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Building a climate-neutral future together

Sino-Swiss Cooperation on Zero Emissions Building

Technical Report

Swiss Experience on Technical Regulation for Energy and Emissions in the Building Sector

Learnings for China's Next Generation of Building Emission Standards

ENGLISH VERSION

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Building a climate-neutral future together

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The Sino-Swiss Zero Emissions Building Project is an international collaboration funded by the Swiss Agency for Development Cooperation in partnership with the Chinese Ministry of Housing and Urban-Rural Development. The project aims to reduce greenhouse gas emissions and enable carbon neural development of the building sector in China by sharing Swiss know-how on sustainable and zero emission building.

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Image: ZEB China Demonstration project. Training building, Long Shan Shu Yuan Middle School, Shoaxing, Zheijiang Province. Courtesy of Shaoxing Future Community Development and Construction Co.

Summary

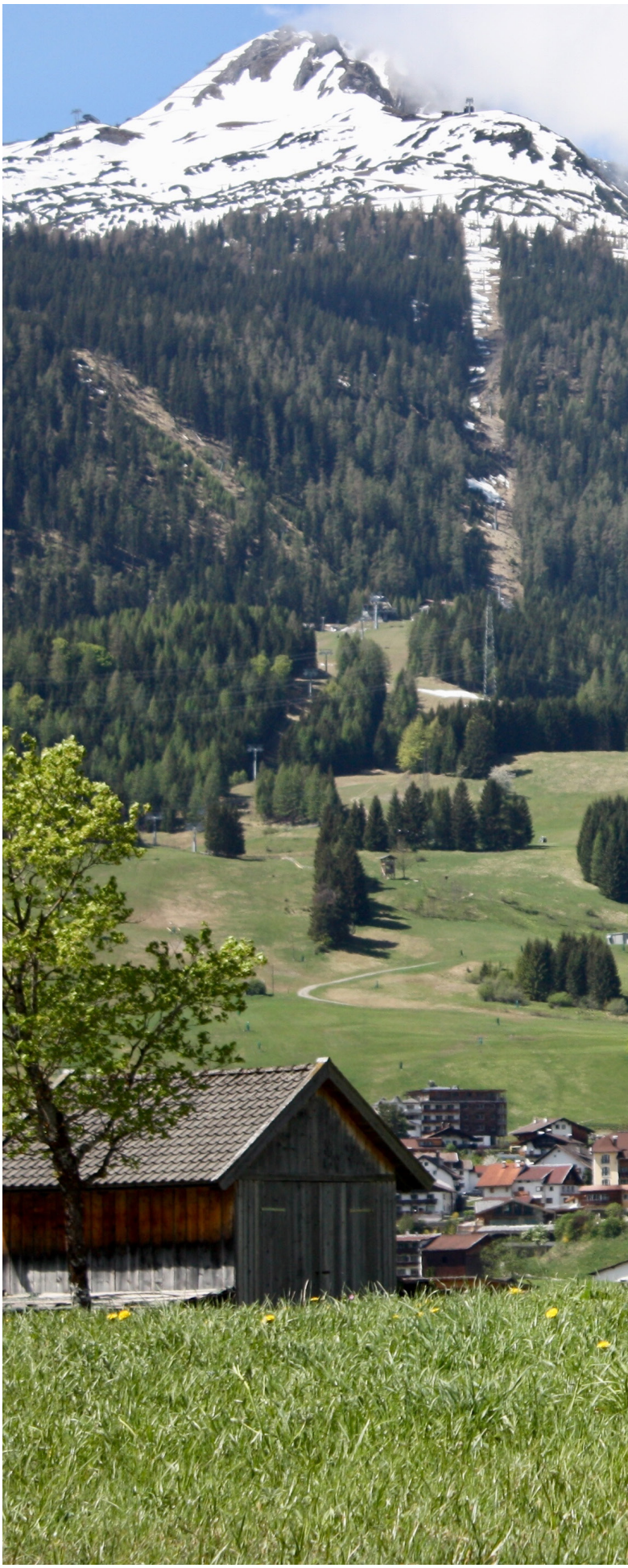
Switzerland has a long-standing experience with policy design and technical regulation (TER) for moving the building sector to more energy efficiency and lower greenhouse gas emissions.

First activities started in the 1970’ ies and since then the policy instruments and technical regulations were constantly developed and improved.

The experience of Switzerland can provide learnings for China in developing their own policies for the long-term goal of a zero-emission building (ZEB) stock to arrive at a net-zero emission economy in the future.

This report provides an insight on the historical development of the policy instru-ments and key achievements, gives in-depth information on the most relevant policy instruments which are in use at date, and summarizes the present status of research on the key features for the evolution of the technical regulation for buildings in Switzerland towards compliance with a net-zero emission target. The report concludes with nine key learnings from Swiss experience for the transition to zero-emission buildings.

The most important learning however is, that successful transformation of the build-ing sector needs a wide-ranging approach which integrates all relevant stakeholders. While legislation is most important to set minimum standards in the market, innovation and “change of attitude” of investors are more driven by market leaders and good ex-amples in form of “lighthouse” projects going far beyond the legally required minimum performance of buildings. Beyond stringent technical regulation, there is also need for an effective enforcement system for the policies, guidelines for the investors, planners, and practitioners as well as high quality education and training of the professionals. Fi-nally, there must be continuous information and awareness raising targeting all relevant stakeholder groups. Only through a fruitful interplay of the different stakeholders and the diversity of policy instruments a fast and far-reaching transition of the building sec-tor can be successfully achieved.



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1. Genesis of Swiss Technical Regulation (TER) for Energy and Emissions in Buildings

Switzerland is in climate zone which is characterised by cold winters and moderately hot summers. Cold temperatures do not only affect the energy consumption of buildings but are the source of serious hygienic problems (e.g. mould), comfort problems (e.g. uncom-fortable surface temperatures, air draft). In the early 1960' ies, when in Switzerland first activities started towards developing a Technical Regulation (TER) for the thermal per-formance of buildings, winters as well as summers have been significantly colder than today. Therefore, the earliest versions of the TER focussed on addressing hygienic and comfort problems. In the 1970' ies, the pathway towards zero emission buildings (ZEB) has started. Approximately fifty years back, the focus of the TER was for a first time ex-tended to energy efficiency and since the 1990' ies also to greenhouse gas emissions. With steadily increasing hot temperature periods in Switzerland due to climate change impact, in the recent decades also summer heat issues were more prominently ad-dressed by the TER.

The evolution of the Swiss TER for the energy and climate performance of buildings can be characterised by five phases. The respective characteristics are highlighted in the following.

1.1. Phase 1 (1960-1973): Ensuring a comfortable indoor climate and preventing structural damage

The period is characterized by a need in the building sector to establish good practice in the technical design for new buildings. The building designs of this time were character-ized by simple concrete or brick walls with high thermal conductivity, lack of insulation materials and poor thermal performance of windows / doors (simple single or two pane windows w.o. gas filling). Consequently, in many of these buildings hygienic or comfort problems occurred due to the building physics.

