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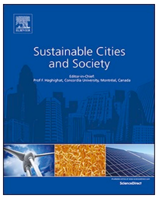

Developing a scenario calculator for smart energy communities in Norway: Identifying gaps between vision and practice

Harald Taxt Walnum[a,*], Åshild Lappegård Hauge[a], Karen Byskov Lindberg[a], Mads Mysen[a], Brita Fladvad Nielsen[b], Kari Sørnes[a]

[a] SINTEF Building and Infrastructure, P.O. Box 124 Blindern, NO-0314 Oslo, Norway
[b] Norwegian University of Science and Technology, NO-7491 Trondheim, Norway

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ABSTRACT

Key Performance Indicators are important instruments, both in defining high-level goals (international or national) and when planning smart energy communities. However, there is often a gap between the high-level goals, and possible and planned measures on the community level. Evaluation of development scenarios against a defined set of indicators and goals can help urban planners and other stakeholders understand the consequences of their strategies. This article presents a scenario calculator designed to link detailed measures with overall climate goals. This tool has been developed in interaction between researchers and potential user groups, through a series of interviews and workshops, in addition to testing of the tool in specific case studies. General feedback has been positive, but several barriers remain before community planners can employ such a tool in their working process and make it count in their decisionmaking processes: 1) community planners lack commitment to the overall environmental visions set by policymakers, and 2) community planners have no legal power to influence actual community development.

1. Introduction

To meet the challenges of climate change and resource scarcity, goals and strategies for reduced greenhouse gas (GHG) emissions and energy use have been agreed upon on many levels: international (Commission, E., 2011; UNFCCC, 2015), national (Klima- og miljødepartementet, 2017), municipal (Bergen kommune, 2016; Oslo kommune, 2015) and neighbourhood (Oslo kommune, 2014). When targets are transferred from higher levels (international and national), down to lower levels (municipal, neighbourhood, building), it becomes increasingly important to take local conditions into account. Often, ambitious targets are set on the basis of higher-level goals, without a clear understanding of the measures necessary to achieve them (Leal & Azevedo, 2016).

Several studies have analysed energy and emission Key Performance Indicators (KPIs) for developing Smart Cities and communities (Marijuan, Etminan, & Möller, 2017; CITYkeys, 2016; Neves & Leal, 2010; Sørnes et al., 2016). KPIs are often applied in gauging whether a given target/goal has been achieved. The choice of KPIs is generally based on parameters that can be measured and where relevant data can be collected. Throughout the planning phase, KPIs are important for connecting community plans with the overall goals. This in turn calls for KPIs with indicators that can link local targets to national and international goals. For example, if a 30% reduction in GHG emissions is the national goal and a 50% reduction per person is the local goal, GHG emissions would be the KPI to be evaluated during the planning and operational phases.

The goals and KPIs form a basis for planning and follow-up of smart energy communities. However, with increasing numbers of goals and KPIs, support-tools are necessary for evaluating whether targets have been achieved on the local level, and relating them to overall strategies on the municipal, national and international levels.

‘Smart cities and communities’ are variously defined in the urban planning and academic literature, according to disciplines and stakeholders (Albino, Berardi, & Dangelico, 2015; Meijer & Bolívar, 2016). At the European level, there is no commonly accepted framework for defining smart cities and smart-city projects (Manville et al., 2014). This article focuses on the *energy aspects* of the ‘smart community’ approach, based on the following definition of 'energy smart communities' (Nielsen et al., 2017):

A Smart Energy Community is an area of buildings; infrastructure and citizens sharing planned societal services, where environmental

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[*] Corresponding author.
E-mail address: harald.walnum@sintef.no (H.T. Walnum).

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targets are reached through the integration of energy aspects into planning and implementation. The Smart Energy Community aims to become highly energy-efficient and increasingly powered by renewable and local energy sources, with less dependency on fossil fuels. Spatial planning and localization consider reduction of carbon emissions also through the community's relationship with the larger region – both in the design of energy systems and by including sustainable mobility aspects of the larger region; sustainable behaviour is encouraged through the overall design, from the building and citizen scale to the community scale. Open information flows, extensive communication among stakeholders and smart technology are central to achieving these objectives.

1.1. Tools for community energy planning

The purpose of PI-SEC project is to assist municipalities and other stakeholders in reaching their climate targets by providing them with tools that can be used also by non-experts.

On the national level there exist numerous energy-system planning tools for achieving national and international climate and energy targets (Bhattacharyya & Timilsina, 2010; Connolly et al., 2010). These include optimisation tools that minimise total costs (e.g. TIMES (Loulou & Labriet, 2008) and PRIMES (E3MLab, 2014)), and scenario tools for investigating 'what-if' scenarios (e.g. LEAP (Energy Community, 2018) and EnergyPlan (Energy PLAN, 2018)). Due to their modular structure, they may be suitable for smaller geographical areas such as local communities as well as national level. However, such tools often have a high threshold for user interaction, requiring trained personnel who are experts in the field.

ELAS (Stoeglehner et al., 2014) and the Finnish KURKE (Hukkalainen et al., 2017) are tools for neighbour-scale energy and climate planning. ELAS is a tool for analysing settlement structures and includes embodied energy associated with the infrastructure construction. However, it focuses on residential buildings only. KURKE is a planning support tool for evaluating the energy and emissions from buildings and transport for areas in Finland. It differentiates the building stock into building categories; for each category all buildings are merged, and energy demand and emissions are calculated as one building stock. Neves, Leal, and Lourenço (2015) have proposed a methodology for decision support in local energy planning which evaluates the impact of overall measures on the community scale.

Tools that incorporate several KPIs in addition to energy and climate targets for sustainable neighbourhood planning include BREEAM Communities (BRE, 2012a), LEED-ND (USGB, 2018), CASBEE-UD (CASBEE, 2007) and SBTool2012 (Larsson, 2012). These are comprehensive tools for overall sustainable development assessment that include building materials, travels and transportation as well as energy and emissions-related targets. However, they are mainly indicator sets to help in evaluating development, and do not include calculation tools to support the computation of the indicators. As their assessment focuses on local targets (Charoenkit & Kumar, 2014), neighbourhood performance is not directly linked to goals set by the municipality or the government, or to international climate goals.

1.2. Scenarios in community energy planning

A scenario is an imagined or projected sequence of events, and may include detailed plans or possibilities. Scenario building is applied in many sectors and is a common way of generating and framing discussions. Scenario development is often used to support decision making, and is widely applied for evaluating GHG emissions and energy targets (see e.g. IEAs Energy Technology Perspectives (IEA, 2017) or the EU Energy Roadmap 2050 (European Commission, 2011)). Scenarios may be developed in many different ways. According to Vergragt & Quist (2011), there are three main classes of scenarios that facilitate pathways to the future by answering the questions (1) what will happen (trend extrapolations and business as usual scenarios), (2) what could happen (forecasting; foresighting; strategic scenarios), (3) and what should happen (normative scenarios). The third type includes the backcasting methodology (Quist, 2007) applied in the Kyoto Protocol (Quist & Vergragt, 2006): it first generates a desirable future, and then looks backwards from that future to the present in order to plan how to achieve the goal (Vergragt & Quist, 2011).

Scenarios are commonly used to assist multiple stakeholders in building new social capital: providing access to new information, strategic options and opportunities for collaboration (Lang & Ramírez, 2017). Scenarios are often developed in a collaborative process involving policymakers, decisionmakers, and other stakeholders (consultants and developers), aimed at identifying the possible future consequences of actions taken today.

In the study presented here, it was important to develop a tool that could fill a gap that had been identified by the stakeholders. Traditional modelling tools for energy systems link energy with emissions, but are targeted at the energy sector and hence lack the necessary neighbourhood-scale details of the building sector and transport sector. Further, we were looking for a tool that could help municipal climate divisions and urban planners to translate emissions-reduction targets into specific, built-environment actions. The tool should be flexible, allowing municipalities to set their own goals and indicators as per their needs.

