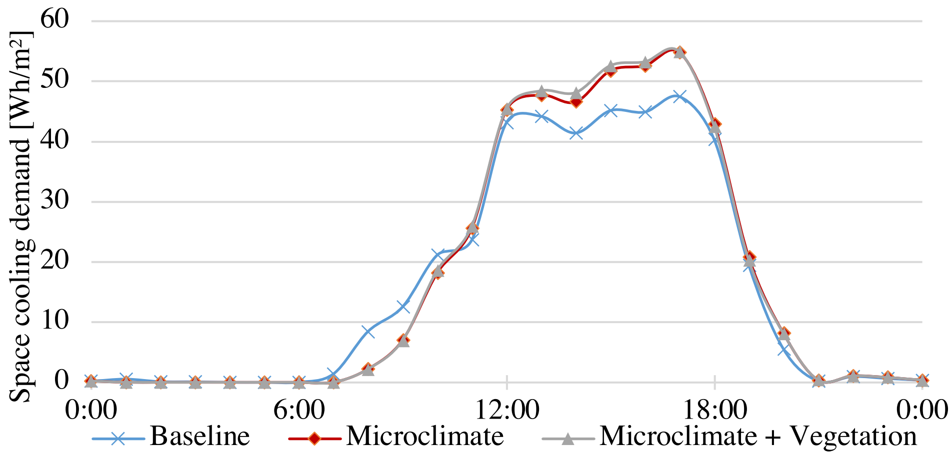


Figure 13b. Hourly space cooling demand per square meter for the district for all three cases.

The hourly demand for cooling in the district for the baseline case and both microclimate scenarios are shown in Figure 26. The results show that during night-time there is no cooling demand in any of the scenarios even on this extreme day. For the baseline case, buildings start cooling earlier, but the peak is considerably lower during the day. For all buildings in the area, the inclusion of microclimate data causes the cooling loads at midday to be higher due to the higher outdoor temperature and humidity. The high variation in wind speed likely does not cause much of an effect in terms of energy demand in the buildings, as wind speed only affects infiltration in the CEA model, whereas all buildings were assumed to be highly airtight. Over the entire day, the inclusion of microclimate results in the simulations causes an increase in the cooling demand of about 6%, whereas further incorporating the effects of vegetation causes an increase of 7% with respect to the baseline.

4.6.2 Urban morphology and energy demand from mobility

4.6.2.1. Methodology

Energy usage in cities is intertwined with their spatial configuration – the denser and more compact the city is, the more concentrated the use of energy. To achieve sustainable communities, cities (and its inhabitants) must reconsider the spatial structure of its mobility network. To facilitate a transition to energy efficient environments, how urban spatial configurations affect energy usage in cities must be understood. Focusing on mobility and transport, which account for 25% of energy usage in cities, this approach asks: what are the factors of urban form and networks that affect patterns of movement and choice of transport mode in relation to energy usage? Using a quantitative analysis of spatial elements influencing mobility choices with Space Syntax, we demonstrated how spatial configuration and degree of walkability relate to energy usage for mobility (Figure 14). By correlating the spatial analysis data with energy consumption data obtained from measured and simulated traffic data, findings show that street segments with both a high level of local and global spatial integration tend to exhibit lower amounts of energy usage for car traffic. This suggests that cities with highly integrated streets advance walkability and the choice for sustainable means of transport (i.e. cycling and public transport) which then reduces energy usage.

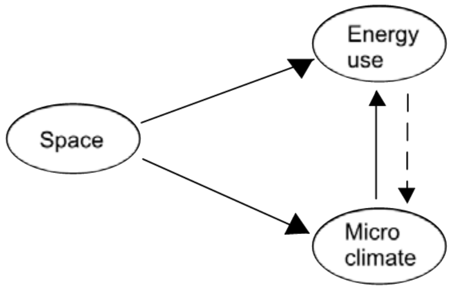


Figure 14 Schematic hypothetic relationship between space, microclimate (or microscale), and energy usage

Aiming to examine a correlation between the configurational street structure, building density, functional mix, walkability and energy usage, a form of mixed-method approach (Creswell, 2009) needed to be applied. Although the study does not contain qualitative research elements per se, some of the data can be said to have a qualitative origin. The spatial configuration of the street structure describes extrinsic properties of space. That is, no meaning is given to the urban form; it purely reveals how function, i.e. movement, follows from the spatial structure of the street network (van Nes, 2017). It is all about built form and function and not about built form and meaning.

Space Syntax methodology is at the basis of analysis of the spatial structure of the street network. This street network is represented in the segment map, based on a hand-drawn axial map following the principle that the fewest and longest set of axial lines of visibility and accessibility cover all convex spaces in a spatial system (Hillier et al., 1993:13). Throughout the years, the calculations with the Space Syntax method have been refined. At present, the two main analysis methods used are segment integration and angular choice (Hillier et al 2007). The latter can predict to-movement potential, while the latter predicts through-movement potential.

Potential to-movement gives an indication of how likely a street is to be a destination of a route. To estimate to-movement potentials, we perform angular segment integration analyses on two scale levels: 500 meters, representing the local or walking scale, and 5000 meters, representing the city-wide scale. Results reveal "how close each segment is to all others in terms of the sum of angular changes that are made on each route" (Hillier & Iida 2005).

Through-movement potentials indicate how likely a street is used as part of a route. Values are obtained through angular choice analysis, which is a result of "counting the number of times each street segment falls on the shortest path between all pairs of segments within a selected distance (termed 'radius'). The ‘shortest path’ refers to the path of least angular deviation (namely, the straightest route) through the system” (Hillier & Iida, 2005).

Values generated by angular choice analyses are then aggregated per case with a 35-meter buffer around both sides of each segment, creating aggregated areas for each integration level. This value is based on various research concluding that a dense street network with a fine mesh size of between 60-80 meter performs better than larger blocks, both when it comes to increased circulation and the exploitation possibilities of the urban block (Jacobs 2000; Siksna 1997:25). Showing angular choice for high and low radius simultaneously helps to find out which areas are well integrated into the local street network, and enjoy good accessibility on city scale. We are applying the natural break – or Jenks – method in this project to classify the resulting spatial values from angular choice as low (L), medium (M) or high (H). This allows for a combination of nine categories (see Table 2).

Table 2 Aggregated angular choice categories

		Angular Choice with Low radius (R = 500 m)		
		Low	Medium	High
Angular Choice with High radius (R = 5000 m)	Low	LL	LM	LH
	Medium	ML	MM	MH
	High	HL	HM	HH

MATSim is an agent-based program for making large-scale transportation simulations. Agents, representing residents, are assigned a home address and a job or study location. Daily activity schedules can be appointed or generated, after which the agents will choose a travel itinerary based on the transportation options available. The agents’ route-choice and mode-choice between their origins and destinations is then made based on travel time and costs. The simulation accuracy depends on the amount and the level of detail of the parameters programmed into the model. Only necessary activities are simulated into the MATSim model. Optional and social activities cannot be aggregated in MATSim.

Since pedestrians and cyclists move around using energy they ‘produce themselves’, the energy usage by cars is the one mode that is useable for comparing energy consumption with to-movement and through-movement potentials. Agent-based MATSim simulations could however demonstrate a change in the agents’ choice of mode of transportation, for example, if a change occurs in the public transport network or a change in the road network.

Energy is calculated per street segment, and relevant parameters should give information about the amounts of vehicles that use a specific street segment, and how much energy each vehicle consumes. For this analysis, data generated through (MATSim) are used as input. This input data are maximum traffic speed (see Figure 15, left) and amount of (private) vehicles observed (see Figure 15, right).

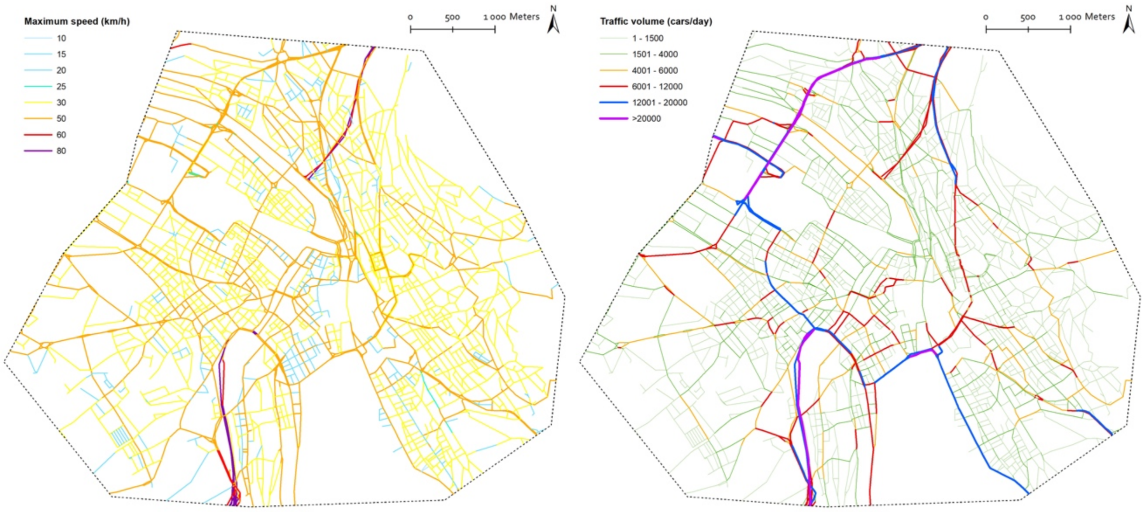


Figure 15 Amount of (private) vehicles observed and maximum traffic speed.

So far, these two case studies have shown that short urban blocks (or a fine-grained urban mobility network within a short metrical distance), integrated main routes running through neighbourhoods with short urban blocks, constituted and intervisible streets from adjacent buildings are complex necessary conditions for enhancing sustainable transport means in terms of facilitating public transport and high degree of walkability.

All these parameters need to be present at the same time to make neighbourhoods attractive to walk. Moreover, neighbourhoods with these spatial features tend to transform themselves naturally to highly urban areas with high building densities and a high degree of land use diversity (Ye and van Nes 2014).

4.6.2.2. Results

Figure 16 (left) is a representation of aggregated choice values on both the local and the global scale. High values have a dark shade, and color red if global integration is higher than local integration and green if local integration is higher than global integration. By correlating the maps in Figure 16 with one another, we see that areas with high or medium local values score lowest in energy usage. High global values seem to push up energy usage systematically., high local values are placed to the right, scoring lowest in energy use, while low local values are consistently placed to the left, scoring high in energy use.

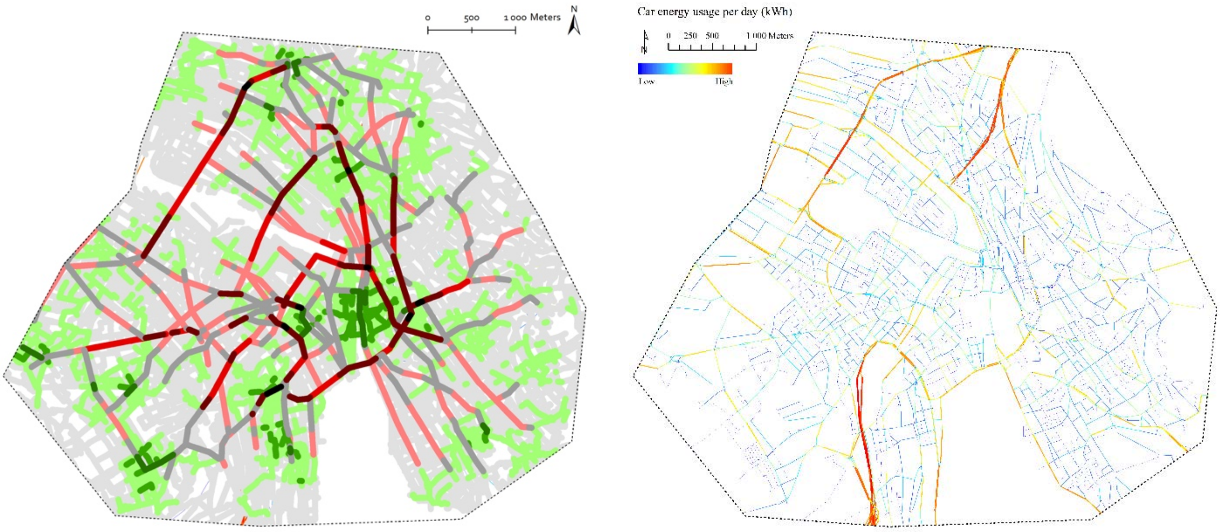


Figure 16 Aggregated angular choice (left) and energy usage for cars (right) in Zürich.

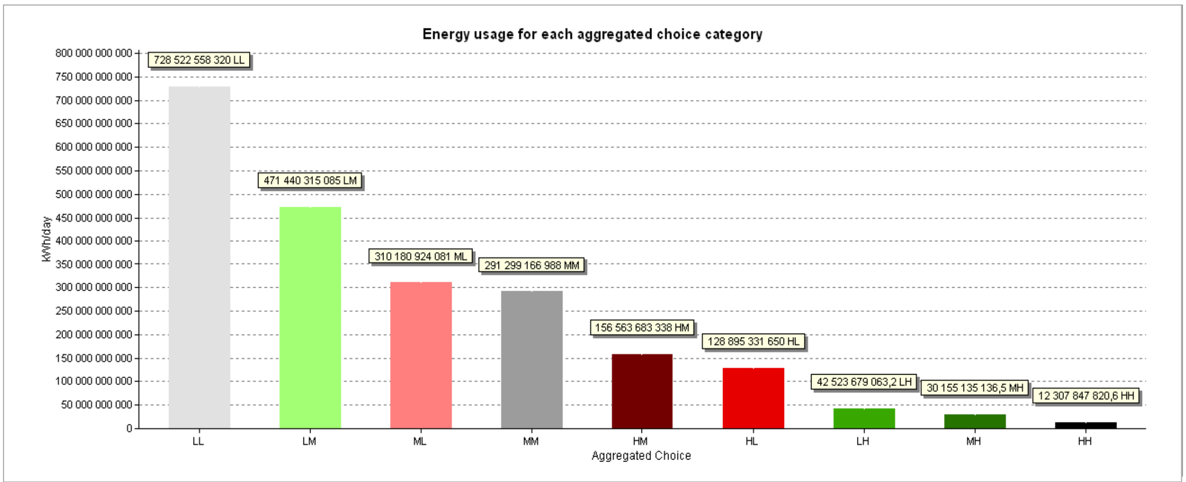


Figure 17 Energy usage for each category of aggregated angular choice for Zürich.

The resulting categories can be interpreted as follows:

- High global, high local choice values (HH): Major road; Connects city districts, often supporting high volumes of traffic. When possible also used intensely by local pedestrians and cyclists.
- High global, medium local choice values (HM): Central road, connecting city districts and the wider region; supports high volumes of regional traffic, and moderate local traffic.
- High global, low local choice values (HL): Regional road, often a motorway or boulevard; supports high speed, large volumes of traffic; little to no local traffic.
- Medium global, high local choice values (MH): District road, connecting neighbourhoods; moderate to high traffic volume, intensely used by pedestrians and cyclists.
- Medium global, medium local choice values (MM): District or local street that supports moderate traffic, often a mix of motorized traffic, pedestrians and cyclists.

