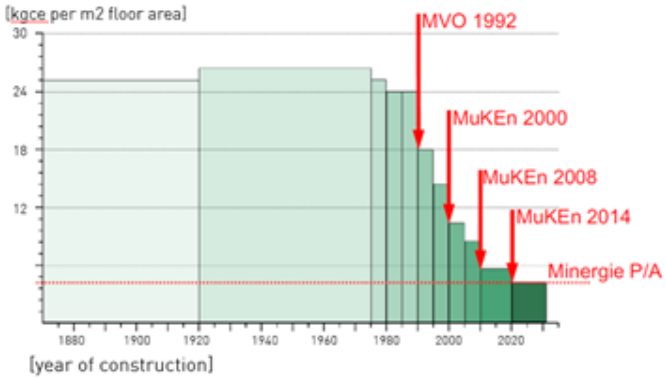
ZERO EMISSION BUILDINGS IN CHINA

A Sino-Swiss Collaboration for Climate Responsive Building and District Development

中国零碳建筑

中瑞合作促进发展有利气候保护的建筑和社区发展



Swiss experience on technical regulation for energy and emissions in the building sector. Learnings for China?

瑞士在建筑领域节能减排技术法规方面的经验
以及对中国下一代建筑排放标准的启示

A project financed by

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
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Implemented by

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South-east view of NEST with its new unit UMAR;
带有新部件UMAR的NEST的东南面
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Version 1.0

Swiss experience on technical regulation for energy and emissions in the building sector. Learnings for China?

Zurich, Switzerland

A project financed by the Swiss Agency for Development and Cooperation (SDC) and the Chinese Ministry of Housing and Urban-Rural Development (MoHURD) and implemented by intep and Skat.

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版本 1.0

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本项目由瑞士发展与合作署（简称SDC，属于瑞士联邦外交部下属机构）与中华人民共和国住房和城乡建设部资助，由intep和 Skat联合团队共同实施

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封面照片: 新建住宅楼的供暖能耗的变化 (见第8页)
中文翻译: intep中国团队

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 instruments 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 building 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 examples 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. Finally, 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 sector can be successfully achieved.

概览

瑞士在推动建筑行业提高能源效率和降低温室气体排放方面有着长期的政策设计和技术法规(TER)经验。
这方面的第一批行动启始于20世纪70年代，从那时起，瑞士的政策和技术法规便不断得到发展和完善。

瑞士的经验可以为中国制定自己的零碳建筑(ZEB)提供借鉴，以实现长期的存量净零排放经济。

本报告深入剖析了这些政策工具的历史发展进程和主要成就，并介绍当前正使用的最相关的政策工具，报告归纳了对瑞士建筑技术法规向净零排放目标演进的关键特征的研究现状。报告还总结了瑞士向零排放建筑过渡的九项重要经验。

其中最重要的经验是，建筑领域的成功转型需要调动所有利益相关方来参与。立法最重要的是制定市场的最低标准，而投资者的创新和"态度转变"更多的是由市场领导者和范例来引导的，因为示范项目往往会远远超出了法定的最低建筑性能要求。在此，除严格的技术规范外，还需要一个有效的政策执行系统为投资者、规划者和从业者提供指导，并对专业人士进行高质量的教育和培训。最后，还必须对所有的利益相关方进行持续的信息输送和提升他们的认识。只有通过不同利益相关方卓有成效的共同努力和多样化的政策手段，才能成功地实现建筑领域迅速而长远的转型。

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Genesis of Swiss Technical Regulation 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. uncomfortable surface temperatures, air draft). In the early 1960'ies, when in Switzerland first activities started towards developing a Technical Regulation (TER) for the thermal performance of buildings, winters as well as summers have been significantly colder than today. Therefore, the earliest versions of the TER focused 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 extended 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 addressed 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.

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 characterized 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 technical 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.

瑞士建筑能源和排放技术法规的起源

瑞士处于冬季寒冷、夏季适度炎热的气候区。寒冷的温度不仅影响建筑的能源消耗，还会导致严重的卫生问题（如发霉）和住房舒适度（如房间阴冷，空气流通不畅）。
20世纪60年代初，当瑞士开始制定建筑热工性能的技术法规时，冬天和夏天都比现在冷得多。因此，最早的TER着重于解决卫生和舒适度问题。
在20世纪70年代，零排放建筑（ZEB）之路已经开始。大约五十年前，TER的重点首次扩展到能源效率，并从1990年代开始关注温室气体排放。由于气候变化的影响，瑞士的高温期持续增加，近几十年来，TER也加强着手夏季高温问题。
瑞士建筑能源和气候性能的TER的演变可分为五个阶段。接下来将分别介绍明各自的特点。

