Selamawit Mamo Fufa and Michael Klinski (eds.)

Embodied Energy, Costs and Traffic in Different Settlement Patterns

Background projects and tools

scattered settlement

Compact

etc 50 [m] Length of the access road / channel etc 100 [m] Length of the access road

3 detached house
Carport
2010
100 m²
green
45 El

1 residential buildin
underground car
1970
20 RU
wood pellets
200 El

3 residential buildin
no garage
2010
30 RU
solar
70 El

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Key words: Building, ELAS, ZERsiedelt, Infrastructure, Scenario planning, Tool, Transport planning.

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Preface

This report has been written within the research project EE Settlement - Embodied Energy, Costs and Traffic in Different Settlement Patterns, which is financed by The Research Council of Norway within the Byforsk programme. The project is a broad and interdisciplinary collaboration between SINTEF Community, Norwegian Institute for Urban and Regional Research (NIBR), Institute of Transport Economics (TØI), Kristiansand Municipality, National Association of Norwegian Architects - Norske Arkitekters Landsforbund (NAL) BYLIVsenteret initiative, and two partners from Vienna, Akaryon, and IRUB, the Institute of Spatial Planning, Environmental Planning and Land Rearrangement at the University of Natural Resources and Life Sciences, Vienna. The report is compiled with contributions from project partners as authors on the specific topics listed below:

ZERsiedelt project: Petra Bußwald (akaryon); Niederl Franz (akaryon); Finker Christian (akaryon)

ELAS project: Peter Lichtenwöhrer (BOKU); Georg Neugebauer (BOKU); Gernot Stöglehner (BOKU)

Relevant tools available in Austria: Peter Lichtenwöhrer (BOKU); Georg Neugebauer (BOKU); Gernot Stöglehner (BOKU)

Relevant tools available in Nordic countries: Selamawit Mamo Fufa (SINTEF), Kamal Azrague (SINTEF), Michael Klinski (SINTEF)

Relevant tools available in Germany: Michael Klinski (SINTEF)

Models and tools for Norwegian transport planning: Iratxe Landa Mata (TØI)

In addition, the report was quality assured by James Kallaos. The editors would like to thank the project partners for their contributions.

Abstract

The objective of this report is to provide a state-of-the art review on relevant existing studies and tools that could be serve as inspiration for tool development and guidelines in the EE Settlement project. The report summarizes the methodological choices and the outcome of two Austrian projects, ZERsiedelt and ELAS, which are considered as a basis for developing a tool in EE Settlement. Relevant tools for buildings, infrastructure, transport and scenario planning from Austria and Nordic countries, and tools for cost analysis from Germany are also summarized. The report also highlights the limitations of existing approaches and helps define the scope for further work in the EE Settlement project.

Sammendrag

Formålet med denne rapporten er å gi en gjennomgang av "state-of-the-art" for eksisterende, relevante studier og verktøy som kan brukes som inspirasjon for utviklingen av verktøyet og en veileder i prosjektet "EE Settlement": Rapporten oppsummerer de metodiske valgene og resultater fra to lignende østerrikske prosjekt, ZERsiedelt og ELAS, som kommer til å brukes som grunnlag for å utvikle verktøyet i EE Settlement. Andre relevante verktøy for bygninger, infrastruktur, transport og planlegging av fremtidsscenarioer fra Østerrike og Norden og kostandsberegningsverktøy fra Tyskland presenteres også i rapporten. Denne rapporten har satt fokus på omfanget og begrensningene som må vurderes i det videre prosjektarbeidet.

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APPENDICES

1 Introduction

The provision of housing for people provides a host of benefits and services, but it also causes a certain amount of environmental and societal disruption. The amount of that disruption, and the impacts caused by it over the life cycle of the housing, depends on a myriad of factors. Besides the different effects from the different housing types, and the quality, materials, and size of the housing itself, there are also other impacts which are often ignored or overlooked. These include the life cycle costs, energy consumption, and greenhouse gas (GHG) emissions which can be attributed to structural and service infrastructure, as well as changes in both demand and capacity for travel and transport. Different housing types may be distributed in different settlement patterns and in different topographic and demographic areas, yielding a wide assortment of expected and observed patterns of impacts.

Most of these issues are not addressed (or only to a minor degree) by existing policies or guidelines, which focus primarily on the efficiency of building-scale operational energy consumption and GHG emissions, while generally disregarding most of the other factors noted above, including other lifecycle stages, occupant behaviour, public costs, and induced demand for transport and other services (Ding, 2007; DOE, 2012; EC, 2008; EPA, 2012; EU 2002/91/EC, 2003; EU 2010/31/EU, 2010; EU 2012/27/EU, 2012; EU 2018/844, 2018; Gjerstad et al., 2007; Kallaos and Bohne, 2013; Pacheco-Torgal et al., 2012; Szalay, 2007). As increasing efficiency changes the relative effect of embodied versus operational impacts (Koezjakov et al 2018), it is becoming clear that a valid assessment of different housing settlements needs to take a life cycle perspective, including embodied energy and GHG emissions in addition to the existing variables.

Current building regulations generally consider only operational energy, while neglecting energy use and affiliated GHG emissions from the rest of the building life cycle. Political plans and strategies reflect almost exclusively energy for the operation of buildings, not the embodied energy[1] in the building's life cycle. Life cycle assessment (LCA) of buildings does include the embodied energy of the building itself, but rarely considers impacts from outside the system boundary of the building, such as the impacts from associated outdoor facilities and infrastructure. Data for embodied energy in settlements, especially associated with outside facilities and infrastructure, are not generally calculated, collected, or tracked in Norway. Little if any data is available from other countries – apart from the Austrian project "ZERsiedelt – Energy relevant aspects of building and future of Housing and Settlement-Structures in Austria", which was completed in 2011. To the best of our knowledge, "ZERsiedelt" is the only project until now that examined embodied energy from different settlement patterns in a detailed manner and with a broad perspective. Furthermore, the Austrian Institute of Spatial Planning, Environmental Planning and Land Rearrangement (IRUB) at the University of Natural Resources and Life Sciences in Vienna (BOKU) has also performed research in this field within the project "ELAS" (Stöglehner et al. 2011), but this project involved rougher estimations regarding embodied energy of infrastructure of settlements compared to ZERsiedelt.

Internationally, several studies (Ewing and Cervero 2010) have shown correlation between settlement structure, accessibility, and travel behaviour in cities. Næss (2012) has given an overview and a theoretical discussion of a selection of research in the Nordic countries. In Norway, the Institute of Transport Economics (TØI) has confirmed the correlation through analyses based on data from the national travel surveys combined with registry data. Estimations of induced transport demand would enhance calculations on energy and costs related to a settlement, providing a more comprehensive assessment of impacts associated with housing.

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[1] Embodied energy is the sum of the direct and indirect energy chain needed to produce and support a product or process, including mining, processing, transportation, and assembly or construction (from components and processes with their own embodied energy), expressed in terms of primary energy. Alternative terms include "grey" "indirect" or "supply-chain" energy (see e.g. Treloar 1998, Lenzen et al. 2008).

1.1 The EE Settlement project

The project *EE Settlement – Embodied Energy, Costs and Traffic in Different Settlement Patterns* addresses these issues and challenges. The main objective is to generate profound basic data on the embodied energy requirements of different dwelling types and settlement patterns, including associated outside facilities and infrastructure - such as roads and services (such as water, electricity and sewage). Moreover, associated investment, operating costs and energy, induced transport demand, as well as the political and societal framework which affects housing development, individual housing preferences, and user decisions will be assessed. Based on the generated data and the assessment results, the project will provide recommendations and a tailor-made web-based tool, to be used for discussion of spatial planning and housing options, as well as for preparation of political decisions. That way, the project will also broaden the basis for the strongly required GHG reductions within a sustainable urban development.

When preparing their masterplans according the Planning and building act, municipalities must adapt to national framework conditions for a sustainable development pattern. This framework is again based on international climate and environment agreements. These framework conditions may be strengthened, especially if the local housing demand today allows municipalities to plan for scattered housing settlements. However, recommendations developed in the project will not be limited to spatial planning issues or national policies but will include a wider range of topics that influence settlement patterns, with recommendations and guidelines for local and regional authorities.

Currently, municipalities like Kristiansand, a coastal city of about 100,000 people in Southern Norway, have a challenge in assessing the consequences of further development within their existing, densely built-up urban areas, versus the consequences of new developments in rural areas, implying urban sprawl. A decision support tool would meet this challenge and help to frame the planning discussion around sustainable development in a broader and longer-term perspective. The house price gradient in urban areas implicates expensive dwellings in densification and transformation projects, and cheaper dwellings when they are built on the urban fringe. This decision on where to build has social dimensions, and influences other factors, such as that lower prices increase the number of square meters demanded.

The vision for the project is to provide guidelines and tools for municipalities, regional and central authorities, as well as for professionals (e.g. architects and spatial planners) and the public, for assessing the consequences and impacts of different housing development options, taking into account energy need, environmental impact and costs over the lifecycle – not only for the buildings, but also for surroundings, infrastructure and transport.

The project is divided into six work packages (WP) that target the main research topics addressed in the project. The overall structure of the work packages, and the connection between them, is shown Figure 1.1.
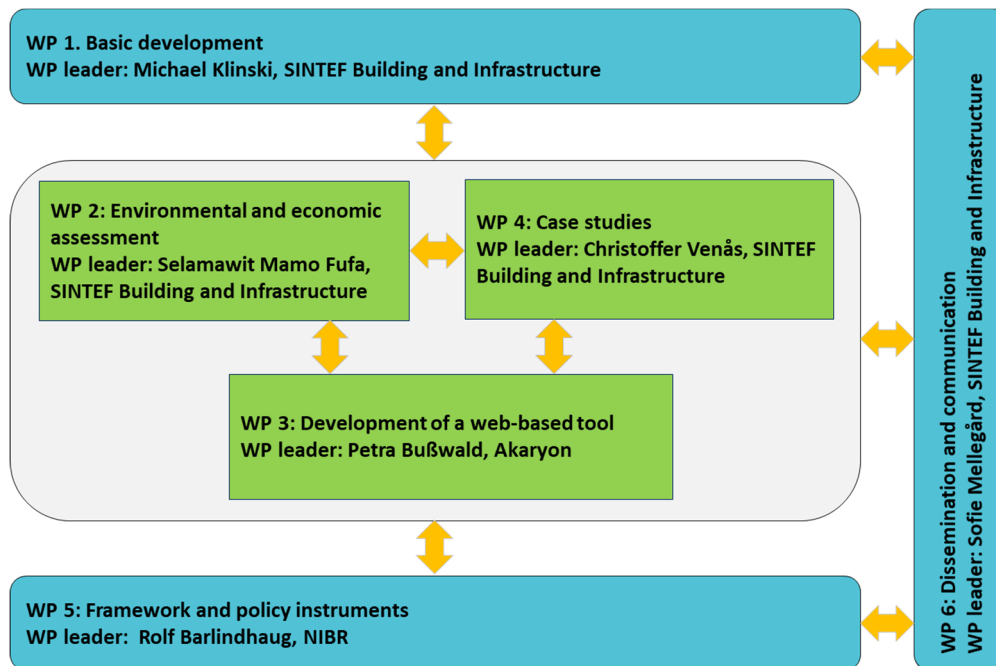
Figure 1.1
EE Settlement project organization plan (SINTEF)

The starting point is the development of a basis in WP 1, where needs will be assessed, and the scope defined more precisely. The environmental and economic assessments in WP 2 and the development of a web-based tool in WP 3 will build on this basis, and assessment results will be inputs in the tool. Case studies in WP 4 will be used to validate the tool and contribute to its improvement. WP 5 examines framework conditions and develops recommendations based on results from WP 2-4, taking into account the needs identified in WP 1. The results generated in the project will be disseminated in WP 6.

1.2 The present report

This report is one deliverable from a state-of-the-art review performed under WP 1, Task 1.1, within the research project EE Settlement. In WP 1, the aim is to create the basis for assessment, examination and tool development. The work includes a state-of-the-art review of current available studies (Task 1.1), a requirement analysis with identification and evaluation of the demands of different municipalities and authorities (Task 1.2), and a definition of the goal and scope of the project (Task 1.3).

The methodology used in this study is based on literature review of existing relevant studies, databases and tools. As EE Settlement to a large extent builds on the outcome from the two Austrian projects noted above, ZERsiedelt and ELAS, the report starts with summaries of the results of those projects, including a description of the functionality of the tools developed in ZERsiedelt and ELAS (Chapter 2 and 3). Chapter 4 gives an overview of other relevant Austrian tools and discusses experiences, possibilities, and limitations in their application. Chapter 5 summarizes tools developed or used in Norway and other Nordic countries, with examples of tools for buildings, infrastructure, transport, and scenario planning. Chapter 6 summarizes tools available in Germany, in this case mainly focusing on follow-up costs of settlement development. Chapter 7 provides an overview and description of the models and tools most commonly used to estimate and model passenger transport demand and travel behaviour. Conclusions and recommendations for further work complete the report in Chapter 8.

Furthermore, an example calculation from the ELAS tool, which is described in Chapter 3, is shown in Annex A. For some of the tools presented in Chapter 4, a more detailed description of characteristics is given in Annex B. Three additional Austrian studies, which do not include tools, but are relevant for EE Settlement, are summarized in Annex C.

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2 Background: ZERsiedelt Project (Austria)

2.1 Project aims and content

The ZERsiedelt project aimed to generate new knowledge and competencies in the field of "Housing and Settlement-Structures in Austria" with the objective of introducing this knowledge into Austrian policies regarding energy and climate.

The focus of the project involved three main areas of research:

1. **Balance of energy-use (grey or embodied energy²)** in connection with
   a. Construction of dwelling-houses according to building-periods (e.g. decades after 1961) and according to types of buildings (e.g. 1-2 family-houses, 3-10 flat-units; greater than 11 apartments in one building) and according to representative constructions: production and transport of all building materials, energy for construction vehicles and plant.
   b. Infrastructure required to connect to a new housing development: including roads and services (water, sewage, electricity, gas, distance-heating, telecommunication and street lighting).
   c. The selection of representative constructions and building periods also allowed for **projection to Austria as a whole,** delivering data on total energy demand and greenhouse gas emissions of the residential sector 1970 – 2010.
2. **Investigation of public "Support Measures",** which financially assist these developments and occupants (e.g. public sponsoring of housing, infrastructure budgets, drinking water, sewage and energy systems). Creating recommendations of an ecological orientation for these "Support Measures".
3. **Discussion of future scenarios,** particularly for "Single-family-settlements", in the context of a possible energy-crisis (e.g. "Peak Oil", sudden rise in energy-prices): Can development of these dwelling-structures become sustainable? How could/would/should these developments be evolved or designed?

Target groups addressed are the mainly scientific community and opinion leaders close to politics (civil servants, urban and regional planners, community leaders) ultimately aiming to influence politics itself and the basis of decision making of Austrian climate and energy policy.

2.2 Results of the project

1. scientific studies/publications
2. a methodology to assess the influence of public support measures on urban sprawl and its environmental impact, and recommendations for an ecological orientation of the analysed public support measures
3. a methodology to calculate embodied energy and GHG emissions for residential settlements, including basic data/indicators needed
4. calculation of total energy demand and GHG emissions of the Austrian residential sector 1970 – 2010
5. a web-based tool for calculation of embodied energy and greenhouse gas emissions for different types of buildings and settlements in German and English
   o in German: https://www.zersiedelt.at/graue-energie-rechner-wohnbau/
   o in English: https://www.zersiedelt.at/grey-energy-calculator-settlements/

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² As noted in footnote 1, 'grey' and 'embodied' are interchangeable. The ZERsiedelt tool used the term 'grey' while most of the literature uses 'embodied'. This report uses the term 'embodied'.

2.2.1 Some details on project results

Scientific insights of Work package 2: Balancing of embodied energy in residential building and associated infrastructure development

The modelling showed, that especially dispersed settlement requires a high amount of embodied energy, particularly for the construction of streets and infrastructure. As seen in Figure 2.1, the energy demand for the construction of infrastructure around single-family homes (SFH) in dispersed settlements exceeds the energy demand for the construction of the building. For the medium storey apartment buildings (MSB) of three or seven floors, the figures in the area "road and wiring" are approximately the same for both heights. Small differences become apparent when it comes to the energy required for "transport & construction".
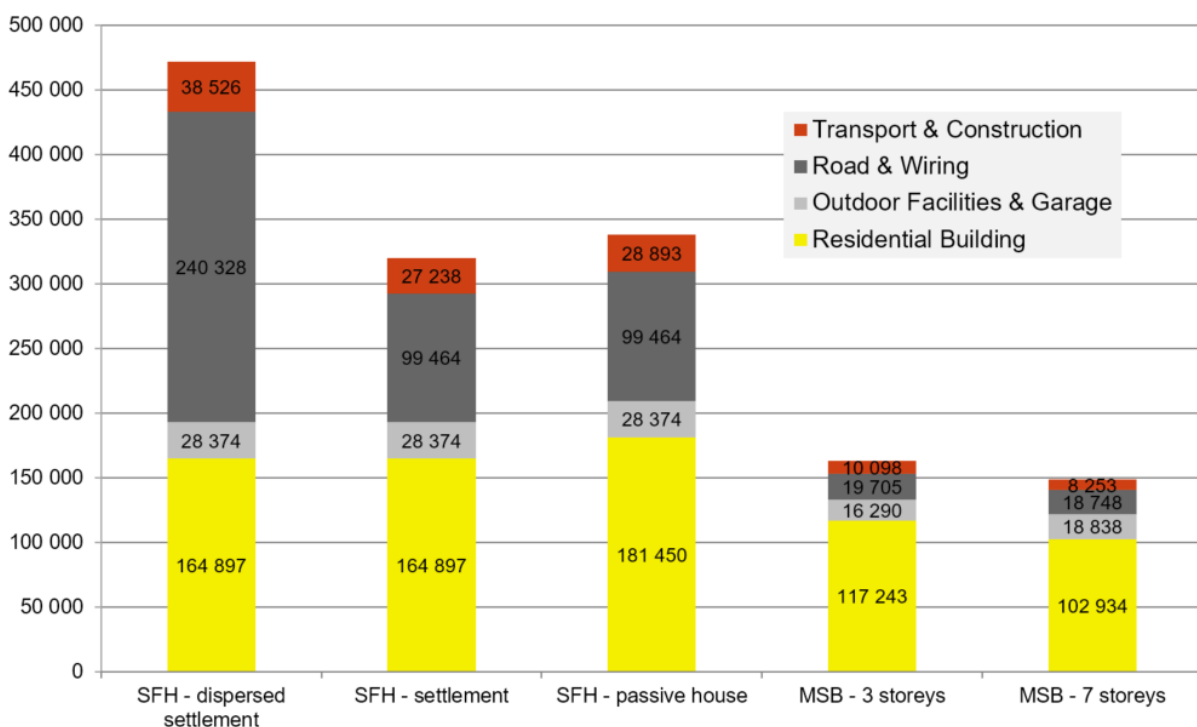
Figure 2.1
Embodied (grey) energy (kWh) in construction of residential buildings[3] and associated infrastructure (without maintenance), standardized to 100 m^2 gross floor. SFH = Single family housing. MSB = medium storey apartment building.

Including the expenditure of energy for maintenance work[4] and extrapolating the embodied energy over a period of 100 years, the differences between various types of housing estates become even more noticeable: A single-family house in a dispersed settlement requires 1,178,471 kWh / 100 years, while a single-family house in a compact settlement requires 702,331 kWh / 100 years. Three-storied MSB housing consumes 276,295 kWh, while seven-storied MSB housing requires 264,089 kWh.

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[3] Single-family house in settlement location (2 floors & basement, plot: 800 m^2), single-family house in dispersed settlement (additionally: 100 m access road, plot: 1,200 m^2), residential building 3 floors and around 132 accommodation units, residential building 7 floors and around 54 accommodation units.

[4] According to own analyses and interviews with experts, the following maintenance mark-ups are necessary over 100 years: building 50%, roads / connections 200%, outdoor facilities 300%, garages 20%

Thus, multi-family houses (three or seven floors) require less than 25% of the embodied (energy expended for single-family houses in dispersed settlements. Additionally, the embodied energy of multi-storey residential buildings amounts to nearly 30 times the annual operating energy, whilst the embodied energy of single-family houses in compact settlement location amounts to nearly 50 times annual energy use, and the embodied energy of single-family houses in dispersed settlement amounts to nearly 100 times annual energy use.

In 1970, operational energy consumption was so high that the embodied energy was comparatively insignificant, consisting of only 7 to 19% of the total energy demand.
By 2010, however, embodied energy was no longer a negligible component, amounting to between around 24 and 48% of the total energy demand, or 50% for passive house constructions. Even in absolute terms the embodied energy for all types of buildings is higher in 2010 than in 1970. For single-family houses in dispersed settlements the demand for embodied energy is approximately the same as for the operation over a lifetime of 100 years. Additionally, the total energy demand of single-family passive houses is higher than for multi-family residential buildings constructed to the current minimum standard. This is due to the additional infrastructure requirements of single-family houses, even passive ones (see Figure 2.2).
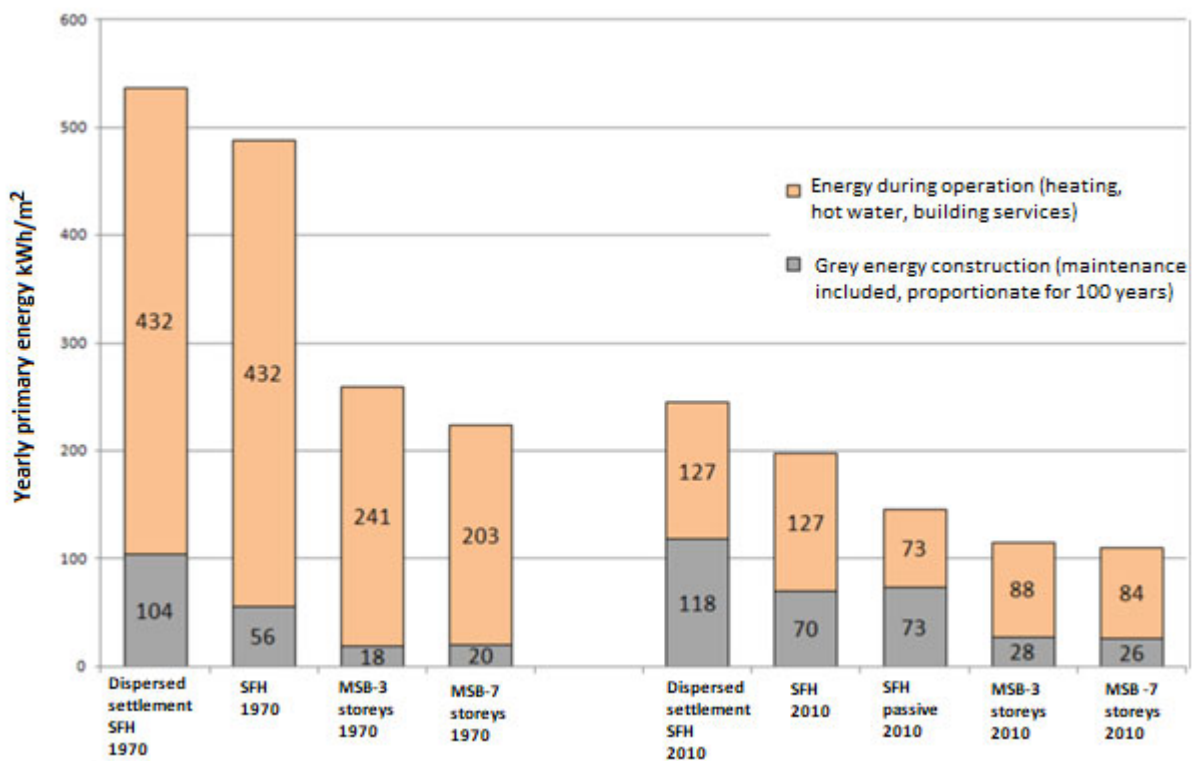
Figure 2.2
Types of housing estates 1970 & 2010, embodied energy and operating energy

A direct comparison of the energy use between single-family houses in settlement locations and multi-family houses (average over three- and seven-storied residential buildings) shows the decline of the total energy spent on housing and an increase of both relative and absolute shares of embodied energy. While operational energy use has declined for both types of housing since 1970, embodied energy has increased over time, due to the use of increasingly complex materials and the improvement of thermal insulation.
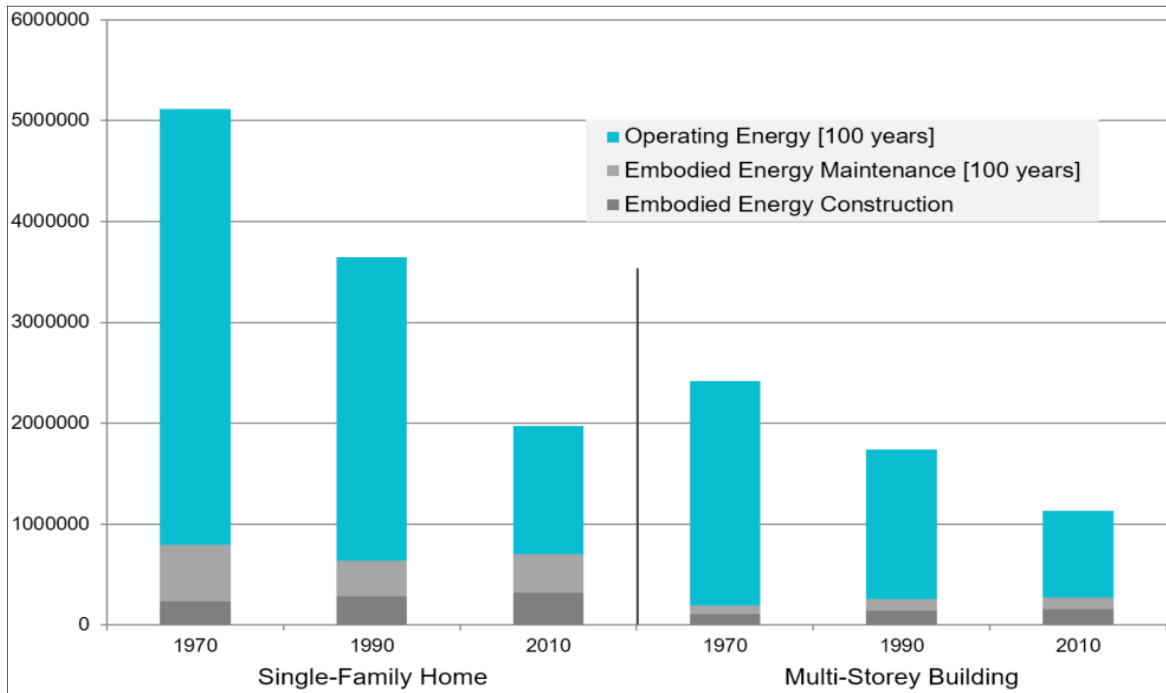
Figure 2.3
Single-family and multi-family house – Embodied energy for construction and maintenance, energy demand during operation, per 100 m² gross floor, 100 years utilization

Extrapolation and projection to Austria: To obtain the embodied energy values for Austria as a whole, the energy parameters have been multiplied with the m² gross floor area completed per year for single-family and multi-storey housing.

The sum of the years between 1970 and 2010 results in 440 TWh grey energy (or 85 million tCO_2eq) for housing in Austria (see Figure 2.4)
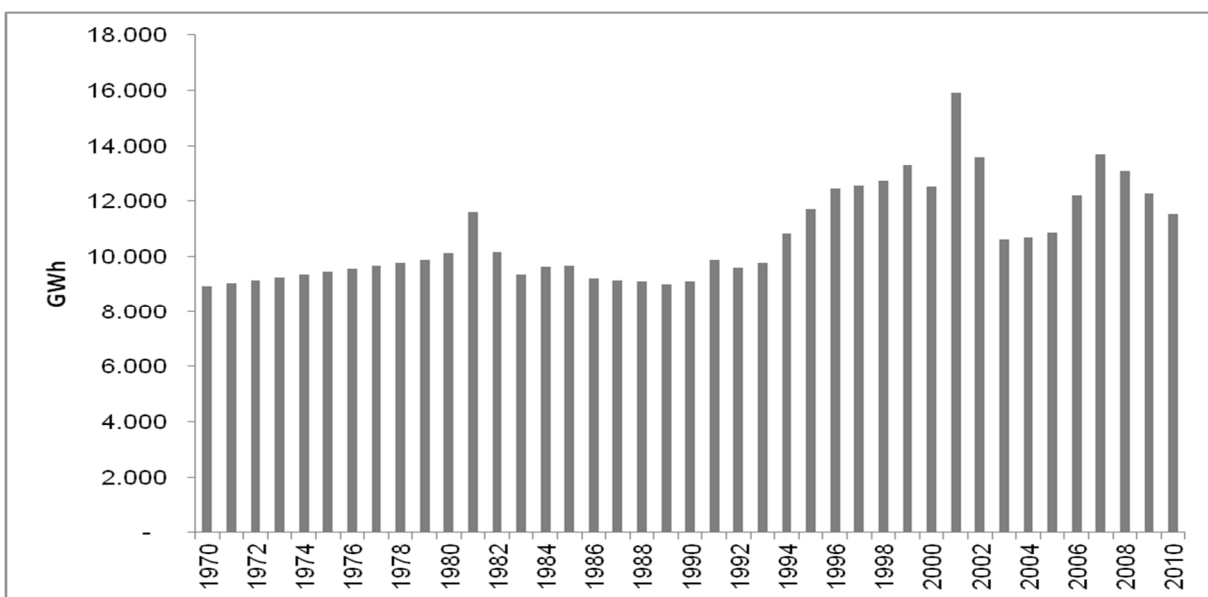
Figure 2.4:
Embodied energy in newly built residential buildings between the years of 1970 - 2010: 440 TWh

In order to visualize the scale of embodied energy consumption, it is useful to compare 40 years of embodied energy and associated GHG emissions with other important energy parameters: The 440 TWh equals approximately the current total Austrian energy demand (and the total Austrian greenhouse gas emissions of a year). Over the period of the 40 years considered, the annual embodied energy represents around 4.8% of the energy consumption in Austria. Regarding the more comparable gross domestic energy consumption[5] of Austria the share lies at least at 3.5%.

It should be noted that only the first construction is included in the extrapolation. If ongoing maintenance were included, the figures would at least double.

Scientific insights of Work package 3: Determination of the support measures for residential building – connection with urban sprawl in Austria, recommendations for reduction of environmental impacts.

Central to this work package was the improvement and the dissemination of knowledge on "public support measures" (e.g. fiscal and regulative support measures of the federal government, federal states, and municipalities), which contribute to residential urban sprawl. Drivers of urban sprawl on both the demand and the supply side (see Figure 2.5) have been determined and analysed.
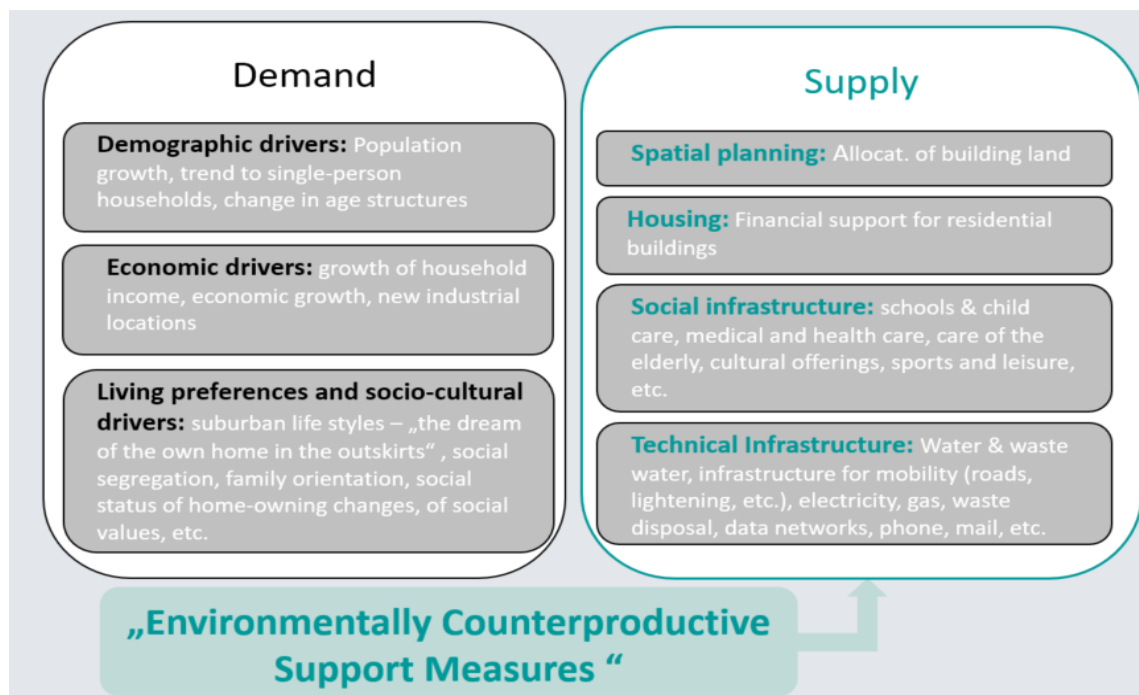
Figure 2.5
Drivers of urban sprawl on the demand- and on the supply side

The demand side: Regression models for Germany show that demand-side parameters, such as a preference for a house in the green belt, rising household incomes, or population growth alone, cannot explain the observable dimension of urban sprawl. In the area of living preferences, a general preference for a house in the green belt could not be determined – the preference is mostly a result of financial restrictions and missing urban alternatives (clean air, security, nature etc.)

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[5] Included in the gross domestic consumption are the domestic production of primary energy, the balances of external trade as well as inventory changes. So, this value indicates the energy demand prior to the conversion in power plants, heating plants, cogeneration units, refineries etc. and gets close to the primary energy consumption.

The effect of increasing prosperity on urban sprawl is ambivalent and can express itself both negatively, enabling living in the urban core area, and positively, through the fulfilment of the wish for a house in the green belt. More significant are the relative prices of urban and suburban / rural living. The demographic development – a shift in the population structure and a trend to smaller households – has an effect. Population size does not have a significant influence.

The supply side: Public support measures having an influence on the settlement possibilities in the countryside, and thereby influencing their availability and costs, play an important role for urban sprawl. A systematic analysis has shown that two categories of support measures exist that result in urban sprawl: Requirements (needed for sprawl to occur), and facilitators (policies or measures that encourage urban sprawl).

Requirements: The most important aspect is the provision of buildable land. Without constant zoning of new buildable land outside the existing settlement boundaries, urban sprawl would not be possible. The public provision of technical infrastructure, especially streets, water, sewage system, power, gas etc. is of similar importance. Both aspects, buildable land and infrastructure, are absolute preconditions for urban sprawl, and are provided almost exclusively by public authorities.

Decisions regarding the "requirements" support measures are mainly taken at the municipal level, although financing is passed on to the federal government. Zoning planning is a matter of the responsibility of mayors and local council representatives, involving all issues raised by direct contact and reliance of community policy on the voters. Regional coordination through the federal states or nationwide regional planning is missing to a great extent. Municipalities profit from resettlement – depending on whether it is a household or a company – through financial compensation or higher local rates. As a result, municipalities are in competition with each another in attracting the population segment which considers the city as well as surrounding communities for fulfilling their living dreams.

Facilitators: In addition to the "requirements", there is a range of further measures which influence the attractivity and affordability of urban sprawl. Among them are: housing subsidies, support of mobility (urban sprawl often means forced mobility, which is subsidized by commuter allowance, mileage allowance, etc.), (unprofitable) provision of social infrastructure (kindergartens, schools, leisure programs, culture, sports, health services etc.). All of these "facilitator" support measures shift the relative attractiveness of housing prices to the rural / suburban area as compared to the city.