The building sector stakeholders, the national Energy Ministry and the Swiss tech-nical standardisation body for the building sector called SIA (Swiss Society of Engineers and Architects) developed first initiatives to develop a common understanding on how to prevent damage of the buildings and health risks for the users due to condensation problems and ensure a minim level of comfort for users.

Major achievements from Phase 1

- Sensitizing market players on the relevance of thermal performance of building envelopes and how to deal with problems caused by building physics.
- Creation of a common understanding of market actors on "good practice standard" for thermal property of buildings to prevent health and comfort problems caused by building physics.

1.2. Phase 2 (1973-1989): Piloting and anchoring TER for building efficiency

In the 1973 the world faced the first oil crisis which resulted in sharply increased energy costs and problems in maintaining national energy security in Switzerland. Based on this experience, a "pioneer" group of Cantons started to develop legally binding TER with focus on energy performance of buildings. Based on economic and security concerns the pressure was growing to develop formal TER for energetic building performance.

In 1975, the SIA issued on a national level the first technical standard on thermal properties of new buildings (SIA 180/1: Thermal insulation, moisture protection and indoor climate in buildings). Application was voluntary; however, first cities and Cantons declared the standard as compulsory.

In 1988 an additional standard on maximum heating energy demand of buildings was issued (SIA 380/1: Heating energy demand of buildings). The purpose of the standard is to ensure a moderate and economical use of energy for space heating in buildings. This standard introduced two different options for ensuring compliance with the standard requirements which up today proved to be very successful:

Option 1: Detailed calculation method for a system-based calculation of end energy demand

Option 2: Simplified proof of compliance by adopting simple and descriptive mini-mum requirements for the thermal performance (U-values) of individual building components (Walls, Roof, Window, Floor against outdoor climate, Wall/Roof against unheated rooms).

Major achievements from Phase 2

- National SIA standards for thermal performance and efficiency of buildings, devel-oped in a participatory process including Authorities, architects, planners and con-struction sector industry.
- Calculation tools (developed by private sector, accredited by Authorities) for design stage proof of compliance with TER.
- Mandatory requirement to submit a technical documentation on thermal building design as a prerequisite for the construction approval by Building Authorities.
- Execution aids for planners with detailed and easily readable explanations of TER requirements, including practical examples for different types of buildings.
- Early and extensive training of all relevant market players and administration staff in understanding and applying the requirements of the TER.
- Development of a Canton / city level enforcement system for compliance check-ing. This is based on self-declaration of the building developer to be checked by the Authorities on random basis.
- Introduction of two different approaches for compliance checking for providing flexibility to Building Authorities regarding their own enforcement capacity: a) Authorities with adequate staff resources: enforcement directly by the Building Authority; b) Authorities with weak staff resources: outsourcing enforcement to Canton ac-credited private controller' s for checking the compliance with TER during design and construction phase.
- Random on-site checks by Buildings Authorities or private controllers on executed construction quality versus approved design quality incl. legally anchored sanction-ing regime.
- Random checks of Building Authorities on work quality of private controllers.
- Periodic evaluation of real-world performance of buildings versus nominal perfor-mance as per the design.
- Fruitful interplay between pioneering and progressive Cantons and national SIA norms helping in driving up requirements on thermal building performance.

In the Phase 2, instruments and tools for large-scale implementation and enforcement of energy efficient buildings were developed, which until today are priority elements of the enforcement system. These are listed in the text box on major achievements below.

By the end of phase 2, Switzerland had very heterogenous TER in the different Cantons. Most Cantons had mandatory TER on energy performance, but the technical details dif-fered significantly.

1.3. Phase 3 (1990-1993): Harmonizing TER

A significant backdraw of the situation in Switzerland at the end of 1980' ies was the heterogeneity of the TER in the different Cantons. This was identified by the nationally operating construction sector to be a significant barrier for efficient adoption of the TER. Architects, planners, craftsmen and construction companies had to deal with different TER depending on the geographical location of the construction sites.

In the year 1990, a constitutional change delegated the responsibility on the TER for the building sector to the Cantons. To avoid market barriers by high diversity, in 1992 the national government together with the Cantons issued a model regulation on ener-gy use in buildings (MVO 92, in later versions called MuKEn). This served as an orienta-tion framework for designing building related TERs at the Canton level. The sample regu-lation combined all successful approaches from the previous phases, including e.g. the calculation methods and minimum envelope qualities of the SIA 380/1 standard, calcula-tion tools and application or documentation forms.

In 1995 a first version of the standard SIA 380/4 "Electrical energy in building con-struction" was issued. It aims at the rational use of electricity in buildings and installa-tions and contributes as a planning aid to optimising the electricity consumption of new buildings and conversions. It defines the relevant parameters and establishes a standard-ised presentation of the electricity demand.

In the year 1990, two important national programs were launched:

The program called "Energie 2000" which run from 1990 – 2000 and is still active today under the name "EnergieSchweiz" was Switzerland' s first energy policy instru-ment with the aim of promoting the rational use of energy and renewable energies through voluntary measures together with partners from business and the public sector, education and

science, the environment and consumption. The program address-es the building sector as one of the priority sectors.

The three action programs IP Bau (Maintenance and renovation of buildings) / RAVEL (efficient use of electricity) and PACER (renewable energies) run from 1990 – 1995. The objective was to contribute to a more qualitatively oriented economic growth, i.e. to a raw material-, energy- and environmentally friendly production with a simul-taneous increased use of "capability capital" (knowledge, know-how) through strengthening education and training of both providers and consumers of services in these areas as well as through information. Knowledge transfer was geared towards use in daily practice. This helped also to create new markets, e.g. for high efficiency windows or photovoltaic systems.

Major achievements from Phase 3

- Model Regulations (MuKEn), providing a "toolbox" for the Cantons in designing their specific TER and ensuring a minimum level of harmonization throughout the Cantons.
- Mandatory TER for building energy efficiency are issued in all Cantons.
- Large and long-term national support pro-grams with a focus on supporting TER im-ple-mentation through voluntary actions, public private partnerships, information dissemina-tion, strengthening education and training of both providers and consumers.

Image: Geneva (Freepik)

1.4. Phase 4 (1994-2014): Ratcheting up of TER and focus shift to renewable energies

In Phase 4 and because of increased environmental awareness and climate change sci-ence, a still continuing shift of focus started towards benchmarking building perfor-mance not only against energy consumption during the operation phase, but by applying an integral benchmarking approach including the climate impact (shift to renewable energies), impacts from all phases of the building life cycle (design and construction, operation, decommissioning) and other environmental aspects (e.g. pollutants from building materials).

At the TER level, the Swiss Cantons did not redesign the major concepts in this peri-od but focused on progressively strengthening the technical requirements. The quanti-tative requirements were stepwise increased (Figure 1), leading to significantly lower energy consumption of new buildings (Figure 2).

