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Abstract

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Reference


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Transformation path for a sustainable building stock in Switzerland

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Abstract

The goal of Switzerland’s climate policy is to reduce CO$_2$ emissions by limiting annual energy consumption to 1 tCO$_2$. One key area that produces a considerable amount of CO$_2$ emissions is the building sector. Switzerland’s goal is for all buildings to operate with zero CO$_2$ emissions by 2060. To reach this goal, there are different ways to assess the energy efficiency and emissions of a building. One method is a diagram that classifies buildings into different classes (A to G, for high to low efficiency), based on the Non-Sustainability Exergy (NSE) diagram. This project plans to propose a new energy class based on an analysis of the residential sector. To create the new class, specific buildings were modelled with possible alterations that could lead to zero-emissions. First, the current energy usage and emissions of the buildings were calculated and they were classified according to the NSE diagram. Using the results, a new energy classification system was defined, along with a tool to help building owners plan renovations using the new system.

Keywords:
Transformation path, Non-Sustainability Exergy, Building technology, Zero-emission building, Swiss building stock.
1. Introduction

1.1. CO₂ emissions and global warming

In the history of our planet, climatic warming and cooling as well as ice ages have occurred periodically. Research today has shown that these variations occur due to average air temperature, which is correlated to the concentration of carbon dioxide (CO₂) in the atmosphere – the higher the amount of CO₂ in the atmosphere, the higher the average air temperature [1]. Measurements show that the Earth’s climate is currently experiencing a temperature increase as well as an increase in the concentration of carbon compounds in the atmosphere. This agrees with the aforementioned correlation, and it would logically follow that a period of warming is occurring.

The question remains whether global warming is part of the Earth’s natural cycle as experienced in the past or human-induced. Some sources claim that CO₂ emissions today, like in the past, are caused solely by natural sources such as the algae in the oceans or increased volcanic activity. However, another school of thought takes into account the quantity of CO₂ emitted into the atmosphere by human activity. Humans release millions of years’ worth of stored CO₂ back to the Earth’s atmosphere at a much faster rate than natural emissions and in much greater quantities. In fact, the concentration of atmospheric CO₂ has increased by about 35% since the beginning of the industrial era [2]. This indicates that humans are inducing a state of warming that is not naturally possible.

To reduce human activity CO₂ emissions, international agreements and regulations such as the Kyoto protocol and 20/20/20 in the European Union have been developed and agreed to by various countries; however, commitment to these goals and successes have varied greatly between nations.

1.2. CO₂ emissions in the building sector

The largest CO₂ emitting sectors are: transportation, agriculture and buildings. This project focuses on the building sector since total energy consumption has been estimated to be as high as 40% in some developed countries. Much of this consumption results in CO₂ emissions yet is easily reducible.

For example, it has been estimated that up to 20% of the energy used in the building sector in Europe is wasted. Therefore, it is essential to improve the energy efficiency of buildings. Based on research and monitoring of real building performance, new methodologies and a systematic approach toward energy efficiency need to be developed.

2. Residential Housing Stock

Total energy usage in Switzerland is divided into five sectors: residential, industrial, services, transportation and agriculture. After transportation, the residential sector consumes the most energy at 28.7% of total consumption as of 2009 [3]. The residential sector also has the highest growth rate in consumption of all the sectors. As part of the building sector, residential housing will therefore be targeted for energy reduction. Commercial and industrial buildings are most likely encompassed within the industrial and services sectors and will not be considered due to lack of data.

2.1. Number of Dwellings

Table 1 contains the number of residential houses with respect to their period of construction [4]. Note that durations of the periods are not consistent and range from a decade to two decades to indefinite. Taking this into account, the rate of construction of new dwellings in Switzerland has remained fairly constant over the years and may even be in declining. Overall, the majority of the residential housing stock consists of houses over a decade old with relatively few new units. The buildings used in this project were constructed between 1946 and 1980.
Table 1: Number of residential houses by period of construction until 2009.

<table>
<thead>
<tr>
<th>Period of Construction</th>
<th>Number of Dwellings</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before 1946</td>
<td>1,086,263</td>
<td>27.1</td>
</tr>
<tr>
<td>1946-1980</td>
<td>1,691,524</td>
<td>42.2</td>
</tr>
<tr>
<td>1981-2000</td>
<td>883,388</td>
<td>22.0</td>
</tr>
<tr>
<td>2001-2009</td>
<td>348,727</td>
<td>8.7</td>
</tr>
<tr>
<td>Total</td>
<td>4,008,351</td>
<td>100</td>
</tr>
</tbody>
</table>

2.2. Energy consumption

The total energy used in Switzerland can be categorized into the following nine end-usage types: space heating, hot water, process heating, lighting, air conditioning and building services, personal electronics, industrial systems, mobility and other. A third of all energy consumption goes toward space heating in the building sector, as seen in Figure 1. In the residential sector specifically, space heating uses more than two thirds of the energy in this sector and is clearly the largest area for improvement [3].

![Energy consumption in 2009 by usage type.](image1.png)

2.3. Energy sources

For space heating in the residential sector, the primary energy source is heating oil as seen in Figure 2. The use of oil has been steadily declining yet it still accounts for 50% of space heating as of 2009. Natural gas follows with an increase in use of 22.5% over the decade. Solar thermal heating has seen a rapid growth of 232%; however, it still only supplies a meagre 0.2% of the space heating load due to the inefficiency of current photovoltaic technology [3].

