

PAPER • OPEN ACCESS

Process of Energy Master Planning of Resilient Communities for comfort and energy solutions in districts

To cite this article: Matthias Haase and Ruediger Lohse 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **352** 012019

View the [article online](#) for updates and enhancements.

Process of Energy Master Planning of Resilient Communities for comfort and energy solutions in districts

**Matthias Haase, SINTEF Building and Infrastructure, Norway*,
Ruediger Lohse, Climate Protection and Energy Agency, Germany**

*Matthias.Haase@sintef.no

Abstract. The paper explains the major steps in Energy Master Planning process. It proposes a definition of target goals. Then, a number of constraints have to be analyzed in order to be able to define site specific framing goals and associated limitations. This process will narrow the numerous design options down to those that offer an optimized fit to the local conditions and the objectives for the building or community. Based on the target definition a Baseline can then be developed. This consists of a snapshot of the current energy use situation. The baseline is one reference point used to evaluate alternative futures. Then Base Cases will be developed that extends the baseline into the future and includes already-funded renovation as well as planned construction and demolition activities. The base case is a future reference point for “business as usual.” Different alternatives – A selected set of scenarios that include different energy measures related to buildings, distribution systems, and generation systems will then be developed. These scenarios are compared to the baseline for energy use change and to the Base Case for investment and operational costs.

1. Introduction

Until recently, most planners of public communities (military garrisons, universities, etc.) addressed energy systems for new facilities on an individual facility basis without consideration of community-wide goals relevant to energy sources, renewables, storage, or future energy generation needs. Because building retrofits of public buildings typically do not address energy needs beyond the minimum code requirements, it can be difficult if not impossible to achieve community-level targets on a building-by-building basis.

As more and more countries push to improve the efficiency, environmental impact, and the resilience of their buildings and communities, the need for early and comprehensive energy master planning is critically important. The best energy master planning is highly dependent on a thorough understanding of framing goals and constraints, both local and regional, and their associated limitations that will dictate the optimum master planning design.

This paper will analyze and contrast the framing goals and limitations that must be considered when energy master planning is conducted for communities in six different countries. The analyses will be based on findings from countries participating in the International Energy Agency’s “Energy in Buildings and Communities Program Annex 73” The analysis will cover design constraints such as emissions, sustainability and resilience goals, and regulations and directives, and regional and local limitations such as available energy types, local conditions, and community objectives and illustrate how a comprehensive consideration of these can be used to guide the planner toward design options that will lead to an optimum solution for a master plan.



Lastly, the paper will propose a comprehensive table of framing goals and associated limitations and a suggested process that the master planner can use to narrow the numerous design options down to those that offer an optimized fit to the local conditions and the objectives for the building or community.

2. Background

The status quo in planning and execution of energy-related projects will not support attainment of current energy goals (Energy Performance of Buildings Directive [1] in Europe and 10CFR-433 in the United States [2]) or the minimization of costs for providing energy security.

Most national and international research and policy energy-related efforts in the built environment focus on renewable energy sources and energy efficiency in single buildings. Significant additional energy savings and increased energy security can be realized by considering holistic solutions for the heating, cooling and power needs of communities – comprising collections of buildings.

Building-centric planning falls short of delivering community-level resilience. For example, the frequency and duration of regional power outages from weather, manmade events, and aging infrastructure have increased. Major disruptions of electric and thermal energy have degraded critical mission capabilities and caused significant economic impacts at military installations.

Organizations that have made first efforts to evaluate and analyze international experiences with planning and implementation of low-energy communities include the International Energy Agency (IEA) Energy Conservation in Buildings and Community Systems (ECBCS) Annex 51, 67, 70 and 75 [3-7], the German-funded EnEff Stadt project [8] (a comprehensive approach to urban areas with local and district heating networks), the World Bank Energy Sector Management Assistance Program (ESMAP) [9] and the Energy Efficient Cities Initiative (EISA) [10]. The U.S.Army pioneered a Net Zero Installations program for selected installations [11], which goes beyond zero energy and includes zero waste and zero water initiatives. Other initiatives e.g.in the center for Zero Emission Neighborhoods (ZEN) [12] recently analyzed tools in use for stakeholder engagement in four ZEN pilot projects in Norway. The results show that the tools have different goals and involve different stakeholders, some are focusing on citizens, while others aim for engagement of professional stakeholders such as construction and energy companies [13]. Other studies aim at developing guidelines for Zero Emission Neighborhoods (ZEN) by focusing on how the definition of ZEN and its KPIs could be assessed and implemented into the planning, design, construction, and operational phases of planned and existing neighborhoods [14].