第一阶段（1960-1973年）：确保舒适的室内气候和防止结构损坏

这一时期的特点是，建筑领域需要在新建筑的技术设计中起带头作用。当时的建筑设计的特点是简单的混凝土或砖墙，具有高导热性，缺乏保温材料，门窗的热工性能差（简单的单层或双层窗户，没有充气）。因此出于建筑物理学的原因，在许多这样的建筑中出现了卫生或舒适度不佳的问题。
建筑领域的利益相关者、国家能源部和瑞士建筑行业的技术标准化机构SIA（瑞士工程师和建筑师协会）首先提出倡议，就如何防止冷凝水问题对建筑物的损害和对用户造成的健康风险以及确保用户的住房舒适度达成了共识。

第一阶段的主要成就:

- 让市场参与者认识到建筑围护结构热工性能的重要性， 以及如何处理建筑物理学造成的问题。
- 建立市场参与者对建筑热性能的 "良好实践标准 " 的共识，以防止建筑物理造成的健康和舒适度问题。

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[1] 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.

[1] The subnational level of Switzerland is politically divided into 26 Cantons (similar to "States" in other countries) with their own political and legal institutions.

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 minimum requirements for the thermal performance (U-values) of individual building components (Walls, Roof, Window, Floor against outdoor climate, Wall/Roof against unheated rooms).

The subnational level of Switzerland is politically divided into 26 Cantons (similar to "States" in other countries) with their own political and legal institutions.
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 on the right.
By the end of phase 2, Switzerland had very heterogeneous TER in the different Cantons. Most Cantons had mandatory TER on energy performance, but the technical details differed significantly.

Major achievements from Phase 2:

- National SIA standards for thermal performance and efficiency of buildings, developed in a participatory process including Authorities, architects, planners and construction 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 checking. 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:
- Authorities with adequate staff resources: enforcement directly by the Building Authority.
- Authorities with weak staff resources: outsourcing enforcement to Canton accredited 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 sanctioning regime.
- Random checks of Building Authorities on work quality of private controllers.
- Periodic evaluation of real-world performance of buildings versus nominal performance as per the design.
- Fruitful interplay between pioneering and progressive Cantons and national SIA norms helping in driving up requirements on thermal building performance.

第二阶段（1973-1989年）：试点和锚定建筑能效的TER

1973年，世界面临第一次石油危机，导致能源成本急剧上升，瑞士在维持国家能源安全方面出现问题。基于这一经验，一个由各州组成的 "先锋" 小组开始制定具有法律约束力的TER，重点是建筑的能源性能。但是基于经济和安全方面的问题，他们在制定正式的建筑能源性能TER时也面临了不断增加的压力。
1975年，SIA在全国范围内发布了第一个关于新建筑热工性能的技术标准（SIA 180/1：建筑的保温、防潮和室内气候）。该标准的使用是自愿的，但是，有第一批城市和州宣布该标准是强制性的。
1988年，颁布了一个关于建筑物最大供热能源需求的附加标准（SIA 380/1：建筑物的供热能源需求）。该标准的目的是确保在给建筑供暖时，更适度和经济地使用能源。

[1]瑞士被划分为26个州（类似于其他国家的 "省"），各州拥有自己的政策和法律机构.

该标准引入了两种不同的方法，以确保符合标准的要求。到今天为止，这两种方法被证明是非常成功的。
方法1：以系统为基础计算终端能源需求的详细计算方法
方法2：通过对单个建筑部件（抵御室外气候影响的墙、屋顶、窗户、地板; 抵御未供暖房的墙/屋顶）的热工性能（U值）采用说明浅显易懂的最低要求来简化合规证明。

瑞士被划分为26个州（类似于其他国家的 "省"），各州拥有自己的政策和法律机构。
在第二阶段，开发了大规模实施和执行节能建筑的工具和手段，这些工具和手段直到今天为止仍是执行系统中的优先要素。这些主要成就都列在下方文本框中。
在第二阶段结束时，瑞士各州的TER应用情况发生了很大区别。大多数州对能源性能有强制性的TER，但技术细节则有很大不同。

第二阶段的主要成就：

- SIA国家建筑物热工性能和能效标准，由有关部门、建筑师、规划师和施工行业共同参与制定。
- 用于设计阶段的计算工具（由私人机构开发，由有关部门认可）可 证明是否符合TER的要求。
- 建筑管理部门批准施工前，强制要求提交建筑热工设计的技术文件。
- 为规划者提供执行辅助工具，提供对TER要求详细且易读的解释，包括提供不同类型建筑的实际案例。
- 对所有相关的市场参与者和行政人员进行早期和大量的培训，以了解TER的要求及其如何操作。
- 建立州/城市一级的执法系统，进行合规性检查。在建筑开发商的自我声明基础上，由当局随机检查。
- 引入两种不同的合规性检查方法，提高建筑主管部门自身执法时的灵活性。
- 设有足够管理人员的相关部门：由建筑管理部门直接执法。
- 没有足够管理人员的相关部门：在设计和施工阶段，将执法工作外包给州级认可的私人机构，以检查是否符合TER的要求。
- 由建筑管理部门或认可的私人机构对执行的建筑质量与以批准的设计质量进行随机现场检查，包括法律上的惩罚制度。
- 建筑管理部门对私人机构的工作质量进行随机抽查。
- 定期评估建筑物的实际性能与理论性能是否存在差距。
- 领先的、进步的各州和国家SIA规范之间相互促进，有助于提高对建筑热工性能的要求。