![Heated floor space by energy source in 2009.](image2.png)
2.4. International comparison of CO₂ emissions

As Figure 3 illustrates, Switzerland is well above the EU-15 average in per capita CO₂ emissions in the housing sector [5]. Notably, the Scandinavian countries, which are further north and have higher heating demands due to climate, score better than Switzerland. Reasons for this may include the primary energy sources in each country as well as the use of gas versus electric heaters. Switzerland also has greater crude oil content in its household energy supply than these other countries.

![Figure 3: Per capita household CO₂ emissions in Switzerland and the EU-15 countries in 2004.](image)

3. Building Sector Energy Policy

Switzerland’s energy policy is founded on the principles of Article 89 of the Federal Constitution: sufficient, reliable, diversified, cost-effective and environmentally-sound energy, with an emphasis on the importance of energy efficiency and renewable sources. In 2007, the Department of the Environment, Transport, Energy and Communications (DETEC) published an action plan on energy efficiency and renewable energy, comprising 18 measures for energy efficiency and eight for renewables [6]. The five measures addressing buildings are:

2. Revision of MuKEn model prescriptions for new builds and refurbishments. As from 2008, 60 kWh/m² per year (vs. the current 90 kWh/m²) for new builds, and max. 140% of new build value for refurbishments. Increasing the minimum share of renewable energy for space and water heating from 20% to 30% for new builds. New rules to ban fossil and electric heating when replacing old systems. Further tightening planned by 2015.
3. Introduction of a harmonised building certificate.
4. Renewed agreements with cantons with more stringent conditions (i.e. adoption of stricter building regulation) for federal co-financing of cantonal programmes.
5. Reduction of legal barriers to refurbishments (rental and tax laws harmonisation of cantonal planning regulations).
4. Transformation Paths & Classifications

4.1. The Non-Sustainability Exergy (NSE) diagram

One obstacle in achieving sustainability in the residential sector is accessibility to information. Building professionals are well versed in ways to improve energy efficiency; however, the stakeholders (in this case, homeowners) must also have a basic understanding of building energy so that both parties can work towards reducing emissions.

One effective way to disseminate information on transformations paths toward energy efficiency is using a diagram, such as the Non-Sustainability Exergy (NSE) diagram [7] seen in Figure 4. This diagram presents energy class ratings for buildings from A (most efficient) to G (least efficient). It displays energy consumption per unit area versus CO₂ emissions.

4.2. Sample transformation paths and issues with the NSE diagram

In the following examples, the NSE diagram is used to improve aspects of the residential housing stock. In Figure 5, a building with oil-based central heating and a decentralized water system is classified by the red bar. By the various stages outlined on the diagram, it can be brought from a potentially F-class building to an A-class building. The main change is the use of a centralized geothermal heating system.

In the transformation example in Figure 6, modifying the building envelope can reduce net energy, but this allows it to move only along the x-axis of the graph. This makes it difficult for efficient buildings to achieve A-class. A similar situation occurs on the y-axis, where the use of renewable energy sources reduces CO₂ emissions per square meter and allows buildings to easily enter A-class.

The flaw in this traditional approach is apparent in Figure 7 – buildings with low emissions due to the use of renewable energy sources (such as wood pellet boilers or photovoltaic cells) yet have high net energy consumption may fall into classes A or B. This is impractical due to the magnitude of renewables needed to mitigate high-energy buildings. This diagram needs to be modified to account for this because as is, theoretically, a net-zero A-class building could use an infinite sum of energy.
Figure 5: Transformation path using a central warm pump and geothermal heating.

Figure 6: Transformation path for the building envelope of Minergie-P building.

Figure 7: Transformation path using a Pellet boiler.
4.3 Modified classification diagram

To account for the discrepancies in the NSE diagram, the modified diagram in Figure 8 was created to weight energy usage and CO₂ emissions by area. Now it is only possible to reach an A-class by having both low emissions and low energy consumption. This classification is therefore much stricter than the NSE-diagram and other existing classes, but it is useful for meeting the goal of net-zero energy homes by 2060.

Figure 8: Modified classification diagram based on the NSE diagram.

4.4 Calculation tool

As discussed previously, it is important that homeowners are able to navigate this diagram and gauge potential renovations. Therefore, a calculation tool to locate a building’s performance on the modified diagram was also created. It is also able to calculate the effects of planned renovations and display them on the diagram and compare renovation methods.

Another important factor is that over 75% of residential houses are privately owned; however, most homeowners cannot afford the capital cost to perform energy-efficient renovations in one step. To account for this, the calculation tool shows different ways to achieve a net-zero household by 2060 in multiple stages. This way, an economically-viable long-term transformation path for a building can be developed.

5. Conclusion

It is important to remember that reducing energy consumption in buildings is just as important to long term sustainability as reducing CO₂ emissions. Most classification systems, including the NSE diagram, tend to focus more on CO₂ reduction when these emissions are actually closely coupled with energy consumption. Indeed, many solutions for CO₂ emission reduction (such as solar and wind technology) would not be capable of meeting current energy demands. The modified diagram better accounts for energy consumption and is much more stringent in classifying A- and B-class buildings. The accompanying calculation tool allows for easy comparison of potential transformation paths so building owners can plan renovations. The end-goal of these measures is to ensure that Switzerland has a fully sustainable building stock with no CO₂ emissions, thus abating the effects of global warming.
References