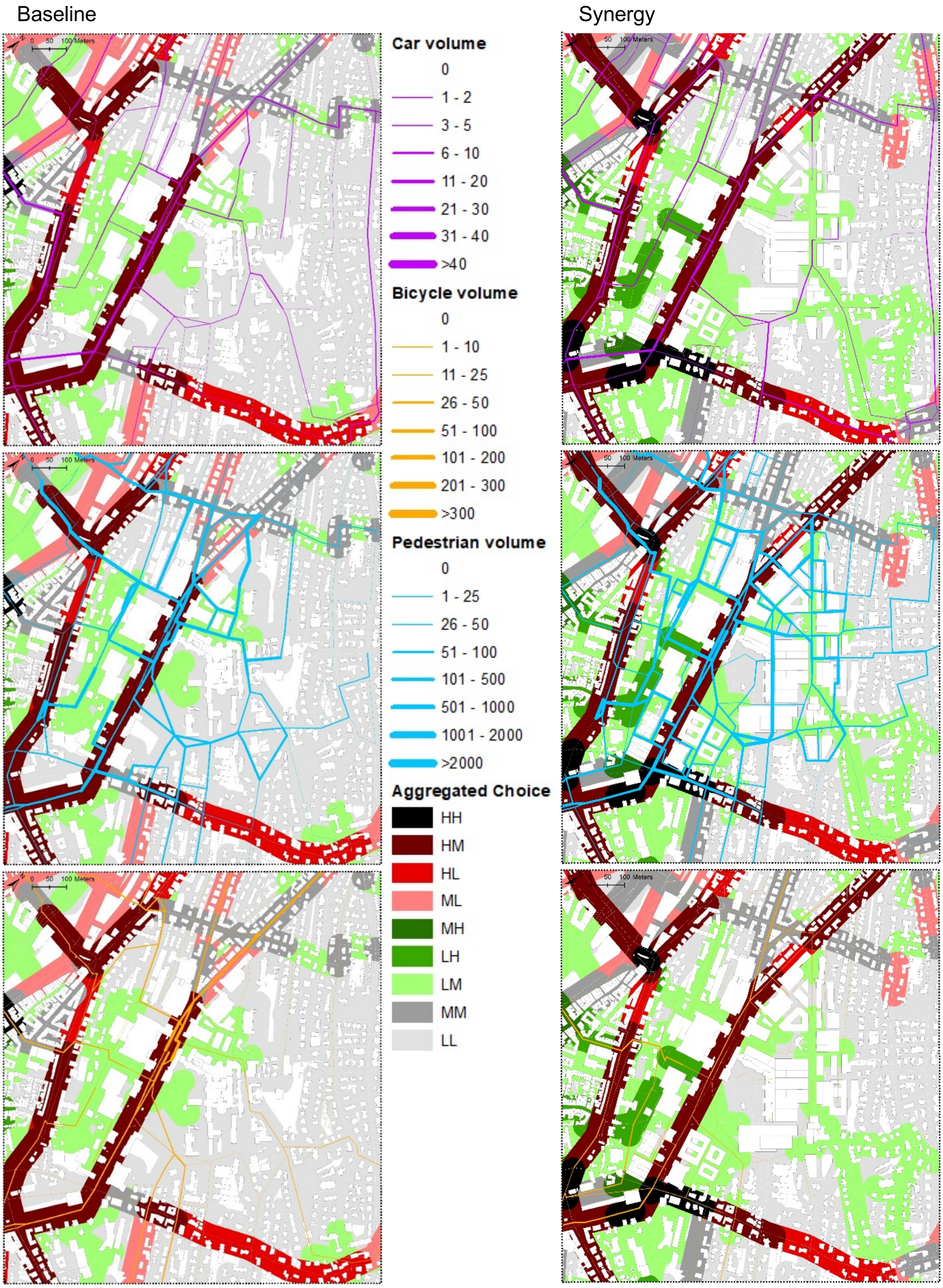
- Medium global, low local choice values (ML): District or local road, predominantly for local motorized traffic travelling within and in between neighbourhoods.
- Low global, High local values (LH): Central street within or in between neighbourhoods; high intensity of local traffic, often unmotorized;
- Low global, medium local values (LM): Neighborhood street; mixed, moderate traffic intensity, mostly local residents.
- Low global, low local values (LL): local road or street serving only the immediate surrounding properties.

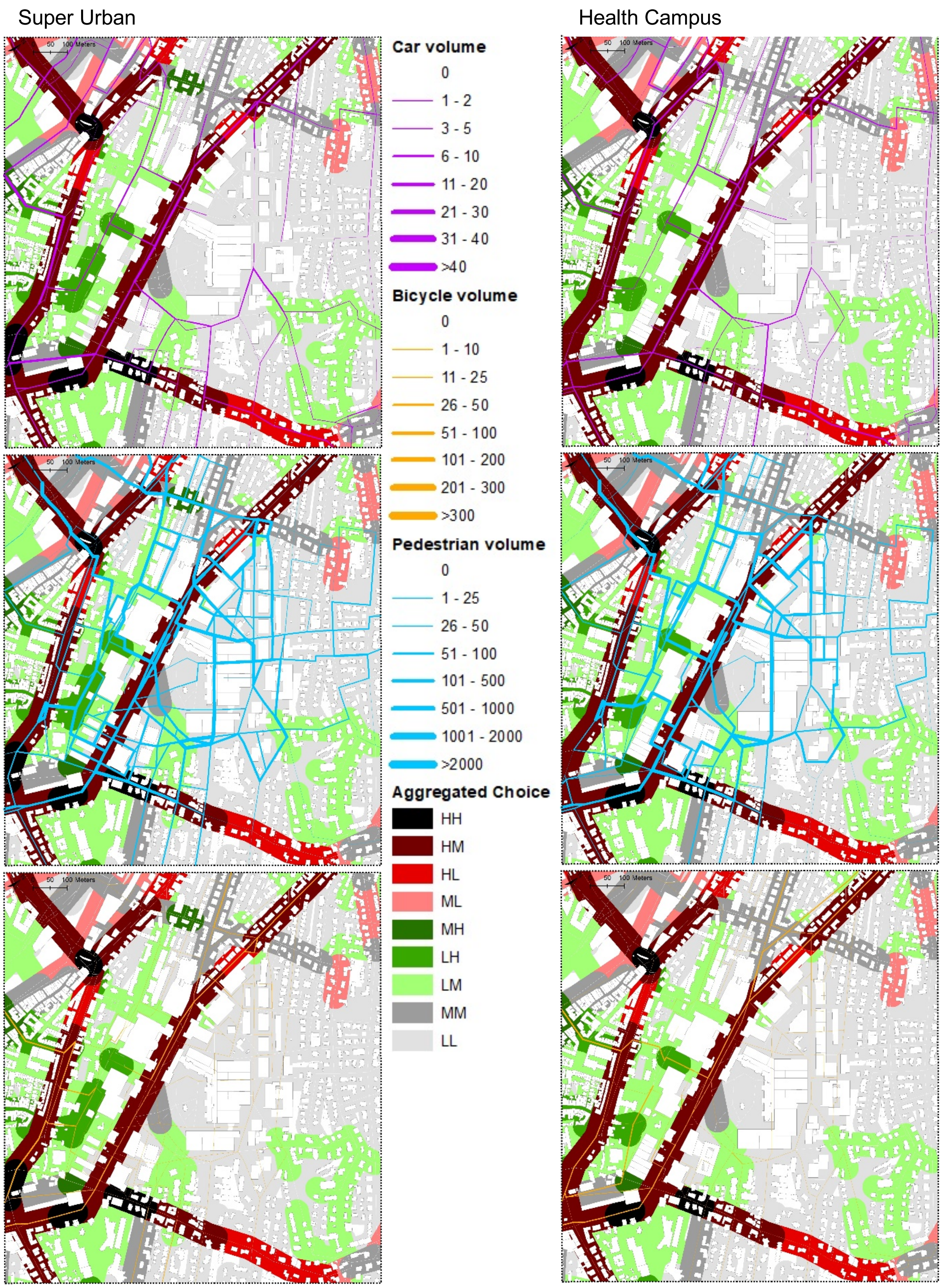
This interpretation allows for an understanding of what these categories of aggregated choice may represent in reality. However, since the analysis of spatial configuration merely describes the extrinsic properties of space, no meaning such as a typology or road standard can be appended to it. Knowledge about the incongruence between potential to or through movement and actual observed and/or facilitated movement can therefore be useful towards planning policies.

The four scenarios for development of the Hochschulquartier in Zürich provide with a denser, more integrated local network for walking and cycling within the district. The Space Syntax analyses reveal that this leads to improved walking connections to the city centre and the central railway station (Figures below). Subsequently, the results from the MATSim simulations confirm that there indeed is an increase in pedestrian traffic on these routes and throughout the area, as well as a more even dispersal of walking trips over the surrounding streets. Despite variations in the improved street network for each scenario, no one scenario stands out in particular. This leads to the conclusion that even a minor change in the street network can have significant implications on the capability of the street network to facilitate sustainable transport means. In line with Space Syntax theories, the analyses have shown that by adding missing connections and by making the network denser, local accessibility can be improved in favor of walking.

In general, bicycle traffic is dispersed more evenly throughout and around the Hochschulquartier, suggesting that the local network is utilized better. However, the simulated bicycle traffic is significantly lower for all scenarios than it is in the simulated present-day situation. This may indicate that there is an inaccuracy in the agent-based model. The Baseline scenario has the least cycling, whereas the Synergy scenario has the highest amount of cycling.

The variations in car usage between the present-day situation and the four scenarios are minimal. A visual analysis leads to the finding that the local network for cars within the Hochschulquartier does not change significantly. This is partly due to the fact that many of the new street segments are modelled as car-free, but it is possibly also related to changes in the available parking facilities, something which Space Syntax does not pick up on.


Baseline
Synergy
Car volume
0
1 - 2
3 - 5
6 - 10
11 - 20
21 - 30
31 - 40
>40
Bicycle volume
0
1 - 10
11 - 25
26 - 50
51 - 100
101 - 200
201 - 300
>300
Pedestrian volume
0
1 - 25
26 - 50
51 - 100
101 - 500
501 - 1000
1001 - 2000
>2000
Aggregated Choice
HH
HM
HL
ML
MH
LH
LM
MM
LL


Super Urban
Health Campus
Car volume
0
1 - 2
3 - 5
6 - 10
11 - 20
21 - 30
31 - 40
>40
Bicycle volume
0
1 - 10
11 - 25
26 - 50
51 - 100
101 - 200
201 - 300
>300
Pedestrian volume
0
1 - 25
26 - 50
51 - 100
101 - 500
501 - 1000
1001 - 2000
>2000
Aggregated Choice
HH
HM
HL
ML
MH
LH
LM
MM
LL

4.7 WP8: District Energy Integration Model (DEIM)

4.7.1 Conceptual framework and application for Hochschulquartier scenario assessment

Based on previous energy-related factors, a framework named District Energy Integration Model (DEIM) has been developed to analyze the energy performance of urban neighborhoods and districts. It serves to assess overall energy demand in urban areas by linking several modules. The four modules consist of available simulation models, ENVI-met, City Energy Analyst (CEA), Space Syntax and MATSim, which have been coupled in a workflow.

The coupling of simulation modules allows the computation of energy demand based on the principal types of factors which shape building and mobility performance such as urban form, design, systems and behaviors. Table 3 provides an overview on the relevant parameters for factor type that were identified in the existing literature and the simulation module that is able to process those. In other words, if the factor constitutes an input or not for the four modeling tools. The analysis also suggests a complementarity between the tools, since Space Syntax and ENVI-met are both tools that mainly use morphological and design input while MATSim and CEA are capable to process parameters of behaviors and systems characteristics.

Moreover, the multi-domain simulation framework constitutes an attempt to tackle the major limitations of the single computational methods which have been discussed in the previous reports describing the partial coupling methods.

Energy Performance							
Mobility				**Building**			
Factors	**Module**			**Factors**	**Module**		
Urban Structure (land use, street network structure)	*INPUT*	Space Syntax MATSim		Urban Form (urban geometry, land cover, vegetation)	*INPUT*	ENVI-met CEA	
Street Design (surface materials, profile)	*INPUT*	Space Syntax		Building Design (building geometry, orientation, façade materials and design)	*INPUT*	CEA ENVI-met	
Transport Systems (type of mobility systems, characteristics of vehicles)	*INPUT*	MATSim		Building Systems (type and efficiency of energy systems)	*INPUT*	CEA	
Travel Behaviors (geographical position, type of activity chain)	*INPUT*	MATSim		Occupant Behaviors (type of building use, number and type of occupants)	*INPUT*	CEA	

Table 3 Energy factors and related modules.

The integration framework is based on the recognition of the factors, their nature and scales responsible for building and mobility energy consumption. Based on this analysis and on the comparison of the software data requirements, a coupling workflow is developed. Figure 2 offer a schematic description of the procedures for the multiple linking between the simulation tools ENVI-met, City Energy Analyst (CEA), Space Syntax and MATSim. In the first stage a common database is created in order to use coherent data regarding the district under study. Space and time resolutions are later adjusted according to the tool’s requirements. Secondly, microclimate simulations are performed by using ENVI-met and results for three selected parameters are used to create new boundary climatic condition for energy modeling in CEA. The MATSim population’s activities in the Hochschulquartier form the basis of the occupant schedules for the energy demand simulations of the four scenarios in CEA.

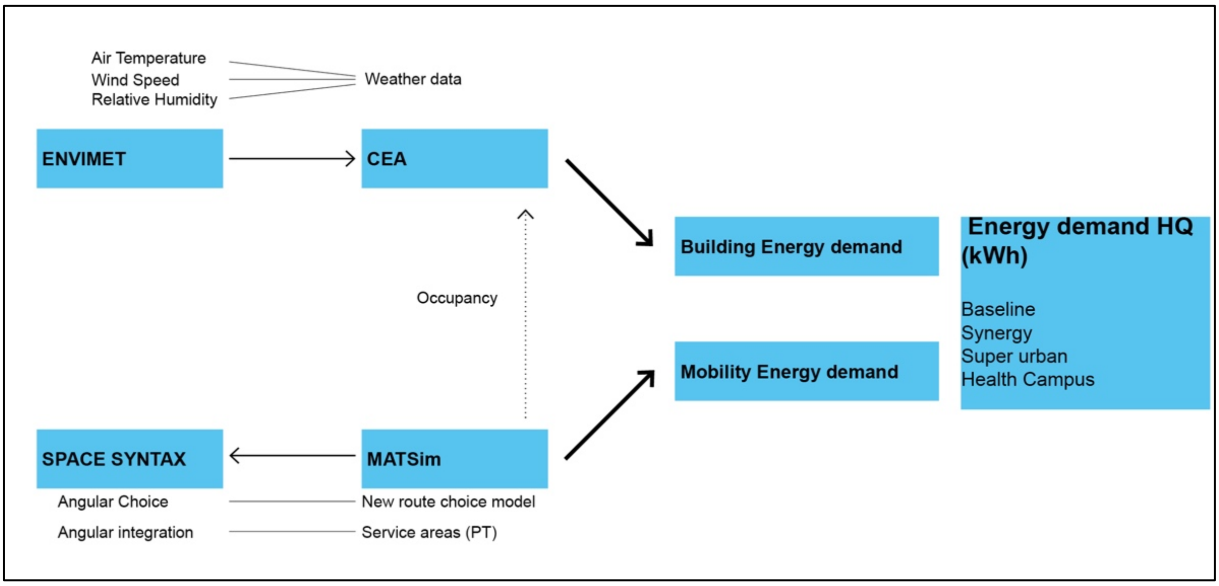


Figure 18 DEIM coupling workflow

4.7.2 Application for HQ scenario assessment

The DEIM was used in order to estimate energy demand during a summer day in the Baseline Masterplan of the Hochschulquartier in Zurich (Baudirektion Kanton Zürich, 2014) and for other three scenarios developed in WP3. The key factors that play a role in defining the energy profile of the HQ were identified and a scenario matrix was developed in a co-creation process which involved research experts in different fields, and relevant local stakeholders. The 2x2 Scenario matrix, has been built on five critical aspects which have the potential of changing the energy performance of the new HQ. The key factors identified are the following:

- type of measures to reduce energy demand
- level of sharing of renewables in the energy mix
- level of integration of electric vehicles (EV)
- level of mixed land use
- type and patterns of transport

As shown in Figure 19, these key factors which constitute the organizing principle of the Scenario Matrix are grouped around the two axes, and results in four scenarios. On the one axis organizing principles have been identified in the composition of energy measures that can be applied to buildings and to the urban fabric, and the degree of integration of electric mobility, while the second group connects land use factors and demand of transport around the compact city concept.