Assessment: For the support measures, we have developed an assessment system built on the criteria "relevance" (interdependency, financial volume) and "historical meaning". The following chart (Table 2.1) shows the results of the assessment, where the pivotal support measures are highlighted

Table 2.1
Results of the assessment of public support measures, own analysis (Akaryon)

Support Measure	Rating					Volume	
	Interdependency A	Volume (public funding) B	Relevance C=A*B/10	Historical dimension D	Total rating E=C*D/10	total	budget-relevant
		0 to 10 points				in Bio. Euro p.a.	
1 Zoning of building land	10	10	10	10	10	2	*)
2 Expansion of public road infrastructure	8	10	8	10	8	3	3
3 Water management	8	2	1,6	8	1,28	0,4	0,4
4 Housing subsidy	4	4	1,6	10	1,6	0,75	0,75
5 Funding for building society savings	2,4	0,5	0,12	5	0,06	0,08	0,08
6 Funding for commuters	4,8	1	0,48	7	0,34	0,2	0,2
7 Mileage allowance	2,4	0,3	0,07	5	0,04	0,06	0,06
8 Parking space obligation	1,6	0,4	0,06	5	0,03	0,08	0,08
9 Offer of public transport	0	10	0	5	0	2	2
10 Expansion of kindergartens and schools	4	2,5	1	10	1	0,5	0,5
11 Expansion of mobile services	3,5	0,75	0,26	7	0,18	0,15	0,15

*) The funding is calculated from zoning profit

Figure 2.6 shows the qualitative assessment, the significance of the impact of support measures on urban sprawl, and an estimation of the financial resources directed annually to the progression of urban sprawl or the maintenance of already spoilt structures.
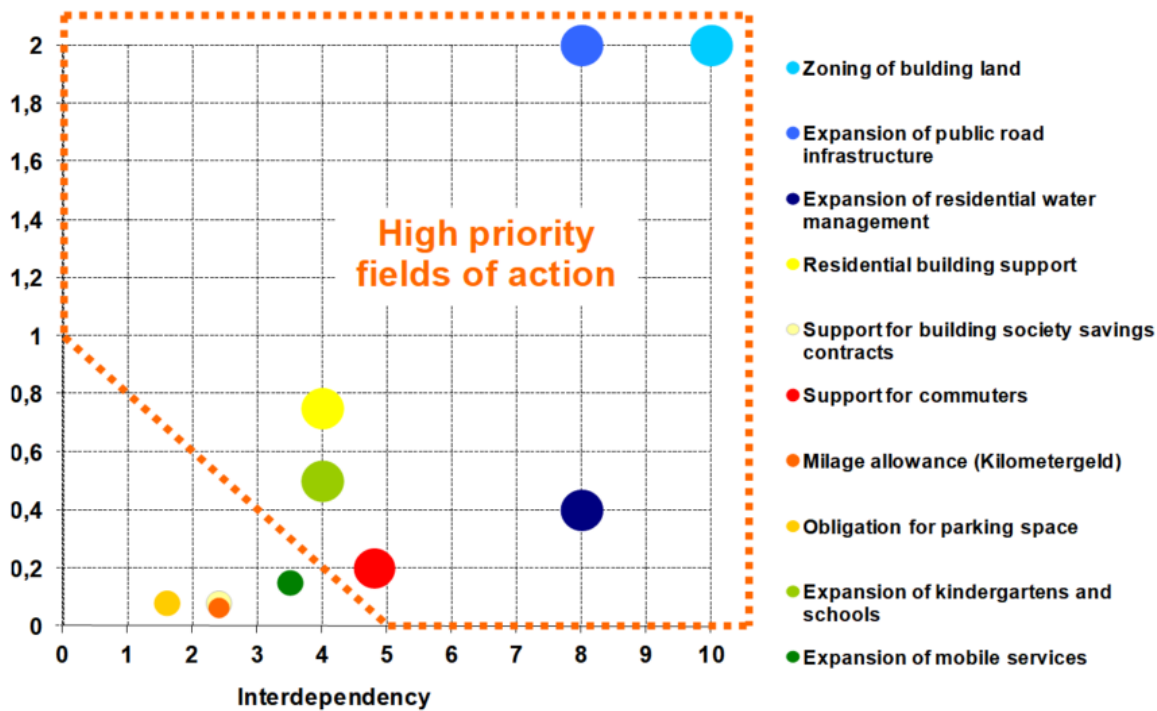
Figure 2.6
Force of the impact of support measures on urban sprawl (Akaryon)

2.2.2 The web-based tool, the embodied energy calculator

The web-based tool allows the selection of input parameters with a graphical user interface (GUI) (Figure 2.7):

1. type of settlement site (green grassland, scattered settlement, or compact settlement) including length of access road

2. number and characteristics of houses:
   a. type of house (detached house, 3-store building, 7-store building)
   b. type of garage (single, double, car port, underground car park cellar)
   c. building period 1970, 1990 or 2010
   d. gross floor area (m^2)
   e. energy carrier for heating (to be selected from 13 fossil and renewable energy carriers)
   f. energy indicator (measured in kWh/m^2)

Results include embodied energy figures for the following components: access road, building, outdoor facilities, garage, land development/infrastructure (e.g. sewage) (Figure 2.8). Absolute figures and percentages are available, as well as annual values, and values for 100 years (including maintenance efforts). Operational energy is also calculated and can be compared to the embodied energy values. Further information on tool characteristics is given in Annex B.
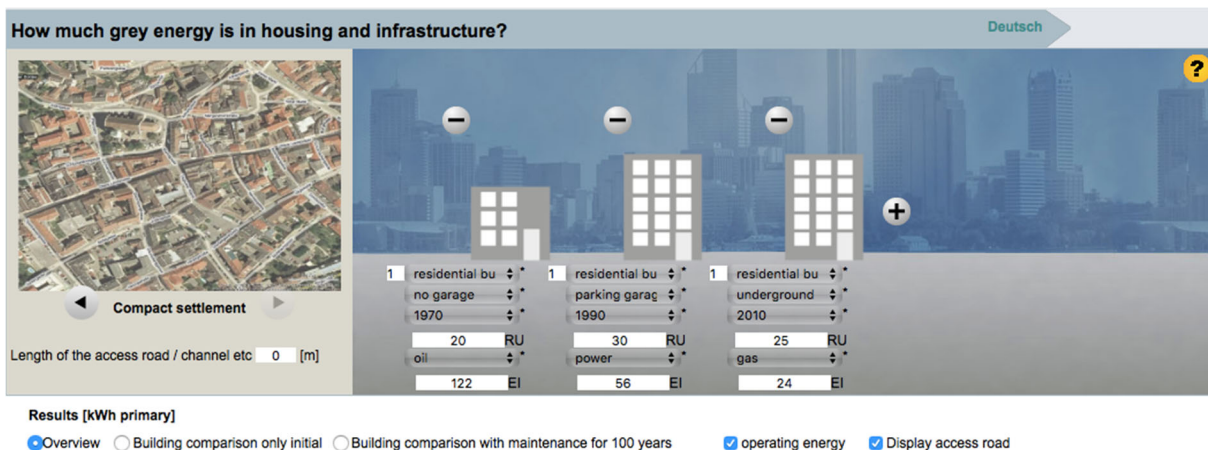
Figure 2.7
Example view of input data pane of the calculator:

Figure 2.8
Example view of result pane

References

Short list

Data used for calculation is mainly taken from Statistik Austria and ArchiPhysik (Version 9.0.0.007). Validation and projections were calculated based on Ecoinvent, GEMIS 4.6, LEGEP and compared to studies like Vogdt et al. and Gruhler et al.

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3 Background: ELAS project (Austria)

3.1 Introduction

The freely available ELAS calculator – **E**nergetic **L**ong-term **A**nalysis of residential **S**ettlement structures – is a tool based on a life cycle network, including heating, electricity, embodied energy and mobility. With the help of the ELAS calculator the user can carry out calculations to assess and optimize whole settlements or individual buildings in terms of energetic, environmental, and socio-economic aspects (Stoeglehner et al. 2014a). In the context of climate change and the energy transition it is necessary to do more than construct energy-efficient buildings. The overall energy input for buildings is sometimes lower than the energy input for the public infrastructure requirements of settlements (Stoeglehner et al. 2011a). Thus, it is essential to assess the whole life cycle and to consider the embodied energy of settlements.

With the help of the ELAS project some important questions are addressed: (1) How do different building types, building periods, or mobility patterns influence the energy consumption of a settlement? (2) How does siting effect the energy demand of a settlement? (3) To what extend does the choice of energy source effect the local environment and our climate? (4) Which regional economic effects are related to the energy consumption of a settlement?

The ELAS calculator addresses these questions and more, by looking at the effects of spatial decisions on the energy demand and supply of settlements. The tool deals with energy demand/supply for the construction of buildings and municipal infrastructure (roads, sewage, street lighting, etc) as well as with associated energy demand/supply for the operation and maintenance of buildings and infrastructure. Another important part of the calculator is the energy demand for mobility, associated with residents. Energy consumption of mobility can vary significantly, depending on respective location of the settlement, demographic structure and provided infrastructure. As a result, the tool calculates the overall energy consumption, related CO_2 emissions and shows ecological impacts as well as regional economic effects. A detailed description of the tool can be found in Chapter 2 of this report.

Regarding the life cycle-network of the ELAS calculator, Figure 3.1 illustrates a rough overview of the concept. Starting with dwelling in the centre, the cycle includes construction, maintenance and operation of buildings and infrastructure. The network further consists of provision, transport, demolition and disposal/recycling of construction materials and the life cycle of energy supply (electricity, heating, cooling). The life cycle of the mobility of residents is also included in the model.

The ELAS calculator was developed in the framework of the ELAS project, carried out from 2009 to 2011. At the beginning of the project a literature review was conducted, from which societal, economical, technological and environmental parameters were identified. These parameters were then used for the ELAS-model.

In the ELAS survey, 10 settlements with different spatial situations from 7 municipalities were analysed. For the survey, a total of 587 households and 1,047 people were questioned. Another part of the field research was the questioning of local representatives to get further information about municipal infrastructure. Data from the ELAS-survey was used as an input for the ELAS-model. Data from statistical institutions was used to supplement the information gained in the field research. Based on the survey results, two scenarios were designed. Finally, the ELAS-calculator was elaborated and provided as a freely available webtool[6] in both English and German.

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[6] http://www.elas-calculator.eu./?lang=en
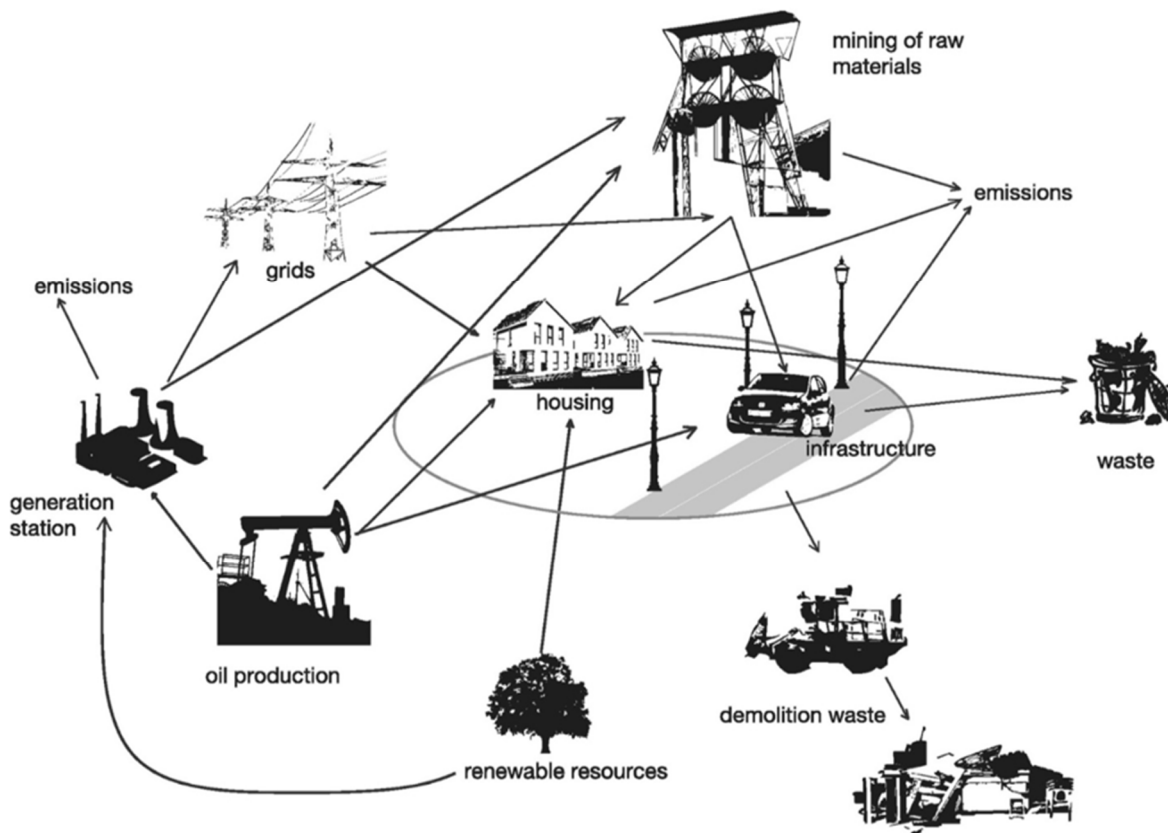
Figure 3.1
'Life cycle-network' of the ELAS calculator with dwelling in the centre (after Stoeglehner et al. 2014a)

The aim of this section is to summarize and describe the model that is used in the ELAS tool, based on the final ELAS-project report (Stoeglehner et al. 2011a) and the work of Stoeglehner et al. (2014a). Section 3.2 highlights basic principles of the tool, followed by a detailed description of the As-Is-Analysis (Section 3.3), also called the Status-Quo analysis of a settlement or an individual building. The next part (Section 3.4) deals with the Planning mode of the tool, where users can plan a completely new settlement (planning from the "Green Field") or can design/adapt/improve an already existing settlement. Section 3.5 introduces two different scenarios that are included in the tool. The brief description (Section 3.6) of the tool results (Energy consumption, Ecological Footprint, CO_2 Life Cycle Emissions, and Regional Economic Analysis) is followed by a calculation example in Freistadt, a small Austrian town in Upper Austria (see Annex A). In the discussion and outlook (Section 3.7), possible fields of application and target groups of the tool are presented, and a brief outlook is given.

3.2 Basic principle of the web-based tool, the ELAS calculator

After starting the online tool, the user is asked to choose a mode. The *Municipal Mode* requires detailed information about the settlement (specification of sewer lines, street lighting, etc.) and allows the user to analyse and plan settlements/building groups. This mode is designed for planners, architects, builders, and municipalities. The *Private Mode* is a kind of basic mode, requiring less detailed information, designed for private individuals.
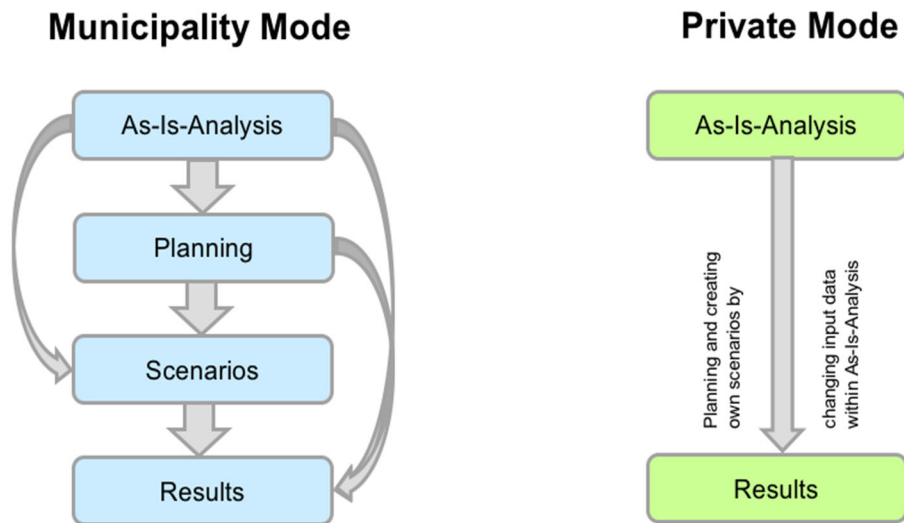
Figure 3.2
Basic principles and functions of the ELAS-Calculator (after Stoeglehner et al. 2014a)

Figure 3.2 illustrates the two variations of the tool. For both modes, changeable default values are available in order to simplify the process of data-input. All default values that are provided by the tool were derived from the ELAS survey and from extensive literature research.

In the municipality mode, it is possible (1) to analyse the status-quo of a settlement or of individual buildings, (2) to change into planning mode and adapt an already existing settlement (renovation, settlement expansion, demolition and relocation of settlements, etc.) or to plan a completely new settlement on the "green field", (3) and to simulate future scenarios. In the private mode, planning is only possible by editing input data. There are also no scenario calculations available for the private mode.

The results that are calculated are split into four parts:
- Energy consumption of the settlement
- Ecological footprint - Sustainable Process Index (SPI)
- CO_2 life cycle emissions
- Regional economic effects (turnover, value added, jobs, imports)

Figure 3.3 shows the process and options of the ELAS-Calculator in more detail. After selecting either German or English, the user can start the tool. Besides the possibility to choose between the private and the municipal mode, the user can also choose among analysing an already existing settlement or planning a new settlement. After that, data input is necessary, starting with data about (1) the specific location, (2) the buildings, residents, heating and hot water supply, (3) the electricity supply, (4) the municipality (road service, lighting, wastewater treatment, waste collection, etc.) (5) mobility, and (6) the specification of prices/costs for the regional economic analysis. Finally, on the last page, all the results are presented, from which scenario calculations can be carried out. Additionally, the user can switch to the planning mode, in order to redesign or relocate the settlement.

Legend

Status-quo Analysis Input

Exclusive Input for planning mode

Language selection → ELAS Calculator **START**

Selection of **Mode** (Private or Municipal)

Selection of **Analysis** (As-Is/Status-Quo or Planning)

Municipal Mode

- Project title
- As-Is-Analysis/Status-quo analysis or Planning

Private Mode

- Geographic location (Country, District Municipality): manually or through municipality code (Austria only)
- Inhabitants (Municipality and District)
- Level of centrality (1-5) through location details
- Distances (km) to higher degree of centrality

- Input of building groups (Building period, type of building, cumulated living space and number of buildings)
- Refurbishment
- Building area
- Number of households
- Residents and age distribution
- Room heating
- Hot water supply

- Electricity consumption (all building groups)
- Electricity generation (e.g. photovoltaics)
- Electricity provider (e.g. common provider, green electricity provider)

- Distance to town centre
- Municipal road services
- Municipal lighting
- Wastewater treatment
- Municipal waste collection
- Private waste collection

- Modal split for whole household in terms of daily and leisure mobility

- Adjustment of prices for regional economic analysis (Austria only)

Location (Site-specific data)

*

Buildings, Residents, Heating and Hot water

△

Electricity

Municipality

Mobility

Regional Economic Analysis (REA)

- Geographic location (Country, District Municipality): manually or through municipality code (Austria only)
- Inhabitants (Municipality and District)
- Level of centrality (1-5) through location details
- Distances (km) to higher degree of centrality

- Input of building groups (Building period, type of building, cumulated living space and number of buildings)
- Refurbishment
- Building area
- Number of households
- Residents and age distribution
- Room heating
- Hot water supply
- New settlement (no As-Is Analysis present)
- Extension of existing settlement (As-Is Analysis, addition of living space)
- Refurbishment of existing settlement structures

- Electricity consumption (all building groups)
- Electricity generation (e.g. photovoltaics)
- Electricity provider (e.g. common provider, green electricity provider)

- Inner road development
- Outer road development (if outside of town centre)
- Municipal road services
- Municipal lighting
- Wastewater treatment
- Municipal waste collection
- (additional) roads for inner development
- Additional road lighting
- (additional) wastewater grid

- Adjustment of prices for regional economic analysis (Austria only)

- Selection of TREND – or GREEN - Scenario

Starting point for new examples

*

△

Planning option Demolition of settlement and construction at different location

Planning option Refurbishment, extension or reconstruction of settlement

Results

Scenarios

Figure 3.3
Overview of the process and different options of the ELAS-calculator (after Stoeglehner et al. 2014a)

3.3 As-Is-Analysis (Status Quo)

The user can start and analyse an already existing settlement with the help of the As-Is-Analysis (also named Status-quo analysis). The following explanations of the tool are structured based on the online tool (http://www.elas-calculator.eu/?lang=en). Starting the tool, the user is asked to enter data about the following six subject areas:

- *Location (Site-specific data)*
- *Buildings (including space-heating and hot water supply)*
- *Electricity (consumption and production)*
- *Municipal services and infrastructure*
- *Mobility*
- *Regional economic information*

In this section, these six subject areas are described in detail. The data sets and calculations are also presented.

3.3.1 Location (Site-specific data)

In this first step, the user's geographic location is questioned, by using degrees of centrality (also centrality levels). This is essential to survey mobility patterns and mobility behaviour. Each degree offers certain services, functions and facilities. As highlighted in Figure 3.4, high degrees of centrality offer a broad variety of services. By adding site details and specifying the federal state, district and municipality an automatic classification into degree of centrality number 4 and 5 is carried out (only available for Austria). Centrality level 1-3 must be specified with the help of a criteria catalogue. Some processes are automated for Austrian use-cases. For the application of the tool in other countries, additional manual data input is necessary. Austrian settlements are assigned to one of the 2,357 municipalities (Statistik Austria 2010). Using the tool in Austria automatically provides the number of residents for each municipality and district. These numbers are then used for the regional economic analysis (REA), or to allocate the construction of a road to a certain settlement (see Section 3.3.4). A different electricity-mix is also used (EU-27 average) for application outside of Austria.

With the help of a criteria catalogue the user can specify the degree of centrality. An overview over the degrees and according facilities can be found in Figure 3.4. The degrees of centrality are also essential for mobility calculations in a subsequent step (Section 3.3.5).

To sum it up, the required data in this step for further calculations are:

- Information about inhabitants (municipality/city and district)
- Distance to the next higher degree of centrality

The degree of centrality can be changed by the user. For the application outside of Austria, the degree of centrality, number of residents as well as the distance to the next higher degree of centrality must be added manually.

Figure 3.4
Specification of the degrees of centrality, including associated services/functions/facilities (own illustration after Stoeglehner et al. (2011a)

3.3.2 Buildings and residents

In this step, the user adds data about *building structures*, *residents,* as well as *space heating and water supply* of a specific settlement.

Buildings structure
The user must define building groups. Buildings of the same type, period of construction, state of renovation, and heating system form such a group. As soon as one of these characteristics is different for a certain building, a new group must be defined. The following illustration shows six individual buildings, merged to three sample building groups (Figure 3.5).
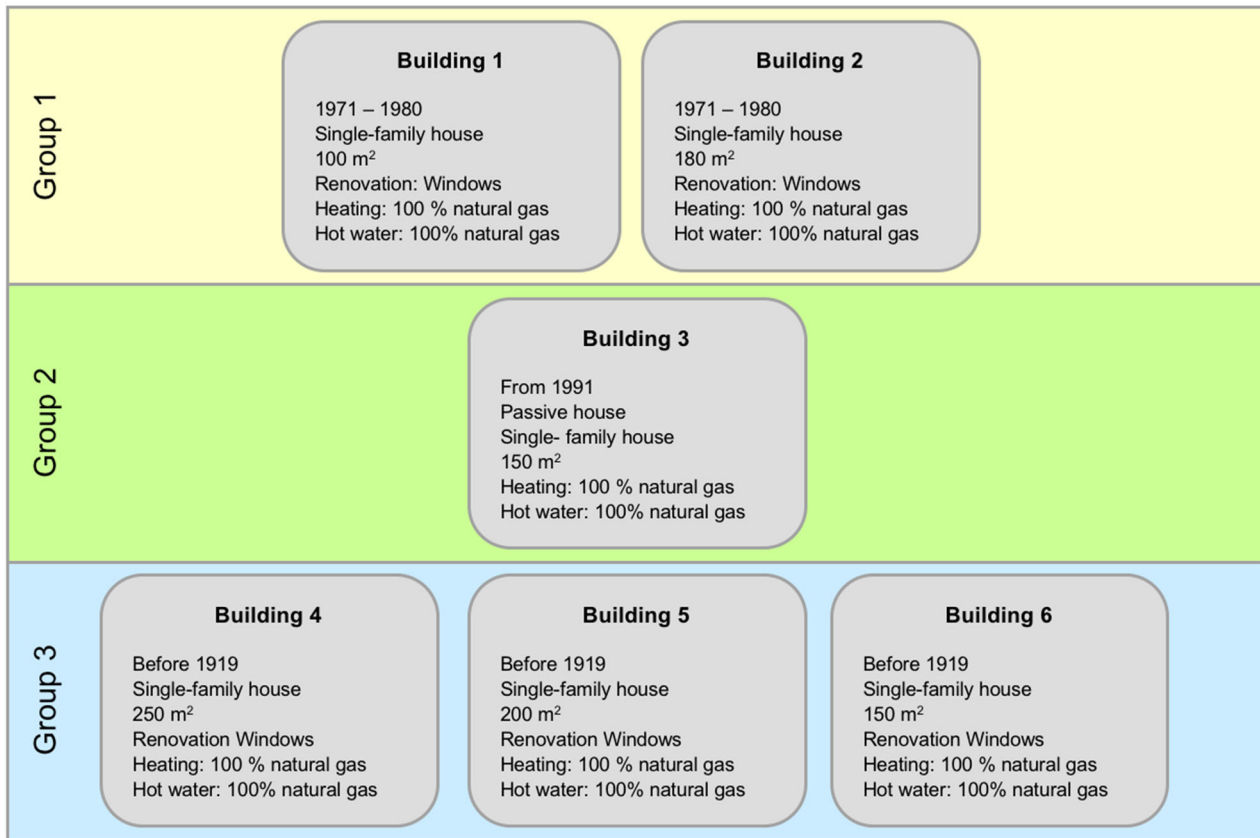
Figure 3.5
Example of three different buildings groups (own illustration after Stoeglehner et al. 2011a)

Concerning the building structure, the following parameters must be added:

- Building period
- Building type: one/two family house, row house, multi-storey building
- Total living space in m^2
- Carried out renovations: windows, exterior wall, basement ceiling and/or attic
- Building standard (starting from building period 1991): new building, low energy house, passive house
- Number of buildings
- Building lot area

The more specific building groups are added, the more individual adaptations can be made in the planning mode. Table 3.1 shows the energy demand for space heating of single-family houses, row houses and multi-storey buildings, split into seven different building periods. For buildings constructed after 1991 the user can choose among three building standards, e.g. Single-family houses: (1) New building – 71 kWh/m^2; (2) Low energy house – 40 kWh/m^2; (3) Passive house – 15 kWh/m^2 (Stoeglehner et al. 2011a).

Table 3.1
Energy demand for space heating [kWh/m²a] (after Jungmeier et al. 1997)

Building period	Single family house	Row house	Multi-storey building
before 1919	132	99	85
1919-1945	137	99	87
1945-1960	162	113	99
1961-1970	131	99	85
1971-1980	134	99	85
1981-1990	91	73	62
from 1991	71	54	51

In case a building has already been renovated, a reduction of energy demand as indicated in Table 3.2 is obtained. If only one or two renovation options are chosen, the percent values are summed up and then used to reduce the overall space heating values of Table 3.1.

Table 3.2
Percentage of different renovation options, used to reduce energy parameters of space heating (after Jungmeier et al. 1997)

Single family house [%]					Row house [%]					Multi-storey building [%]				
Building period	dä1	dä2	w	total	Building period	dä1	dä2	w	total	Building period	dä1	dä2	w	total
before 1919	20	38	6	64	before 1919	20	26	6	52	before 1919	14	26	7	48
1919-1945	14	43	7	64	1919-1945	14	31	6	51	1919-1945	12	35	5	52
1945-1960	12	53	7	72	1945-1960	12	39	7	59	1945-1960	11	43	6	60
1961-1970	12	44	8	64	1961-1970	17	32	11	60	1961-1970	10	33	7	50
1971-1980	20	38	7	65	1971-1980	20	26	6	52	1971-1980	14	32	7	53
1981-1990	8	34	8	51	1981-1990	14	23	8	45	1981-1990	0	19	10	29

dä1 = basement ceiling and/or attic, dä2 = outer walls, w = exchange of windows, total = dä1 + dä2 + window

Residents
In this section, the following data is required:
- Number of households
- Number of residents
- Age groups
  - I (under 15 years),
  - II (15-29 years),
  - III (30-59 years),
  - IV (more than 60 years).

Default values for age groups originate from Statistik Austria (2009a) and may be changed. The number of households is used to calculate the electricity consumption. Respectively the number of residents and age groups are used to analyse mobility behaviour.

Space Heating and Hot Water Supply
After adding data about building groups and residents, the ELAS calculator automatically calculates default values for space heating and hot water supply.

Energy rating describes the annual energy for space heating in kWh/m^2 depending on the building type, period and renovation. *Energy rating* also refers to *energy consumption indicator* or *energy performance indicator*. Depending on the previously added total living space in m^2 the total annual space heating demand (kWh) is subsequently calculated. The total annual hot water demand (kWh) is calculated by multiplying the number of residents with the average annual hot water demand per person (1,000 kWh default value). It is always possible to change the suggested values of the tool. Default values for space heating and hot water demand per person are based on Austrian average statistical values (Jungmeier et al. 1997).

Additionally, the type of heating system can be specified for both space heating and hot water supply. The user can allocate percent values to each technology. The following heating systems can be specified:

- Pellets, wood briquettes
- Wood chips
- Log wood
- Solar thermal
- Heat pump, compact heating unit for passive houses
- Electric heating
- District heating (biomass)
- District heating (e.g. gas, waste incineration, fossil oil)
- Natural gas
- Heating oil
- Hard coal
- Lignite

Finally, the Ecological Footprint - Sustainable Process Index (SPI)[7] is calculated based on the values corresponding to each energy technology (also see Section 3.6.2).

3.3.3 Electricity

This step addresses electricity consumption, domestic electricity production (e.g. PV) as well as the relevant electricity mix.

Electricity demand

Suggested standard values for the electricity demand of households are based on the ELAS survey. Starting point for calculations is the average electricity consumption per household of a family house/row house and a multi-storey building (Table 3.3). The overall electricity demand of the settlement is the result of the number of households multiplied with the respective average electricity demand of each household.

Table 3.3
Average electricity consumption per household in kWh/a (after Stoeglehner et al. 2011a)

Electricity consumption per household (kWh/a)	
Single family house / Row house	Multi-storey building
3,900	2,350

Domestic electricity production

---

[7] The Sustainable Process Index as an ecological footprint is compliant with life cycle analyses described in the EN ISO 14040 (ISO 2006).

The user can specify how many kWh of electricity are annually produced de-centrally from renewable resources within the settlement or at individual buildings. Possible technologies comprise PV, wind power or biogas CHP. If more technologies are used, the total electricity production must be stated. Domestic electricity production reduces the electricity demand and the ecological footprint. For the regional economic analysis (REA) (see section 3.3.6) the feed-in tariffs must be specified.

Electricity mix

Using the private mode, there is the possibility to select either conventional electricity as a resource or eco-electricity. Conventional electricity corresponds with the average electricity mix of Austria. Conventional electricity mix is also used in the municipality mode, if the settlement is in Austria. For any other country, the "EU 27 electricity mix" is used. Table 3.4 presents the composition of each electricity mix. For determining the Sustainable Process Index, the electricity demand values are multiplied with the associated SPI values of the electricity mix.

Table 3.4
Composition of each electricity mix used in the ELAS calculator (after Stoeglehner et al. 2011a)

	Conventional electricity mix [%] (according to IEA 2008)		EU 27 electricity mix [%] (according to IEA 2008)		Eco-electricity mix [%] (according to Ökostrom AG 2009)	
Composition	Hydro power	43.9	Coal	27.9	Hydro power	84.5
	ENTSO-E-Mix	27.55	Nuclear power	27.8	Wind	10.0
	Natural gas	12.1	Natural gas	23.4	Biomass	3.5
	Coal	7.5	Hydro power	10.6	Biogas	1.0
	Biomass	4.6	Wind	3.5	PV	1.0
	Wind	2.2	Oil	3.1		
	Oil	1.3	Biomass	2.3		
	Waste incineration	0.8	Waste incineration	0.9		
	PV	0.03	Geothermal	0.2		
	Biogas etc.	0.02	PV	0.2		
			Biogas etc.	0.07		

3.3.4 Municipal Services and Infrastructure

Query number four of the tool deals with energy consumption of municipal services and municipal infrastructure. Services and infrastructure in question are road networks, road services, street lighting, sewage treatment and waste collection.

Road network

The road network is divided into
- internal development (streets within the respective settlement) and
- external development (if the settlement is located far from the town/city centre).

There is also a differentiation according to responsibilities:
- Municipal roads and
- country roads.

For the calculations of the internal development, the municipal roads are entirely assigned to the corresponding settlement, whereas country roads are not only used by settlement residents. Thus, the number of metres of country roads are divided by the residents of the district and multiplied by the number of residents of the settlement. The sum of municipal roads of the internal development and the proportional meters of country roads, in case of external development are then summed up.

In case the settlement is not located within the town/city centre the user must define the external development first: distance of the settlement to the town/city centre and road type (municipal or country road). The allocation of country roads works the same as previously described. However, the length of municipal roads are divided by the residents of the whole municipality and multiplied by the number of residents of the settlement. The distances that are calculated in the background can be used for calculations of municipal services and for the operation and construction of infrastructure.

Road Services

This section deals with road services that can be allocated to the settlement. It is assumed that road services are carried out with vehicles, and the corresponding energy that is used can be assigned to the settlement. Using the number of tours and the assigned kilometres (as described in the road network section), the total energy consumption can be calculated. The default values for various road services originate from the ELAS survey (Table 3.5).

Table 3.5
Road services and number of trips per year (default-values) (after Stoeglehner et al. 2011a)

Road cleaning	Mowing and trimming	Snow clearance	Sanding	Snow Pole setting	Others
3	4	20	15	2	0

In order to get kWh as the relevant parameter for energy consumption, the number of kilometres are converted into kWh. The kWh values include energy consumption and embodied energy like fuel production. The cumulated energy demand (CED) was used to calculate the energy consumption values. The conversion factors for municipal vehicles (including waste collection vehicles) are shown in Table 3.6. Finally, the SPI values are calculated for both municipal vehicles and waste collection vehicles.

Table 3.6
Conversion factors from km to kWh for municipal vehicles and waste collection vehicles (after Stoeglehner et al. 2011a)

	Conversion factor km -> kWh
Vehicles for municipal services	0.967
Waste collection vehicles	1.241

Street Lighting

One part of municipal services is street lighting. In case there is any street lighting in the settlement, the number of lamps is calculated using the road network (internal development) multiplied by 0.031 lamps/meters of road. The default value for electricity consumption is 268 kWh per lamp and year. Both values were aggregated by the ELAS survey. The corresponding electricity mix is then used to calculate the SPI value.

Sewage Treatment

The annual waste water per person in Austria (128.48 m^3)[8] is used to calculate the total annual waste water of the settlement. Sewage treatment is either performed by a central sewage treatment plant or by a decentralized sewage treatment plant (e.g. reed bed). Depending on the technology, both costs and ecological pressure can vary.

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[8] Data retrieved from http://www.umweltbundesamt.at/umweltschutz/wasser/abwasser: calculated from the total amount of wastewater (1,064 Mio m3/a) and the number of inhabitants (8,281,295) in the year 2006.

When choosing a central sewage treatment plant, another technological differentiation between a two-stage (mechanical, biological) and a three-stage (mechanical, biological, chemical) treatment is provided by the tool. There is also the possibility to specify the length in kilometres of the sewer line between the settlement and the sewage treatment plant and the energy consumption of the sewer pumps (if installed) for the settlement per year in kWh.

Depending on the technology of the sewage treatment plant different SPI calculations are carried out. Electricity consumption per m^3 sewage is estimated with 1.53 kWh. The SPI is again calculated using the respective electricity mix (also for sewer pumps). For decentralized sewage treatment plants, no additional SPI is calculated.

The length (in km) of the sewer line is important for the REA: costs are allocated the same way as presented for the road calculations, since the sewer line is not only used by residents of the settlement (see section 3.3.6).

There is also the possibility that the settlement is not linked to a sewer line. In this case it is assumed that waste water is collected in a cesspit that must be emptied. The calculation of the number of kilometres is based on centrality level 4. Conversion factors (km -> kWh) and SPI values for waste collection vehicles are used.

Waste Collection
In total 8 different fractions that are either collected by a waste disposal company or are collected at disposal points (within walking-distance) can be selected. These fractions are (1) Residual waste, (2) Plastic, (3) Glass, (4) Green waste (tree or lawn clippings), (5) Bio-waste, (6) Used paper, (7) Used metal and (8) Bulky waste.

If a fraction is not selected, it is assumed that the residents dispose the fraction in question at the nearest waste collection point (except fractions that can be composted, like green and bio-waste). It is assumed that residents use their cars twelve times per year to carry their waste to waste collection points (total amount of km multiplied by 2, considering the whole round trip).

The way the waste is collected is also important for the SPI calculations. As mentioned before, in case the waste is disposed by the residents at waste collection points, cars are used for transportation. Otherwise the use of waste collection vehicles is necessary.

For waste collection vehicles, different shipping volumes are used (Table 3.7). It is assumed that each vehicle carries the waste for 20 km until it reaches the waste collection point (again multiplied by 2, considering the whole round trip). Summing up the covered distance for each fraction, results in the overall distance of the waste collection vehicles. The conversion into kWh is again carried out with the factors used in Table 3.6.

Table 3.7
Shipping volumes of waste collection vehicles split into fractions (after Stoeglehner et al. 2011a)

	Residual Waste	Used Paper	Plastic	Used Metal	Bulky Waste	Glas	Tree clipping or lawn clipping	Bio-waste
Tons/trip	7	7	4.15	3.5	4.5	10	7	7

Based on the number of residents of the settlement the total amount of waste for each fraction is calculated. For Austria, each of the 9 federal states show different amounts of waste per fraction and person.

3.3.5 Mobility

The tool requests the annual distance in kilometres travelled by all members of the households older than 15 years. Mobility is divided into three categories:

- Everyday mobility (trips undertaken in everyday life)
- Short breaks (1 to 3 overnight stays) and
- Main vacation (4 or more overnight stays)

Default values for everyday mobility are derived from the ELAS survey, data for vacation mobility is derived from Statistik Austria (2009b). Means of transport that might be of relevance in the future like bio-gas bus, hybrid car, electric vehicle, E85 car, natural gas car or bio-gas car are set to 0 km (default values can be changed).

Everyday mobility

Typical means of transport for everyday mobility are:

- Pedestrian
- Bicycle
- Electric bike
- Train / commuter train
- Tram / Metro
- Bus
- Bio-gas Bus
- Trolley Bus
- Moped / Motor-cycle
- Car
- Hybrid car
- Electric vehicle
- E85 car
- Natural gas car
- Bio-gas car

A total of 75 different modal splits were used for everyday mobility, using 5 different centrality levels, 3 different age groups (age groups 2-4) and 5 different mobility reasons (Trips for: 'Work/School', 'Shopping', 'Children', 'Leisure', 'Doctor's appointment/Public authorities'). For trips within the same centrality level, an average of 1.5 km for each trip was assumed.

In order to get the number of kilometres it was necessary to collect the number of paths for each degree of centrality and age group. The number of paths were gained from the ELAS survey. Additionally, the following assumptions were made:

- School attendance (age > 15) and work are carried out at least in centrality level 4
- Residents of centrality level 1 must get to centrality level 2 for shopping, due to the lack of local supply
- Trips for children and leisure are carried out within the centrality level the residents live in
- Doctor's appointments and trips to government agencies must be carried out at least in centrality level 3
- All residents that live in a centrality level < 5 need to get to centrality level 5 at least once every month (e.g. to visit the opera)

The exact number of person kilometres (pkm) can then be calculated based on the number of residents of each age group summed up across the building groups. The conversion factors into kWh for each means of transport are shown in Table 3.8.

Table 3.8
Conversion factors from pkm to kWh (after Stoeglehner et al. 2011a)

		kWh/pkm
Everyday Mobility	Car	0.436
	Moped/Motor-cycle	0.365
	Tram	0.09
	Bus	0.138
	Trolley bus	0.117
	Train	0.143

Vacation mobility

Compared to everyday mobility there is no differentiation between age groups and centrality levels. Data for vacation mobility was used from Statistik Austria (2009b). Typical means of transport for short breaks and main vacations are:

- Electric bike
- Train / commuter train
- Bus
- Bio-gas Bus
- Car
- Hybrid car
- Electric vehicle
- E85 car
- Natural gas car
- Bio-gas car
- Aircraft
- Ship

For Austria an average of 150 km for short breaks (one direction) and 300 km for main vacation (one direction) were assumed. For distance calculations regarding vacation mobility, the distance calculator[9] was used. Table 3.9 shows the average distances for different vacations and Table 3.10 shows corresponding modal splits.

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[9] Source: http://distancecalculator.globefeed.com/World_Distance_Calculator.asp. Used for distance calculations.

Table 3.9
Distances for short breaks and main vacations (after Stoeglehner et al. 2011a)

Short breaks		
Destination	**Short breaks weighted distance [km]**	**Outward and return journey [km]**
National	150	300
Europe	611	1,222
Worldwide	5,022	10,044
Main vacation		
Destination	**Short breaks weighted distance [km]**	**Outward and return journey [km]**
National	300	600
Europe	916	1,831
Worldwide	5,166	10,332

Table 3.10
Modal splits for vacation mobility (after Stoeglehner et al. 2011a)

	Car [%]	**Train [%]**	**Bus [%]**	**Aircraft [%]**	**Ship [%]**
Short break – National	78.70	16.13	4.62	0.49	0.05
Main vacation - National	83.48	11.97	4.50	0.04	0.00
Short break – Europe+Worldwide	56.71	9.31	14.74	18.88	0.35
Main vacation – Europe+Worldwide	40.85	5.47	8.56	44.65	0.46

3.3.6 Regional Economic Analysis (REA)

The regional economic analysis (REA) calculates economic effects caused by a settlement. Activities related to a settlement like construction, renovation, continuous operation, etc. cause spending (turnovers) that result in economic effects. These economic activities are presented with the help of Input-Output tables (Miller & Blair 2009). For the regionalisation of input-output coefficients national data provided by Eurostat (2007) were used. As an outcome of the REA, regional and national *turn over and value added,* originated *jobs* and induced *imports* are calculated and presented on the "Results" page. In the tool, the user can specify the prices per unit for heating or electricity, municipal services or for mobility. All prices include value-added tax (VAT)and all values correspond to one year. In case a settlement outside of Austria is addressed, the REA is not followed.