“In 1995 a first version of the standard SIA 380/4 ‘Electrical energy in building construction’ was issued.“

Exterior view of the “Solar Fitness & Wellness” unit
“太阳能健身中心”外观
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Phase 3 (1990-1993): Harmonizing of 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 energy use in buildings (MVO 92, in later versions called MuKEn). This served as an orientation framework for designing building related TERs at the Canton level. The sample regulation combined all successful approaches from the previous phases, including e.g. the calculation methods and minimum envelope qualities of the SIA 380/1 standard, calculation tools and application or documentation forms.
In 1995 a first version of the standard SIA 380/4 "Electrical energy in building construction" was issued. It aims at the rational use of electricity in buildings and installations and contributes as a planning aid to optimising the electricity consumption of new buildings and conversions. It defines the relevant parameters and establishes a standardised 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 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. The program addresses 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 simultaneous 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 programs with a focus on supporting TER implementation through voluntary actions, public private partnerships, information dissemination, strengthening education and training of both providers and consumers.

“1995年，发布了第一版 SIA 380/4 ‘建筑的电能’标准。“

The east side of the unit "SolAce" with the green-blue glazed solar thermal collectors, on the left side on the second floor;
“SolAce”东面，带蓝绿色发光的太阳能集热器，二层左面
© Roman Keller | Flickr: bit.ly/3w3OxV4

第三阶段（1990-1993年）：协调TER的工作

20世纪80年代末，瑞士的一个重要情况是各州的TER并不相同。国家级的建筑部门认为这阻碍了TER的有效应用。
建筑师、规划师、技术人员和建筑公司不得不根据建筑工地的地理位置来对待不同的TER。
1990年，宪法修改后，将建筑领域的能源税责任下放给各州。为了避免版本过多带来的不便，1992年，国家政府与各州共同颁布了建筑能源使用示范条例（MVO 92，后来的版本称为MuKEn）。这成为在州一级与设计建筑有关的TER的一个方向框架。该示范条例结合了前几个阶段的所有成功方法，包括SIA 380/1标准的计算方法和最低围护结构质量，计算工具和申请或文件表格。
1995年，SIA 380/4标准的第一版 “建筑施工中的电能 “ 被发布。它的目的是促进在建筑和设备中合理使用电力，并作为一种规划和辅助手段来优化新建筑和改造的电力消耗。它定义了相关参数并建立了一个标准化的电力需求表述。
1990年，瑞士启动了两个重要的国家计划。

■ 名为 “能源2000 ” 的计划从1990年运行至2000年，至今仍以 “瑞士能源 ” 的名义活跃着，它是瑞士的第一个能源政策工具，旨在通过与来自商业和公共部门、教育和科学、环境和消费的合作伙伴一起采取自愿措施，促进能源和可再生能源的合理使用。该计划将建筑领域作为需优先考虑的一个领域。

■ 1990-1995年，三个行动方案：IP Bau（建筑物的维修和翻新）/RAVEL（电力的有效利用）和PACER（可再生能源），一直在进行。其目的是促进更注重质量的经济增长，实现原材料、能源和环境友好的生产，即通过加强对在这些领域的从业者和消费者的教育和培训，以及通过信息，同时增加对 “能力资本” （知识、技能）的使用，并通过日常实践来实现知识传授。这也有助于创造新的市场，例如高能效的窗户或光伏系统。

第三阶段的主要成就：

- 示范条例(MuKEn)为各州设计有针对性的TER提供了一个 “工具箱” ，并确保最低水准地统一各州的法规。
- 所有的州都发布了强制性建筑节能TER。
- 大型和长期的国家支持计划，重点是通过自愿行动、公私合作、信息传播、加强对从业者和消费者的教育和培训来支持TER的实施。

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 science, a still continuing shift of focus started towards benchmarking building performance 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 period but focused on progressively strengthening the technical requirements. The quantitative requirements were step-wise 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 Cantons 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 further 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-Scociety”. The core of the concept – developed 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 concept, 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.