In the version of 2014, the MuKEn was amended by requirement for new buildings to respect a maximum share of fossil fuels for heating purposes (i.e. 10% or in some Can-tons a minimum of 20% of the maximum energy demand as per TER has to be covered either by renewable energies or the energy demand or has to be reduced through fur-ther improvement of building envelope efficiency).

As a very effective feature of the sample regulations on maximum share of fossil fuels, a set of descriptive solutions was developed. These descriptive solutions provide a choice of simply understandable technical measures or combinations thereof (e.g. use of a electric heat pump or improved envelope efficiency in combination with connection to renewable based district heating) to achieve compliance with the TER. The market has made active use of this option, despite that the descriptive solutions lead in average to slightly higher qualities of building materials as no individual optimization is possible beside choice of the sample solution to be adopted (sample solutions include some "safety margins" as compared to system-based calculations).

During the phase 4, several voluntary and legal instruments were developed which strongly influenced and promoted further evolution of the TER:

- Conceptual framework for a "2000-Watt-Society". The core of the concept – devel-oped by the Swiss Federal Institute of Technology (ETH) domain – is the limitation of per capita energy consumption at a level equivalent to 2000 Watt total and 500 Watt non-renewable permanent primary energy power demand (equivalent to 17'520 resp. 4'380 kWh/a) for achieving global energy equity at a sustainable level. With this con-cept, the idea of sharp reduction of energy consumption and the need for a transition to renewable energies was getting into the political and societal discussion for the first time. In consequence, the concept was adopted by various municipalities for their strategic orientation on energy and climate actions.
- With the "SIA Energy Efficiency Pathway" issued in 2006, the Swiss norming body SIA published a tool for practitioners for implementing the goals of the 2000-watt society in the building sector. The methodology applied is characterized by an overall energy view: In addition to operating energy, its gray energy and location-dependent mobili-ty are also included. It specifies target values for greenhouse gas emissions and non-renewable primary energy.
- MINERGIE labeling scheme: Development of a simple low energy building label, which up today was further developed into a set of standards with different ambition levels, including nearly zero and zero emission building standards (MINERGIE, MINERGIE-P (-Passive), MINERGIE-A (-active), MINERGIE Eco (other ecological aspects).
- GEAK certification scheme: Methodology for a voluntary building certificate, covering information on envelope efficiency and total energy performance including green-house gas emissions (for new and existing buildings).
- Swiss energy act and energy ordinance (since 1999): The act and its ordinance pro-vide the regulatory framework for achieving an adequate, diversified, secure, econom-ical, and environmentally sound energy supply. One of the main achievements was the introduction of quantitative long-term reduction targets for per-capita energy consumption in Switzerland, with separate targets on total energy consumption and consumption of electricity. It also includes targets for production of renewable ener-gies. In addition, the act spec-

	new buildings	retrofit
Model regulations 1992	0,3 W/m²K	0,5 W/m²K
Subsidy – program 1997		0,3 W/m²K
Model regulations 2000	0,3 W/m²K	0,3 W/m²K
Subsidy – program 2006		0,23 W/m²K
Model regulations 2008	0,2 W/m²K	0,25 W/m²K
Model regulations 2014	0,17 W/m²K	0,25 W/m²K

Figure 1: Evolution of heat transfer coefficient (U-value) for walls. Source: Christoph Gmür, Canton Zurich, Office of Waste, Water, Energy and Air, Swiss-US Energy Innovation Days 2015

ifies the main energy policy instruments for each sector, including the building sector. More details on the present status are provided in sec-tion 2.1 of this report.

- Swiss act on CO2-emissions and CO2-ordinance (since 2000): The act and its ordinance provide the regulatory framework and relevant instruments for reducing greenhouse gas emissions, in particular CO2 emissions attributable to the energetic use of fossil fuels (combustibles and fuels), with the aim of contributing to limiting the global temperature increase to less than 2 degrees Celsius. It specifies the quantitative re-duction targets of Switzerland.
- Integration of primary energy related weighting factors in the calculation method of the norm SIA 380/1 (thermal insulation, moisture protection and indoor climate in buildings). By multiplying the design end energy use with energy source related weighting factors, a simple and pragmatic way was found to upgrade this focal norm for energy and climate performance of buildings to a primary energy perspective. There are separate limits for weighted and non-weighted energy consumption of buildings, which both must be fulfilled. The weighting factors are set as following:
  - Electricity = 2.0
  - Fossil fuels = 1.0
  - District heat = 0.4 – 1.0 (depending on the fossil fuel share of the heat source)
  - Biomass = 0.5
  - Other renewable energies = 0

Major achievements from Phase 4

- Legal basis with high ambition on energy efficiency and greenhouse gas emissions, providing effective national policy instruments and quantitative reduction targets, including large scale subsidy program for building retrofit.
- Evolution of Model Regulations (MuKEn) towards near zero energy buildings and a primary energy consideration.
- Visionary and significant voluntary action to develop concepts for zero emission buildings.
- Energy and climate impact related green building labelling and certification schemes, applicable for existing buildings, new buildings and building retrofits (MINERGIE “family”, GEAK).

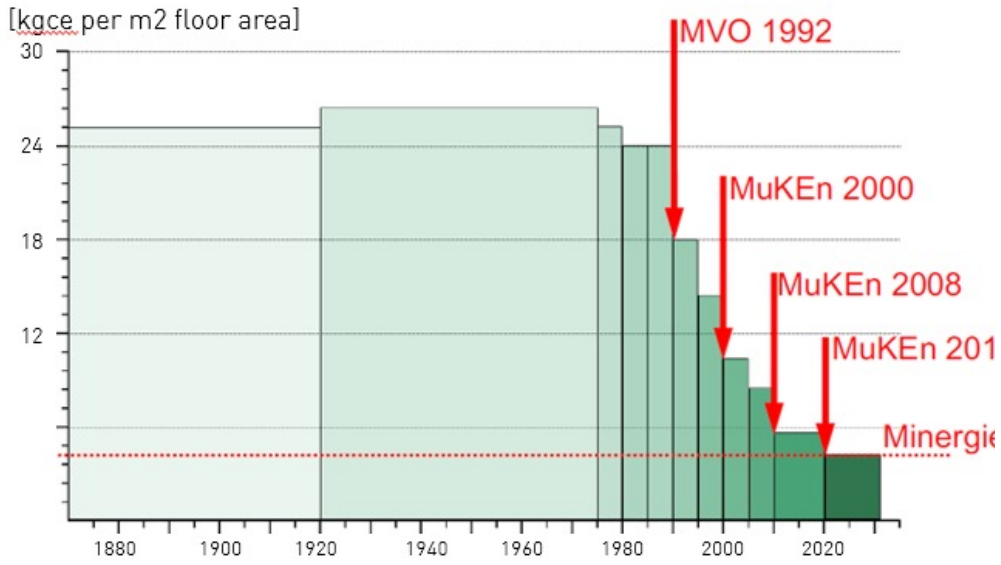

Figure 2: Evolution of heating energy demand (QHW) in new residential buildings (room heating and domestic hot water). The red arrows indicate the date of introduction of a new version of the sample regulations with stricter requirements. Source: Jules Pikali, OekoWatt, Energienetz Zug, Roundtable Zug, 27. September 2018 | bit.ly/3N2KiQM

1.5. Phase 5 (2015-2021): Net-zero emission readiness of TER

Since the mid of the past decade, the challenge of climate change issues has become much more urgent and action is significantly strengthened to address this in the policy instruments.