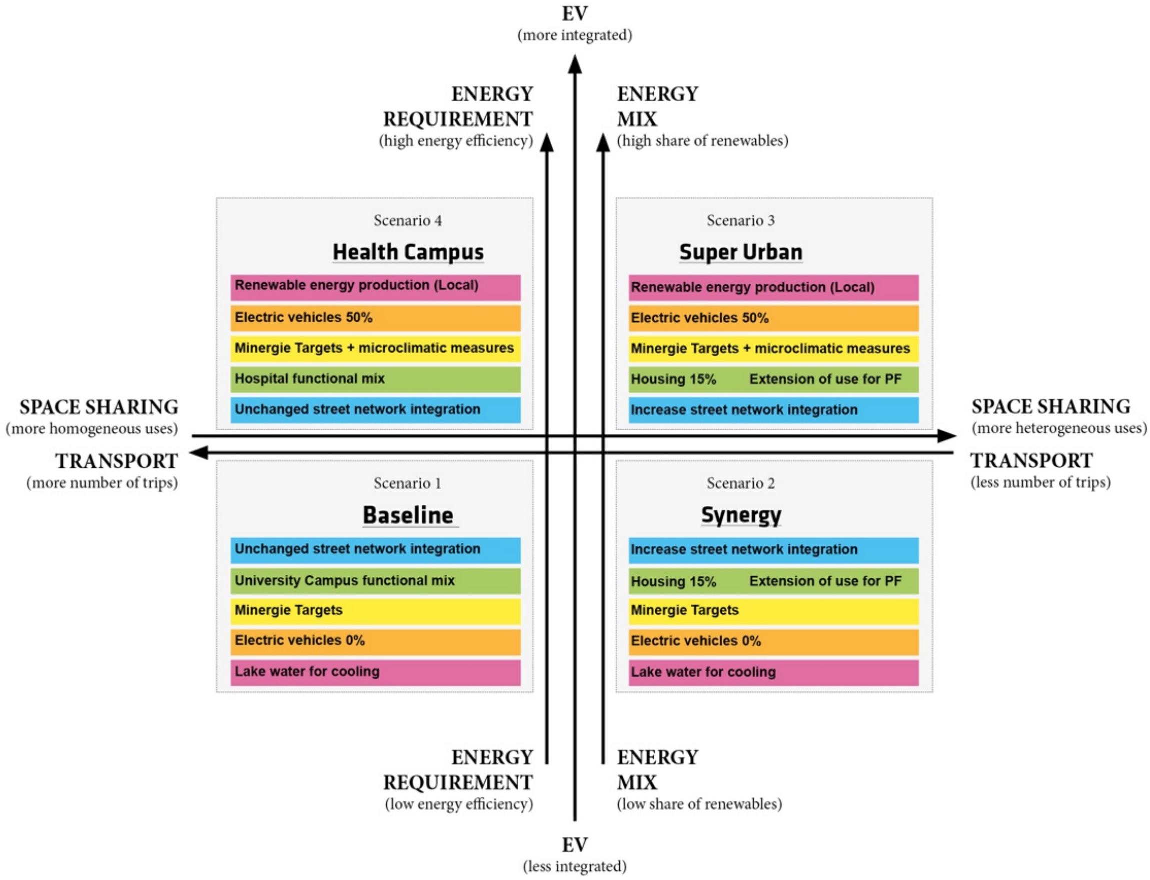


Figure 19 Zurich Scenario Matrix

1. Scenario 'Baseline' (BL)

This scenario is based on one of the visions of the project for the HQ as published in September 2014 (Kanton Zurich, Masterplan Hochschulgebiet. Zürich-Zentrum). The scenario describes a future where the three institutions ETH, USZ and UZH separately develop their spatial plans, maintaining the uses specified in the Masterplan. The assumption is that each of the institutions realizes an extension, thus substantially increasing the total built volume in the area by 40% of the existing gross floor area.

Mobility	Overall accessibility by 'slow' modes as in the original Masterplan; accessibility by motorized modes largely unchanged and missing integration of EV.
Urban Design	Space sharing: Each institute individually develops their spatial plans. Urban form: Largely based on the Syntheseplan, with little regard to the optimization of building geometry for enhancing the buildings energy performance and absence of microclimate control measures.

Energy Balance	Energy demand: Energy performance improved through construction materials and insulation of new buildings. Energy supply: Connected to centralized district heating and electricity grids along with district cooling from lake water.

2. Scenario 'Health Campus' (HC)

This scenario features a shift towards higher shares of hospital functions by using the actual mix of medical service, education and research. It presents an extreme case, where building uses with the highest energy demand are supplied increasingly through local renewable production.

Mobility	Electric vehicles (EVs) are integrated in the local energy system; public transport remains the main mode of access to the area without any change of the street network compared to the Baseline.
Urban Design	Space sharing: Functional mix of existing hospital buildings are applied to all the others. Urban form: Building shapes are designed to improve the microclimatic conditions.
Energy Balance	Energy demand: Energy performance improved through construction materials and insulation of building with high standards. Energy supply: Connected to centralized district heating, cooling and electricity grids, along with district cooling from lake water. Building roofs serve for solar energy generation including storage to match demand and supply in order to increase the share of renewable sources in the energy mix.

3. Scenario 'Synergy' (SY)

This scenario builds on a mix of functions and focuses on a better integration of uses compared to the Baseline. Energy supply systems remain unchanged, employing centralized infrastructures and limited production within the area. The integration within the university cluster of space for housing, amenities and facilities results in a 24/7 livable area that promotes walking and biking for mobility within the campus. This mix of functions has the potential, from an energy point of view, to decrease peaks and balance the total energy demand of the area, and to increase the overall efficiency (joint energy footprint of mobility and use of space).

Mobility	Focus is on existing public transport systems and improving walkability and bikeability in the area by making the area more accessible.
Urban Design	Space sharing: Integration of existing uses in terms of distribution, and increase in the share of residential buildings. Urban form: Integrate the different functions in order to create a more livable built environment; spatial design measures do not include microclimate control techniques or building geometry optimization.
Energy Balance	Energy demand: Energy performance improved by insulation of building with high standards.

	Energy supply: Connected to centralized district heating and electricity grids along with district cooling from lake water.

4. Scenario 'Super Urban' (SU)

This scenario features a synergetic mix of functional use and shared spaces, combined with a high mix of local, decentralized and distributed energy solutions. The main focus is on multi-functional, highly integrated and livable solutions from an energy and spatial perspective. A combination of university spaces and residential buildings, amenities, and offices is optimized for the balancing of the energy demand.

Mobility	Pedestrian and bike-friendly area; external accessibility is increased by a better connection to the city center through improved public transportation services and dynamic shared mobility services; electric vehicles (EVs) are integrated in the local energy system.
Urban Design	Space sharing: Integration of existing uses in terms of distribution, as well as the reuse of space in its off-hours to host other functions; resulting in a higher efficiency in building functional program. Urban form: Increased importance as a result of multi-functionality and high interaction, with emphasis on the design of building-street interface to support the walkability in the area; building geometry is optimized for reducing energy consumption.
Energy Balance	Energy demand: Focus on peak reduction through the choice of uses that are complementary throughout the day. Energy supply: Connected to centralized district heating and electricity grids along with district cooling from lake water. Building roofs serve for solar energy generation including storage to match demand and supply in order to increase the share of renewable sources in the energy mix.

4.7.2.1. Building energy demand

4.7.2.1.1. Effect of functional distribution on energy demands in the area

The yearly demands for the district for each scenario are shown in Figure 20. Due to the large share of functions with high demands for processes, lighting and appliances, the demand for electricity in all scenarios is comparable to the total demand for heating including domestic hot water and processes. Due to the highly insulated building envelopes assumed and the relatively large window-to-wall ratios in all new buildings, the demand for space cooling is also significant in all scenarios. As expected, the energy demands are highest for the Health Campus scenario, mainly due to the increased demand domestic hot water and process heating, cooling and electricity. The demands are lowest for the Synergy and Super Urban scenarios due to the increase in residential buildings in these scenarios, which lead to an overall decrease in process energy and space cooling demands.

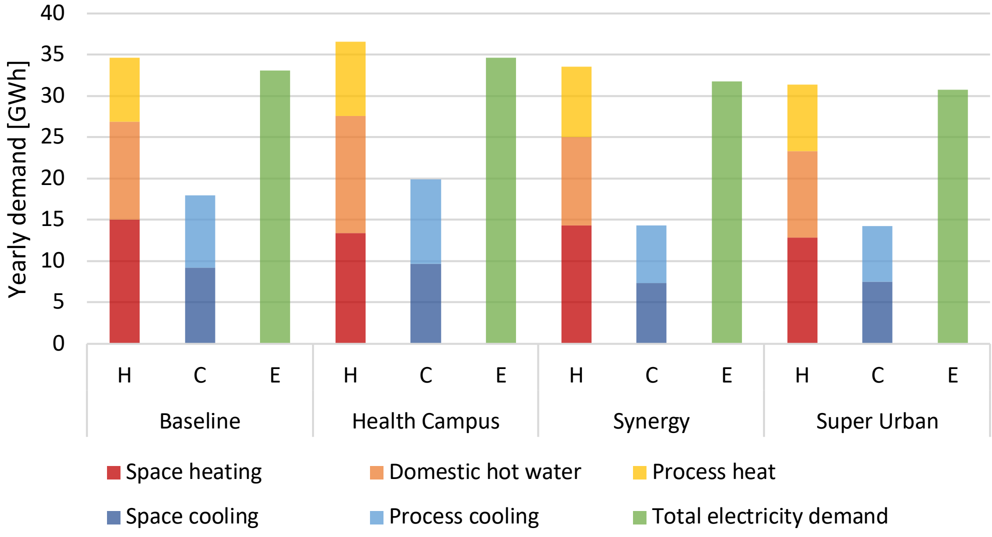


Figure 20 Yearly demands for heating, cooling and electricity for each scenario.

A key assumption in the definition of the SPACERGY scenarios was that the introduction of residential buildings in the Synergy and Super Urban scenarios would lead to peak shaving and a more balanced load throughout the day. Looking at the hourly demand on a week in winter (Figure 21) the peaks are indeed significantly decreased for these two scenarios with respect to the baseline, while the demand on weekends is higher due to the presence of building residents during the weekends. However, this effect is largest in the Health Campus scenario, since hospital buildings not only have night time occupancy, but also have demands for domestic hot water and process heating during off-peak times. Even during peak times, the hospital has the lowest heating demand due to internal gains from processes and occupants. Hence, the heating demand curve is flattest for the Health Campus scenario.

The presence of occupants during off-peak hours and weekends also explains the larger cooling demand in the Health Campus scenario, as observed in Figure 22. While the peak demands for the Baseline and Health Campus scenarios on weekdays are very similar, on weekends the demand in the Baseline scenario is about 25% lower due to the lower share of hospital buildings in the area. Since residential buildings in Switzerland are typically not equipped with cooling systems, the inclusion of residential buildings in the Synergy and Super Urban scenarios leads to an overall lower cooling demand in the area, with weekday peaks about 25% lower than for the other two scenarios.

The electricity demands in the area show a consistent pattern across all scenarios (Figure 23). Similarly to the other energy demands, the Baseline scenario proves to have the highest demands on weekdays, but the Health Campus scenario shows the highest demands on weekends, thus leading to the observed higher yearly electricity demand in this scenario. The three other scenarios have very similar demands on weekends, whereas the Super Urban scenario has the lowest electricity demand on weekdays.

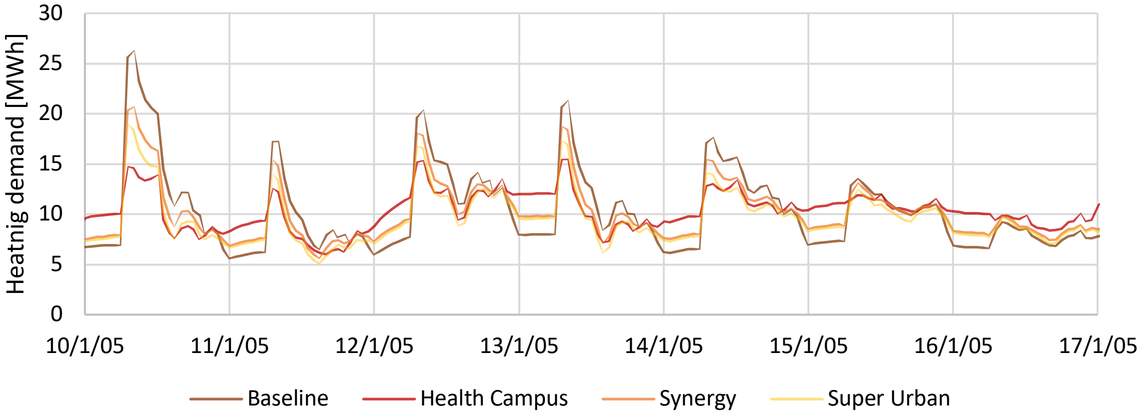


Figure 21 Total demand for heating (space heating, domestic hot water and process heating) for all buildings in each scenario during a week in winter.

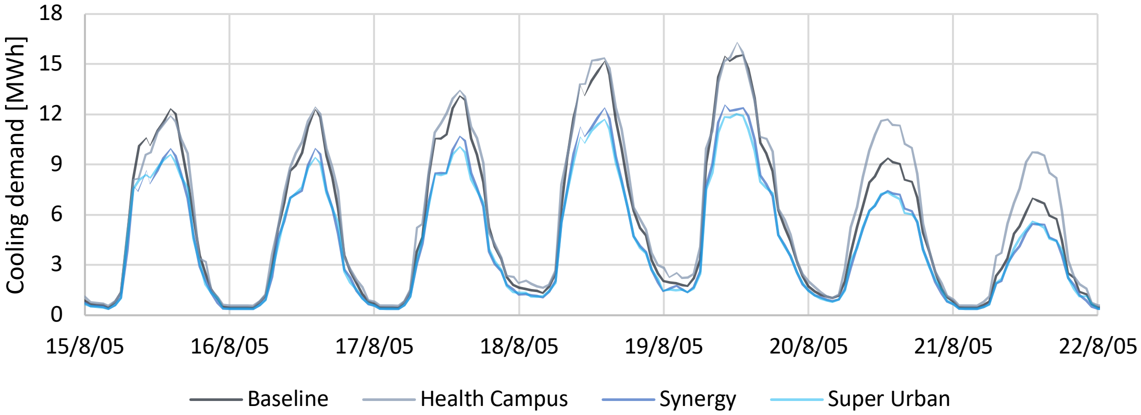


Figure 22 Total demand for cooling (space and process cooling) for the district for all buildings in each scenario during a week in summer.

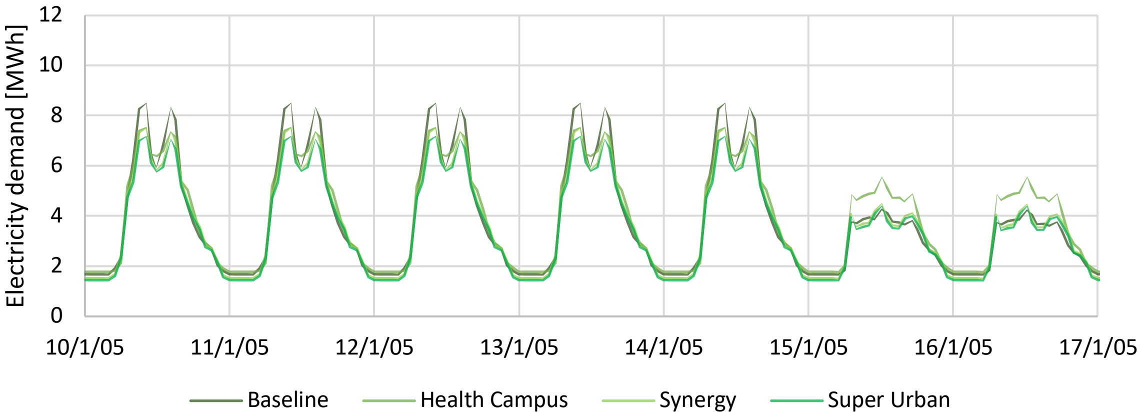


Figure 23 Total demand for electricity for lighting, appliances and processes for all buildings in each scenario during a week in winter.

4.7.2.1.2. Effect of occupant modeling approach on energy demands in the area

An analysis of the impacts of occupant models on the energy demand simulations carried out for the Hochschulquartier status quo (Mosteiro-Romero, Hischier, Becker, Fonseca, & Schlueter, 2019) showed that the variation in the area's energy demands when switching from the deterministic schedules to the stochastic model were relatively minor compared to the effects seen when using the MATSim population as the basis for occupant modeling. Figure 24 shows the number of occupants and the demands for space conditioning and lighting and appliances in the classrooms in the area for the deterministic and stochastic CEA schedules and for the MATSim population schedules. The effect of changing the population model from the deterministic baseline at different scales is shown in Figure 25 through the normalized mean absolute deviation (NMAD) defined for a given demand per square meter q as follows:

$$NMAD_q = \frac{1}{N}\sum_{i=1}^{N}\frac{\sum_{t=1}^{n}\left|q_{i,k}(t) - q_{i,d}(t)\right|}{\sum_{t=1}^{n} q_{i,d}(t)}$$

where $q_{i,k}(t)$ and $q_{i,d}(t)$ are the demand per square meter at time *t* for building *i* for occupancy model *k* and for the deterministic model, respectively, *n* is the number of time steps, and *N* is the number of buildings in the sample being considered.

As expectable, the variation is largest on an hourly basis, and is greater for electricity demands given that the demand for appliances was directly connected to occupant presence. However, on a yearly basis, the effect of occupants led to a deviation of less than 10% for all energy demands compared.