	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
图1：墙体的传热系数（U值）的演变
© Christoph Gmür, Canton Zurich, Office of Waste, Water, Energy and Air, Swiss-US Energy Innovation Days 2015

第四阶段（1994-2014年）。提升TER，并将重点转向可再生能源

在第四阶段，由于环境意识的提高和气候变化学科的发展，人们开始持续关注建筑性能的基准，不仅仅是运行阶段的能源消耗，而是采用整体的基准方法，包括气候影响（转向可再生能源）、建筑生命周期的所有阶段（设计和施工、运行、废弃）的影响和其他环境方面（如建筑材料的污染物）。
在TER层面，瑞士各州在这一时期没有重新调整主要内容，而是侧重于逐步加强技术要求。量化要求逐步提高（图1），使新建筑的能耗大大降低（图2）。
在2014年的版本中，对MuKEn进行了修订：要求新建筑必须遵守化石燃料供暖的最大份额（即10%，或者在一些州，根据TER，最大能耗量里必须至少20%由可再生能源来达到，或者必须通过进一步提高建筑围护结构的能效来减少能耗）。
包含化石燃料最大份额的样本法规的一个非常有效的做法是制定了一套详细的解决方案。

这些详细解决方案提供了简单易懂的技术措施或其组合方式（例如，使用电热泵或提高围护结构的能效并与可再生的区域供热相结合），以符合TER的要求。市场已经积极利用这一方案，尽管该方案导致了平均建筑材料的质量略高，因为除了选择样本方案外，不可能进行单独优化（基于系统的计算比较，样本方案还包括一些 "安全系数"）。

在第四阶段，制定了一些自愿性和法律文本，这些文本有力地影响和促进了TER的进一步发展。
■ “2000瓦特社会 ” 的概念框架。这个概念的核心由瑞士联邦理工学院（ETH）开发。它是将年平均人均能源消耗限制在相当于2000瓦特总功率和500瓦特不可再生的永久一次能源需求的水平（相当于17 ‘520和4’ 380千瓦时/年），以实现全球能源公平的可持续状态。有了这个概念，大幅减少能源消耗和向可再生能源过渡的想法第一次在政治和社会上被得到讨论。因此，瑞士各个城市采纳了这一概念，并作为其能源和气候行动的战略方向。

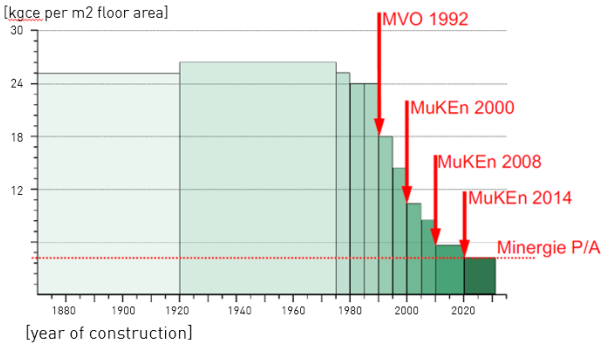


Figure 2: Evolution of heating energy demand (QHW) in new residential buildings (room heating and domestic hot water)
The red arrows indicate the date of introduction of a new version of the sample regulations with stricter requirements.
图2：新建住宅楼的供暖能耗（QHW）的变化（房间供暖和生活热水）。
红色箭头表示新版本的样本法规出台的时间，要求更加严格。
© Jules Pikali, OekoWatt, Energienetz Zug, Roundtable Zug, 27. September 2018 | bit.ly/3N2KiQM

■ 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 mobility 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 greenhouse gas emissions (for new and existing buildings).

■ Swiss energy act and energy ordinance (since 1999): The act and its ordinance provide the regulatory framework for achieving an adequate, diversified, secure, economical, 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 energies. In addition, the act specifies the main energy policy instruments for each sector, including the building sector. More details are provided in section 2.1 of this booklet.

■ Swiss act on CO_2-emissions and CO_2-ordinance (since 2000): The act and its ordinance provide the regulatory framework and relevant instruments for reducing greenhouse gas emissions, in particular CO_2 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 reduction 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

2000-Watt-District Erlenmatt West, Basel
2000瓦社区 Erlenmatt 西面, 巴塞尔
© Losinger Marazzi AG: bit.ly/38KfBkk

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).

■ 随着2006年发布的 “SIA能源效率途径”，瑞士规范制定机构SIA为从业人员发布了一个在建筑领域实现2000瓦特社会目标。所采用的方法是整体能源观。除了建筑运行能耗，建筑的灰色能源和与地点有关的出行交通能耗也被考虑在内。它规定了温室气体排放和不可再生一次能源的目标值。

■ MINERGIE认证标签体系：这是一个简单的低能耗建筑标签，到今天为止，该标签进一步发展成一套具有不同目标水平的标准，包括近零和零排放的建筑标准（MINERGIE、MINERGIE-P（-被动）、MINERGIE-A（-主动）、MINERGIE Eco（其他生态方面）。

■ GEAK认证体系：这是自愿性建筑认证证书，包括围护结构能效和总能源性能，温室气体排放信息（对新建筑和既有建筑而言）。

Zero Energy Building, Männedorf
零能耗建筑，Männerdorf
© Stiftung Umweltarena Schweiz: bit.ly/3F9GbQ9