In this phase, no significant new policy instruments have been introduced, but the existing ones have been developed and strengthened reflecting actual progress and tar-gets.

All energy and climate related activities are now guided by a National Energy Strate-gy (2017) and a national Climate Strategy (2021). Both provide inter alia guidance for the further development of policies, instruments and activities in the building sector. The target of net-zero greenhouse gas emissions in the year 2050 has been adopted in Swit-zerland in 2019.

The strategic targets in the building sector for 2050 are “zero greenhouse gas emis-sions” for the overall building stock. All new buildings must comply with “nearly zero energy building requirements”.

At the level of TER for buildings, an increasing number of Cantons have issued bans for fossil fuel based heating systems for new buildings and retrofits. The limits set in the TER for the maximum thermal conductivity of the building envelopes (see also Figure 1) today have reached a level, which only can be lowered, if new building materials be-come available. With the typical insulation materials in Switzerland which are clay bricks or concrete with insulation layers of 15 – 30 cm thickness (mainly glass wool, rock wool, wood fibre panels or XPS hard foams), the added embodied emissions from any extra centimeter of insulation tends to overweigh the benefit of reduced direct emissions during the operation phase of the building. Therefore focus is on decarbonisation of the existing building stock through transition to renewable energies. In Switzerland, today most new buildings are being equipped with renewable energy based heating systems (see Figure 4).

Major achievements from Phase 5

- Consistency of strategies and policy instruments with the target of net-zero GHG emission in the year 2050.
- TER with a strong impact on the choice of heating system in new buildings and heating system retrofits, favoring renewable energies.

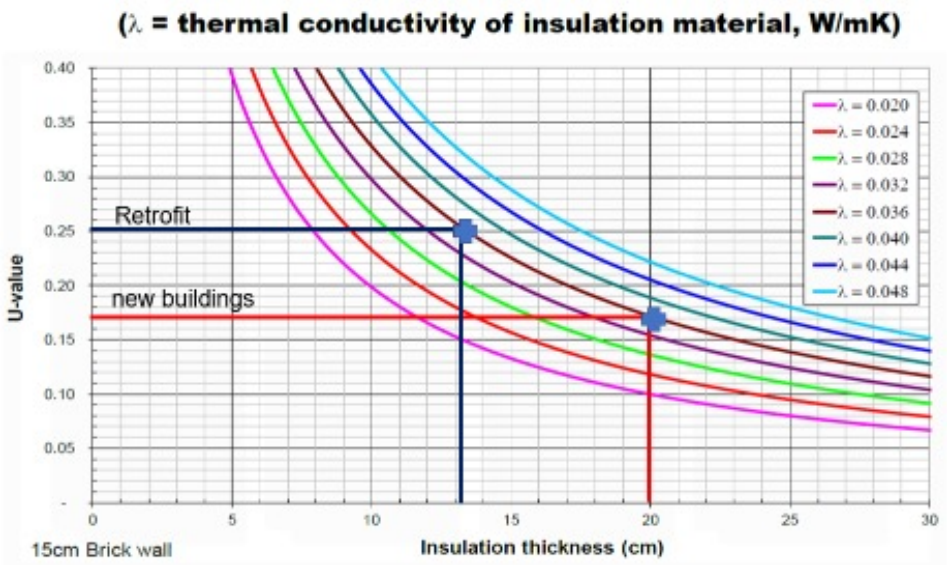

Figure 3: Thermal conductivity of a 15 cm brick wall depending on insulation thickness and insulation quality. The two crosses mark the present status of the Swiss TER as per MuKEN for minimum quality of exterior walls of new buildings and buildings under retrofit. The blue and red lines show, that in new buildings more than 20 cm if insulation thickness is required, in retrofit typically more than 15 cm. Source: Christoph Gmür, Canton Zurich, Office of Waste, Water, Energy and Air

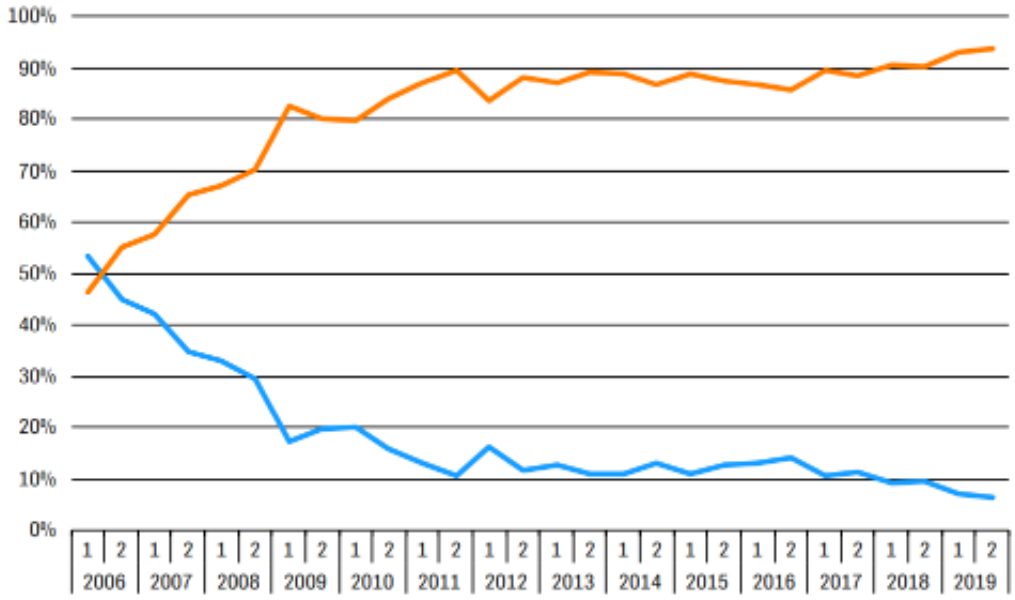

Figure 4: Market share of fossil and renewable energy based heating systems in new residential buildings in Switzerland. The blue line shows the share of fossil fuel based heating systems, the orange line the share of renewable energy based systems. The graph is for the sector of multi-family residential buildings. In single family residential buildings, the share of renewable energy based systems is even higher. Source: bit.ly/3LK3NNu

