Project description for the BYFORSK initiative – Template and guidelines

EE Settlement – Embodied Energy, Costs and Traffic in Different Settlement Patterns

PART 1: Scientific quality and innovative idea

1.1 Vision and objectives

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 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 main objective is to generate profound basic data on embodied energy required in different dwelling types and settlement patterns, including associated outside facilities and infrastructure like roads and services (such as water, electricity and sewage). Moreover, associated investment, operating costs and energy, generated traffic and also the political and societal framework which affects housing development, individual housing preferences and user decisions will be assessed. Based on the gained data and the assessment results, the project will provide recommendations and a tailor-made web-based tool in order 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 greenhouse-gas reductions within a sustainable urban development.

Settlements can follow different patterns, from dense urban cities with tall apartment buildings, to scattered housing patterns in the countryside. Different settlement patterns bring along different impacts, not only caused by different building types and their energy need and landscape consumption, but also caused by embodied energy within the buildings, energy and investment needed for necessary infrastructure, operating cost for public services and generated demand for transport. Many of these issues are not – or only to a minor degree and not within a broader picture and a holistic approach – addressed by existing policies, guidelines or tools. This is so despite the large potential for energy and greenhouse gas emission savings should be obvious. The main challenge for addressing the whole picture of consequences and impacts connected to different settlement patterns is the total lack of data for embodied energy required for infrastructure. Evolving these basic data will establish the prerequisite for developing tools on this issue, which do not exist today.

Currently, municipalities like Kristiansand have a challenge in assessing 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 discuss sustainable development in a broader and long-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. Then the decision on where to build also has a social dimension. In addition, we know that lower prices increase the number of square meters demanded.

Recommendations and tools that will be developed in the project, address all the three thematic areas of the call and underpin the goal of a sustainable society. The project supports the social sustainability of the city by providing policy makers with a tool that shall facilitate urban planning and strengthen public governance by making decisions more transparent. The economic dimension is endorsed by facilitating a more efficient and effective allocation of public resources, as the project also considers energy required for building and maintaining associated facilities and infrastructure, as well as operating costs, which can have a direct economic impact on the municipality's budget and affect indirectly private households. Environmental sustainability is also central, as the project covers a range of issues, namely transport, mobility, land use, buildings and energy, which are key to reduce the environmental impact of current and forecasted urban

development and to develop eco-friendly cities. There is a distinct correlation between these subthemes and sub-items. Thus, assessments, recommendations and the tool bring together key environmental issues (land use, buildings, energy and transport) with efficient and effective infrastructure and link both with good governance and planning, as well as with contributions for appropriate policy instruments. By integrating a broader range of considerations into the assessment, decisions on housing development can be made on the basis of a more equal understanding across interested parties, taking into account the various sustainability dimensions.

1.2 Approaches, hypotheses and choice of method

Current building regulations only consider operation energy. Also political plans and strategies reflect almost exclusively energy for the operation of buildings, not the embodied energy in the building's life cycle. On the other hand, life cycle assessment (LCA) of buildings is usually focused on embodied energy of the building itself, without considering the impact from associated outdoor facilities and infrastructure. Data for embodied energy associated with outside facilities and infrastructure are not known at all in Norway, and there are neither available data from other countries – with the exception of the Austrian project "ZERsiedelt – *Energy relevant aspects of building and future of Housing and Settlement-Structures in Austria*", which was completed in 2011. As far as we know, "ZERsiedelt" is the only project that have examined embodied energy by different settlement patterns in a detailed manner and a broader perspective until now. Furthermore, the Austrian Institute of Spatial Planning and Rural Development (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.

The results of the ZERsiedelt project, show great significance of embodied energy associated with roads and other infrastructure such as drainage and rainwater sewers, drinking water supply, power lines and data cables, road lighting etc. Therefore, the total energy demand related to a building will be strongly influenced by the settlement pattern. Detached houses in scattered settlements not only require more energy for materials, construction and operation, but also require significantly more material, energy and investment in infrastructure. In the ZERsiedelt project, a free online calculation tool was developed and recommendations for policy makers were provided. (Bußwald 2011, Stejskal et al. 2011).

According to the ZERsiedelt project results, a detached house of Passive House standard situated in a scattered settlement will use almost as much energy over its lifecycle as an equal large dwelling in an apartment building from the 1970s, when infrastructure is included. Compared to a modern apartment, the detached house in the scattered settlement would use considerable more energy. Additionally, the single-family house would generate more individual car traffic. (Klinski et al., 2012). These results would not necessarily be the same in Norway. Nevertheless, it is important to show the effect of embodied energy in new energy efficient homes, especially if one takes into account the energy that goes to roads and other infrastructure. As mentioned, current practice in building LCA usually does not include this aspect.

In our approach and context, *embodied energy* means the energy that is needed to produce, transport and install materials for the building, outdoor facilities and infrastructure, including local energy consumption during the construction process as well as energy use for maintenance and replacement of components. Energy consumption during the operation of the building is therefore not included in the term. The term *embodied energy* has so far not been established with an adequate translation into Norwegian. Currently used terms are both *bunden/bundet energi* and *innebygd energi*. In many other languages, a corresponding translation of *grey energy* is used, as in German, French, Spain and Italian. In this proposal, we use *embodied energy*.