■ 瑞士能源法和能源条例（自1999年）：该法案及其条例为实现充足、多样化、安全、经济和环保的能源供应提供了监管框架。主要成就之一是为瑞士的人均能源消耗引入了量化的长期削减目标，并对总能源消耗和电力消耗分别制定了目标。 它还包括可再生能源的生产目标。此外，该法案规定了包括建筑领域的每个行业领域的主要能源政策工具。更多细节见本手册第2.1节。

■ 瑞士关于二氧化碳排放法和二氧化碳条例（自2000年）： 该法案及其条例规定了减少温室气体排放的监管框架和相关工具，特别是减少化石燃料（可燃物和燃料）能源使用所产生的二氧化碳排放，目的是将全球气温上升限制在2摄氏度以内。 它规定了瑞士的量化减排目标。

■ 在SIA 380/1法规（建筑的隔热、防结露和室内气候）的计算方法中整合与一次能源相关的权重因素。 通过将设计终端能源使用量与能源相关的加权系数相乘，找到了一个简单实用的方法，并将这个建筑能源和气候性能的重点规范提升到一次能源的角度。建筑物的加权和非加权能耗有单独的限制，两者必须同时满足。权衡系数设定如下。

- 电力=2.0
- 化石燃料=1.0
- 区域供热=0.4 - 1.0
  （取决于热源中的化石燃料份额）
- 生物质=0.5
- 其他可再生能源=0

第四阶段的主要成就。

- 在能效和温室气体排放方面具有较高雄心的法律基础，提供有效的国家政策工具和量化的减排目标，包括大规模的对建筑改造补贴计划。
- 示范条例（MuKEn）向近零能耗建筑和考虑一次能源的方向发展。
- 富有远见和重要的自愿行动，以发展零排放建筑的概念。
- 与能源和气候影响有关的绿色建筑标签和认证体系，适用于既有建筑、新建筑和建筑改造（MINERGIE "家族"，GEAK）。

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 targets.
All energy and climate related activities are now guided by a National Energy Strategy (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 Switzerland in 2019.
The strategic targets in the building sector for 2050 are “zero greenhouse gas emissions” 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 maxi-mum thermal conductivity of the building envelopes (see also Figure 1) today have reached a level, which only can be lowered, if new building materials become 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 centimetre 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).

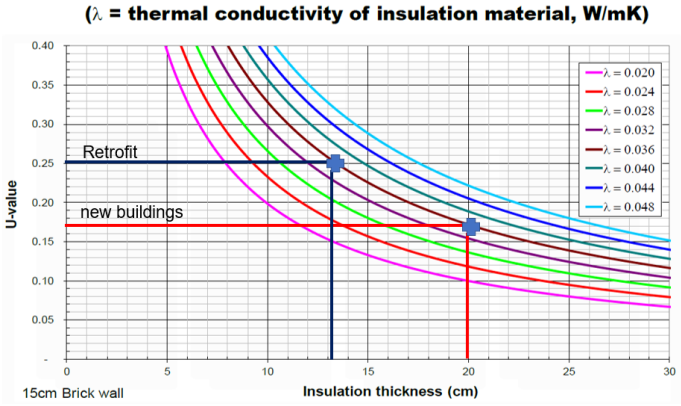


Figure 3: Thermal conductivity of a 15 cm brick wall depending on insulation thickness and insulation quality
The two crosses mark the present status of the Swiss TER as per MuKEN for minimum quality of exterior walls of new buildings and buildings under retrofit. The blue and red lines show, that in new buildings more than 20 cm if insulation thickness is required, in retrofit typically more than 15 cm.
图3：15厘米砖墙的导热系数取决于保温层厚度和保温质量
两条交错十字线标志着瑞士TER按MuKEN规定的新建筑和改造建筑的外墙的最低质量。蓝线和红线表示，在新建筑中，如果要求做保温层，那么其厚度要超过20厘米，而在改造建筑中通常则需超过15厘米。

Major achievements from Phase 5:

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

第五阶段（2015-2021）：为净零排放TER做好准备

自过去十年中期以来，气候变化问题已经变得日趋紧迫，瑞士在政策中也加强了解决这一问题的行动。
在这个阶段，没有引入重要的新政策，而是将现有的政策工具进行发展并加强反映实际进展和目标。
所有与能源和气候有关的活动现在都由国家能源战略（2017年）和国家气候战略（2021年）来指导。除此之外，这两项战略还为建筑部门的政策、设备和活动的进一步发展提供指导。瑞士已于2019年通过了2050年温室气体净排放的目标。
2050年建筑领域的战略目标是所有建筑存量 "温室气体零排放"。所有新建筑必须符合 "近零能耗的建筑要求"。
在建筑物的 TER 方面，越来越多的州已对新建筑物和改建建筑基于化石燃料的供暖系统发布了禁令。
今天，TER中为建筑围护结构的最大导热系数设定的限制（见图1）已达到了一个水平，只有在新的建筑材料出现时才能有所降低。在瑞士，典型的保温材料是粘土砖或混凝土，保温层厚度为15-30厘米（主要是玻璃棉、岩棉、木纤维板或XPS硬泡沫），任何所增加的额外的一厘米保温层所产生的材料隐含能耗往往已超过了建筑在运行阶段减少直接排放所获得的好处。因此，今后的重点必须是通过过渡到可再生能源来实现既有建筑的脱碳。如今在瑞士，大多数新建筑都配备了基于可再生能源的加热系统（见图4）。