Construction, conversion/renovation, demolition
Considering construction, conversion/renovation and demolition, the following spending are included in the REA:

- Road construction (additional roads)
- Construction of municipal infrastructure (sewer, water supply, electricity supply)
- Residential buildings, annex buildings (garages, garden sheds…), swimming pool, design of the site (sealed surfaces, garden, retaining walls …)
- Renovation of residential buildings
- Demolition of residential buildings (assumes the settlement remains, so costs for infrastructure demolition are not included)

Costs are differentiated according to energy standards (low energy house, passive house) and to building types. Spending for planning and approval process (e.g. costs for infrastructure planning etc.) are not considered in the REA. Table 3.11 shows the used data base for the calculations.

Table 3.11
Cost items and the derived data for the calculation of regional economic effects in terms of construction, conversion/renovation and demolition

Cost item	Unit	Price incl. VAT [€]	Data derived from
Living space construction			
Single family house			
Low energy house		1.531	
Passive house		1,631	
Row house	m^2		ILS (2010)
Low energy house		1,267	
Passive house		1,527	
Multi-storey building			
Low energy house		1,240	
Passive house		1,494	
Living space renovation			
From 0 to low energy house	m^2	265	Krojenic et al. (2009)
From 0 to passive house		505	
From low energy h. to passive h.		241	
Living space demolition	m^2	72	Winkler (2010)

Continuous operation and infrastructure

Costs for the operation of residential buildings (electricity costs and heating costs) and infrastructure (costs for road maintenance, snow clearance, street lighting, sewer maintenance, waste collection) are included in the REA. Not included are costs for maintenance and modernisation of residential buildings. An overview on data sources for the calculations can be found in Table 3.12.

Table 3.12
Cost items and the derived data for the calculation of regional economic effects in terms of continuous operation and construction of infrastructure

Cost item	Unit	Price incl. VAT [€]	Data derived from
Living space operation			
Hard coal	t	615.91	Regionalenergie Steiermark (2010a)
Natural gas	m^3	0.8118	Regionalenergie Steiermark (2010b)
Heating oil	m^3	1,143.44	Stoeglehner et al. (2011a)
District heating (fossil)	MWh	74.38	AK Wien (2008)
District heating (biomass)	MWh	103.95	Regionalenergie Steiermark (2010b)
Log wood	stacked m^3 or stere	112.24	AK NÖ (2009)
Solar thermal	MWh	150.94	Solarserver (2010)
Geothermal energy			
Excluding electricity costs	MWh	69.57	Regionalenergie Steiermark (2010b)
Including electricity costs	MWh	112.86	
Electric heating	MWh	37.14	Heizungsfinder (2010)
Excluding electricity costs	MWh	217.14	
Including electricity costs			
Wood chips	m^3 loose material	68.75	Regionalenergie Steiermark (2010b)
Pellets	t	410.58	Regionalenergie Steiermark (2010b)
Electricity – Costs	kWh	0.18	Statistik Austria (2009c)
Electricity – Feed-in tariff	kWh	0.38	Energie-Control GmbH (2011)
Infrastructure construction and operation			
Construction of additional roads	m	525	Braun et al. (2005)

Cost item	Unit	Price incl. VAT [€]	Data derived from
Construction of additional street lighting	piece	2,207	Own calculations
Costs for construction/development (sewer, water supply, electricity supply)	m	400	Amt der Oberösterreichischen Landesregierung (https://www.land-oberoesterreich.gv.at)
Operation street lighting Electricity Maintenance	kWh piece	0.18 27.70	Own calculations
Snow clearance, tree/lawn clipping, road cleaning	m	2.08	Egger (2009)
Road maintenance	m²	1.50	Landesvereinigung Bauwirtschaft Baden-Württemberg (2005)
Sewer operation	m	2.02	BOKU (2009)
Waste disposal	t*km	0.41	MCI (2002)

External effects (mobility)

In view of external effects only mobility is considered in the REA. There is a differentiation between everyday travel and mobility for leisure/vacation. Everyday travel include travel to:

- Workplace
- School/educational provisions
- Shopping,
- Doctor's appointment
- Visits to public authorities
- Travel for child-related needs
- Leisure activities

Mobility for leisure/vacation include:

- Day trips and weekends away
- Holidays and short holidays – mobility costs only.

Table 3.13 highlights the data used for the calculation of external effects.

Table 3.13
Cost items and derived data for the calculation of regional economic effects in terms of mobility

Cost item	Unit	Price incl. VAT [€]	Data derived from
Motorised individual transport	km	0.51	ÖAMTC (https://www.oeamtc.at)
Public transport	km	0.11	ÖBB (https://www.oebb.at/de/
Air travel	km	0.15	Various airlines

3.4 Planning a Settlement

The planning mode is available for users that want to plan a completely new settlement (without an existing As-Is-Analysis) as well as for users that already added data about an existing settlement and are now ready to redesign or remove the settlement (with existing As-Is-Analysis).

With existing As-Is-Analysis

After proceeding to the planning mode, the user is asked whether to redesign the settlement or to completely remove the settlement and place it somewhere else.

In the latter case, demolition of all the building groups is necessary. The user can add data about the new settlement in the same way as described in the As-Is-Analysis. However, the relocation of a settlement creates a so called "ecological backpack". This ecological backpack consists of ecological footprint values (from the Sustainable Process Index, (SPI), explained in detail in section 3.6.2) values derived from the demolition-process and the SPI values of the demolished building groups (Remaining SPI - for buildings that are demolished and have not reached a depreciation period of 66 years). This remaining "backpack" is added to the newly planned buildings.

If the user decides not to relocate the settlement and keep the already existing one, the following planning options arise:

- Expansion of the settlement (adding and modelling buildings as shown in Figure 3.6)
- Insulation of individual building groups (Mineral wool: 2.71 kWh/m^2; XPS-fossil: 5.26 kWh/m^2; Cellulose: 1.33 kWh/m^2)
- Demolition of individual building groups (consideration of ecological backpack: 136.44 kWh/m^2)

Energy and SPI calculations for new buildings are based on a model house. For the physical dimension of this model house, data from Oswald (2003) was used. Energy consumption and transport of construction equipment were calculated based on the ecoinvent database (ecoinvent 2010).

Data for residents, space heating, hot water supply, and additional municipal infrastructure can also be added. On the Result page, two additional categories for "infrastructure expansion" and "building measures" are generated.
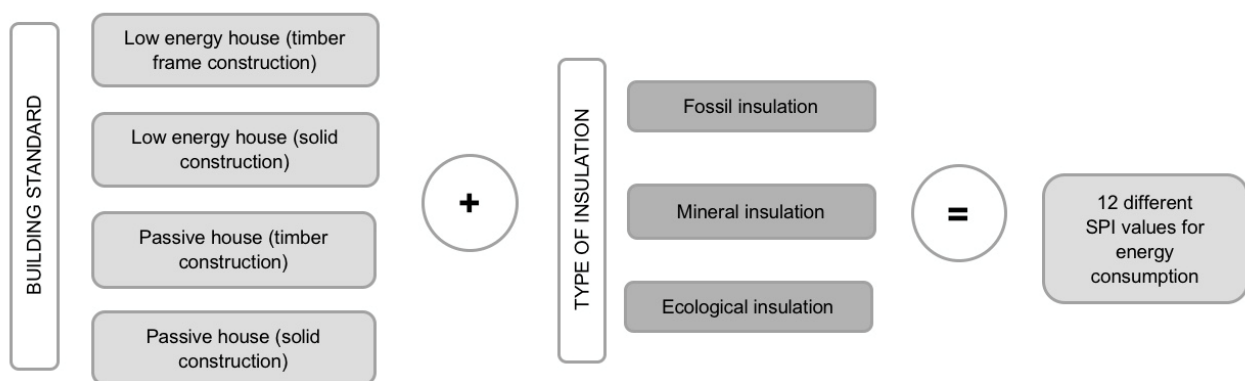
Figure 3.6
Possible configurations of buildings in the planning mode, considering building standard and type of insulation (own illustration after Stoeglehner et al. 2011a)

Without existing As-Is-Analysis

Besides the As-Is-Analysis, the user can start the tool with the basic setting "Plan a new settlement". This mode allows the user to plan a new settlement completely from scratch. A main differentiation between the status-quo analysis and this mode is the starting point of the development. Since new buildings are constructed after the year 2010, only building standards and insulation types as shown in Figure 3.6 are possible. In this mode, the user can also add various municipal infrastructure.

3.5 Scenarios

Scenario calculations show the impacts for the year 2040. The applied *trend scenario* (conservative version based on trend forecasts) and *green-scenario* (optimistic view based on an environmentally conscious society) are briefly described in this section.

Trend-scenario

The following assumptions were made in order to calculate results in terms of electricity and mobility:

- Increasing electricity demand of 2.2% each year (derived from Kratena and Würger 2005)
- Change of electricity-mix (Table 3.14)
- In terms of every-day mobility, the overall number of kilometres will increase by 25 %
- Share of bio-gas cars will increase to 10% and electric cars to 15%

The increasing number of kilometres and the modification of modal splits in the trend-scenario is based on data from Streicher et al. (2010). Numbers from Kommission der Europäischen Gemeinschaften (2007) were used to calculate the share of bio-gas cars.

Table 3.14
Electricity mix for Austria in the Trend-scenario (after Stoeglehner et al. 2011a)

Electricity mix Austria [%] – Trend-scenario								
Hydro power	Biomass	Wind	Other green electricity	Natural gas	Oil	Coal	Other energy sources	Nuclear
49	8	10.9	2.1	19.2	0.6	6.4	0.3	3.5

The electricity mix for other countries is based on assumptions for the EU (VDMA 2010) and is summarised in Table 3.15.

Table 3.15
Electricity mix used in the Trend-scenario for other countries (after VDMA 2010 and Stoeglehner et al. 2011a)

Type of power plant	%	Type of power plant	%	Type of power plant	%
		Brown coal	8	Hydro power	12
		Hard coal	6.5	Wind	23
		Natural gas	12	Solar	5
		Gas decentral	4	Biomass (liquefied)	1.5
		Oil	1	Biogas decentral	2.5
		Diesel decentral	1.5	Other renewables	4
Nuclear total	**19**	**Fossil total**	**33**	**Renewable total**	**48**

Green-scenario

For the green-scenario the following assumptions are made:

- Overall electricity consumption of settlements will decrease by 33%
- 100% green electricity (Electricity mix: 60% hydro power, 30% biomass, 10% wind)
- Increase of total kilometres correspond to the trend-scenario (25%)
- Share of bio-gas cars will increase to 70% and electric cars to 30%
- Bus will operate 100% biogas

The scenarios show the user the scope of future impacts related to the settlement. Depending on the scenario, results are presented accordingly on the "Results" page.

3.6 Results

Four main results are presented by the ELAS tool: (1) Energy consumption, (2) Ecological Footprint (SPI), (3) CO_2 Life Cycle Emissions and (4) Regional Economic Effects. The results that can be found on the "Results" page of the ELAS calculator are briefly described in this section.

3.6.1 Energy Consumption

Results of the energy consumption are presented differently, according to the operation mode of the calculator. After running the calculations, the results are presented in five categories/areas:

- Space heating and hot water supply
- Electricity
- Municipal services
- Mobility (every day)
- Mobility (leisure/vacation)

Electricity consumption, space heating and hot water supply are summarised directly from the user entries. Fuel consumption minus efficiency losses is used to sum up the energy consumption of mobility.

Using the planning mode, the categories *building measures* and *infrastructure expansion* are added on the "Result" page. Embodied energy for the construction, demolition and renovation of buildings/streets/sewers etc. is included. Embodied energy refers to the cumulated energy demand (CED) (Öko-Institut e.V. 1999) and is calculated from the energy consumption of the production chain of products (e.g. bricks). Embodied energy was calculated using the LCA database ecoinvent (ecoinvent 2010).

3.6.2 Ecological Footprint (Sustainable Process Index, SPI®)

There are different types of ecological footprints available. One calculation method is the Sustainable Process Index, SPI® (Krotschek and Narodoslawsky 1996). The SPI transforms all material and energy flows that are necessary, to produce goods or to carry out services, into areas. This usually addresses the production and the use of goods, including relevant emissions. The greater the value of the footprint, the more harmful it is for the environment. Generally, the transformation of material and energy flows is based on two main principles of sustainability:

- Principle 1: Anthropogenic material flows must not alter global cycles of matter. For instance, for the carbon cycle this means that no more fossil carbon can be emitted, than oceans are able to absorb or sediment.

- Principle 2: Anthropogenic material flows must not alter the quality of the local environment. The SPI defines the tolerable dissipation rate of material flows into the local environment.

The overall footprint area consists of 7 partial footprints:
- *Area consumption (e.g. land occupation)*
- *Area for non-renewable material*
- *Area for renewable material*
- *Area for fossil carbon*
- *Area for emission to water*
- *Area for emission to soil*
- *Area for emission to air*

The overall footprint on the result page comprises all activities of the settlement. The basis for the SPI calculations was derived from former projects and from the ecoinvent (2010) database. The results are again divided into the five categories/areas presented in Section 2.5.1.

3.6.3 CO_2 Life Cycle Emissions

The amount of CO_2 emissions can be calculated with the help of the Sustainable Process Index. Since the SPI is split into 7 partial footprints, the CO_2 emissions are derived from the part "Area for fossil carbon". With the help of this partial footprint, the CO_2 emissions can be calculated. Furthermore, the natural carbon cycle serves as a basis for the calculations. The ocean sea bed is the only permanent CO_2 sink, since the overall carbon balance of biomass is balanced (emitted CO_2 during combustion of biomass is later fixed during the process of biomass accumulation). Based on the sedimentation rate of the ocean bed ($500 \ m^2/kg*a$) the total emitted amount of CO_2 per year can be evaluated. Moreover, the term "lifecycle emissions" contains CO_2 emissions for the whole life cycle of products (e.g. insulation, fuel, etc.) and are relevant in a global perspective. The results are presented in the five categories/areas mentioned in Section 3.6.1.

3.6.4 Regional Economic Effects

Settlements are regional economic factors. A regional economic analysis (REA) presents economic effects, particularly related to energy consumption caused by settlements. Results of the REA are turn over, value added, imports and jobs. They are presented for Austria and for the respective federal states where the settlement is located.

- Turnovers represent the sum of all net turnovers in euros per year and are presented for the relevant category/area.
- Value added is triggered by all activities of the settlement. It is presented in euros per year for the relevant category/area. Domestic added value is of special significance.
- Imports comprise the sum of all imports needed for the supply of goods and services in euros per year for the relevant category/area.
- Jobs represent the sum of all jobs created or secured in full time equivalents per year for the relevant category/area.

A detailed presentation of the results can be found in the calculation example (see Annex A).

3.7 Discussion and Outlook

The ELAS-calculator is a freely available online tool that is capable of analysing, modifying and optimising whole settlements or single buildings, by linking energy demand, energy supply, siting of settlement structures, and mobility (Stoeglehner et al. 2016).

From an energetic point of view a couple of issues arise when dealing with settlements. Depending on the construction and operation of buildings, energy consumption can vary vastly. One important aspect is embodied energy associated with buildings and municipal infrastructure. Also, the location of settlements has a huge impact on energy consumption. The location of a settlement affects energy consumption for infrastructure (e.g. sewer lines, road construction), while also influencing mobility of residents. Finally, longevity of buildings is another aspect to consider (Stoeglehner et al. 2014a). To address these challenges and more, the ELAS calculator was developed.

The tool can be used to check compliance with energy policies, encourage energy saving, foster energy efficiency and encourage use of renewable energy sources. Additionally, Stoeglehner et al. (2014a) and Stoeglehner et al. (2011a) characterise certain target groups and fields of application:

- Target group 1 - **Legal bodies**: Contribution to international and national energy policies and climate protection targets; Prevention of scattered settlements, Support for integrated spatial and energy planning; Improvements/adaptions of land policy, building codes and housing subsidies etc.
- Target group 2 – **Decision makers and planners**: Comparison of different settlement locations; Iterative optimisation of settlement locations and settlement arrangements; Improving spatial planning (land use plans, master plans, zoning plans etc.); Legitimation of planning decisions; Supporting strategic environmental assessments (SEA)
- Target group 3 - **Developers**: Estimation of energy demand and environmental impacts as well as site and design optimisations; Comparison of site alternatives; Assessment of renovation benefits; Marketing purposes
- Target group 4 - **Private individuals**: Information about different locations, insulation types, heating devices, etc.; Comparison of different building types, dwelling size; Assessment of ecological footprint; Consequences of the choice of energy provision; Estimation of long-term energy spending

Except for private individuals, the municipal mode of the tool is the more favourable option.

Another interesting field of application is the support of decision makers throughout planning processes. According to Stoeglehner et al (2014a) the tool is capable of covering the following situations in planning processes: (1) The user can compare different sites by using the same type of settlement; (2) After the decision for a certain site, it is possible to compare different settlement variants (e.g. various densities and dimensions of a settlement, different energy efficiencies, different energy sources or ways of on-site energy production); (3) The user can also compare options of renovation, re-densification or can analyse possible outcomes of a settlement expansion.

The calculations are based on statistical data and data derived from the ELAS-survey, conducted at the beginning of the project. However, in addition to the provided data, estimations and assumptions based on questionnaires, studies and statistics were necessary in order to create the underlying model. Although a probability of error cannot be provided, the assumptions for the calculations are transparent. Additionally, the default values in the ELAS application can be changed by the user, to avoid errors and to calculate in-depths results for different application areas (Stoeglehner et al. 2016). The ability to easily modify the default values is important, since two different modes of the calculator are available (private and municipal) and various target groups are addressed.

Embedding current statistical data is a way to adapt, improve, and revise the model. In Austria, the recent national mobility report BMVIT (2016) is available and could serve as a possible new database for mobility calculations. The study includes data about mobility behaviour, modal splits, historical and future developments, etc. Additionally, new data about population, labour market, commuters, etc. (Statistik Austria 2015) is available and could be included in the model. Further improvements like the integration of mix of function is suggested. For a holistic approach, not only housing, but also industrial and commercial areas should be considered. After Stoeglehner et al. (2011b) preferable tools integrate steering elements of spatial and energy planning like *mix of function*, *density*, *siting* and *choice of resource*. A detailed list and description of various tools for integrated spatial and energy planning can be found in Stoeglehner et al. (2014b). The set of different tools can be used as inspiration for new developments and research projects.

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4 Relevant tools available in Austria

4.1 Integrated spatial and energy planning tools

Spatial planning plays a major role in the energy transition, since energy consumption and the provision of renewable energy depend considerably on spatial patterns (Stoeglehner et al. 2014a). According to Stoeglehner et al. (2011a) two main aspects of integrated spatial and energy planning are essential: (1) Reduction of energy consumption (e.g. efficient energy supply, reduction of traffic volume) and (2) support of renewable energy use (e.g. keeping free space for renewable energy production). With that in mind, it is crucial to include energy related aspects in spatial planning. One way to support decisions in spatial planning is to use tools that reflect system elements and are able to steer the system of spatial planning and energy supply (Stoeglehner et al. 2011a). These system elements represent a mix of functions, density, siting, and choice of resources.

In this context, tools should be capable of e.g. calculating energy demand, creating forecasts, or reflecting on outcomes of planning decisions. The term "tool" is used as a synonym for calculators, matrices, checklists in the form of excel sheets, webtools, etc. This summary is based on the work of Stoeglehner et al. (2014a). In the study, a total of 160 tools were collected, from which 20 were selected for an in-depth analysis. For the in-depth investigation, only tools covering the following topics or characteristics were selected:
- Energy saving, energy efficiency
- Renewable energy sources
- Reference to spatial planning
- Reference to mobility
- Assessment and optimisation of planning projects

The selected tools had to refer to either spatial planning or mobility and address at least one other topic. Furthermore, tools should convey a systematic perspective. Additionally, the tools had to be freely available and free of charge. Tools were not included if the model or the approach was not traceable or documented. After selecting the 20 tools, they were tested with the help of a model settlement. The model settlement consists of multiple building groups and a specification of public infrastructure (see Figure 4.1). With the help of the model settlement, input parameters for the tool application were generated.

Settlement size
Length: 99 m
Width: 89 m
Area: 8717 m^2

Roads
Road width: 8,5 m
Exploitation length: 179 m
Exploitation area: 1517 m^2
Distance to town centre: 300 m

Multistorey building
Living area: 2400 m^2
Number of dwelling units: 24

Row houses
Living area: 900 m2
Number of dwelling units: 6

Single family houses
Living area: 540 m2
Number of dwelling units: 3

Figure 4.1
Characteristics of the model settlement used for the tool application (after Stoeglehner et al. 2014a)

A detailed list of tools can be found in the following section (4.2). The aim of this summary is to highlight and summarise results from the tool application in integrated spatial and energy planning (Stoeglehner et al. 2014a).

4.2 A comparison of different tools

The tools selected (Table 4.1) were analysed and compared regarding their fields of application and their achievable results in Stoeglehner et al. (2014a). The comparison of the tools was carried out, with the help of the data used in the model settlement - presented in the previous section.

In total four fields of applications were detected. The user can apply the tool to either (1) carry out a status analysis, (2) use it for planning, (3) develop scenarios and compare alternatives or (4) to rate possible alternatives.

Table 4.1
Comparison of 20 tools, concerning fields of application and achievable results (after Stoeglehner et al. 2014a).

No	Tools	Status analysis	Planning	Scenario development and comparison of alternatives	Rating	Buildings & site quality	Embodied energy	Energy demand	Renewable energy source	Mobility	Technical infrastructure	Social infrastructure	Waste	Costs	Socio-economic assessment	Environmental assessment	Time horizon	Overall assessment
1	ELAS	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓
2	Grauer Energierechner (zersiedelt.at)	✓				✓	✓	✓			✓						✓	✓
3	Checkliste für energieoptimierte Planungsprozesse	✓	✓	✓	✓	✓		✓	✓	✓	✓		✓			✓		✓
4	Checkliste zur Nach-haltigkeitsbewertung Wohnbau		✓			✓		✓	✓	✓	✓	✓	✓			✓		✓
5	e5-Maßnahmenkatalog	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓			✓	✓	✓
6	EFES	✓	✓		✓			✓	✓	✓								
7	Energieausweis 2.0	✓	✓	✓	✓	✓		✓			✓	✓		✓		✓		✓
8	Energiebaukasten	✓		✓				✓	✓	✓				✓			✓	
9	Energiespar Gemeinde	✓	✓	✓	✓			✓						✓		✓		✓
10	Energiezonenplanung		✓	✓				✓	✓		✓				✓			
11	KlimaCheck	✓	✓		✓				✓	✓								✓
12	MAI	✓	✓	✓							✓			✓		✓	✓	✓
13	MOR€CO Haushaltsrechner	✓	✓	✓		✓				✓				✓			✓	
14	MOR€CO Siedlungsrechner	✓	✓			✓				✓		✓				✓		
15	NIKK		✓	✓		✓					✓	✓		✓	✓		✓	✓
16	PVGis	✓	✓						✓									
17	RegiOpt	✓	✓	✓	✓										✓	✓		✓
18	RESYS	✓	✓	✓	✓			✓	✓	✓	✓		✓	✓		✓	✓	✓
19	Solarkataster	✓	✓						✓									
20	TQB	✓	✓		✓	✓		✓	✓	✓	✓	✓	✓			✓		✓

In terms of results that can be achieved, a total of 13 different categories were distinguished. Tools can deliver results about:

1) buildings & site quality
2) embodied energy
3) energy demand
4) renewable energy sources
5) mobility
6) technical infrastructure
7) social infrastructure
8) waste
9) costs
10) socio-economic assessment
11) environmental assessment
12) time horizons and finally tools may provide
13) an overall assessment.

All categories of achievable results were derived from output parameters given by the tools.

To get a better understanding about the achievable results, some examples from the tool analysis are presented:

- Mobility includes e.g. energy demand and/or costs associated with mobility.
- Environmental assessment includes e.g. the calculation of ecological footprints or CO_2 lifecycle emissions.
- Energy demand and Renewable energy sources respectively deliver results about primary energy demand, potentials for renewable energy sources, energy ratings of buildings, overall energy demand of settlements, etc.

Tools like the ELAS-calculator may also be used in various decision-making processes. The ELAS-tool can support decisions concerning energetic analysis, renovation of settlements, site comparisons, settlement extensions, embodied energy calculations, etc. Thus, multiple possibilities to support decision making processes arise, depending on the chosen tool (see Table 4.2). Tools can also be assigned to different spatial scales. Few tools function at a regional scale, while others consider municipalities or parts of municipalities. Many tools consider settlements and some aim for single sites or single objects.

Table 4.2
Comparison of tested tools in terms of spatial scale and decision-making situation (after Stoeglehner et al. 2014a)

Spatial scale	Decision-making situation	Tool
Regions	Analysis of regional energy systems	RegiOpt, RESYS
Municipalities	Energetic status-quo analysis of a municipality	Energiebaukasten, Energiespargemeinde, RESYS
	Assessment of grid-bound heat supply system	Energiezonenplanung, RESYS
	Status-quo analysis of climate protection activities	KlimaCheck
	Analysis of local energy systems	RegiOpt, RESYS
	Assessment of existing and/or planned energy relevant measures	e5
Settlements	Assessment of existing/planned settlements, concerning energy efficiency	EFES
	Energetic analysis of settlements (Planned and existing)	EAS, Energieausweis 2.0
	Refurbishment of settlements vs. demolition and reconstruction	ELAS
	Site comparison concerning mobility	EFES, ELAS, MOR€CO-Siedlungsrechner, Energieausweis 2.0
	Internal and external settlement expansion (brownfield & greenfield development)	EFS, ELAS, MOR€CO-Siedlungsrechner Energieausweis 2.0
	Demolition and reconstruction at different site	ELAS
	Assessment of grid-bound heat supply system	Energiezonenplanung
	Estimation of infrastructure costs of settlement extensions	NIKK
Single sites / Single objects	Sustainability assessment of buildings/sites	Checkliste zur Nachhaltigkeitsbewertung Wohnbau, Stadt Salzburg
	Energetic status-quo analysis of buildings	Energiebaukasten, Energiespargemeinde, ELAS
	Calculation of embodied energy for construction, operation and maintenance of buildings and infrastructure	Grauer Energierechner, ELAS
	Site comparison concerning housing and mobility	MAI, MOR€CO-Haushaltsrechner
	Assessment of solar potential	PVGis, Solarkataster
	Analysis of existing/planned buildings concerning site & economic, energy & supply, site comparison concerning mobility & CO_2 emissions, resource efficiency	TQB
Universal	Energitical optimization of planning in spatial planning and energy supply respectively	Checkliste für energieoptimierte Planungsprozesse

Another differentiation is the tool complexity and the level of detail. Some only need minimal input data to present a rough estimate of the situation (e.g. NIKK). Others require a lot of detailed information, and consequently also require appropriate skills from the user (e.g. EFES).

For NIKK (tool 15 in Table 4.1), Energieausweis 2.0 (tool 7), RESYS (tool 18) and Grauer Energierechner (tool 2; grey energy calculator), a more detailed description of characteristics is given in Annex B. For more information on the Zersiedelt embodied (grey) energy calculator and the ELAS calculator, see Chapters 2 and 3 of this report.

4.3 Experiences and steps of the tool application

This section reveals experiences concerning the application of 20 different tools for integrated spatial and energy planning. For a better understanding, this section is divided into three steps: (1) Familiarisation phase, (2) Parameter input, (3) Interpretation of results (also see Figure 4.2).
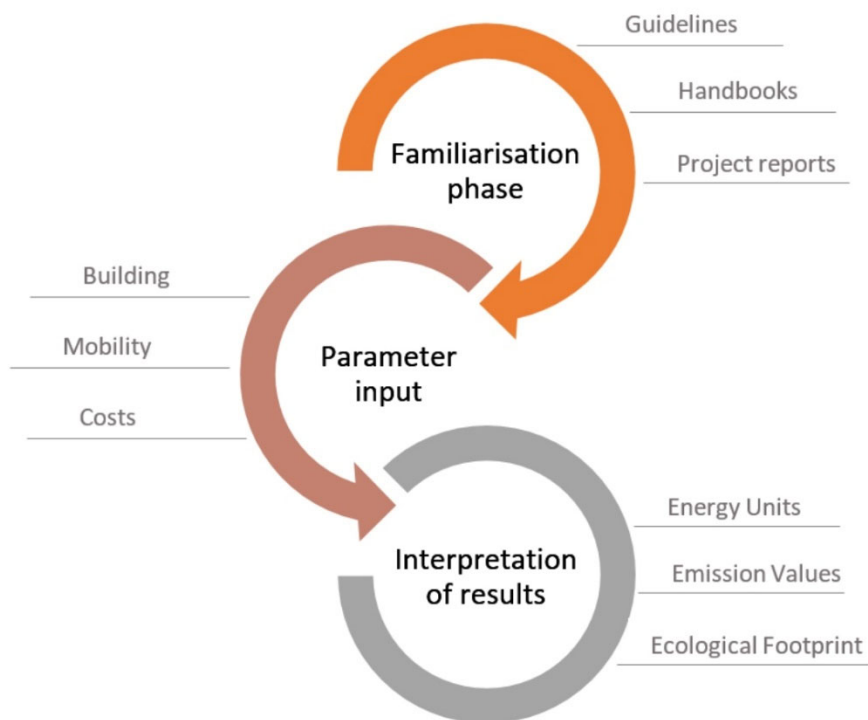
Figure 4.2
Three steps to summarise the experiences of tool application (own illustration after Stoeglehner et al. 2014a).

4.3.1 Familiarisation phase

During the first step, it is important to familiarise the user with the chosen tool. Documents like guidelines, handbooks or project reports help the user to understand data requirements and familiarise with the user interface of the tool. Depending on the complexity of the tool, it should be noted that this first step takes a couple of hours of reading and testing.

For the Austrian analysis, documents provided by the developers of the tools were used. Depending again on the tool, it is possible that no supporting documents are available. In this case the lack of support must be compensated by testing the functionalities of the given tool. A necessity for the tool application is the ability to install programmes and to work with Excel-sheets. Another basic requirement is a stable internet connection for running certain tools online.

4.3.2 Parameter input

The next step, after installing and starting the tool, is to enter parameters. For Austria, the applied parameters were derived from the model settlement defined in Section 4.1. Feeding the tool with data is the most time-consuming step. Each tool needs very specific information about e.g. buildings types, mobility behaviour or costs for energy supply. Some tools automatically suggest statistically derived parameters (default-values) that can be adapted if more specific data is available. Suggested default-values are often derived from regional or local analyses. Depending on the application, these parameters may not be helpful in an international context. For example, the ELAS calculator uses suggested parameters derived from settlement analysis in Austria (see Stoeglehner et al. 2011b).

Replacing default values with specific and detailed data input by the user leads to more detailed calculations and a result closer to reality. On the contrary, it is not a necessity that tools that require a lot of data to calculate the best results. Therefore, sometimes tools that only need little data are the most relevant ones for users. Another important aspect is that users must understand the parameters they are working with and what kind of data they need to put into the tool. Comments and background information about the required data, provided by the developers, simplify the whole process of parameter input.

4.3.3 Interpretation of results

The final step addresses the interpretation of results. An essential part of understanding the results is the traceability of calculations. Likewise, traceability of the interconnection between parameters and the weighting of parameters is essential. Only when traceability is given can results be fully understood, possible errors detected, and the user can continue with further analysis.

Another crucial part is the presentation of results. Some tools use different techniques like benchmarking or ratings. Other tools use variant comparisons or optimization methods. The most common way of presenting results is by using energy units, emission values, ecological footprints or simple data output in monetary form. At this stage it is recommended to read supporting documents and literature in order to properly interpret the results presented by the tools. It is important to realize that tools are only capable of presenting results, while the interpretation of results must be carried out by the users themselves. Tools are therefore a good complement to skilled personnel in the decision-making processes.

4.4 Conclusions for the tool application in integrated spatial and energy planning

There are many tools with different possibilities and limits of tool application that can be used for spatial and energy planning. Tools that can model complex systems are especially noteworthy. Hence, the following subsections (4.4.1-4.4.8) present seven conclusions that can be drawn from the application of 20 tools in Austria.

4.4.1 Spatial scale

As shown in Table 4.2, tools can be applied for different spatial scales, from whole regions to single sites and objects. On the regional level only few tools are available, whereas tools considering single sites and buildings are more common. A possible explanation for the lack of tools on the regional level is the complexity of regional connections. Hence, the development of these tools constitutes a huge challenge for researchers. However, future investigations and tool development on this level is suggested, also to support authorities in planning processes.

4.4.2 Residential function as a starting point

The starting point for the development of most tools is the residential function. For instance, when examining mobility, tools use housing as a starting point to compute modal splits or to calculate distances, routes, energy consumption etc. Mix of function is addressed in terms of mobility assessment, based on the residential function.

However, there are only few tools available addressing industry, commercial areas or shopping. The relation between energy demand and density is presented by all relevant tools. Although density is an important steering element for spatial and energy planning, high densities might lead to a reduced perception of quality of life. Regarding resources, some tools assess the potential of renewable energy sources. Others show consequences of using certain energy sources by calculating ecological footprints, CO_2 emissions or deduce regional economic effects.

4.4.3 Tools support planning through learning processes

Most tools not only allow a status-quo analysis, but also support the user to further evaluate and assess planning decisions. Additionally, depending on the usability of the tool, some fulfil the expectation to deliver quantitative facts and can thus be used to support planning and learning processes, as shown in Figure 4.3 (derived from Argyris 1993; Innes and Booher 2000; Stoeglehner 2010; Stoeglehner et al. 2016). The illustration shows a planning process in three main steps: (1) visions and objectives representing the value base of the undertaking, (2) action plans including concrete measures and activities and finally (3) anticipated impacts as results. During a typical planning process, action plans and measures are derived from visions and objectives. Thereupon anticipated impacts of preliminary plans are evaluated. In case the anticipated impacts are not acceptable it is possible to optimise action plans and measures until tolerable impacts can be achieved (Single loop). This can be done by changing site properties or technological characteristics, etc. If this optimisation does not deliver the desired impacts, the visions and objectives (value base) must be altered (Double loop). If the second loop is applied, the value base is changed, and additional action plans and measures can develop, preferably leading to acceptable impacts. To sum it up, tools may support double loop learning and contribute to qualitative planning decisions in terms of energy related aspects.
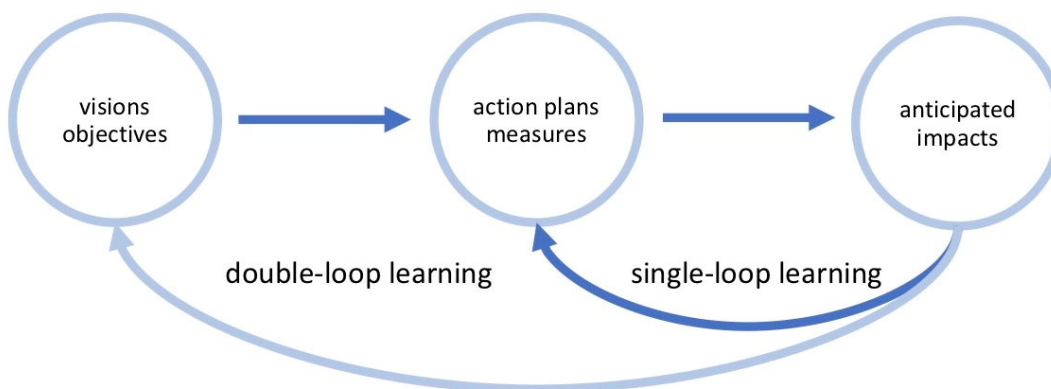

Figure 4.3
Single- and double-loop learning (own illustration after Argyris 1993; Innes and Booher 2000; Stoeglehner 2010, Stoeglehner et al. 2016)

In addition, the supply of quantitative results calculated by tools – concerning energy consumption, potentials of renewable energy sources, CO_2 emissions, ecological footprint, or economic data about infrastructure costs, regional economic effects, and effects on the job market – support learning processes and awareness raising. Spatial dimensions can be linked with energy consumption, energy saving potentials, and provision of renewable energy sources, as well as with environmental and socioeconomic consequences. Thus, not only factual knowledge can be improved, but also the values that drive decisions can be questioned, reflected, and adapted in terms of energy efficient planning.
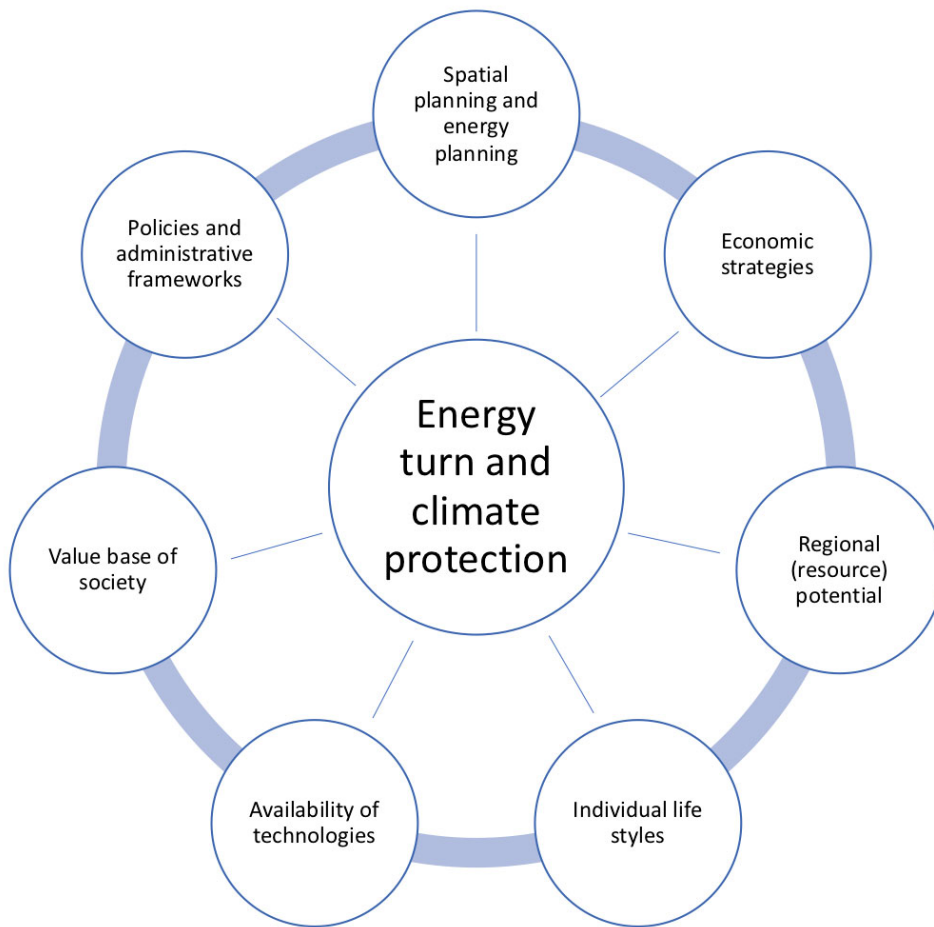
Figure 4.4
Energy turn/transition and climate protection in a holistic view (after Stoeglehner et al. 2014b).