Within the PI-SEC project (PI-SEC, 2018), urban planners have expressed the need for scenario-building tools for decision support in planning smart energy communities. Therefore, a tool has been developed that aims at helping them to set ambitious but realistic goals, and to plan and follow up development scenarios to achieve these goals. This tool is designed not only to identify community development pathways, but also to help users to understand the consequences of specific actions.

1.3. User involvement in developing decision-support tools

Decision-support tools for smart energy communities can be seen as 'climate services', providing support and facilitation for decisions concerning climate mitigation or adaptation. Vaughan and Dessai (2014) emphasize the need for cooperative involvement in climate services, with scientific experts, users and policymakers developing the tools together. Collaboration with users helps to contextualize research and knowledge, resulting in scientific knowledge that is custom-made to specific decision-processes and situations (Goosen et al., 2014; Hygen, Bruin, & Wageningen, 2016; Lucio & Grasso, 2016; Meadow et al., 2016; Swart et al., 2016; Vaughan & Dessai, 2014). The exchange of information among users and climate-service developers leads to confidence in tools, guidance documents and services (Lemos & Morehouse, 2005). Simply having a wide range of tools and user guides will not necessarily result in better climate adaptation or mitigation. Climate services in the form of education, networking and consultations are needed for tools and user guides to be applied successfully (Hauge et al., 2017). As noted by McNie (2013), if the aim is to develop climate services that are context-relevant, trustworthy, and understandable to users, there must be a focus on synchronization between user demands and such climate services

1.4. Scope of the PI-SEC project

Planning Instruments for Smart Energy Communities (PI SEC) is a Norwegian research project set to run from April 2016 to March 2019, funded by the Research Council of Norway. The aim is to develop effective planning tools for integrating energy issues at the property level, by promoting knowledge about the parameters important for cities focusing on smart and sustainable energy, and how these parameters can be connected with the planning, operation and monitoring of new and existing areas.

This article presents the findings of the Scenario Calculator tool, with a description of the tool itself in Section 2, and an evaluation of its practical use in Section 3, exemplified by a Norwegian case study. Discussion and conclusions are provided at the end.

2. The PI-SEC scenario calculator and methodology

The main purpose of the Scenario Calculator is to aid the process of energy planning in communities. This is accomplished by compiling energy- and emissions-relevant data for the community and combining these data with calculation routines for selected KPIs. The tool follows the project from the early planning stage, through the design and construction phases, and as a monitoring and follow-up tool after project conclusion. Its main advantage is in the planning phase, where it can work as a decision-support tool. The Scenario Calculator employs scenarios to evaluate the effect of strategic measures on the overall goals and targets of the community. By linking measures on the scale of the individual building to overall community targets, it helps planners to understand what is necessary to reach the goals set. The tool is built in Microsoft Excel and has been designed to enable quick and easy evaluation of new scenarios, assisting discussion throughout the planning process.

2.1. Methodology

The concept underlying this tool is to use KPIs related to the goals for the neighbourhood to evaluate possible scenarios during planning. The choice of KPIs is based on a literature survey of goals and KPIs for energy and emissions planning, and a multi-attribute decisionmaking (MADM) process to reduce the number of KPIs to a reasonable level (Walnum et al., 2017). Table 1 lists the KPIs available in the Scenario Calculator, including available units. In addition, the KPIs are split into relevant categories and sub-categories, e.g. thermal and electric energy demand, energy source, building type/ownership, and mode of transport. Currently, the tool contains energy use and emissions from stationary sectors and transport. However, it is possible to include embodied (material) energy and emission data for buildings.

The main principles of the scenario evaluation are based on the Futurebuilt[1] (Future Built. no., 2019) guidelines on calculations for climate-gas emissions from buildings and area (Selvig, Enlid, & Arge, 2014). As per the guidelines, the development scenarios are compared with a description of the initial (current) situation and a baseline scenario. The baseline scenario starts with the current situation and includes planned renovations and new buildings within the project time-horizon. Renovations and new buildings are defined with energy use, and heating/ cooling systems according to current regulations on technical requirements for building works. Buildings slated for demolition are not included. Both energy use and energy consumption for various buildings and transport demand are calculated on an annual basis. As the model structure does not allow for stochastic input, the input data on energy demand should preferably reflect the climatic conditions of a mean year.

The tool contains two options for weighting energy end-use: CO_2-equivalent-factors (CO_2-eq) and Primary Energy Factors (PEF); it is also possible to change the values of the factors according to the preference of the user. In Norway, the CO_2 emissions from a building's energy use are sensitive to the weighting factor for electricity, as almost 80% of the heat demand in buildings is met by electricity (Lindberg & Magnussen, 2010). The possibility of evaluating scenarios with differing values of the emission factor is therefore a valuable and important feature of the tool. A similar method is proposed in the forthcoming new Norwegian standard for GHG-emissions calculation for buildings (prNS 3720), which proposes using CO_2 emission factors for both European and Norwegian electricity mix in the calculations (Standard Norge, 2018). In the case study presented in Section 2.3, the average European electricity mix at 116 gCO_2-eq/kWh_{el} according to (Standard Norge, 2018) is used. PEF Primary Energy Factors (PEF) is the preferred weighting factor in the latest recast of the EPBD (European Commission, 2016), and reflects the primary energy needed to provide 1 kW h of an energy carrier. The typical value for electricity in Europe is 2.5 kWh_{PE}/kWh_{el} (CEN, 2013). For Norway, where 99% of the electricity is generated from hydropower, determining a PE-factor for electricity use is challenging; despite discussions over the last decade, no official consensus has been reached (ADAPT Consulting, 2016). Therefore, using CO_2 factors in Norway is preferred over PEF when evaluating sustainability measures and goals.

The transport module is based on the concept that the buildings and the people in them (residents, employees and users) are what determine transport within the community. This is inspired by the klimagassregnskap.no tool (Selvig et al., 2010) and is according to prNS 3720. The tool does not describe how to design an area that reduces transport needs, or how to achieve the shift from private cars to public transport, but it calculates the effect of altered habits. Norway, like many other countries, has national or regional regulations on the distances between, for instance, housing and public transport hubs. Further, data on the main travel habits to be considered are available in Norway through the Institute of Transport Economics (Transportøkonomisk institutt); regulations on distances between buildings and public transport are available from the National Road Administration (Vegvesenet). The Norwegian Environment Agency (Miljødirektoratet) has set the distances to green spaces, water views, etc. All these should be considered as frames and basis for input when using the scenario calculator as a decision-support tool. Based on the information described in the scenarios, total number of kilometres for each transport equipment is calculated and multiplied by well-to-wheel emission factors. In the case study discussed in Section 2.3, well-to-wheel factors proposed in (Standard Norge, 2018) are applied.

2.2. How to use the scenario calculator

The following section provides a step-by-step explanation of how the tool works, by first setting up a project and defining its baseline future development, and then developing alternative future scenarios (Fig. 1).

2.2.1. Step 1: defining the project

First, a framework of the project is defined by setting parameters, like start and end year for the project, together with the location and size of the area.

2.2.2. Step 2: building a neighbourhood, the initial situation

The initial situation of the neighbourhood is defined by its ‘current status’. For new development areas, the current situation is ‘empty’. ‘Current status’ includes describing the neighbourhood by the following modules:

2.2.2.1. Buildings. First, the building's *energy demand* is defined, taking into consideration its size (Gross Internal Area (GIA)), the energy standard, and number of residents/employees. Energy demand is split into the following purposes: heating, domestic hot water production, cooling, and utility electricity consumption.

