Definition of reference scenario to be used by all FEEB&D partners

ROMANO, Elliot, et al.

Abstract

Scenario definition for the built environment at regional and national scale. Following Switzerland’s commitment on the path of the energy transition, the new Energy Act [BFE (2017)], which defines the first package of the Energy Strategy 2050 (ES 2050), sets energy efficiency as one of the main pillars of this transition. Within the new Act, the Confederation and the Cantons are expected to adopt plans in the built environment in order to exploit through retrofits as much as possible the potential of energy efficiency, renewable energies, and waste heat. According to OFEN [2012], the building stock consisting of 1.64 million buildings (among which 1.36 million are residential buildings) in Switzerland accounts for 46% of the total national final energy demand. By 2050, the new energy policy targets a decrease of energy use in buildings by around 35 TWh compared to the trend (baseline scenario) as defined by the energy perspectives [Kirchner, A, & al., 2012]. By 2035, the first package of measures, which came into force in 2018, should achieve a reduction by 23.4 TWh (67% of the 2050 perspective). Energy demand [...]

Reference


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Deliverable Report

D.3.1.3: Definition of reference scenario to be used by all FEEB&D partners

Work package: 3, task 3.1.3: Scenario definition for the built environment at regional and national scale

Lead authors:
Elliot Romano
Stefano Cozza
Jonathan Chambers
Stefan Schneider
Selin Yilmaz
Martin Patel

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1 Prototype, report, demonstrator, other
1 Related milestone(s)

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2 Summary

Following Switzerland’s commitment on the path of the energy transition, the new Energy Act [BFE (2017)], which defines the first package of the Energy Strategy 2050 (ES 2050), sets energy efficiency as one of the main pillars of this transition. Within the new Act, the Confederation and the Cantons are expected to adopt plans in the built environment in order to exploit through retrofits as much as possible the potential of energy efficiency, renewable energies, and waste heat.

According to OFEN [2012], the building stock consisting of 1.64 million buildings (among which 1.36 million are residential buildings) in Switzerland accounts for 46% of the total national final energy demand. By 2050, the new energy policy targets a decrease of energy use in buildings by around 35 TWh compared to the trend (baseline scenario) as defined by the energy perspectives [Kirchner, A, & al., 2012]. By 2035, the first package of measures, which came into force in 2018, should achieve a reduction by 23.4 TWh (67% of the 2050 perspective).

Energy demand forecasting models are highly dependent on the different trends related to socio-economic factors, such as population, GDP growth, fossils fuels prices and the level of activity in the industry & services sectors. In view of the evolution over time, forecasts should reflect as much as possible the current economic and social circumstances. This is also valid for the built environment, where the characteristics of the building stock (age of buildings, energy sources used for space heating and hot water) as well as the current and future regulation on energy retrofits and for new constructions have major impacts on the energy demand.

The aim of this report is to provide fundamental assumptions influencing the evolution of energy demand in the built environment until 2050. Such common assumptions could be then used by the different FEEB&D participants in the framework or their research, they would help to harmonize the underlying hypotheses when evaluating the contribution to goal achievement under the ES 2050.

In this report, information and data from various sources (e.g. OECD, BFS, BFE, BAFU, IEA, Prognos) were collected in order to define scenarios. These data originate from various sources. Not only does this report provide an inventory of existing forecasts regarding the socio-economic variables, it also focuses on relevant assumptions for the built environment based on federal office data or data published by research groups. For example, our report provides information on energy sources and the energy demand of residential buildings as well as on the so-called energy performance gap. The report also presents a preliminary approach to determine more accurately than so far the energy reference area of residential buildings using various explanatory variables.

Simultaneously to this report, the Joint activity and Scenario Modelling (JA&SM) developed a set of scenarios. For the purpose of comparison, the relevant information is also included in the current report. A harmonized set of scenario definitions favours the collaboration within the research community.

The JASM scenarios use the GDP and population assumptions from the ARE [Bundesamt für Raumentwicklung] scenarios. To get a consistent dataset with the other socio-economic assumptions needed for the definition of the scenarios (such as sectoral gross value added, production indices or heating floor areas),

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2 This figure also includes electricity consumption. Under building we understand the physical building and not the statistical entity (building entry) denoted by the EGID in the national building and dwelling register.

3 URL: [https://www.are.admin.ch/dam/are/de/dokumente/verkehrsperspektiven%202040.pdf.download.pdf/VPep%202040_Erqen-zungsbericht_Prognose_2050_final.pdf](https://www.are.admin.ch/dam/are/de/dokumente/verkehrsperspektiven%202040.pdf.download.pdf/VPep%202040_Erqen-zungsbericht_Prognose_2050_final.pdf)
the JASM team developed a reduced-form econometric model. The model is calibrated to the corresponding assumptions in the Swiss Energy Strategy scenarios from Prognos, and it uses only GDP and population as inputs.

3 Long-term forecast

The starting point of our long-term perspectives is the evolution of the demographic and economic parameters. They represent an essential driver for energy demand.