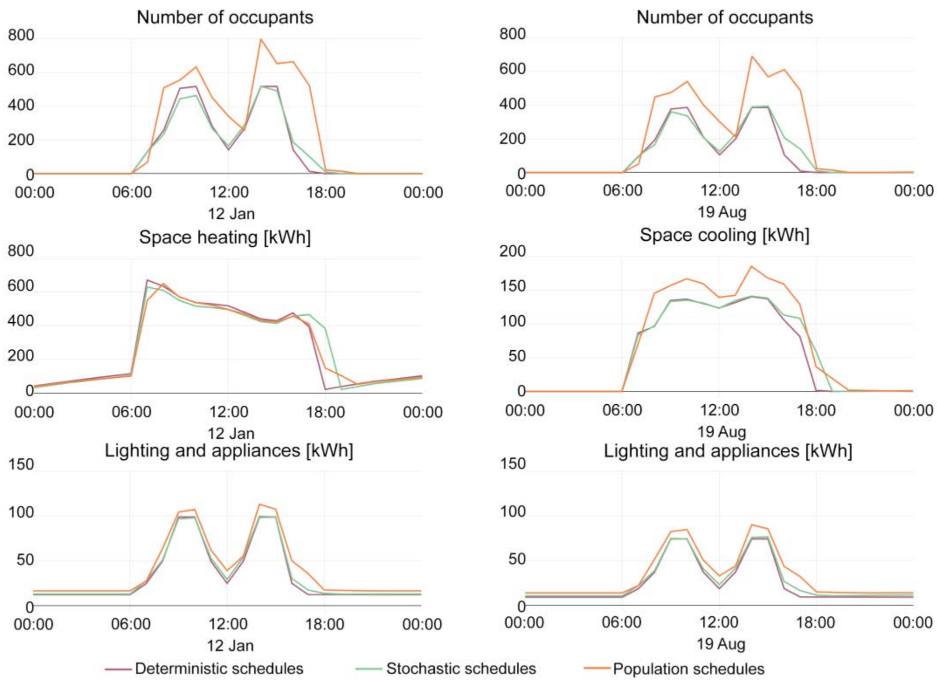


Figure 24 Cumulative hourly demands for space heating, electricity for lighting and appliances, and number of occupants in all classroom buildings in the status quo on the coldest (left) and hottest (right) week of the year.

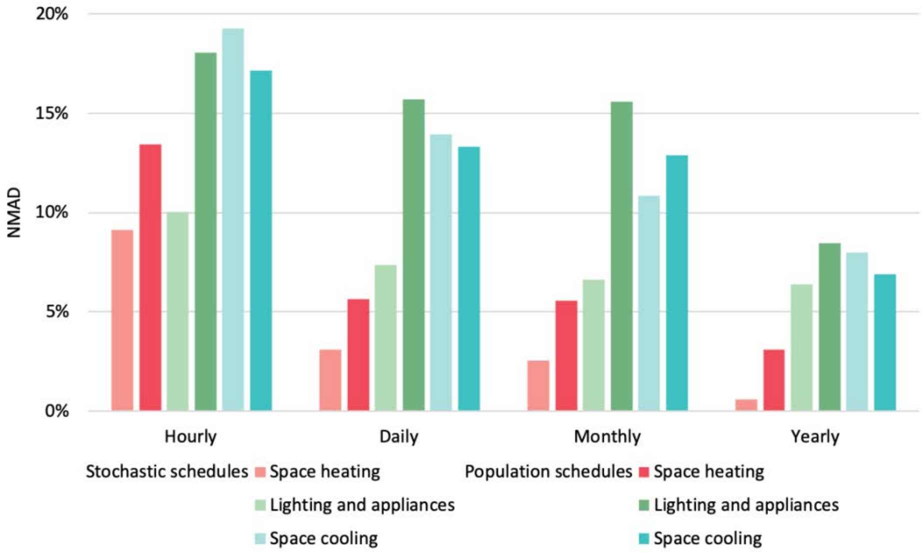


Figure 25 Normalized mean absolute deviation (NMAD) at different time scales of analysis of the heating, cooling and electricity demands in the buildings in the area for the Stochastic schedules and Population schedules with respect to the Deterministic schedules.

Due to the importance of demand peaks for supply system sizing, the larger deviation in the results on an hourly basis implies that occupants may have a significant effect on the demand peaks in buildings in the area. The deviation in the peak power demand for different energy services for each model with respect to the deterministic baseline is shown in Figure 26. The results show that the variation in all demands for the stochastic model and in the peak heating demand for the population model are all within 5% of the deterministic baseline, meaning that the choice of occupancy model likely has no effect on system sizing. Peak cooling and lighting and appliance demand in the population model varies by an average of 15% from the deterministic baseline, with a maximum deviation of around 40%, meaning that the choice of occupant model would have a considerable effect on the systems planned for a given building.

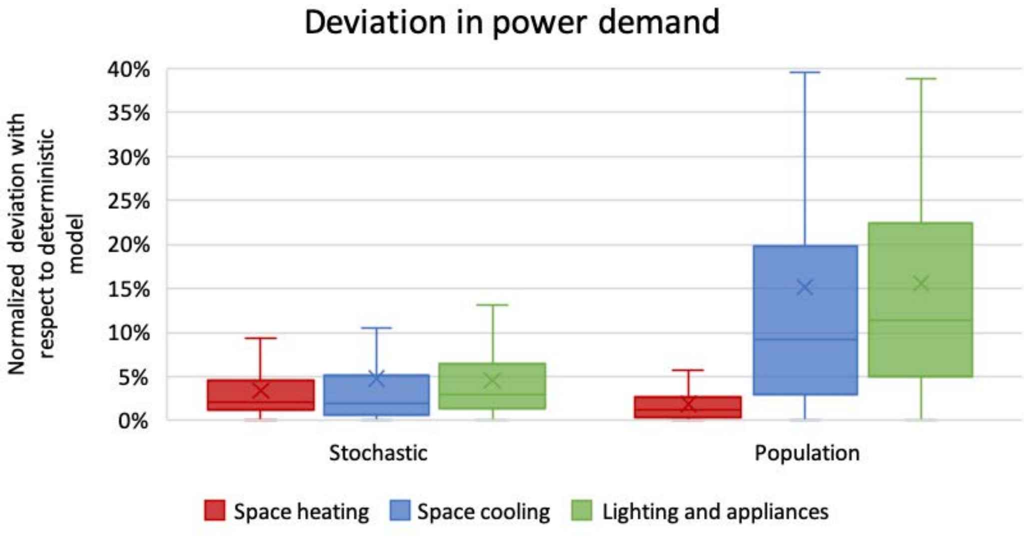


Figure 26 Normalized absolute deviation in the peak power for different energy demands for the stochastic and population models with respect to the deterministic baseline.

4.7.2.1.3. Effect of urban microclimate on cooling demand in the area

Figure 27 shows the space cooling demand on the hottest day of the year for each of the four scenarios. The patterns throughout the day are fairly similar for all scenarios, although the peaks are 20-23% lower for Synergy and Super Urban due to the increase of uncooled residential buildings. When accounting for the effects of urban microclimate, there is a noticeable dip in the peak demand for all scenarios, with a decrease in the peak power required ranging from 3% for the Synergy scenario to 6.5% for the Health Campus scenario. However, due to the higher night time temperatures the cooling demand during these off peak hours is 50-75% higher when accounting for microclimate in the area. Thus, there is an overall increase in the cooling demand on the hottest day of the year of 4% for the Baseline scenario to 6% for the Health Campus scenario.

Regarding peak cooling demand, practically all buildings show a decrease in the peak space cooling demand due to the reduced outside air temperature in the area for the case with microclimate (Figure 27). There are a few significant outliers with increases in peak cooling demand of more than 5%. These are older buildings which were assumed to keep their original air-based cooling systems, while all new buildings were assumed to be equipped with chilled ceiling cooling systems. Thus, while the outdoor temperature during peak cooling times is lower, the latent loads due to the increased outside air humidity causes the overall cooling demand to be higher for the case with microclimate effects.

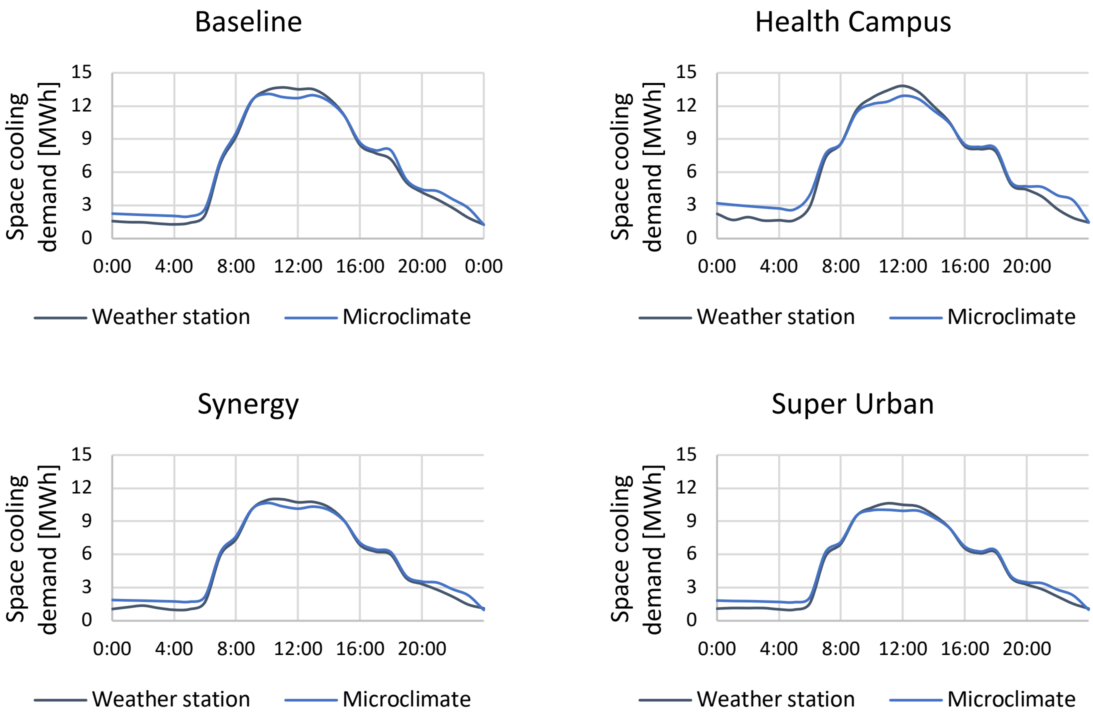


Figure 27 Total space cooling demand in the district on the hottest day of the typical year for all four scenarios.

The average variation in peak power demand due to microclimate effects (Figure 28) is 5-7% for all scenarios, with Health Campus showing the greatest susceptibility to microclimate effects. When compared to the effect of occupant modeling (Figure 26), microclimate effects appear to have a smaller impact on peak power demand and hence system sizing, but a larger impact on the overall cooling demand of the area.

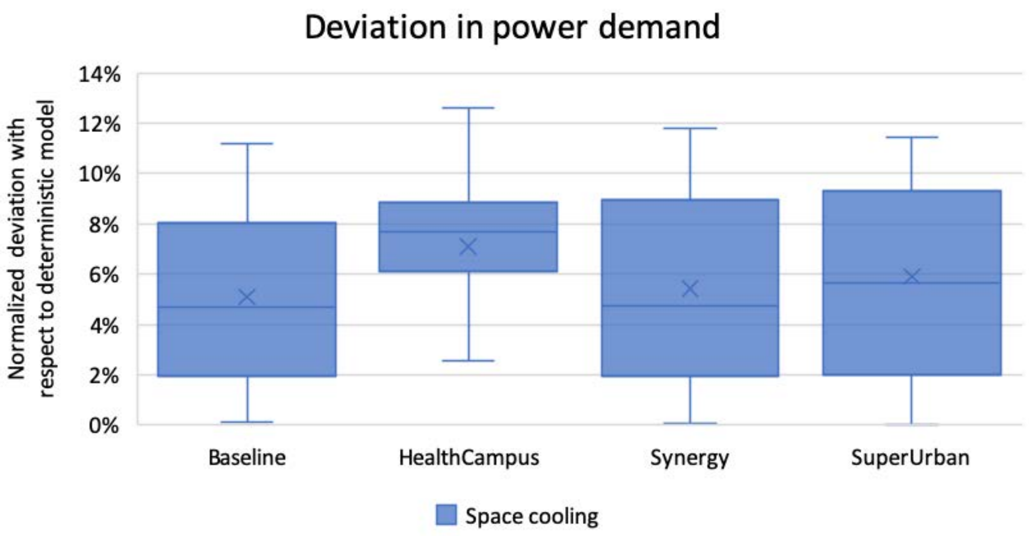


Figure 28 Normalized deviation in the peak space cooling demand for each scenario when considering microclimate effects.

4.7.2.2. Mobility energy demand

Hochschulquartier is traversed by a few street segments with high through-movement potential on the city scale (R=5000). As shown in the maps of page 37 and 38, these high values on city scale, represented in red, do not change significantly in the four scenarios. Most car and bicycle traffic seems to follow these streets with high through-movement potential on the city scale. On the local scale (R=500), there are some considerable improvements in through-movement potential between Hochschulquartier and the east bank of the historic city centre. However, the values do not increase in the masterplan area itself, with exception of the Synergy scenario. Here, the newly introduced promenade sees a distinct increase in through-movement potential.

The volumes of cars, bicycles and pedestrians are simulated only for agents with a destination inside the Hochschulquartier. Therefore, any through-traffic or other traffic with a local destination in the area is not represented in the data.

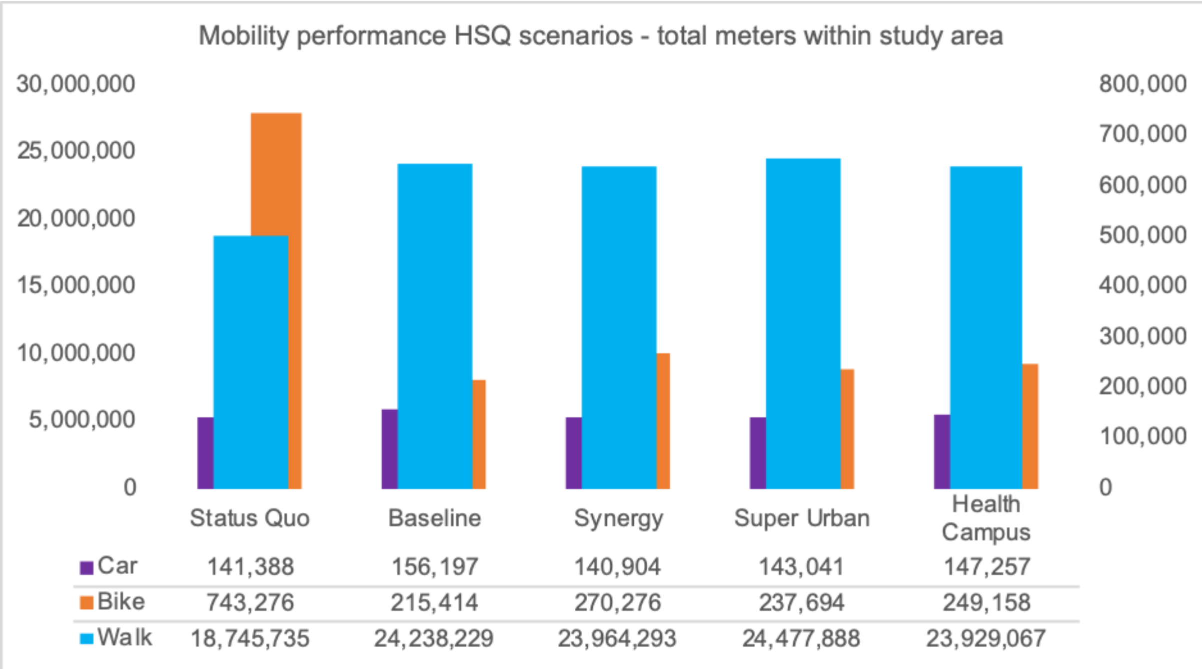


Figure 29 Mobility performance of the Hochschulquartier scenarios.

A large part of pedestrian traffic seems to follow the shortest path to the central railway station in the northwest of the study area. In all scenarios, the amount of walking is higher than the Status Quo. The differences between the scenarios are marginal (Figure 29). The highest amount of walked distance occurs in the Super Urban scenario. Interestingly, the amount of distance driven by cars is not lower as a consequence. In fact, the Super Urban scenario shows the highest number of cars and the second highest amount of driven kilometres within the area. Bicycle usage is highest in the Status Quo. This is significantly higher than in any of the four scenario simulations with approximately a factor 3. Of the scenarios, the Synergy scenario has the highest amount of distance travelled by bicycle (and lowest car usage).