It was therefore important to collect data on EUI from existing Commercial Buildings Energy Consumption Surveys and from existing standards (ASHRAE Std 100 [15], German VDI 3807 [16], Switzerland SIA 380.1 [17] etc.). EUIs are a necessary requirement for efficient energy management and for establishing national or agency-specific energy targets.

The development of districts requires a distinct understanding of the situation now as well as a vision of the future district in order to be able develop suitable pathways for this transition. In order to be able to do that a district needs to be modelled that consists of several buildings (new, retro-fitted or a combination of both), sufficiently described so that the future district can actively manage their energy consumption and the energy flow between them and the wider energy system. The energy master planning process requires an analysis of different scenarios, which include new construction to different levels of energy efficiency, major renovation of all or some buildings comprising building stock under consideration with Deep Energy Retrofit of these buildings, minor renovations with energy-related scope of work, or demolition of some old buildings. Such analysis requires building energy modeling. In this research work we collected models of representative buildings from several countries and compared them.

However, in community-wide energy planning, it is important to understand the various constraints, which frame the planning goal and the way towards an optimized solution. The planners need to know the design constraints such as emissions, sustainability and resilience goals, and regulations and directives, and regional and local limitations such as available energy types, local

conditions, and community objectives. In order to be able to apply principles of a holistic approach to community energy planning and to provide the necessary methods and instruments to master planners, decision makers, and stakeholders it is essential to identify and frame the constraints that bound the options towards an optimized energy master planning solution.

3. Energy Master Planning

The energy master planning process (EMP) for building communities is carried out in several, at least three stages starting with the concept phase, the first planning and iterations. In the big picture of a refurbishment or newly set up compound EMP is one part of the total design process which usually claims between 5 and 20% of the total cost budget. Interactions between EMP and the other constructive planning has to be set up from day one to avoid costly iterations. In a few EU countries a small number of best practice projects provides first experience in the interaction of BIM (building implementation management) systems and EMP processes. It is important to create a better understanding of the practical application of different interfering constraints on different stages of the energy master planning EMP process which addresses energy master planners, architects, spatial planners, public and private real estate management and financiers.

EMP can be carried out in a hierarchic “top down” approach or in a “bottom up” process, in [21] both methods are compared. The decision making on hard and soft constraints is often required when existing buildings and infrastructure is refurbished under cost limit constraints. The EMP process is usually carried out in two stages. In the first stage of EMP (concept phase) more holistic and even generic constraints resulting from limitations from the spatial planning and mission related indicators have to be considered. The second stage adds the assessment of constraints on the level of components. To minimize risks of failure and abundant cost budgets in the EMP process it is of advantage preparing a set of pre- selected scenarios with technical solutions for a number of selected types of compounds and neighborhoods and their specific needs.