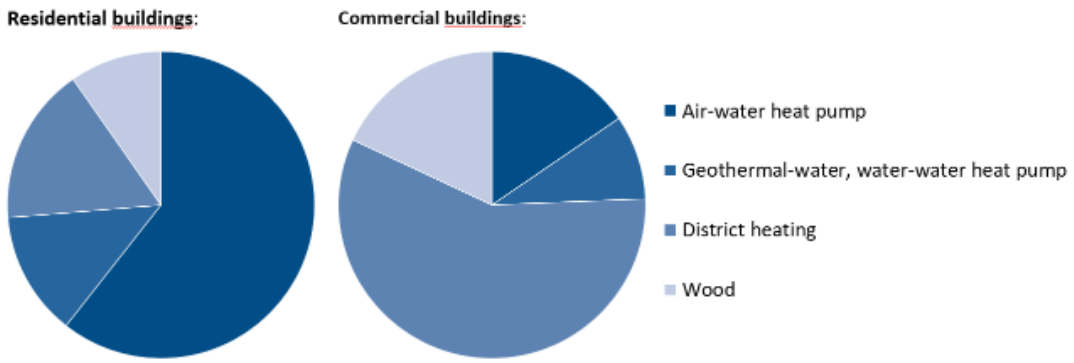

Figure 5: Technology split of renewable based heating systems in Switzerland. Source: INFRAS, based on unpublished data from the building programme of the Canton of Bern, 2017-2020

2. Swiss policy instruments and their relevance for ZEB

2.1. Energy act and act on CO2 emissions

Related to buildings, the acts and their respective ordinances integrate the overarching legal provisions for the following:

Energy act

- Production of electricity at building level, including accounting for In-house consump-tion.
- Remuneration for feed-in electricity produced at the building level.
- End user subsidies for renewable based heating systems.
- Financial support for training and professional formation of stakeholders in the build-ing sector on energy efficiency of buildings.
- Financial support for information dissemination and technical consultancy of building owners and other stakeholders towards energy efficient buildings.
- Provisions for monitoring and reporting of status and progress on energy use in the building sector.

Act on CO2 emissions

- Obligation for the Cantons to issue adequate TER for building sector to contribute adequately to the national GHG reduction targets.
- CO2-tax on fossil based heating fuels with partial earmarking of revenues for subsidis-ing building energy efficiency and decarbonisation measures.
- Financial support to the Cantons for providing subsidies to building owners for imple-menting measures to increase energy and climate performance.
- Financial support for information dissemination and technical consultancy of building owners and other stakeholders towards emission reduction of buildings.
- Financial support for training and professional formation of stakeholders in the build-ing sector on energy and climate issues.
- Provisions to the Cantons for monitoring and reporting of status and progress on greenhouse gas emissions in the building sector.

Relevance for ZEB

The energy act and the act on CO2 emissions are the legal “backbone” at the national level to drive the progress on efficient energy use and CO2 emissions in the building sector. As mentioned earlier, the technical parameters are not administered at the na-tional level, but at the level of Cantons. The acts however ensure, that a high degree of harmonisation amongst the Cantons is reached.

A learning from the long implementation history of ZEB in the building sector in Switzerland is, that when delegating the authority for technical regulations to the Can-tons, strong guidance must come from the national level. The ambition of the Cantons was not uniform to drive TER towards ZEB level. The diversity was however useful, as some of the Cantons were taking a visionary pioneering role, while the laggers had to be pushed by the national level.

With the planned revision of the act on CO2 emissions in 2021, a significant new in-strument was planned, which limits yearly emissions of all existing buildings to initially 20 kg CO2eq per sqm. of floor area (2023), with further reduction steps of 5 kg CO-2eq every five years. The installation or replacement of fossil based system would have been banned in all cases.

The revision of the acts however had been declined in a public vote.

2.2. SIA Standards

The Swiss Society of Engineers and Architects (SIA) is Switzerland' s leading professional associa-tion for construction, technology and environment specialists. The SIA 's widely-applied body of standards for the building sector provides recognized regulations for planning and construction in Switzerland. The Society continuously reviews, revises and updates the standards and supplies information about their application. The standards and the corresponding codes of practice and documentation are drawn up on the basis of parity by planners, building owners, contractors, sup-pliers and public authorities, universities and colleges. The SIA is also involved in training of the professionals in effective implementation of the standards.

In Switzerland there is a wide consensus, that the challenges of a zero-emission building stock can only be addressed through effective partnerships on a professional and interdisciplinary basis. With this, the SIA is a key element in transformation of the Swiss building stock.

While initially, the SIA was driving the ambition level of the standards, since 2009 the cantonal and national governments are setting the pace of improving the ambition level of the standards for buildings in Switzerland, based on the policy priorities.

At date, most of the methods for calculating building energy demand as stipulated in the SIA standards are harmonized with the European Norms, some of the approaches of Euopean Norms have been taken over from Swiss norms.

An overview on the most relevant Norms for is given below, incl. a non-exhaustive list of their key features.

2.2.1. SIA 180: Thermal insulation, moisture protection & indoor climate in buildings (2016)

Purpose:

Ensuring a comfortable indoor climate and prevent structural damage

Interesting features for ZEB China:

- low relevance, mainly definition of some parameters and calculation methods
- Specifies the minimum u-values for building envelope components in new constructions and bldg. renovations

2.2.2. SIA 380/1: Heating energy demand of buildings (2016)

Purpose:

Ensuring a moderate and economical use of energy for space heating in buildings. It thus makes a contribution to an ecological construction method

Interesting features for ZEB China:

- For each new or building or building renovation two options are offered for compliance checking:
- Detailed, system-based calculation of heating and cooling energy demand via heat balance
- Simplified compliance by adopting descriptive minimum requirements for the thermal performance (U-values) of individual building components
- Detailed specification of method for system-based calculation of heating and cooling energy demand through a detailed heat balance. The standard also specifies the standard parameter values to be used.
- For 12 building categories system-based limit values are specified. The building specific limit value is calculated bas on a fixed allowance and a building category specific incremental allowance a s a function of building form factor and average outdoor temperatures at building site.
- Limits for U-value [in W/m2K] of building envelope components against exterior climate in new constructions in absence of detailed calculation: Roof, wall, floor= 0.17; Windows= 1.0; Doors= 1.2
- Limits for U-value [in W/m2K] of building envelope components against exterior climate for bldg. renovations in absence of detailed calculation: Roof, wall, floor = 0.25; Windows = 1.0; Doors = 1.2

2.2.3. SIA 380/4: Electrical energy in buildings (2006)

Purpose:

The standard is aimed at the rational use of electricity in buildings and installations and, as a planning aid, helps to optimize the electricity consumption of new buildings and conversions. It defines the relevant parameters and establishes a standardized presentation of the electricity demand.

Interesting features for ZEB China:

- Floor area based good practice limits for electricity consumption from lighting, ventilation, room cooling and operating equipment in residential (e.g. cooking, freezing, washing) and commercial buildings (e.g. IT equipment, elevators).