On the basis of the data to be developed for embodied energy, the project will estimate the annual proportion of embodied energy in the building and the embodied energy in associated infrastructure and outdoor facilities (the proportion corresponds to embodied energy divided by the number of years of life). Furthermore, the annually total energy requirement for operational energy for the building will be calculated. One could, for example, distinguish between a typical detached house, typical row houses and a typical apartment building, as well as between dense urban areas, contiguous small house settlement and scattered

small house settlement. These typical buildings and settlement patterns will in addition be used to model the residents' energy needs for transport, as well as for estimation of investment and operating cost for infrastructure and also of the energy need and cost for the operation of services such as waste disposal, snow removal etc.

Internationally, several studies (Erving & Cervero, 2010) have shown correlation between settlement structure, accessibility and travel behavior in cities. Næss (2012) has given an overview and a theoretical discussion of a selection of research in the Nordic countries. In Norway, Institute of Transport Economics (TØI) has confirmed the correlation through analyzes based on data from the national travel surveys combined with registry data. The main conclusion is that, on average, car use is highest in rural areas, and that highly dense urban areas show less car usage than cities with low density. In large cities, residential areas near the city center, and residential areas with high density, good accessibility by public transport or good local access to jobs and services show lower car use rates. In small and medium-sized towns car usage is high, particularly if the town is less self-sufficient in terms of jobs, shops and services.

Estimations on generated transport demand will enhance calculations on energy and costs related to a settlement, providing thus a more comprehensive assessment of impacts associated with housing. When comparing residents' energy needs for transport in different dwelling types and settlement patterns, the focus will primarily be on the daily travel activity within the region. This means that long-distance travel (including air travel) will be excluded from the analysis. Moreover, since differences in energy use for local passenger transport are primarily related to the proportion of journeys made by car, the extent of car use will be the main indicator.

In parallel to the analyses by modelling, calculations and estimations, the project will examine how framework conditions such as regulations, subsidies, tax incentives and households' preferences affects individuals' housing demand and location decisions. Policy recommendations will be an outcome of both the environmental and economical assessments and this framework examination. The online tool will be based on the technical and economical assessments and underpin the recommendations.

Preferences and demand for new housing meet public restrictions on the supply side. Norway has juridical binding zoning plans that authorize the development of land for housing. In a "bottom up" planning system as in Norway, landowners and developers are allowed to draft and forward zoning plans. Under the Planning and Building Act, development of these detailed plans must nevertheless conform to the municipality's general plan. When preparing their masterplans, municipalities have to adapt to national framework conditions; at first a national expectation document expressing the targets for the future development pattern (Ministry of Local Government and Modernisation) and secondly the national framework for planning functions, especially the national framework for coordinated land- and transport planning. These frameworks are again based on international climate and environment agreements.

Currently the housing stock in Norway consists of 2.5 million homes and grows annually by approximately 1 percent through new construction. From year 1980 to year 2013 housing space per person increased from 36 to 58 square meters, mostly explained by high income growth during this period. Relative prices between housing and other consumption, influenced by favourable taxation of home ownership, house prices and (low) interest rates, in addition to changes in household structures, households' housing and location preferences are additional explanations behind this development.

The main challenge when developing a holistic picture of different housing development is the lack of data concerning embodied energy required for infrastructure. To investigate the influence of different settlement patterns separately (in contrast to the impact of different design, material choice or energy standard of the building, which is an issue in current LCA, as far as LCA is carried out at all), it would be necessary to fix the design of the houses as representative reference buildings. Furthermore, it would be essential to create realistic typical building models with the associated infrastructure in typical settlement structures. For this reason, practitioners from municipalities and regional authorities, as well as associations and relevant private professionals will be involved during workshops at the initial (yet crucial) phase of the project to map their needs. This participation, along with further stakeholder consultations to discuss intermediate results and provide feedback on the tool prototype, will ensure that project results are relevant and will be used in practise. In addition, an advisory board will be established to follow-up the project more closely.

The proposed project will build on existing knowledge, in particular concerning embodied energy in buildings, worked out in the Norwegian ZEB project[1] (Fjeldheim, Kristjansdottir et al. 2015; Fufa, Schlanbusch et al. 2016), embodied energy in infrastructure (Venkatesh, Hammervold et al. 2011, Krantz, Larsson et al. 2015), cost of infrastructure (Preuß and Floeting 2009), travel behaviour in different types of location for different building types (Hanssen and Engebretsen 2006) and factors influencing housing demand, based on housing and location preferences (Barlindhaug 2010, Ruud m.fl. 2013). A key reference work for defining the appropriate methods to conduct the impact assessment of different settlement patterns and policies as well as for developing the project's tool will be the above mentioned ZERsiedelt project. Yet, the project will create complete new knowledge for Norwegian conditions; assessment and recommendations will reflect Norwegian circumstances, and the tool will be developed according to the needs of Norwegian municipalities and authorities.

A multidisciplinary collaboration is essential for identifying needs, for modelling buildings and settlements and for developing recommendations. Especially for the initial basic development, inputs from different technical disciplines and social science are needed for creating consistent models for analysing. Comprehensive recommendations will be developed in cooperation between all the research disciplines and stakeholders represented in the consortium.

PART 2: Implementation and organisation

2. 1 The project plan, project management and organisation

The project will be 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 in Figure 1.