The energy transition and climate protection must be seen in a holistic way. Besides spatial (and energy) planning there are various other influencing factors, like the value base of society, various policies and administrative frameworks (e.g. subsidies), economic strategies, resource potentials, individual life styles, and the availability of technologies (Figure 4.4). For community-based planning processes all of these factors should be integrated in order to develop concepts, objectives, and action plans. With the help of tools these factors can be understood, reflected, and integrated in decisions for both planning processes and everyday activities. To sum it up, tools may widen the factual knowledge and are able to support learning processes and provide additional legitimacy in planning processes.

4.4.4 Combining different tools

A combination of different tools for integrated spatial and energy planning is possible. Some tools work on a system level, whereas others operate on a very detailed level. It can thus be suggested that during a planning process, parameters generated by detail-oriented tools can be used as input parameters for tools on the system level. Hence a sequence of tool applications might be useful.

4.4.5 Ratings and benchmarking

Some tools use ratings or benchmarking to compare alternatives. Unfortunately, these comparisons are prone to misinterpretations. Looking once again at the relation between energy demand and density, one could argue that high density results in higher energy efficiency. If the rating only considers energy efficiency, the densest

structures are highlighted. The problem is that high densities might lead to a loss in quality of life. Therefore, a meaningful rating should consider many factors that go far beyond e.g. energy efficiency. As a result, users should be aware of this problem and be careful when dealing with ratings or benchmarking.

4.4.6 Tools are never congruent

In general tools do not compute "wrong" results. However, if a user wants to calculate for instance the energy demand of a settlement, each tool will deliver different results. Each tool sets different system boundaries and covers different aspects. In other words, every tool is based on a different model and calculates with a different database. Despite these different methodological approaches, the tested tools calculated similar results throughout the application in Austria. This was especially true for mobility or heat demand of buildings, whereas results for embodied energy varied vastly. It can be concluded that a comparison of different planning options is not acceptable, if the options were calculated with different tools. For planning processes, it is essential to agree on certain tools and to stick with the selected ones. In this context, it is important to know the underlying methods and system boundaries, in order to choose the one most likely to meet the users' needs.

4.4.7 Required knowledge of the user

It is crucial for users to understand the underlying principles of the model associated with the respective tool. Correspondingly strengths and weaknesses of the tool should be known, in order to appropriately apply the tool in the planning process and for decision-makers to choose the best planning alternative.

4.4.8 Concluding remarks

Numerous planning tools for integrated spatial and energy planning are available and are qualified to support decisions-makers in various ways. According to Stoeglehner et al. (2016) tools (1) help to understand basic system interrelations of integrated spatial and energy planning, (2) support double loop learning, (2) and lead to more sustainable decisions on local and regional levels. Hence, energy efficient spatial structures can be promoted by reducing energy consumption and optimising energy supply. Furthermore, the quality of planning processes can be improved with regard to contents and by supporting communication and participation.

Due to the application of tools, a lot of knowledge and experience is already available that has yet to be integrated and realised in planning processes. Planners are now challenged to use this knowledge in order to foster and advance the energy transition.

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5 Relevant tools available in Nordic countries

This chapter presents a summary of relevant tools that have been developed or used in Norway and other Nordic countries.

5.1 Examples of tools available for buildings

5.1.1 Introduction

Operational energy use has traditionally been identified as the main contributor to GHG emissions in buildings. However, due to stricter energy requirements and improving energy efficiency, the relative share of life-cycle emissions is shifting from operational to embodied. This trend is even more pronounced in low-energy buildings – where the changing share of emissions can be due to the lower absolute operational energy consumption, as well as an increasing amount of embodied emissions from the use of advanced materials, and higher quantities of materials (e.g. increased insulation). Consequently, there is a growing interest in addressing embodied emissions. Life cycle assessment (LCA) is a robust and accepted method to evaluate a building's life-cycle impact. The LCA results are often normalized by a floor area metric and by lifetime, to get comparable results.

The credibility of LCA results relies mainly on the quality of the underlying data, which can be found in established life-cycle inventory (LCI) databases accessible through LCA modelling tools. Table 5.1 summarizes examples of data sources commonly used in Norway.

Table 5.1 Data sources

Database	Website
Generic LCI databases	
Ecoinvent	Link
European Life Cycle Database (ELCD)	Link
GaBi	Link
Global LCA Data Access (GLAD)	Link
Generic LCA databases for the construction sector	
Ökobau.dat	Link
EPD databases	
EPD Norge	Link to published EPD Link to digital EPD
The international EPD system	Link
IBU	Link to published EPD Link to digital EPD
PEP Ecopassport	Link

In Norway, several analyses (including operational energy, embodied energy and emission) of buildings have been performed in accordance with international and national standards to increase transparency and comparability. Below is an overview of core national and international standards that are in use today to evaluate buildings.

- Byggteknisk forskrift -TEK 17/ Regulations on technical requirements for construction works
- NS 3457-3: 2013. Klassifikasjon av byggverk. Del 3 Bygningstyper /Classification of Construction Works – Part 3 Building Types
- NS 3451: 2009: Bygningsdelstabell / Table of Building Elements

- EN 15978: 2011 Sustainability of Construction Works – Assessment of Environmental Performance of Buildings – Calculation Method
- NS 3720: 2018 Metode for klimagassberegninger for bygninger / Method for Greenhouse Gas Calculations for Buildings
- EN 16258: 2012. Methodology for calculation and declaration of energy consumption and GHG emissions of transport services (freight and passengers).
- EN 15804:2012+A1:2013. Sustainability of construction works Environmental product declarations Core for the product category of construction products.
- SN/TS 3031: 2007. Calculation of energy performance of buildings - Method and data
- NS 3701:2012 Kriterier for passivhus og lavenergibygninger – Yrkesbygninger/ Criteria for passive houses and low energy buildings - Non-residential buildings
- NS 3700:2013 Kriterier for passivhus og lavenergibygninger – Boligbygninger /Criteria for passive houses and low energy buildings - Residential buildings
- ISO 52000: 2017. Energy performance of buildings - Overarching EPB assessment - Part 1: General framework and procedures. NS 3454: 2013. Livssykluskostnader for byggverk - Prinsipper og klassifikasjon / Life cycle costs for construction works - Principles and classification.

Examples of commonly used tools to evaluate buildings in Norway is summarized under Chapter 5.1.2.

5.1.2 Examples from Norway

klimagassregnskap.no (KGR): is a web based Norwegian tool developed by Civitas together with Statsbygg. The tool is used to calculate the GHG emissions from both new or existing building projects during early planning phase and design/construction phases (see Figure 5.1).
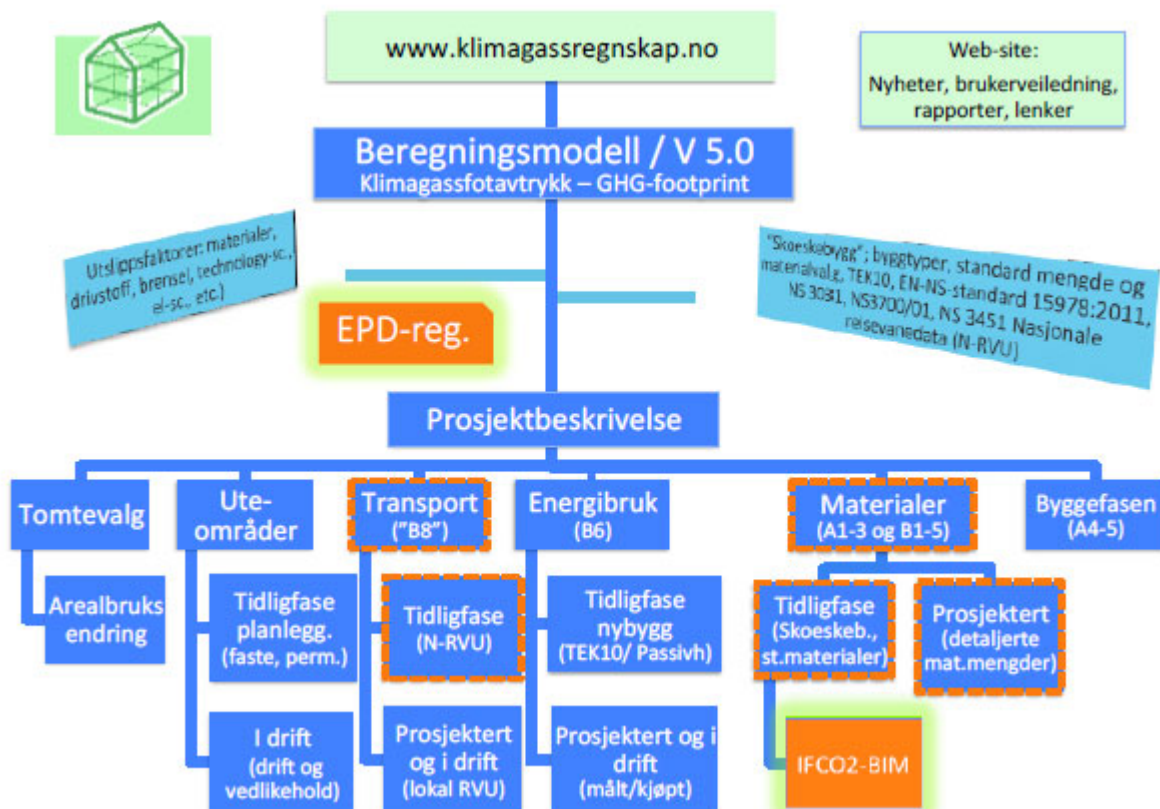

Figure 5.1
An overview of modules and databases in KGR version 5 (Civitas & Statsbygg 2014).

In the general project Module, the user specifies the goal of the project, the main characteristics of the building (e.g. building category, heated floor area, number of users, location) and the system boundaries (Figure 5.2).

Figure 5.2
Example of project description, goal, system boundary and compulsory project data (Civitas & Statsbygg 2014)

The operational modules includes:

o *Materials*: GHG emissions from the basic materials used in building components are calculated based on the material quantities and the emission factors from the production (A1-A3 life cycle modules) and replacement of materials (B2-B5 life cycle modules). The designed solution submodule requires relatively detailed material quantity data whilst the early-phase module requires only data on building function, heated floor area, and geometry. In the early-phase module, the quantities of materials are calculated based on around 50 model reference buildings obtained in KGR tool. The emission factors used for material data are cradle-to-gate (A1-A3). The GHG emission results can be presented in $kgCO_{2eq}/m^2/yr$ of heated floor area of individual building components as well as in comparison with reference buildings (e.g TEK 10 and Passive house, see Figure 5.3).
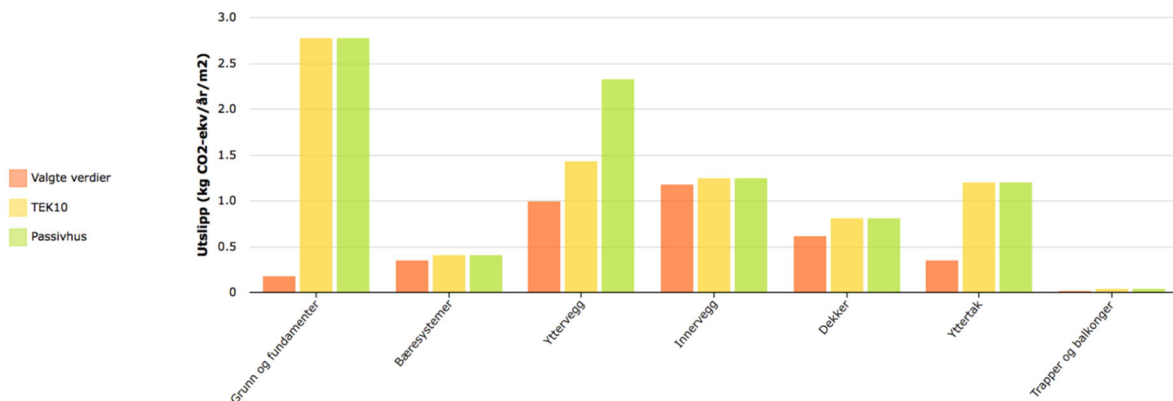
Figure 5.3
Examples of GHG emission results in the early phase material module (Civitas and Statsbygg 2014)

o **Construction module**: calculates the GHG emissions from transport, construction machinery and stationary energy use during the construction period of the building. The input to the construction module includes description of transport in/out of the construction site (e.g. number of journey and average distance per vehicle type, percentage of trips under/over 50km/h and fuel used), quantity and type of fuel used by the construction machinery and quantity of fuel/electricity used for stationary energy use.

o **Energy use**: GHG emissions are linked to energy needs in the building, the level of technology and the source of supply energy. There are two modules to calculate GHG emissions from energy use: "new building module" and "existing building module". The GHG gas emissions are calculated based on the energy need for heating, cooling and electricity specific energy need and the building planned energy supply (Figure 5.4).
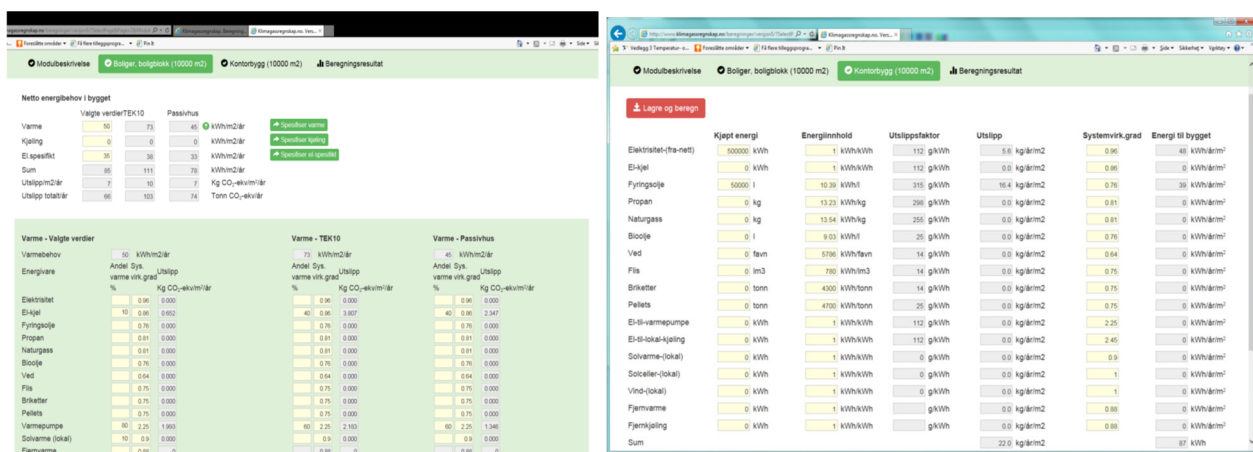
Figure 5.4
Example of input data for energy use module: new building (left) and existing building (right) (Civitas & Statsbygg 2014)

o **Transport in use phase**: The GHG emissions from the transportation module are calculated from the transportation of people and goods during the use phase of the building. The module combines the number of building users, their daily trips (including the means of transport used, trip length and speed) and the location of the building.

KGR has been used in many Norwegian building projects, including the pilot buildings of government programmes Framtidens Byer (Future Cities) and Framtidens Bygg (Future Buildings), Statsbygg projects, and building projects seeking BREEAM-NOR certification. Since 2007 five versions of the tool have been developed, version 1 in 2007, version 2 in 2009, version 3 in 2011, version 4 and 4.1 in 2012/2013 the last version 5 was available in 2014. Statsbygg and Bionova Ltd have signed a five-year agreement in 2017 to deliver a new model based on One Click LCA to replace KGR. One Click LCA Norge is the Norwegian edition of One Click LCA customized on assignment from Statsbygg that replaces KGR.

One Click LCA: is a Building Life Cycle Metrics software developed by Bionova Ltd. One Click LCA provides an automated LCA process using a web interface and can be used as a plug-in tool. It uses BIM to extract construction materials data and provide results as a total for whole building and per m^2 of building area (different area definitions can be used). Additionally, other units may be available for some tools - such as impacts per m^2 of building per year of building use,or impacts per user or occupant. The tool also provides two types of LCC tools: an automated tool with LCA integration and a simpler template-based LCC tool.

Similarity between One Click LCA Norge and KGR.: The entire energy calculation and reference building methodologies remain essentially the same. Large portions of background data for transport stay the same. The solution generates reference buildings according to the Norwegian requirements, the transport profiles are based on the national travel survey (RVU) datasets, energy calculations are based on Norwegian regulations, and data classification is based on Norwegian standards. The tool is also compliant with BREEAM NOR and is available in Norwegian. Training and support materials are also made available in Norwegian, while advanced guidance materials are available in English.

Differences between One Click LCA Norge and KGR: Table 5.2 shows the main calculation method differences.

Table 5.2
Differences between One Click LCA Norge and KGR (Bionova)

Main differences		
Parameter	**One Click LCA Norge NS 3720**	**Klimagassregnskap.no**
Calculation method	Based on NS 3720 standard (itself based on EN 15978) Proprietary method)	Proprietary method
Calculation scope	Based on NS 3720 standard; always holistic building view	Different modules, which may be combined as desirable
Emission factors	Always life-cycle based, CML IA 4.1. compliant as per EN 15804+A1, as CO_2 equivalent (as required by NS 3720)	Mix of direct emissions and life-cycle-based factors, may have some carbon only factors
Calculation database	Generic materials and process database and nearly all Norwegian and European EPDs	Limited database; EPDs can be added by end user
Supported energy norms	TEK10, TEK17 and updated passive house standards	TEK10 and then valid passive house standards
Accounted impacts	Non-biogenic carbon, biogenic carbon and land use changes (LULUC) impacts separately	Overall carbon impacts
Materials calculation	Life-cycle based, accounting transport, construction, use phase and end of life handling (cradle to grave)	Material manufacturing only (cradle to gate)
Reference building method	Structural materials use is based on geometry of building and on structural engineering.	Structural materials demand is simplified with fixed values, scaled according to number of floors.
Transport calculation method	Based on NS 3720, allows adjusting different user groups transport parameters separately	Based on klimagassregnskap.no documentation, transport distances divided by two, some parameters (e.g. transport of goods) not adjustable separately
Other differences		
Parameter	**One Click LCA Norge NS 3720**	**Klimagassregnskap.no**
Type of software	Commercial software; available for 50+ countries, with continuous updates	Non-commercial software; discontinued end of 2018
Modules	NS 3720 (which includes the entire scope of a new building project), BREEAM-NOR LCA, BREEAM-compliant LCC, CEEQUAL-compliant LCA, site selection module and dozens of other modules	Modules for different parts of the building and building processes; planning, construction and in use.
License types	Starter: allows row-by-row LCA generation and includes email support and pre-recorded training videos. Business: license includes (in addition to all features in the starter license) integration with commonly used design	Same for all users

	software for automated LCA import; option to download product EPDs used in the project directly from the software; industry average benchmark values; email support and live webinar training.	
	Expert: includes (in addition to all features in the business license) 3D LCA visualisation directly in the BIM model; sustainable materials suggestion and benchmarking and private materials database; private webinar training, email support and live chat support.	
BREEAM NOR compliance	Yes for all of Mat 01 and several other modules – maximum 14 BREEAM credits	For BREEAM Mat 01 carbon calculations only
Database content	Generic databases and EPDs from dozens of programs, with over 10 000 datapoints. Possible to have private data.	Generic database, user updateable
Integrations	Integrations to IFC, Excel, Revit and other software tools	IFC import tool
Differences to expect in project results if the same project is accounted for using One Click LCA Norge with same data and results compared to KGR		
Emissions source	*Order of magnitude for difference to expect*	
A1-A3Materials (manufacturing only)	Broadly comparable. Due to updates in emission factors, changes of +/- 20 % are possible. If more systems, e.g. energy producing systems are added, the scope is different, and the emissions will be higher.	
A-D Materials (over the life-cycle, A-B-C-D)	Results over the life-cycle will be higher. This is because materials may be replaced, and transportation, losses, repairs and end of life processing will occur and influence calculations.	
B6 Operational energy use	Results will be in almost all cases clearly higher, as all emission factors are life-cycle based, thus bringing into scope of calculations emissions other than direct combustion emissions, e.g. from losses, infrastructure and processes. Further, for proper accounting for including e.g. solar cells or other systems, the corresponding products need to be added in the materials module (where they will generate emissions).	
B8 Operational transport	Results will be in most cases clearly higher. This is explained partly due to changes in methodology, wherein KGR transport distances were divided by two. Also, the impact factors are likely higher in many cases as they base on different life-cycle inventory. Transport settings are fully visible and user controllable in the One Click LCA Norge which allows adjusting and understanding the specific drivers for all transport impacts.	

Figure 5.5 shows One Click LCA's NS 3720 results report (Binova)

	Sektor	Klimagassutslipp kg CO2e	Biogent karbonlagring kg CO2e bio	Klimagassutslipp, LULUC kg CO2e	
A1-A3	Byggematerialer	402 285	110 608	0	Detaljer
A4	Transport til byggeplassen	14 298		0	Detaljer
A5	Byggeplass	43 926	0	0	Detaljer
B4-B5	Utskiftning og renovering	54 696		0	Detaljer
B6	Energibruk i drift	4 302 651		0	Detaljer
B8	Transport i drift	7 294 063	0	0	Detaljer
C1-C4	Livsløpets slutt	7 868		0	Detaljer
D	Utover livsløp (ikke inkludert i totalen)	-44 459		0	Detaljer
	Total	12 119 787	110 608	0	
		Vis graf	Vis graf	Vis graf	
	Resultater per nevner				
	Per år (på 60 år)	201 996	1 843	0	
	Per m2 BTA (på 60 år)	3 030	28	0	
	Per m2 BTA per år (på 60 år)	50	0	0	
	Per bruker per år (på 60 år)	1 443	13	0	

Figure 5.5
An example of One Click LCA's results report in accordance with NS 3720 (Bionova)

Reference building calculation rules with One Click LCA:

Reference buildings follow regulations and today's practice, and do not assume any particular environmental specifications for materials. The reference buildings model was developed and validated on assignment from Statsbygg together with Civitas and Context AS, who have implemented the previous reference buildings models in KGR. One Click LCA implements and ensures all reference buildings created represent relevant building type created to fulfil the following regulations and standards relevant for materials and energy GHG accounting: TEK 17; NS 3031:2014; NS 3720:2018; NS-EN15978:2011; NS3451:2009; NS 3457-3:2013; Statsbygg and Futurebuilt rules for GHG accounting for construction projects. For passive house energy level modelling, the tool allows using NS 3701:2012 and NS 3700:2013

One Click LCA Norge includes two modules which include the reference building, the early-phase (tidligfase) tool and the design and construction phase (NS 3720) tool. The early-phase tool is based on a reference building with a fixed area and number of floors, scaled by gross floor area (Bruttoareal, or BTA). The design and construction phase tool uses a reference building creation tool which allows the adjustment of building area and number of floors (split to heated and unheated, aboveground and underground floors), scaled to size for realistic material use.

Furthermore, the following reference building calculation rules applied with One Click LCA

- The *building assessment boundary* related to the building elements include the scope 2-building according to NS 3541: Table of building elements. The building installations (groups 3-heating, ventilation and sanitation; 4-Electric power; 5-Tele and automation; 6-Other installation) and group 7- Outdoor are not calculated for the reference building.

- The scope of the reference building for *life cycle modules* includes A1-A3 materials, A4 transport, B4-B5 replacement of materials, B6 operational energy, B8 operational transport, and C3-C4 end of life waste processing.
- Assumes that the *biogenic carbon* and *land use* carbon flows are zero (0).
- The user is responsible for creating the reference building *transport scenario* for the *defined site* with the right number of users, visitor flows, and other parameters (to the extent known).
- The reference building is assumed to be calculated for a *defined site*. In cases when the reference building must be created prior to the final site being known, of the most likely area/sites shall be used.
- *Foundation* materials are calculated based on the gross floor area of the building to meet the conditions of the soil of the building site. The gross floor area of the building is used as a proxy for the building mass. Building shape does not influence the calculations, as the mass of the building is assumed to remain constant. The default foundation type is strip (footing) foundations. If this is not applicable, the user needs to apply the type of soil condition, and depth to bedrock for this foundation to represent the chosen site. If the site has varying depths to bedrock, the user can split the building total area between the different piling depths or between footings and piling. With varying number of floors above different soil types, the shares should be weighted by floor area above each soil type.

Mandatory choices in LCA Parameters and other inputs for the reference building are shown in Table 5.3.

Table 5.3
Mandatory choices for reference buildings (Bionova)

Choice	Mandatory choice	Why mandated
Service life default setting	Technical service life	Otherwise replacement impacts might differ if assumptions differ
Transport distance default setting	Nordic	Otherwise transportation impacts might differ if assumptions differ
Local compensation (for adjusting electricity of manufacturing for generic materials)	Nordic	Otherwise reference building will not be representing Norwegian reference building
Assessment period	Same as in the actual building	NS 3720 allows free choice of assessment period, so the reference building must be the same as for actual building
Number of floors (above and below ground)	Same as in the actual building	Reference model calculates amounts of structural materials based on floors and predefined floor heights. If this changes, reference needs to be rebased.
Transport: The number of users and distances and the goods transport scenario	Same users and distances as in the actual building	As site is chosen and has strong impact on the transport impacts, these variables must be fixed – only transport mix can be varied. If site is not yet known, use the most likely region instead.
Foundation system matching the site requirements	Foundation meeting requirements of the actual building	As site is chosen and has determining impact on foundations, the foundations must be suitable for the site. If the site is not yet known use the most likely case instead.
Construction site impacts	Nordic default	Choose the "Gjennomsnittlig byggeplass påvirkning – Norden" and apply BTA as value in the "Byggeplassdrift" query.
Site clearing and land use changes (if required)	Site clearing and land use changes as mandatory	In most conditions, these should not need to be included. However a site may be built on virgin land, and in such case the clearing and land use changes that the site itself actually would require shall be included.

openLCA[10]: is an open source "freemium"[11] software for LCA and sustainability assessment, developed and supported by GreenDelta since 2006. It allows the modelling of very simple to very complex systems. It provides modelling and analysis features, such as multi-level process parameters, graphical modelling, an auto-

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[10] www.openlca.org
[11] Freemium: Free software with options available for purchase

complete function for life cycle systems, a Sankey diagram for visual representation of flows, or contribution analysis for processes and flows. In addition, openLCA provides import and export possibilities for common LCA data formats. Additional modules and extensions (native and third-party) are available and may be added. openLCA comes with an empty database, whilst openLCA Nexus[12] provides a list of free and paid databases and LCIA packages[13]. A comprehensive help guide, other guiding documents, manuals, and example case studies that can be imported into openLCA are all available at the openLCA website.

LCAbyg: is a free open source tool developed by the Danish Energy Agency to assess the life cycle environmental impacts of buildings (Birgisdóttir, H. and Rasmussen, F. N. 2016; SBi 2019). LCAbyg helps to calculate a building's environmental profile and resource consumption by entering information about the building components and possible building energy consumption. It was launched in spring 2015. The environmental data is based on freely available German database, Ökobau. The system boundary is defined according to EN 15978 with 9 indicators showing the environmental impact and resource use. LCAbyg version 4.0 beta contains a catalogue of examples of building parts and installations related to new construction in Denmark. The catalogue can be used to execute the LCA on a preliminary basis or to replace the building parts or installations that have not yet been defined in a project so that a complete building model is obtained. It is possible in LCAbyg 4.0 beta to create own building parts independent of the catalogue or use sample constructions as a starting point and adapt them as needed.

SimaPro: is a detailed LCA tool developed by PRé Consultants, which contains a variety of impact assessment methods. SimaPro comes with a large set of data libraries coving about 6,000 processes. The software covers all the details of life-cycle analyses. The software can be used to design analysis models in different fields of engineering. However, the software is expensive, and it takes a significant investment of time for users to gain competency with the software.

ZEB tool for GHG emission calculation: ZEB tool is an excel based tool developed by the Norwegian ZEB research centre to evaluate the life cycle GHG emissions of buildings (Wikk et al.2017). The tool is developed in compliance with the international standard ISO 14040/44 (ISO 14040 2006, ISO 14044 2006) for LCA, European standard EN 15978 (EN 15978 2011) for the assessment of the environmental performance of buildings and EN 15804 (EN 15804 2014) for assessment of building materials or products. The LCA system boundary is defined in accordance with the Norwegian ZEB centre ambition level definition (Kristjansdottir et al. 2014, Fufa et al. 2016) and the modular life cycle system as defined in EN 15978 (EN 15978 2011). Furthermore, the physical building system boundary is structured according to NS 3451: 2009 Table of Building Elements (NS 3451 2009) in order to obtain an overview of the parts of the building that have been included, to facilitate the quantification of mass and energy flows and their corresponding CO_2eq emissions, as well as to facilitate a more structured and detailed comparison with other projects. Global warming potential (GWP) calculated in terms of carbon dioxide equivalents (CO_2eq) is used as a proxy indicator. A functional unit of $1m^2$ of heated floor area (Bruksarea, or BRA) over a reference study period of 60 years is considered when analysing the emissions from the whole building. In addition, the total embodied emissions of the building, building components and materials are calculated. The life cycle inventory includes specific emission factors from Norwegian environmental product declarations (www.epd-norge.no) when the building material supplier is known, verified LCA reports from manufacturers, or generic emission factors from the ecoinvent V3 database when building material suppliers are unknown. Operational energy use is calculated in accordance with SN/TS 3031 (SN/NS 3031 2016), either calculated through energy simulations in software such as SIMIEN or IDA-ICE in the design phase or measured in terms of net energy need (kWh) on-site during the use phase. A user manual is available, as well as articles and reports describing the use of the tool to evaluate several building concepts and pilot buildings (Figure 5.6) (Wikk et al 2018a, Wikk et al 2018b, Schlanbusch et al.2017, Wikk et al 2017).
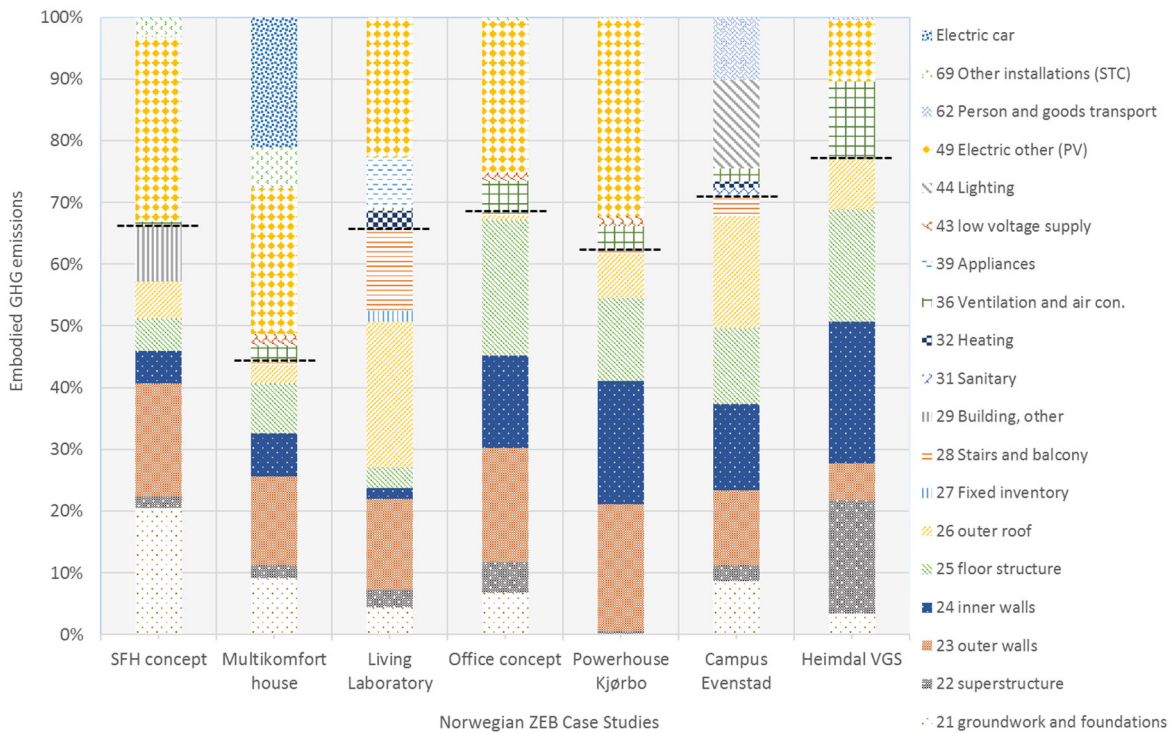
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[12]https://nexus.openlca.org/
[13] https://nexus.openlca.org/database/openLCA%20LCIA%20methods

Figure 5.6

An example of GHG emission results per building element for the Norwegian concept and pilot buildings (Wiik et al. 2018)

Proficient tool

Proficient tool is a spin-off version of the ZEB tool developed under the European project Proficient. The background GWP and cumulative energy demand (CED) data from the production stage (A1-A3) have been collected from EPD-Norge, IBU and the International EPD System in an EPD library, together with generic data from ecoinvent v3.1. The tool combines four design parameters (south window area, north window area, insulation thickness and window type) to find an optimal design solution in terms of embodied emissions, embodied energy, or operational energy use, generating over 1000 iterations/results. It is also able to perform a parametric analysis by combining operational energy use of buildings with embodied material emission and embodied energy calculations to find the optimal building design solution in terms of various parameters such as climate or insulation thickness. The methodology used to develop the tool and the potential use of the tool is presented in (Lolli et al. 2017).

	Embodied Emissions GWP (kgCO2eq)	Embodied Energy CED (MJ)	Heat Transfer Co-efficient (W/m2K)		
Building Lifetime	60 years				
Building Perimeter	36 m				
Heated Ground Floor Area	80 m2				
Heated Building Area	160 m2				
Heated Building Volume	420 m3				
Floor to Ceiling Height	2,4 m				

	Embodied Emissions GWP (kgCO2eq)	Embodied Energy CED (MJ)	Heat Transfer Co-efficient (W/m2K)	Operational Energy Use (kWh)	Operational Energy Emissions (kgCO2eq)
1. Groundwork and Foundatio	0	0,00	-		
2. Outer Walls	7373	234471,38	0,10		
3. Inner Walls	1759	62866,21	-		
4. Floor Structure	4826	237945,84	0,85		
5. Outer Roof	2479	118961,33	0,09		
6. Stairs and Balconies	0	0,00	-		
7. Technical Equipment	12144	91821,61	-		
Whole Building (A1 - A3)	16437	654245		2 011 620	583 370

Appliances

FU: /m2	102,73	4089,03		12572,63	3646,06
FU: /yr	273,96	10904,08		33527,00	9722,83
FU: /m2/yr	1,71	68,15		209,54	60,77

Figure 5.7
Embodied emissions, operational energy use and embodied energy considered in proficient.

5.1.3 Limitations and lessons learned

There are a growing number of tools used to evaluate the embodied emissions of individual buildings. The methodology used in those tools can be used as a background or basis when developing the tool in EE Settlement. For example, the reference building description provided in Klimagassregnskap and One Click LCA, and the system boundary and GHG emission calculation methodology in the ZEB tool can be used as starting points. However, the methodologies in these tools might be too detailed to be directly used in the project. It should also be noted that, this review is only intended to provide an overview of commonly used tools in Norway. It neither covers all available tools nor provides overly detailed descriptions of the tools. There may be other relevant tools which are not covered in this analysis.

5.2 Examples of tools available for the infrastructure

Infrastructure is defined as built-up structures and services that support the functions and operations of cities, including plants, facilities, and networks for: personal and freight transportation; water supply, distribution, and treatment; stormwater and wastewater management; drainage and flood protection; solid waste management; information and communications (ICT); and power generation and distribution. Hence, infrastructure and urban form are strongly linked. Indeed, transport, energy, and water infrastructure are powerful instruments in shaping where urban development occurs and in what forms (Hall, 1993; Moss, 2003; Muller, 2004).

The creation of sustainable cities implies a proper planning of both buildings and infrastructure in order to avoid great social, economic and ecological costs. Indeed, infrastructure systems tend to be planned individually, in isolation from each other and from urban planning (Neuman, 2011). Assessment approaches linking the analysis of the area being planned with the infrastructure services needed at a specified time in the future with a life cycle analysis of an infrastructure network, is therefore needed.

The assessment approaches and tools require integrated knowledge about the dynamics that drive complex systems, and the ability to evaluate the consequences of present and future planning and policy choices. Several tools have been developed and this section presents a list of relevant ones.

5.2.1 Tools available for the water sector

Currently there are no tools available for the Norwegian context that allow evaluation of the water sector, or the impact of water services ion urban development. Tools are being developed to evaluate the sustainability of the water sector that could be of valuable input for the present project. These include:

DiVA[14] is a Norwegian national project (Digital Vann og Avløp forvaltning) financed by the Norwegian Research Council involving different water industry professional experts working together at national level towards the improvement of Norwegian water infrastructure management approaches. DiVA is designed to be used by engineering consultant companies that often are engaged by water utilities to develop their master and rehabilitation plans (Leland-Try et al., 2017). A guide to DiVA , as well as an LCA tool to evaluate the CO_2 footprint of actions to be taken, is available at the DiVA website.

bedreVANN[15] is a tool allowing the evaluation of standard of services, investment needs and the development of the costs for politicians. This tool allows the municipalities to measure their own earnings performance over time, both standard and costs. In turn it provides a basis for prioritizing future work for the development of water services to a good standard at a proper cost level

Klimagassregnskap for vannbransjen[16]: Norskvann has contracted Asplan Viak to develop a tool to evaluate the carbon footprint of the water sector in the Norwegian context, which should be available by the end of this year. The tool will allow the evaluation of different components of the water sector, as shown in Figure 5.8. For the impact factors and other inputs, the tool uses the following sources:
- ecoinvent v3.4
- ECAM (Energy Performance and Carbon Emissions Assessment
- Monitoring)
- "Calculation of the carbon footprint from Swedish wastewater treatment plants" (SVU 12-120).

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[14] https://diva-guiden.no/
[15] https://bedrevann.no/
[16] https://norskvann.no/index.php/10-nyheter/1874-klimagassregnskap-for-vannbransjen-nytt-verktoy-underveis

- IPCC 5. hovedrapport
- Asplan Viak – FoU, klimafotavtrykk av Vannbehandlingsanlegg.

Oppsett av klimregnskap

Figure 5.8
Components included in the GHG emissions accounting in the water sector (Borg, 2018)

Aquaenvec[17] tool is a web-based tool aimed at helping decision making. It considers both the environmental impact and cost criteria of the activities of the urban water cycle. The general use of the Aquaenvec tool is illustrated in Figure 5.9.