2.2.4. SIA fact sheet 2040: SIA efficiency pathway

Interesting features for ZEB China:

- Long term pathway green buildings

- Minimum requirements for energy demand and GHG emissions of geen buildings compatible with long term climate targets

- Life cycle approach looking at construction phase, operation phase and induced mobility by the building

- Primary energy perspective with energy source specific weighting factors for primary energy and C02-emissions to be applied on design consumption of end energy.

2.2.5. SIA fact sheet 2031: Energy performance certificate for buildings

Purpose:

Specify the requirements for a national energy certificate for buildings.

Interesting features for ZEB:

- Used for new and existing buildings
- Important driver in the market of property sales for buildings with high energy and climate performance
- Also used as basic requirement for receiving subsidies for energy and climate related efficiency measures in buildings
- Combination of Swiss methodology and elements of the Energy Performance Certificate of the EU

2.3. Model Regulations of the Cantons on energy in Buildings

The “Model Regulations of the Cantons on energy in Buildings” (MuKEn) are the “overall package” of model regulations on energy in the building sector. The MuKEn was jointly developed by the Cantons based on their enforcement experience. They form the “common denominator” of the Cantons and aim to achieve a high degree of harmonisa-tion in the area of cantonal energy regulations in order to simplify construction planning and licensing procedures for building owners and professionals working in several can-tons. Harmonisation is further supported by the use of jointly developed forms and en-forcement aids.

Instead of a total harmonisation of the energy law provisions of all Cantons, the model provisions aim to harmonise provisions on individual, definable sub-areas. Each “package of regulations” for a sub-area forms a “module”. This ensures the flexibility for the Cantons to make differences where this is indicated by specific circumstances such as specific building uses in touristic areas in Switzerland.

To ensure harmonisation, there is a “basic module” which must be adopted in detail by all cantons. In this sense, it is a kind of “compulsory module”. By adopting this “basic module”, the cantons fulfil the requirements of the national energy act.

The other modules contain more extensive regulations that can be adopted by the Cantons if they wish to set additional priorities in one of the corresponding areas. How-ever, minor differences may arise due to different building procedure regulations. For example, de minimis limits may concern the obligation to provide evidence in one Can-ton and the obligation to obtain a permit in another. However, if a module is adopted, it must be adopted unchanged for reasons of harmonisation.

In the following an overview on the different modules is provided.

Basic Module

Part A General Provisions

Part B Thermal insulation of buildings

Part C Requirements for technical systems in buildings

Part D Requirements for heat demand of new buildings

Part E Self-generation of electricity in new buildings

Part F Requirements for renewable energy use in heating system replacement

Part G Electrical energy (SIA 387/4)

Part H Obligation to refurbish central electric heating systems

Part I Obligation to refurbish central electric water heaters

Part J Consumption-based heating and hot water cost billing in new buildings and in major renovations

Part K Heat use in electricity generation plants

Part L Large consumers

Part M Exemplary function of public authorities

Part N Cantonal energy performance certificate (GEAK)

Part O Subsidies

Part P GEAK Plus obligation for subsidies

Part Q Enforcement / Fees / Penalty Provisions

Part R Final and transitional provisions

Additional Modules:

Module 2: Consumption-based heating cost billing in existing buildings

Module 3: Outdoor heating and outdoor swimming pools

Module 4: Holiday homes and holiday flats

Module 5: Obligation to equip building automation in new buildings

Module 6: Obligation to refurbish decentralised electric heating systems

Module 7: Confirmation of execution

Module 8: Optimisation of operation

Module 9: GEAK order for certain buildings

Module 10: Energy planning

Module 11: Thermal insulation / utilisation

2.4. Subsidy programs at national/ cantonal/municipal/private sector level

To promote renewable energy use and energy efficient buildings, Switzerland invests in research, innovation and the consistent use of support instruments. This contributes significantly to longer-term energy security. However, not only the federal government, Cantons and municipalities, but also energy suppliers and private institutions such as companies and foundations support the generation of renewable energies and the im-provement of energy efficiency through subsidies. Some of the subsidies

This inter alia includes:

- a national «Building programme» with direct financial support for building owners
- supplementary direct financial support from Cantons, cities, and municipalities
- Financing and tax deductions for energy and climate related renovation activities
- Promotion of energy generation at building sites
- Lighthouse building programme of the federal government.

Under the national Building Programme , typically around 20 – 30 percent of the total investment cost is covered by grants to be paid upon commissioning of the works.

2.5. Program «EnergieSchweiz»

The national program «EnergieSchweiz» was launched in the year 1991 as Switzerland' s first energy policy instrument with the aim of promoting the rational use of energy and renewable energies through voluntary measures together with partners from business and the public sector, education and science, the environment and consumption.

Today, the programme, together with other energy and climate policy instruments, contributes to the implementation of the Swiss Energy Strategy 2050.

Under the umbrella of EnergieSchweiz a set of diverse voluntary measures are im-plemented to support the targets of the Swiss energy and climate strategy. In the build-ing sector, these include information and advice for the general public and special tar-get groups in form of a website (www.energieschweiz.ch) and general as well as in depth information material and guidelines. The program also supports training and further education for specialists in energy-related sectors, and quality assurance for the market penetration of new technologies.

With such measures, EnergieSchweiz aims to help new technologies and concepts that can contribute to improving energy efficiency in the fuel, heating and electricity sectors, or to the spread of renewable energies, to achieve a market breakthrough.

2.6. Green Building Labels in Switzerland

In Switzerland, the most widely used building labels have been developed by the na-tional and cantonal authorities, together with the building sector stake-holders. This fam-ily of building labels is promoted by Swiss Federal Office of Energy according to its vi-sion for the Swiss building stock 2050.

Four different labels are implemented with different priorities and application focus:

Building energy certificate of the cantons (GEAK):

- Used for existing and new buildings
- Provides information on the performance of a building regarding primary energy use and greenhouse gas emissions
- Also used a an instrument for accessing finan-cial support, e.g. under the Building Pro-gram

MINERGIE:

- Includes a family of sublabels with different ambition levels “Basic”, “Plus” (ZEB build-ings) and “Eco” (additional requirements on health and building ecology issues).
- Is a planning and certification scheme for new buildings and building renovation
- Provides certification for entire buildings as well as building components.
- Has a strong focus on quality assurance to pro-vide building users and owners with liv-ing com-fort, efficiency and value retention.
- High market penetration with approx. 15% of new buildings and 3% of building reno-vations in Switzerland being MINERGIE labelled.

SNBS (Swiss Standard for Sustainable Build-ings):

- Provides a wide reaching set of sustainability criteria for green buildings
- focus on building, its use, and its location (ac-cess, location, etc.)
- combines approaches and concepts of sustain-able building in Switzerland (Minergie, Miner-gie-ECO, 2000-Watt-Areale) and brings them to-gether towards holistic planning.
- Builds on established SIA standards.