3.1 Demography

Population growth (inhabitants) and structure (households’ size) are two major factors driving the development of residential buildings. Existing scenarios for these variables are recurrently published by the Federal Statistical Office (BFS) in their studies on the long-term evolution of population and households (Kohli et al. (2015)).

3.1.1 Inhabitants

The scenarios according to the Energy Perspectives 2050 - named thereafter SES-2050 scenarios - were quantified by Prognos [2012] on a population-growth assumption according to the "intermediate" demographic scenario of the BFS, published in 2010. The scenario accounts for the trend observed following the entry into force of the bilateral agreements on free movement of persons with the EU. As a result, the permanent resident population, according to the scenario is expected to increase to around 9 million by 2050 (+ 25% in comparison to 2000).

More recent long-term forecasts are given by the perspectives of Federal Office for Spatial Development [ARE, 2016]. Their scenario is based on the latest study on the evolution of the Swiss population and updates the plausible developments regarding the Swiss population in the forthcoming decades [BFS, 2015]. The new evolutions depend on the realization of different assumptions. The 2015-reference values indicate that the number of permanent residents in Switzerland amounts to 8.3 million. It increases to 9.5 million in 2030 and reaches 10.2 million in 2045. ARE’s scenarios hence assume a higher demographic growth than the SES-2050 scenarios (figure 1).

![Figure 1: Population growth – number of inhabitants](image-url)

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4For details see Panos E., 2019.
5SES scenarios quantified by Prognos in 2012. URL: [http://www.bfe.admin.ch/php/modules/publikationen/stream.php?extlang=de&name=de_564869151.pdf&endung=Die%20Energieperspek-
tiven%20f%FCr%20die%20Schweiz%20bis%202050](http://www.bfe.admin.ch/php/modules/publikationen/stream.php?extlang=de&name=de_564869151.pdf&endung=Die%20Energieperspektiven%20f%C3%BCr%20die%20Schweiz%20bis%202050)
Households

According to the reference scenario for households developed by the Federal Statistical Office [BFS, 2017], over the coming decades, the number of private households will continue to increase. This development will be mainly driven by migration. Between 2017 and 2045, the number of households will increase by 23% from 3.7 million to 4.6 million. It will be 4.0 million in 2025, 4.2 million in 2030, 4.4 million in 2035 and 4.5 million in 2040. In the "low" and "high" scenarios, the number of households is expected to be between 4.2 million and 4.9 million by 2045 (Figure 2a).

Figure 2b shows the paths for the decreasing household size (number of people in household) and the increasing number of households for the period 2010 – 2050.

Scenario recommendation

Given the requirement for data consistency with the rest of the socio-economic indicators (sectoral gross value added, heating floor areas) which will be given in the current report, we will assume in the following the population growth according to the latest ARE forecasts.
3.2 Economic indicators

3.2.1 Gross Domestic Product (GDP)

The SES-2050 scenarios rely on an annual growth rate of 1.2% for the real-term gross domestic product (GDP). In a more recent report, the SECO [2016] provides a new scenario for longer-term GDP development with annual real-term rates ranging from 0.5% to 0.7% in the 2020 – 2040 period.

In the development of their own economic growth forecast scenarios, JASM [2018] use the GDP and population assumptions from the ARE forecasts, which assumes a higher economic growth than the SES scenarios.

As an alternative source, the OECD provides long-term baseline projections (up to 2060) of GDP trend [OECD, 2018]. The forecast is based on an assessment of the economic climate in individual countries and the world economy, using a combination of model-based analyses and expert judgement. The indicator is measured in USD at 2010 Purchasing Power Parity. The OECD forecast for Switzerland assumes an average growth rate of 1.83% over the 2020-2060 period with annual rates ranging from 1.54% to 2.05%.

The GDP growth rate forecasts from the four above-mentioned sources are compared in the following figure.

![Figure 3: GDP growth in JASM, SE-2050, SECO, and OECD.](image_url)

The growth rate forecasted by OECD is the highest, while the latest ARE figures (used by JASM) are above the SECO and SE-2050 perspectives. It should be pointed out here that long-term forecasts in principle cannot take into account cyclical fluctuations. The associated volatilities in relative growth generally appear high, such as recent experience shows - between negative growth of 1.9% in 2009 and positive growth of 3.6% in 2007.

3.2.2 Investments in assets (residential vs non-residential)

Data on historical investments in assets in Switzerland are provided by OECD [2018]. The respective shares of the investment in the dwellings and other buildings is also published by the OECD [2018]. The figures correspond to the aggregated investments in new construction and retrofits. The data are published in US 2010 dollars. A linear model explains the relation between real GDP per capita and the specific investment per capita as shown on figure 4. The correlation between both variables is as high as 94%.