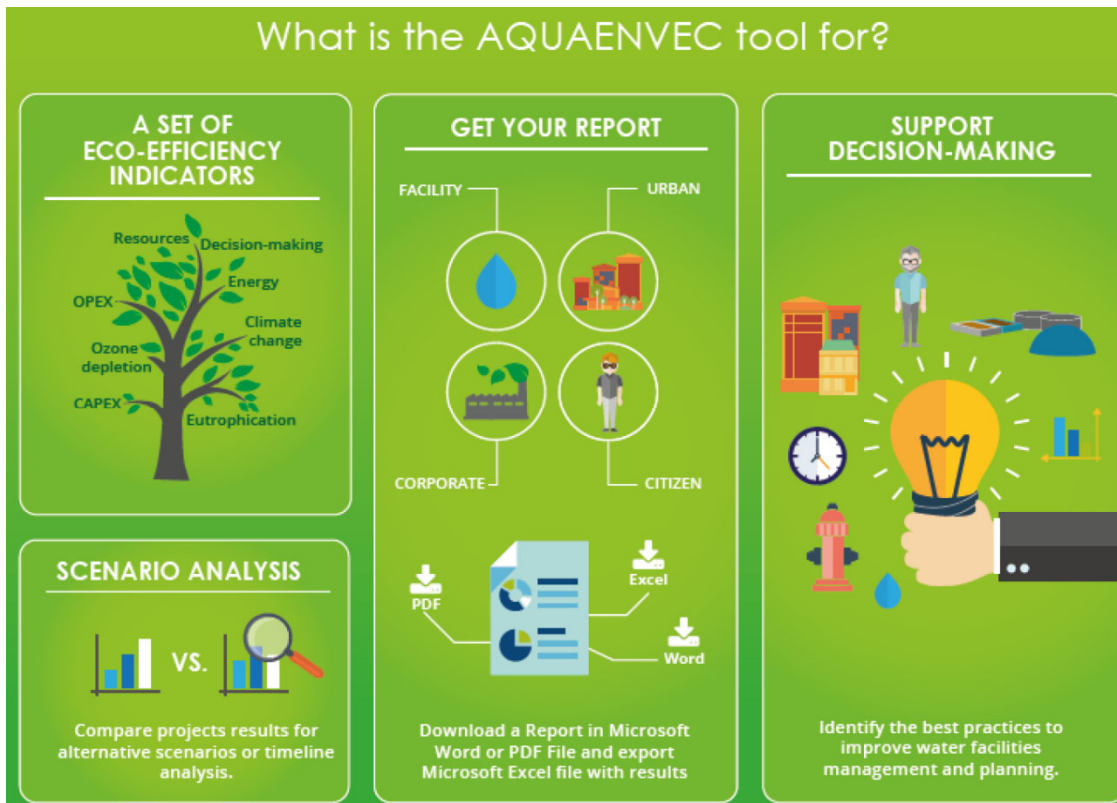[17] http://tool.life-aquaenvec.eu/en

Figure 5.9
Use of the Aquaenvec tool

5.2.2 Tools available for the transport and road infrastructures

Energy use and GHG emissions associated with the road transport system depend not only on vehicle operation, but also on the life cycle of road infrastructure (Brattebø et al., 2013) which includes road construction and operation (including maintenance), demolition, and waste processing of obsolete road infrastructure. Typically, these GHG emissions and energy use are divided into direct and indirect ones - where direct refers to on-site processes during construction (e.g. earthworks), and operation (e.g. transport of resurfacing materials), while indirect refers to the embodied component associated with the offsite production of materials and energy carriers used during construction and operation (upstream processes), and to demolition and waste processing of obsolete road infrastructure (downstream processes) (Brattebø et al. 2013).

Several models for the assessment of the impacts of different stages of road infrastructure planning have been developed, as reported by Karlsson et al. (2017). Karlsson et al. (2017) has listed the following models: which have been developed in Europe: Dubocal (van't Wout et al. 2010), LICCER (Brattebø et al. 2013), CEREAL (2014), EFFEKT (Straume 2011), Joulesave (ECRPD 2010), Klimatkalkyl (STA 2015) and RoadRes (Birgisdóttir 2005). The models are different in terms of system boundaries and impact categories included, depending on what stage of planning they are intended to be used. Dubocal, CEREAL and RoadRes, for example, are meant for later stages of road infrastructure planning, where more detailed road design is known., Other models have been specifically designed for the earlier stages of planning (i.e. the choice of road corridor), including EFFEKT, Joulesave, Geokalkyl, Klimatkalkyl and LICCER. Some of these models are further described below:

EFFEKT: The Norwegian road administration employs the EFFEKT model, which assesses direct and indirect energy use and GHG emissions of road infrastructure based on a limited set of data, reflecting

Norwegian conditions in the early stages of road infrastructure planning. Other models are available for quantifying energy use and GHG emissions related to road infrastructure, but the EFFEKT model is unique in the ability to calculate both direct and indirect contributions from a limited set of data. This makes the EFFEKT model suitable for use in the early stages of road infrastructure planning when exact road designs are not yet known, but decisions about road corridor alternatives must be taken.

LICCER: The LICCER-model is specifically designed for use in early stages of road infrastructure planning. In this stage, decisions remain regarding the exact location of the road, in combination with required road elements (e.g. tunnels and bridges). The LICCER-model can be used to inform both route selection and construction types (e.g. road, bridge or tunnel). A brief overview of the model is provided below.

The LICCER-model is developed as an MS-Excel tool that should be easy to use and transparent in terms of background data and calculations. With the LICCER-model it is possible to quantify energy use (cumulative energy demand) and GHG-emissions (CO_2-equivalents) in all life cycle stages of the road, from materials (production to demolition) and use (traffic impacts are included) (see Figure 5.10). Different types of roads, bridges and tunnels are included in the model, as well as supporting road furniture such as guardrails and road lighting. The model is described in detail by Brattebø et al. (2013).
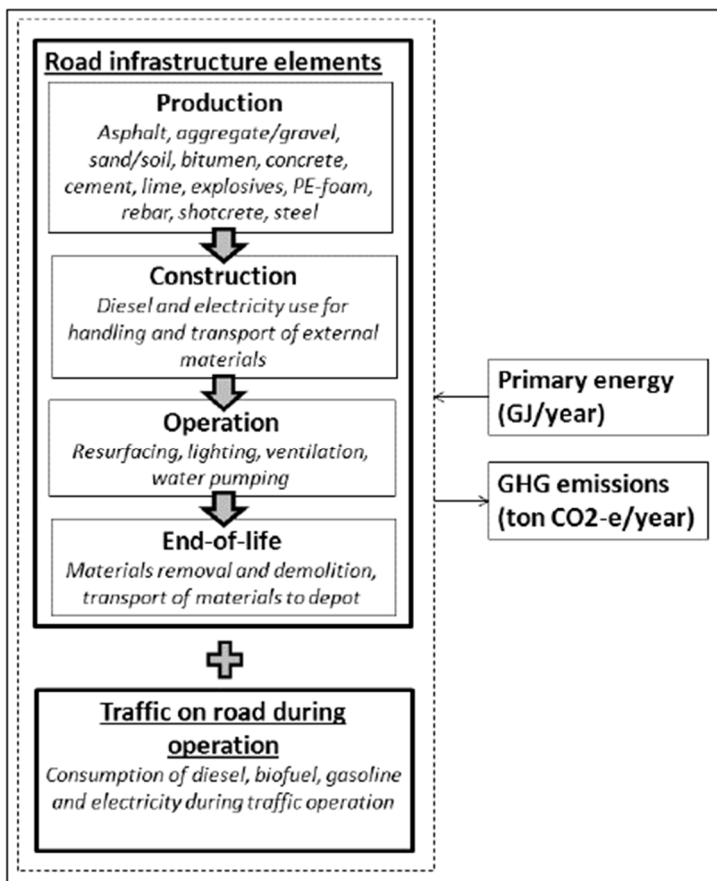

Figure 5.10
Simplified system boundaries in the LICCER model (Brattebø et al., 2013).

Klimatkalkyl is the Swedish transport administration's model for energy and climate calculations of transport infrastructure in a life cycle perspective. Klimatkalkyl can calculate climate impact based on the included

standard measures, components, project-specific quantity data for material and energy resources, or road maintenance contracts, which are based on maintenance measures. It can be used as a tool for decision support, as basis for project improvements, and for providing consistent following-up of projects and plans. It allows the user to:

- Compare alternative routings in a project
- Identify hot spots–what contributes most to energy use and climate impact in a project
- Analyse how different measures affect energy use and climate impact–work with improvements
- Follow up climate and energy performance

5.2.3 Limitations for tools available for infrastructures

The tools presented above are often developed for the evaluation of a specific infrastructure with respect to a defined criterion (e.g. carbon footprint, cost, etc.), and to our knowledge, apart from the scenario planning tools introduced in the next section, no tool evaluating the energy use and embodied energy associated with infrastructure for new settlements is available for the Norwegian context. However, databases and system descriptions used for the aforementioned tools are of great importance for the development of a tool to evaluate new settlements.

5.3 Examples of scenario planning tools

The uncertainty inherent in future changes makes modelling social, economic, environmental, and infrastructure systems even more complex, interdependent, and difficult to predict. Recently, tools that help decisions-makers have been developed to compare scenarios, such as scenario planning (Holway et al., 2012) or Urban Precinct Design (e.g.: Newton et al., 2013; Marchant and Plume, 2017). Scenarios are proposed and evaluated with respect to indicators such as traffic congestion, infrastructure costs, air quality, open space, etc. allowing the evaluation of the pros and cons of the different scenarios.

Within the city, scenario planning activities include for example (Holway et al., 2012):
- Area planning
- Neighbourhood planning,
- Infrastructure (water, sewer, street and stormwater) planning
- Project impact assessment
- Climate change mitigation and adaptation strategies development
- Regulatory analysis

At smaller scale, scenario planning can for example be used to compare design alternatives at a site plan or building scale for neighbourhoods as well as understand the capacity of infrastructures.

5.3.1 Existing tools

The scenario planning tools are land use evaluation tools which can be used for modelling at multiple scales: site, district, city, and region. The tools are generally based on a GIS or database system and allow users to create scenarios and assess them against defined goals with respect to various indicators relating for example to land use, housing, demographics, economic growth, development feasibility, fiscal impacts, transportation, environmental factors (including GHG, embodied energy, costs, and others), and quality of life. As an example, Figure 5.11 shows the layout of the interface of such tools, here the CommunityViz tool.
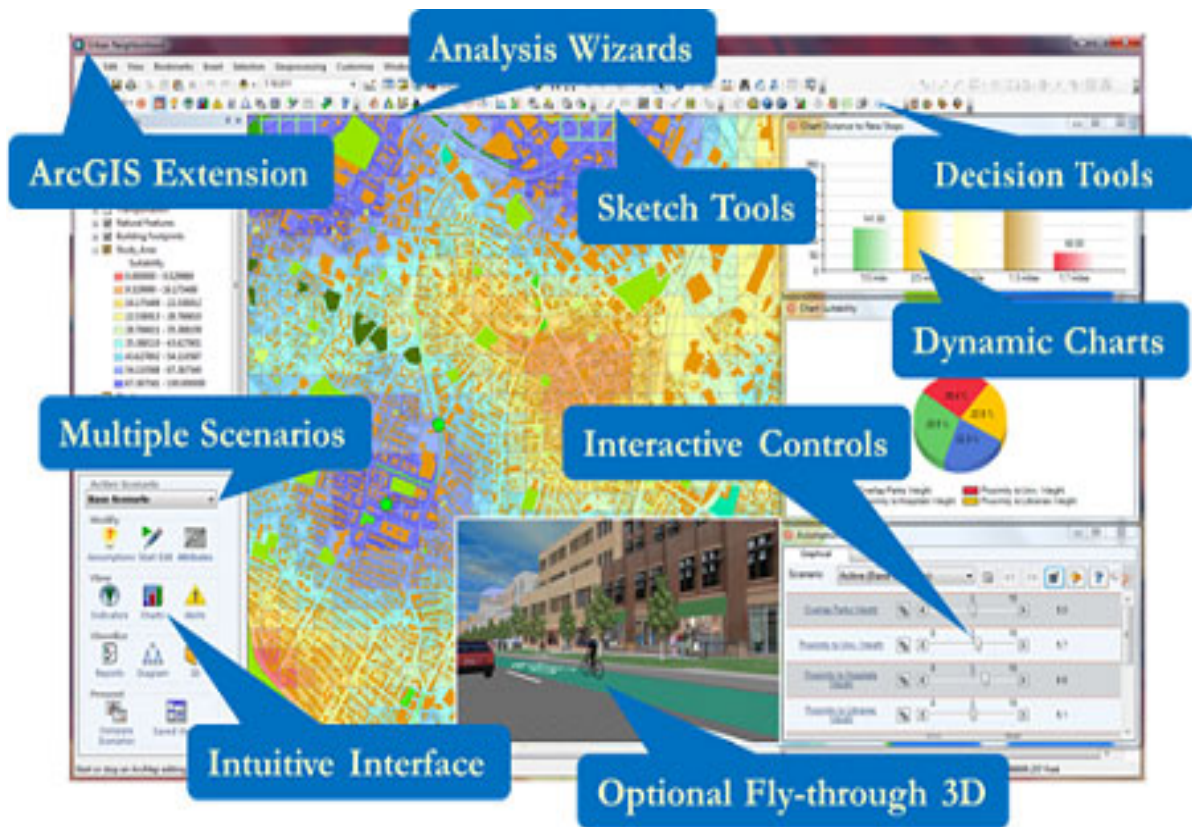
Figure 5.11
Layout of the interface of the ComunityViz tool[18]

The list of tools is rather extensive - as examples the following could be mentioned: CommunityViz with extension Scenario 360 (International), Envision Tomorrow (Only in US), I-PLACE³S (Only in US), and INDEX (Only in US), Urbansim (International), Urban Footprint (initially for US but now in transition to international application), CCAP Precinct (only in Australia), UrbanViewer (only in Australia), Umi standing for Urban Modeling Interface (International), and 4D-GIS (International). Each of these tools provides a variety of features and unique capabilities, more information is available in (Holway et al., 2012) and at their home websites.

Table 5.3 show a selection of tools available internationally with their key characteristics, including the presence or not of the embodied energy indicator.

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[18] Source: http://communityviz.city-explained.com/communityviz/scenario360.html

Table 5.3
Selection of tools available internationally with their key characteristics

Tools	Description	Scale of Analysis	Open Source?	Visualisation Capabilities	Summary of Approach	Sustainability indicators?
CommunityViz[19]	CommunityViz originated through The Orton Family Foundation to enhance the quality of life in rural places and regions by supporting better decision-making through decision-making tools for alternative scenarios. The software is an open framework that guides users through populating a geodatabase enhanced with spreadsheet-type capabilities.	Building to regional	No	2D maps, 3D maps, Graph & Charts	Spatial, GIS-based	Yes
UrbanSim[20]	Developed at the University of Washington, UrbanSim is a simulation platform for supporting planning and analysis of urban development, incorporating the interactions between land use, transportation, the economy, and the environment.	Building to regional	Yes	2D maps, 3D maps, Graph & Charts	Spatial, G+IS-based	Yes
UrbanFootprint[21]	This is an open source map-based model, developed by Calthorpe Associates as part of the Vision California process in order to facilitate more informed planning by practitioners, public agencies, and other stakeholders. UrbanFootprint comprises a suite of tools and analytical engines aiming at decreasing the time and resources required to get up and running with scenario development, while significantly increasing the technical capacity of state, regional, and local users to analyse the fiscal, environmental, transportation, and public health impacts of plans and policies.	Building to regional	Yes	2D maps, 3D maps, Graph & Charts	Spatial, GIS-based	Yes
Umi[22]	Developed by the Sustainable Design Lab at Massachusetts Institute of Technology (MIT), Umi is a Rhino-based design environment for architects and urban planners for modelling the environmental performance of neighbourhoods and cities, including operational and embodied energy use, walkability and daylighting potential.	Building to regional	Yes	2D and 3D models, Graph & Charts	Spatial	Yes

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[19] http://communityviz.city-explained.com/index.html

[20] http://www.urbansim.com/

[21] https://urbanfootprint.com/

[22] http://urbanmodellinginterface.ning.com/

5.3.2 Examples from Norway

The Norwegian ZEN Centre: As reported in the annual report 2017 from ZEN, Bodø municipality has been working with Urbanetic (Singapore) to develop a modern urban planning tool for designing and managing sustainable green cities (Simon Flack, 2018).

Urbanetics' Fabric platform is a computational and data management tool that gives urban planners and stakeholders the ability to design for sustainability and significantly improve the understanding of the built environment with the complex and dynamic nature of interrelationships of its components (Simon Flack, 2018). As aforementioned tools, it allows high-performance interactive visualization of city or precinct data in 3D offering to real estate developers, planners, and city councils the possibility to make better decisions by simulating scenarios and testing the impact of choices in the present and future (Figure 5.12).

Bodø municipality plans to use the platform to create a digital-twin of the city via the integration of Fabric with the city's Internet of Things (IoT) platform. The main goals will be to incorporate future ZEN metrics and key performance indicators (KPIs) directly into the planning tools allowing urban planners, architects, and communities the tools needed to design climate neutral neighbourhoods and greener cities.
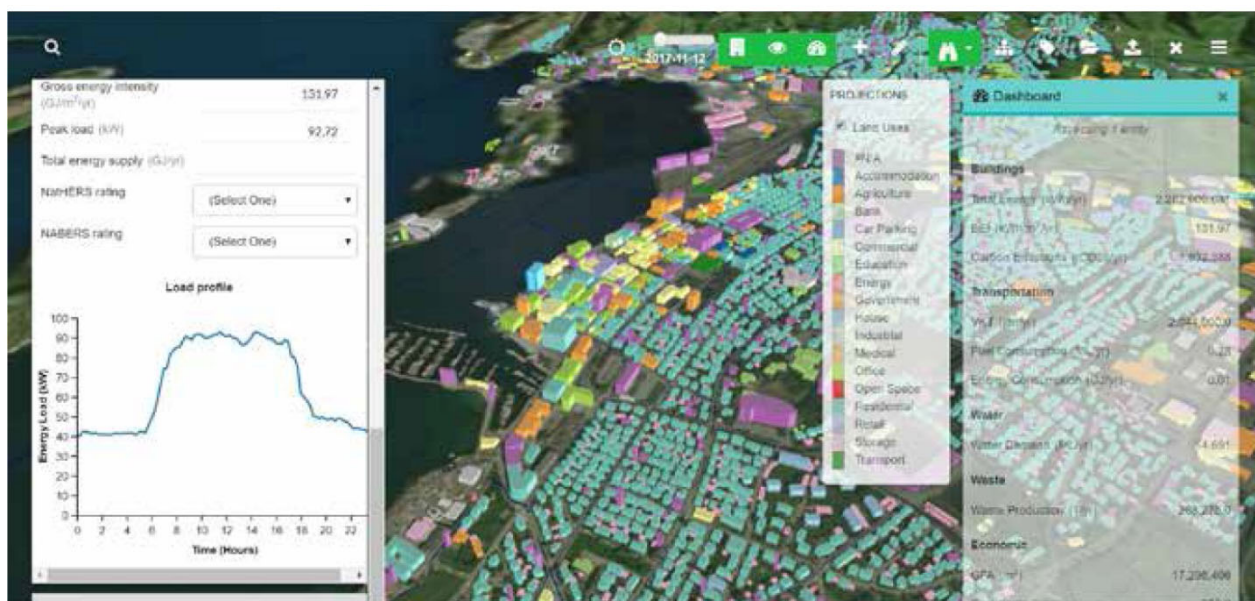

Figure 5.12
Screenshot of Urbanetic Fabric building and land-use analysis, Bodø municipality (Simon Flack, 2018).

PI-SEC (Planning Instruments for Smart Energy Communities) scenario calculator: is an excel based scenario calculator tool developed under the PI-SEC project aiming to aid energy planning and monitoring in "smart energy" communities. The tool compiles energy and emission relevant data with calculation routines for the selected KPIs to evaluate possible scenarios (Walnum et al. 2017; Walnum et al., 2019). The tool is designed to evaluate the project throughout different project phases (early planning phase, design phase, construction phase and as-built phase), but it can be mainly used as a decision support tool in the early planning phase. The tool enables the calculation of energy use and emissions from stationary sectors and transport. It enables a quick comparison of current situation and reference/baseline scenario (which includes planned renovations and new buildings within the project time horizon, with no additional measures regarding emissions reductions or introducing renewable energy, renovations, and future scenarios. The tool contains

CO_2eq and Primary Energy Factors (PEF) for weighting energy end-use. The transport module calculates the effect of altered habits based on the concept that the buildings and the people in them (residents, employees and users) are what determine transport within the community.

The tool uses the following selected main KPIs related to the targets of the communities to evaluate possible scenarios during planning phase: energy use (in kWh, $/m^2$, /inhabitants, /user), CO_2 emissions (in tonnes CO_2eq, $/m^2$, /inhabitants, /user), % of RES in district heating (in % of total mix), % of buildings with energy certification (in % of total stock), Installed Capacity of RES (in kWh, $/m^2$, /inhabitants, /user); Generated Energy by RES (in kWh, $/m^2$, /inhabitants, /user); # Buildings with installed Solar PV (total numbers); # Buildings connected to a thermal district infrastructure (total numbers); % of travels by bike, walking or public transport (% of each mode of transport); # fossil free construction sites (total numbers); # registered oil boilers (total numbers).

5.3.3 Limitations for scenario planning tools

The scenario planning tools can provide valuable support for the modelling for the planning of new settlements. These tools require a rather extensive amount of data to be able to model alternative scenarios representing possible development of complex urban systems that may occur over time at a specific site. Furthermore, the data collection, the calibration of the tool, and the processing of the models are rather complicated and require specific knowledge about the models and the area under study to be able to make assumptions and evaluate the validity of the scenarios and results. Therefore, the use of such tools requires a financial commitment to dedicate internal staff resources or for external consultants.

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6 Relevant tools available in Germany

The German REFINA program[23] (Research for the Reduction of Land Consumption and for Sustainable Land Management), with more than 110 subprojects ran from 2006 to 2012.[24]. Several innovative concepts for reducing land usage and promoting sustainable land management were developed and implemented within the program, which was funded by the Federal Ministry of Education and Research. The concepts intended to meet multiple goals simultaneously, such as the protection of the environment and conservation of nature, economic growth, socially compatible housing, quality of urban building, and mobility. The program bundled the competence of many institutions, projects, and people in cooperation across traditional sectoral and administrative boundaries.

Several cost-benefit analysis models and tools were developed within the REFINA framework, mainly focusing on follow-up costs of settlement development, facilitating the calculation of short-, mid- and long-term impacts on revenues and expenditures of different development approaches (Preuß, 2009; Preuß and Floeting, 2009). The tools and models are primarily directed to public administration and policy makers in municipalities but may also be relevant for developers and action groups. The cost-benefit tools developed use a basic cost model to calculate follow-up costs for technical infrastructure, accounting for initial construction, long-time operation, maintenance, repair and potential modernization. One of the tools uses data on population development as a basis to generate estimates of future demand for social infrastructure such as nursery schools and primary schools. Table 6.1 provides an overview of tools and models developed in the REFINA project.

According to Preuß (2009), the complexity of the tools and models differs significantly, and their operation requires users to invest various degrees for time and effort. Most relevant for EE Settlement is the software tool "Folgekostenschätzer", a follow-up cost estimator with one module for technical infrastructure and another for social infrastructure. The module for technical infrastructure is a free assessment tool that can be used to estimate the short-, medium- and long-term consequential costs of a residential area designation associated with technical infrastructure and green spaces, especially at an early planning stage. Based on the follow-up cost estimator, several tools were developed that are specially tailored to individual German Länder (regional states). Short descriptions of these tools, and some others, with corresponding links are available at https://aktion-flaeche.de/folgekosten-rechtzeitig-kalkulieren (the portal for municipal land saving; in German).

Some of these tools are also available at https://www.was-kostet-mein-baugebiet.de/, where a simplified version of the "Folgekostenschätzer" can be used online. Based on the two estimator modules, a more advanced "Fiscal Impact Analysis" (FIA) calculator was also developed. The FIA tool accounts for the impact of residential and mixed-use areas on the financial situation of municipalities and citizens. The calculator also links fiscal impact assessments with questions of general public service and infrastructure planning. The FIA tool is available to municipalities as part of qualified advice.

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[23] https://refina-info.de/en/index.html
[24] In German: Reduzierung der Flächeninanspruchnahme und ein nachhaltiges Flächenmanagement (REFINA)

Table 6.1
Overview of tools and models developed in the REFINA project (Preuß, 2009).

Tool/Model (Developer)	Target Group	Spatial Plane of Reference	Type of Use	Benefits (Revenues)	Costs (Expenditures)	Scenarios/ Strategies	Miscellaneous
Software tool: Folgekosten-Schätzer; Module: Technical Infrastructure (REFINA Cost transparency)	Local government; Municipal Policymakers; Citizen initiatives	Individual sites; Building area; Land-use planning	Residential	Not shown	Technical infrastructure, green areas	Comparison of different scenarios involving gaps between buildings, plots in core areas and/or areas on the periphery	MS Excel application; Possibility of site-related data entry; Adjustable time period, max. 100 years; Tool accessible for no charge at www.was-kostet-mein-baugebiet.de
Software tool: Folgekosten-Schätzer; Module: Social Infrastructure (REFINA Cost transparency)	Local government	District; Residential Area; City-periphery area/region	Residential	Not shown	Social infrastructure	Freely definable scenarios (existing building, new building)	MS Access application; Possibility of site-related data entry; Adjustable time period; Integrated population forecast; Interface with MESO reporting system; Tool accessible in conjunction with consultancy services
Software tool: LEANkom (REFINA LEAN2)	Local government	Individual sites; Building area; Total building area; City	Residential	Real estate transactions; Property tax; Municipal share of income tax; Unconditional grant allocations / cost allocations	Preparation of building land / financing technical and social infrastructure Open space-and compensation areas Public transport Transport of schoolchildren Planning costs	Comparison of freely selected strategies and subsequent comparison of varying development approaches or complex urban development strategies	Self-developed software solution; Interfaces with ArcGIS and MS Excel; Site-related and cross-municipal data entry; Integrated population modelling for building areas and districts; 20-year forecasting time period; highly adaptable to specific municipal demands
Software tool: fokosbw (FH Nürtingen and STEG)	Local government	Building site; District/city (social infra-structure)	Residential	Real estate sale; Property tax A and B; Municipal share of income tax; Unconditional grant allocations	Preparation of building land / financing costs; technical and social infrastructure	Four predefined courses of action for land development in internal and external areas	Portrayal of typical population structure and development of areas with new housing estates; Forecasted time period: 25 years; A web-based demo version is also available at www.fokosbw.de

Tool/Model (Developer)	Target Group	Spatial Plane of Reference	Type of Use	Benefits (Revenues)	Costs (Expenditures)	Scenarios/ Strategies	Miscellaneous
Infrastructure cost model: Gießen-Wetzlar Region (REFINA Nachhaltiges Siedlungsflächen-management Stadtregion Gießen-Wetzlar)	Local government	Pilot region; Gießen-Wetzlar	Residential; Commercial	Not shown	Technical infrastructure	Two scenarios that account for land for settlement expansion and existing sites; Trend scenario; Land recycling scenario	Consideration of site-specific characteristics of land Employs benchmarks and specific outlay factors for develop-ment investment and cost Calculation of the follow-up costs for infrastructure until 2020
Cost-calculation model: (REFINA FIN.30)	Local government	City	Residential	Site-related revenues (real estate sales) according to selected building land model city-wide revenue (e.g. funding support) No consideration of proportional income tax and municipal financial equalization (site-specific and citywide)	Preparation of building land / financing technical and social infrastructure	Varying residential densities: freely selectable or dwelling type with defined inhabitant density - single-family, two-family, terraced homes	MS Excel application; Consideration of area-specific cost levels for technical and social infra-structure; Individual entry of site characteristics; Creation of a ranking of potential housing areas; Forecasted time period: 15 years; Creation of cost-effectiveness classifications; Planned link to ArcGIS
Cost-calculation model for regional settlement management (REFINA Regionales Portfoliomanage-ment)	Local government	Pilot region Bonn, Rhein-Sieg/ Ahrweiler	Residential Commercial	Private usufruct of real estate Impacts of structural investment on the surrounding area/ neighbour-hood	Internal and external development; Social infra-structure; Noise; Flood control; Preparation of plot; Environmental costs of land utilization	Different planning scenarios	Linked with GIS; Consideration of the costs and benefits of various types of zoning practices from an economic perspective in terms of regional socioeconomic optimization (private enterprise, infrastructure, ecology); Calculation of the ecological worth according to a value-based costs equivalence approach; Time period: approx. 20 years

References

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7 Models and tools for Norwegian transport planning

7.1 Introduction

This chapter describes some of the main tools, models and data used in Norway to conduct passenger transport analysis. The aim is not to provide an exhaustive and detailed description of all tools but rather give an overview and description of those most commonly used to estimate and model passenger transport demand and travel behavior. The chapter also discusses whether these tools can contribute to what is one of the main scopes of this project, i.e. calculating the energy embedded in transport generated by individuals that settle down in new developed residential areas.

We broadly distinguish between models to estimate changes in transport demand and travel behaviour and guidelines to calculate trip generation. These may be supplemented by further methods that are better suited to account for unexpected trend changes and disruptions. All these tools have their strengths and weaknesses and there is no tool that is good for all types of analysis and assessments. The selection of the most relevant tool(s) mainly depends on the time and spatial scope of the analysis, the type of changes to be analyzed, as well as the type of resources and data available. Combining different tools may allow for a more comprehensive analysis.

These tools can be used for several purposes ranging from visualizing the impact of specific measures on traffic flows to providing information for more comprehensive impact analysis of large and complex projects. Although the type of data required by each of these tools may differ, both transport and traffic models as well as guidelines for trip generation rely on travel data. The most comprehensive set of travel data in Norway is provided by the National Travel Survey (NTS).

The chapter is structured as follows. First, we present each of these overarching categories of tools (sections 2 - 3). The focus is to describe the type of data they required, which information they provide and, thus, what they can be used for, as well as their main limitations. Second, we dedicate a section (4) to describing the National Travel Survey, as this represents a key source of data for carrying out transport analysis and estimations and for calibrating transport models. Last, we discuss whether these models and tools can be used to calculate the energy embedded in transport generated by individuals that settle down in new developed residential areas (section 5), which is the ultimate goal of this project.

7.2 Transport and traffic models

Basically, transport and traffic models estimate travel demand and behaviour based on the values of a series of given explanatory variables, assumptions and travel time and costs functions. Transport models have traditionally been built upon four sequential steps (VD, 2018a; Tørset et al., 2012):

- **Trip generation**. In this step the *number of trips* that are originated is estimated. Trip generation is influenced by conditions such as economy, car access, driving license, land use, demographics, attitudes, preferences and cultural values. Trip generation is usually estimated based on data on a limited set of conditions.
- **Trip distribution**. In this step, the model estimates trip's *origin-destination (OD)* pairs between given zones. The scale of these zones can vary across models. The traffic between a zone and all other zones can be set up in a traffic matrix.
- **Travel mode choice.** In this step the *transport mode* used (i.e. car, public transport, bike, walk) is estimated. This depends a. o. on the transport offer, the competitive relationship between means of transport and personal preferences.
- **Route distribution**. The last step estimates which *route* is selected between two areas. This is mainly based on travel time and cost functions between trip's origin and destination.

In the traditional four-step modelling approach, travelers' behaviour is simplified to these four choices, which are sequentially modeled. There are, however, different types of models and not all of them cover all four steps. Moreover, models have evolved over time. They have become less sequential as well as more complex by integrating further models into model systems and by increasingly allowing for more iterations between these four steps.

These models require data to estimate transport demand and behavior as well as to calibrate the models. Input data is usually obtained from travel surveys, existing registers and official statistics (e.g. population, jobs, income level, land use) and registers describing the transport offer (e.g. road network, public transport). Travel surveys are also used to calibrate the model along with a. o. traffic counts and ticket statistics (Kwong, 2018).

7.2.1 Types of models

There are different ways to categorize models. According to a handbook published by the Norwegian National Road Administration (2018a), models for passenger travel can be divided in two broad types: transport or strategic models and traffic models. Additionally, within traffic models, Tørset et al. (2012) distinguish between tactical and operational models. According to them, the following threefold categorization[25] is quite popular:

- **Transport models**, also referred to as **strategic** or **macro models**, are used to modelall steps in the traditional four-step approach. They have a low degree of detail and resolution but cover a long time period. They are usually applied to larger projects and areas where complex effects regarding transport volume, pattern and mode choice (e.g. changes in number of trips due to e.g. population growth, shifts in the number of trips between zones due to migration flows and/or changes in modal choices due to e.g. changes in car ownership rates) are expected because they can model travelers' choices and provide an overview of demand. The National Transport Model and the Regional Transport Model are strategic models used in Norway.

- **Tactical models** are **traffic models** and have a narrower perspective than strategic or transport models. They are normally used for medium-term planning and can simulate changes in route (and sometimes mode) choices at the **meso** level given a transport demand level. Such models can for instance be used to assess traffic distribution and/or congestion and to prioritize traffic flows or users on a certain portion of the network. Aimsun and Contram are model tools used in Norway to conduct tactical analyses.

- **Operational models** are also **traffic models,** but they simulate changes in route choices at the **micro** level. They are very detailed and cover short time horizons. They can be, for instance, used to prioritize traffic flows at single crossroads and nodes. Aimsun micro, SIDRA, and VISSIM are model tools used in Norway to conduct operational analyses.

Strategic models estimate the number of trips per day and per hour, while tactical and operational models can estimate traffic on the network at intervals of 5 to 15 minutes (Kwong, 2018). A further key difference between traffic (tactical and operational) models and strategic models is that tactical and operational models do not usually estimate total transport demand, i.e. the number of trips and destination is given - often as a result of estimations done by strategic models (Kwong, 2018). However, Flügel et al. (2014) indicate that it is not always possible to draw a clear distinction between these three types of models.

Tørset et al. (2012) also provide a further categorization of tools, which are specifically used in urban transport analysis. To the already described strategic and traffic management models, they add **elasticity**

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[25] This description is based on VD (2018a) and Tørset et al. (2012)

models, which are used to simulate changes in demand within a transport mode category (e.g. public transport) based on changes in at least one of the explanatory variables. Examples of such models are the Intercity model, the UA-model and Trenklin.

Flügel et al. (2014) provide a more comprehensive categorization. They go beyond the classical distinction between strategic, tactical and operational models, which depends on the planning-management perspective they scope, and distinguish also between tools depending on the model components they focus on, i.e. **travel demand models** (which focus on where and by which mode people travel), **network assignment packages** (which focus on which routes people choose) and **transport models** (which couple both). They further distinguish between models within each of these categories attending to how they account for time and temporal dependencies (static vs. dynamic), their resolution (macro, meso, micro) and whether they account for uncertainty (deterministic vs. stochastic) and heterogeneity.

Our description of models clings to the traditional categorization into strategic, tactical and operational models.

7.2.1.1 Strategic models

Strategic models usually follow the four-step approach described above, although they have increased the level of iteration they allow for. They estimate travel demand between zones based on a wide range of variables including those pertaining the socio-demographic (e.g. population growth), economic (e.g. fuel costs) and contextual dimensions (e. g. transport network, land use). The area they cover can vary, and so does the size of the zones considered in the model. The transport model system in Norway consists of the National Transport Model (NTM), the Regional transport model (RTM) and sub-area models (DOM).

The National Transport Model (NTM)

The National Transport Model (NTM) covers trips that are longer than 70 kilometers in Norway and delivers matrices between approximately 1600 zones for four different types of modes (car drivers, car passenger, airline and public transport) and five different travel purposes (work related trips, commuting trips, visitation trips, leisure trips and other private travel) (VD, 2018a).

The NTM functions according to the four-step approach described in previous section, with mode and destination being estimated simultaneously. Like the RTM, the NTM is in reality integrated by several models. Based on results of the project commissioned by the National Transport Authorities, Rekdal et al. (2014) provide a comprehensive description of the data required and collected and of the estimations conducted to develop, implement and calibrate the latest version of NTM (version 6). According to this description, the NTM6 comprises the following model modules:

- **Network models** consist of simplified versions of the Norwegian road and public transport (rail, ferry, air) networks and of algorithms for calculating the most favorable routes between all zones (ca. 1600) and their associated distances, travel time and costs. EMME and CUBE are the two most widely used network modelling tools in Norway.
- **Joint destination and mode choice models** for each of the five travel purposes described above and depending on whether trips covered by the NTM (over 70 km) are shorter or longer than 200 kilometers. This means that NTM6 comprises ten destination and mode choice models, one for each of the five trip purposes for trips ranging between 70 and 200 km and one for each of the five trip purposes for trips longer than 200 km. Each model calculates slightly different choice probabilities for each population segment. Population segments are constructed upon register data describing car access, gender and age, as well as survey-based data describing whether the trip comprises an overnight stay, travel companionship and access to a company car.

- **Travel frequency models** estimate the number of home-based long trips for each of the five travel purposes and the two distance ranges (below and above 200 km). The number of trips is estimated with separate models for five age groups, i. e. 13-24 years, 25-34 years, 35-54 years, 55-66 years and 67+ years. The variables that are included in the model comprise socio-economic and demographic variables (e.g. gender, age, type of household, income), variables pertaining the dwelling location (e.g. number of population/jobs), and logsums from 'destination and travel mode choice' models.

NTM6 does not include an own model module for car access, as this is already integrated in the RTM model. NTM6 aggregates data on population segments from the basic statistical unit[26] included in RTM into larger zones (ca. 1600).

Data required (input). Rekdal et al. (2014) provide a description of the data required to develop, implement and calibrate NTM6. The core sources are survey-based travel data, data on road and public transport networks, register data, traffic counts and statistics. **Travel data** used in the NTM6 is provided by the National Travel Surveys (NTS) from 2005 and 2009. Both include data on individual and households' characteristics as well as information on travel habits and choices (section 4 provides a more thorough description of NTS data). **Data** on road and public transport networks (e.g. transport costs, departure times, waiting times) is fed into the network models described above to determine **transport standard or 'level of service'** (LoS-matrices). **Register data** (e.g. the Cadastre) is collected to describe the zones (ca 1600) covered by the model in terms of population, number of workplaces by industry, number of hotels, number of cabins, etc. Some of this data is already available through data files that are used in regional models. **Data** is also required **to calibrate** the model system. This includes **traffic counts and statistics** for flight, rail, ferry and road traffic.

Information provided (output). The NTM6 delivers 35 tour matrices categorized by travel purpose, distance, and mode of transport (Rekdal et al., 2014). 5 out of these matrices are flight journeys and 10 matrices are delivered for each of the modes car drivers, car passengers and public transport for medium (70-200km) and long (above 200 km) traveling. The matrices include the number of average trips made during a normal month or a summer month upon which it is possible to calculate average daily traffic numbers for the whole year.

According to the detailed categorization provided by Flügel et al. (2014), we could, thus, describe the NTM as a trip-based and zonal attraction-based travel demand model that provides estimates for segments of population and assigns traffic in a macroscopic, deterministic and static manner.