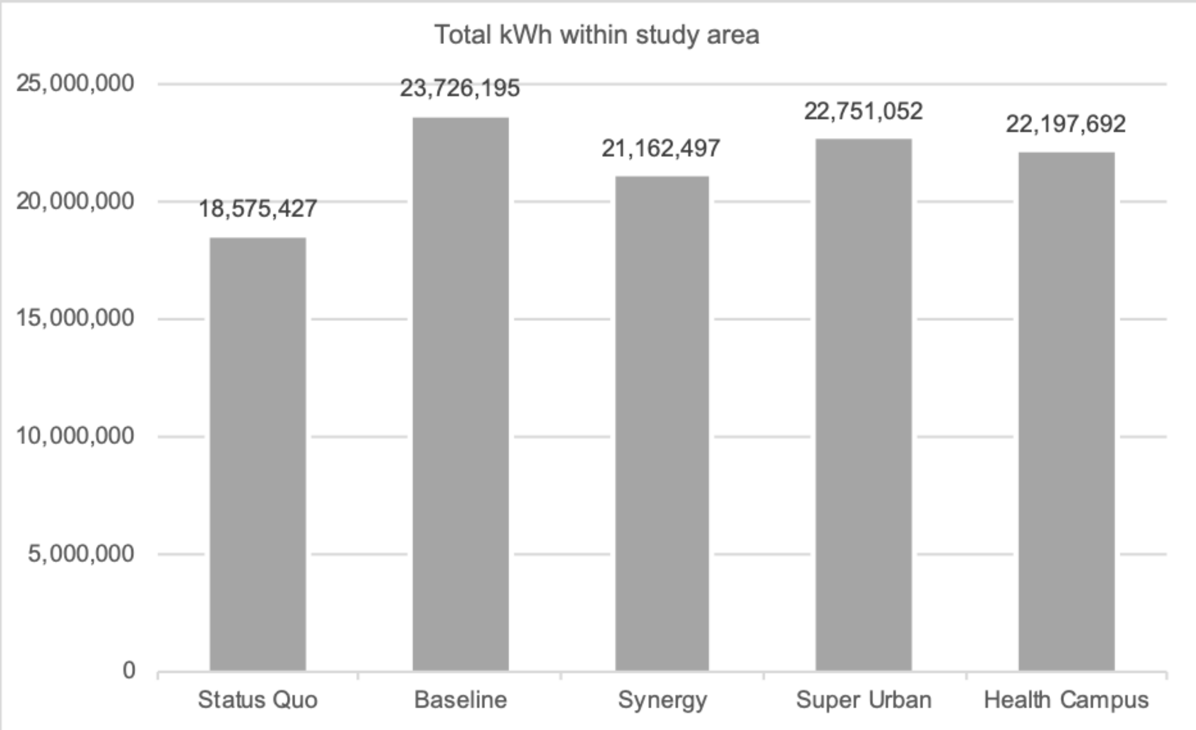


Figure 30 Total energy demand for car traffic to and from the Hochschulquartier.

Compared to the Status Quo and Baseline scenario, the walking network within Hochschulquartier becomes denser in the Synergy, Super Urban and Health Campus scenarios. However, the results do not display a clear relationship with any change in the share of bicycles and cars.

In fact, as Figure 30 shows, the energy demand for car traffic to and from Hochschulquartier is higher than the Status Quo in all four scenarios. In Zürich, for both the micro and macro scale, a positive correlation was observed between integration and energy usage. This means that walkable destinations (the higher the local choice value) show an unexpected energy consumption contrary to our assumptions. A possible explanation for this may be related to car ownership in Zürich. Being relatively low (around 50%), low car ownership in the agent-based model may exacerbate the share of local traffic. This may also explain the reduced bicycle usage in the MATSim simulations of the scenarios. Further refining of the model may resolve this inaccuracy. In any case, the study has demonstrated that the share of car users does not increase as the amount of walking does.

4.7.2.3. Assessment of infrastructure alternatives per scenario

To comply with the vision of 2000-Watt Society a mix of different sources and technologies for production and storage of energy needs to be implemented. Based on an analysis of the existing infrastructure in the area along with input from stakeholders obtained during the SPACERGY interviews, the development of district cooling infrastructure and local renewable electricity production were identified as key areas for investigation in the area. Hence, all four SPACERGY scenarios assumed that a free cooling network based on lake water would be developed, whereas two scenarios, namely Health Campus and Super Urban, assume an aggressive push for the implementation of solar photovoltaic (PV) technologies in the area. In order to analyze the feasibility and performance of these technologies in the SPACERGY scenarios, CEA energy system modeling tools along with newly-developed methods for free cooling modeling and optimal photovoltaic placement and battery charging.

The layout of the district cooling network in each SPACERGY scenarios was created using a Steiner minimum spanning tree algorithm. Network operation and pressure and thermal losses were then modeled in CEA to evaluate the impact of the different functional mixes in each scenario on the feasibility of the network and their impact on the design of the cooling solution. Finally, an economic and environmental analysis of the network performance is carried out and compared to a fully decentralized system based on vapor compression chillers as a benchmark.

Regarding PV, CEA includes a tool to assess the technical potential for PV placement based on setting a minimum irradiation threshold for each surface in the buildings in the area and subsequently determining optimal tilt angles and spacing for the panels in each surface. In order to account for economic constraints, a methodology for cost-optimal PV placement based on the selection of building surfaces that maximize the net present value of the investment was developed and applied to the two scenarios with PV. Finally, a methodology to optimize battery storage was developed and implemented to analyze the potential for battery storage coupled with PV for both placement scenarios, as well as in order to analyze the additional storage potential provided by the use of electric vehicles in the area as distributed batteries.

4.7.2.3.1. District cooling network layout and performance

The thermal network simulations enable us to size the district cooling network. **Error! Reference source not found.** shows the main characteristics of the DLWC system for each scenario, while the network layout for each scenario along with the pipe size are shown in Figure 31. The network length is very similar for all scenarios, with the Baseline scenario having the longest network at 14’314 meters. The pump capacity differs significantly between scenarios due to different peak pressure losses in each scenario.

Key Figure	Baseline	Health Campus	Synergy	Super Urban
Piping to Hochschulquartier	3’132 m	3’132 m	3’132 m	3’132 m
Piping in Hochschulquartier	11’182 m	11’138 m	11’038 m	11’039m
Lake water takeout	7.51 million m^3/yr	8.51 million m^3/yr	6.61 million m^3/yr	6.62 million m^3/yr
Pump capacity	20.34 MW	18.26 MW	16.04 MW	14.5 MW
Pump electricity	5.54 GWh/yr	6.34 GWh/yr	4.52 GWh/yr	4.69 GWh/yr

Table 4: Key figures of the DLWC system

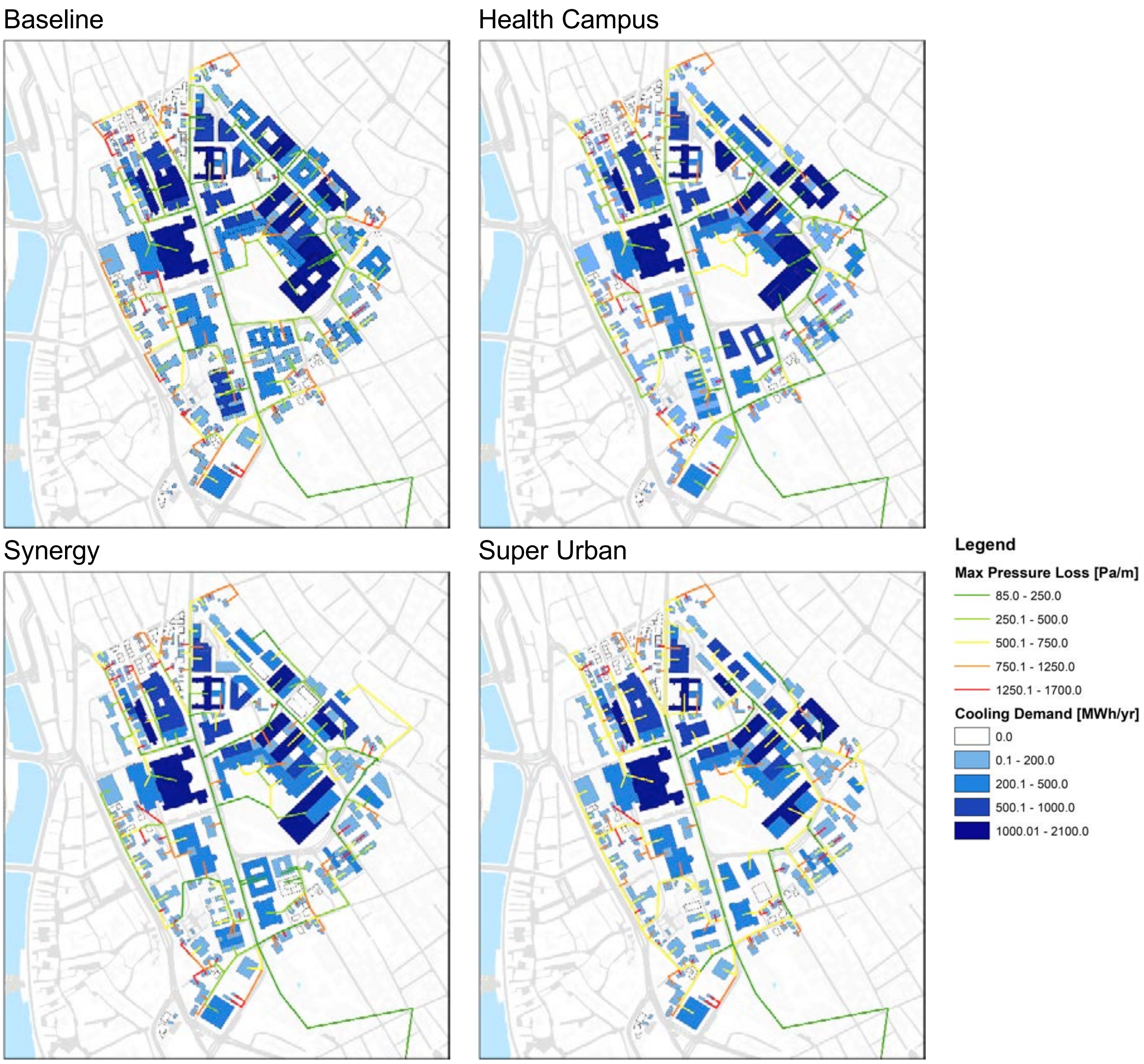


Figure 31 Thermal network layout and pipe diameter for each scenario and cooling demands supplied.

The pump electricity demand is a key indicator when assessing the system and is the only energy input to the free cooling network. In order to compare scenarios, we consider the energy efficiency ratio EER_{sys}, defined as the ratio of cooling delivered to electricity demand to supply it. On average, the energy efficiency ratio of the free cooling network is 6.7, with the network in the Synergy scenario being the most efficient (EER_{sys} = 7.06) and the Health Campus scenario the most inefficient (EER_{sys} = 6.23). The DLWC system further saves an average of 58% in electricity compared to decentralized vapor compression chillers (Table 5).

For the reference system there is a vapor compression chiller installed in every consuming building of the scenarios.

Due to the large capital expenditure for the cooling network, a high utilization is necessary to make the project profitable. For the predicted cooling demand of the SPACERGY scenarios it is not economically viable to implement a DLWC system. The economic viability may however be improved by connecting other large consumers in surrounding areas, such as the Kunsthaus museum or the data center at ETH building RZ, which is outside of the SPACERGY perimeter.

Key Figure	Baseline	Health Campus	Synergy	Super Urban
Cooling units	168	164	161	161
Total capacity	43.15 MW	36.56 MW	33.57 MW	35.46 MW
Electricity demand	13.26 GWh/yr	14.11 GWh/yr	11.39 GWh/yr	11.42 GWh/yr

Table 5: Key figures of the reference cooling system

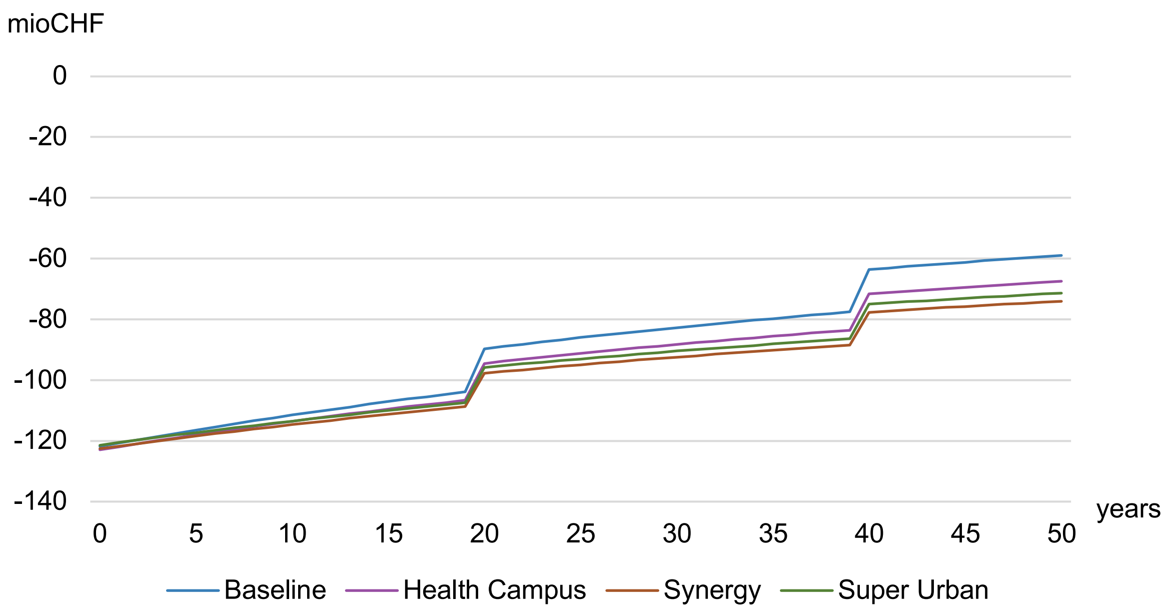


Figure 32: NPV curve of the DLWC System

We can observe much lower operational GHG emissions for the lake water cooling system than for the reference system due to the lower electricity consumption. The savings in operational emissions make the DLWC system an environmentally viable solution for cooling the Hoschulquartier as can be seen in the GHG emission curve depicted in Figure 33. The total savings in GHG emissions is the largest for scenario Baseline and amounts to 47.3 thousand tons of CO_2-eq over the whole lifetime.

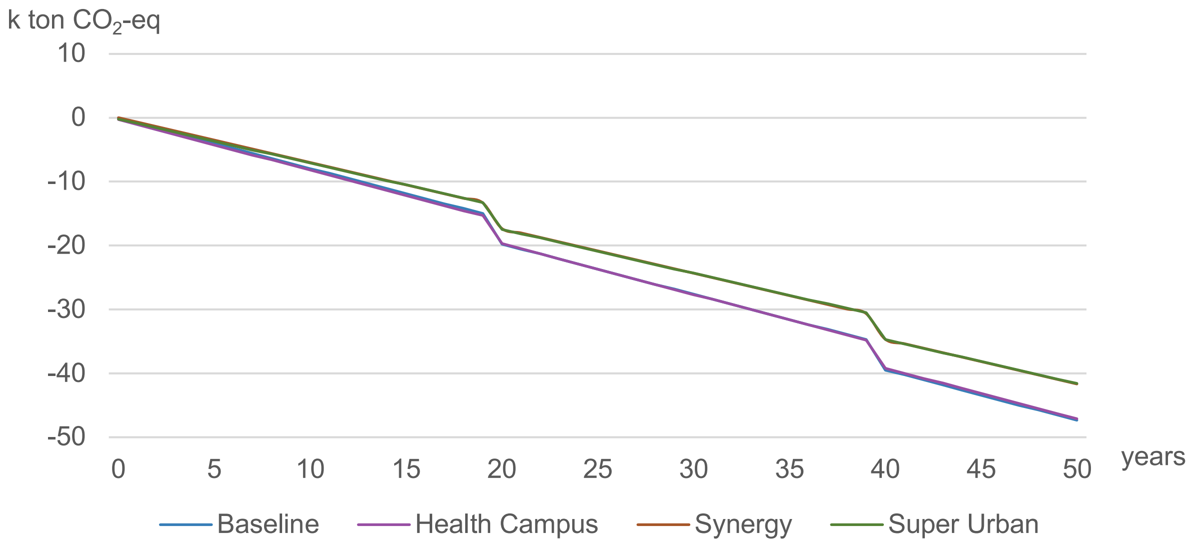


Figure 33: GHG emission curve of the DLWC system compared to the decentralized chiller scenario

The PEN demand curve over the lifetime of the district cooling system is shown in Figure 34 and makes apparent how little the embodied PEN demand affects the overall PEN savings of the DLWC system.