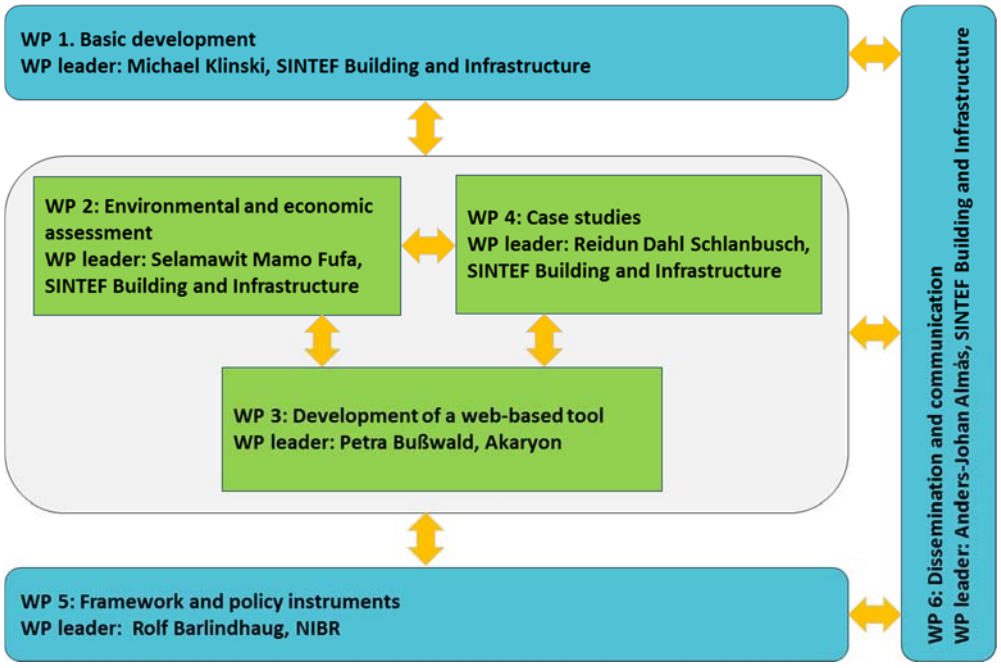

Figure 1: Project organisation and implementation

The starting point of the project is the development of a basis in work package 1, where needs will be assessed and the scope will be defined more precisely. Assessments in work package 2 and the development of a web-based tool in WP 3 can build on this basis, and assessment results will be inputs in the tool. Case studies in WP 4 will, inter alia, quality assure the tool and give contributions for its improvement. WP 5

[1] The Research Centre on Zero Emission Buildings

examines framework conditions and evolves recommendations, based on results from WP 2-4, taking into account the needs identified in WP 1. All results generated in the project, will be spread in WP 6.

WP 1: Basic development
WP leader: Michael Klinski, SINTEF Building and Infrastructure

In this work package, the aim is to create the basis for assessment, examination and tool development within the project. 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 demand of different municipalities and authorities (Task 1.2) and defines the goal and scope of the project (Task 1.3). Practitioners from municipalities and regional authorities, as well as associations and relevant private professionals will be closely involved at this initial phase of the project to map their needs.

Task 1.1: State of the art
- Literature studies (Norwegian, Nordic, and other countries) including also LCA databases and tools (e.g. GEMIS, klimagassregnskap.no, openLCA, ecoinvent and environmental product declarations (EPDs)) and emission factors included in planning tools (e.g. CAD, BIM) – deduction of missing factors and quality of existing factors (comparison of existing data pool)
- Results from Austria (knowledge transfer in the workshop and report)

Task 1.2: Assessment of needs
- Needs in case municipalities
- Needs in the public in general (e.g. other municipalities, regional and central Authorities)
- Input from other interested parties

Task 1.3: Modelling of typical buildings, sites / settlements, infrastructure
- What types (incl. Energy Performance levels) and construction periods should be selected?
- Defining specific representative models
- Defining building components and infrastructure that are included in these models (list with quantities).
- Defining appropriate specific indicators, benchmark sizes, timeframe etc. for the analyses
- Development of use cases for project results (guidelines and tool) – which questions shall these results help to answer? In which way they will be used and will benefit most?

WP 2: Environmental and economic assessment
WP leader: Selamawit Mamo Fufa, SINTEF Building and Infrastructure

In this work package, the aim is to assess the representative models according to specific indicators defined in WP 1 and create results that will be used as input in the development of the tool in WP 3 and the framework examination in WP 5. Providing a wider perspective on environmental and economic impacts, the assessment will include the annual proportion of embodied energy in the building and in the associated infrastructure and outdoor facilities, as well as the annually total energy demand for operational energy for the building (Task 2.1), the infrastructure investment and operating costs (Task 2.2) and the energy need and cost for the operation of services related to the typical buildings and settlement patterns (Task 2.3). Furthermore, the typical buildings and settlement patterns will be used to model the residents' energy needs for transport (Task 2.4).

Modelling the residents' energy needs for transport differs methodically from the energy and cost assessment for buildings and infrastructure and cannot rely on the same groundwork. Therefore, Task 2.4 requires a more detailed description (see under Task 2.4 below). The Institute of Transport Economics (TØI) will be responsible for this task.

Task 2.1: Calculation of embodied energy and operating energy
This task extends the scope of current LCA practice beyond the evaluation of embodied energy of the building itself, including associated infrastructure and outdoor facilities. In addition, the overall demand for operating energy of the building will be calculated.

Task 2.2: Calculation of investment and operating costs for the associated infrastructure
This task is a cost assessment of infrastructure related to typical buildings and settlement patterns. The cost of the buildings themselves are therefore not included.