The Regional Transport Model (RTM)

The Regional Transport Model (RTM) system comprises five regional models that overlap with the Norwegian Public Road Administration's five regions: North, Mid, West, South and East, as shown in Figure 7.1).

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[26] Basic statistical units ('grunnkrets' in Norwegian) are subdivisions of municipalities, used by Statistics Norway to provide stable and coherent geographical units for regional statistics. There are approximately 14,000 basic statistical units in Norway, most of which include only a few hundred inhabitants. In cities, units have only a small geographical extent.
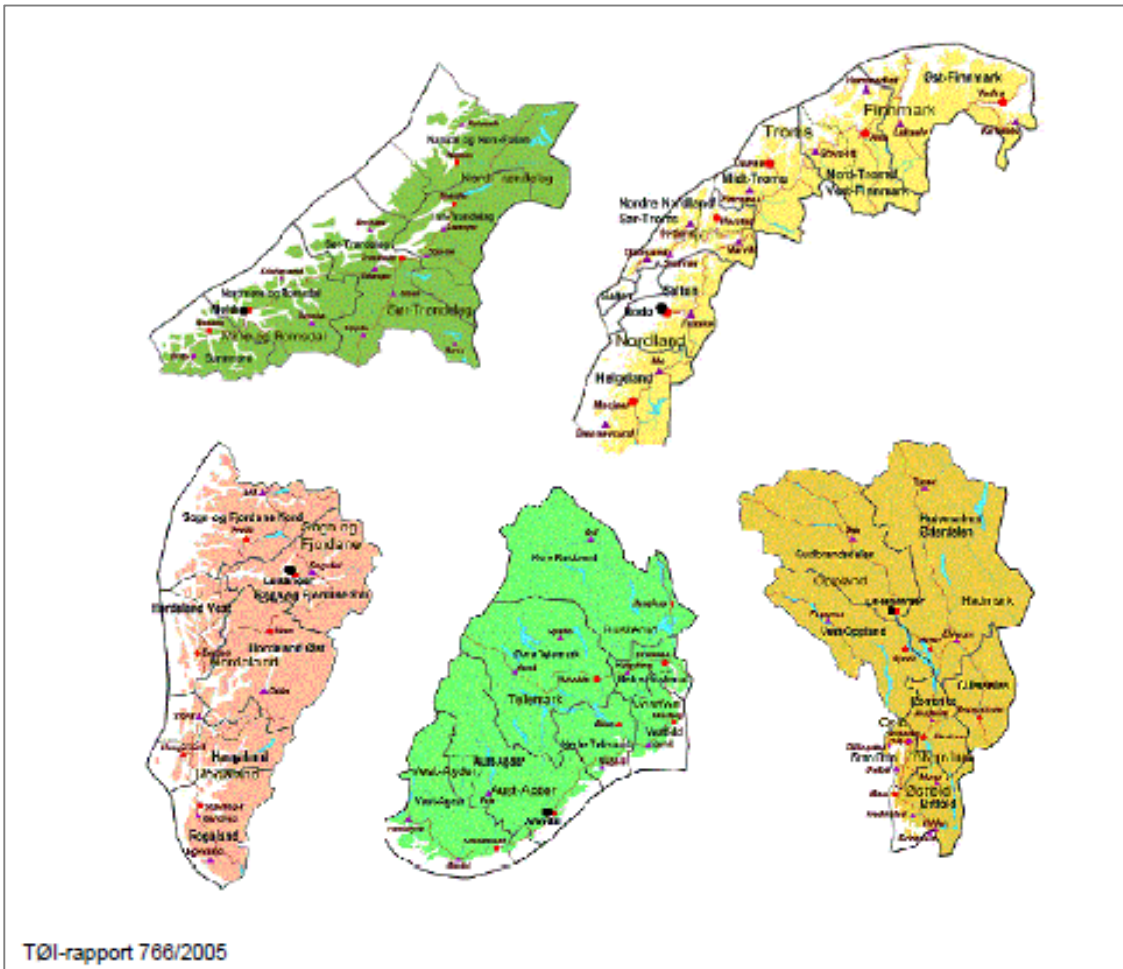
Figure 7.1
The five regional models in the Regional Transport Model system (Source: Madslien et al., 2005, p. 6)

The RTM covers daily trips that are shorter than 70 kilometers[27] and models tour matrices between all basic statistical units within each of these regions for five travel modes (car drivers, car passengers, public transport, bicycles and walking) and for five travel purposes (commuting trips, work related trips, pick-up and delivery trips, leisure trips and other private travel) (VD, 2018a).

RTM was initially developed by the Institute of Transport Economics and Møreforsking AS on behalf of the Norwegian Transport Authorities (Madslien et al., 2005). Since then, there have been three versions of the model and a fourth version is expected to be deployed in 2018 (Kwong, 2018).

In reality, the RTM is a model system integrated by several models. The following figure published in Madslien et al. (2005) provides an overview of the RTM system.

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[27] RTM was initially set up to cover trips up to 100 kilometers (Madslien et al., 2005).
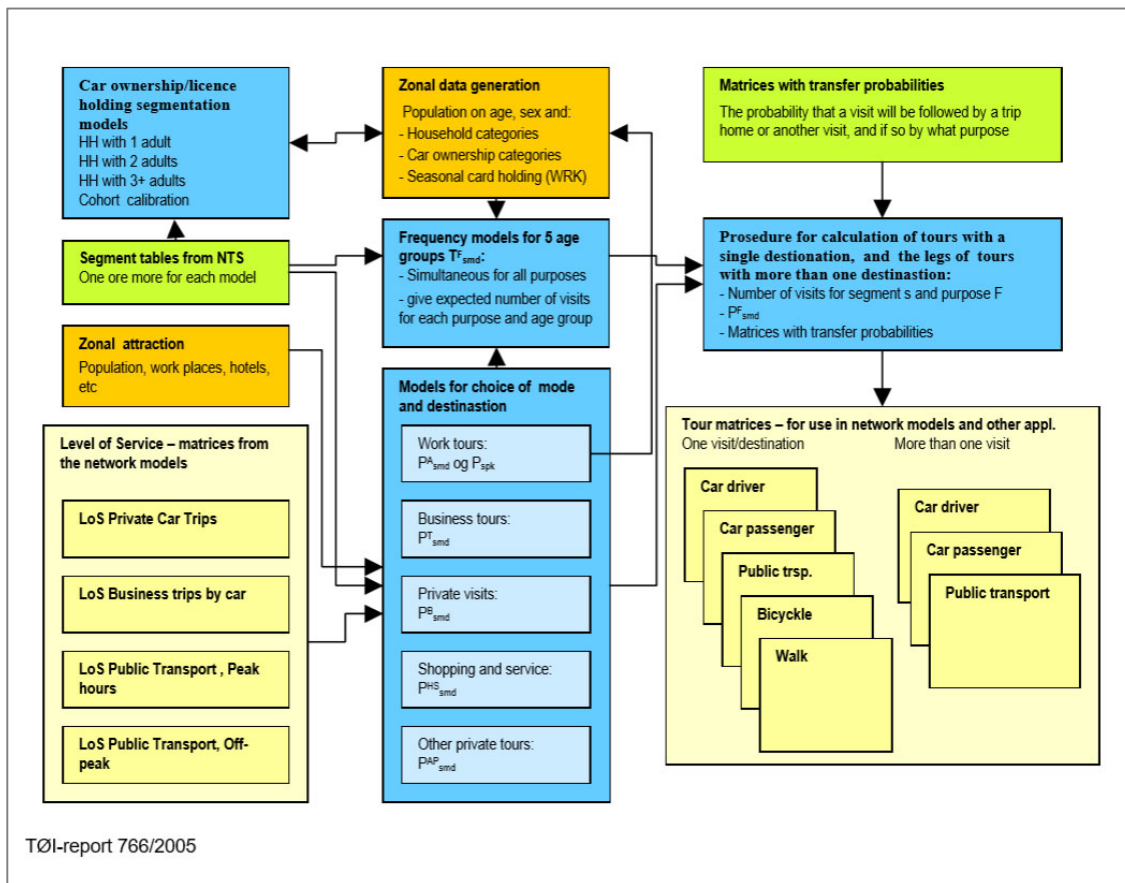
Figure 7.2
Structure of the Regional Transport Model (Source: Madslien et al., 2005, summary, p. iii)

As the NTM, the RTM also includes a **'network' model** as well as a **model for 'choice of mode and destination'** and a **'frequency' model**. In the models for choice of mode and destination, travel mode and choice of destination are estimated simultaneously (Madslien et al., 2005). For commuting trips, the model also estimates the probability of holding public transport periodical cards simultaneously with travel mode and destination. In the travel frequency model, the number of trips is estimated for population segments and travel purposes simultaneously (Madslien et al., 2005). Additionally, the RTM includes a **'car ownership and driver license'** model (which the NTM does not include). This model is estimated by age, gender, household composition, population density and income and calibrated against forecasts on driving license possession which considers cohort effects.

The RTM is designed to take into account the effect of changes regarding the following aspects (Madslien et al., 2005):

- Demographics (age, gender, household composition)
- Car access and driving license
- Level of service of public transport
- Specific costs (e.g. periodical transport cards) and time values (gendered based) that affect generalized costs and utility functions used to estimate destination, travel mode and travel frequency
- Zonal workplace and population densities that feed into the destination and travel mode model
- Assumptions made regarding trip chains.

The last version of the model takes further aspects into consideration related to aspects that affect traffic flow and speed such as congestion, road curvature and queue times.

Data required (input). The main data sources are similar to those described in the NTM. **Data on travel habits and choices** (survey based) is essential both as input data for estimating transport volume and patterns as well as for calibrating estimations of RTMs. Due to its key role in transport analysis, we have dedicated section 4 to this type of data. **Data** on **transport standard** or **'level of service'**, which describes accessibility to destinations with different modes of transport (in terms of travel times and travel costs). **Register data** to describe the basic statistical unit in terms of population, number of workplaces by industry, number of hotels, number of cabins, etc.

Information provided (output). The RTM produces tour matrices between all basic statistical units within each of the five regions (North, South, Mid, West, East) for five travel modes (car drivers, car passengers, public transport, bicycles and walking) and five travel purposes (commuting trips, work related trips, pick-up and delivery trips, leisure trips and other private travel). The RTM does not take into account that road users can also choose to switch travel time (not only itinerary) (Tørset et al., 2012).

The last version of the model includes an independent module to calculate energy use and emissions from any type of vehicle.

Sub-area models (DOMs)

These models are developed and adapted from the RTM and its model area is significantly reduced but can lie across regions (VD, 2018a). The advantage of these models is that the analysis can focus on a particular area, reducing the amount of calculation time required, and that this sub-area can be situated across two regions. On the other hand, it will require a great deal of work to adapt the model to the area (VD, 2018a).

The RTM23+ model used in the Oslo region is an example of a sub-area model based on the RTM (Kwong, 2018). Rekdal (2007) describes the work done to establish RTM23, while Rekdal & Larsen (2008) provide a description of the work done to develop this beta version into RTM23+. RTM23+ covers the counties of Oslo and Akershus, as well 19 municipalities (or 800 basic statistical units) in the four surrounding counties and produces 45 matrices for different travel purposes and modes of transport (Rekdal & Larsen, 2008).

A recently published report (Voldmo et al., 2018) has documented the results of a PROSAM project that tested whether RTM23+ is able to model the impact of completed transport projects and make estimations that reflect observed changes in traffic volumes and habits between 2007 and 2014. The report shows that the model manages to reflect main trends in this period, i.e. that the number of trips with public transport has increased more than the number of car trips. However, results also show some discrepancies between modelled and observed values in both the reference (2014) and the base year (2007) regarding modal shares and the number of trips with public transport outside the municipal area. Furthermore, the report shows that the most important driving force for changes in travel demand during this period was population growth, whereas single transport measures (e.g. Nøstvedt tunnel, Kolsås subway line) explain the least and their effects are mainly limited to their influence areas (Voldmo et al., 2018).

7.2.1.2 Tactical and operational models

AIMSUN (and CONTRAM)

Tørset et al. (2012) provide a description of Aimsun, which substitutes Contram. Aimsun estimates traffic flows for different types of vehicles (light-weight vehicles, heavy vehicles, busses) on hourly, half-hour and quarter-time resolution. At the meso level, the analysis area can be a city, town or neighbourhood (e.g. to assess the effects of the development of new areas). The micro version of Aimsun can be used for more detailed studies of traffic flows and congestion on road junctions and smaller areas (e.g. a street, lanes). The model

provides a digital map that allows for animations showing the geometry of the road network, improving thus user-friendliness.

The demand matrix is not calculated by Aimsun and must be determined in advance and fed as input in the model. This data can be provided by traffic counts, processed demand matrices calculated by RTM representing an estimation of today's traffic situation, or a combination of both.

Car passengers, motorcyclists, cyclists and pedestrians are not represented in the model, but pedestrian flows and behavior can be considered by connecting Aimsun to another module called Legion. This module allows for encoding a pedestrian network and entering pedestrian matrices. The transport network is encoded using Elveg data adapted to the model which includes data on speed limit, lane and inclination. Aimsun estimates speed more accurately than Contram because it includes inclination rates. Nevertheless, emissions are not accurately estimated because it does not take into account the effects of driving up the slope. Parking may be included in the model if the define parking zones and enter traffic flows from/to them, but street parking cannot be modelled.

VISSIM

VISSIM is an operational model or microscopic network assignment package that estimates traffic flow dynamics on network sections while considering route choice exogenous, i.e. local traffic dynamics, for instance at intersections or on freeway stretches, that do not allow for a route choice (Flügel et al., 2014).

VISSIM has been, for instance, used by Rambøll on behalf of the Norwegian Public Roads Administration to simulate traffic flows on the E18 in Oslo and explore the alternative use of the right lane for public transport (Ramboll, 2018).

SIDRA

SIDRA stands for Signalised & unsignalised Intersection Design and Research Aid and is an operational model for estimating, comparing and assessing capacity and traffic flows at intersections (Rognlien, 2018). Together with Aimsun and Vissim, Sidra is among the most widely micro-simulation tools used in Norway (Kwong, 2018).

One of the advantages of the model is that users can adjust most conditions, so that the model can be adapted to reflect reality (Rognlien, 2018). SIDRA can model different categories of vehicles and provides estimates of capacity in various terms (Rognlien, 2018). It can, for instance, be used to estimate capacity of a signal system in terms of a. o. optimal runtime time, delay and queue length in each lane, etc (VD, 2007).

7.2.1.3 Supplementary and/or alternative models

The national and regional transport models are quite complex but, despite of it, do not cover all types of traffic equally well. The models reviewed are mainly designed to analyze the effects of measures on car-based mobility and on public transport (as a whole, without distinguishing across types of public transport). Walking and cycling are estimated in RTM, but the model disregards many factors that can influence choosing or not these transport modes. Congestion levels are also insufficiently taken into account. Moreover, they cannot account appropriately for effects of measures for pedestrians and cyclists on single stretches due to the size of the basic statistical units. Due to the limitations and the complexity of transport and traffic models described above, both supplementary and alternative (easier-to-use) models have been developed.

EFFEKT

EFFKT is a simple road selection model, which can be used for analyzing effects of changes that apply to small road networks and single road stretches. EFFEKT has also a module for analyzing effects of measures for pedestrians and cyclists (VD, 2018a).

INMAP

INMAP redistributes Statistics Norway's projections for population and employment at the municipal level to the basic statistical unit level, based on assumptions related to land use, so that the distribution of population growth reflects the expected land use development within municipalities. This output can be entered in RTM (Knapskog et al., 2018). According to Knapskog et al. (2018), INMAP's advantage is its relatively low use threshold, although it requires understanding a range of parameters and settings and how they interact with each other. Besides, INMAP redistributions are currently limited to historical growth series, land use plans and accessibility to key functions through the transport system (estimated by RTM) and assumes that the industrial structure remains unchanged (Knapskog et al., 2018).

TRENKLIN

Flügel & Hulleberg (2016) provide an overview of this elasticity model and its application. Trenklin models the effects of minor rail route changes such as an increase of frequency or a reduction of travel time upon the existing rail market, i.e. it does not estimate whether these changes lead to a modal shift (e.g. from car to rail) but how these changes affect the number and distribution of passengers across departures and between train stations for three different travel purposes.

The model considers the level of crowding / train capacity utilization and how this affects the passengers value of time and, thus, travel costs and it requires a detailed description of reference scenario, i.e. the rail service offer in terms of departure and arrival times, waiting times, frequency, train equipment per departure (seating and standing passenger capacity), rates, time and distance matrices between stations, distribution of desired arrival time.

Flügel & Hulleberg (2016) conclude that Trenklin is well suited for estimating the effects of minor and detailed route planning changes such as those aimed improving travel times and frequencies (which would not be captured in the RTM), but not to analyze major changes such as the deployment of new rail services or the opening/closing of rail stations, as the tool only considers changes pertaining the rail market and does not consider other modes and shifts between them.

RUTER MPM23

RUTER MPM23 is an easy-to-use, spreadsheet-based modelling tool that estimates travel mode shares (car drivers and passengers, walk, bicycle, train, bus and tram / metro) segmented by travel purpose, distance, and location/zones for Oslo and Akershus (Flügel et al., 2015). Input data in the model includes description of the transport offer / level of service, which is obtained from RTM23, as well as variables regarding car and driver's license holdings, access to free parking, access to entry parking and satisfaction with the public transport offer. Further explanatory variables include gender, season, trip distances and purposes (Flügel et al., 2015).

RUTER MPM23 can be considered as a simplification of the RTM as far as it covers a smaller geographical area and does not estimate changes in the number of trips, destination or route/time departure choices. On the other hand, MPM23 can be considered more detailed as it includes school trips, distinguishes between different types of public transport and models (although in a limited manner) satisfaction with public transport services. Both models focus on modelling weekdays, but the level aggregation / disaggregation of estimations and predictions differ (Flügel et al., 2015).

The model has undergone some improvements such as a finer segmentation of geographical zones, a better breakdown in rush and non-rush, the estimation of ticket type (periodic or single) with transport mode choice in a joint choice model, a distinction between tram and subway, and inclusion of 'park & ride' as an independent choice alternative (Flügel & Jordbakke, 2017).

STRATMOD

STRATMOD supplements traditional transport models, as it estimates the effects of measures in urban areas (e.g. location of homes and jobs, improvements in the public transport offer or the bike infrastructure, restrictive car measures, expansion of the public transport offer) on public transport, cycling and walking. It also captures the effects of changes in quality factors (e.g. crowding and delays in public transport, traffic congestion, accessibility and characteristics of the cycling network).

The STRATMOD model is developed as a strategic model that includes quality factors at larger zones, and with flexible choice of time values and price sensitivity. STRATMOD consists of three sub-modules: the zonal model, the financing model and the optimization model. Data fed into the model includes data from the RTM, survey-based data and public transport data to estimate congestion and delays.

ATP model

ATP stands for Areal and Transport Planning and the ATP model is both a method and tool to analyze the relationship between land use and transport. The ATP model is a GIS based planning tool that estimates potential traffic (number of trips for pedestrians, cyclists, users of public transports and motorists) based on data from the NTS and on detailed data on the transport network and the location of dwellings, businesses and workplaces[28]. This tool allows for conducting three types of assessments:

- In location analysis the model can be used to estimate the accessibility of users to selected parts of the city, so that planners can assess the consequences of placing housing, business areas, services and facilities for people's accessibility (measured in travel time), transportation needs (measured in travel distance) and travel choices.
- In transport services analysis the model can be used to assess the consequences of transport (e.g. new roads, changes in the capacity of public services) for peoples' accessibility to key destinations.
- In traffic analysis the model estimates traffic flows on the network between certain sites and facilities, such as the number of school trips to a certain school, work trips to specific workplaces or shopping trips to particular shopping malls. Such estimations can be used to assess the consequences of, for instance, changing the location or removing the parking lots of a particular business for employees' commuting trips.

Activity- or agent-based models

Activity-based models differ from traditional four-step models travel demand models. While traditional four-step models are based on zonal attraction, activity-based models are based on the assumption that travel is undertaken in order to perform activities in different locations, and these models, thus, predict activities and their associated locations (Flügel et al., 2014). A further difference (related to the former) is that traditional four-step models are trip-based and static (i.e. "*they predict the rate at which individuals travel from each origin to each destination by each considered mode (…) per time slice*" (Flügel et al., 2014, p. 12), while activity-based models are dynamic, all-day based and, therefore, are better suited to account for trip sequences and temporal dependencies. Moreover, activity-based travel demand models apply generally at the micro level, generally account for uncertainty, and consider heterogeneity (Flügel et al., 2014). Example of such models are DaySim and MATSim (Multi-Agent Transport Simulation).

7.2.2 Application areas of existing models

Transport and traffic models can be used for a series of purposes. They can be used to show the effects of single transport projects (e.g. toll pricing, new infrastructure), transport strategies (e.g. improvement of public offer) and/or demographic changes (e. g. population forecasts) on transport demand at a national,

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[28] Description based on http://www.atpmodell.no

regional or local level; to estimate reference paths for transport development; and to compare effects of different measures in order to prioritize among them (JBV & SVV, 2013). Transport and traffic models can also be used to assess the broader impact of transport projects (VD, 2018a); to provide data for socioeconomic analysis (JBV & SVV, 2013); to inform urban development strategies (VD, 2018b); and to assess the effect of transport measures and instruments for the climate (Madslien & Kwong, 2015).

That being said, there is no model that is good for all types of analysis and assessments. Whether we choose a strategic, tactical or operational model will depend on the spatial and time scope of the analysis. The Norwegian Public Road Administration's Handbook on impact analysis (VD, 2018a) suggests the use of different transport analysis tools depending on the type of project and expected effects (e.g. changes in the number of trips, destination, travel mode, route) and the type of data and models that are available.

For a transport project on a single link that does not affect the traffic volume and pattern, it is suggested to use traffic registrations of simple road selection models such as EFFEKT. This is also suggested for projects applying to small road networks in which only limited and simple itinerary changes are expected. If the transport project applies to a larger road network that can lead to complex changes in route choices, then it is suggested to use transport models with fixed vehicle matrices such as Aimsun, RTM or NTM, depending on the area affected. For changes in the transport system that are expected to affect travel patterns (i.e. changes in the number of trips, destination and travel mode choice), then it is suggested to use a transport model with action-dependent transport pattern (RTM, NTM). For transport projects that expectedly affect location (and, thus, transport) patterns, there is no standardized method, but it is suggested to use RTM or NTM for partial analysis (VD, 2018a).

Tørset et al. (2012) also provide some guidance on how to select the appropriate method and tool for carrying out urban transport analysis. Relevant questions to guide the selection include whether tools provide the degree of detail needed; constrain the level of deviation to one that can be accepted; allow for including relevant explanatory factors; as well as whether required data is available. According to Tørset et al. (2012), the time perspective of changes or measures (i. e. whether they are expected to have long-term or short-term effects) and whether measures are expected to lead to qualitative or quantitative changes are also important aspects to take into account when selecting the model. Tørset et al., (2012) suggest that changes such as land use changes, economic growth and changes in car accessibility require the use of strategic tools (e.g. RTM) because these changes will lead to changes in transport demand and patterns (ODs). However, if one expects only changes regarding time and/or route choices (but not on demand and patterns/ODs), tactical and operational tools can be appropriate, as these models depart from a given demand matrix. Sometimes the combination of both will be required (Tørset et al., 2012).

Sometimes it may also be appropriate to combine tools. However, coupling models is not straightforward as their structure may not be compatible (Flügel et al., 2014). In general, transport models show a good level of predictability for changes regarding variables included in the model and to compare effects of various measures (JBV & SVV, 2013). However, this only applies if we consistently employ the same model, as estimations across models vary (Flügel & Hulleberg, 2016).

7.2.3 Limitations of transport models

Transport models have limitations that may pose considerable challenges depending on level, scope and detail of analysis required. Although each tool has its own strengths and weaknesses, limitations can generally be resumed as follows:

1. Models are a **simplification of reality**. Depending on the degree of detail and amount of data, transport models will be suitable to illuminate more or less complex situations. Yet, models will hardly be able to account for all the interrelationships that apply in the real world and transport models do not take into

account all key variables affecting travel behavior and transport demand (JBV & SVV, 2013). There is a range of factors not included in models such as social, cultural and attitudinal changes, technological development, economic changes, new policies, climate change (JBV & SVV, 2013), and local conditions at the zone level (often at the basic statistical unit level) are usually limited to demographics, not business structure, activities, schools, etc. (Tørset et al., 2012).

For instance, the RTM fails to take into account certain types of travel purposes (school trips)[29] (JBV & SVV, 2013) and it takes into account only a limited number of variables that explain cycling and walking, although this should be improved in RTM4 (Tørset et al., 2012). As a strategic tool to estimate regional changes, the RTM does consider land use, but only in terms of number of residents and employees at the basic statistical unit level. This implies that RTM is not detailed enough to model the extent and distribution of short trips conducted within and between neighbouring zones (Dalen et al. 2016), as this land use description can hide variations within each zone. However, more detailed data may not be available and, if it is, there may not be good practices for effective data collection (Dalen et al. 2016).

2. Models **predict poorly many of the relevant conditions and changes** influencing transport and travel behavior, **even if they are included in the model**. (e.g. parking fees, toll fee, fuel charges and public transport prices.). This can be due to a lack of/inaccurate data about variables that affect the choice of destination and travel mode. One example is lack of good data on parking standards and access to parking (Dalen et al., 2016). A further reason for poor predictions is that models usually rely on assumptions based on previous experiences and historic trends and, thus, do not allow for handling unexpected changes in variables considered in the model (JBV & SVV, 2013). This was the reason for conducting Metode 21, a project whose aim was to suggest supplementary methods that are better suited to account for uncertainty and changes that may have important consequences, even if they are unlikely to happen. According to results from the project, methodological approaches that allow for creativity include scenarios, wild cards, weak signals, qualitative interviews and expert panels (JBV & SVV, 2013).

3. Models still allow for a **low level of iteration**. Although transport models have increasingly become more iterative, there is still room for improvement, especially what land use concerns. Land is treated as an exogenous variable, i. e. the current land use affects the outcome of the model, but the model does not take into account that changes in estimates could affect future land use (Dalen et al., 2016; Tørset et al., 2012).

4. Linked to the above, models are mostly **constrained to cross-sectional assessments**. The use of cross-sectional data does not allow to take into account longitudinal series (JBV & SVV, 2013).

5. The large majority of **models are quite complex** and this can be a considerable barrier that constrain models' use and application. Increased complexity can reduce transparency and usability, and it demands a considerable amount of resources (in terms of knowledge and time) (JBV & SVV, 2013). Although urban growth agreements have fostered cooperation across stakeholders, have improved skills on transport modelling, and have led to some changes regarding how land use is considered in regional transport modelling, data from interviews and experiences shows that many municipal and county planners have still little knowledge on transport models and are reliant on the Norwegian Public Roads Administration to use them and are skeptical to use them and the results they provide (Hagen et al., 2018).

6. Further limitations include the **large amount of data** (Kwong, 2018) and **computing power** (JBV & SVV, 2013) required by transport and traffic models, but this may vary across models. According to Flügel et al. (2014), estimating traffic assignment and travel times in congested urban areas requires coupling adjusted static and macro travel demand models or agent-based models with dynamic meso and microscopic

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[29] RTM does not model school trips in the models for 'choice of mode and destination' because RTM does not include a description of this type of school transport, although it estimates the number of school trips (Madslien et al., 2005)

network assignment packages. However, this requires larger amounts and more detailed/disaggregated data than estimating increases in travel demand derived from e.g. population growth (Flügel et al., 2014).

7.3 Guidelines to estimate trip generation by type of building

Other tools used in transport estimations and analysis are guidelines to estimate trip generation. Key sets of data in these estimations are travel and register data. The basic principle is to link geo-located travel data (e.g. NTS) with registry data (e.g. the Cadastre) to calculate the average number of trips produced and the modal shares associated to, e. g. certain residential areas, workplaces, commercial facilities. These guidelines and key figures can be used either to estimate trip generation and modal shares in new developments or as a departure point to replicate the method and calculate adjusted figures.

Meland (2005) conducted a literature review to provide an overview of the use of trip generation figures and of the methods for mapping and collecting them. The review shows that at that time the use of trip generation figures in traffic calculations was only mentioned in a few sources. Among them, Meland (2005) highlights the 'Trip generation' report and handbook published by the Institute of Transport Engineers and a PROSAM report, which illustrates how to calculate and use trip generation figures related to workplaces and shopping centres.

According to Meland (2005), the **'Trip generation' report and handbook** published by the Institute of Transport Engineers (**ITE**) were a good starting point for establishing and systematizing a method and elaborating a trip generation report. Since then, the ITE has published several editions of the 'Trip Generation Manual' and deployed a web-based tool to estimate site trip generation[30], all of which can be purchased on the institute's website. The 10th Edition includes the web-based app, updated manuals and data and the 3rd edition of the 'Trip Generation Handbook' which, a. o. provides techniques for estimating person and vehicular trip generation rates, as well as guidelines for the evaluation of mixed-use developments and the establishment of local trip generation rates (ITE, 2018).

PROSAMs report seems especially relevant, since this chapter focuses on describing tools that are used and applicable to Norway. **PROSAM** was established in 1987 and stands for 'Cooperation for better traffic forecasts in the Oslo area' (PROSAM, 2018). PROSAM develops and maintains a database and forecasting tools that allow users to calculate transport and traffic consequences of road, public transport and land use changes. Besides the report reviewed by Meland (2005) to estimate trip generation figures associated to workplaces and shopping centres (report no. 103/2003), PROSAM has also published reports on how to estimate and use trip generation figures for grocery stores (rapport no. 121/2005), dwellings (no. 137/2006) and areal-intensive commercial concepts (no. 167/2008). Several publications on a. o. traffic counts, travel surveys, forecasts, model evaluations, as well as links to relevant databases and statistics are provided on PROSAM's website (PROSAM, 2018).

Due to the scope of this project, it is especially relevant to deem some attention to **PROSAM's report on trip generation for dwellings** (Hanssen & Engebretsen, 2006), which describes a method for calculating trip generation.

Car trip generation figures are calculated by running logistic regression analysis on travel data (provided by National Travel Survey conducted in 2001, as well as by local surveys in two of the four study areas) linked to register data describing the residential areas in terms of location (distance to Oslo centre and other centres), availability and standard of public transport, socioeconomic conditions (household size and income) and land-use (density and land use mix). The dependent variable of the regression model is the likelihood of traveling as a car driver. The model for car traffic generated by residents consists of two models: one for weekdays and one for weekends, while there is only one model for visitor traffic. Based on the coefficients

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[30] Available at https://itetripgen.org/index.html

obtained from the regression analysis, tables are produced that show the number of expected car trips given different dwelling and settlement categories. Categories are constructed based on the explanatory variables, i. e. conditions such as location, land use, distance to public transport and household size. Both estimated car trips and categories are provided in intervals. Next figure reproduces a table published in the report (Hanssen & Engebretsen, 2006, p. 3).

Beregning av bilturproduksjon for boligområder
Antall bilbevegelser per hushold (sum til/fra). Gjelder for mandag-fredag. [1) 5)]

Km fra Oslo sentrum [2)]	Bebyggelse [3)]	Personer i husholdet [4)]			
		1 person	2 personer	3 personer	4 personer
0-2,4 km	Høy tetthet/urbant	0,7 - 1,2	1,5 - 2,7	2,3 - 4,1	2,9 - 5,0
	Middels tetthet/urbant	0,9 - 1,3	2,1 - 2,9	3,1 - 4,3	3,9 - 5,3
2,5-4,9 km	Høy tetthet/urbant	0,7 - 1,2	1,6 - 2,7	2,4 - 4,0	3,1 - 5,0
	Høy tetthet	1,2 - 1,4	2,5 - 3,0	3,8 - 4,4	4,7 - 5,4
	Middels tetthet/urbant	1,0 - 1,4	2,3 - 3,0	3,4 - 4,5	4,2 - 5,5
	Middels tetthet	1,2 - 1,6	2,7 - 3,5	4,0 - 5,0	4,9 - 6,1
	Lav tetthet	1,3 - 1,6	3,0 - 3,5	4,4 - 5,1	5,4 - 6,1
5,0-9,9 km	Høy tetthet/urbant	0,8 - 1,4	1,6 - 3,0	2,4 - 4,4	3,0 - 5,5
	Høy tetthet	1,1 - 1,5	2,3 - 3,3	3,5 - 4,8	4,3 - 5,9
	Middels tetthet/urbant	1,0 - 1,5	2,3 - 3,3	3,4 - 4,8	4,2 - 5,8
	Middels tetthet	1,3 - 1,7	2,8 - 3,7	4,1 - 5,3	5,0 - 6,4
	Lav tetthet/urbant	1,3 - 1,5	2,8 - 3,3	4,2 - 4,8	5,2 - 5,9
	Lav tetthet	1,4 - 1,7	3,0 - 3,8	4,4 - 5,5	5,4 - 6,6
10-19,9 km	Høy tetthet/urbant	0,8 - 1,4	1,7 - 3,2	2,6 - 4,7	3,2 - 5,7
	Høy tetthet	1,2 - 1,6	2,6 - 3,6	3,8 - 5,2	4,7 - 6,3
	Middels tetthet/urbant	1,0 - 1,7	2,3 - 3,7	3,4 - 5,3	4,2 - 6,4
	Middels tetthet	1,4 - 1,9	3,0 - 4,0	4,4 - 5,7	5,4 - 6,9
	Lav tetthet/urbant	1,2 - 1,7	2,8 - 3,8	4,1 - 5,4	5,1 - 6,5
	Lav tetthet	1,4 - 2,0	3,2 - 4,3	4,6 - 6,1	5,7 - 7,3
20km +	Middels tetthet/urbant	1,4 - 1,9	3,0 - 4,1	4,4 - 5,8	5,4 - 6,9
	Middels tetthet	1,6 - 2,4	3,4 - 5,0	4,9 - 6,9	5,9 - 8,1
	Lav tetthet/urbant	1,4 - 2,4	3,0 - 4,9	4,5 - 6,7	5,5 - 7,9
	Lav tetthet	1,6 - 2,7	3,5 - 5,4	5,1 - 7,4	6,2 - 8,6

Figure 7.3.
Example of trip generation figures provided in Hanssen & Engebretsen (2006, p. 3)

Automatic field traffic counts are used to account for traffic related to deliveries of goods, supplies, services, health personnel, etc. These traffic counts are adjusted to exclude traffic that is not linked to the residential areas but may be due to services located near them (e.g. kindergarten).

According to the report, the advantage of the method is that data can be updated, expanded and improved. A drawback is that, as travel data is insufficient to account for traffic generated by non-residents, traffic counts are required. Further limitations of trip generation figures are related to the challenges to link travel data to register data, as well as to the further use and interpretation of estimated trip generation figures. Meland (2005) indicates that little attention has been given to assess how estimations' variation can affect decisions (and what implications this may have), how accurate estimations should when these are to be used in planning process, and how often estimations and data, upon which they are based, should be updated.

A further guideline to estimate trip generation figures is the handbook published by the Norwegian Road Authorities (VD, 2014). This handbook comprises a description of traffic estimations and presents methods to describe traffic on the network and on certain points of it, as well as to calculate traffic generated from / to specific zones (trip generation). It presents three methods to estimate the number of trips generated:

historical figures, regression modelling and category analysis modelling. Based on historical figures, the handbook suggests figures for trips generated by dwellings, industrial areas, shopping and offices.

7.4 The National Travel Survey (NTS)

As the review has illustrated, travel data is a key input to transport models and tools as well as for calibrating transport models. Although automated traffic counts are useful in mapping transport flows on different transport modes, links and nodes, they do not say anything about the travel motivations and very little about the trips characteristics (e.g. start and end points, stops underway, travel party) and the travellers themselves (e.g. residence, age, gender, income, etc.).

The most comprehensive source of travel data in Norway is the National Travel Survey (NTS). The first NTS was conducted in 1985 and, since then, seven NTS have been completed (Hjorthol et al., 2014). The eighth NTS is currently ongoing, and it differs mainly from previous NTS in form and periodicity. The first seven NTS were conducted in time intervals of seven (1985, 1992), six (1998), three (2001) and four (2005, 2009, 2013/14) years and, with the exception of 1985, during which data was collected in face-to-face interviews, data was collected through telephone interviews (Hjorthol et al., 2014). Since 2001, respondents have received a letter per post before being interviewed providing some information on the survey and a diary, in which they could register their daily trips for a given date (Hjorthol et al., 2014). This diary has been removed from the currently ongoing NTS (2016-2019). The NTS (2016-2019) started in 2016 and, contrarily to previous NTS, it is a continuous survey, i.e. data is collected continuously. A further major change introduced in the ongoing NTS is that respondents are given the opportunity to complete the survey online. If they do not so, they are contacted by the interview company and asked to complete the survey by telephone.

The purpose of the NTS is to collect data that can be used to describe the Norwegian population's travel habits (i.e. residents with a registered address in Norway). A sample of residents in Norway who are 13 years of age or older is randomly drawn from the National Population Register. Results are used in national and regional transport planning; to develop transport models, which are used to estimate the consequences of various transport measures; and further research (TØI, 2018).

Respondents are asked a series of questions pertaining both individual and households' characteristics, as well as their travel choices and habits on a given day. Data collected on these questions are key inputs for transport models to estimate travel frequency, destination and mode choices. Questions on individual characteristics include a. o. questions on respondents' age, gender, household structure, access to car and other transport resources, income, employment situation and workplace location. Questions regarding travel choices and habits include questions on the number of daily trips (if any), mode of transport selected, trip purpose and destination, as well as on the characteristics of the trips (e.g. whether the trip was integrated by several legs and (if so) its sequence, whether the respondent travel alone or with other travel companions, etc.). The questionnaire also includes a section comprising retrospective questions on long distance travel (including questions on whether the trip implied staying overnight), because it is difficult to capture these sort of trips, as they make up a very small share of daily travel (i.e. they are trips that do not take place frequently and the probability of respondents having had such a trip is low). A copy of the questionnaire employed in the last completed NTS (2013/14) is provided in the annex for a more detailed insight into the type of data collected. Since 2001, significant efforts have been made to geo-locate start and endpoints for travel, residence and workplaces (Hjorthol et al., 2014). The methods for geo-locating have been constantly improved and expanded to include other information collected in the survey (e.g. since 2013/2014 public transport interconnections have also been geo-located) and access to register and geographical data. These improvements are very important because it provides a better basis for the development of transport models and enables more detailed geographic analysis.

The NTS is usually enhanced by supplementary regional surveys conducted among regional population sub-samples commissioned by transport and regional authorities, which are especially interested in mapping travel habits and choices of their residents. In the currently ongoing NTS (2016-2019), supplementary surveys have been commissioned, a. o., to follow up key indicators of urban development agreements signed between local authorities and the national government to achieve the zero growth goal[31]. Supplementary travel surveys largely collect the same type of data as the NTS, but they may exclude and/or include certain types of questions. Supplementary surveys typically exclude questions pertaining long-distance travel, and include other questions to collect data on special variables of interest.