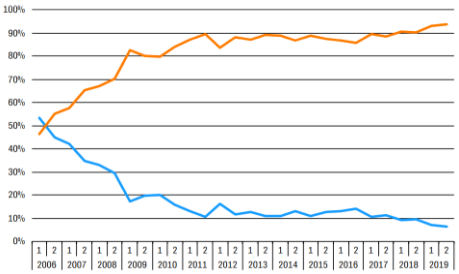
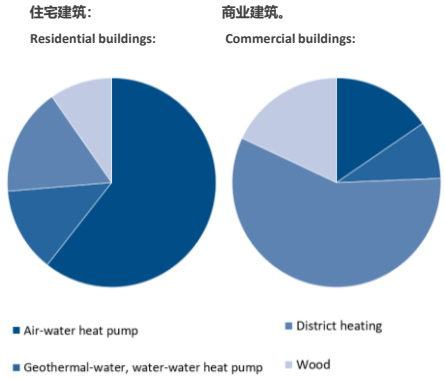


Figure 4: Market share of fossil and renewable energy based heating systems in new residential buildings in Switzerland
The blue line shows the share of fossil fuel based heating systems, the orange line the share of renewable energy based systems. The graph is for the sector of multi-family residential buildings. In single family residential buildings, the share of renewable energy based systems is even higher.
Source: bit.ly/3LK3NNu
图4：瑞士新住宅建筑中基于化石和可再生能源的供暖系统的市场份额
蓝线表示以化石燃料为基础的供暖系统的份额，橙线表示以可再生能源为基础的供暖系统的份额。该图是针对多户住宅建筑而言的。在单户住宅建筑中，基于可再生能源的系统所占比例甚至更高。



第五阶段的主要成就：

- 战略和政策与2050年温室气体净零排放的目标相一致。
- 对新建筑的供热系统选择和供热系统改造有很大影响的TER，侧重可再生能源。

02

Swiss policy instruments and their relevance for ZEB

Energy act and act on CO_2 emissions

Description
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 consumption.
- 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 building 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 CO_2 emissions:
- Obligation for the Cantons to issue adequate TER for building sector to contribute adequately to the national GHG reduction targets.
- CO_2-tax on fossil based heating fuels with partial earmarking of revenues for subsidising building energy efficiency and decarbonisation measures.
- Financial support to the Cantons for providing subsidies to building owners for implementing 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 building 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.

二

瑞士政策工具及其与ZEB的相关性

能源法和二氧化碳排放法

说明
在建筑方面，这些法案及其各自的条例整合了以下方面的总体法律规定。

能源法:
- 建筑物层面的电力生产，包括内部消耗的核算。
- 在建筑层面产生的电力费用。
- 对终端用户有关基于可再生能源供热系统的补贴。
- 为建筑领域的利益相关方提供有关建筑能源效率的培训和给专业培训提供财政支持。
- 为建筑业主和其他利益相关方提供信息和技术咨询的财政支持，以实现节能建筑。
- 建筑领域监测和报告能源使用状况和进展。

对二氧化碳排放法规:
- 各州有义务为建筑领域发放足够的TER，以便为国家温室气体减排目标做出充分的贡献。
- 对以化石燃料基础的供暖方式征收二氧化碳税，并将部分收入用于补贴建筑节能和脱碳措施。
- 为各州提供财政支持，为建筑业主实施提高能效和改善气候措施提供补贴。
- 为建筑物业主和其他利益相关方的信息和技术咨询提供资金支持，以实现建筑物的减排。
- 为建筑领域利益相关方在能源和气候问题上提供培训并给专业培训提供财政支持。
- 为各州监测和报告建筑行业温室气体排放的状况和进展提供经费。

“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 Cantons, strong guidance must come from the national level.“

Building materials, renewable energies and building design work together in this Swiss building.
瑞士建筑基于建筑材料、可再生能源和建筑设计的共同协作。
© BFE | buildings: bit.ly/3ONMDRf

Relevance for ZEB

The energy act and the act on CO_2 emissions are the legal “backbone” at the national level to drive the progress on efficient energy use and CO_2 emissions in the building sector. As mentioned earlier, the technical parameters are not administered at the national 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 Cantons, 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 CO_2 emissions in 2021, a significant new instrument was planned, which limits yearly emissions of all existing buildings to initially 20 kg CO_2eq 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.

SIA Standards

The Swiss Society of Engineers and Architects (SIA) is Switzerland’s leading professional association 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, suppliers 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 European Norms have been taken over from Swiss norms. An overview on the most relevant Norms for is given in Table 1, incl. a non-exhaustive list of their key features.