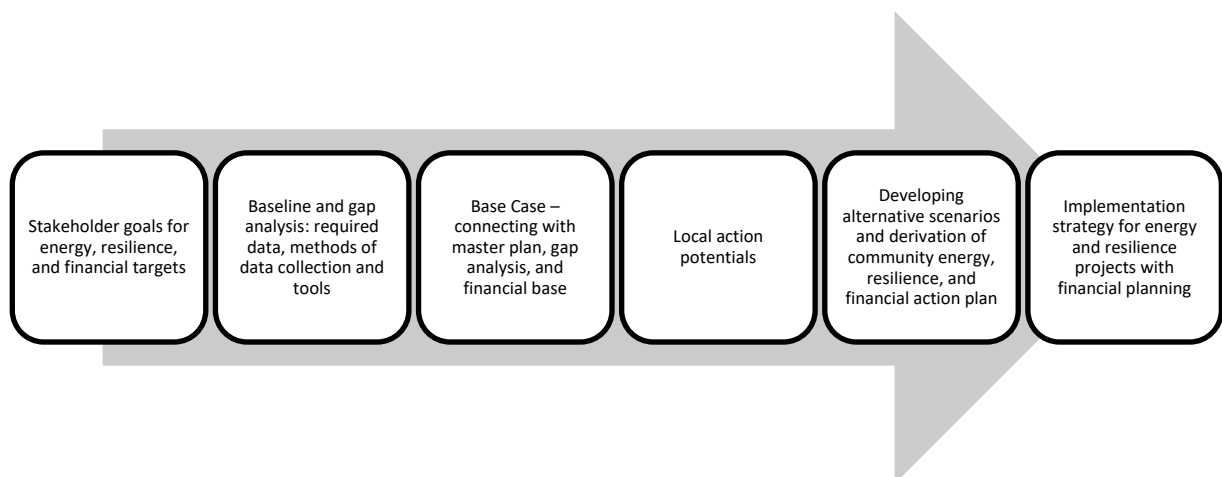


Figure: Different stages in Energy Master Planning (EMP)

3.1. Stakeholders goals and Constraints

One of the first steps in energy master planning is to determine the framing constraints. Having this as an early step will typically significantly reduce the possible solution sets for both individual buildings/structures/facilities and the entire district as a whole. Framing constraints in this context are defined as any constraints that will influence/restrict the possibilities for using or installing particular technologies or utilizing specific solutions in the district or in individual buildings/structures. The framing constraints can be divided into two subgroups; the natural constraints and the imposed constraints.

The natural constraints cover e.g. locational threats and resources. Locational threats deals with all natural threats that influence the possible choices of technologies or solutions and could be e.g. regional or local air quality, extreme temperatures or high winds. Locational resources deal with the availability of energy on-site or nearby. It covers both renewable energy sources for the location, e.g. wind, solar etc. and existing available energy infrastructure, e.g. power lines, gas pipes, district heating etc. Harnessing adequate amounts of energy from renewable energy sources usually requires quite a lot of space, e.g. it may be difficult to harness solar energy in big cities where roof or land area is not available and it may be difficult to utilize wind turbines since they require open spaces to be efficient. Therefore, the spatial possibilities are also part of the natural constraints.

The imposed constraints are constraints that for the most part is relevant for individual buildings or facilities (e.g. requirements on maximum energy consumption, emissions or requirements on specific indoor climate parameters) but the imposed constraints can also apply to the entire district (e.g. local plans or national energy targets). The energy planner, owner or operator of the district could also choose to impose special voluntary operational constraints that are more restrictive than e.g. legislative constraints, e.g. 100% renewables, possibility for islanding for a certain length of time etc.

3.1.1. List of constraints.

- Natural Locational Constraints – Resources and threats
- Distribution System & Storage Constraints
- Building and Facility Constraints:
- Indoor Environment Constraints
- Building Equipment and District System Constraints

Natural locational constraints can typically be categorized into resources and threats. In EMP processes, energy resource limits such as the unavailability of natural gas, or low biomass or wind resources will limit your technology options. As with all constraints, these should be identified and applied early. Fuel and water resource limits can of course be identified via local utility providers. Chilled water, hot water, and steam resource limits can be identified via the capacity of the local central plants that supply them. These resource limits must be considered with regard to the resource demand from any users on the district system outside the building or campus under consideration.

3.1.2. European Building Performance Directive (EPBD)

In Europe, the European Building Performance Directive (EPBD) creates the framework for the national building performance legislation of the EU member countries. EPBD set targets for the overall energy efficiency improvements in the building stock and for the partition of renewable energy to be integrated in the building sector. The pathway towards a 80- 90% carbon neutral building sector includes cross sectoral strategies such as:

- Energy demand limits for newly built and extensively renovated buildings
- Energy certification formats to provide transparency on the energy demand of the building
- Integration of information and communication systems in order to adapt the energy supply to the energy demand of the users, create transparency on the actual performance and consumption of the building users
- E- mobility as a cross cutting approach for power use
- Building refurbishment roadmaps in order to implement strategic building refurbishment targets for the next 30 years

The EPBD has to be implemented under consideration of the subsidiarity principle on the national legislation of each EU member countries. After the recent update of the EPBD in 2018, July, member countries are requested to provide national implementation programs within the next 24 months.