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6 Purchasing power parities (PPPs) are the rates of currency conversion that equalise the purchasing power of different currencies by eliminating the differences in price levels between countries. In their simplest form, PPPs show the ratio of prices in national currencies of the same good or service in different countries. PPPs are also calculated for groups of products and for each of the various levels of aggregation up to and including GDP. The basket of goods and services priced is a sample of all those that are a part of final expenditure: household consumption, government services, capital formation and net exports, covered by GDP. This indicator is measured in terms of national currency per US dollar.
The estimated relation can thus be used to determine the forecast of the investment in residential and other buildings based on the forecasted GDP per capita (Figure 5a & Figure 5b) as described in section 3.2.1. It should be pointed out that in such a simple model, the investment rate in assets is not influenced directly by the average age of the buildings but take into account the past retrofits.

Figure 4: Investment in buildings (dwellings & other) per capita and year as a function of GDP per capita and year (historical data 1990-2016, in real terms).

Figure 5a: Forecasts of the investment per capita in residential buildings according to GDP scenarios
3.2.1 Added value by sector

Structural changes occur in the economy sector over the period from 2000 to 2050.

Industry

In the SES scenarios, the growth trend for the different industries are based on a study by Ecoplan [Müller A. & al., 2011] commissioned by the Federal Chancellery and the Federal Office of Statistics. Beyond 2030, values are forecasted by the Prognos team [SES-2050]. The gross added-value reaches a level of CHF 198 billion in 2050 (real, in 2010 prices). Moreover, the structural change observed in the recent past is expected to continue over the considered period. The structural changes imply, for the consumption-related sectors (food and clothing) and the energy-intensive primary goods sectors (paper industry, metals, minerals), a decline of their shares in the economy. On the other hand, the capital-intensive industries, such as high-tech sectors, will increase their shares in the economic activity. These include mechanical engineering, electronics and especially chemistry.

Based on more recent data on the added value by sector and the long-term GDP growth forecasts (previously mentioned), forecasts for gross added value can also be provided. Parallel to the preparation of the present report, the JASM group performed its own forecasts for the added value in the industrial sector. Each forecast relies on a different econometric model but on the same GDP scenario (ARE) in order to derive the gross value added for the industrial sector. In the JASM Scenarios definition, the industrial sector added value reaches CHF billion 248, while the UNIGE forecast rise to a value of CHF billion 298 (all values in real terms relative to year 2010). Figure 6a, 6b, and 6c illustrate the growth of the industrial according to the different working groups.
While the gross value-added in the tertiary sector according to the SES scenarios reaches around CHF (2010) 556 billion in 2050 (Figure 7a), JASM applies an econometric model to the tertiary sector and provides a value of CHF (2010) 681 billion at the same horizon (Figure 7b).
3.2.2 Fuel prices

Energy prices and their long-term perspectives influence estimates of energy demand and technology choices. IEA ETP [2017] provides different pathways for fossil energy prices up to 2060. The 2°C Scenario (2DS), which sets out a rapid decarbonization pathway in line with international policy goals, has been the main climate scenario in the ETP series for many years. It has been widely used by policy makers and business stakeholders to assess their climate strategies. Another fossil-fuels forecast is provided by the EU trends 2016 report (TREN, 2016) (Figure 8).
Domestic prices should be calculated on the basis of international prices forecasts, considering changes in exchange rates, conversion costs and taxes (incl. CO₂ tax). Domestic fuel prices used in the SES-2050 scenarios are shown in table 1.

<table>
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<th>Fuel</th>
<th>Sources</th>
<th>Units</th>
<th>2000</th>
<th>2010</th>
<th>2020</th>
<th>2030</th>
<th>2035</th>
<th>2040</th>
<th>2050</th>
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<td>Fuel Oil</td>
<td>Prognos 2012</td>
<td>Rp/l</td>
<td>55.4</td>
<td>85.4</td>
<td>110</td>
<td>122.6</td>
<td>126.9</td>
<td>129.5</td>
<td>134.4</td>
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<tr>
<td>Natural gas</td>
<td>Prognos 2012</td>
<td>Rp/kWh</td>
<td>6.5</td>
<td>9.1</td>
<td>11.8</td>
<td>13.3</td>
<td>13.9</td>
<td>14.3</td>
<td>14.9</td>
</tr>
<tr>
<td>Wood</td>
<td>Prognos 2012</td>
<td>CHF/Ster</td>
<td>45.4</td>
<td>52.8</td>
<td>91.3</td>
<td>112.5</td>
<td>119.6</td>
<td>124.4</td>
<td>130.0</td>
</tr>
<tr>
<td>District Heating</td>
<td>Prognos 2012</td>
<td>CHF/GJ</td>
<td>16.7</td>
<td>21.6</td>
<td>28.1</td>
<td>31.9</td>
<td>33.1</td>
<td>34</td>
<td>35.3</td>
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<tr>
<td>Unleaded 95</td>
<td>Prognos 2012</td>
<td>CHF/l</td>
<td>1.53</td>
<td>1.64</td>
<td>1.84</td>
<td>1.94</td>
<td>1.98</td>
<td>2</td>
<td>2.04</td>
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<tr>
<td>Unleaded 98</td>
<td>Prognos 2012</td>
<td>CHF/l</td>
<td>1.58</td>
<td>1.69</td>
<td>1.88</td>
<td>0.198</td>
<td>2.02</td>
<td>2.04</td>
<td>2.09</td>
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<tr>
<td>Diesel</td>
<td>Prognos 2012</td>
<td>CHF/l</td>
<td>1.57</td>
<td>1.72</td>
<td>1.97</td>
<td>2.09</td>
<td>2.13</td>
<td>2.15</td>
<td>2.19</td>
</tr>
</tbody>
</table>