Task 2.3: Estimation of energy demand and operating costs for services
Besides the assessment of operating costs for infrastructure in Task 2.2, this task will assess costs for operating necessary services (such as waste disposal and snow removal activities), which are not directly associated with public infrastructure, but which nevertheless are strongly affected by settlement structures. The energy demand for such services will also be assessed.

Task 2.4: Estimation of residents' energy needs for transport
The aim of task 2.4 is to build-in information about dwelling types into existing analysis on generation of transport demand. The purpose is to see if there is a correlation between dwelling types and choice of transport mode beyond that what is known (localization, density, quality of public transport, etc.). Previous approaches (Hanssen and Engebretsen 2006, Engebretsen and Christiansen 2011) will be followed and further developed. The main data source will be the national transport survey 2013/2014 (more than 60,000 respondents and nearly 200,000 trips). Using geocodes for residences and trips, we can add information about the buildings and spatial characteristics based on data from The Norwegian Cadastre property register, spatial statistics (Statistics Norway), registry of commuting (Statistics Norway/TØI), registry of businesses and enterprises (Statistics Norway/TØI) and data from network model (TØI). Coupling the travel survey (using own weighting procedures) with this geographical information provides representative data across all types of regions, including rural areas, for analyzing the research questions. Moreover, it allows for the generalization of results into models, which then can be used in impact assessments (TØI has developed such models for land use and transport planning, which have been used in the regional land use and transport plan for Oslo and Akershus, see Strand et al 2013).

WP 3: Development of a web-based tool
WP leader: Petra Bußwald, Akaryon

This work package will include and combine the results of WP 1 and WP 2 and provide an interactive way to access the results (compared to sole “static” studies). It will allow users to enter input parameters and customize results according to their requirements (e.g. number and type of houses of a settlement, materials used, length of road and sewage system). The methodology used to develop a tool under ZERsiedelt project will be a key reference for developing the tool. The model will be generic, but from the beginning of the work, Norwegian conditions and requirements have to be reflected. To ensure this, the work will be carried out in close cooperation with the Norwegian partners, and SINTEF Building and infrastructure will be responsible for task 3.2.

The purpose of the tool is helping to assess the environmental and economic impact of different types of buildings and settlements. In this way, the tool supports decision making concerning housing and settlement development. Targeted user groups are professionals, policy makers and decision makers in municipalities and other authorities, as well as major developers and professionals like architects and spatial planners in general. In addition, interested private users may use the tool in a simplified mode, assessing individual "living options" and their ecological footprint.

The tool will be web-based, building on open source development components. The interface will be available in Norwegian and in English (potentially also in German, if realisable within the project duration and budget). The functionality shall ensure a very low barrier for usage of the tool. It shall be possible to make rough estimations based on only few input data. Calculations will be more precise if users can/want to provide more specific input. Users shall be able to save scenarios and compare different scenarios.

Further specifications of the tool will be developed in the light of the results of task 1.1 (needs) and 1.2 (modelling, use cases) and refined according to feedback from case studies in WP4.

Task 3.1: Development of a generic model that can be used in several countries (bilingual)
Data structures will be developed that best represent the data and their interrelations, on the input side as well as on the output side. Mathematical models have to be established that depict the results of WP 2 especially and allow to calculate indicators according to the requirements defined in WP 1. The whole system will be designed in a modular way to allow calculation of a whole settlement as well as "zooming" on a part of a settlement to gain insights on detailed aspects.

Task 3.2: Adaptation to Norwegian conditions and needs (in parallel to task 3.1, not afterwards).
Inter alia, the model will address a multi-regional/-national approach, allowing to adjust calculation factors to Norway respectively Norwegian regions (e.g. emission factors for district heating may differ according to the local situation) as well as to other European regions, in order to allow future steps within an even bigger context.

WP 4: Case studies
WP leader: Reidun Dahl Schlanbusch, SINTEF Building and Infrastructure

In this work package, case studies from selected municipalities or regions will be carried out for:
- Testing and quality assurance of the tool, allowing corrections, adjustments and improvements of the prototype developed in WP 3, based on case results and feedback
- Development of recommendations for the municipalities involved, which also would be useful input for the recommendations and guidelines to evolve in WP 5.

In Addition will existing challenges in Norwegian cases be used for the assessment of needs and the modelling in WP 1.

Task 4.1: Applying the tool prototype to evaluate case studies from Kristiansand municipality, developing recommendations based on the results
Existing challenges in Kristiansand form an important part of the background for the project. The case study will prove if the tool prototype is adequate to address these challenges, and give important indications on required (or desirable) improvements of the tool. Concrete recommendations for the municipality will be provided.

Task 4.2: Applying the tool prototype to evaluate case studies from further municipalities or regions, developing recommendations based on the results
During the first year of the project, the additional case studies will be announced, and interested municipalities will be invited to apply. 2-3 case-municipalities or regions will then be selected. Tromsø municipality already expressed its interest.

Task 4.3: Applying the tool prototype in cities in Austria
During the first year of the project, also the Austrian case studies will be announced, and interested municipalities will be invited to apply. 2-3 case-municipalities or regions will then be selected. IRUB in Vienna will conduct these studies.

WP 5: Framework and policy instruments
WP leader: Rolf Barlindhaug, NIBR

This work package examines how framework conditions such as regulations, subsidies, tax incentives and households' preferences affects individuals' housing demand and location decisions. Policy recommendations that reflect Norwegian conditions will be an outcome of WP 5 based on this examination, taking into account the knowledge of the national and international survey in WP 1, the environmental and economical assessments in WP 2 and the results of the case studies in WP 4. Comprehensive guidelines and recommendations for policy makers will be developed in cooperation between all the research disciplines

and stakeholders represented in the consortium. In the following, the approach for task 1 of this work package is described more detailed.