Second, the building's *energy use* is calculated, according to the choice of energy technologies and their efficiency or COP, which determines the carrier of the energy eventually consumed.

$$Emissions_{b,h,tec} = Area \bullet H_d \bullet cov_{tec} \bullet \eta_{tec} \bullet f^{CO2}{}_{source}$$

The equation above shows how the emissions from one technology covering the heat demand of a single building are calculated. H_d, cov_{tec}, ηtec and $f^{CO2}_{source,}$ represent the heat demand (kWh/m^2), the coverage factor (%), efficiency (%) and the emission factor (CO_2eq/kWh) respectively.

Within the tool, buildings may be described individually, or as a group of buildings with the same properties. If any means of on-site

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[1] Futurebuilt is a collaboration between Norwegian municipalities in the region around Oslo, the government and interest groups, to promote climate-friendly architecture and urban development

Table 1
Main key performance indicators (KPIs) available in the PI-SEC Scenario Calculator.

KPIs	Units	Reference
energy use	kWh, /m2, /inh., /user	(CITYkeys, 2016; Transform, 2015)
CO2 emissions	tonnes CO_2-eq, /m2, /inh., /user	(CITYkeys, 2016; Transform, 2015)
% of RES in district heating	% of total mix	(City Council Oslo, 2016)
% of buildings with energy certificates at each of the grades	% of total stock	(Ministry of Petroleum & Energy, 2016)
installed capacity of RES	kW, /m2, /inh., /user	(Wiik et al., 2018)
energy generated by RES	kWh, /m2, /inh., /user	(Transform, 2015)
# buildings with installed solar PV	total number	(Bergen kommune, 2016)
# buildings connected to a thermal district infrastructure	total number	(Transform, 2015)
% of travels by bicycle, on foot or public transport	% of each mode of transport	(Bergen kommune, 2016; City Council Oslo, 2016)
# fossil-free construction sites	total number	(City Council Oslo, 2016)
# registered oil boilers	total number	(City Council Oslo, 2016)

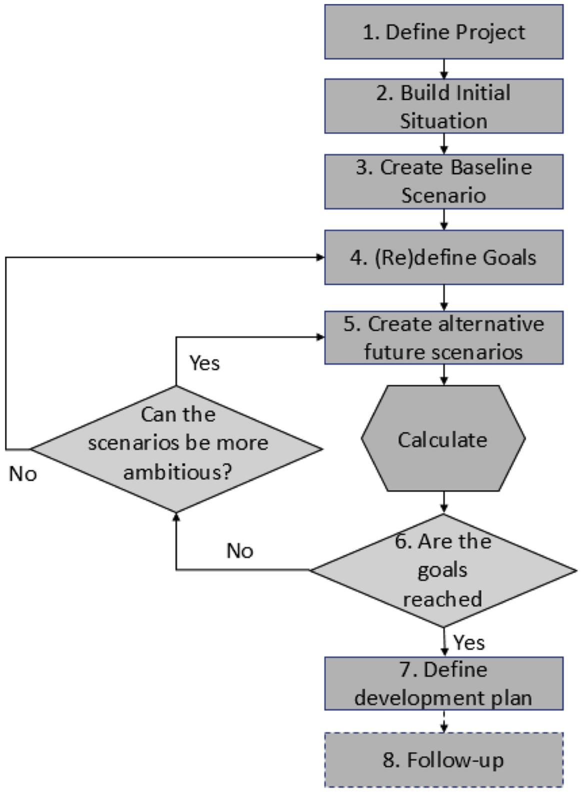

Fig. 1. Schematic view of the process using the Scenario Calculator.

renewable energy production (e.g. solar PV) are already installed, these can be included by adding the module size, installed peak power and average annual production.

Finally, on the basis of the above, total energy use and energy production (normalised to an average climatic year), and the related CO_2 emissions are calculated, separately and summed up in building categories. The figures are provided by energy carrier (electricity, biofuel, solar, fossil fuel and district heating), and/or building ownership (private, public and residential buildings).

As input data can be difficult to obtain for existing buildings, recommended values based on normative figures from building regulations valid at the year of construction are available within the tool. As the available data are related to the Norwegian climate and building standards, they are suited for use only in Norway. However, the tables with recommended values may be altered and adapted to other regions.

2.2.2.2. Street utilities. Estimated annual energy use for sectors not included in either stationary or transport sector are included here, e.g. street lighting and snow-melting systems.

2.2.2.3. Local energy plants. Energy demand in buildings may be provided from central units for energy production located within the neighbourhood. Such local production can replace the use of imported electricity and/or district heat to the area. These production units are connected to the local thermal or electric grid, and include options such as biofueled Combined Heat and Power systems, solar thermal collectors and Photovoltaic (PV) plants. For each energy plant, the energy source, total efficiency, installed capacity and yearly production are specified. Capacity and production data can be specified for heating, cooling and electricity. Produced electricity is calculated with CO_2 emissions equal to the difference between the CO_2 emissions related to production and the CO_2 emissions for electricity from the grid. This means that production with renewable sources (e.g. PV) will result in a reduction in total CO_2 emissions for the area. Produced heat or cooling that replace the use of district heating/cooling for buildings connected to district heating will change the district heating CO_2 factor accordingly. For CHP plants, CO_2 emission are allocated to heat and power production according to the energy method (Tereshchenko & Nord, 2015). Although not the most accurate method, it is simple and requires little information about the system, making it suitable for non-experts in the early stages of planning.

2.2.2.4. District heating. A third option for providing heat to buildings is through the district heating network located outside the boundaries of the neighbourhood. Emissions related to the use of district heating are based on the yearly average distribution between the energy carriers used for heat production.

2.2.2.5. Transport. The number of travels generated by people living or working in the built environment is calculated on the basis of the number of residents, employees, and users for the individual buildings described in the building module. Information on travel habits for each building category (according to DIBK (2017)) is supplied by the user and can be based on travel surveys (see e.g. (Hjorthol, Engebretsen, & Uteng, 2014)) that provide figures on travels generated by residents/employees/users, mobile splits, average travel distances and number of passengers. In addition, it is possible to adjust a parking factor (0–1) which reduces the share of travels by private car (if below 1), in line with the availability of parking spaces (Selvig et al., 2014).

Table 2 shows the main input data needed for describing the initial situation and each scenario.

2.2.3. Step 3: creating the baseline scenario

When the current situation has been described, a baseline scenario towards the end-year of the project is created. This scenario includes planned renovations and new buildings, but no additional measures regarding emissions reductions or introducing renewable energy (e.g. a business-as-usual development). Renovations and new buildings are defined as to energy demand according to current regulations on technical requirements for building works. Heating and cooling systems reflect the minimum solution that satisfies current regulations.

Table 2
Main input data.

Buildings (per building)	Street utilities	Local energy plant	District heating	Transport (per building category)
Category	Type	Type	Energy supply (type, efficiency [%] and coverage [%])	Generated trips per user
Area [m^2]	Units	Energy source	Distribution losses	Travel method distribution
Ownership (private, public or housing cooperative)	Energy consumption [KWh/unit]	Efficiency [%]		Average travel distances
Residents/ employees/ users [#]	Energy supply (type and efficiency [%])	Energy production (peak [kW] and yearly production [kWh])		Passengers per travel
Energy consumption (heating, DHW, cooling and electricity) [kWh/m^2]				Parking capacity (parking factor [0-1] and distribution of reduced car transport due to low parking capacity
Energy supply (type, efficiency [%] and coverage [%])				
RES (type, peak [kW] and yearly consumption [kWh])				

2.2.4. Step 4: (Re-)define goals

At this step, the goals for the project are decided, both selection and quantification. Overall goals and the relevant KPIs can be *selected* from predefined drop-down lists, based on appropriate goals and KPIs identified in the PI-SEC project (Walnum et al., 2017). Target *quantification* is determined according to the individual project/neighbourhood. To help in setting appropriate values for the goals selected, the initial and baseline scenarios can be calculated for the defined KPIs. After Step 6 (see below), goals can be re-defined if necessary.