7.5 Discussion and concluding remarks

This chapter has reviewed some of the most utilized tools and models in Norwegian transport planning. As previously said, there is no 'good-for-all-purposes' tool. The selection of models will mainly depend on the type of project and changes (quantitative, qualitative) being assessed, the expected effects (time and geographical perspective), the type of data available and the degree of detail and accuracy needed from estimations (Tørset et al., 2012; VD, 2018a). In this last section, we aim to discuss whether the reviewed tools and models are appropriate to estimate the energy embedded in transport generated by future dwellers of new developed settlements.

A new residential development will likely lead to changes in the number of trips between zones. Strategic models seem, thus, in general more appropriate to estimate these trips than operational and tactical ones, although the later may be relevant to, e.g. assess how to link the new residential development to the existing transport network. Within existing strategic models, the RTM seems to be the most relevant because we are interested in estimating daily travel and not long-distance travel. The RTM can also be applied to a particular area of interest such as an urban area (e.g. DOM-Ager, DOM-Bergen, etc.). The advantage of using a DOM is that it has fewer zones than the RTM, which makes it faster and easier to use. Another alternative is to use guidelines for calculating trip generation figures associated to that residential development, given certain values for each of the relevant explanatory variables.

We argue that these tools only to a limited extent allow planners to estimate the energy embedded in transport generated by future dwellers of new developed settlements and – at any case – their use would require a considerable amount of resources and knowledge from those interested in calculating these figures. In the following we substantiate this conclusion.

First, a newly developed residential area implies likely a change in land use. Strategic models allow for estimating the effects of land use changes on transport volumes, travel mode and destination choices and traffic distribution, but only to a limited extent. The RTM will model an increase in the number of trips generated given an increase in the number of residents, but trip distribution (ODs) will not change as long as land use changes are not entered manually in the model (Knapskog et al., 2018). Moreover, the RTM only considers certain land uses (in terms of residents, workplaces) and, thus, underestimates the traffic generated to certain areas that may have a low number of jobs but still manage to generate a lot of visits such as shopping malls (Knapskog et al., 2018). This may be especially relevant in the case of new residential development projects that envision the construction of associated facilities and services that can attract many visitors/non-residents. There are relevant data sources that could be used to assess the attractiveness of a zone in order to provide more accurate traffic estimates, but their use requires further standardization. A further possibility is to use guidelines described in section 3 to estimate trip generation figures associated to new residential areas, but estimates will likely greatly vary from case to case and need to be adjusted. Although the ATP model can incorporate the relationship between land use and transport by adding a new

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[31] With this goal the Norwegian National Government establishes that the growth of passenger transport in Norwegian metropolitan areas is to be taken by public transport, bicycle and walking, i.e. that there is no increase in car passenger travel, despite expected population growth. (Miljøverndepartementet, 2012).

layer, it does not estimate travel demand between zones. As a GIS-based tool, it rather allows for visualizing a range of conditions such as the shortest route between two points, the average travel times to a certain location; traffic flows on the network; transport needs of different locations; how far one can travel from a particular location with different transport modes given a certain travel time (and how far one can travel from a particular location given different travel times) and/or how many users live or work within a certain area surrounding a particular location/transport facility (catchment area).

Second, models – including the RTM – leave aside a range of relevant explanatory factors. A recently published report within this project (Landa-Mata et al., 2018), illustrates that there is enough evidence of the importance of several urban structure factors for travel behavior. They broadly include distance from the dwelling to the city center, parking availability and pricing, densities, land use mix, public transport standards, as well as workplace location. However, the RTM only takes into account certain land uses, a limited number of factors describing public transport standards and parking, as well as issues (e.g. congestion) that affect the level of service and the attractiveness of public transport vs. car use.
A third aspect that limits the use of existing transport models and tools to estimate traffic generated by future dwellers in newly developed residential areas is that they hardly account for preferences and attitudes (beyond car ownership). The type of dwellings and associated infrastructure (including that at the micro level) will probably play a key role in determining who will live in these areas. These dwellers have lifestyles, as well as preferences and attitudes towards transport that may influence mobility needs and travel choices. Supplementary tools such as scenarios, wild cards and weak signals can enhance transport models in this respect, as they stimulate the ability to fantasize, imagine and develop new ideas, making prognostic assessments, and dealing with unexpected changes and consequences (JBV & SVV, 2013).

Fourth, existing models may not be detailed enough to estimate traffic generated and modal shares because the basic statistical unit of analysis employed may hide variations at a more disaggregate level (Dalen et al., 2016). This may also apply in cities, even if the size of the 'basic statistical unit of analysis' is smaller than elsewhere. Dalen et al. (2016) investigate whether a more detailed categorization of land use can improve transport estimations. For this, they test the effect of a range of land-use indicators (table 7.1) on transport volumes (number of trips), mode choices and duration of short trips by conducting simple and multiple linear regression on travel data collected by the NTS and RTM estimations. Regression results are compared for the number of trips and travel mode distribution and further regression analysis is additionally conducted to find what explains differences between NTS and RTM mode distribution estimations. Based on results, Dalen et al. (2016) conclude that although the RTM has appropriate land use variables (number of jobs and residents) to estimate the number of trips at the basic statistical unit level, estimations could be enhanced by adding job density (number of jobs per decare) and centrality indicators (population within a 2500-meter radius). Centrality and density variables could also help to provide higher accuracy of RTM estimations on modal share, and especially on car and walking shares. The difference in car and walking shares between NTS and RTM are explained by variables such as the population within 2500 m and 1000 m radius and the number of residents and jobs per decare. The difference in cycling shares between NTS and RTM is explained by centrality indicators, although there are also important regional differences. There are no differences in public transport shares between NTS and RTM and this indicates that the selected land-use indicators do not improve public transport shares estimations. Last, although selected explanatory variables explain little of the variation in the duration of short trips, inclusion of centrality, density and road network indicators increase the variance explained by the regression model.

Table 7.1
Explanatory variables and indicators tested by Dalen et al., (2016)

Land use factor	Indicators
Population and job densities	Population in the 'basic statistical unit' Population per decare of residential area Workplaces in the 'basic statistical unit' Workplaces per decare of workplace area Number of jobs in retail in the 'basic statistical unit' Number of residents and jobs per decare of residential and workplace area Number of jobs per resident
Geometric shape of the built up area	Compactness, residential area Compactness, workplace area Compactness, residential and workplace area
Interconnections of the road network	Number of cross arms (intersection) per decare of residential area Number of cross arms (intersection) per decare of workplace area Number of cross-arms (cross-country) per decare of residential and workplace area Total road length per decare of residential area Total road length per decare of workplace area Total road length per decare of residential and workplace area
Centrality measures	Distance (along the network) from the 'basic statistical unit' center to the nearest municipality center Population within 2500 m radius from the 'basic statistical unit' population gravity center Population within 1000 m radius from the 'basic statistical unit' population gravity center

Also, Strand et al. (2013) estimate and compare the transport consequences of different geographical distributions and concentrations of an expected population growth of 32 percent by employing different methods and models: the sub-regional model RTM23+ and a model they developed based on travel data collected by the NTS in 2009 coupled to register data at the basic statistical unit level[32]. The different geographical distributions and concentrations of this growth are depicted by a range of scenarios that can briefly be summarized in three main scenarios: 1) continuation of existing local plans, 2) concentration of new development to a few city areas and 3) densification in many local concentrations.

Both methods produce similar results and indicate that scenario 2, as expected, is the most favorable for reducing car use. This is also the alternative recommended in Oslo and Akershus regional land use and transport plan (Akershus Fylkeskommune & Oslo Kommune, 2015). Results from the RTM23+ show that, in Oslo, scenario 2 would imply the lowest number of car trips. In Akershus, there are almost no differences in the estimated number of car trips between scenarios. Strand et al. (2013) attribute this to the demand model of RTM23+ as well as to the lower level of concentrations in Akershus, as compared to Oslo center. Scenario 2 would also lead to higher number of walk trips, although differences for this indicator between scenarios are smaller than when estimating the number of car trips. Similar can be said on modal share distributions. Scenario 2 would, according to estimations made by the model, result in lower car use in Oslo, with less

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[32] This work served (among others) as basis for the regional areal and transport plan for Oslo and Akershus (Akershus Fylkeskommune & Oslo Kommune, 2015).

clear results for Akershus. Scenario 2 would also contribute to the largest reduction of travelled distances by car in both Oslo and Akershus.

The model developed by Strand et al. (2013) to assess the probability of choosing the car for travelling from/to the dwelling and the number of car trips includes similar indicators as those used by Dalen et al. (2016) and some of the studies reviewed in Landa-Mata et al. (2018): local density of population and jobs, distance to city centre, public transport service, and other contextual indicators, supplemented with socioeconomic and demographic indicators.

Last, EE Settlement is mainly interested in the energy embedded in the transport generated by dwellers in the new developed residential areas. SINTEF has recently developed an independent model for estimating the speed, energy use and emissions of any type of road based vehicle (Hjelkrem et al., 2017). The model takes into account road (e.g. width, curvature), vehicle (e.g. fuel, weight, resistance) and driver (e.g. acceleration) properties, as well as traffic flow conditions and speed (Hjelkrem et al., 2017). This energy model has been implemented in the last RTM version by incorporating it into the CUBE user interface. By doing so the energy requirement of the traffic estimated by the RTM can be calculated. However, experience with the use of this energy model is still scarce. Moreover, these calculations may not be straightforward and easy to conduct for planners and developers. There are still barriers that constrain the use of transport models (Hagen et al., 2018) upon which these energy modelling calculations would be applied.

Based on these arguments, we conclude that, although models reviewed have proven to be useful in transport planning analysis, they are too complicated and (yet) insufficient to assist municipal planners and developers to estimate the energy embedded in transport generated by dwellers of new housing settlements and, thus, to help them prioritize where and under which conditions new housing should be developed. Guidelines to calculate trip generation figures may be more flexible with regards exclusion/inclusion of explanatory variables to use. However, this flexibility also challenges their ability to compare estimations.

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8 Concluding remarks

The results from this study shows that there are relevant tools with different possibilities and limitations that has been used by different decision makers. Most of the tools are often developed for the evaluation of single sites, specific buildings and/or infrastructure using selected indicator (e.g. GHG emissions) and operate on a very detailed level. Some of these tools are developed following relevant national and international standards with clear description of the methodological choices considered. Only few spatial planning and/or scenario planning (with integrated scenario approach in spatial planning) tools are available that can be used for planning new settlements. The methodological choices and system descriptions used in the aforementioned tools, such as ZERsiedelt (Chapter 2) and ELAS (Chapter 3), are of great importance for the development of a tool in EE Settlement. It is also important to consider the possibility of integration of detail-oriented tools, such as ZEB tool as input parameter for the tool development in the project.

Furthermore, the following recommendations can be made for further work during the tool development:
- Compliant with relevant national and international standards
- Transparency of the background data and the methodology used, easy to understand the results including with a possibility of detecting potential errors
- Flexibility for easy data input, consider different scenarios and easy to keep the databases and tool updated
- User friendliness to different user group
- Third-party verification, if possible, to assess the quality of the tool

The results from the evaluation of tools used to conduct passenger transport analysis shows a range of tools that can be used from visualizing the impact of specific measures on traffic flows to providing information for more comprehensive impact analysis of large and complex projects. The evaluation of whether these tools enables to calculate the energy embedded in transport generated by individuals that settle down in new developed residential areas identified the following limitations which needs to be considered in further work: a) only some of the tools are found that can be used for estimating the effects of land use changes on transport volumes, travel mode and destination choices and traffic distribution to a limited extent. b) existing models may not be detailed enough to estimate traffic generated and modal shares. c) preferences and attitudes as well as certain socio-economic characteristics (e.g. education), that may influence mobility needs and travel choices, are not incorporated in the transport models. Further data collection, standardization of databases and testing new relevant indicators is needed.

Annex A: Calculation example from the ELAS calculator

The ELAS (Energetic Long term Analysis of residential Settlement structures) calculator is described in Chapter 3 of this report, "Background: ELAS project (Austria)". In this annex, a calculation example of the city of Freistadt in Upper Austria is presented. Using the municipality mode, also planning options are included in the calculation example. Planning options are highlighted in grey (background). The example consists of four multi-storey buildings with a total living area of 7,966 m². Based on the As-Is-Analysis, 1000 m² of living space was added. Mineral insulation was added to the already existing building and was also used for the building additions. The number of households increased from 109 to 119, hence the number of residents from 237 to 263. Also, the provision of space heating and hot water was changed (space heating 100 % biomass and hot water 80 % biomass + 20 % solar thermal). All the data input is presented in the following section.

Data input

Site-specific Data			
Site			
Nation	**Austria**		
Federal state	**Upper Austria**		
District	**Freistadt**		
Municipality/city	**Freistadt**		
Municipal index (MI)	**40601**		
Inhabitant information			
Inhabitants of town/city:	**7,421**		
Inhabitants of the district:	**64,862**		
Degree of centrality			
Degree of centrality	**4**		
Distance to degree of centrality 5	**40.00**		km
Electricity			
Total electricity consumption of households	**256,150.00**		kWh
Own electricity production	**0.00**		kWh
Buildings and Households			
Building period 1981 - 1990			
Building type	**Multi-storey building**		
Building standard	**-**		
Number of buildings	**4**		
Total living area	**7,966**		m²
Area building site	**0**		m²
Already renovated	**-**		
Number of households	**109**		
Number of residents	**237**		
Age distribution (below 15 / 15 - 29 / 30 - 59 / over 60)	**39 / 49 / 102 / 47**		
Energy performance indicator	**62.00**		kWh / (Year · m²)
Total space heating demand	**493,892**		kWh / Year
Provision of space heating	**Natural gas**	**100**	%
Hot water demand per person	**1,000.00**		kWh / Year
Total hot water demand	**237,000**		kWh / Year
Provision of hot water	**Natural gas**	**100**	%

Planning options

Renovation (insulation)	Mineral insulation		
Demolish building	No		
Additional living space (building additions)	1000 m2		
Insulation of building additions	Mineral insulation		
Number of households	119		
Number of residents	263		
Age distribution (below 15 / 15 - 29 / 30 - 59 / over 60)	40 / 49 / 114 / 60		
Additional electricity consumption	25,183		kWh
Energy performance indicator	25.00		kWh / (a*m2)
Total space heating demand	224,150		kWh / a
Provision of space heating	District heating (Biomass)	100	%
Total hot water demand	263,000		kWh / a
Provision of hot water	District heating (Biomass)	80	%
	Solar thermal	20	%

Municipal Services and Infrastructure

Road network

Internal development (municipal road)	**350**	m
Additional internal development (municipal road)	**0**	m
Internal development (secondary road)	**0**	m
Additional internal development (secondary road)	**0**	m
Distance to center of town/city (total)	**0**	m
External development (municipal road)	**0**	m
External development (secondary road)	**0**	m

Road service

Road cleaning	**3**	Tours / Year
Mowing and trimming	**4**	Tours / Year
Snow removal	**20**	Tours / Year
Sanding	**15**	Tours / Year
Snow pole setting	**2**	Tours / Year
Others	**0**	Tours / Year

Street lighting

Electricity consumption (existing)	**5,896.00**	kWh
Electricity consumption (additional)	**0.00**	kWh
Number of lighting devices (existing)	**22**	
Number of lighting devices (additional)	**0**	

Sewage treatment

Original amount of sewage per year	**30,449.76**	m^3
Additional amount of sewage per year	**3,340.00**	m^3
linked to sewer lines?	**Yes**	
Treatment plant	**central**	
Sewage treatment technology	**Three stage (mechanical, biological, chemical)**	
km sewer line from settlement to treatment plant (existing)	**2.80**	km
km sewer line from settlement to treatment plant (additional)	**0.00**	km
Electricity consumption sewer pumps (total)	**0.00**	kWh

Organised waste collection

Residual waste	**Yes**
Used paper	**Yes**
Plastic	**No**
Bio waste	**No**
Tree clipping, lawn clipping	**Yes**

Used glass	**No**	
Used metal	**No**	
Bulky waste	**No**	

Waste collection point		
Distance	**1.90**	km

Regional Economic Analysis (REA)

Construction of living space		
One family house – low energy	1,531.00	€
One family house – passive house	1,631.00	€
Row house – low energy	1,267.00	€
Row house – passive house	1,527.00	€
Multi-storey building – low energy	1,240.00	€
Multi-storey building – passive house	1,494.00	€
Re-construction of settlement		
Renovation – from 0 to low energy standard	265.00	€
Demolition – building waste removal	72.00	€
Operation of living space		
Residential heating		
Heating costs - pellets	**410.58**	€
Heating costs – wood chips	**68.75**	€
Heating costs – log wood	**112.24**	€
Heating costs – solar thermal	**120.75**	€
Heating costs – ground heat pump	**112.86**	€
Heating costs – electrical heating	**37.14**	€
Heating costs – district heating (biomass)	**103.95**	€
Heating costs – district heating (gas, waste, etc.)	**74.38**	€
Heating costs – natural gas	**0.81**	€
Heating costs – fossil oil	**1,143.44**	€
Heating costs – coal, coke	**615.91**	€
Elektricity		
Electricity costs - consumption in kWh	**0.18**	€
Cost saving for electricity – feed-in production	**0.38**	€
Municipal infrastructure operation		
Building		
Road construction – additional meters of road	**525.00**	€
Road construction – additional lighting points (default 20 per km of road)	**2,207.00**	€
Development costs – sewer, water, electricity	**400.00**	€
Operation		
Services – electricity costs lighting	**0.18**	€
Services – lighting maintainance	**27.70**	€
Services – road services	**2.08**	€
Services – road maintainance	**1.50**	€
Services – sewer operation	**2.02**	€
Waste removal-km – costs of tours	**0.41**	€
External Effects (mobility)		
Every day mobility		
Motorised individual transport – car, motor cycle-km	**0.51**	€
Public transport - train, bus ... - km	**0.11**	€
Leisure/vacation		
Motorised individual transport – car, motor cycle-km	**0.51**	€
Public transport - train, bus ... - km	**0.11**	€
Other transport - airplane-km	**0.15**	€

Results

Figure A1.1 shows a summary of results related to one year of the considered settlement. For the presentation of the results, the user can choose among various units (standard units: kWh, m^2 and kg). The summary on the right (grey background), shows the results of the settlement expansion based on the As-Is-Analysis and after the planning mode was completed by the user.

Figure A1.1
Summary of results related to one year (right side - planning based on As-Is-Analysis)

The following graphs display the detailed results of the calculations, divided into energy consumption, ecological footprint and regional economic effects. At the Result page of the tool, there is the possibility to create a print-preview of all the input-data and results. The calculations can be saved locally as an ELAS-file (*.elas) that can only be imported into the online-tool. In terms of energy consumption.

Figure A1.2 shows different areas/categories of origin (1) Space heating and hot water supply (2) Electricity, (3) Municipal services, (4) Every day mobility and (5) Leisure/vacation mobility. After the planning two additional categories, (6) Building measures and (7) Infrastructure expansion, are presented.
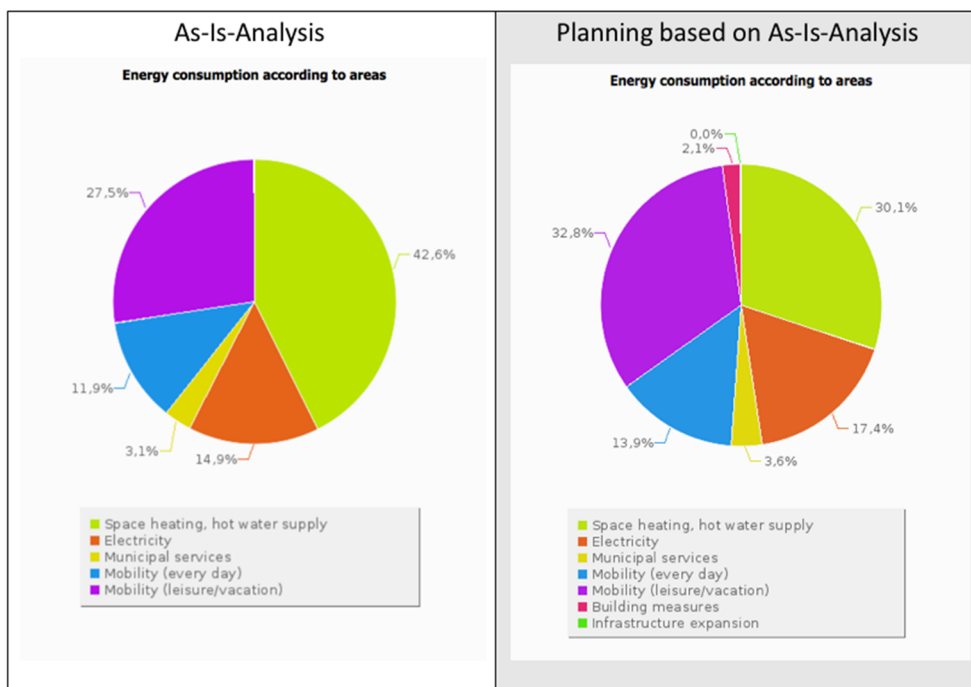
Figure A1.2
Energy consumption split into five categories/areas (As-Is-Analysis) and seven categories/areas (including results of the planning mode)

The ELAS-calculator also computes ecological effects that are caused by settlements. In Figure A1.3 and Figure A1.4 CO$_2$ life cycle emissions and SPI values are illustrated.

As-Is-Analysis		
Result area	**Result**	**Distribution**
Space heating, hot water supply	96,800 kg	18.7 %
Electricity	169,853 kg	32.8 %
Municipal services	14,880 kg	2.9 %
Mobility (every day)	67,991 kg	13.1 %
Mobility (leisure/vacation)	167,573 kg	32.4 %
Total	**517,098 kg**	**100 %**

Planning based on As-Is-Analysis		
Result area	**Result**	**Distribution**
Space heating, hot water supply	45,873 kg	8.6 %
Electricity	186,552 kg	34.9 %
Municipal services	16,083 kg	3.0 %
Mobility (every day)	75,279 kg	14.1 %
Mobility (leisure/vacation)	188,732 kg	35.3 %
Building measures	21,550 kg	4.0 %
Infrastructure expansion	0 kg	0.0 %
Total	**534,069 kg**	**100 %**

Figure A1.3
Presentation of CO2 life cycle emissions

As-Is-Analysis		
Result area	**Result**	**Distribution**
Space heating, hot water supply	51,440,179 m^2	33.5 %
Electricity	50,197,686 m^2	32.7 %
Municipal services	4,210,441 m^2	2.7 %
Mobility (every day)	14,349,387 m^2	9.4 %
Mobility (leisure/vacation)	33,152,888 m^2	21.6 %
Total	**153,350,581 m^2**	**100 %**

Planning based on As-Is-Analysis		
Result area	**Result**	**Distribution**
Space heating, hot water supply	11,839,162 m^2	9.1 %
Electricity	55,132,796 m^2	42.2 %
Municipal services	4,545,260 m^2	3.5 %
Mobility (every day)	15,891,739 m^2	12.2 %
Mobility (leisure/vacation)	37,338,858 m^2	28.6 %
Building measures	5,921,142 m^2	4.5 %
Infrastructure expansion	0 m^2	0.0 %
Total	**130,668,957 m^2**	**100 %**

Figure A1.4
Presentation of SPI values

Figure A1.5 displays the results of the regional economic analysis. The economic effects are calculated for Austria, for the federal state (depending on where the settlement is located) and for other federal states. Imports also include those of third countries. Besides changes in the four main categories turn over, value added, imports and jobs, also considerable changes of the results living space construction and living space operation can be seen in the grey shaded part of the graph on the bottom (results of the planning based on the As-Is-Analysis).

As-Is-Analysis

Regional Economic Effects related to one year *minimize*

Summmary REA	
Turn over in Austria	591,433 €
Value added in Austria	271,619 €
Import to Austria	97,080 €
Jobs in Austria	3.4
Turn over in your federal state	488,233 €
Value added in your federal state	198,183 €
Imports from abroad or other federal states	170,516 €
Jobs in your federal state	2.8
Turn over in other federal states	103,200 €
Value added in other federal states	73,436 €
Imports from other federal states	73,436 €
Jobs in other federal states	0.6

Value added effects according to initiator - Austria

Category	Turn over	Value added	Imports	Jobs
Living Space, construction	0 €	0 €	0 €	0.0
Living Space, operation	136,619 €	61,182 €	21,647 €	0.5
Municipal Infrastructure, construction and operation	7,229 €	3,915 €	804 €	0.0
External Effects (Mobility)	447,585 €	206,522 €	74,629 €	2.9
Total	**591,433 €**	**271,619 €**	**97,080 €**	**3.4**

Value added effects according to initiator - Oberösterreich

Category	Turn over	Value added	Imports	Jobs
Living Space, construction	0 €	0 €	0 €	0.0
Living Space, operation	123,824 €	51,880 €	30,948 €	0.5
Municipal Infrastructure, construction and operation	6,164 €	3,251 €	1,468 €	0.0
External Effects (Mobility)	358,245 €	143,051 €	138,100 €	2.3
Total	**488,233 €**	**198,183 €**	**170,516 €**	**2.8**

Planning based on As-Is-Analysis

Regional Economic Effects related to one year *minimize*

Summmary REA	
Turn over in Austria	721,248 €
Value added in Austria	333,538 €
Import to Austria	117,062 €
Jobs in Austria	4.4
Turn over in your federal state	592,892 €
Value added in your federal state	243,040 €
Imports from abroad or other federal states	207,561 €
Jobs in your federal state	3.4
Turn over in other federal states	128,356 €
Value added in other federal states	90,498 €
Imports from other federal states	90,498 €
Jobs in other federal states	1.0

Value added effects according to initiator - Austria

Category	Turn over	Value added	Imports	Jobs
Living Space, construction	66,607 €	33,013 €	9,298 €	0.5
Living Space, operation	145,905 €	65,224 €	23,334 €	0.7
Municipal Infrastructure, construction and operation	7,287 €	3,948 €	810 €	0.0
External Effects (Mobility)	501,449 €	231,353 €	83,621 €	3.2
Total	**721,248 €**	**333,538 €**	**117,062 €**	**4.4**

Value added effects according to initiator - Oberösterreich

Category	Turn over	Value added	Imports	Jobs
Living Space, construction	53,794 €	24,828 €	17,482 €	0.5
Living Space, operation	131,540 €	54,691 €	33,866 €	0.4
Municipal Infrastructure, construction and operation	6,213 €	3,279 €	1,479 €	0.0
External Effects (Mobility)	401,345 €	160,241 €	154,733 €	2.5
Total	**592,892 €**	**243,040 €**	**207,561 €**	**3.4**

Figure A1.5
Illustration of regional economic effects related to one year for the As-Is-Analysis and for the planning mode based on the As-Is-Analysis

Annex B: Tool characteristics – NIKK, Energieausweis 2.0, RESYS, ZERsiedelt

This annex is a supplement to Chapter 4 of this report, "Relevant tools available in Austria".

Comparison of different tools for integrated spatial and energy planning

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Vienna, 09.04.2018

1   NIKK

Niederösterreichischer Infrastrukturkostenkalkulator

1.1   Tool characteristics

Aim of the tool and main functions

- Evaluation of investments and costs (operation and maintenance) of existing settlements and settlement expansions, including technical and social infrastructure
- Comparison of possible planning options for municipalities:
  - Comparison of costs and revenues (over time) within certain building areas
  - Option to compare different building areas (projects)

Type of tool

- Web-based tool (no installation required)
- Login required

Model

Data input
- Specification of settlement development (total area, building structure, ...)
- Specification of technical infrastructure (road network, sewer, pipelines, ...)
- Specification of special facilities (roundabout, waste water treatment plants, bridges,...)
- Settlement development (degree of development, pace of development, ...)

Calculation/model
- Cost and revenue calculations over time
- Comparison of different sites and planning options
- Providing default values for local conditions derived from statistical data, including expert estimations
- Included costs: construction, operation, maintenance ...
- Included revenues: taxes, local fees, funding, ...

Output/Results
- Presentation of relevant costs and revenues of the settlement
- Presentation with tables and charts
- 4 main results:
  - Costs and revenues
  - Demographic development
  - Number of employees
  - Land consumption

Sample Screens

Registration and Login

General data input: Specification of total area, building structure etc.

Specification of building typologies; Multiple building typologies can be added or deleted

Results

- Presented Costs:
    - NIKK presents spending for technical (streets, supply and disposal infrastructure, etc.) and social infrastructure (schools, playgrounds, etc.)
    - Considered costs: construction and operation
- Presented Revenues:
    - Refinancing through funding, financial equalisation
    - Local taxes and fees, etc.

Results are presented in the form of tables (possibility to export tables as .csv files) and with charts:

- Costs and revenues
    - Balance per year or cumulative
    - Detailed presentation of relevant infrastructure (technical, social and financial aspects) for every year
    - Responsibility for expenses (comparison between public and private financing)
- Demographic development for each year
- Economic development for each year (presentation of number of employees)
- Land consumption (for buildings, infrastructure etc.)

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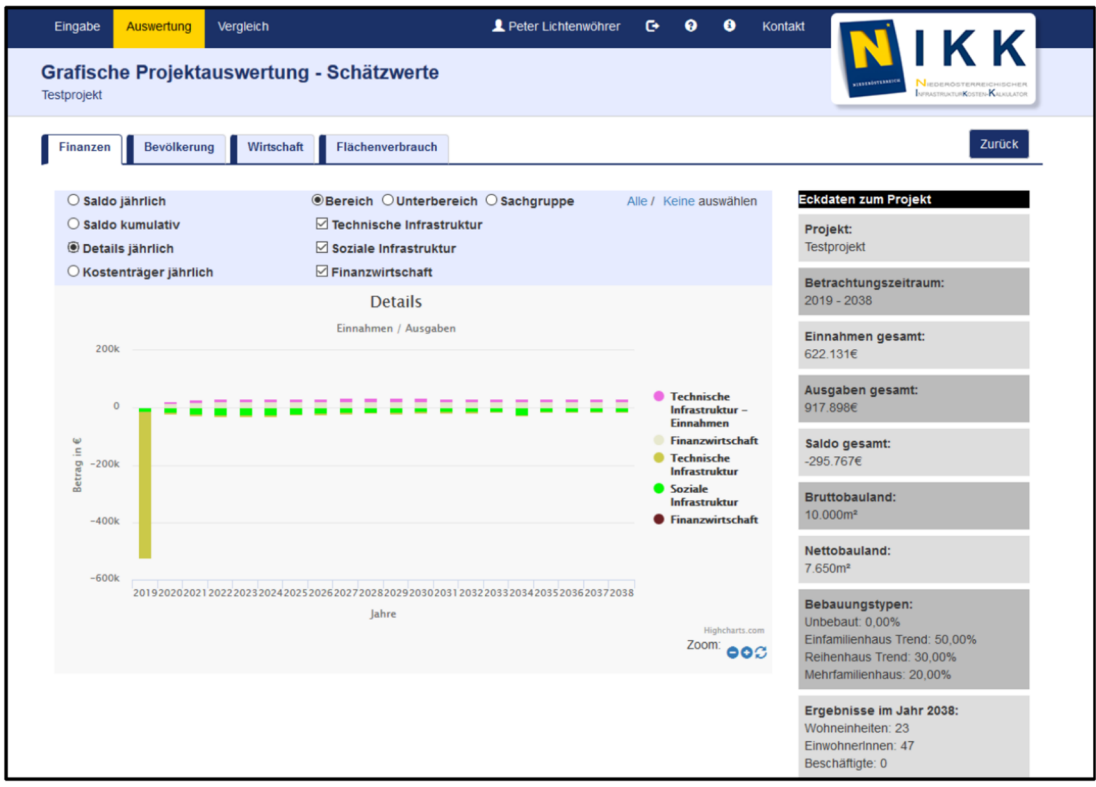
Presentation of results, including technical and social infrastructure as well as financial aspects
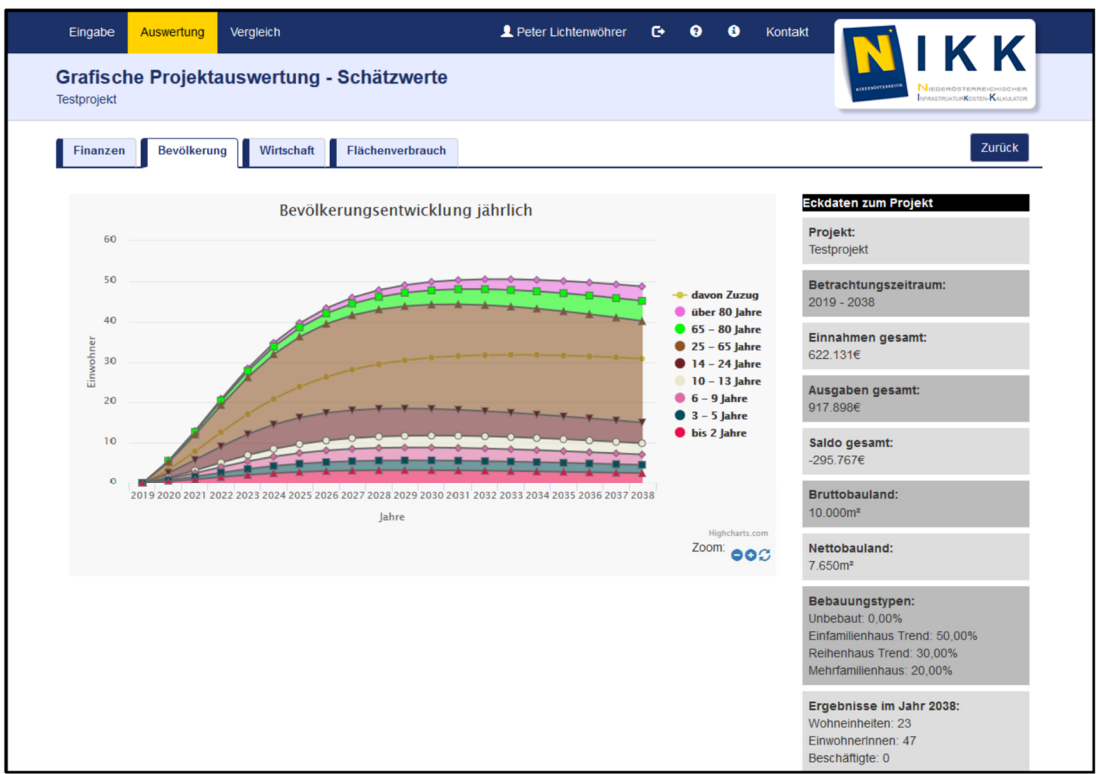
Results of demographic development for each year

1.2 Tool application and Experiences

Use of the tool

- For an economic assessment (costs and revenues) of existing settlements and settlement expansions in Lower Austria
- Can be used for
    - Settlement areas, commercial areas and mixed areas
    - Already existing areas or for new developments
- Comparison of different planning options – adaptations of different parameters possible

Target groups

- Cities, municipalities
- Planners/consultants
- Researchers

Reference users

- Lower Austrian municipalities[1]
- Used by students at Universities
- Legal bodies (regional planning section)

Experiences

PROS	CONS
Little time requirement, due to default values – few input needed	planning in existing settlement areas under development
Good basis for decision-making	
Possibility to compare different planning options	
Possibility to plan efficient developments	

1.3 Availability and Developers

- Freely available: www.nikk.dialogplus.at[2]
- Only available in German

Developed by:

- Universität für Bodenkultur, Wien – IRUB https://www.rali.boku.ac.at/irub/
- Technische Universität Wien – Raum IFIP http://www.ifip.tuwien.ac.at/
- Dialog Plus e.U.- Büro für Kommunikationstechnologie und Beteiligung https://dialogplus.at/
- Emrich Consulting – Raumplanung + Kommunikation https://www.emrich.at/

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[1] Recommended by the Office of the Government of Lower Austria / Department of Spatial Planning and Regional Policy
[2] The calculator is currently available as test system.