Table 1: Projected fuel prices for Switzerland [SES-2050]

Using standard conversion factors, the energy prices listed in Table 1 are displayed in figure 9 in terms of CHF/GJ.

Next to the SES 2050 domestic prices, different studies provide alternative scenarios for domestic fuels prices. Based on Panos et al. 2017, figure 9b provides the price paths for different fuel products excluding the CO₂ taxes.
Zuberi and Patel (2017) make the simplifying assumption that final energy prices in industry will develop according to the same growth rates as projected by Prognos (2012) and TIMES/MARKAL for Swiss households. The factor representing the ratio of final energy prices for industry to that of household was estimated based on IEA (2017) and used to scale down the projected consumer prices. The resulting energy prices for industrial consumers are displayed in Figure 9c. (Figure 9c).

### 3.2.3 Electricity prices

In the framework of the JASM, wholesale electricity prices are provided as an output of *Swissmod* electricity market model [Schlecht & Weigt, 2014]. The forecast of the prices is given for 2020, 2025 and 2030. Figure 10 shows the annual average of the hourly prices. In comparison, the forward price for the 2020 calendar product on the EEX exchange is also provided in the following graph.
However, the generation prices are an insufficient information for final consumers, as they exclude the grid costs. In the built environment, retail electricity tariffs from the grid play a major role in technology choices. For example, the benefits of self-consumption from solar panels grow, as tariffs increases, improving the panels’ economic profitability.

As reported by Densing et al. 2014, several reports contain assumed future retail electricity prices, which includes the grid (transmission and distribution) fees. The studies covered by Densing et al. are briefly described below.

**VSE (2012):** The report was published by the Swiss electricity association (Verband Schweizerischer Elektrizitätsunternehmen VSE) in 2012. The scope of the study is the Swiss electricity system until 2050; hence it does not consider the other sectors of the energy system while focusing in more detail on electricity. The study considers three scenarios of price forecasts.

**SCS (2013):** The model SCS-Energiemodell of the study with the same name is developed by the consulting company SCS Supercomputing Systems AG. The published information of the study so far is a slide-presentation (version 1.2, June 2013; model version 1.4 of May 2013) consisting of 131 slides. The scope of the study and of the model is electricity dispatch in a single future year, that is, generation capacities are an input to the model (capacity expansion planning is not an implicit model result). The scenarios encompass an example scenario and eight other scenarios, including two scenarios with demand and capacity data from the BFE energy perspectives (scenarios NEP+E and WWB+C+E).

**Cleantech** (F. Barmettler et al., 2013): The scope of the study is the entire energy system. It only considers a single scenario for electricity prices. In contrast to the other studies, the study reports examples of inputs and corresponding outputs of the proposed simulation model. At the time of the survey, the study mentioned that the model was work-in-progress with various possible model extensions, for example to calculate an optimized dispatch instead of using the current, fixed merit order.

Figure 11 presents the different retail price scenarios described. The BFE scenario represents the values according to the SES 2050 Perspectives.
3.2.4 Social discount rate

A discount rate is used to convert flows of costs and benefits over time into a net present value. There are two reasons for doing this. The first is to determine whether a project is worthwhile. The second reason is to compare several projects that achieve the same objective but have different timeframes. The use of discounting allows to convert the different flows of costs and benefits into a single net present value number for decision-making.

The choice of the discount rate is a key parameter when, for example, determining the priority list of investment projects or evaluating a public policy, in particular when they have long-lasting benefits and costs [Gollier & Mahul, 2017]. Policy evaluators are still struggling with the concept and the way to implement efficient valuation procedures. The best illustration of this conflict is provided by the recent U.S. report [EPA, 2015], which left open the choice of the social discount rate, and in which the social cost of carbon has been estimated for three different discount rates: 2.5%, 3%, and 5%.

Economists have used the Ramsey rule [Ramsey, 1928] to estimate the efficient risk-free discount rate. This rule is based on the idea that in a growing economy, investing for the future increases intertemporal/inter-generational inequalities. The discount rate net of the rate of pure preference for the present can then be interpreted as the minimum rate of return of a safe investment that compensates the undesirable welfare impact of this investment. In a recent international country, Gollier et al., [2017] estimates the efficient risk-free discount rate for Switzerland at 1.39%.