Task 5.1: What affects individuals' and households' housing demand and housing location patterns today?
Many studies of residential mobility show that housing preferences, location preferences and housing demand vary with life stages (Clark and Huang 2003, Barlindhaug 2010, Barlindhaug 2013). While about 13 percent of the population moves every year, it follows that the vast majority of residential mobility takes place in the existing housing stock. Mostly due to high population growth the housing stock yearly increase with around 30 000 new dwellings. The location of these dwellings will be a challenge for the municipalities.

In urban areas, young people seek towards central locations where housing prices are the highest, and compensate for high square meter prices by choosing less living space. Families with children have other preferences. Gkartzios and Scott (2010) studied counterurbanisation floods in the greater Dublin area and found that the main motives for moving to the rural areas were living in a better, larger and cheaper house and that the area was the most appropriate for bringing up children. The area was also associated with a better quality of life, lower density, reduced noise and there was a slower pace of life and lack of crime. The pull factors dominated in explaining the move; especially the social environment in rural areas, but also the physical environment and lower house prices. Gkartzios and Scott (2010) point out that this migration pattern is associated with unsustainable patterns of spatial developments. Urban sprawl is developing; nearly 60 percent of the counterurbanisation moves to a new property. They ask for planning interventions in urban areas that could take more considerations of consumer preferences and satisfying this demand.

In this task, we will utilize the Norwegian data from EU-SILC 2015 (European Survey of Living and Income Conditions) to uncover how households in the different life stages live today. Most important would be to reveal the housing and location choices of recent movers (moved in the period 2010-2015) and their subjective motivations for their decisions. The survey also provides the opportunity to study future moving plans. EUSILC 2015 is a sample survey containing answers from some less than 7000 individuals 16 years and older. NSD provides the survey for research purposes, but data does not give information on municipality level, except for the four largest cities.

We will in addition order registry data from Statistics Norway of the population of recent movers, for example for the years 2015 and 2016. Different data registers will be utilized, so that socioeconomic background variables can be combined with features of the residences that are moved from and to, as well as detailed geographical information about localization before and after a move. It will be important to make analyses of recent movers in the case-municipalities selected.

Task 5.2.: What instruments should municipalities and governing authorities develop and use to increase the sustainability of the settlement pattern, in light of the results of the project?
Local political authorities seem to plan for satisfying the housing demand of their inhabitants, or to attract new inhabitants. This will not necessarily result in a sustainable settlement patterns. Municipal autonomy has to adopt to governmental framework conditions. Without strong framework conditions, municipalities who voluntary follow a settlement pattern that work against their inhabitants' interests, may lose inhabitants to neighbor municipalities. Owner occupation is favorable taxed today and increase housing demand. A more neutral taxation may influence housing demand and the mix of building types in new construction.

Task 5.3: Recommendations and guidelines for municipalities and policy makers
When preparing their masterplans according the Planning and building act, municipalities have to 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 will not be limited to spatial planning issues or national policies, but will include a wider range of topics that influence settlement patterns, with guidelines also for local and regional authorities.

WP 6: Dissemination and communication
WP leader: Anders-Johan Almås, SINTEF Building and Infrastructure

The aim for dissemination within the project is to ensure that data and other results generated in the project is effectively spread among the partners, from the project to potential users and to the scientific community, policy developers and other relevant stakeholders. This is planned to be achieved through meetings, workshops, publications, web and Social Media, as well as established communication channels of partners. In particular, local and regional stakeholders and professionals such as architects and spatial planners will be addressed by producing new guidelines. A project website will be developed and used for publication of the tool, main findings and results of the project. The website will be managed and maintained by SINTEF Building and Infrastructure, and will be regularly updated with relevant information and project updates.

Task 6.1: Workshops
Two main workshops with additional invitees will be held in the project:
- Workshop 1 at the start of the project to give input to the assessment of needs and discuss the goal and scope of the project.
- Workshop 2 after about two-thirds of the project period to discuss the results of the assessments and evaluate the prototype of the tool.

Task 6.2: Presentations and publications
- Events with presentation of the findings in case-municipalities
- Presentation and publication of the findings of the project (results, tools, guidelines and recommendations) in a public closing conference
- Presentation in yearly BYLIV events and "Brød & Miljø" breakfast meetings (Norske Arkitekters Landsforening)
- Publication of the findings in scientific conferences and journals

Task 6.3: User/public oriented communication
The findings of the project will be communicated through several channels including
- Journals such as Plan, Kommunalteknikk, Byggeindustrien / Bygg.no
- Designated website with available tools as well as dissemination through the partners' websites and Futurebuilt.
- Two guides within the SINTEF Building Research Design Guides (Byggforskserien)

2. 2 Consortium, expertise and work method

This project brings together a consortium of national and international partners with substantial competence and experience in research, academic and consultancy fields, as well as public and industry partners which significantly contribute to assessment of needs, case-studies, recommendations and dissemination. The research partners cover expertise on energy efficiency in buildings, life cycle assessment, infrastructure (SINTEF Building and Infrastructure), transport (TØI), housing and regional development (NIBR and IRUB) and environmental informatics (Akaryon). SINTEF Building and Infrastructure, NIBR and TØI are leading research institutes on their respective fields. Both NIBR and TØI are part of the Oslo Centre for Interdisciplinary Environmental and Social Research (CIENS)[2], which will facilitate the consideration of different perspectives (economic, environmental and social) throughout the project as well as the dissemination of project results among a broad audience. Cooperation with Akaryon and IRUB from Austria assures international knowledge sharing with the most advanced and relevant research institutions in Europe concerning the topic of the project. Contributing public and industry partners are Kristiansand municipality and the BYLIVsenteret. Involving Kristiansand as a premise provider and the BYLIVsenter with its hands on work with municipalities throughout the country will ensure the practical relevance of the project and its results.