2000-Watt-Areal (2000 Watt site):

- Provides planning guidelines for net zero emis-sion ready sites
- Instead of looking at the individual buildings, the concept of the 2000-watt sites fo-cuses on the site and the people as a unit
- includes criteria and requirements for six focal areas:
- transparent management system
- participatory communication
- diverse site uses
- sustainable supply and disposal (energy, water, waste)
- economical, resource-saving and climate-friend-ly buildings
- mobility

Besides these national labels, also some interna-tional green building labels such as BREEAM, LEED, DGNB are being used. This is mostly in project for in-ternational clients which have their corporate stan-dards. In large scale projects, there is often parallel cer-tification with international and Swiss labels.

3. Swiss Stakeholder landscape for ZEB

The list below provides an overview of the stakeholder landscape in Switzerland. Only the most relevant stakeholder for driving the sector towards zero emission buildings are listed.

It is important to mention, that the progress in Switzerland towards transition of the building sector towards ZEB historically and today is driven by the fruitful interaction of the different stakeholder levels. The initiative for innovation and improvement of TER towards ZEB often originates from Municipalities. They are in close contact with the citi-zens and professionals in their territory, have higher agility and "feel the pulse" much more directly than the higher administration levels.

3.1. Government Administration / Policy level

Swiss Federal Office of Energy SFOE

- national regulator for energy use
- support programs and training guidelines
- provide guidance to Cantons for their TER
- coordinate development of national labels for green buildings
- communication and awareness activities
- support for light house projects
- finance national resßearch programs

Federal Office for the Environment (FOEN)

- national regulator for climate change mitigation and adaptation activities
- financing of decarbonisation and efficiency improvement of building sector through a nation tax on CO2 emissions

Cantons

- regulatory body for technical regulation in the building sector
- subsidy programs for decarbonisation and efficiency improvement of buildings (partly funded by national CO2-tax)
- Training and information on TER implementation for trade and building owners
- Leading by example through own projects

Municipalities

- Leading by example and pushing the Cantonal level to be more proactive
- Enforcement of technical regulation in the building sector
- "product independent" basic consultancy and information for building devel-opers and owners (especially in cities)
- for some: "topping up" subsidies

3.2. Associations, Industry, Trade

MINERGIE

- Building label with high market penetration
- Driver of innovation by providing forerunners in the market visibility and quality control

2000-Watt-Society

- Development of long-term visions and concepts for the building sector
- Provide planning and monitoring guidelines
- Facilitate societal and technical transition towards net-zero emissions

SIA and Trade Associations

- Development of technical standards and guidelines
- Provide trade specific information and training on ZEB related issues
- Ensure acceptance of TER with the trade
- Promote sustainable practices in the trade

3.3. Science, Universities, Research

National research programs and networks

- Basic research in the field of energy technology, socio-economic aspects, social impacts, behavioural science, transition pathways, etc.

Universities and Vocational training institutes

- Education and professional training of architects and engineers
- providing the market with adequate number of skilled professionals
- Ensuring the specific skills for ZEB in the trade
- Ensuring field level implementation of TER

3.4. Building owners, Investors

- leading by example with lighthouse projects
- anchor leading edge approaches through corporate policies for own building portfolio.

4. Outlook on next generation of TER for a ZEB compliant building stock in Switzerland

At date, there is no decision on the concept for the long-term evolution of the technical regulation for buildings in Switzerland. The issue is still under research. There is consen-sus, that any TER fit for a net-zero emission world has apply a holistic approach and must cover the full building life cycle and not only the operating phase.

The National Research Programme "Managing Energy Consumption" (NRP 71, 2020) studied the social, economic and regulatory aspects of the change in energy strategy, thereby examining how private and public actors could be prompted to use energy efficiently. One of the sub-studies was developing a concept for next generation of tech-nical energy regulations in buildings (Project EnTeR). The purpose of the project was to assess the role of technical regulations in the transformation of the building stock and its integration into the future energy system.

The following conclusions were drawn from this research:

- International analysis reveals that TERs, despite their previous success in increasing the energy efficiency of the building stock, seem to be reaching their economic lim-its. Particularly when it concerns the decarbonisation of the building sector. The literature lists therefore the following five challenges:
  - (i) Further increase in energy efficiency
  - (ii) consider grey energy and emissions
  - (iii) increase the share of renewable energies
  - (iv) close the "performance gap"
  - (v) accelerate the renovation rate
- The MuKEn plays a key role in the transformation of the Swiss building stock into a sector that is nearly CO2-free by 2050. To achieve the CO2 target, additional or more restrictive regulations, especially those applied to the replacement of oil and gas heating systems, must be included in a new TER. The current requirements of MuKEn 2014 on the building envelope for existing and new buildings have been judged to be adequate.
- To achieve the long-term CO2 target in the building sector, implementation has to reach a very high level of effectiveness. For this, the TER has to be very easy to under-stand and simple to apply, and high flexibility regarding the acceptable technical solutions must be given.
- In cities, a district solution with thermal networks would be appropriate for 50-80% and in more densely populated or industrialized agglomerations for up to 50% of the neighbourhoods. The investment costs of such district solutions are between 20 and 25% lower than standalone building solutions.
- To provide the best possible regulatory environment for encouraging the building stock to develop in the intended direction, a TER concept based on life-cycle thinking is being proposed. The life-cycle perspective allows to formulate effective measures in the three main phases (construction, operation and decommissioning) of a property. The separation allows a TER to be specifically aligned to the phase-specific relevant actors.

The approaches proposed for the three phases of the life cycle are summarised in the following.

4.1. Planning & Construction Phase:

Regulate the maximum deliverable thermal power output of the energy system (in W per square meter floor area) instead of regulating directly the energy demand as with today' s TER. The maximum deliverable thermal power output of a heating or cooling system is used as a proxy for the energy efficiency of the building. The thermal power rating of a well-designed system is set to provide adequate comfort level at the maxi-mum / minimum outdoor temperatures in a year for the respective building. If the TER provides a power limit rather than an energy limit, the designer has to make sure that the building efficiency is adequate to cope with the restricted power level. The ad-vantage of this is, that the design process has to ensure compliance with a single key parameter. In the details of the design, there is a high flexibility and room for optimiza-tion. The single parameter also makes compliance checking for the authorities extreme-ly simple.

4.2. Operating phase:

While the energy demand is determined by the design (see above), the only parameter to be regulated for the operating phase is the energy mix. This can be done by setting limits for the CO2-emissions per floor area. The actor can comply with the CO2 limits by reducing his consumption, choosing CO2 or CO2-free energy products and/or increasing his own energy production at the building site (e.g. photovoltaics, combined heat and power generation, etc.).

4.3. Decommissioning phase:

The share of non-operating emissions from building materials can account for as much as 40% of total emissions over the lifetime of a building and more. To avoid loss of re-sources from decommissioning of buildings and make maximum use of the embodied emissions contained in the material stock of a building to be decommissioned, a circular economy of building materials with an upfront recycling fee for building materials based on “embodied emissions” is proposed. By imposing a embodied emissions related fee on building materials, the owner will be motivated to return his materials and the industry will develop recycling processes, which are fully decarbonized in the future. This is a market based economic instrument which will encourage innovation and also influences the design processes.