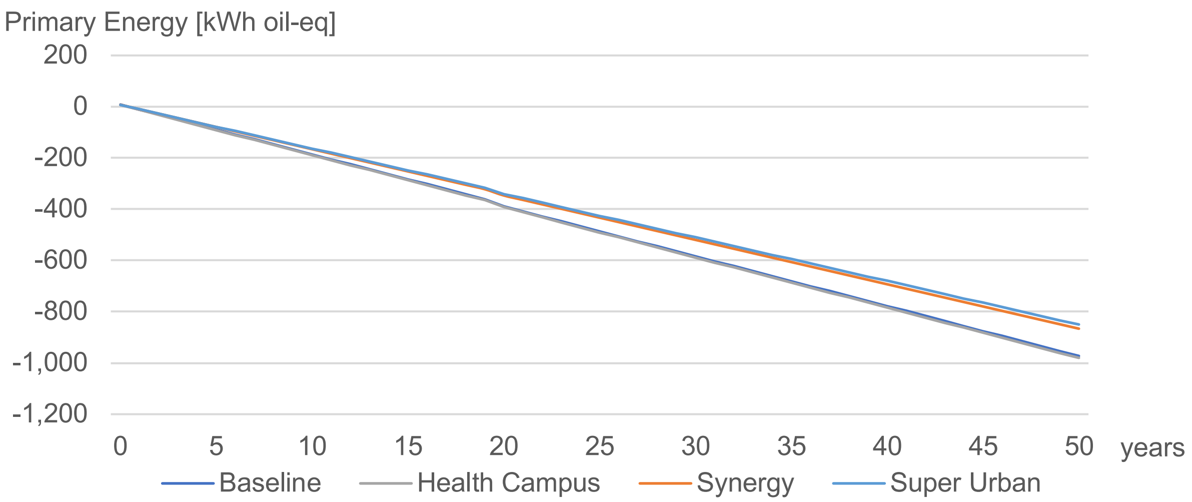


Figure 34: Primary energy demand curve for the DLWC system with respect to decentralized chiller scenario

4.7.2.3.2. Optimal PV placement and battery storage

For the PV potential calculation according to technical feasibility, a rather conservative threshold for PV installation of 800 kWh/m^2/year was used. Hence, solar panels are installed only on building surfaces that exceed this level of insolation. The monthly PV potential for each scenario is shown in Figure 35. Again, given the similar building volumes, the amount of electricity produced in each case is very similar at approximately 16.8 GWh/year for each case. Unsurprisingly, most electricity is produced by roof-mounted PV, which produces 78% of the overall solar electricity in the Health Campus scenario and 73% in the Super Urban scenario.

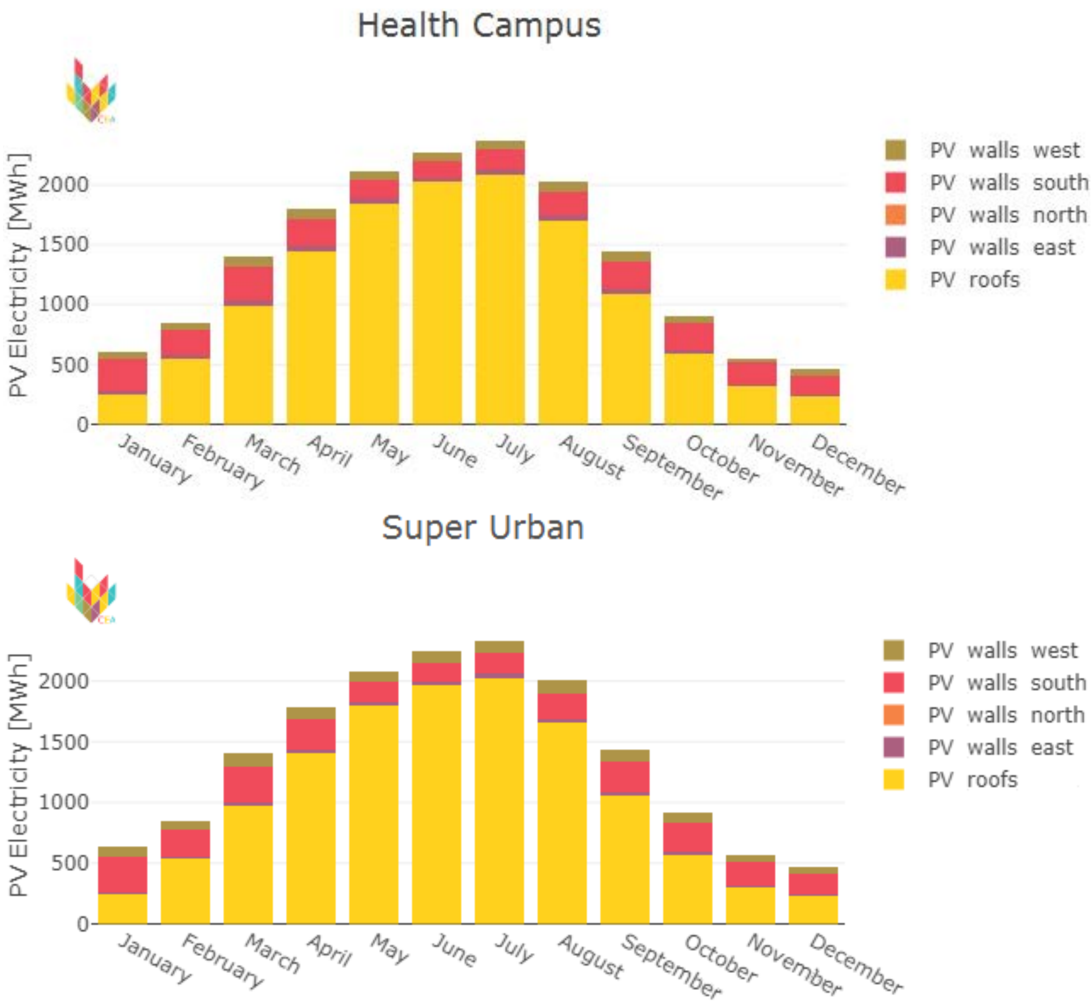


Figure 35. Monthly PV electricity generation potential on roofs and façades of all buildings in the area for each of the two scenarios.

Figure 36 shows the percentage of each roof that is covered by solar panels as a result of the PV placement optimization algorithm. In order to maximize local electricity production, the Health Campus and Super Urban scenarios assumed an aggressive push for PV in the area. Hence, we considered every building's roof, included protected historical buildings, to be available for solar panel installation. No solar panels were placed on building façades when the optimization algorithm was used. The feasibility of reaching the proposed roof coverages would also depend on the presence of additional rooftop installations, such that the NPV of a few buildings might have a smaller yield.

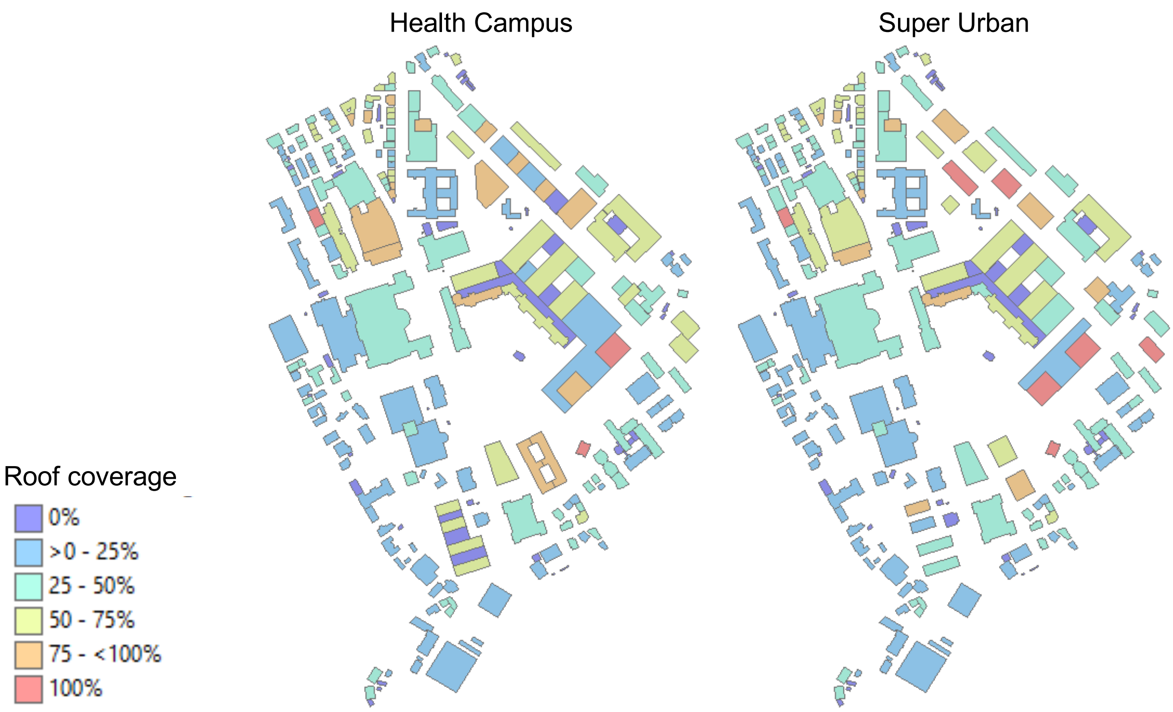


Figure 36. Spatially represented results for the resulting roof coverage of each building in Health Campus (left) and Super Urban (right) scenarios.

General conclusions can be drawn from the results presented above. Firstly, two types of buildings are the most attractive for PV installation: those with the biggest footprints and the tall towers. In the first case, a big rooftop area on which solar panels can be installed leads to bigger yields. In the case of towers, the insolation on roof surfaces is very high and they have a high demand with respect to the size of the roof, thus it is more likely that the electricity that is produced will be consumed on site, leading to higher revenues. On the other hand, the buildings which are in the vicinity of tall towers do not get significant irradiation due to their height and shading and therefore their potential for PV energy generation is limited. It is also worth mentioning that for all the buildings studied the surfaces which are chosen to be covered with PV are placed on the roof, meaning that the installation of PV on vertical walls of the buildings is not profitable for investigated cases.

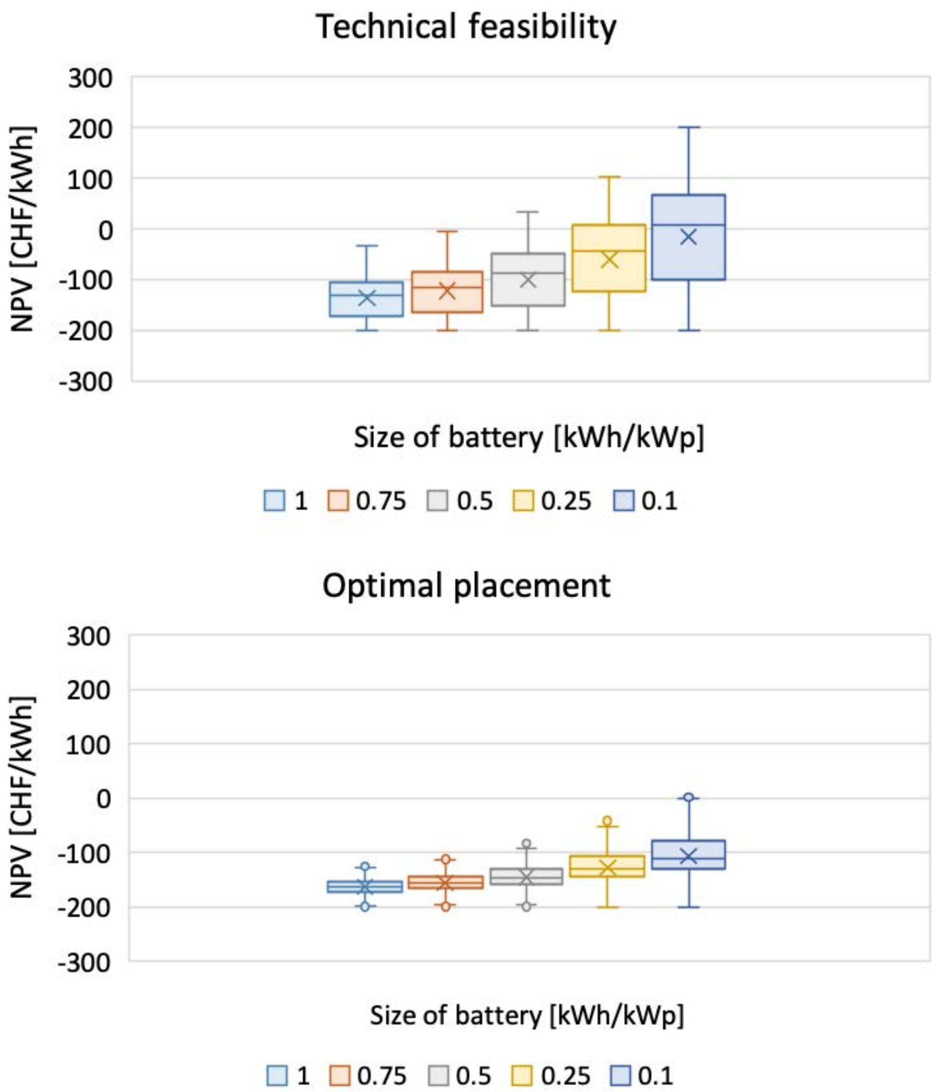


Figure 37. Net Present Value of installed battery in CHF/kWh for different battery sizes for Health Campus scenario when PV is placed according to technical feasibility (top) and when PV is optimally placed (bottom).

Given the PV placement results from both the minimum threshold method and the optimized placement, the optimization algorithm was run for the batteries installed at each building of the Health Campus and Super Urban scenarios. The NPV of investment for each building was calculated for battery sizes of 0.1 to 1 kWh per kW-peak of installed PV. The distribution of buildings' NPV per kWh of battery capacity for different sizes of the battery with respect to the capacity of the installed PV panels is presented in Figure 37 and Figure 38. A battery that does not bring any revenue would have an NPV of -200 CHF/kWh.

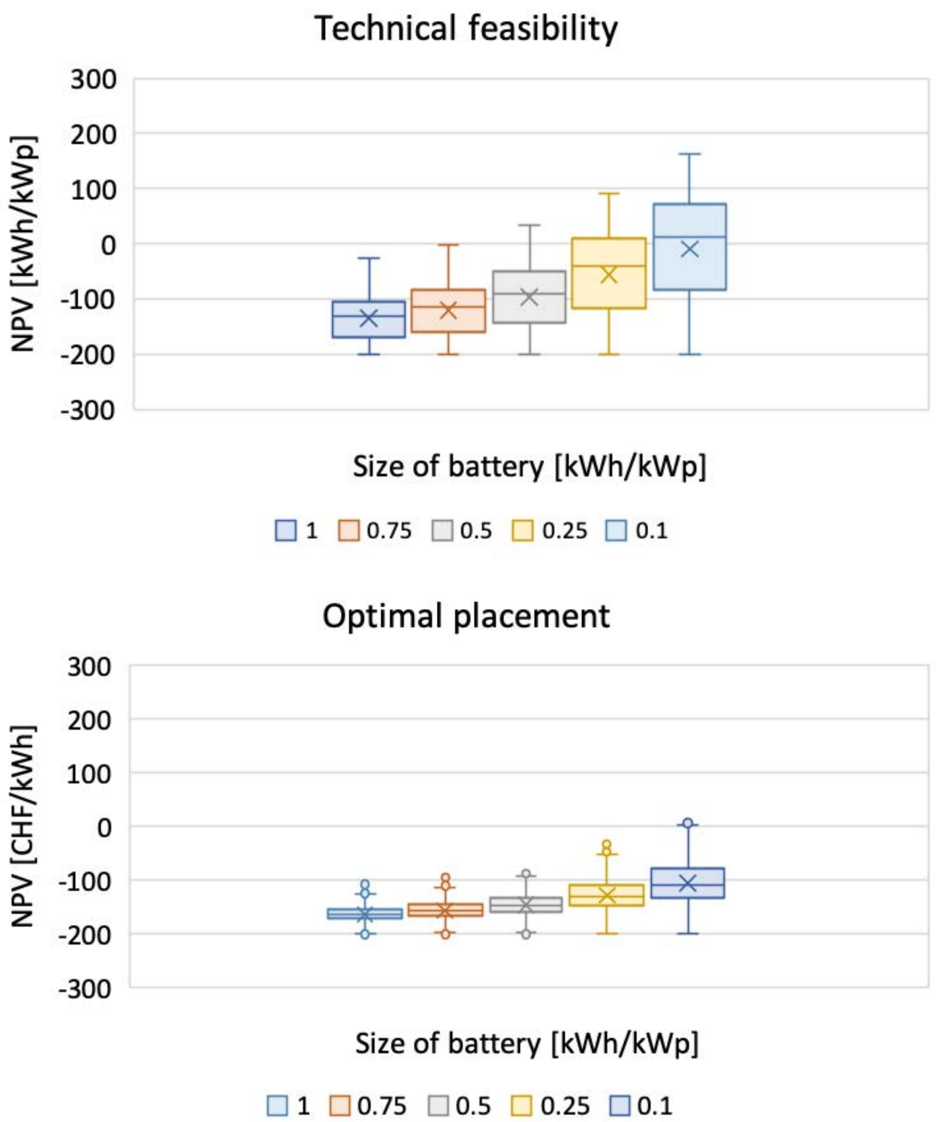


Figure 38. Net Present Value of installed battery in CHF/kWh for different battery sizes for Super Urban scenario when PV is placed according to technical feasibility (top) and when PV is optimally placed (bottom).