[2] The Oslo Centre for Interdisciplinary Environmental and Social Research (CIENS) brings together nine research institutes with a combined staff of about 500 persons, whose aim is to help solve the substantial and complex challenges arising in the interface between environment, business, and politics.

All partners will contribute in all WPs (apart from the technical development of the tool), and there will be a close cooperation between researchers. In addition to the concrete collaboration in tasks, purposive cooperation will be ensured by conducting workshops and partner meetings. Where appropriate, partner meetings will be combined with advisory group meetings. An advisory group will be established, aiming to involve both public bodies (such as NVE, the Norwegian State Housing bank, Enova and the Ministry of Local Government and Modernisation), some regional or municipal authorities and stakeholders from the industry. For the two workshops, the group of invitees will be extended. The project plan is summarized in Table 1.

Table 1: Project plan

Activities and milestones		Contribution	2017		2018				2019				2020	
			3	4	1	2	3	4	1	2	3	4	1	2
	Start-up, status and closure meetings with advisory board	All												
WP1	**Basic development**													
	Task 1.1: State of the art	All												
	Task 1.2: Assessment of needs													
	Task 1.3: Modelling of typical buildings, sites / settlements, infrastructure													
WP2	**Environmental and economic assessment**													
	Task 2.1: Calculation of embodied energy and operating energy	SINTEF, TØI												
	Task 2.2: Calculation of investment and operating costs for infrastructure													
	Task 2.3: Estimation of energy demand and operating costs for services													
	Task 2.4: Estimation of residents' energy needs for transport													
WP3	**Development of a web-based tool**													
	Task 3.1: Development of a generic model that can be used in several countri	Akaryon, SINTEF												
	Task 3.2: Adaptation to Norwegian conditions and needs													
WP4	**Case studies**													
	Task 4.1: Apply the tool to case studies from Kristiansand municipality	All												
	Task 4.2: Apply the tool to case studies from further municipalities													
	Task 4.3: Apply the tool in a city in Austria													
WP5	**Framework and policy instruments**													
	Task 5.1: Factors affecting individuals' and housholds' housing demand	NIBR (all)												
	Task 5.2: Instruments that municipalities and governing authorities should de													
	Task 5.3: Guidelines for policy makers													
WP6	**Dissemination and communication**													
	Task 6.1: Workshops	All												
	Task 6.2: Presentations and publications													
	Task 6.3: User/public-oriented communication and publications													

The scientific project team consists of six WP leaders who all are experienced researchers in the field of sustainability with its various aspects. Michael Klinski will be project manager and WP 1 leader. He has experience from managing other NFR and EU projects within building energy research. Klinski has work and research experience from Norway, Germany and Austria and has been member of the management team for the EU Concerted Action EPBD. Selamawit Mamo Fufa will be leading WP 2. She has expertise in the area of life cycle sustainability assessment and has been involved in different projects related to LCA of materials, components and buildings. Fufa will lead the work package in close co-operation with Kamal Azrague, Senior researcher with strong experience in infrastructure-related projects. Within WP 2 Øystein Engebretsen (TØI) will be responsible for Task 2.3. Engebretsen has long experience in research on travel behaviour, especially related to urban structure and localization, including methodological issues related to the needs of this project. Petra Bußwald (Akaryon) will be responsible for WP 3. She has been leader of the Austrian ZERsiedelt project and has multi-year experience from Austrian and international research projects in the energy context delivering interactive tools as output of research. With her background in Technical mathematics and environmental informatics she is working at the interface of mathematical/environmental assessment models elaborating their transfer into tools that allow multiple user groups to work with the data and make optimum use of the models. Reidun Dahl Schlanbusch will be responsible for WP 4. She has experience from a range of sustainability projects related to buildings, including tool and methodology development based on life cycle assessment. Project experience includes the ZEB and ZEN research centres. She also has experience as work package leader. Rolf Barlindhaug (NIBR) will be leading WP 5 and do the research on this WP. He has long experience in research management, also NFR-projects, and is highly experienced in housing research. Anders-Johan Almås will be responsible for WP 6. He has experience from several NFR and EU projects. He is now leading the innovation arena of the CRI research centre Klima 2050

(www.klima2050.no). Almås is a senior researcher and holds a PhD in sustainable buildings. We refer to the respective CVs for more information about the WP leaders and the leader of Task 2.3.

It is an ambition that one Post doc fellowship and three Master students will be related to the project. Key researchers within the project will be involved in the supervision. The Post doc fellow will work mainly on the environmental and economic assessment (WP2) and the case studies (WP4). Three Master students will work in close association with the Post doc fellow in WP2 and WP4 and/or with framework and policy instruments (WP5), depending on the requirement of the project. The close collaboration of NIBR and SINTEF, both situated in Oslo makes it a research hub where close interaction between Post doc, Master students, supervisor at HiOA (where NIBR is associated) and co-supervisors can occur.