2.2.5. Step 5: creating alternative future scenarios

Alternative future scenarios investigate various measures for achieving the goals and KPIs set in Step 4. Here, projects for construction of new buildings and/or renovation of existing buildings can be described with the desired energy-performance levels and heating technologies, in addition to the installation of building-integrated renewable energy systems such as solar collectors and PV.

On the energy-supply side, it is possible to create new installations of local energy plants or alter the district heating system if there are plans for improving energy efficiency or changing the share of renewable energy sources.

The transport data can be altered, e.g. through reducing parking capacity within the neighbourhood, or establishing a public transport hub. Both measures have the potential to alter the modal split for the neighbourhood.

It is possible to develop scenarios aligned with different ambition levels as to the goals set in Step 4. Hence, the effect of different measures and combination of measures can easily be investigated and evaluated in Step 6.

2.2.6. Step 6: analysing and evaluating results

When the current situation, baseline scenario and future scenarios have been defined, the local energy system is calculated and the results for each of the selected KPIs are displayed in graphical charts. This means that the results frame immediately provides stakeholders with insights as to what measures and ambition levels are necessary to reach the project goals.

The development between the initial and final situation is considered linear. An example of output from the scenario calculator is shown in Fig. 2, with CO_2 emissions at the start of the project (Initial 2015) and at the end of the project in 2030 for a baseline scenario and an alternative future scenario. The initial goal of the KPI for the end year is shown in the same results chart, to enable evaluation of whether the goal has been achieved. Similar outputs are available for all indicators listed in Table 1.

If the goal has not been achieved, it is possible to modify the scenarios, or add new and more ambitious scenarios in Step 5. By re-calculating the system, the goals and KPIs are re-evaluated. If the results

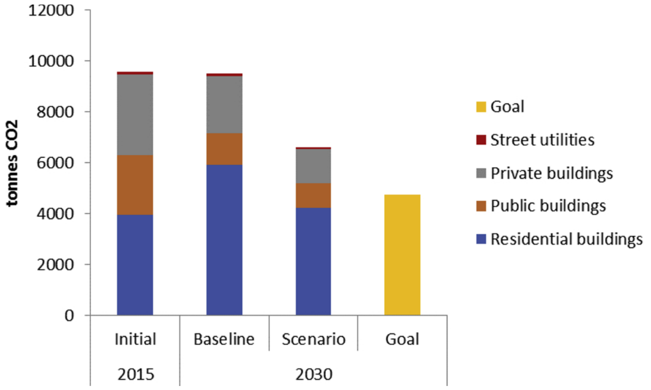

Fig. 2. Example of results from scenario calculation (CO_2 emissions from stationary energy use).

show that it is not feasible to reach the goals without being overly ambitious, modifying the goals in Step 4 may be considered.

2.2.7. Step 7: define development plan

A roadmap with an action plan can be made, on the basis of the best scenario as to goal achievement and feasibility. This is possible thanks to the detailed structure of the tool, which identifies measures on the level of the individual building and modal shifts in transportation. This also allows allocation of specific responsibilities to individual stakeholders.

2.2.8. Step 8: follow-up

The flexibility of the tool as to building-specific and manual input makes it suitable for follow-up throughout the project, and beyond.

2.3. Demonstration and testing of the scenario calculator at furuset

During development, the tool was tested on a real-life case at Furuset in Oslo. In addition, several demonstrations and interviews with potential users have been conducted.

2.3.1. Description of the area

Furuset in the Grorud Valley is an Oslo suburb from the 1970s (Oslo kommune, 2014). Initial development, conducted in line with municipal plans, included a nursing home, schools, nursery schools, a shopping mall, commercial buildings, public transport (metro) and walk- and driveways in the whole area. The cooperative building society OBOS was responsible for construction of approx. 2800 flats. Later came several minor additional developments, such as Furuset Forum in 1998, the extension of Furuset centre in 2001, the Ahmadiyya mosque in 2011 and the construction of storage and production facilities along the E6 motorway. Furuset is served by underground (metro), as well as local, express and regional buses. Residents come from some 140 different nations. As of 2014, there were approx. 3800 residents and about 1500 jobs within the boundaries of the local development plan.

2.3.2. Development plans

The planning and building authority started work on the Furuset development plan in 2009. In December 2014 a proposal for climate-efficient urban development at Furuset was submitted for political decision (Oslo kommune, 2014).

The proposed plan includes the development of new buildings with a gross area of approx. 390 0000 m^2 : housing, commercial buildings and social infrastructure. This could result in the construction of some 1700 flats. If a ‘lid’ is built over the motorway, the number of new flats could be increased to around 2300. About 27% of the existing buildings (GIA) are planned to be rebuilt or renovated.

2.3.3. Goals

Furuset is Oslo's designated priority project within the FutureBuilt-programme (Future Built, 2018). The objective of FutureBuilt is to develop climate-efficient buildings and urban areas and reduce GHG emissions. The ambition of Oslo municipality for the Furuset area is to facilitate a 50% reduction in CO_2 emissions within the fields of transport, energy use and materials, as against the baseline development scenario (see Table 3). The City of Oslo has a similar goal, to reduce GHG emissions by 50% by 2020 and by 95% by 2030, as against 1990 levels (Byrådet Oslo kommune, 2016). However, these goals are not directly comparable, because emissions are calculated differently. In the FutureBuilt calculations which were used for the Furuset goals, electricity is given an emission factor (according to the ZEB definition (Fufa et al., 2016)), whereas for the Oslo targets, the emissions from electricity are set to zero. As most buildings in Furuset use electricity for heating and cooling, the latter method would not give any reason to increase the energy efficiency of the existing building stock. However, as seen in the results below, with the Futurebuilt method it would make sense to aim for a sharp reduction in energy use associated with cooling and heating, in both new and existing buildings.

2.3.4. Applying the PI-SEC scenario calculator

A model of the Furuset area has been developed in the Scenario Calculator according to the steps described in Section 2.2. To illustrate the possibilities within the tool, several development scenarios with different levels of ambition have been studied. The scenarios are listed in Table 4, coupled to the measures on building categories and system level. Included measures are highlighted in green.

In the baseline scenario, all new buildings and 27% of existing buildings that are rebuilt or renovated are constructed according to the building regulations in force at project start in 2010, TEK10 (DIBK, 2010). According to TEK10, 60% of heat demand is to be covered by non-fossil sources and without direct electric heating. Buildings with TEK10 standard in the baseline scenario are equipped with heat pumps that cover 60% of heating requirements (electricity supply to heat pumps is not considered as ‘direct’ electric use); electric boilers cover the remaining 40%.

The development scenarios are categorised into building- and transport-specific measures. Buildings are split into categories based on how easy/complicated it is to improve their performance. For new and fully renovated buildings, it is relatively simple to improve the technical standard and heat supply beyond the baseline. The next step is to upgrade public buildings, as these are under municipal control. Further, most of the apartment blocks in the area have centralised electric boilers for domestic hot water (DHW) production, which simplifies a potential connection to a local district heating system. Private buildings are the most challenging, as the municipality has no legal authority to demand that such owners to upgrade. As there are plans for connecting the Furuset area to the district heating (DH) network of Oslo, DH is evaluated in the scenarios. In addition, consideration is being given to building a pilot seasonal storage system for storing heat from waste incineration in summer. This alternative is considered in scenario S03-S08 (DH mix equal to 100% waste). In this case, the emissions related to waste incineration are not allocated to DH. In scenario S06, the area of solar PV systems needed for achieving the CO_2 emission targets has been installed.

As to transport, possibilities for gradual decarbonisation of the transport sector are considered. In metropolitan Oslo, there is considerable focus on reducing the use of private cars, and on electrification. This is reflected in the scenarios.

2.3.5. Results

This section shows selected results for stationary energy use and mobility of the scenarios in Table 3. Emissions from material use are not included in this case study.

Table 3
Goals for the Furuset area.