与ZEB的相关性

能源法和二氧化碳排放法是国家层面的法律 “主干”，推动了建筑领域高效能源利用和二氧化碳排放的进展。如前所述，技术参数不是在国家层面上进行管理的，而是各州自行管理。但是，这些法案保证了各州之间的高度和谐。

从瑞士建筑行业长期实施ZEB的经验来看，当把技术规范的权力下放给各州时，必须由国家层面提供强有力的指导， 因为各州在推动TER向ZEB水平发展的决心并不统一。

然而，这种不同在某种程度上来说也是有好处的，因为一些州正发挥着远见卓识的示范作用，而相对落后的州则必须由国家来推动。

随着计划在2021年关于二氧化碳排放法案的修订，瑞士计划制定一项重要的新草案，即将所有既有建筑物的年排放量在最初计划的每平方米20公斤二氧化碳排放量（2023年），以每五年5公斤逐步递减。并且在任何情况下，都将禁止安装或更换化石能源系统。

然而，这项修订法提议在公开投票中案被否决了。

SIA标准

瑞士工程师和建筑师协会（SIA）主要是一个由瑞士建筑、技术和环境专家组成的专业协会。SIA广泛适用于建筑行业的标准体系为瑞士的规划和建设提供了公认的规章制度。该协会不断审查、修订和更新标准，并提供有关如何使用的信息。可以说，这些标准和相应的实践守则和文件是由规划师、建筑业主、承包商、供应商和公共机构、大学和学院共同制定的。SIA还参与了对专业人员的培训，以有效地实施这些规定。

在瑞士有一个广泛的共识，即只有通过专业和跨学科的有效合作才能应对零排放建筑的挑战。

因此，SIA是瑞士建筑转型的一个关键因素。

最初，SIA推动了标准的目标水平，但自2009年起，各州和国家政府根据政策的优先次序，确定了提高瑞士建筑标准目标水准的步伐。

目前，SIA标准中规定的大部分建筑能源需求计算方法都与欧洲规范相一致，欧洲规范中的一些方法也被瑞士规范所取代。

表1对最相关的规范进行了概述，包括其主要特征的非详尽清单。

“零碳建筑在瑞士建筑行业悠久实施历史中的一个所得经验是，在将技术法规的权力下放给各州时，必须有来自国家层面的强大的指导作陪伴“

Cities and districts need a holistic approach for managing the energy-building interplay.
城市和地区需要用整体的方法来管理建筑能源的互动
© BFE | energeiaplus: bit.ly/3LWmgqx

Table 1: Overview of SIA standards with high relevance for direct and indirect GHG emissions of buildings

SIA 180: Thermal insulation, moisture protection and 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

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 through 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

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).

表1:与建筑的直接和间接温室气体排放高度相关的SIA标准概览

SIA 180: 建筑物的隔热、防结露和室内热环境（2016）。

目的：确保舒适的室内气候和防止结构破坏

对中国ZEB的借鉴：

- 相关性低，主要是一些参数的定义和计算方法
- 规定了新建和改建的建筑围护结构的最小u值。

SIA 380/1: 建筑物的采暖能源需求（2016）。

目的：确保建筑空间采暖能源的适度和经济使用，从而对生态建设方法做出了贡献。

对中国ZEB的借鉴：

- 对于每一个新建筑或改建建筑，都提供了两种可选方式来进行合规性检查。
- 通过热平衡对供热和制冷的能源需求进行详细的、基于系统的计算
- 通过采用对单个建筑部件的热性能（U值）的描述性最低要求，简化了合规性。
- 通过详细的热平衡来详细规定有关供热和制冷能源需求的基于系统的计算方法。该标准还规定了要使用的标准参数值。
- 对12个建筑类别规定了基于系统的极限值。建筑物的具体限值是根据一个固定限值和一个建筑类别的具体增量限值来计算的，这个增量限值是建筑外形因素和建筑现场平均室外温度的函数。
- 在没有详细计算的情况下，对新建筑的建筑围护结构部件抵御户外气候的U值[单位：W/m2K]的限定。
    - 屋顶、墙壁、地板=0.17
    - 窗 = 1.0
    - 门=1.2
- 在没有详细计算的情况下，用于建筑的翻新： 对建筑围护结构抵御户外气候的U值[单位：W/m2K] 的限定。
    - 屋顶、墙壁、地板=0.25
    - 窗 = 1.0
    - 门=1.2

SIA 380/4: 建筑物中的电能 (2006)

目的：该标准的目的是在建筑和设施中合理用电，作为规划的辅助手段，有助于优化新建筑和改建建筑的用电。它定义了相关的参数并建立了一个标准化的电力需求表述。

对中国ZEB的借鉴：

- 基于建筑面积的，良好的实践证明的，对住宅（如烹饪、冷冻、洗涤）和商业建筑（如IT设备、电梯）的照明、通风、房间冷却和操作设备的耗电量的限定。

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.