It can be deduced from these results that the profitability of the battery installation increases significantly if the installation of solar panels is not optimized and they are placed according to technical feasibility. There are two main reasons why the investment in the batteries is not profitable if the placement of PV is optimized, namely the high cost of the batteries per kWh and the fact that the PV placement is already optimized to maximize the profits and self-consumption. On the other hand, if PV is placed according to technical feasibility, it is not profitable to install a battery bigger than 0.5 kWh/kWp of PV installation for most of the buildings. However, if the size of the battery is equal to or smaller than 0.5 kWh/kWp, then there is a significant number of cases for which battery investment is profitable.

As discussed in the previous section, the installation of additional batteries is not profitable when PV is optimally placed on the buildings. However, since the installation of batteries for the case of PV placement according to technical feasibility case gives a positive NPV, it should be determined what is the most profitable option for each building, either to (a) optimize the installation of PV and not to install the batteries at all, or (b) to install PV according to the technical possibilities and install a battery which results in bringing a positive NPV. Even though the placement of PV according to technical feasibility proved to be worse than the optimized placement of PV, the addition of a battery system has the potential to significantly improve the profitability. To this end, a preferred size of the battery system was defined for each building in which PV panels were placed according to technical feasibility.

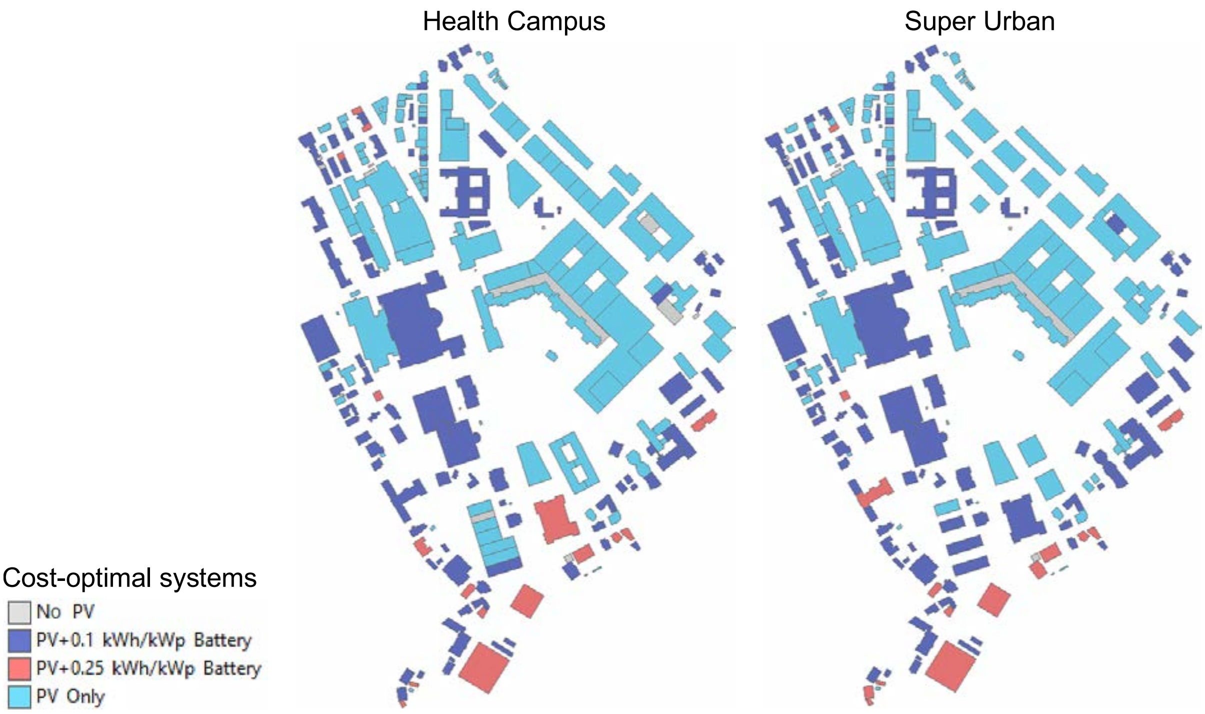


Figure 39. Spatially represented results presenting the optimized preferred configuration to obtain maximum NPV for the Health Campus (left) and Super Urban (right) scenarios when PV is placed according to technical feasibility criterion.

Figure 39 presents the method that results in the highest revenues for each building. For the majority of the buildings the placement of PV without batteries is the cost-optimal strategy. However, for a number of buildings, the installation of a small battery is advised. Such an installation is feasible for big buildings, however, in the case of small buildings the size of the battery and the additional revenues are too small to be considered. Additional installation, operation and maintenance costs which are not considered in this analysis would make the investment in such small batteries unprofitable.

Given the results presented in the previous sections, an optimal use of the vehicle-to-grid technology was investigated for the Health Campus and Super Urban scenarios for the cases when PV is optimally placed and the installation of a traditional battery system is not profitable due to the large investment costs in the battery system. Existing parking spots for each car park were assigned to a nearby building which has significant potential for the savings resulting from the installation of a battery system. Since the PV and battery analysis is performed for a lifespan of 20 years for all the presented scenarios, the discounted savings resulting from using vehicle-to-grid technology over a 20-year period are also presented. The spatial distribution of the results is presented in Figure 40 for both Health Campus and Super Urban scenarios.

Figure 40. Nominal discounted savings (in CHF) which can be obtained over a period of 20 years if the batteries of electric vehicles are utilized with a vehicle-to-grid technology in Health Campus (left) and Super Urban (right) scenarios.

The results indicate that for the majority of the cases the use of vehicle-to-grid technology brings limited savings. Only the new main building of the hospital, where a parking garage is planned to be built, can achieve significant savings. Having a large number of parking spots which are occupied throughout the day, its discounted savings account to over 40,000 CHF and their nominal value is equal to over 70,000 CHF which makes it a potential candidate for the use of a vehicle-to-grid distributed battery system. On the other hand, the feasibility of vehicle-to-grid technologies is nowadays widely discussed with no clear answer whether it is profitable or not (Gough, Dickerson, Rowley, & Walsh, 2017). It requires specialized hardware, especially bi-directional inverters which have significant losses and might contribute to increased EV battery degradation, which was not modelled in this study. All things considered, it can be stated that the hospital building has the highest potential for the savings resulting from the optimal use of the vehicle-to-grid technology, however, its feasibility needs further investigation.

The yearly costs and annualized environmental impacts of each combination of cooling and photovoltaic systems analyzed is shown in Figure 41. In general terms, the best-performing solution from the perspective of minimizing annualized CO_2 emissions always coincided with the solution with the lowest primary energy demand. In every scenario, the best solution in terms of minimizing CO_2 emissions and primary energy always includes the installation of a district cooling network for the area. Given the high construction costs, however, the cost-optimal solution in each scenario involves the use of decentralized vapor compression chillers for cooling. In terms of electricity, for those scenarios where photovoltaic technologies were assessed, the technically-feasible installation always leads to lower CO_2 emissions and primary energy, whereas the cost-optimal solution always led to the lowest costs, including with respect to foregoing PV technologies altogether.

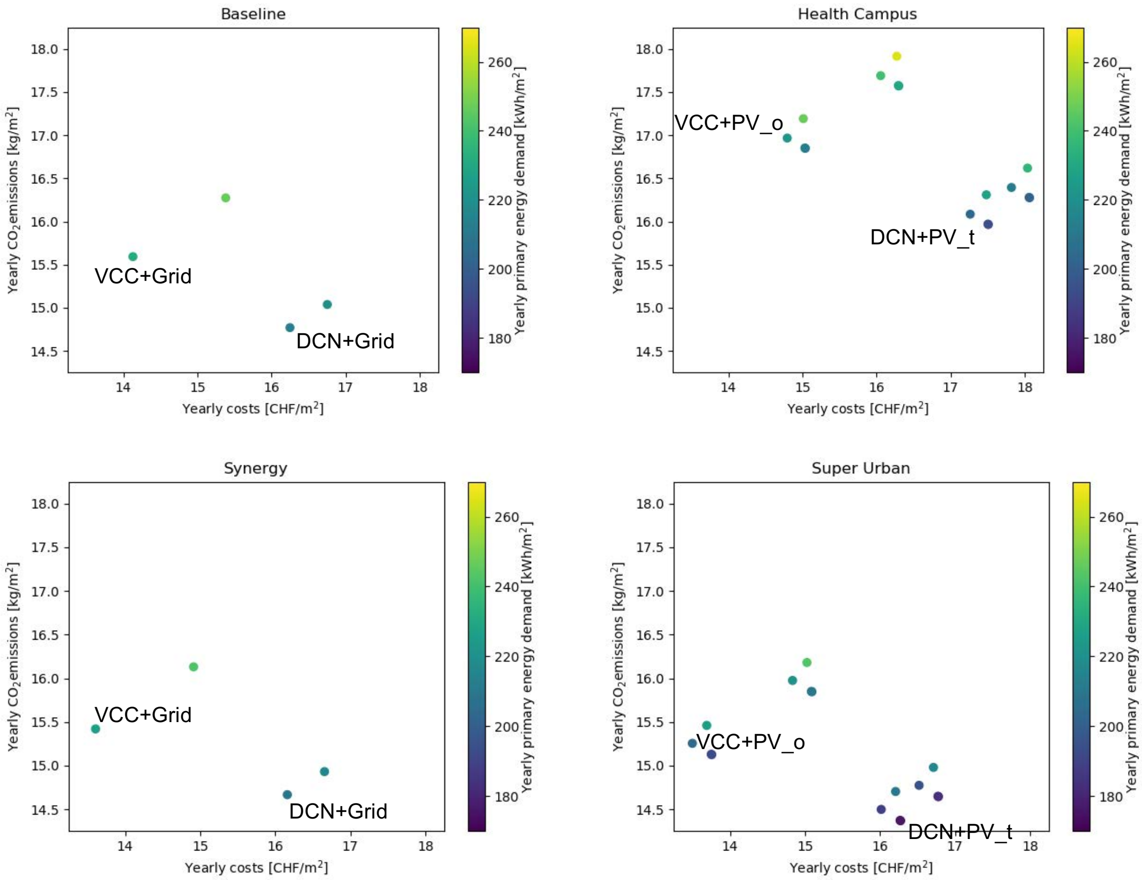


Figure 41 Economic and environmental performance of each combination of systems considered for each scenario. DCN: District Cooling Network. VCC: Vapor compression chiller. PV_t: Technically-feasible PV installation. PV_o: Cost-optimal PV installation.

The results with respect to solar panel placement indicate that the installation of PV panels is beneficial both in economic and environmental terms with respect to the baseline solution, i.e., the use of the grid for the full electricity demand in the area. Thus, the installation of solar technologies appears to be a net positive for the area from both perspectives and is therefore worth exploring further. The decrease in CO_2 emissions is in the order of 0-3% for all scenarios, but given that this reduction in emissions can come at a net zero or even profitable investment, it would be worth deploying solar technologies in the area. Regarding cooling systems, the district cooling network leads to CO_2 emission reductions in the order of about 5% with respect to decentralized vapor compression chillers, but it comes at a cost of about 15% higher costs per kWh for all scenarios. The assumption that additional users may connect to the free cooling grid does not appear to have a large enough impact to economically justify or environmentally dismiss the construction of a district cooling network. These results also appear to indicate that the relatively low impact microclimate effects and occupant behavior had on the cooling demand patterns would probably not affect the choice of infrastructures for the Hochschulquartier significantly.

4.8 WP9: Implementation and evaluation of synergies towards guidelines

For making guidelines and recommendations for planners and urban developers that have a large chance to support energy efficient built environments depends on reliable research results. In the SPACERGY project we are dealing with two types of research:

1. The building – energy usage for heating and cooling – micro climate relationship
2. The street network configuration – energy usage for transport relationship

Regarding the relationship between the building microclimate and energy usage for heating and cooling, one has to deal with each local context. The local climate conditions and the various cultures to deal with cold and warm local temperatures are context-dependent. Conversely, the relationship between the street network configuration and energy usage for transport seems to be context-independent. In this context, we are dealing with unambiguous human intentions; travel-time efficiency and profit-maximising. Therefore, it is possible to apply the model built up in the SPACERGY project on other cities. The implementation and synergies towards guidelines have the following two levels: the context-dependent based ones – applicable only to each specific case studied, and the general ones – applicable to the case studies used in SPACERGY as well as other towns and cities.

4.8.1 Integration Microclimate – Energy

The obtained microclimate results show an evident atmospheric Urban Heat Island phenomenon in both districts. However, the characteristic higher temperatures in the urban areas compared to the rural area, have different patterns along the 24 hours studied. While in the *Hochschulquartier* local temperatures are higher during the night for the two days analyzed, in Almere local temperatures are higher during the daytime.

The consideration of these local climatic patterns in energy demand calculation in the Zurich case leads to a general increased building cooling demand on the hottest day between 1,4% and 2%, and a lower building heating load between 2% and 3% during the coldest day. The effect of microclimate on the peak cooling demand was more noticeable, with a 5% decrease in peak cooling power on the hottest day of the year.

A sensitivity study identifies the variables of Occupied hours, U-values, and Floor Space Index, as significant predictors of variation in both heating and cooling demand when microclimate boundary conditions are used in CEA.

Similarly, in the Floriade case study the inclusion of microclimate data causes the cooling loads at midday to be higher due to the higher outdoor temperature and humidity. Over the entire day, the inclusion of microclimate results in the simulations causes an increase in the cooling demand of about 6%, whereas further incorporating the effects of vegetation causes an increase of 7% when only building and surface materials are taken into account.

Each scenario developed for the Zurich case study involved an underlying guiding assumption regarding the effects of various urban measures on the performance of the area. The parameters changed amongst scenarios included: changes in the functional mix from a more monofunctional, purely health-oriented scenario to a more mixed-use district; the incorporation of microclimatic measures to mitigate the demands in the area; and the integration of local renewable electricity production technologies and electric vehicles.

The move from the Baseline to the monofunctional Health Campus led to increases in heating (+6%), cooling (+11%) and electricity demand (5%), mainly due to increases in the demands for processes and domestic hot water, which led to 17–20% increases in their respective demands. The increase in residential functions in the Synergy and Super Urban scenarios, on the other hand, led to an overall decrease in the demands for heating (-3% to -10%), cooling (-20%) and electricity (-4% to -7%). The large decrease in cooling demand is mainly due to the fact that residential buildings are typically not cooled in Switzerland. One key assumption in the definition of the scenarios, however, was that the mixed-use scenarios would lead to load balancing and peak shaving, however the most stable load was actually observed in the Health Campus scenario. This is due to the fact that hospitals are the only buildings in the area that have 24-hour active occupancy, and hence a large baseload and relatively constant demand throughout the day.

Regarding microclimate measures, while there was a clear microclimate effect in all scenarios, the effect was very similar in each case. Hence, the effect of microclimate on cooling demand on the hottest day of the year was fairly similar for all scenarios. Due to the decreased air temperature in the area mid-day, the maximum power demand for all scenarios was actually higher when accounting for microclimate effects (-3% to -7%). However, given the higher night time temperatures due to heat storage in the building and street materials, the overall demand on the hottest day of the year actually increases (+4% to +6%). The peak reduction is indeed higher for the scenarios with microclimatic measures, but so is the increase in total cooling demand. The variations between scenarios are, however, mostly negligible.

The installation of district cooling infrastructure proved to have a positive environmental impact for all scenarios, with a decrease in yearly CO_2 emissions of 40–44% with respect to a standard vapor compression chiller system, but at a much larger operational cost (+66–+93%). Increasing the cooling demand by more than 50% was not enough to make the system feasible nor decisively dismiss it from an environmental perspective. This would appear to indicate that the effects of urban microclimate and building occupant behaviour (both of which were quantified to contribute to a deviation in total demand of less than 10%) would not be significant enough to affect the decision on whether to build a large district cooling infrastructure.