3.3 CO₂ emissions targets

According to the objectives defined by the Federal Council for 2030 and 2050 with respect to the Paris agreement (i.e. -50% GHG emissions by 2030 and -70 to -85% by 2050), annual emissions per capita emissions must be decreased from 4.31 tonnes of CO₂ equivalents per year in 2014 to 3 tonnes of CO₂ equivalents per year in 2030, and to between 1 and 2 tonnes of CO₂ by 2050.

The built environment generates about a half of Switzerland's CO₂ emissions [BAFU 2016], and plays an important role in climate policy. According to the CO₂ Ordinance [BAFU 2016], emissions from buildings must be reduced by 40% by 2020 compared to 1990 levels (see Figure 12).
The main economic measures to achieve the targets are the CO₂ tax on fuels, the emission trading system (ETS), the implementation of the buildings program and the obligation for fuel importers to offset part of their CO₂ emissions. For the economy as a whole, a potential increase in the CO₂ tax to CHF 210 per tonne of CO₂ would result in a gross domestic product in 2030 that is about 0.4% lower than what Switzerland [BAFU, 2018].

The Conference of Cantonal Energy Directors (EnDK) has set the objective of reducing CO₂ emissions from buildings to 20% below 1990 levels by 2050 (ODYSSEE, 2018). This target value is based on the assumption that the heating requirements of new and replacement buildings will increase only slightly in the future, and that they will be heated to a large extent in a CO₂-neutral manner. According to the cantonal guidelines, by 2050, only 10 to 15% of the space heat will be produced by fossil fuels, i.e. mainly using natural gas (which has a lower CO₂ content than fuel oil). Oil heating systems will only be used in exceptional situations.

### 3.4 Buildings characteristics

Within the scope of FEEB&D, a number of building characteristics should be considered more closely because they have an influence on the energy demand. These characteristics, such as age of the buildings, the energy reference areas or roof surface are discussed hereafter.

#### 3.4.1 Age of buildings

The Swiss Federal Register of Buildings and Dwellings (RBD) [BFS, 2018] contains mainly information on residential buildings. Although there is no mandatory registration or maintenance requirements for Buildings without residential use, a very large number of those buildings are included in the database, including industrial buildings, garages, hospitals, warehouses, etc.

Basic data, such as age, size and energy supply provide an up-to-date overview of the building and dwelling stock. Figure 13a provides the share of the dwellings’ total surfaces for single and multi-families houses according to their construction year.
In the scope of JASM the residential building stock is modelled using PSI's building stock model (see Figure 14, [Panos, E., 2019]). The model is based on dynamic material flow analysis with population development and average income as driving forces.

Figure 13a: Age distribution of floor space - Share of residential buildings' total surface (single and multi-family buildings) by construction year

Figure 13b: Age distribution of number of buildings - Percentage of residential buildings (single and multi-family buildings) by construction year

Figure 14: Projection for Single- and Multi-families residential buildings (JASM scenario)
3.4.2 Energy retrofitting in CH

According to Mennel and Sulzer [2018], the current model regulations of the cantons in the energy sector (MuKEn:2014) is the appropriate way to master the retrofit marathon required by the Energy Strategy 2050. Meanwhile, further developments of the MuKEn are crucial in order to ensure that the impact of regulation in the built environment does not come to an end. New regulation principles must be investigated in order to provide the right tools and fine-tuning for the retrofit in the next generation. Research questions should consequently focus on the needs for a regulation which should to be adapted or supplemented in the next revision of the MuKEn.

The authors analysis shows that if the current MuKEn:2014 is implemented nationwide, the CO₂ reduction and energy efficiency increase will be in line with the target path of the Energy Strategy 2050. However, today's measures are not enough to achieve the 2050 targets. If there were no regular further development of the MuKEn, the CO₂ targets for 2050 would be missed by 30% to 70% if the MuKEn:2014 were maintained unchanged, depending on the implementation by the cantons (figure 15).

![Figure 15: Objectives achievements of CO2 reduction with MuKen (Source: Immobilia, November 2018)](image)

3.4.3 Performance gaps and limits of targets

As the built environment (residential and tertiary sector) is responsible for almost 50% of the final energy consumption in Switzerland, retrofitting of buildings offers a large energy saving potential. Termed as 2000-Watts Society, the Swiss society of engineers and architects (SIA), the federal government, the ETHZ and the City of Zurich formulated in 2011 an intermediate target for 2050 for primary energy consumption and CO₂ emissions in the built environment SIA/2040 [SIA, 2011].

The SIA energy efficiency path fixes an average consumption of 2000 Watts of non-renewable primary energy and 2 tonnes of CO₂ equivalent, per capita and year, by 2050. The path defines limits for the six buildings categories (housing, administration, schools, retail outlets, shops, restaurants) and it proposes a suitable calculation method for each of them.

