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Cardiff, UK, 11\textsuperscript{th} and 12\textsuperscript{th} February 2016
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Introduction

The COST Action TU1104 ‘Smart Energy Regions’ started in March 2012 and ended in March 2016. During its four years of activity, the Action established a network of more than 70 researchers from 27 European countries and Israel, allowing the exchange of experience and engagement with local policy-makers and stakeholders.

The Action organised a Training School on energy retrofit for fifteen early-stage researchers, and enabled twenty-two researchers to conduct Short Term Scientific Missions in partner institutions. The main outputs of the Action are three publications collecting contributions from Action members on the topics of low carbon policy, technology, skills, training, supply chains, and cost and value. These and the other outputs of the Action can be found on the Action website: www.smart-er.eu

The international conference ‘Smart Energy Regions’ took place in Cardiff, UK, on 11th and 12th February 2016. The event gathered Action participants, international keynote speakers and invited delegates. This publication collects the papers and posters presented at the conference. Papers were presented orally according to the following thematic sessions:

1. Energy policy, strategy, cost and value;
2. Urban planning and infrastructure;
3. Energy retrofitting of the built environment;
4. Building energy demand and supply, and low carbon technologies;
5. Energy design tools, modelling and data management for the built environment.

The papers and posters presented at the conference are collected in this publication. The papers were selected and reviewed by the following members of the conference Scientific Committee:

- Ingrid Kaltenegger, JOANNEUM Research, Austria
- Werner Lang, Technische Universität München, Germany
- P. Amparo López-Jiménez, Universitat Politècnica de València, Spain
- Jo Patterson, Cardiff University, United Kingdom
- Jaime Roset-Calzada, Universitat Politécnica de Catalunya, Spain
- Derek Sinnott, Waterford Institute of Technology, Ireland
- Fabrizio Varriale, Cardiff University, United Kingdom

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COST - European Cooperation in Science and Technology

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www.cost.eu
**Bottom-up modelling of continuous renovation and energy balance of existing building stock: case study Kočevje**

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**Abstract:** A dynamic bottom-up model of the building stock is developed and implemented in a case study of Kočevje urban region. In the model, national register of real estate is cross-linked to data from other registers, e.g., the energy performance certificates (EPC) and the subsidized energy renovation measures. Regular updates of the data in registers enable continual improvement of the model. The renovation potential is determined with respect to the age of building components after the last renovation, while the energy performance of the building stock is based either on the EPC for a particular building if available or on the energy indicators of corresponding building type from IEE EPISODE building typology and IEE RePublic_ZEB. Thus, the bottom-up model of the building stock (BuilS) enable a profound overview of the total heat demand, final energy use and CO$_2$ emissions of the entire stock.

In the case study Kočevje, various strategies for improving the buildings towards more sustainable ones are presented with projections to 2030. The strategies, reference and intensive renovation scenario, are compared with more ambitious strategy that the municipality is looking towards in the frame of Covenant of Mayors commitment. The bottom-up model was validated against the metered energy use of buildings connected to district heating. In the case study the model shows how the implementation of various strategies lead to different impacts and how the ambitious municipal plans are going to produce independence from fossil fuels by fostering the use of wood biomass as a locally available sustainable energy supply. The Kočevje case study analysis demonstrates, at the local level how a concept of increasing renewable energy sources utilisation and building energy efficiency stimulated by progressive measures can respond to low carbon society and sustainable energy self-supply challenges.

**Keywords:** modelling, renovation scenarios, building stock, region policies

**Introduction**

Slovenia accepted ambitious targets for deep renovation of existing buildings described in the national strategic documents. For example, National energy efficiency action plan 2014–2020, in short NEEAP 2020, (AN URE 2020) and Long-term strategy for mobilising investment in the renovation of national buildings stocks (DS SNEPS) the national target to improve energy efficiency (EE) by 20 % by 2020 is defined, in line with the requirements set out in Directive 2012/27/EU (Energy Efficiency Directive). The existing building stock represents the sector with the greatest potential for achieving energy savings. To meet the national EE target, a quarter of that building stock, or around 22 million m$^2$ of useful floor area, has to be renovated. The improved energy performance will reduce the energy consumption in buildings by almost 10 % in the period 2014-2020.