Main goals	● 50% reduction in GHG emissions from stationary energy use ● 50% reduction in GHG emissions from transportation ● 50% reduction in GHG emissions from building materials
Secondary goals	● 40% of stationary energy use to be supplied by renewable energy sources ● Increase energy efficiency of existing buildings ● Establish a local energy network that utilises available surplus heat sources

Table 4
Future scenarios for Furuset.

			Individual heat technologies (for all buildings)		District heating						
					New and renovated buildings			New and renovated buildings, and public buildings and DHW		All buildings	
			Direct electric heating & heat pumps	Direct electric heating	Current mix	Current mix	100% waste	100% waste	100% waste	100% waste	100% waste
Scenario number			**Baseline**	**S01**	**S02**	**S03**	**S04**	**S05**	**S06**	**S07**	**S08**
BUILDINGS	New and renovated buildings	technical standard	TEK10	Low energy	Low energy	Passive	Low energy	Low energy	Low energy	Low energy	Low energy
		heat supply	individual	individual	distr. heat	distr. heat	distr. heat	distr. heat	distr. heat	distr. heat	distr. heat
	Existing public build. & DHW for blocks of flats	technical standard	current	current	current	current	current	current	current	current	Low energy
		heat supply	individual	individual	individual	individual	individual	distr. heat	distr. heat	distr. heat	distr. heat
	Remaining buildings and their heat demand	technical standard	current	current	current	current	Current	current	current	current	Low energy
		heat supply	individual	individual	individual	individual	individual	individual	individual	distr. heat	distr. heat
	PV		none	none	none	none	none	none	17.6 MW_p	none	none
TRANSPORT	Public transport hub			x		x	x	x	x	x	x
	Public transport shifts from bus to metro 20% -> 60%						x	x	x	x	x
	All buses have electric drive								x	x	x
	Reduced parking capacity (f=0.4)				x	x		x	x	x	x
	50% of all private cars are electric									x	x
	50% of all goods transport is by electric vans/trucks										x

2.3.5.1. Emissions from stationary energy use. Fig. 3 shows the CO_2 emissions from stationary energy use, both as total and as emissions per inhabitant. With a baseline scenario, total emissions will be approximately equal to the current situation, even with a much greater building volume. However, the number of residents is also increasing, so specific emissions are drastically reduced, even with the baseline scenario. This is due mainly to the replacement of older, energy-intensive buildings with more energy-efficient buildings. The results show that achieving the goal of 50% reduction compared to baseline will require more comprehensive intervention with the existing building stock – either the installation of a waterborne heating system and connection to a low-carbon district heating system (S07), or through a comprehensive refurbishment strategy (S08). Scenario S06 calls for a solar PV area of about 110 000 m^2 to achieve the goals: and that is not realistic with a total GIA of about 570 000 m^2.

Comparison of stationary energy use in Fig. 4 with the stationary CO_2 emissions in Fig. 3 shows that measures that reduce CO_2 emissions do not necessarily reduce energy use as such.

2.3.5.2. Mobility. Fig. 5 shows the CO_2 emissions from transport generated by buildings at Furuset. As expected, with more residents and more activity, emissions increase. All the measures described above give small contributions to reducing CO_2 emissions – and it is the sum of all these contributions that can make target achievement feasible. Fig. 6

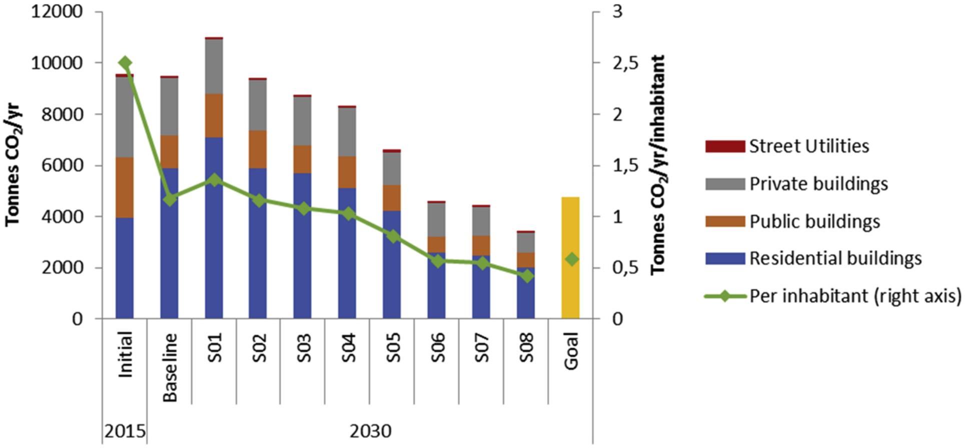

Fig. 3. CO$_2$ emissions from stationary energy use with European electricity mix, total and per inhabitant.

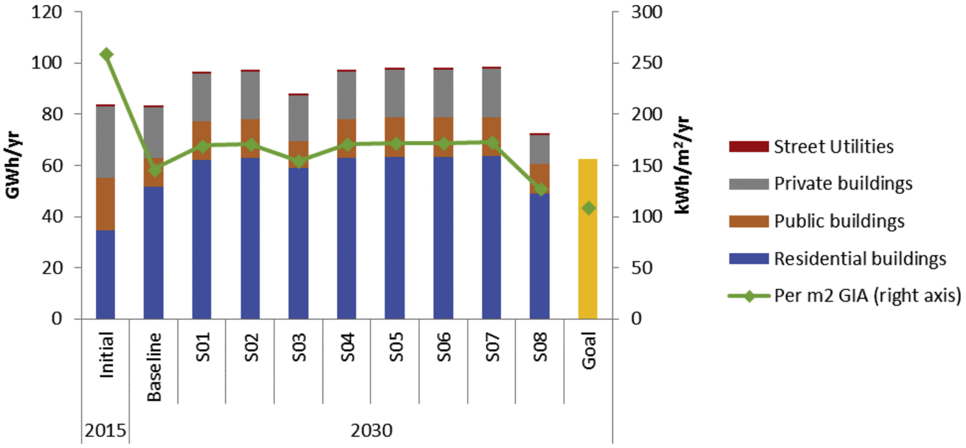

Fig. 4. Stationary energy use: Total and per m^2 GIA.

shows the modal split for the various scenarios, and the background for how emissions are reduced through the change in modes of transport. The modal split is calculated on the basis of trips for each mode.

3. User evaluation of the scenario calculator

3.1. Methodology

The PI-SEC scenario calculator has been evaluated through nine qualitative group interviews and two workshops. In total, the participants in these interviews and workshops were 28 employees from two city municipalities (most of them from the Climate Division and the Agency for Planning and Building Services), two scientific experts, ten energy consultants, and two representatives from a public organization with experts in energy planning. The group interviews and workshops were conducted between 15.09.2017 and 22.03.2018. One interview had only one participant; most interviews involved three respondents, and the largest workshops had eight participants from the municipalities and five researchers present. The interview guide for feedback on the PI-SEC scenario calculator included the following

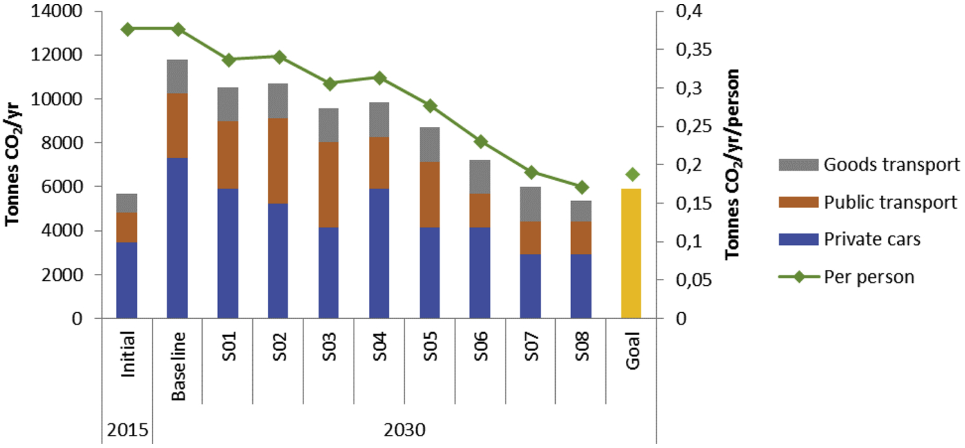

Fig. 5. CO$_2$ emissions from transport generated by buildings: total and per person (residents and users).