The next phase of this still ongoing research is used to formulating effective and efficient regulation, its specific content, thresholds, and enforcement.

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5. Nine learnings from Swiss Experience for transition to ZEB

In the following, nine hypotheses for a successful transition to a zero-emission building stock are presented. They are based on the learning from long-standing and successful experience of Switzerland on policy development and technical regulation towards effi-cient and decarbonised buildings. It can provide important learning for the transition towards a zero-emission building stock in China in the long term.

1. Only a target-defined policy framework with a clear and long-term reduction path with gradual ratcheting up of TERs gives the necessary predictability for investors, plan-ners, and technology providers

The more ambitious the TER is, the more important it is for all stakeholders in the build-ing sector to have clear long-term orientation and predictability. Economic science shows, that acceptance for far reaching transition is higher, if all concerned entities have a clear planning ground for their activities and technology pathways and with this can decide individually, if they want to already anticipate the next step of stringency of TER. This can provide them immediate and long-term economic incentives in the market, provides them a possibility for leading by example and ensures sustainability of the in-vestment.

2. Successful policy implementation for ZEB needs a diverse ecosystem of measures with three main pillars

A successful policy environment builds on three main pillars:

- Norms, legislation and enforcement
- Education and capacity building
- Incentives, leadership and motivation

However, the target of a zero-emission building stock can only be achieved by an active interplay of a diverse set of instruments. E.g., a strong and far-reaching legislation will risk failing, if not supported by strong communication and capacity building efforts. It will also not be successful, if resources and competences at the enforcement level are inadequate. The only benchmark for the success is the achieved level of change in phys-ical “field reality”. Successful transition needs a balanced set of policy instruments with “push” and “pull” elements, leadership, consistency of action and strong peer-groups at all stakeholder levels. This will provide the necessary momentum for a fast and wide-reaching transition of the building sector.

3. Effective TER must be simple and easy to apply and must be supported by practical guidelines

Most countries (including Switzerland) have very complex TER for buildings. Due to the complexity of issues involved, only a system-wide optimization leads to economically optimal high-performance buildings. Non-specialists typically are not able to understand the consequences of the detailed regulations on a system-wide basis for making their choices. In Switzerland it therefore has proved to be very successful to “translate” the complex system-wide requirements in simple to understand prescriptive (sample) solu-tions. By applying adequate safety margins, it is ensured that the performance of buildings designed on basis of prescriptive requirements is equivalent to system-wide opti-mized buildings. The “sample solutions” in Swiss TER and the related practical guidelines are widely used and well accepted. They are a key element in Switzerland for effective policy implementation in the building sector.

4. Monitoring and field evaluation of real-life performance is a key element to success-ful implementation

In Switzerland, periodic field evaluation of the “real-life” success of policy implementa-tion in the building sector is a well-established tool since more than a decade. Only through these sample-based field studies it was observed that there is in many cases a relevant gap between design performance and real-life performance of a building which is depending on individual user behavior. In other words: The regulation does not fully achieve its goal. The more stringent the building standards are, the higher is the ob-served variance against the design energy demand. Typically, the variance is much larger in direction of excess energy demand than towards inferior energy demand. This per-formance gap is a major challenge for the effectiveness of any TER for zero emission buildings and must be addressed adequately in the TER, e.g. by mandatory performance monitoring and optimization of buildings in their operation phase.

5. Flexibility in the enforcement organization helps to achieve effective implementa-tion

In Switzerland, the principle of private performance controls in execution of building projects is implemented, which also could be interesting for China. The private control-lers are accredited with the building related enforcement authorities for approving de-signs and checking adherence to TER in the execution process. With this, they assist and strengthen the enforcement authority. This only allowed to create the necessary en-forcement capacity and power in all Cantons, including the ones with weaker financial and human resource capacities.

6. Effective norms and regulations for ZEB need to refer to primary energy demand and life-cycle emissions

For a net-zero emission world it is prerequisite, that TER does not only regulate on-site emissions during operation but must cover the full lifecycle emissions of a building. Hence there is need to address the primary energy demand during operation, the em-bodied energy and emissions of the construction and minimize resource loss and emis-sions in decommissioning of buildings.

7. Robust technology that is applied and optimized on a district scale is needed to in-crease market reach of ZEB effectively

For reaching at a net-zero emission building stock, the todays approach of TER with op-timization at the level of individual buildings will be inadequate. The potential for opti-mum solutions often requires solutions at a district scale, such as district heating, dis-trict level energy storage solutions or resource optimized balancing of energy produc-tion at building sites. The TER must be open to district level optimization in future. Spe-cial emphasis also must be given to the performance risk technically too complex and unreliable systems. With many high-tech solutions the user does not even has adequate information for assessing if his system has a performance problem. Hence in many cases there is constant underperformance. This can be addressed by periodic performance checks and optimization. On the opposite and if designed properly, passive technologies are robust, reliable and often cost-effective solutions. An example is external movable shading systems versus fixed structural shading elements. The TER should include ade-quate provisions to maintain robust performance of the buildings.

8. The fast decarbonization of the energy sources of heating systems is becoming a pri-ority for achieving carbon emission goals on time

While from an overall perspective a resource optimized strategy for decarbonization of the building sector firstly addresses the efficiency potentials of the building stock and minimizes losses and only in the second priority replaces the fossil fuel based heating system (which then has a lower rating) with a renewable energy based system, this may be inappropriate when transition speed becomes crucial. The replacement of the heat-ing system is a simple and cost-effective way of decarbonizing the operation phase of a building, be it a new building or a replacement of the existing heating system due to end of life in an existing building. On the other side, improvement of the building enve-lope may also be economically viable, but it is investment-intensive, technically more complex and often goes along with temporary negative impacts for the building users. The technical life span of a building envelope is also significantly longer than of a heating system. Therefore economically optimized replacement rate is higher for the latter. Consequently, the political priority should be put on immediate decarbonization of the heating systems.

9. A net-zero emission building stock can only be achieved with a high renovation rate and an optimized share of replacement buildings

While today in China – due to the high dynamic in the building sector –the focus is mainly on TER for new buildings, the example in Switzerland and other western coun-tries urge, that for compliance with net-zero emission targets, the decarbonization of the already existing building stock must be addressed at an early stage. Looking at the urgency of climate change action and the technical lifetime of buildings of several dec-ades, any major intervention in existing buildings will have long term impact. If today the level of ambition e.g. in replacement of a heating system is set too low, it tomorrow will be a barrier for target achievement. All investments towards maintenance of the existing building stock may in the long-run bear a risk to be stranded, if they are not compliant with ZEB requirements already today. Decision makers from politics, admin-istration and private sector need to be convinced about the urgency of immediate ac-tion also for the existing building stock. This requires ramping up the rate of ZEB compli-ance building renovations as well as planning for replacement of low-performance buildings which cannot be transformed to zero emission buildings at reasonable cost.

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