In the case of Germany, the EPBD is transferred into different legislative constraints of relevance for the EMP process:

- Energy efficiency regulation (EnEG) [18]: relevant for the design of heating supply units and methodologies for cost calculation and billing of heating supply costs in the building sector; since 2005 efficiency of lighting systems has been adopted in order to provide energy performance certificates.
- Energy efficiency ordinance (EnEV) [19]: since 2002 the energy saving ordinance has been revised three times in order to adapt EPBD regulations on the national level. However, the EnEV has to be adopted into the building ordinances of each German Federal State. Newly constructed non-residential buildings are calculated by a method using a reference building in accordance with the German Standard DIN V 18599. Non-residential buildings have to achieve certain energy requirements such as the annual primary energy demand for heating, hot water, ventilation, air conditioning and lighting cannot exceed the annual primary energy consumption (QP) of a reference building, regarding the same geometry, useable floor area, orientation and utilization with the predefined technical reference execution in the EnEV. Additionally, the upper limiting values of the average heat transfer coefficient (\bar{U}) are not to be exceeded.
- Since the EnEV 2009, this calculation method has also to be applied for residential buildings. In this case the planned residential buildings cannot exceed the requirements of the annual primary energy consumption (QP) of the reference building and in the EnEV predefined maximum transmission heat loss ($H'T$) of the entire building envelope.

Table 1. End energy demand values for non- residential buildings according to EnEV 2012 (average values) in Germany and total net energy requirements according to TEK17 [20] in Norway

Building usage	ENEV 2012		TEK17
	Heating / DHH	Electricity	Total net energy requirement
	(kWh/m ² yr)	(kWh/m ² yr)	(kWh/m ² yr)
Middle class hotel	85	55	170
Restaurant	205	95	180
Cinema	55	80	180
Gyms	120	35	145
Multipurpose Convention Centers	240	40	180
Swimming pool (indoor)	385	105	145
Non food commerce small	135	45	180
Shopping malls	70	75	180
Hospitals	175	80	225 (265)*
Office building (heating only)	105	35	115
Office building (heating/cooling)	110	85	115
Cultural building			130
Light industry/workshop			140 (160)*
School building			110
University/university college			125
Nursing home			195 (230)*
Kindergarten			135

* Numbers in parentheses are buildings with reduced possibility for heat recovery from ventilation

For the renovation of residential and non-residential buildings, a verification according to the EnEV is not necessary, if the change of the building envelope is $< 10\%$ of the total individual component area. A complete verification, respectively a verification of the individual measures on the building envelope should be carried out for all other renovations. The thresholds for primary energy (QP) and the transmission heat loss over the envelope ($H'T$, resp. \bar{U} for non-residential buildings) can exceed the requirements of the reference buildings by a maximum of 40% in the complete verification.

3.2. Local action potentials and development of alternatives

At the end of the gathering of existing framework, the number of potential technical solutions will be limited, the needs for refurbishment will be known, also energy saving potentials in the buildings, heating, ventilation and air-conditioning (HVAC), energy supply. From recent years man made and natural threats will be available for the neighbourhood which will be cross-checked with data sets from insurance companies to reframe risk scenarios from current and predictable future threats.

Usually the work and cost effort of EMP is mainly defined by the number of scenarios considered in the modelling process. Especially in Europe, costs often hamper the broader use of hourly modelling processes. An analysis of 10 refurbished neighbourhoods (“Quartierssanierung”) in south west Germany shows, that the EMP is only carried out by using calculation tool which refer to monthly or even annual data sets [21]. However, the challenges created by the broader use and production of renewables require the broader application of hourly based modelling tools. One strategy of increasing the use of accurate modelling tools which is pursued in the Annex 73 is to lower the impediment “costs” by reducing the number of scenarios modelled. To minimize the modelling work effort for the EMP processes a number of pre- selected scenarios will be available which fit to the specific requirements of typical compounds and neighbourhoods. The scenarios will provide a set of simplified supply schemes and suggestions for energy efficiency and energy resilience approaches.

3.3. Implementation

In the following, the approach for the decision making is differentiated in the concept and the design phase of the EMP of a top- down or a bottom- up approach. So far, an overarching rule when to use an EMP “top down” or “bottom up” approach is not in place in literature of EMP. In management and design theory “top down”, “waterfall-” or “cascading management” is mostly known in the context of hierarchic structures where a leading person defines the overall target and often a set of sub- targets. The next lower hierarchies take decreasing pieces of the activities which can be derived from the overall target and well overseen from the respective leadership of the hierarchy.