On the other side, many EU municipalities and/or regions joined The Covenant of Mayors (CoM), the initiative of the European Commission to sign a voluntary agreement to reach and exceed the goal of 20 % reduction of CO$_2$ emission by 2020 also at the local and/or regional level and to contribute to 20-20-20 by 2020 climate and energy policy targets. Thus, a number of various local and regional activities specified in the sustainable energy action plans (SEAPs) is complementing the national policies and measures.
The Kočevje region is one of the most naturally preserved areas of Slovenia and Central Europe. The forests cover more than 90% of the total area. The municipality started to work on sustainable energy policies systematically in 2008, when the local energy concept (LEK 2008) was adopted. It includes the analysis of existing condition in the field of energy use and supply (which emphasizes the public buildings) and possibilities of use of local renewable energy sources (RES). In the local energy concept the EE and RES targets in the region are defined and the action plan agreed. In 2014 Kočevje signed the Covenant of Mayors and started to prepare the SEAP aiming at significant reduction of energy related CO₂ emissions.

In the urban area of the city of Kočevje the prevailing way of building heating is district heating system, powered by wooden biomass and fuel oil. Most of the individual houses in sub-urban area use wood and fuel oil as a heating source for heating. Municipality plans to replace oil as a fuel source powering the district heating system with innovative cogeneration system with wooden biomass gasification process to considerably lower the carbon footprint from building heating, to increase local energy self-supply and to increase level of renewable energy sources in national power grid. Energy renovation of the existing building stock is ongoing, supported by national and municipal incentives for housing and public buildings. EE and RES measures on demand and supply side are being implemented to support the goal to reach almost zero emission Kočevje region.

Planning and monitoring of the impacts of variety of policies and measures in building sector has become a complex task in particular due to the fragmentation of the building stock and several data gaps. Usually, the top-down building models are used, taking into account the statistical data on the floor area per year of construction of the building stock diversified per building type (i.e. residential houses and apartment buildings; buildings for non-residential use). The weakness of such models is that they disregard or only roughly consider the actual condition of the building stock, which is a result of the actual renovation dynamics, characterized by the information on the renovation done and on the basic technical details of the implemented works on building elements, energy systems or on the building as a whole.

The research in this paper aims to develop a bottom-up model of the building stock in the Kočevje region by integrating publicly available databases and surveys, relevant for forecasting the impacts of climate and energy related policies and measures in the region. The scope of the study is to validate the bottom-up model of the building stock and to forecast the impacts of sustainable energy policies in the region through dynamic modelling of energy performance of buildings.

Modelling energy use in buildings is an important step towards designing and implementing policy measures related to energy savings in buildings. Swan and Ugursal (2009) reviewed available models for assessing the effects of energy saving measures (ESM, also referred to as energy efficiency measures, represent actions aimed at reducing energy demand in buildings) in the residential sector, and concluded that so-called bottom-up modelling of buildings is required to determine the impacts of new technologies. But on the other hand, a bottom-up model of the building stock typically comprises building physics modelling for calculating the energy usage of individual buildings, and extrapolation of the results to a region or a country (Mata et al., 2013).

Kavgic et al. (2010) reviewed selected bottom-up building stock models for energy use in the residential sector and proposed that they should: (a) estimate the baseline energy demand of the existing building stock; (b) explore the technical and economic effects of different CO₂ emission reduction strategies over time, including the impacts of new technologies; and (c) identify the effects of the strategies on the quality of the indoor environment.

In the framework of the Intelligent Energy Europe project TABULA (Loga et al., 2012) a building typology of existing dwelling stock was developed using different types of buildings and periods of building construction in each country. Later on the work on typology was upgraded and new schemes of renovation monitoring as well as modelling of energy balance scenarios were developed in the scope of EPISCOPE (2015) project, which consists now of 20 European countries. When dealing with
the bottom-up model, the typology approach is a good tool for determining the energy performance of buildings, where no data on the current state of the building is available.