Finally, for the two scenarios with PV installation, CO_2 emission savings of about 5% could be achieved through PV installation with an increase in electricity costs of only 0.2%. Even cost-optimal alternatives that even made profits of around 2% showed a decrease in yearly CO_2 emissions of 3.5%. The decreases in CO_2 emissions are modest due to the relatively low carbon intensity of the Swiss grid, however primary energy demand was decreased by 15–25%. Given that the CO_2 performance could be improved without increasing the electricity costs in the area, PV appears to be a very promising technology for the area. The introduction of batteries appeared to have minimal impact due to the high self-consumption rates in the area, but the presence of electric vehicle charging stations in the new main building of the university hospital proved to be potentially beneficial from an economic perspective. In spite of the CO_2 savings created by the installation of photovoltaic panels, the Health Campus scenario incurred the highest CO_2 emissions due to its overall higher energy demands. In terms of primary energy, however, the scenarios with no photovoltaic installations performed worst. Due to the combination of lowest demand and least carbon-intensive technologies, the Super Urban scenario had the lowest emissions, primary energy demand and costs of all scenarios.

4.8.2 Street network configuration – Energy usage for transport

As it turns out, the spatial structure of the street network, combined with the topological relationship between buildings and streets, influences energy usage for transport. The findings are much in line with the existing four theories based on Space Syntax research: the theory of natural movement (Hillier et al., 1993), the theory of the natural movement economic process (Hillier 1996, van Nes 2017), the theories of spatial combinatorics (Hillier 1996) and the theory of the natural urban transformation process (Ye and van Nes, 2014). As research has shown, the spatial configuration of the street network is the underlying driving force for the densification processes of the built mass, the degree of land use diversity, the degree of movement flows through the street and road networks, and the dispersal of economic/commercial activities (van Nes 2017). Figure 42 shows a diagrammatic representation of the theory of the natural movement economic process and the theory of the natural urban transformation process.

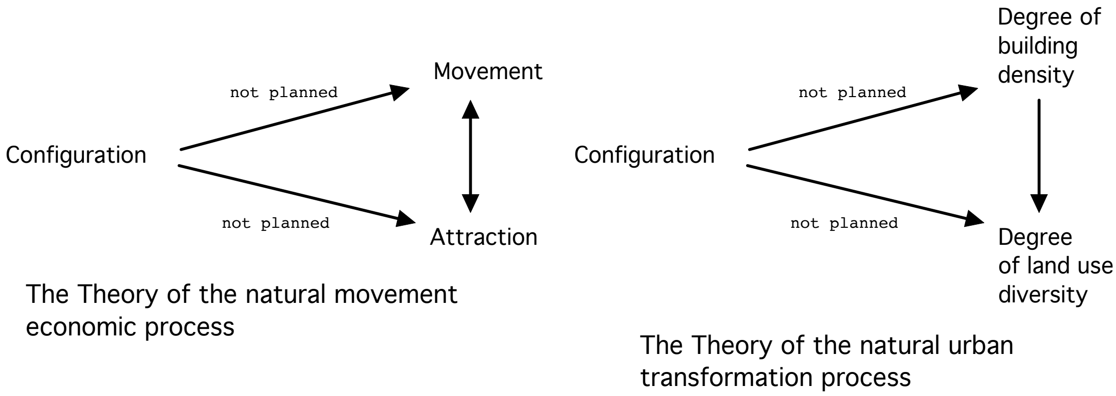


Figure 42 The theory of the natural movement economic process (left) and the theory of the natural urban transformation process (right).

Based on these theories, application of the Space Syntax method can make predictions on movement and route-choice. The method's strong post-dict capability regarding predicting potential movement patterns and dispersal of economic activities has been widely corroborated (Hillier et al., 1993, 1998, van Nes, 2002, van Nes et al., 2012). The topological and geometrical structure of the street network and the position of streets within the system allow calculations to be made of through-movement potentials and to-movement potentials of every street segment in relation to all others. The correlations of the Space Syntax analyses of the street network in Zurich as well as in Bergen show similar results: a well-integrated, connected and fine-grained street network, combined with a high degree of building – street permeability and intervisibility reduces energy usage for transport per user. Therefore, it is possible to test out various scenarios based on the street network configuration, combined with the urban micro scale tools (the building-street relationship). Therefore, the following can be stated:

If you want to improve walkability and a high degree of public transport use instead of the private car in neighbourhoods, then the following spatial parameters must be present at the same time:

- On a macroscale level: The main routes must be well-connected to the local streets in the vicinity
- On a mesoscale level: Short urban blocks (contribute to a fine-grained street network with short walking distances)
- On a microscale level: Buildings must have active frontages with both doors and windows connected directly to the street. Streets need to be intervisible from buildings from both sides.

All these parameters have to be present at the same time to reduce energy usage for transport.

From the scenario studies focusing on the urban structure (through Space Syntax) and travel behaviour (through MATSim), it comes forward that a change in street pattern changes movement patterns. The Hochschulquartier scenarios allowed examining of the overall effects of adding new streets and connections within a well-established street network. The clearest difference was found with the existing situation. Compared to the Status Quo, all the scenarios bring about profound changes in the way the public domain is organised. The concepts introduce a new, central axis as well as improved internal circulation, creating a denser network of public spaces and more to- and through-connections with the adjacent districts. The Space Syntax analyses demonstrated that the changes chiefly benefited the local network: the angular choice values with a low metric radius increased in the Hochschulquartier district and in the streets leading down to the city centre. Being of high local integration, these values were demonstrably extended up the hill towards and into the study area based on the improvements in street pattern there. The Synergy scenario performs the best at this.

The changes were also reflected by the agent-based simulations, which showed an increase in the amount and the dispersal of pedestrians going to- and from the area compared to Status Quo and Baseline. The amount of energy used by cars went up compared to Status Quo, but not significantly. On the one hand, this can be explained by the fact that there is an overall increase of travellers. In terms of percentage, the share of cars can be said to go down. On the other, the changes in street pattern served the local scale, and they are largely car-free pedestrian zones. This means that the trip by car did not become more or less attractive because of these changes. However, the Synergy scenario, with the biggest improvement in local integration, does display the least amount of energy for cars and the lowest amount of kilometres driven by cars within the area.

The analyses showed how amongst other parameters, improving the street network locally can have considerable implications for the choice of mode and choice of route, and therewith the overall energy performance of the users. Other factors, however, showed to have an influence such as functional programme, street design, public transport offer and parking (and charging) availability. This came forward from the Super Urban scenario. Whereas the Space Syntax demonstrated that the local through-movement potential did not increase as successfully as in Synergy, the adherence to the urban fabric and aforementioned factors led it to being the scenario with highest amount of walking in the area.

Concludingly, from the point of view of mobility energy demand, the Synergy scenario scores best in absolute terms. There are many aspects of the urban structure that contribute to this result, and increasing to- and through-movement potential by adding new street segments is an important factor to achieve this.

5 Conclusions and outlook

5.1 Conclusions

This report discusses methods applied and results obtained in the SPACERGY project. Three urban case studies were selected as Living Lab environments. On these three development projects, different approaches and methods were developed and tested with the main scope of addressing the integration between multiple dimension involved in the districts' energy transition. Knowledge and tools have been developed along the project in order to address the main challenge of integrating space and energy dimensions along the process of transition towards low carbon urban transformations. The results show that such integration requires i) active approaches to involve key actors for the creation of a multidisciplinary knowledge base, ii) envisioning of possible and desirable scenarios resilient to external drivers of changes, iii) energy tools and models able to assess energy demand on a district scale by including mobility and building energy components. SPACERGY had 3 case studies from three different countries. We learned the following lessons from the project.

First of all, GIS turned out to be a useful platform to correlate spatial data with energy data for mobility. Useful knowledge was derived through this project on the relationship between energy usage for transport and the spatial structure of the built environment. The tools and the conclusions are applicable to other cities. Moreover, these tools can also be applied to test out new plans when there is a plan with buildings facades and street network changes are present. In the scope of challenges relating to sustainable urban development, cities should accommodate our needs (housing, jobs, transport, energy etc.) within the technological and social organizational limitations that exist. Amongst those limitations are access to resources such as education, (affordable) housing, the job market, but also so-called free goods like light, air, water and green space. As this research has shown, the degree of access to such resources is to an important extent bound by spatial restrictions. This observation is the starting point for urban planners to optimize cities spatially to meet the needs of the present and the future. It is also a possible starting point for a computational theory of sustainable development. While the global perspective on sustainability is too multi-faceted and complex to admit any straightforward computational model, the localized theory of sustainability as a property of individual spaces is a prime candidate for integration into existing computational models of space, most notably GIS.

The workshops with the stakeholders gave us useful input for scenario testing for the three case study areas. The local communities and researchers have a different approach and operate with different concepts to address the same issue. Likewise, the researchers in SPACERGY come from different disciplines and also have different concepts and methods for finding solutions to the same issues.

The largest challenge is to develop a common conceptual framework that is both operational for researchers as well as for planners. The Space Syntax jargon, such as 'angular choice with a low metrical radius' is difficult to understand for stakeholders and planners. When adding the mathematical formula on how to calculate angular choice with a low metrical radius, it makes it even more difficult. Therefore, the concept 'through-movement potentials on a neighborhood level' is at least a more operational concept for stakeholders and planners. By testing on three case studies with a divergent context in terms of urban structure and local differences in cultural, climatic and microclimatic conditions, it was shown that the method is transferable to other cities. As such, it is context-independent, under the condition that the working model is able to operate with different types of input data in varying formats and standards. Thus, the necessity to gain and spread knowledge about which urban form factors yield the best energy performance is a strong argument for more standardized management and sharing of data.

Regarding the energy performance of buildings and related spatial attributes two key challenges can be highlighted from the obtained results. The first is that the integration of spatial and energy measures to design efficient districts has to take into account the possible impacts of climate change on cooling demand in temperate climates. Moreover, the indirect effect of urban form on microclimate differently affects the energy demand for space cooling in the Almere and Zurich case, increasing the energy loads between 1.4% and 7%. As the future global rising in temperatures is also expected to affect microclimate in the urban canopy layer, the planning and design of new districts are called to deal with new solutions to mitigate the magnitude of urban heat island phenomena and related energy consumption.

Secondly, the consideration of form factors and building energy performance needs to address the physical relations created at the neighborhood level. As found in the Almere and Zurich districts, the predominant factors influencing the effects of microclimate on building energy performance are the ones depending on context characteristics such as the compactness of the surrounding and the presence of vegetation.

Finally, microclimate effects and occupant behavior both were found to affect the peaks in demand in the case studies under consideration, the scale of the variation they caused appeared to be too small to affect the decision to build large scale infrastructures such as district-scale thermal networks. The decision to build such infrastructures appears to hinge on a tradeoff between increased economic costs and improved environmental performance. However, solar photovoltaic technologies showed a net benefit both in economic and environmental terms in the Zurich case study.

5.2 Next steps after end of project

More research is needed, however, on the share of other modes of transport, notably public transport, walking and cycling. Further studies will include energy-calculations for public transport, simulated or observed data on pedestrians and cyclists, and subsequent correlating of the data with the results presented in this report. The aim is to test if and how a change in the street network, combined with a change in microscale conditions, would alter the share of private vehicle usage versus the more sustainable alternatives. The usefulness of this model is a first step to build an energy classification for different street and road types. However, this model needs testing on other cities before making it operational for evaluating urban plans. At least, this model is a first step to understand the spatial conditions for enhancing sustainable mobility means.

For the transport energy calculations, measured data as well as simulated data on vehicular traffic was used for addressing the mobility (or, person transport) component of transport. Other transport, however, notably transport of goods, has not been part of the research. This is considered by the authors to be a vital missing link in the wider discussion about sustainable transport that has much larger implications for how our societies and economies are organised.

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8 Appendix

8.1 Appendix 1: SPACERGY Workshops

As part of the SPACERGY project, workshops and interviews were carried out with stakeholders and decision makers. These are summarized in the following sections.

8.1.1 SPACERGY Workshop 01: Almere

Design oriented scenario workshop for the Floriade 2022+ area, Almere

Date: Wednesday September 28th 2016 | 09:30 – 16:00

Location: Drijfveer, Almere

Invited participants:

- Spacergy project participants (TU Delft, HIB Bergen, ETH Zurich)
- Representatives of the Municipality of Almere
- Representatives of the Province of Flevoland
- Representatives of Nuon (electricity) and Alliander (grid operator)
- Representatives of TNO

Aim:

After 2022, the Floriade area in Almere will be converted into a smart urban residential area, within the context of the transition to a 'Smart & Growing Green City'. This workshop aims at discussing external trends and preliminary design oriented scenarios for the area. Based on this discussion, more definite design oriented scenarios will be created and evaluated within the Spacergy project.

Figure 43 Floriade site visit.

Figure 44 Scenario-building workshop in Almere.

8.1.2 SPACERGY Workshop 02: Bergen

Design oriented scenario workshop for the Myndemyren area, Bergen

Date: Friday October 7th 2016 | 10:30 – 16:00

Location: Høgskolen i Bergen (HIB), Bergen

Invited participants:

- Spacergy project participants (TU Delft, HIB Bergen, ETH Zurich)
- Per Ås Moen, Magne, Hanna Hugosson (Bergen Municipality)
- Grethe Vikane, Unn Jenny Utne Kvam (Bergen Public road administration)
- Sigrid Bjercke, Marit Rødseth (Province)
- Torgeir Flo (Fylkesmannen)
- Representative for the new light rail
- Representative for giving building permissions

Aim:

Development scenarios for Mindemyren; Presentation and discussion on four internal scenarios; Evaluation and reflection regarding Almere and Bergen cases

Figure 45 Myndemyren site visit

Figure 46 Scenario-building workshop in Bergen.

8.1.3 SPACERGY Workshop 03: Zurich

Design oriented scenario workshop for the Hochschulquartier area, Zurich

<u>Date:</u> Friday October 28th 2016 | 09:00 – 18:00

<u>Location:</u> ETH Zürich, Campus Zentrum, ML building

<u>Invited participants:</u>

- Spacergy project participants:
    - Prof. Arno Schlüter, Martín Mosteiro Romero, Anja Willmann, Dr. Amr Elesawy (Architektur und Gebäudesysteme, ETH Zürich)
    - Prof. Kay Axhausen, Henrik Becker (Verkehrsplanung und Transportsysteme, ETH)
    - Remco de Koning (Institutt for byggfag, Høgskolen i Bergen)
    - Prof. Arjan van Timmeren, Daniela Maiullari, Dr. Karel Mulder (Chair Environmental Technology & Design, TU Delft)
- Mr. Felix Schmid (Departement der Industriellen Betriebe, Stadt Zürich)
- Dr. Martin Jakob (TEP Energy GmbH)
- Student stakeholders: Stefan Caranovic, Paul Neitzel

<u>Aim:</u>

This workshop aims at defining comparable, plausible and tangible scenarios for the area from a combined top-down and bottom-up perspective and assessing them under different external trends. Based on the scenarios drafted in this workshop, more definite design-oriented scenarios will be created and evaluated within the Spacergy project.

Figure 47 Scenario-building workshop in Zurich

Figure 48 Presentation of results for discussion.

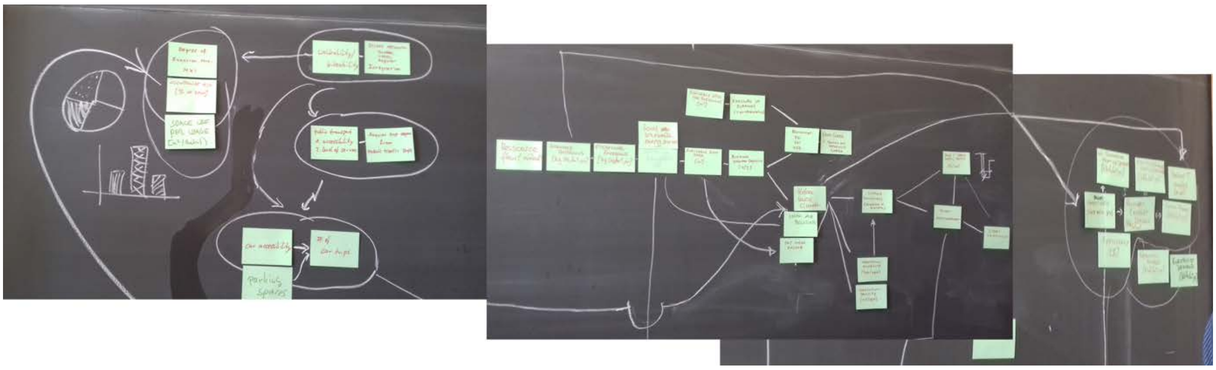

Figure 49 Selected indicators for scenario assessment.