The “bottom up” approach is known in the context of management methods which sees the top leadership in the position to define overall targets and delegate actively the design, execution and controlling of the sub- targets and work processes. This method is used in flat and matrix hierarchies and requires a high level of autonomy and also participative processes with end users, decision makers and multi- competence teams.

Transferred to the EMP it can be observed, that “top down” EMP are often used in military or comparable compounds with clearly hierarchic management structures. As no general rule exists, the assumption of “top down” in the context of EMP shall be, that a compound is refurbished or newly built with the first priority to the functionalities which can be derived from the mission of the compound after the refurbishment. Energy or environment related aspects are one out of many decision-making criteria in the overall design process. Often the design approach is to follow the minimum requirements for the efficiency of buildings, equipment and processes. In comparison the management of natural and man-made risks are considered to have more impact on the mission and have a higher priority in the design process. In consequence, the EMP process allows larger tolerance bands for energy efficiency or energy resilience in a top down process. As one proof of this assumption: In some European countries, i.e. German military buildings are even exempted from the

energy targets relevant for other buildings of the Federal Government and only need to fulfill the minimum energy requirements.

Discussion

The paper explains the major steps in Energy Master Planning process. It proposes first a definition of target goals. Then, a number of constraints have to be analyzed in order to be able to define site specific framing goals and associated limitations. This process will narrow the number of design options down to those that offer an optimized fit to the local conditions and the objectives for the building or community. Based on this target definition a Baseline can be developed. This consists of a simulation of the current energy use situation. The baseline is one reference point used to evaluate alternative futures. Then Base Cases will be developed that extend the baseline into the future and include already planned/funded renovation as well as planned construction and demolition activities. In that sense, the Base Case is defined as a future reference point for “business as usual” and starting point for further economic analysis. Different alternatives will then be developed – a selected set of scenarios that include different energy measures related to buildings, distribution systems, and generation systems. These scenarios are compared to the baseline for energy use change and to the Base Case for investment and operational costs. The pre-selected scenarios contain characteristics for the constraints which have to be considered for different types of compounds, which could be for example:

- High-sensitive service areas require full power, heating, cooling back up often combined with short term storages to cover black outs caused by natural and manmade threats.
- Building installation: hygienic constraints provide limitations for the distribution of heating/cooling in the service/surgery/care areas, in most of the cases ventilative systems are preferred to static space heating systems such as radiators. Ventilative systems in surgery areas require high level air quality to minimize the distribution of pathogenic bacteria. In low intensity care and housing areas the heating/cooling can be distributed also by radiators. Sterilization requires high temperature systems such as low-pressure steam. Hot water systems have to be designed and operated on temperature levels which allow to limit the growth and distribution of pathogenic bacteria.
- Building construction: minimum legal requirements for the energy design which affects demand of building and communities by setting target or maximum values for the overall energy demand of one or a group of buildings. In the majority of the European member countries the European Building Performance Directive sets targets for source energy demand and respectively for
- Indoor environment: indoor air quality in surgery and intensive care areas is requiring systems which are able to provide conditions close to clean rooms, including filter systems, disinfection, steam based moisturization with mould-critical pathways in combined heating/cooling systems; hot water systems for care purposes also require minimal pathogenic risks in the storage and distribution.

Conclusions

The proposed approach provides a coherent method for Energy Master Planning. However, when it comes to the implementation and the two alternative approaches of bottom-up vs. top-down implementation the bottom up EMPs often appear in design challenges with ambitious targets such as energy efficiency, resilience, short implementation time or other imposed constraints. One approach for a “bottom up” approach is to initiate a “net zero” compound or other specific targets which are pursued with small tolerance bands or other limitations on the EMP process. Then the design challenge is “how can we match these ambitious energy targets under those fuel and carbon footprint constraints”, the design group is interdisciplinary and integrates different hierarchies and even end users of the compound and the respective buildings.

Recent discussion on the adoption of the EPBD 2018 into German national targets show, that the focus of the discussion is moving from the single building towards targets of a community of buildings. The adoption of EPBD 2018 will have to be translated on the level of a community. This provides certain flexibilities for the constraints on the building level, e.g. if a historic building cannot fulfill the target values on the building level, buildings in the neighborhood or an energy supply based mainly on renewables can compensate the “failure” of the individual.

Further work

Individual building computer-based energy models are currently available for general use that could be exploited for Base Case development.