The presented bottom-up model enables to determine more accurately the status of the building stock in terms of energy performance characteristics. This is achieved by cross-linking publicly available databases on the building stock, national surveys on energy use in buildings and records on implemented subsidised energy efficiency measures as well as the data on the structure of energy supply. The integration of EE and RES measures on the demand and supply side of the building stock is demonstrated through the application of the bottom-up model in Kočevje region.

**Methodology**

**Data sources**

Several data sources were used in the bottom-up model of the building stock in order to ensure sufficiently accurate and comprehensive analysis of dynamic energy balance of the building stock in the region:

- Databases from Geodetic Administration of the Republic of Slovenia (GURS, 2015);
- Eco Fund (Eko sklad, 2015), Slovenian Environmental Public Fund;
- National energy efficiency action plan 2014-2020 for Slovenia (MzI, 2015);
- Statistical Office of the Republic of Slovenia: contains information on the number and area of completed dwellings (new construction, extensions, conversion according to the CC-SI classification), the number of demolished dwellings and others. (SURS 2015b);
- Intelligent Energy Europe TABULA (ZRMK, 2012a), EPISCOPE (Episcope, 2014), RePublic_ZEB (RePublic_ZEB, 2015);
- Register of Energy performance certificates (EPC, 2015);
- REUS - Survey of the energy efficiency in Slovenia (REUS, 2015).

The main sources for bottom-up modelling are the register of real estates (REN), the register of energy performance certificates (EPC register), the database of Eco fund subsidies and REUS survey (Figure 1). One of the biggest challenges is linking the energy performance related data of a particular building across all relevant databases, since each data source has been established separately throughout the past 8 years since 2007. REN register, managed by Geodetic Administration of the Republic of Slovenia (GURS), keeps complete (actual) data on the renovation of thermal envelope components up to 2008 with minor updates up to 2014. Eco fund keeps data of conferred national subsidies for thermal envelope components and building systems from 2008. EPC register was established in 2013 by the responsible ministry and covers up to date 3% of the building stock per building only. It stores the energy indicators and data on energy carriers per certified building. REUS survey is based on a poll that was conducted through interviews on 1006 households, regarding key areas of energy consumption in households and shows indicators on the status of the buildings and technical equipment of households as well as the building owners’ intention of modernizing buildings and systems (REUS, 2015).
A bottom-up building stock model (BuilS) is a spatially referenced parameterised per-building model developed with the purpose of determine the energy performance of the building and further build the energy balance of the building stock. The presented model addresses two main challenges: (1) having a precise and open bottom-up building model that is continually improving with new information on buildings (e.g. REN, EPC register and REUS) and (2) having a model that enables to adopt strategies of cities/regions/country for building stock renovation and shift towards sustainable energy supply.

The model uses “three layers” for calculation. The first layer is a long-term model of the building stock. It quantifies the expected future annual stock and reference floor area on the basis of the assumed past and future demand (MzI, 2015), i.e. the assumed development in persons, persons per dwelling and reference floor area per dwelling, potential for (partial/full/deep) renovation, based on the assumption for renovation and new build rates. This layer of the model also follows the ageing development of each type/age segment of the stock, with predicted lifetime of building component and it’s technologies for heating and DHW, after which the building becomes the potential for renovation, based on the proposed scenarios of renovation rates for each age band (construction periods: 0-1945, 1946-1970, 1971-1980, 1981-2001, 2002-2008, 2009-to date) (ZRMK, 2012). According to these scenarios, the model identifies the adequate number of buildings for renovation, depending on the initial state before renovation (concerning thermal envelope components and heating systems) (Figure 2).