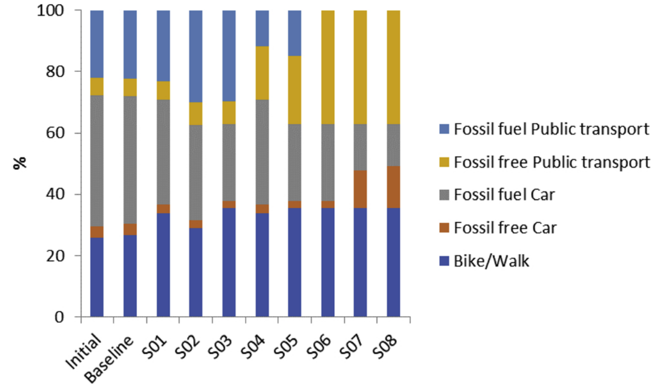

Fig. 6. Modal split.

topics (adjusted for different types of respondents):

- background: the need for a tool to measure environmental improvements on the neighbourhood level: what tools are in use, and evaluation of these tools;
- evaluation of PI-SEC Scenario Calculator key indicators;
- evaluation of the utility of the PI-SEC Scenario Calculator as a planning tool;
- challenges and opportunities involved in implementing the PI-SEC Scenario Calculator.

Notes were taken during the interviews and workshops, and discussions at one of the workshops were transcribed. Texts from the interviews were thematically categorized and analysed. Quotations, mainly based on extensive notes, are used to illustrate the findings in the Results and Discussion sections below.

3.2. Results

3.2.1. General feedback

In general, informants in the municipalities find the tool useful for planning of specific areas with environmental ambitions. No other tool for this purpose is in use in Norway today:

> There is a need for this tool in our municipality. (…) It’s great to see a tool that gives you this kind of output. The Climate Division doesn’t work with this topic today, nobody in our municipality does. *(Municipality)*

Experts in energy planning saw the baseline concept in the Scenario Calculator as a great advantage. They also opined that this makes project drafting easy in an early phase.

However, there is not much focus on stationary energy in municipal planning at present, and the high-level climate targets are not detailed in a way that makes it possible to identify necessary measures on CO_2 emissions on this level. The Scenario Calculator might prove helpful in boosting competence here.

> In general, not enough consideration is given to climate aims – from the overarching ones and down to individual projects and areas. *(Municipality)*

Some expert informants also noted that the Scenario Calculator fit well with BREEAM Communities requirements for an energy plan (Criteria ‘RE 01′ in the BREEAM Communities Technical Manual (BRE, 2012b)). In Norway, it is also in line with requirements for energy plans for economic support from Enova. Enova SF is owned by the Ministry of Climate and Environment and contributes to reducing GHG emissions through allocation of governmental subsidies (SF, E. Enova Web page, 2018).

3.2.2. Format

It was also discussed at feedback meetings and workshop whether the tool should be excel-based or web-based. The former may be more useful, because an excel sheet allows the tool structure and all parameters to be adjusted in an intuitive way. It is also simpler to introduce local adaptions. This makes it easier to follow, and the user remains in control. By contrast, a web-based version would require investments and decisions on ownership, development and revision of the tool.

From the municipal level it was indicated, at workshops and in some meetings, that the tool should be on the web and connected to a map (GIS-based). Informants from the municipalities felt that visualization was important, and that energy labelling of buildings – red or green buildings, or labelling of buildings worthy of preservation – would make clearer the basis for decisions. Visual display of different energy scenarios on maps was considered highly valuable.

Municipal respondents also noted that it would be useful to link the Scenario Calculator to *costs,*. as tis would enable cost–benefit analyses of the various scenarios. One challenge with cost is that prices change rapidly and are highly dependent on available and applied technology. This makes it difficult to include reasonable normative figures that do not become outdated. One solution is to let users supply their own cost-data on each measure. This would further increase the user entry level. A web-based tool connected to GIS and costs would require further development and investment.

3.2.3. User group

When the Scenario Calculator was launched, municipality representatives had stated that it did not appear too complicated to use. However, later in the development process and in both municipalities, applying the tool seemed unrealistic. These municipalities use consultants for other tools and systems, and then purchase their reports. Municipal staff did not feel they had the capacity to complete the number-blanks in the Scenario Calculator:

> Mostly, we use the information that we can get directly from maps. When we have to retrieve data from other digital systems, that often involves purchasing. With the Scenario Calculator, we would have ordered analyses from a consultant. However, if we could get the file punched [already filled in], and could experiment with different scenarios, then the situation would be different (…) If the user threshold is low, perhaps we can try. *(Municipality)*
> The Climate Division would have to emplace staffing requirements if they were to use the Scenario Calculator themselves. *(Municipality)*

Other informants (in an organization working to promote low-carbon buildings and areas) said that the target group for the Scenario Calculator must be carefully selected. They felt it was too complicated for the municipality employees to use, and that energy consultants might be a more realistic target group. The tool might be usable for large municipalities/cities, but small municipalities would probably have to work together with energy consultants in applying the Scenario Calculator. After testing and demonstration of the Scenario Calculator together with the municipalities participating in the research project, the researchers also realized that the obstacles to implementing the Calculator in municipalities were high.

3.2.4. Obstacles to implementing the scenario calculator in municipalities

Interviews show that a major obstacle to implementing the Scenario Calculator and making the results count in decisionmaking processes is the lack of responsibility for environmental visions for a given area. Who owns the visions? In the municipalities, environmental targets are often decided at political level (top–down). Implementing such visions further down in the hierarchy is a challenge. As noted, there is no clarity as to how to manage to fulfil environmental visions in a chosen neighbourhood area.

> Green Strategy rarely provides the premises for developing an area.

> On the area level, coherence between targets and strategy is weak. *(Municipality)*

The 'owners' of visions for the municipality (politicians or the climate division) do not ask for definite figures on CO_2 reductions – and if no one asks, why deliver? However, this may be changing as expertise grows in the municipalities, and because Enova requires definite figures in energy plans in applications for subsidies. In addition, some informants in the municipalities mentioned that developers have high ambitions:

> The developers often have greater ambitions than the municipalities, and the municipality acts as a brake. *(Municipality)*
>
> Our Climate Division has a strategic focus, we don't have to do the job. We haven't worked very much with figures. Last year, we prepared the first climate budget, and discussed how to go about measuring. Gradually, more figures are being. CO_2 impact is a simple way to measure. Then the municipality may document what we are doing to fulfil the Paris Agreement. Climate divisions aren't mandated to require anything, or to impose sanctions. Such requirements wouldn't be legal. *(Municipality)*

4. Discussion

The main advantage of the PI-SEC Scenario Calculator tool is the ability to evaluate the goal feasibility and achievement of any KPI for all future scenarios defined for a given neighbourhood. This can be very helpful for community planners in understanding the measures needed to achieve their goals, so that they can set realistic targets. The fact that individual buildings (or small groups of buildings) are evaluated separately links local action to the overall goals of the municipality. This makes it possible to distribute responsibility and commitment among the actors and stakeholders within the project.