The partners behind this project are SINTEF Building and Infrastructure (SINTEF), The Norwegian Institute for Urban and Regional Research (NIBR) , The Institute of Transport Economics (TØI), Kristiansand municipality, BYLIVsenteret, Akaryon and the Institute of Spatial Planning and Rural Development (IRUB) at BOKU University in Vienna.

SINTEF is the largest independent research organization in Scandinavia. SINTEF performs R&D for EU and international programs, government and non-governmental organizations, service providers, large industrial companies and SMEs.

Within the unit *Building and Infrastructure* the department *Architectural Engineering* possess expertise in architecture and building techniques, building processes, technical installations, energy and indoor climate, environmental and life cycle assessment, user behaviour and social aspects. The main objective is to contribute to better planning, construction, and operation of buildings in order to reduce environmental impact and maximize value for users, building owners, and for society at large. The *Infrastructure* department has expertise on water treatment and water infrastructures, roads, railways, tunnels and increased utilization of the underground. The department has gained expertise in strategic planning of infrastructure systems and related environmental (including LCA and energy aspects), economic and socio-economic issues e.g. through the development of a sustainability based framework to support transition planning towards more sustainable urban infrastructure systems. This assessment framework has been implemented and tested in different pilot cities or regions through several EU projects (e.g. PANTURA, TRUST, DESSIN) and national research projects financed by NFR (e.g. DIVA, Klima 2050).

The Norwegian Institute for Urban and Regional Research (NIBR) is a social science research institute at HiOA, the Oslo and Akershus University College of Applied Sciences. NIBR's key qualifications lie in place and governance studies, nationally and internationally, in selected policy areas. By combining cutting-edge expertise across disciplinary borders, NIBR produce integrated and robust analysis with great emphasis on relevance for clients. Fields of study are Housing studies, City and place, Democracy and governance, Health and welfare, Climate and environment, Migration and integration, Planning Studies, Regional and territorial development. NIBR possesses comprehensive experience in conducting research-based evaluations for public institutions, nationally and internationally. The evaluations include general reforms in public administration and governance systems, as well as restructuring processes within specific sectors and institutions. Multi-disciplinary and complementary methods are key traits characterising NIBR's evaluation research. NIBR's researchers span the social sciences and planning disciplines: Sociology, Political science, Economy, Demography, Anthropology, and Geography.

The Institute of Transport Economics (TØI) is an independent and non-profit, Norwegian institution for multidisciplinary and applied transport research. Its wide sphere of research activity includes a research group dedicated to investigating the social conditions explaining travel behaviour and mobility, whose expertise will be key to conduct a comprehensive assessment of the energy bounded to transport when building housing facilities. TØI has proved competences on estimating trip production depending on conditions such as housing location and land use patterns (Hansen & Engebretsen 2006), as well as estimating the extent of car use derived from implementing different urban planning strategies (Engebretsen et al. 2011, Strand et al. 2013 and Christiansen et al. 2015). This research is based on the largest dataset to describe the Norwegian population's travel behaviour, the National Travel Survey, for which TØI has been responsible for over 25 years. TØI has also developed extensive knowledge in simulating traffic volumes for different types of settlement structures, which has served as knowledge basis for land use and transport

policy. Intertwining these competences with those brought by further consortium partners will provide a solid and broad knowledge basis (WP1) to conduct the comprehensive assessments (WP2) scoped by the project.

Kristiansand is a city, municipality and the county capital of Vest-Agder County in Southern Norway. Kristiansand is the fifth largest city in Norway with a population of 88 600. Greater Kristiansand has a population of 137.000, and comprises the municipalities of Søgne, Songdalen, Iveland, Vennesla, Birkenes, Lillesand and Kristiansand. Historically, Kristiansand has been a green city for decades. The Kristiansand municipality is at the forefront when it comes to waste recycling, action on climate change and bicycle use for transport. Despite this great development, Kristiansand has a challenge with the largest densely populated area (*tettstedsareal*) per capita compared to the biggest cities in the country, something that contributes to growth in urban sprawl and the highest proportion in use of private cars. Current challenges in Kristiansand form an important part of the background for the project. Kristiansand contributes to the corresponding case studies, provides data for these studies as well as for the assessments (where appropriate and available) and give input to the requirement analysis and definition of the scope in the initial phase of the project.

BYLIVsenteret is owned by the National Association of Norwegian Architects (NAL), which is a professional ideal members organization working to promote good and sustainable architecture and urban development. BYLIVsenteret is a continuation of NAL's longtime work with projects regarding sustainable urban development, including Framtidens byer, Framtidens bygder, Norwegian Wood and the start of what is now FutureBuilt. *BYLIVsenteret* provides professional advice and guidance to local authorities in their work on sustainable urban development and promotes a holistic understanding of sustainability with an equal ratio of social, financial and environmental sustainability. BYLIVsenteret offers professional advice and practical guidance in all phases of a project, from early stage visionary processes, planning and execution of architectural and planning competitions, strategic plans, proper localization and joint use etc. BYLIVsenteret works hands on with municipalities throughout the country. BYLIVsenteret cooperates with County Councils and Government agencies to ensure that their advices are coherent with national objectives and regional plans, and to ensure that we complement the others. The Centre will contribute to the assessment of needs and to the development of recommendations. Moreover, they will play an important part in the dissemination of results via own yearly conferences and seminars, as well as contributions to the popular "Brød & Miljø" series.