The first layer of the model considers four different initial buildings states – unrefurbished, partial, full and deep renovation (Figure 2). When considering possible renovation of buildings, different levels of renovation lead to the change of the initial state, e.g. a partly renovated building (roof renovated in 2008) can in the future be subject to full renovation (if renovation of a façade and boiler replacement are implemented) in order to reach the level of fully renovated building. The initial state of the building offers different potential for renovation, where four possible levels of the initial state are assumed (ZRMK 2012b):

- **Unrefurbished:** Based on the existing data, the building has not been subject to any renovation in the past; therefore, it has potential for renovation on all components of the thermal envelope (walls, roof, and windows) and technical systems. Unrefurbished buildings can be subject to partial, full and deep renovation.

- **Partial Renovation:** Based on the existing data, the building was subject to renovation of one or two building envelope components (walls, roof or windows) in the past, therefore the building has
potential to have one or two components of the thermal envelope (walls, roof or windows) and technical systems renovated. Buildings with partial renovation can be subject to partial, full or deep renovation.

- Full Renovation: Based on the existing data, buildings identified as fully renovated are of two types. First, the building was subject to renovation of two building envelope components (walls, roof or windows) in the past and technical system for heating, therefore the building has potential for renovation of only one component of the thermal envelope (walls, roof, and windows). Second, it has all three thermal envelope components renovated and has a potential for replacement of heating system. Due to limited potential the buildings in full renovation category can be subject to partial renovation only.

- Deep Renovation: the building has experienced major renovation works in the past, all building components of the thermal envelope had been renovated, heating system replaced and thus the building is considered to have low energy demand for space heating. Deeply renovated buildings have no further potential for renovation.

In the BuilS model, one of the above initial state was attributed to each building in the case study, according to available energy related data on exact building in data sources described in 2.1. Renovation rate in the model is a weighted rate according to the renovation level (Figure 2) and expected energy savings, respectively. For the purpose of this work, the model adopts Slovenian national strategy renovation rates (MzI 2015a), i.e. maximum annual renovation rate in the building category is adopted from reference and intensive building renovation scenarios.
The second layer of the model is an energy and emission layer. The input data are the results from the first layer and additional data sources concerning heating systems and energy carriers in buildings. If the building is connected to a district heating network or the energy carrier for heating and domestic hot water is known from an EPC the information is allocated to the particular building in the model. The rest of the building stock is assumed to be supplied by statistical distribution of energy carriers (Figure 3). In the model the energy use of the building is either estimated on the basis of building typology ((EPISCOPE, 2015), (RePublic_ZEB, 2015)) or allocated from EPC register, if an EPC is available for particular building.

The last third layer takes into account scenarios for sustainable renovation of the building stock (at local, regional or national level), e.g. more intensive renovation rates in specific year due to increased incentives, increased share of building connected to district heating network due to network expansion in a city district.

Results for Kočevje case study

Modelling of initial state

The bottom-up model was applied on Kočevje city region, which includes residential and non-residential buildings. The vast majority of past renovation rates of thermal envelope components were deducted from two main sources – Register of Real Estates (REN 2014) (Table 1) and Eco fund subsides (Eco fund 2009-2014) (Table 2). Weighted renovation rates according to useful surface area for case study is presented in Figure 4.

![Figure 3 - Share of used energy carriers for space heating (left) and domestic hot water (right) for single-family houses (SFH), multi-family houses (MFH) and non-residential buildings (NR).](image-url)
Table 1 - Share of recorded renovation measures on thermal envelope in the municipality Kočevje according to the total useful surface area of the building stock (REN, 2014).