The effectiveness of energy retrofitting is usually established on a theoretical basis using the procedures established in building codes, e.g. the SIA 380/1 for heating demand in Switzerland. However, results from such calculations may differ significantly from measured values, as the pre-retrofit performance of buildings tends to be underestimated (pre-bound), and the post-retrofit performance tends to be overestimated (re-bound). This deviation is named Energy Performance Gap (EPG). (de Wilde, 2014). Several studies on the topic have shown that the size of the EPG varies greatly (Branco et al., 2004; Burman, Mumovic and Kimpian, 2014; De Lieto Vollaro et al., 2015; Herrando et al., 2016; Lehmann, Khoury and Patel, 2017).

Researchers have identified limits to progress in energy efficiency improvement due to the existence of the EPG (Cayre et al., 2011; Sunikka-Blank and Galvin, 2012; Galvin, 2014; Grossmann et al., 2016; Ménard, 2016; Gram-Hanssen and Georg, 2017; van den Brom, Meijer and Visscher, 2017). The EPG should hence
be taken into account in future research regarding energy consumptions simulations and objectives achievements on energy savings.

While information on the energy performance gap in Swiss buildings is still scarce [Cozza S. 2019], Schneider, Khoury et al. [2017] have assessed the energy saving potential, thereby accounting for the EPG in Switzerland. To this end, the authors compared theoretical and realistic space heating saving potential estimated under normative procedures (SIA 380/1). For different building categories and construction periods, the theoretical (TSP) and realistic saving potential (RSP) for space heating are calculated on the basis of: (i) measured final energy demand for heating (SH and DHW) before and after retrofit; (ii) design value for SH after retrofit. In table 2, values for RSP and TSP values for different retrofits are given, and the fraction of achievable potential is computed.

<table>
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<th>Building categories</th>
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<td>AF</td>
<td>52%</td>
<td>52%</td>
<td>48%</td>
<td>51%</td>
</tr>
<tr>
<td>Total CH stock</td>
<td>Q_{ach}</td>
<td>1.8</td>
<td>1.7</td>
<td>1.0</td>
<td>4.6</td>
</tr>
<tr>
<td></td>
<td>AF</td>
<td>52%</td>
<td>52%</td>
<td>48%</td>
<td>51%</td>
</tr>
<tr>
<td></td>
<td>( Q_{ach} )</td>
<td>0.7</td>
<td>1.4</td>
<td>0.7</td>
<td>3.1</td>
</tr>
<tr>
<td></td>
<td>AF</td>
<td>52%</td>
<td>52%</td>
<td>48%</td>
<td>51%</td>
</tr>
<tr>
<td></td>
<td>( Q_{ach} )</td>
<td>0.4</td>
<td>0.7</td>
<td>0.3</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>AF</td>
<td>50%</td>
<td>51%</td>
<td>44%</td>
<td>49%</td>
</tr>
<tr>
<td></td>
<td>( Q_{ach} )</td>
<td>12.1</td>
<td>16.3</td>
<td>9.4</td>
<td>38.1</td>
</tr>
<tr>
<td></td>
<td>AF</td>
<td>51%</td>
<td>49%</td>
<td>44%</td>
<td>48%</td>
</tr>
</tbody>
</table>

Table 2: Theoretical and realistic space heating saving potentials of the Swiss building stock [Schneider, Khoury, et al., 2017]

On the basis of different case studies, the EPG is not close to zero [Cozza S., 2019] due to the intrinsic characteristics of the theoretical model, which should be used exclusively to compare different buildings under standard conditions of usage. An energy rating, as contained in the EPC, does not claim to foresee the real consumption of that building, and it is therefore misleading to use it as a predictor of consumption.

### 3.4.4 Energy reference area

The energy reference area (ERA) is defined in the SIA standard 416/1 (2007 edition) as the sum of the total heated and/or cooled floor area below and above ground level, included within the thermal envelope.

The Swiss Federal Office for Energy [SFOE 2018] publishes ERA values on an annual basis. The basis of the statistics are data from cantonal insurance companies dating from 1995, as well as housing censuses conducted in 1990 and 2000. For the following years, the ERA values have been calculated by the Federal Office of Energy (BFE) using statistics on investments in buildings.
ERA values by SES Scenarios

ERA values reported in the SES scenarios (table 3) originate from Wüest & Partner [2011]. For dwellings, the energy reference surface area is increasing over time as GDP and population are growing.

<table>
<thead>
<tr>
<th></th>
<th>2000</th>
<th>2010</th>
<th>2020</th>
<th>2035</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Households</td>
<td>416.5</td>
<td>486.7</td>
<td>560.5</td>
<td>631.4</td>
<td>665.8</td>
</tr>
<tr>
<td>Industry</td>
<td>67.3</td>
<td>70.3</td>
<td>76.4</td>
<td>77.8</td>
<td>80.7</td>
</tr>
<tr>
<td>Services</td>
<td>139.7</td>
<td>151.8</td>
<td>161.6</td>
<td>176.5</td>
<td>191</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>623.5</td>
<td>708.8</td>
<td>798.5</td>
<td>885.7</td>
<td>937.5</td>
</tr>
</tbody>
</table>

*Table 3: ERA of buildings by economic sector [Wüest & Partner, 2011]*

ERA values have also been estimated by industrial sector. Table 4 also reports on vacant floor space.