Akaryon (www.akaryon.com) is a research based Austrian SME owned by the two founders. Interest for sustainability topics is part of the corporate mission. To work in this field, the two founders and their 10 persons team combine knowledge in Mathematics, Statistics, ICT, Environmental Informatics and Environmental Management. The clear business focus are research based web/mobile environmental informatics solutions – with some already on the market and others in the development phase. New projects are both generated within Akaryon as well as brought in from other stakeholders (such as universities, research institutes, companies, NGOs, associations and governmental units). The long track record collected since its foundation in 1999, illustrates an outstanding experience in transferring complex sustainability assessment models into interactive applications, that allow effective dissemination and use of environmental research results. In the project, Akaryon will be a subcontractor of SINTEF.

IRUB, the Institute of Spatial Planning and Rural Development, part of the Department of Spatial, Landscape and Infrastructure Sciences (RaLI) at BOKU University[3] in Vienna, is involved in fundamental and applied research in the following fields: spatial planning, integrated spatial and energy planning, planning aspects of risk management, including the spatial aspects of climate change and natural disaster risk management, land rearrangement, environmental planning and assessment as well as regional and rural development. The objective of the work at IRUB is to raise issues of current interest from the viewpoint of sustainable development and scientifically deal with these issues in order to represent and discuss them on national and international level. Results of IRUB research are intended to support planning and decision making processes. A research focus lies on the development of strategic planning and assessment methods, inter alia, for integrated spatial and energy planning. Examples are the ELAS-calculator, a life-cycle assessment tool for calculating the total energy balance of settlements including heating, electricity, mobility of residents

[3] Universität für Bodenkultur, Wien – University of Natural Resources and Life Sciences, Vienna

depending on the location of the settlement, as well as embodies energy in buildings and infrastructure; or a tool to appraise the regional resilience towards energy crises.

2. 3 Resources

See the budget in the electronic application. It is applied for 11.980 mill NOK from BYFORSK, and the partners have agreed to contribute with in total 1.250 mill NOK in-kind.

PART 3: Benefit to society and impact

3. 1 Benefit to society and impact

Basis data for embodied energy including that in associated facilities and infrastructure to residential buildings can be very important for the development of urban strategies and policies and the definition and implementation of appropriate policy instruments, especially when assessments consider the political and societal framework as well as the cost of municipal services and generated traffic in different settlement structures. Being able to see embodied energy associated with homes and infrastructure in a context beyond the individual's premises, can produce informed and more equal decisions which, in turn, find more support among citizens, improving thus governance capacity. Long-term and comprehensive data is essential for decision support.

The online tool to be developed will support county authorities (*fylkeskommuner*), municipalities and major developers by making the consequences visible when it comes to different options regarding building types, settlement patterns and further development in urban or rural areas. Moreover, as the tool will be developed in consultation with relevant interested parties and attending to their needs, its uptake will be facilitated, thus, enhancing the expectations of the project's results of having a real impact in urban planning.

As an impact, it can be expected that future decisions, made on the basis of new insights and appropriate tools, will result in less landscape consumption, less energy needs in general, less municipal costs and less traffic. Governance processes and public discussions on housing, urban and regional development will be facilitated. In this way, the project will provide significant support for strengthening cities and urban areas as a solution arena for a sustainable society.

3. 2 Knowledge sharing, communication and dissemination

Knowledge sharing, dissemination and communication of results plays a key role in the project. Workshops will be arranged to define the scope of the work (at the beginning of the project) and evaluate the findings of the project. A selection of external stakeholders will be invited to participate in the workshops along with the advisory group. The partners will participate at relevant conferences, presenting project findings and will prepare popular science papers published at national and international relevant journals/internet sites. Dissemination to the different stakeholders in the building sector, as well as among professionals working with urban and regional development will also be ensured through several channels such as Byggeindustrien, Teknisk Ukeblad, Dagens Næringsliv, Plan, Kommunalteknikk and Gemini. Furthermore, we aim exchange with the Norwegian Research Centre on Zero Emission Neighbourhoods in Smart Cities (ZEN) and will provide input to relevant work packages. ZEN and EE settlement have complementary activities that will be linked together in the further development towards a zero-emission society.

For supplementary information, see WP 6.

PART 4: Other information

4.1 Environmental impact

The research carried out within this project is expected to contribute to improved sustainability by promoting knowledge on instruments for evaluation of environmental impact of buildings, settlements, infrastructure and transport. The project will enable to the development of a more sustainable built environment.

4.2 Ethical perspectives

This project will be carried out in accordance with SINTEF´s and the scientific partners' ethical standards. Due to their policies, the institutes must be perceived as setting high ethical standards, and safeguarding health, environment, and safety aspects in all activities. Results of the project will be anonymized wherever appropriate. The project will adhere to prevailing ethical guidelines for research in Norway (NSD).

4.3 Gender issues (Recruitment of women, gender balance and gender perspectives)

Each of the involved partners consider gender balance as a core aspect of their work, and measures will be taken to ensure gender balance throughout the project. There is a positive gender dimension in the project whereby both genders are present in relevant decision-making roles and the management structure. Three of the six work package leaders will be female researchers.

4.4 Information about other public support

It is not assigned other public support to the project. All undertaking partners have confirmed that they have not been awarded public support for the costs they will have for the implementation project.

4.5 Information about dependency between project partners

None of the project-performing or financing project partners is part of the same group or has a similar dependency to any other partner.

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