The tool is relatively detailed, as it enables input on energy use, energy technologies and energy carriers down to the level of the individual building. Constructing the initial neighbourhood model requires extensive work, which is always a challenge when new tools and calculation methods are to be introduced. Further, time and expertise are required to understand how to utilize the tool; for municipalities, it might be most efficient to outsource this work to energy and environmental consultants. The accuracy of the results produced with the tool has not been validated with historical data, so care should be exercised. However, we are of the opinion that the Scenario Calculator can provide useful support for decisionmaking.

General feedback from testing the Scenario Calculator on users and experts is positive. Our respondents note the need for such a tool in decisionmaking processes aimed at making areas more sustainable. Users are interested in further development of the Scenario Calculator, first of all for it to become a web-based tool with GIS connection, and second, that it should include economic aspects such as investment and operational costs of the neighbourhood, to enable cost–benefit calculation of the various scenarios.

However, there remain considerable obstacles to implementing the Scenario Calculator, due to the frames for decisionmaking and lack of follow-up on climate goals in the municipalities. Commitment to the low-carbon targets set by the climate division is low in other municipal divisions, and almost non-existent as regards implementation and practice. In addition, it is hard to find staff who could responsibility for a tool like the Scenario Calculator. In general, the relevant staff-members lack the time and resources needed to collect the necessary data. In the introduction to this article, we referred to Vaughan and Dessai (2014), who highlight the need for collaboration involving users, scientific experts and policy developers to develop climate services to make the tools operational (Lemos & Morehouse, 2005). This type of process has been desired, but has been driven mainly by the researchers in this project. The main challenge is that those working in the municipal climate divisions set climate targets that require response from employees in other divisions. As noted, climate divisions are not authorised to emplace sanctions, and they have no routines for following up on targets.

5. Conclusions, and further development

In close interaction between researchers and potential users, Norway's PI-SEC research project has developed a Scenario Calculator tool. The main goal with this PI-SEC Scenario Calculator is to assist the planning process for new and existing development areas in municipalities and help municipal planners to identify appropriate development strategies that increase the chances of achieving the energy and climate goals set for the given community. The project has shown that the need for a tool that can link overall goals to local measures, so that goals do not become empty words. Especially important here is that there should be only minimal increases in the workloads of those involved.

The main barrier to implementing the Scenario Calculator is the difficulty in finding responsible end-users for overall low-carbon neighbourhood planning and implementing the sustainability targets further down in the organization. This might indicate that the PI-SEC Scenario Calculator is unsuitable – but it could also be that an inappropriate user-group has been selected. Here we might note that IEA/EBC Annex 63 (Quitzau et al., 2018) recommends that each municipality should have a politically anchored 'energy expert': employees with responsibility for measuring and calculating energy and sustainability scenarios. Probably, the answer is somewhere in-between these two explanations. If energy planning can be located in-house in Norwegian municipalities, that may serve to make the tool more relevant to them and to integrated energy planning in the future.

Further work and research should focus on evaluating the integration between the PI-SEC calculator and municipality data sources such as GIS and other relevant databases. In addition, guidance should be developed on following up and ensuring responsibility for climate targets at the municipal level.

Competing interests statement

There are no significant competing financial, professional, or personal interests that might have influenced the performance or presentation of the work described in this manuscript.

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References

ADAPT Consulting (2016). *Determining primary energy factors for electricity.* Available from:https://www.energinorge.no/contentassets/b7bef8bd8ce248a0a2d52fbb776cbcc1/2016-01-19—determining-primary-energy-factors.pdf.

Albino, V., Berardi, U., & Dangelico, R. M. (2015). Smart cities: Definitions, dimensions, performance, and initiatives. *Journal of Urban Technology, 22*(1), 3–21.

Bergen kommune (2016). *Grønn strategi: Klima- og energihandlingsplan for Bergen. Behandlet av Byråd 26. mai. 2016.* Available from: https://www.bergen.kommune.no/bk/multimedia/archive/00290/Gr_nn_Strategi_-_me_290416a.pdf.

Bhattacharyya, S. C., & Timilsina, G. R. (2010). A review of energy system models. *International Journal of Energy Sector Management, 4*, 494–518.

BRE (2012a). *BREEAM communities manual 2012 - technical manual SD 202 - 1.1.2012.* Available from:http://www.breeam.com/communitiesmanual/#_frontmatter/breeam_communities.htm%3FTocPath%3D.

BRE (2012b). *BREEAM communities technical manual*.

Byrådet Oslo kommune (2016). *Tilleggssak til Klima- og Energistrategi for Oslo. Byrådssak 33/16*.

CASBEE (2007). *CASBEE for urban development: Comprehensive assessment system for building environmental efficiency. Technical manual 2007.* Tokyo: Institute for Building Environment and Energy Conservation (IBEC): GXK Co. Ltd Editor.

CEN (2013). *prEN 15603:2013. European standard: Draft overarching standard EPBD*.

Charoenkit, S., & Kumar, S. (2014). Environmental sustainability assessment tools for low carbon and climate resilient low income housing settlements. *Renewable and Sustainable Energy Reviews, 38*, 509–525.

City Council Oslo (2016). *Byrådets forslag til budsjett 2017 (Budget proposal 2017)*. Available from:https://www.oslo.kommune.no/getfile.php/13226778/Innhold/Politikk%20og%20administrasjon/Budsjett%2C%20regnskap%20og%20rapportering/Budsjett%202017/unzipped_krnl_fileid_225093/PDFS_Budsjett-2017.pdf?download=1.

CITYkeys (2016). *Deliverable 1.4: Smart city KPIs and related methodology – Final, CITYkeys, Editor.* Europe, Horison 2020. Available from:http://www.citykeys-project.eu/citykeys/cities_and_regions/Project-deliverables.

Commission, E (2011). *European Commission's communication' Energy roadmap 2050' (COM(2011) 885 final of 15 December 2011)*.

Connolly, D., et al. (2010). A review of computer tools for analysing the integration of renewable energy into various energy systems. *Applied Energy, 87*(4), 1059–1082.

DIBK (2017). *Forskrift om tekniske krav til byggverk (Byggteknisk forskrift) (TEK17), in FOR-2017-06-19-840, Kommunal- og moderniseringsdepartementet, Editor.* Available from:https://dibk.no/byggereglene/byggteknisk-forskrift-tek17/.

DIBK (2010). *Forskrift om tekniske krav til byggverk (Byggteknisk forskrift) (TEK10), in FOR-2010-03-26-489, Kommunal- og moderniseringsdepartementet, Editor*.

E3MLab (2014). *PRIMES MODEL detailed model description.* Available from:https://ec.europa.eu/clima/sites/clima/files/strategies/analysis/models/docs/primes_model_2013-2014_en.pdf.

Energy Community (2018). *LEAP introduction.* [Accessed: 2018 11.14]; Available from:https://www.energycommunity.org/default.asp?action=introduction.

Energy PLAN (2018). *Advanced energy system analysis computer model.* [Accessed: 2018 11.14]; Available from:http://www.energyplan.eu/.

European Commission (2011). *Energy roadmap 2050 - impact assessment and scenario analysis, in accompanying the document: Communication from the Commission To The Council, The European Parliament, The European Economic And Social Committee And The Committee Of The Regions.* Available from:https://ec.europa.eu/energy/sites/ener/files/documents/roadmap2050_ia_20120430_en_0.pdf.

European Commission (2016). *Clean energy for all Europeans - the winter package.* [Accessed: 2016 11.12]; Available from:https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/clean-energy-all-europeans.

Fufa, S. M., et al. (2016). *A Norwegian ZEB definition guideline. ZEB project report 29*.

Future Built (2018). *Future built.* [Accessed: 2018 01.31]; Available from:https://www.futurebuilt.no/English.

Future Built. no Future Built. No. [Accessed: 2018 05.28]; Available from: http://www.futurebuilt.no/.

Goosen, H., et al. (2014). Climate adaptation services for the Netherlands: An operational approach to support spatial adaptation planning. *Source Regional Environmental Change, 14*(3), 1035–1048.