<table>
<thead>
<tr>
<th>Year</th>
<th>Walls</th>
<th>Roof</th>
<th>Windows</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>0.59 %</td>
<td>1.59 %</td>
<td>1.10 %</td>
</tr>
<tr>
<td>2001</td>
<td>0.54 %</td>
<td>1.19 %</td>
<td>0.64 %</td>
</tr>
<tr>
<td>2002</td>
<td>0.71 %</td>
<td>1.06 %</td>
<td>0.95 %</td>
</tr>
<tr>
<td>2003</td>
<td>0.96 %</td>
<td>1.56 %</td>
<td>0.78 %</td>
</tr>
<tr>
<td>2004</td>
<td>1.30 %</td>
<td>0.94 %</td>
<td>1.30 %</td>
</tr>
<tr>
<td>2005</td>
<td>1.52 %</td>
<td>1.14 %</td>
<td>1.37 %</td>
</tr>
<tr>
<td>2006</td>
<td>1.71 %</td>
<td>1.70 %</td>
<td>1.72 %</td>
</tr>
<tr>
<td>2007</td>
<td>0.53 %</td>
<td>0.39 %</td>
<td>0.34 %</td>
</tr>
<tr>
<td>2008</td>
<td>0.63 %</td>
<td>0.20 %</td>
<td>0.42 %</td>
</tr>
<tr>
<td>2009</td>
<td>0.15 %</td>
<td>0.11 %</td>
<td>0.00 %</td>
</tr>
<tr>
<td>2010</td>
<td>0.64 %</td>
<td>0.22 %</td>
<td>0.24 %</td>
</tr>
<tr>
<td>2011</td>
<td>0.54 %</td>
<td>0.15 %</td>
<td>0.00 %</td>
</tr>
<tr>
<td>2012</td>
<td>0.91 %</td>
<td>0.10 %</td>
<td>0.11 %</td>
</tr>
<tr>
<td>2013</td>
<td>0.02 %</td>
<td>0.00 %</td>
<td>0.02 %</td>
</tr>
<tr>
<td>2014</td>
<td>0.00 %</td>
<td>0.00 %</td>
<td>0.00 %</td>
</tr>
</tbody>
</table>

Table 2 - Share of subsidised energy efficiency measures on thermal envelope in the municipality Kočevje according to the total useful surface area of the residential building stock (Eco fund, 2009-2014).

<table>
<thead>
<tr>
<th>Year</th>
<th>Walls</th>
<th>Roof</th>
<th>Windows</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>0.07 %</td>
<td>0.00 %</td>
<td>0.61 %</td>
</tr>
<tr>
<td>2010</td>
<td>0.39 %</td>
<td>0.05 %</td>
<td>0.93 %</td>
</tr>
<tr>
<td>2011</td>
<td>0.26 %</td>
<td>0.02 %</td>
<td>0.94 %</td>
</tr>
<tr>
<td>2012</td>
<td>0.35 %</td>
<td>0.00 %</td>
<td>0.34 %</td>
</tr>
<tr>
<td>2013</td>
<td>0.27 %</td>
<td>0.07 %</td>
<td>0.15 %</td>
</tr>
<tr>
<td>2014</td>
<td>0.13 %</td>
<td>0.33 %</td>
<td>0.13 %</td>
</tr>
</tbody>
</table>

Figure 4 - Renovation rate for single- and multi-family houses of subsidised measures in municipality Kočevje according to the useful surface area.
For case study Kočevje, the results show (Figure 5) the biggest potential for energy savings in the residential sector for buildings built in the period 1946 – 1980. It also shows that a majority of buildings built after 1980 have not been subjected to any renovation yet and it is expected the considerable share will be subjected to renovation in the near future, since the life-time period of construction element is 30 years.

**Figure 5** - Initial potential for renovation for single-family houses (left), multi-family houses (middle) and non-residential buildings (right) in Kočevje with respect to total useful floor area.

The initial potential for renovation of buildings in Kočevje is presented on Figure 5 with support of Geographic Information Systems (GIS) (Figure 6), which offers the opportunity to characterize building stocks in some systematic dimensions using geo-referenced information for buildings.

To this goal, we developed an application with Google maps API, which enables a powerful way of presenting the energy balance of the building stock. For case study Kočevje, an application was developed which shows several aspects of the building stock, resulting from the analyses. Figure 6 shows the potential for renovation of thermal envelope’s components. The buildings where roof, façade and windows where potential for renovation are marked as red with radius 3. Buildings with 2 components for renovation have radius 2, and buildings with potential for renovation of 1 component – radius 1. Enhanced image reveals that the vast majority of the buildings have a big potential for renovation on thermal envelope.