<table>
<thead>
<tr>
<th>Branch of activity</th>
<th>2000</th>
<th>2010</th>
<th>2020</th>
<th>2035</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alimentation</td>
<td>7193</td>
<td>7217</td>
<td>7739</td>
<td>7501</td>
<td></td>
</tr>
<tr>
<td></td>
<td>H0</td>
<td>B</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hôtel</td>
<td>707</td>
<td>698</td>
<td>576</td>
<td>709</td>
<td>664</td>
</tr>
<tr>
<td>H0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Habitation</td>
<td>2467</td>
<td>1797</td>
<td>1435</td>
<td>1165</td>
<td>1176</td>
</tr>
<tr>
<td>H0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Papier</td>
<td>195</td>
<td>215</td>
<td>219</td>
<td>196</td>
<td>136</td>
</tr>
<tr>
<td>H0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemie</td>
<td>3677</td>
<td>3391</td>
<td>4799</td>
<td>6121</td>
<td>8300</td>
</tr>
<tr>
<td>H0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minéraux</td>
<td>1761</td>
<td>1695</td>
<td>1662</td>
<td>1707</td>
<td>1763</td>
</tr>
<tr>
<td>B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Métaux</td>
<td>1311</td>
<td>1158</td>
<td>1194</td>
<td>1221</td>
<td>1256</td>
</tr>
<tr>
<td>B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Produits métalliques</td>
<td>3357</td>
<td>3511</td>
<td>3538</td>
<td>4405</td>
<td>3097</td>
</tr>
<tr>
<td>H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electro technique</td>
<td>1058</td>
<td>1053</td>
<td>1097</td>
<td>863</td>
<td>707</td>
</tr>
<tr>
<td>B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Construction machines</td>
<td>3201</td>
<td>3406</td>
<td>4115</td>
<td>4905</td>
<td>6191</td>
</tr>
<tr>
<td>H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energie</td>
<td>1197</td>
<td>1208</td>
<td>1245</td>
<td>1474</td>
<td>1946</td>
</tr>
<tr>
<td>B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Utilité et chauffage</td>
<td>49899</td>
<td>47245</td>
<td>56535</td>
<td>58128</td>
<td>61342</td>
</tr>
<tr>
<td>H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-utilité et chauffage</td>
<td>9695</td>
<td>11266</td>
<td>7971</td>
<td>8196</td>
<td>8649</td>
</tr>
<tr>
<td>B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>59953</td>
<td>58511</td>
<td>64506</td>
<td>68324</td>
<td>68991</td>
</tr>
<tr>
<td>H</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Totaux</td>
<td>82250</td>
<td>89723</td>
<td>91504</td>
<td>89796</td>
<td>95465</td>
</tr>
</tbody>
</table>

*Source: Program 2012*

*Table 4: ERA (in 1000m²) by activity sector in the industry (including vacant spaces) [Wüest & Partner, 2011]*

A model for ERA forecasts
Given the historical data on energy reference areas, investments and population, UNIGE has undertaken a model for the forecast of ERA. This model is still in development stage, and the first results on ERA forecast depending on different economic growth assumptions previously are given in Table 5a to 5c.

<table>
<thead>
<tr>
<th>in millions m²</th>
<th>2000</th>
<th>2010</th>
<th>2020</th>
<th>2035</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Households</td>
<td>416.5</td>
<td>459.9</td>
<td>528.2</td>
<td>639.2</td>
<td>758.2</td>
</tr>
<tr>
<td>Others buildings</td>
<td>220.8</td>
<td>237.2</td>
<td>259.2</td>
<td>294.0</td>
<td>335.8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>637.3</td>
<td>697.1</td>
<td>787.4</td>
<td>933.2</td>
<td>1094.0</td>
</tr>
</tbody>
</table>

Table 5a: ERA of buildings (GDP: OECD scenario)

<table>
<thead>
<tr>
<th>in millions m²</th>
<th>2000</th>
<th>2010</th>
<th>2020</th>
<th>2035</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Households</td>
<td>416.5</td>
<td>459.9</td>
<td>528.2</td>
<td>602.0</td>
<td>659.3</td>
</tr>
<tr>
<td>Others buildings</td>
<td>220.8</td>
<td>237.2</td>
<td>256.9</td>
<td>282.7</td>
<td>307.2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>637.3</td>
<td>697.1</td>
<td>785.1</td>
<td>884.8</td>
<td>962.0</td>
</tr>
</tbody>
</table>

Table 5b: ERA of buildings (GDP: JASM scenario)

<table>
<thead>
<tr>
<th>in millions m²</th>
<th>2000</th>
<th>2010</th>
<th>2020</th>
<th>2035</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Households</td>
<td>416.5</td>
<td>459.9</td>
<td>528.2</td>
<td>544.2</td>
<td>588.6</td>
</tr>
<tr>
<td>Others buildings</td>
<td>220.8</td>
<td>237.2</td>
<td>252.6</td>
<td>264.4</td>
<td>279.2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>637.3</td>
<td>697.1</td>
<td>780.7</td>
<td>808.6</td>
<td>867.8</td>
</tr>
</tbody>
</table>

Table 5c: ERA of buildings (GDP: SECO scenario)

### 3.4.5 Roof surfaces

The interactive application available on www.toitsolaire.ch (Klauser, 2016) now covers all Swiss buildings. It determines the suitability of a building for solar energy production. According to available studies, total roof surface available and well exposed to solar radiation is estimated between 140 km² (Gutschner et al., 2002) and 396 km² (Cattin et al., 2012). For those surfaces, the current technically feasible energy potential in Switzerland varies from 38 to 58 TWh/year.