Hauge, Å. L., et al. (2017). User guides for climate adaptation of buildings and infrastructure in Norway – characteristics and impact. *Climate Services, 6*, 23–33.

Hjorthol, R., Engebretsen, Ø., & Uteng, T. P. (2014). *2013/14 National travel survey – Key results.* TØI. Available from:https://www.toi.no/publications/2013-14-national-travel-survey-key-results-article32972-29.html.

Hukkalainen, M., et al. (2017). Energy planning of low carbon urban areas - Examples from Finland. *Sustainable Cities and Society, 35*, 715–728.

Hygen, H.-O., Bruin, K., & Wageningen, A. (2016). *Co-designing climate service platforms with users: Promises and pitfalls. From research to actions and transformations* Bergen.

IEA (2017). *Energy technology perspectives 2017 - catalysing energy technology transformations*.

Klima- og miljødepartementet (2017). *Meld. St. 41 (2016-2017) Klimastrategi for 2030 – norsk omstilling i europeisk samarbeid.* https://www.regjeringen.no/no/dokumenter/meld.-st.-41-20162017/id2557401/.

Lang, T., & Ramírez, R. (2017). Building new social capital with scenario planning. *Technological Forecasting and Social Change, 124*, 51–65.

Larsson, N. (2012). *Part A, user guide to the SBTool 2012 assessment framework.* iiSBE.

Leal, V. M. S., & Azevedo, I. (2016). Setting targets for local energy planning: Critical assessment and a new approach. *Sustainable Cities and Society, 26*, 421–428.

Lemos, M. C., & Morehouse, B. J. (2005). The co-poduction of science and policy in integrated climate assessments. *Global Environmental Change Part A, 15*, 57–68.

Lindberg, K. B., & Magnussen, I. H. (2010). *Reducing GHG emissions from the Norwegian building stock - measures and policies. Tiltak og virkemidler for redusert utslipp av klimagasser fra norske bygninger.* Norwegian Water Resources and Energy Directorate (NVE).

Loulou, R., & Labriet, M. (2008). ETSAP-TIAM: The TIMES integrated assessment model part I: Model structure. *Computational Management Science, 5*(1), 7–40.

Lucio, F. D. F., & Grasso, V. (2016). The global framework for climate services. *Climate Services, 2-3*, 52–53.

Manville, C., Cochrane, G., Cave, J., Millard, J., Pederson, J. K., Thaarup, R. K., et al. (2014). *Mapping smart cities in the EU.* Brussel: European Parliament.

Marijuan, A. G., Etminan, G., & Möller, S. (2017). *SCIS key performance Indicator guide*.

McNie, E. C. (2013). Delivering climate services: Organizational strategies and approaches for producing useful climate science information. *Weather Climate and Society, 5*.

Meadow, A. M., et al. (2016). From principles to action: Applying the National Research Council's principles for effective decision support to the Federal Emergency Management Agency's watch office. *Climate Services, 1*, 12–23.

Meijer, A., & Bolívar, M. P. R. (2016). Governing the smart city: A review of the literature on smart urban governance. *International Review of Administrative Sciences, 82*(2), 392–408.

Ministry of Petroleum and Energy (2016). *Forskrift om energimerking av bygninger og energivurdering av tekniske anlegg (energimerkeforskriften for bygninger), in FOR-2009-12-18-1665, NVE, Editor.* Available from:https://lovdata.no/dokument/SF/forskrift/2009-12-18-1665.

Neves, A. R., & Leal, V. (2010). Energy sustainability indicators for local energy planning: Review of current practices and derivation of a new framework. *Renewable and Sustainable Energy Reviews, 14*(9), 2723–2735.

Neves, A. R., Leal, V., & Lourenço, J. C. (2015). A methodology for sustainable and inclusive local energy planning. *Sustainable Cities and Society, 17*, 110–121.

Nielsen, B., Juhasz-Nagy, E., Lindkvist, C., Wyckmans, A., Andresen, I., & Bær, D. (2017). *Planning Instruments for Smart Energy Communities Report 2.2: A preliminary toolkit of municipal planning instruments*Trondheim: NTNU. https://www.ntnu.edu/smartcities/pi-sec/publications.

Oslo kommune, K.-o. (2015). *Det grønne skiftet: Klima- og energistrategi for Oslo.* Available from:https://www.oslo.kommune.no/politikk-og-administrasjon/miljo-og-klima/miljo-og-klimapolitikk/klima-og-energistrategi/.

Oslo kommune, P. B. E. (2014). *P.-o.b., Områderegulering for klimaeffektiv byutvikling på Furuset. Planbeskrivelse.* Available from:https://www.futurebuilt.no/content/download/5324/50708.

PI-SEC (2018). *PI-SEC web page.* [Accessed: 2018 10.31]; Available from:https://www.ntnu.edu/smartcities/pi-sec.

Quist, J. (2007). *Backcasting for a sustainable future: The impact after 10 years.* Eburon Uitgeverij BV.

Quist, J., & Vergragt, P. (2006). Past and future of backcasting: The shift to stakeholder participation and a proposal for a methodological framework. *Futures, 38*(9), 1027–1045.

Quitzau, M.-B., et al. (2018). *Implementation of energy strategies in communities (Annex 63) volume 3: Application of strategic measures*.

Selvig, E., Enlid, E., & Arge, N. (2014). *Regneregler for klimagassberegninger i Future Built - Bygg og områder*.

Selvig, E., et al. (2010). *Klimagassregnskap.no/versjon 4. Civitas: klimagassregnskap.no*.

SF, E. Enova Web page (2018). *SF, E. Enova web page.* [Accessed: 2018 31.05]; Available from:https://www.enova.no/about-enova/.

Sørnes, K., et al. (2016). *Analysis of goals and KPIs in design projects, in PI-SEC project report 1.1.*Oslo. Available from:https://www.ntnu.edu/smartcities/pi-sec/publications.

Standard Norge (2018). *prNS 3720 - Method for greenhouse gas calculations for buildings. For public inquiry*.

Stoeglehner, G., et al. (2014). Sustainability appraisal of residential energy demand and supply - a life cycle approach including heating, electricity, embodied energy and mobility. *Energy, Sustainability and Society, 4*(1), 24.

Swart, R., et al. (2016). Co-designing climate service platforms with users : Promises and pitfalls. *4th Nordic Conference on Climate Change Adaptation: From Reserach to Action and Transformation*.

Tereshchenko, T., & Nord, N. (2015). Uncertainty of the allocation factors of heat and electricity production of combined cycle power plant. *Applied Thermal Engineering, 76*, 410–422.

Transform (2015). *Work package 1: Becoming a Smart Energy City, State of the art and ambition*Available from:http://urbantransform.eu/wp-content/uploads/sites/2/2015/07/WP1-revised-final-report.march-2015.pdf.

UNFCCC (2015). *Adoption of the paris agreement.* Accessed 14th Dec 2015 http://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf.

USGB (2018). *LEED v4 for NEIGHBORHOOD DEVELOPMENT.* Available from:https://www.usgbc.org/resources/leed-v4-neighborhood-development-current-version.

Vaughan, C., & Dessai, S. (2014). Climate services for society: Origins, institutional arrangements, and design elements for an evaluation framework. *WIREs Climate Change, 5*, 587–603.

Vergragt, P. J., & Quist, J. (2011). Backcasting for sustainability: Introduction to the special issue. *Technological Forecasting and Social Change, 78*(5), 747–755.

Walnum, H. T., et al. (2017). *Preliminary toolkit for goals and KPIs. PI-SEC report 1.2 Oslo: Sintef. PI-SEC report.* Oslo: SINTEF Buildings and Infrastructure.

Wiik, M. K., et al. (2018). *Zero emission neighbourhoods in smart cities: Definition, key performance indicators and assessment criteria: version 1.0. Bilingual version.* FME ZEN.