**Figure 6** - An overview of the current state of the building stock with GIS-based approach and Google Maps API (left: all buildings in Kočevje; middle: buildings with potential for renovation on thermal envelope; right: enhanced overview of the potential).
Validation

Well thought out validation is essential when describing the physical processes in buildings and dealing with the complexity of building energy modelling. Ideally, the performance of a building energy simulation tool (excel model, analysis software) should be validated against measured data from a real building. However, such data is not always available as the urban indoor and outdoor environments too complex to be instrumented sufficiently. So as stated by Zmeureanu et al. (1987), sufficient testing should be conducted to assure that the probability of failure is sufficiently low to be acceptable.

The differences between theoretical and actual energy consumption are thought to arise from a multitude of factors. Theoretical energy use is based on normalized conditions, based on quasi steady-state method, such as indoor temperature of 20 degrees in the vast majority of buildings and heating degree days, heating of the entire floor area, infiltration rate assumed on the basis of the characteristics of the construction elements, etc. The way that occupants use the building in reality probably differs from these assumptions. According to several authors (Gill et al., 2010, Santin, 2010, Haas et al., 1998), occupant behaviour and lifestyle is thought to be a key factor in the discrepancy between theoretical and actual heating energy use and is correlated to energy performance itself.

To this point, ‘BuilS’ bottom-up model was validated against the measured energy consumption of the buildings connected to the district heating network in Kočevje. In the period from 2008 to 2014, 196 buildings (residential and commercial) have/had been supplied by local biomass district heating network in the city of Kočevje. The district heating network has gradually been expanding during this period, thus the number of connected buildings increased, while on the other hand there had been some disconnections as well. A comparison of the normalized measured energy consumption and simulated energy use in the BuilS model for the observed period is presented on Figure 7. The objective was to observe if the predicted energy consumption for heating and domestic hot water falls within the range of accepted deviation.

Figure 7 - Comparison of the measured and modelled energy consumption.

In the period between 2009 and 2014 the average deviation is 4.83 % which is below acceptable targeted 10 % deviation. Only for the first year 2008 the deviation is higher – 15.4 %, the difference can be attributed to many factors. The key factor that must be taken into account for the first year only is the optimization of the local district heating substations. Performance in the first year of operation of the biomass district heating network might not be fully optimized yet, thus consumption was a bit higher.
Building stock renovation scenarios

First two observed scenarios, reference and intensive scenario are taking into account as well the share of used technologies, which follows the national strategies and local state and limitations. Share of heat pumps and biomass boilers is slowly increasing, while share of energy carriers oil and liquid gas is decreasing. Third scenario strictly follows real local policy and is considered as an upgrade of a reference scenario, regarding the renovation rates on thermal envelope. From municipal plans for the expansion of biomass district heating network it was deducted which exact buildings in the future are going to be connected to the grid. This scenario presents a realistic applicability of the model on-site and demonstrates its potentials, e.g. measuring the effects of local policy on carbon footprint.

Key results are presented in Figure 8 and Figure 9. For the building stock in case study Kočevje the total energy need for heating is structured according to the energy rating of buildings (Figure 8), whereas energy rating of particular building is based on its energy need for heating (Qnh), obtained either from EPC or from building typology. In the base case of 2015, the estimated total final energy of the residential building stock in Municipality Kočevje is 116.406 GWh/year, with an emission factor of 0.232 kg CO₂/kWh. This gives a specific total average energy need for heating of 161 kWh/m²/year and a specific emission level of 37.4 kg CO₂/m²/year.

![Figure 8 - Total energy need for heating for the case study Kočevje.](image)

Reference scenario, intensive and local policy scenario give substantial reductions in annual total heat demand and CO₂ emissions compared to 2015. The total average energy need for heating decreases from 161 kWh/m²/year to a level of about 111 kWh/m²/year in 2020, and to around 66 kWh/m²/year in 2030. With the given changes in the energy mix, and an overall CO₂ emission factor increases from 0.232 to 0.258 kg CO₂/kWh in trend scenario, although considerable improvements are recorded in annual CO₂ emissions. These are later reduced from 37.4 kg CO₂/m²/year in 2015 to 26.3 – 26.8 kg CO₂/m²/year in 2020, 15.8 – 17.5 kg CO₂/m²/year in 2030.