As this potential relies on available roof surfaces, the long-term trend of the roof size of buildings is examined on the basis of the RBD data. For the purpose of the analysis, whenever total residential ground footprint is not given the roof surface is computed by dividing total floor are (ERA) by the number of floors in each building. The analysis differentiates residential buildings (excluding single house) from other buildings. The blue line in figure 15a & figure 15b shows the trend regarding the average roof surface of buildings. This trend is increasing over time as shown on the graphs.

![Figure 17a: Average roof size forecast (blue-line) for residential – buildings](image-url)
3.5 Energy Consumption

3.5.1 Energy sources in residential buildings

A survey on the energy sources in residential buildings was carried by the BFS [2018] among a sample of 15,000 people randomly drawn throughout Switzerland (response rate around 60%). Respondents were asked to complete an online questionnaire regarding their building's heating system or provide the BFS with their landlord's or manager's contact details. The survey's results (figure 18) indicate that almost 90% of the Swiss residential buildings which are the main place of residence for at least one person are served by a central heating system which covers one or more buildings. Less than 5% are connected to district heating. Although the use of fuel oil is continuously declining, two out of three buildings are nowadays still heated by fossil fuels (fuel oil or gas). Since the 2000, the number of heat pumps has increased considerably. Today, almost one in every five buildings has this type of heating. 20% of all buildings have a secondary energy source (for complementary energy supply), which is wood for over half of them, followed by solar thermal panels and other.
By 2000, approximately 80% of the low-temperature heat required for rooms and for the heating of hot water was produced by burning combustibles. Around a million gas and oil boilers were in use in Switzerland in 2000, and these accounted for approximately half the country’s CO_2 emissions [BFE, 2005].

Over the last decade, alternative solutions have emerged through the replacement of oil and gas boilers by more efficient solutions, in particular heat pumps. Heat pumps make use of ambient renewable energy from the ground, ground water, rivers, lakes and outside air, and upgrade it to a useful temperature level. The heat source is constantly renewed through sunlight, precipitation and geothermal energy. The substitution trend (Figure 19) concerning the number of boilers used for the generation of low-temperature heat should be confirmed in the future.

![Substitution trend of fossil boilers by non-fossils solutions](image)

**Figure 19:** Substitution trend of fossil boilers by non-fossils solutions (“Ersatz” means replacement; “Umbau” means reconstruction) (Wüest & Partner, 2011)

### 3.5.2 Load profile

Hourly heat demand profiles for space and process heat in the end-use sectors are provided by Vögelin et al. [2016]. Profiles are estimated on the basis of daily heat demand patterns derived from statistical analysis of gas consumption patterns for heating and consumer behaviour in Germany, adapted by using the heating degree days and ambient temperatures of Switzerland. The residential hot water demand profiles are based on statistical estimation of consumer behaviour from surveys conducted mainly in Switzerland and Germany. The following profiles are available on the JASM database per typical day and season:

- Space heating profile in industry
- Space heating profile in residential existing multifamily houses
- Space heating profile in residential existing single-family houses
- Space heating profile in residential new multifamily houses
- Space heating profile in residential new single-family houses
- Space heating profile in services
- Water heating profile in industry
- Water heating profile in residential

As shown in Figures 20a and 20b, Vögelin et al. [2016] presents respectively the consumption profile for water heating and space heating in the residential sector. Each curve corresponds to a probability density function, describing the variations in the load profile during the year across the seasons (winter – WIN;

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7 More information can be found on http://data.sceer-jasm.ch
summer – SUM; INT – in between), the type of day (week - WK, or week-end-WE), and the hours of day. The probability of the INT period gathers probability observed during spring and autumn seasons.

Figure 20a: Water heating profile in residential building (Vögelin et al. [2016])

Figure 20b: Space Heating profile in residential (Vögelin et al. [2016])

3.5.3 Number of appliances by households

The SES 2050 scenarios includes forecasts on the number of household appliances (e.g. heating systems, washing machines, freezers). The trend is determined either by the energy reference area (itself correlated to GDP/capita) or by the number of persons or households. The total number of each appliances is given in Figure 21.
It should be pointed out that the techno-economic characteristics of existing and new energy technologies used on the energy demand and the energy supply side evolve over time and improve according to exogenously specified trends including learning rates.

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