In the future, building models should be developed and further customized to function as archetypes to predict energy use in districts and adapted to different climate conditions and energy use requirements. To be used for community planning, all prototype models have to be fully parametrized for detailed modelling inputs in order to be able to build-in site-specific constraints.

A list of site-specific constraints is needed that can help the master planner in determining the solution room. Further, a list of building models would be useful that could be implemented for Base Case modelling.

Different baselines could then be internationally compared (for different countries as Australia, Austria, Canada, Denmark, Finland, Germany, Norway, UK and USA). This work is planned as a next step in IEA ECB Annex 73. These need to be put into context (cultural and economic) and constraints pattern should be developed. Such a database of collected models represent their national/agency building stock, that include energy systems specific to their representative climate conditions, and that have representative operation schedules. Another important step will be to develop a common approach to calibration of building models to existing energy use data available from metering and sub metering.

References

- [1] EPBD. 2018. Directive (EU) 2018/844 of the European Parliament and of the Council of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings.
- [2] 10 CFR 433, U.S. Code of Federal Regulations, Part 433.
- [3] IEA. 2011, 2012, 2013. International Energy Agency, Annex 51, Energy Efficient Communities. Jank, R., A Zhivov, R Liesen, et.al. 2012. Net zero building cluster energy systems analysis for US army installations, *ASHRAE Transactions*. Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
- [4] Strasser, H., et.al.. 2018. IEA EBC annex 63-implementation of energy strategies in communities, *Energy and Buildings*.
- [5] Annex 67 - Energy Flexibility, <http://www.annex67.org/>, Access date: Feb 2019
- [6] Annex 70 - Building Energy Epidemiology, <https://energyepidemiology.org/>, Access date: Feb 2019
- [7] Annex 75 - Cost-effective Building Renovation at District Level Combining Energy Efficiency & Renewables, <http://annex75.iea-ebc.org/>, (ongoing) Access date: Feb 2019
- [8] EnEff Stadt. 2014. Germany Energy Efficient Cities Program.
- [9] ESMAP. 2014. Energy Sector Management Assistance Program, <https://www.esmap.org/node/55386>
- [10] EISA. 2007. U.S. Congress Energy Independence and Security Act of 2007
- [11] Zhivov et al. 2014b. 2014. Energy Master Planning Towards Net-Zero Energy Communities/Campuses, *ASHRAE Transactions*. Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
- [12] Other initiatives e.g.in the center for Zero Emission Neighborhoods (ZEN centre)
- [13] Baer, D. 2018. "Tools for Stakeholder engagement in Zero Emission Neighbourhood Developments Mapping of tools in use in Trondheim, Steinkjer, Elverum and Bodø" ZEN

- Report 13. Research Centre on Zero Emission Neighbourhoods in Smart Cities (FME ZEN). ISBN: 978-82-536-1617-9
- [14] Wiik, M. K., Fufa, S. M., Baer, D., Sartori, I. & Andresen, I. 2011. "The ZEN Definition – A Guideline for the ZEN Pilot Areas. Version 1.0". ZEN Report 11. Research Centre on Zero Emission Neighbourhoods in Smart Cities (FME ZEN), ISBN 978-82-536-1608-7
- [15] American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) Standard 100-2015 -- Energy Efficiency in Existing Buildings. Atlanta.
- [16] German VDI 3807, VDI-Richtlinie: VDI 3807 Blatt 1 Verbrauchskennwerte für Gebäude - Grundlagen. In German.
- [17] Switzerland SIA 380.1 «Thermische Energie im Hochbau», Ausgabe 2009. In German.
- [18] EEG, Erneuerbare-Energien-Gesetz, https://www.erneuerbare-energien.de/EE/Redaktion/DE/Dossier/eeg.html?cms_docId=73930, Access date: Feb 2019
- [19] ENEC 2012, Energieeinsparverordnung, <http://www.enev-online.com/index.htm>, Access date: Feb 2019
- [20] TEK17, Regulations on technical requirements for construction works, DiBK, <https://dibk.no/globalassets/byggeregler/regulation-on-technical-requirements-for-construction-works--technical-regulations.pdf>, Access date: Feb 2019
- [21] Lohse et al. 2012, "Strategiepapier zur Bewertung der wirtschaftlichen Verbesserungspotentiale bei der energetischen Quartiersplanung", (in German) Working paper in the context of the German Contracting Initiative 2012- 2013