Despite the significant growth in building stock reference area by 16.1 % from 2015 to 2030, these emission intensity improvements yield significant overall emission reductions (tons CO₂/year) of...
around 25% in 2020 and 46 – 51% reductions in 2030, compared to the 2015 level, where buildings emit 18,567 tons of CO$_2$ emissions. With respect to the estimation of carbon emissions in 2008, the later were reduced from 24,000 tons of CO$_2$/year to lower than 19,000 CO$_2$/year.

All the observed scenarios (reference, intensive and local) show great promise in the fulfilling the regional contribution to national goals for the reduction of final energy use and GHG emissions. According to policy targets and EPISCOPE benchmark levels (5% reduction in 2020 and 30% reduction in 2030 according to 2015) are met in both the observed years – 2020 and 2030. The primary energy is reduced in all scenarios, one of the focal points is the impact of the local energy policy implementation in practice, where the expansion of local district grid is considered in 2016, 2020 and 2025. The primary energy is reduced for 14 %, 33 % and 44 %, respectively.

**Figure 9 - Carbon emissions for the building stock case study Kočevje as calculated using BuilS model.**

**Discussion and conclusion**

The goal of this study was to show that a bottom-up model enables to set a correct baseline regarding energy use of the existing building stock. Such a model is a powerful tool to evaluate the impact of public policies on buildings, in particular those related to climate and energy. A bottom-up building stock model (BuilS) has been used to estimate the energy consumption of the entire building stock (domestic and commercial building sector) over the observed period. The modelling follows three layers: (1) identification of the potential, (2) building renovation and (3) applying different sustainable scenarios. One of the most significant barriers for development of such a detailed model is the availability and applicability of databases that contain data related to buildings energy efficiency.

The simulated impact of the policies depend significantly on the type of available data in terms of their quantity and quality, as the later can improve the level of accuracy of the model. The relevant data derive from various sources, e.g. surveys, public databases and various reports on implemented policies eg. incentives. For the BuilS model, the main data sources are the register of real estates, the register of energy performance certificates, the database of Eco fund subsidies and REUS survey.
The paper points out the importance of regular monitoring of the building stock through continually upgraded databases with new entries regarding building renovation on the level of each building. The main shortcoming of available databases is the data integrity on energy efficiency at a building level, since the renovations implemented after 2008 (a nationwide survey on buildings for REN was carried out in Slovenia in 2007) have not been systematically recorded (EPISCOPE, 2015). Furthermore, REN does not have complete data on energy carriers that buildings use for heating or domestic hot water. However, the lacking data on heating systems and energy carriers exist in several independent records (information of regular inspection of heating systems, air conditioning systems and energy management entries) but have not been properly structured yet.

Overall, the validation results indicate that BuilS model predicts the energy use well. A case study Kočevje was simulated and validated through measured energy consumption of the buildings connected to district heating network. The total average deviation between simulated and measured annual energy consumption in the observed period between 2008 and 2014 is 6.34%. In case study Kočevje the application of BuilS model showed the reduction of CO₂ emissions for 25 % (beyond the 20% target from CoM).

The model BuilS can be adjusted to individual building stock, regardless the geographical area, if building typology and corresponding energy related characteristics (eg. energy rating). The usual problem of energy modelling of building stock is incomplete data on the energy supply at a building level. For modelling at least the structure of the energy supply in the geographical region is necessary. The accuracy of the modelling increases with availability of the data on the supply side, eg. connection to district heating networks, regional preference of a particular energy carrier, eg. biomass. Modelling energy balance of a city/region is interesting for stakeholders from several points of view: (1) modelling the baseline of energy use and emissions, (2) planning and monitoring of sustainable energy policies in the region, (3) optimizing EE and RES investments according to the climate and energy targets. The development of energy performance certification of buildings and accelerated preparation of SEAPs under Covenant of Mayors facilitate the acquisition of better quality data for bottom-up modelling of continuous renovation and energy balance of existing building stock.

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