2 ENERGIEAUSWEIS

für Siedlungen

2.1 Tool characteristics

Aim of the tool and main functions

- o Assessing the energy efficiency of settlements
- o Comparison of different development options for different locations
- o Optimisation of whole settlements in the light of compact settlement structures, short every-day travel distances and high quality of living
- o Optimisation of costs related to settlement development
- o Aim to increase the willingness of situating single objects within energy efficient settlement structures

Type of tool

- - Excel-Tool (no installation required - offline use)
- - No login required

Model

Data input
- Location and size of potential settlement
- Settlement structure (e.g. building typology)
- Distances of settlement to essential public infrastructure and technical infrastructure (e.g. network connections)
- Available building area of municipality
- Environmental quality, including recreation areas
- Topography of local situation

Calculation/model
- Model is split into multiple excel sheets
- Assessing of the settlement location
- Assessment of development and settlement structure
- Calculation of up to five sites
- Consideration of development costs
- Default values available

Output/Results
- Energy efficiency for the whole settlement and for parts of the settlement (range between A and G)
- Strength and weaknesses of settlements
- Development costs
- CO_2 emissions (mobility)
- Evaluation of land use
- Possible residential units
- Quality of location
- Benchmarking (comparison to standard settlement)

Sample Screens

Welcome Screen and brief instruction of the tool

Data input - location

Externe Infrastruktur

		Standort 1	Standort 2	Standort 3	Standort 4	Standort 5
Kanalsystem		Trennsystem				
Leuchtenabstand Straßenbeleuchtung		35,0 m (default)				
		Südrand (fiktiv)	Zentralbereich (fiktiv)	0	0	0
Erschließungslängen extern						
Straßenfläche		500 m²	20 m²	m²	m²	m²
Wasserversorgung		59 Lfm (default)	2 Lfm (default)	- Lfm (default)	- Lfm (default)	- Lfm (default)
Abwasser		59 Lfm (default)	2 Lfm (default)	- Lfm (default)	- Lfm (default)	- Lfm (default)
Straßenbeleuchtung		59 Lfm (default)	2 Lfm (default)	- Lfm (default)	- Lfm (default)	- Lfm (default)
		Zurücksetzen	Zurücksetzen	Zurücksetzen	Zurücksetzen	Zurücksetzen
Bewertung Erschließungslängen extern		D	A	unvollständig	unvollständig	unvollständig
Sonstige Infrastrukturinvestitionen						
Lärmschutzwand		Lfm	- Lfm	- Lfm	- Lfm	- Lfm
Sonstige Kosten (Brücken, volle Vorfluter, Retentionsanlagen, Hochwasserschutz)		- €	- €	- €	- €	- €
		Zurücksetzen	Zurücksetzen	Zurücksetzen	Zurücksetzen	Zurücksetzen

Gemeinde Testgemeinde
ausgestellt von Testuser
03.05.2014

Data input – infrastructure

Umweltqualität

	Projekt 1	Projekt 2	Projekt 3	Projekt 4	Projekt 5
Bezeichnung / Projekttitel	Variante 1 - geringe Dichte	Variante 2 - mittlere Dichte	Variante A - erhöhte Dichte	Variante B - hohe Dichte	0
am Standort	Südrand (fiktiv)	Südrand (fiktiv)	Zentralbereich (fiktiv)	Zentralbereich (fiktiv)	0
Private Grünflächen	ja	ja	teilweise	teilweise	
Öffentliche Grünflächen	niedrig / 3%	mittel / 6%	8,09565217391304 %	mittel / 6%	0
Ausgestaltung der öffentlichen Grünflächen	Wiese	Spielplatz	Park	Spielplatz	
Breite Straßenraum	größer/gleich 8m	kleiner 8m	größer/gleich 8m	größer/gleich 8m	
Ausgestaltung des Straßenraums	Standard	begrünt	begrünt	Standard	
Maßnahmen Verkehrsberuhigung	teilweise	nein	ja	teilweise	
	Zurücksetzen	Zurücksetzen	Zurücksetzen	Zurücksetzen	Zurücksetzen
Ausgestaltung des Standorts	D	C	A	D	unvollständig

Data input – environmental quality

Projektbeschreibung

2,3 EinwohnerInnen/Wohneinheit (def... Zurücksetzen

	Projekt 1	Projekt 2	Projekt 3	Projekt 4	Projekt 5
Bezeichnung / Projekttitel	Variante 1 - geringe Dichte	Variante 2 - mittlere Dichte	Variante A - erhöhte Dichte	Variante B - hohe Dichte	
am Standort	Südrand (fiktiv)	Südrand (fiktiv)	Zentralbereich (fiktiv)	Zentralbereich (fiktiv)	
Bruttobauland	3,50 ha	3,50 ha	2,30 ha	2,30 ha	ÖNV ha
Öffentliche Grünflächen	niedrig / 3%	mittel / 6%	eigene Eingabe 0,20 ha	mittel / 6%	
	0,11 ha	0,21 ha		0,14 ha	- ha
Verkehrsfläche	0,61 ha (default)	0,61 ha (default)	0,30 ha	0,40 ha (default)	ÖNV ÖNV
Nettobauland	2,78 ha	2,68 ha	1,80 ha	1,76 ha	- ha
	Zurücksetzen	Zurücksetzen	Zurücksetzen	Zurücksetzen	Zurücksetzen
abeform der Bebauungsweise / Teilflächen	Prozent	Prozent	Fläche / Projekt	Fläche / Projekt	
Nettobauland / verfügbare Fläche	2,783 ha	2,678 ha	1,800 ha	1,760 ha	ha

Teilfläche 1

	Projekt 1	Projekt 2	Projekt 3	Projekt 4	Projekt 5
Bebauungsform	Reihenhäuser (Trend)	Reihenhäuser (Trend)	Mehrfamilienhäuser	Mehrfamilienhäuser	
Anteil am Nettobauland	20,000 % (max. 20 %)	20,000 % (max. 20 %)	0,900 ha (max. 0,9 ha)	0,600 ha (max. 0,61 ha)	ha (max. 100 ha)
Grundstücksgröße	500 m² (default)	500 m² (default)	- m² (default)	- m²	- m² (default)
Bebauungsgrad	niedrig / 29%	mittel / 27%	hoch / 35 %	mittel / 27%	
Geschoßanzahl	3 (default)	3 (default)	3 (default)	4	3 (default)
Wohneinheiten	11	11	106	73	0
der Gebäudeachse von West-Ost-Orientierung	0-20 Grad	21-45 Grad	0-20 Grad	0-20 Grad	
Bewertung der Teilfläche	B	C	A	A	Eingabe unvollständig
	Zurücksetzen	Zurücksetzen	Zurücksetzen	Zurücksetzen	Zurücksetzen

Teilfläche 2

	Projekt 1	Projekt 2	Projekt 3	Projekt 4	Projekt 5
Bebauungsform	Einfamilienhäuser (Trend)	ihenhäuser (flächenspar..	ihenhäuser (flächenspar..	ihenhäuser (flächenspar..	
Anteil am Nettobauland	30,000 % (max. 30 %)	40,000 % (max. 40 %)	0,900 ha (max. 0,9 ha)	0,600 ha (max. 0,61 ha)	ha (max. 100 ha)
Grundstücksgröße	790 m² (default)	391 m² (default)	391 m² (default)	391 m² (default)	- m² (default)
Bebauungsgrad					
Geschoßanzahl	3 (default)	3 (default)	3 (default)	3 (default)	3 (default)
Wohneinheiten	11	27	23	15	0
der Gebäudeachse von West-Ost-Orientierung	0-20 Grad	21-45 Grad	0-20 Grad	0-20 Grad	
Bewertung der Teilfläche	E	B	A	A	Eingabe unvollständig
	Zurücksetzen	Zurücksetzen	Zurücksetzen	Zurücksetzen	Zurücksetzen

Teilfläche 3

	Projekt 1	Projekt 2	Projekt 3	Projekt 4	Projekt 5
Bebauungsform	milienhäuser (flächenint..	milienhäuser (flächenspar..		Mehrfamilienhäuser	
Anteil am Nettobauland	50,000 % (max. 50 %)	40,000 % (max. 40 %)	ha (max. 0 ha)	0,550 ha (max. 0,56 ha)	ha (max. 100 ha)
Grundstücksgröße	750 m²	629 m² (default)	- m² (default)	m² (default)	- m² (default)
Bebauungsgrad	niedrig / 29%			mittel / 27%	
Geschoßanzahl	3 (default)	3 (default)	3 (default)	3 (default)	3 (default)
Wohneinheiten	19	17	0	50	0
der Gebäudeachse von West-Ost-Orientierung	21-45 Grad	0-20 Grad		21-45 Grad	
Bewertung der Teilfläche					

Data input – specification of project details

Results

The last section of the Excel-file highlights the results:

- Assessment of energy **efficiency**, concerning
  - settlement location and
  - settlement structure and building development including an
  - overall assessment
- Presentation of results with the help of **indicators**, ranging from A (most efficient use of resources) to G (least efficient use of resources)
- Main indicators that are calculated and highlighted:
  - Development costs in €
  - CO_2 emissions by means of mobility
  - Space allocation
  - Possible residential units
  - Quality of location and building development
- **Benchmarking** of the settlement – the settlement in question is compared to a conventional sample settlement. The user can easily see deviations and decide whether or not the settlement in question is "better" or "worse" than the sample settlement
- **Scenarios**: Comparison of scenario (a) "loose development" and (b) "dense development" of the settlement in question. With the help of scenario calculations, it is possible for the user to assess the scope of possible dwelling units.

Presentation of results, following the idea of energy performance certificates

2.2 Tool application and Experiences

Use of the tool

- For an overall assessment of energy efficiency of settlements
- Used to optimise settlement structures and to calculate relevant costs
- Comparison of different development options and comparison of these development options at different locations

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Target groups

- Cities, municipalities
- Planners/consultants
- Researchers

Reference users

- Austrian municipalities[3]
- Used by students at Universities
- Legal bodies (regional planning section)

Experiences

PROS	CONS
Good basis for decision-making	Not considered: parameters dealing with energy performance of single objects
Possibility to compare different planning options	Limitation to five locations in one excel file
No installation required	

2.3 Availability and Developers

- Freely available: http://www.energieausweis-siedlungen.at/?page_id=235
- Only available in German

Developed by:

- Universität für Bodenkultur, Wien – IRUB https://www.rali.boku.ac.at/irub/
- Emrich Consulting – Raumplanung + Kommunikation https://www.emrich.at/
- Amt der NÖ Landesregierung, Abteilung Raumordnung und Regionalpolitik – www.raumordnung-noe.at

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[3] Recommended by the Office of the Government of Lower Austria / Department of Spatial Planning and Regional Policy

3 RESYS

Energiewende-Rechner

3.1 Tool characteristics

Aim of the tool and main functions

- Calculation of energy demand for municipality buildings and mobility, residential area, industry, infrastructure, mobility
- Calculation of local energy potential for renewable energies
- Calculation of energy yields of renewable energy plants installed
- Simulation of demand and yield curves, auxiliary power requirements
- Cost estimates focusing on investment costs for the expansion of renewable energy sources
- GHG assessment

-

Type of tool

- Web-based tool, Login required
- Each login can be assigned a number of municipalities/regions to be regarded

Model

Input
- statistics
- information about energy production and consumption
- target planning (demand and supply side)

Calculation/model
- Energy demand simulation from only 30 statistical parameters
- energy yields from renewable energy plants
- GHG assessment
- all calculations on hourly basis
- to come: storage simulation

Output/Results
- energy demand and its temporal course (per hour)
- potential for renewable energy sources
- benchmarking of regional measurements
- investements costs to fulfill target planning (energy plant investments)
- GHG assessment

Sample Screens

Login-page

Input-Page for basic data like number of residents and employees. Based on these data the most matching calculation-model will be chosen.

Solar Geothermie Biomasse Potential Kombin. Wärme Wärme Wind Wasser Speicher

Klärgas

Weitere Anlagen zur kombinierten Erzeugung Wärme, Strom, Treibstoff   > Performancedaten editieren

Name	El. Leistung bzw. Treibstoff-Leistung in kW	Inputleistung in kW	Wärmeleistung in kW	Anteil Sommerbetrieb 0 … 1	Anteil wärmegeführt 0…1
Biogas mit BHKW1 (zentral)	0	0	0	1	1
Biogas mit BHKW2 (dezentral)	0	0	0	1	1
Biogas mit Netzeinspeisung, Treibstoffproduktion	0	3	0	0	0
Biomasse BHKW groß	0	0	0	0	1
Biomasse BHKW klein	0	0	0	0	1
Biomasse Vorrangkessel	0	102,2727	90	1	1
BTL-Anlage	1	2,5	1,25	1	1
Biotreibstoff BHKW	0	0	0	0	1
Abfall-BHKW	0	0	0	0	0
Abfall-Vorrangkessel	0	7,954545	7	0	0
Erdgas/Biomethan-BHKW	0	0	0	0	0

Vorgabewerte - Gemeindetyp abhängig

Ergebnisse

Wärme	1.074,4299	[MWh/a]
Ungenutzte Wärme	0	[MWh/a]
Strom	0	[MWh/a]
Treibstoffe	4,4397	[MWh/a]
Biomethan gereinigt	26,28	[MWh/a]

Energieinput

Feste Biomasse	616,121	[MWh/a]		22	[%]	
			vom theoretischen Potential	2.831	[MWh]	
davon fossiler Anteil im Abfall	32,2264	[MWh/a]				
Flüssige Biomasse	0	[MWh/a]		0	[%]	
			vom theoretischen Potential	886	[MWh]	
Gasförmige Biomasse	591,7888	[MWh/a]		5	[%]	
			vom theoretischen Potential	11.936	[MWh]	
Erdgas/Biomethan	0	[MWh/a]				
Hilfsstrombedarf	35,3711	[MWh/a]				

Another Input-Page with calculated results directly below the inputs

▼ Diagramme

Energieinput

Legend:
- Feste Biomasse
- Flüssige Biomasse
- Erdgas/Biomethan
- Strom Wärmepumpe
- Strom Heizung
- Abfall
- Fossil

(Y-axis: kW — 0 to 25,000)
(X-axis months: Jänner, Februar, März, April, Mai, Juni, Juli, August, September, Oktober, November, Dezember)

(Right bar chart Y-axis: MWh/a — 0 to 180,000)
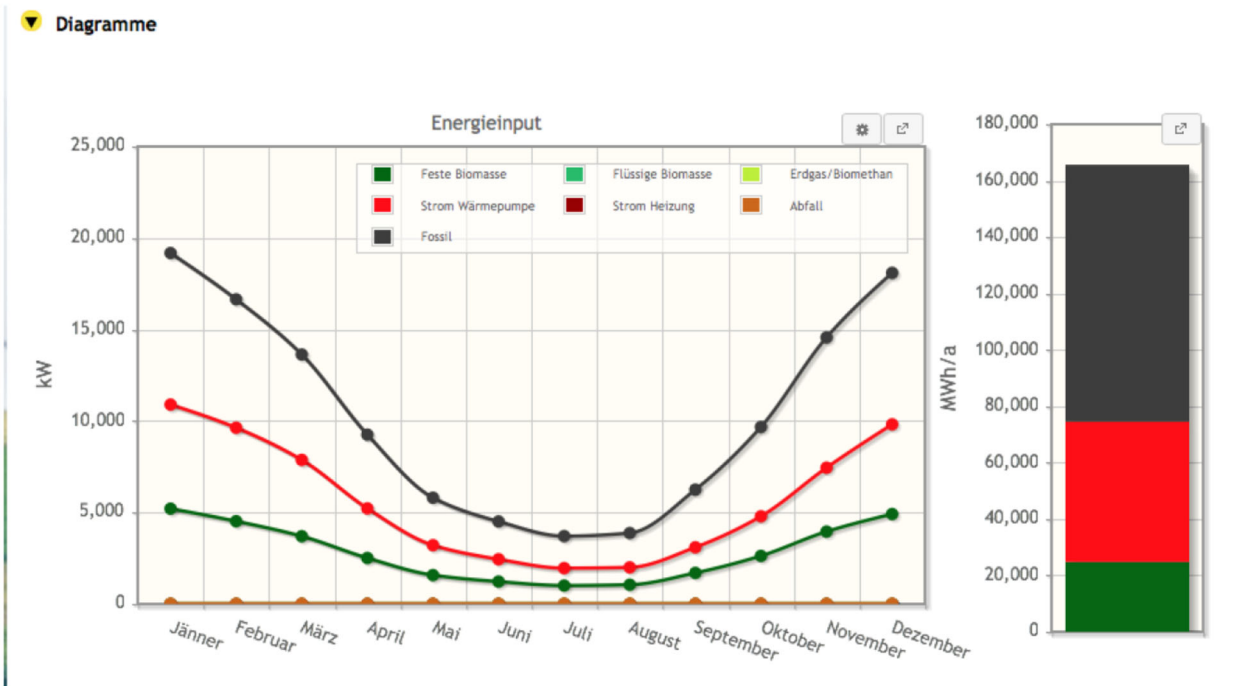
Output/Results: Calculated data displayed in diagrams
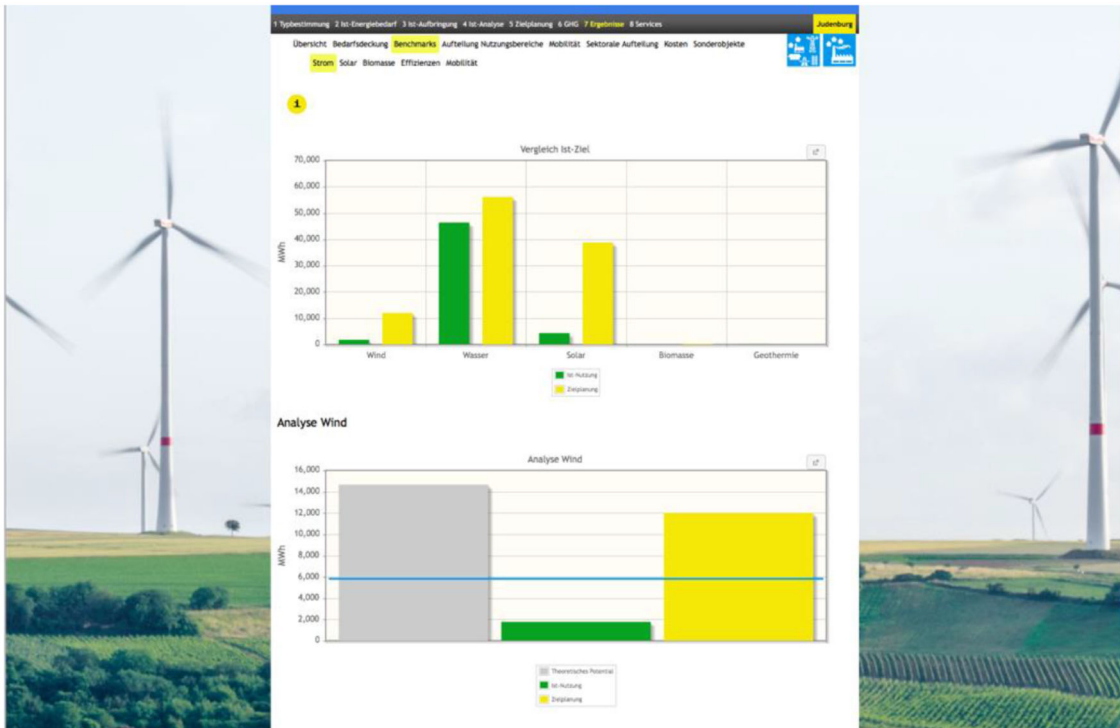
Output/Results: benchmarks are displayed in diagrams or in tables

Results

- Numerous tables and graphs, most of them can be displayed in different resolutions (hourly, daily, monthly, …)
- Development of scenarios (trends, efficiencies, ..)
- Comparison of scenarios
- Comparison of municipalities
- Aggregation of municipalities to regions
- Result value range:
  - Energy demand for the whole municipality region (residential, municipality, infrastructure, industry, mobility)
  - energy yields and investment costs of renewable energy plants
  - Energy potentials of renewables
  - GHG assessment of energy strategy
- Soon to come
  - Storage performance parameters
  - Storage investment costs
  - GHG assessment of storage integration

3.2 Tool application and Experiences

Use of the tool

- Overall energy planning for regions – covering all energy-related activities/infrastructure
- Accompanying from early stage until monitoring phase

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Target groups

- Cities, municipalities, regions
- Energy planners/consultants
- Researchers / projects

Reference users

- So far mostly used in project contexts, guided by experts:
- Cities: Frankfurt/Main, Graz, Judenburg
- Regions: KEM-Region Traunstein, KEM-Region Nockberge, Ökoregion Kaindorf und der KEM-Region Kulmland
- Municipalities: Jois, Neusiedl, Jois, St. Georgen und Purbach

Experiences

PROS	CONS
only few input needed to get first results	Still a lot of complexity, especially in scenario building, interpretation and use of results
results presented in time-related/hourly graphics	Many input and result pages
different export options	Embedding in regular processes and tasks is unclear (general problem, not only for this tool)

3.3 Availability and Developers

- http://resys-tool.at
- Available in German and English, login required

Developed by:

- akaryon GmbH Coordination/ICT/modelling - DI Petra Bußwald, busswald@akaryon.com, +43 599 10095167 (main contact)
- Energy modelling: Ingenieurbüro Dr. Günter Wind, Technisches Büro Lunzer
- Energieagentur Obersteiermark
- Energieberaterin Arch. DI Anja Stenglein

4 ZERSIEDELT

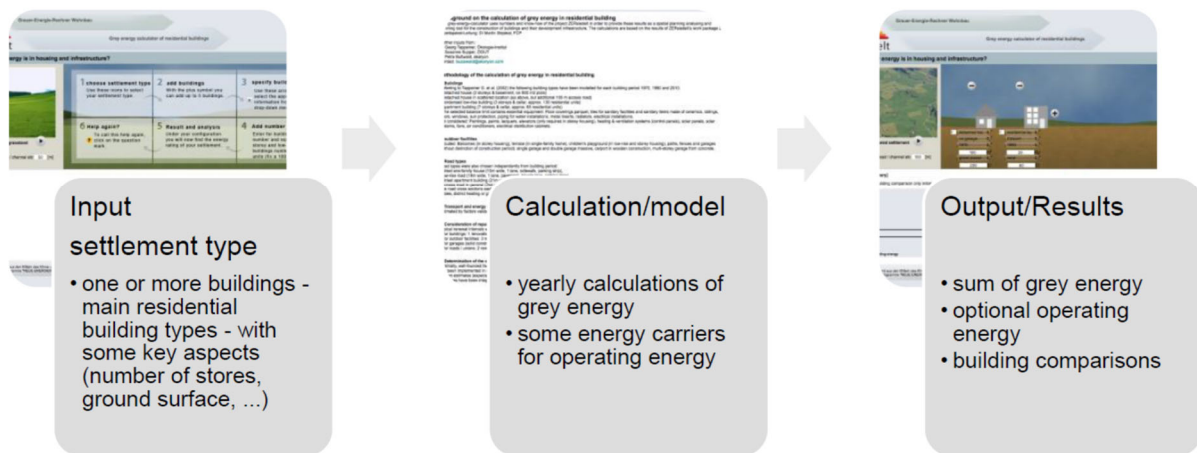**Graue-Energie-Rechner Wohnbau**

4.1 Tool characteristics

Aim of the tool and main functions

- Calculation of grey energy in housing and infrastructure
- Comparison of different building types regarding grey energy
- comparison with operation energy

Type of tool

- Web-based tool, no login required
- Calculations are performed on client side only

Model

Input

settlement type
- one or more buildings - main residential building types - with some key aspects (number of stores, ground surface, ...)

Calculation/model
- yearly calculations of grey energy
- some energy carriers for operating energy

Output/Results
- sum of grey energy
- optional operating energy
- building comparisons

Sample Screens

Start-Page: Choose a settlement type

Live-calculated results based on dynamic input of settlement and building types

Results

Mainly in form of tables for single settlements/buildings and their comparison:

- Grey energy for access roads, infrastructure (sewage, other supply nets, parking, …), building
- Operating energy for building

4.2 Tool application and Experiences

Use of the tool

- development of residential areas, comparison existing/new
- early stage respectively "quick look" – due to only rough calculations, with little differentiation in data input

Target groups

- planners of residential areas

Reference users

- Not known (as no login required)

Experiences

PROS	CONS
no specifc know-how needed to use the tool	no saving/export functionality
Really easy to use	Would need more differentiation – too low connection to real projects
Graphical input	

4.3 Availability and Developers

- Freely available: https://www.zersiedelt.at/
- Available in German and English

Developed by:

- akaryon GmbH - DI Petra Bußwald, busswald@akaryon.com, +43 599 10095167 (Main contact)
- Österreichische Gesellschaft für Umwelt und Technik ÖGUT
- FCP Fritsch
- Chiari & Partner ZT GmbH (FCP)
- Ökologie-Institut

Annex C: Additional Austrian databases and studies – Certification of Settlements, Austrian Mobility Survey, Site Certificate

This annex gives a short presentation of relevant results from recent projects, conducted in Austria.

Additional databases and studies

A list of additional suggested literature and explanatory notes from Austria

Dipl.-Ing. Peter Lichtenwöhrer *

Dipl.-Ing. Dr. Georg Neugebauer*

Univ.-Prof. Dipl.-Ing. Dr. Gernot Stöglehner*

*Institute of Spatial Planning, Environmental Planning and Land Rearrangement
Department of Landscape, Spatial and Infrastructure Sciences
BOKU – University of Natural Resources and Life Sciences
Peter-Jordan-Straße 82 | A-1190 Wien | peter.lichtenwoehrer@boku.ac.at

Vienna, 17.04.2018

1 Certification of settlements

Mair am Tinkhof, O., Strasser, H., Prinz, T., Herbst, S., Schuster, M., Tomschy, R., Figl, H., Fellner, M., Ploß, M., Roßkopf, T. (2017): Richt- und Zielwerte für Siedlungen zur integralen Bewertung der Klimaverträglichkeit von Gebäuden und Mobilitätsinfrastruktur in Neubausiedlungen. Bundesministerium für Verkehr, Innovation und Technologie, Wien. Online: https://nachhaltigwirtschaften.at/resources/sdz_pdf/berichte/schriftenreihe_2017-39_richt-zielwerte-siedlungen.pdf
Status: 17.04.2018.

A written summary in English can be found in the report from page 13 to 15, including objectives, methods and main results of the research project.

Main objectives:

- Definition of target values for climate compatibility of new settlements
- Evaluation of grey energy
- Evaluation of operational energy and
- Evaluation of energy used for mobility

Sample results: Benchmarks and target values are listed in the following table:

	Energy Use	PE tot. [kWh/m²a]	THG [kg CO2-eq./m²]
Residential buildings	Grey energy building	26 - 33	5,8 - 8
	Operational energy building	47 - 100	2,9 - 8
	Grey energy and operational energy daily mobility	49 - 113	6,7 - 28,5
	Target value per m²	**206**	**15**
		PE tot. [W/P•a]	THG [kg CO2-eq./P•a]
	Target value per Person	**1.040**	**684**
Office buildigns	Energy Use	PE tot. [kWh/m²a]	THG [kg CO2-eq./m²]
	Grey energy building	25 - 33	6,5 - 8
	Operational energy building	73 - 90	5,1 - 7
	Grey energy and operational energy daily mobility	27 - 121	6,3 - 30,6
	Target value per m²	**371**	**27**
		PE tot. [W/P•a]	THG [kg CO2-eq./P•a]
	Target value per Person	**181**	**115**
School buildings	Energy Use	PE tot. [kWh/m²a]	THG [kg CO2-eq./m²]
	Grey energy building	26 - 33	7,1 - 8
	Operational energy building	69 - 100	5,2 - 8
	Grey energy and operational energy daily mobility	21 - 67	4,7 - 16,6
	Target value per m²	**116**	**19**
		PE tot. [W/P•a]	THG [kg CO2-eq./P•a]
	Target value per Person	**60**	**44**

Table 1: Benchmarks and target values (Tinkhof et al. 2017).

2 Austrian mobility survey

Tomschy, R. et al. (2016): Oesterreich unterwegs 2013/2014. Ergebnisbericht zur oesterreichweiten Mobilitaetserhebung „Oesterreich unterwegs 2013/2014. Bundesministerium für Verkehr, Innovation und Technologie, Wien. Online: https://www.bmvit.gv.at/verkehr/gesamtverkehr/statistik/oesterreich_unterwegs/ Status: 17.04.2018.

The main outcomes are presented in the Management summary (Chapter 0 = „Kapitel 0" of the report):

- Survey carried out from October 2013 to October 2014
- Based on 18,232 surveyed households
- 83 % of individuals are mobile during working days…
- …with an average of 36 km/day
- Half of the trips are carried out by motorised private transportation
- Differences between cities and rural areas
- Different means of transport for different types of trips
- Differences between age and gender
- Differences between previous surveys

Here are some main findings:

Merkmal	Außer-Haus-Anteil	Wege pro Person und Tag	zurückgelegte Tageskilomter	tägliche Unter-wegszeit
Werktage	83%	2,8	36	70
Samstage	77%	2,5	37	66
Sonn- und Feiertage	66%	1,9	35	58
durchschn. Wochentag	79%	2,6	36	68

Table 2: Mobility indicators for Austria – whole year, all days (Tomschy et al. 2016)

Explanations Table 2:

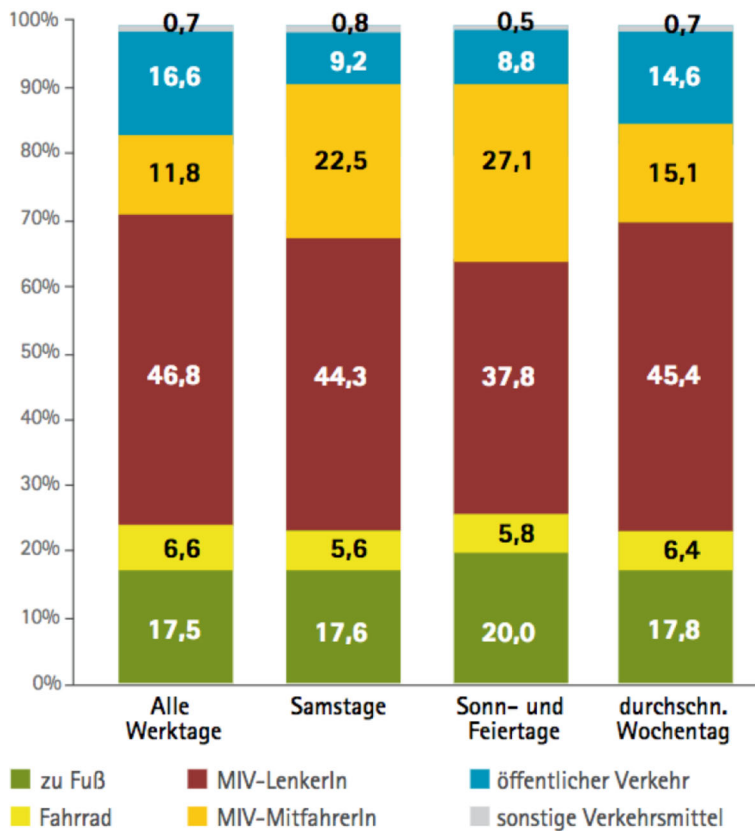|	
Werktage…	Working days
Samstage…	Saturdays
Sonn- und Feiertage…	Sundays and public holidays
Durchschn. Wochentag…	Average working day
Außer-Haus-Anteil…	Staying out of home
Wege pro Person und Tag	Ways/person/day
Zurückgelegte Tageskilometer	Covered distance per day
Tägliche Unterwegszeiten	Daily minutes on the way

Figure 1: Modal split in % for the whole year and all days – Share of trips per main means of transportation (Tomschy et al. 2016)

Explanations Figure 1 and Table 3:

Alle Werktage…	All working days
Durchschn. Wochentag…	Average week day
Zu Fuß…	On foot
Fahrrad…	Bicycle
MIV-LenkerIn…	Motorised private transport - driver
MIV-MitfahrerIn…	Motorised private transport – passenger
Öffentlicher Verkehr…	Public transportation
Sonstige Vekehrsmittel	Other types of transportation

Mittlere Wegelänge je Hauptverkehrsmittel (Gesamtjahr, Werktage)

zu Fuß	Fahr-rad	MIV-Lenker-Innen	MIV-Mit-fahrer-Innen	öffentl. Verkehr	sonstige Verkehrs-mittel	Österreich gesamt
1,4 km	3,5 km	16 km	16 km	17 km	45 km	13 km

Verkehrsleistung in Prozent (Gesamtjahr, Werktage)

zu Fuß	Fahr-rad	MIV-Lenker-Innen	MIV-Mit-fahrer-Innen	öffentl. Verkehr	sonstige Verkehrs-mittel
2%	2%	57%	15%	22%	2%

Table 3: Above: Mean distance of trips for each means of transportation, Below: Traffic volume in % (Tomschy et al. 2016)

Hauptverkehrsmittel	zu Fuß	Fahrrad	MIV-LenkerInnen	MIV-MitfahrerInnen	öffentl. Verkehr	sonstige Verkehrsmittel
Wien	24,6	4,0	24,7	7,7	38,3	0,6
Großstädte (o. Wien)	19,5	13,0	38,9	10,8	17,3	0,4
zentrale Bezirke	14,4	7,7	51,5	13,3	12,6	0,4
periphere Bezirke	15,3	5,8	56,5	13,1	8,4	0,9

Table 4: Modal split presented in % divided into main spatial types – for the whole year and only for working days (Tomschy et al. 2016)

Explanations Table 4:

Großstädte (o. Wien)…	Major cities without Vienna
Zentrale Bezirke…	Central districts
Periphere Bezirke…	Peripheral districts
Zu Fuß…	On foot
Fahrrad…	Bicycle
MIV-LenkerIn…	Motorised private transport - driver
MIV-MitfahrerIn…	Motorised private transport – passenger
Öffentlicher Verkehr…	Public transportation
Sonstige Vekehrsmittel	Other types of transportation

Hauptverkehrsmittel	zu Fuß	Fahrrad	MIV-LenkerInnen	MIV-MitfahrerInnen	öffentl. Verkehr	sonstige Verkehrsmittel
Arbeitsplatz	7,6	6,6	60,1	5,1	20,2	0,5
Schule/Ausbildung	20,5	5,7	8,5	15,7	49,2	0,4
Begleitwege	16,0	2,4	66,8	8,7	6,1	0,1
Einkauf	25,1	7,6	45,5	13,0	8,7	0,1
private Erledigung	17,3	5,9	46,6	15,3	14,1	0,9
Freizeit	29,7	9,9	30,2	16,6	12,2	1,3

Table 5: Modal split in % according to type of trips – for the whole year and only for working days (Tomschy et al. 2016)

Explanations Table 5 and Table 6:

Arbeitsplatz…	Workplace
Schule/Ausbildung…	School/Education
Begleitwege…	Accompanying trips
Einkauf…	Shopping
Private Erledigungen…	Private matter
Freizeit…	Leisure time
Jahre…	Years/Age
Männlich…	Male
Weiblich…	Female
Verkehrsmittel…	Means of transportation

Hauptverkehrsmittel	zu Fuß	Fahrrad	MIV-LenkerInnen	MIV-MitfahrerInnen	öffentl. Verkehr	sonstige Verkehrsmittel
6-14 Jahre	26,0	9,7	0,0	33,8	30,2	0,3
15-19 Jahre	11,9	5,2	21,2	19,3	41,3	1,1
20-24 Jahre	11,7	3,6	54,6	7,0	22,5	0,6
25-34 Jahre	16,5	4,2	53,8	7,3	17,5	0,6
35-44 Jahre	14,5	6,0	61,7	5,9	11,5	0,4
45-54 Jahre	13,7	7,2	59,1	8,2	11,2	0,6
55-64 Jahre	17,9	7,4	49,1	10,9	13,8	0,9
65 und älter	25,8	8,1	38,8	14,6	11,5	1,1
männlich	13,9	7,4	53,7	8,3	15,7	1,0
weiblich	20,9	5,9	40,2	15,1	17,5	0,4

III

Table 6: Modal split in % according to age and gender – for the whole year and only for working days (Tomschy et al. 2016)

Merkmal (Werktage)	Außer-Haus-Anteil	Wege pro Person	zurückgelegte Tageskilomter	tägliche Unter-wegszeit
Herbst 1995	82%	3,0	28 km	70 min
Herbst 2013/2014	85%	2,8	34 km	70 min

Table 7: Mobility indicators according surveyed year – for autumn and only for working days (Tomschy et al. 2016)

Explanations Table 7 and Table 8:

Außer-Haus-Anteil…	Staying out of home
Wege pro person…	Trips per person
Zurückgelegte Tageskilometer…	Covered distance in kilometres per day
Tägliche Unterwegszeiten	Daily minutes on the way
Herbst…	Autumn/Fall
Zu Fuß…	On foot
Fahrrad…	Bicycle
MIV-LenkerIn…	Motorised private transport - driver
MIV-MitfahrerIn…	Motorised private transport – passenger
Öffentlicher Verkehr…	Public transportation
Sonstige Vekehrsmittel	Other types of transportation

Verkehrsleistung (Werktage, Mio. Personen-km)	zu Fuß	Fahrrad	MIV-LenkerInnen	MIV-MitfahrerInnen	Eisenbahn	sonstiger öffentlicher Verkehr	sonstige Verkehrs-mittel	Summe
Herbst 1995	5,2	2,3	116,2	31,0	22,8	27,2	1,3	206,2
Herbst 2013/2014	5,1	5,2	158,7	33,5	34,0	31,2	4,7	273,4

Table 8: Traffic volume in Mio. passenger km after surveyed year – for autumn and only for working days (Tomschy et al. 2016)
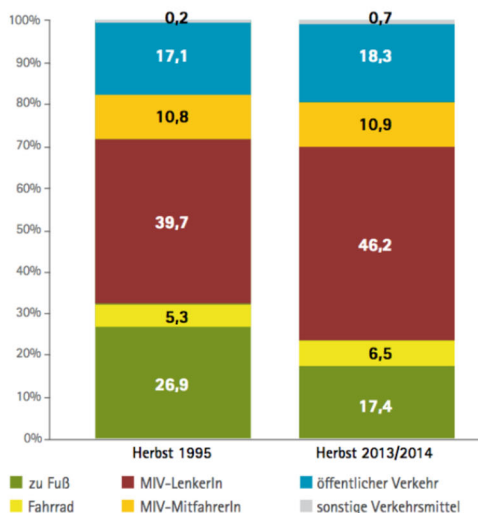

Figure 2: Modal split in % after surveyed year – for autumn and only for working days (Tomschy et al. 2016)

Explanations Figure 2:
Share of trips according to main means of transportation:

Herbst 1995	Autumn 1995
Zu Fuß…	On foot
Fahrrad…	Bicycle
MIV-LenkerIn…	Motorised private transport - driver
MIV-MitfahrerIn…	Motorised private transport – passenger
Öffentlicher Verkehr…	Public transportation
Sonstige Vekehrsmittel	Other types of transportation

3 Site certificate – Possibilities and requirements of transferring the Swiss „2000-Watt Site" certificate to Austria

Link to English summary:

> https://nachhaltigwirtschaften.at/en/sdz/projects/site-certificate.php

Site certificate

Possibilities and requirements of transferring the Swiss "2000-Watt Site" certificate to Austria

Short Description

Within the framework of the project "Zertifizierung von Siedlungen / Quartieren" (engl. Site certificate) the possibility of transferring the Swiss "2000-Watt Site" certificate to Austria was assessed by stakeholders from Austria and Switzerland: in how far can the existing Swiss system "2000-Watt Site" certificate (for newly build areas) as well as ongoing and planned propositions to expand the system to city planning processes and existing areas provide a basis for Austria? Preparatory work regarding the project questions took place during the program „klimaaktiv building and renovation" of the BMLFUW and within the framework of the program "building of tomorrow/ city of tomorrow" of the bmvit.

Setting

In Austria, different well established systems (klimaaktiv, ÖGNB) for the evaluation of buildings exist - as well as the e5 quality and certification program is applied in many municipalities and cities. Furthermore a broad range of national and international research activities and programs exist, which focus on the implementation of sustainability standards on individual building and village level. Those are based on knowledge about the insufficiency of exclusively optimizing buildings.

The necessary next step has to be the optimization of building complexes/ villages/ districts including the related resource demand for energy, mobility and infrastructure. This means higher complexity and a wider range of topics, additional actors with different interests, new definition of responsibilities (who ist the "overall planner", who is the "process designer"), often instruments for integrated planning and obligatory implementation are missing.

Targets and results

The Swiss "2000-Watt Site" certificate is a system for planning, evaluating and ensuring the quality of newly build areas; developed on the basis of the "2000-Watt Gesellschaft". Thereby the existing building standard (Minergie) and qualitative evaluation are considered. Furthermore is the certification process of the existing "Energiestadt" label for municipalities carried out ("Energiestadt" and the Austrian e5 program match with regards to their requirements and process of the evaluation and certification of municipalities).

The results of the exploration project provide a basis for defining the time horizon to find a target value definition that can be compared to the Swiss one and whether the existing Austrian evaluations systems will be used or what supplements are needed. Included is a written guideline for further processing of the requirement level and target values for Austria (what needs to be researched and decided by whom).

Abbildung 1: Switzerland – Austria: Analogies and challenges. Source: ÖGUT

Project Partners

Project leaders
→ ÖGUT - Österreichischen Gesellschaft für Umwelt und Technik
→ Salzburger Institut für Raumplanung SIR

Project partners
→ Intep – Integrale Planung GmbH, Schweiz
→ Enco-AG, Energiestadt Schweiz

EMBODIED ENERGY, COSTS AND TRAFFIC IN DIFFERENT SETTLEMENT PATTERNS
BACKGROUND PROJECTS AND TOOLS

The objective of this report is to provide a state-of-the art review on relevant existing studies and tools that could serve as inspiration for tool development and guidelines in the EE Settlement project.

The report summarizes the methodological choices and the outcome of two Austrian projects, ZERsiedelt and ELAS, which are considered as a basis for developing a tool in EE Settlement. Relevant tools for buildings, infrastructure, transport and scenario planning from Austria and Nordic countries, and tools for cost analysis from Germany, are also summarized.

The report also highlights the limitations of existing approaches and helps define the scope for further work in the EE Settlement project.

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