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

Table INFRAS. Source: sia | schweizerischer ingenieur- und architektenverein (www.sia.ch)

Model Regulations of the Cantons on energy in Buildings

The "Model Regulations of the Cantons on energy in Buildings" (MuKEn)[2] 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 harmonisation in the area of cantonal energy regulations in order to simplify construction planning and licensing procedures for building owners and professionals working in several cantons. Harmonisation is further supported by the use of jointly developed forms and enforcement 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. However, minor differences may arise due to different building procedure regulations. For example, de minimise limits may concern the obligation to provide evidence in one Canton 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.

[2] bit.ly/38008MU

SIA概况介绍2040：SIA效率途径

对中国ZEB的借鉴：

- 长期的绿色建筑之路
- 符合长期气候目标的绿色建筑的能源需求和温室气体排放的最低要求
- 生命周期的方法是指建筑阶段、运营阶段和因建筑所发生的交通流动性。
- 从一次能源的角度出发，对一次能源和C02排放采用特定的能源加权系数，用于终端能源的设计能耗。

SIA概况介绍2031：建筑的能源性能证书

目的：明确规定国家建筑能源证书的要求。

ZEB的特殊之处

- 用于新建和既有建筑
- 对具有高能源和气候性能的建筑来说，是房产销售市场的热点
- 也可作为获得建筑能源和气候相关措施补贴的基本要求。
- 结合了瑞士的方法和欧盟的能源性能证书的内容

INFRAS制表。资料来源：SIA | 瑞士工程师和建筑师协会(www.sia.ch)

各州关于建筑能源的示范条例

《各州建筑能源示范条例》（MuKEn）[2]，是建筑领域能源示范条例的 “整体方案” 。MuKEn由各州根据其执法经验共同制定。它们构成了各州的 “共同标准”，旨在实现各州能源法规的高度统一，以简化建筑业主和在各州工作的专业人士的建筑设计和许可程序。通过使用共同开发的表格和执法辅助工具，进一步支持法规和谐工作。
示范条例的目的不是完全统一所有州的能源法规定，而是统一个别可定义的子领域的规定。每个子领域的 "一揽子规定 "构成一个 "模块"。这就保证了各州在特定情况下的灵活性，如瑞士旅游区的特定建筑用途，可以做出不同的规定。

为了确保和谐，有一个 必须由所有州详细采用的 “基本模块” 。在这个意义上，它是一种 “强制性模块” 。通过采用这个 “基本模块”，各州可以达到国家能源法的要求。
其他模块包含了更多的规定，如果各州希望在相应的某个领域制定额外的优先事项，则可以采用这些规定。然而，由于建筑程序规定的不同，可能会出现微小的差异。例如，最小限定在一个州可能涉及提供证据的
义务，而在另一个州则可能涉及获得许可的义务。然而，如果一个模块被
采用，出于统一原因，它则必须不经改变地被采用。
以下是对不同模块的概述。

[2] bit.ly/38008MU

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

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 improvement 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[3], typically around 20 – 30 percent of the total investment cost is covered by grants to be paid upon commissioning of the works.

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 implemented to support the targets of the Swiss energy and climate strategy.
In the building sector, these include information and advice for the general public and special target 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.

[3] bit.ly/3kDoI93

基本模块

- A部分　一般规定
- B部分　建筑物的隔热性能
- C部分　对建筑中技术系统的要求
- D部分　对新建筑的采暖需求的要求
- E部分　新建筑中的自发电
- F部分　对供热系统更换中可再生能源使用的要求
- G部分　电能（SIA 387/4）
- H部分　翻新中央电热系统的义务
- I部分　翻新中央电热水器的义务
- J部分　新建筑和重大改造中基于消耗的供热和热水成本计费
- K部分　发电厂的用热情况
- L部分　大型消费者
- M部分 公共机关的示范作用
- N部分 州级能源性能证书（GEAK）
- O部分 补贴
- P部分　GEAK Plus补贴的义务
- Q部分 强制执行/收费/罚款条款
- R部分　最后和过渡性条款

附加模块。

- 模块2：现有建筑中基于消耗的供热成本计费
- 模块3：室外供热和室外游泳池
- 模块4：度假屋和度假公寓
- 模块5：在新建筑中配备建筑自动化的义务
- 模块6：翻新分散式电加热系统的义务
- 模块7：确认执行
- 模块8：优化操作
- 模块9：某些建筑物的GEAK订单
- 模块10：能源规划
- 模块11：保温/利用

国家/州/市/私人部门层面的补贴方案

为了促进可再生能源的使用和发展节能建筑，瑞士长期投资于研究和创新并持续使用支持工具。这极大地促进了长期的能源安全。然而，不仅是联邦政府、各州和各市，还有能源供应商和私人机构，如公司和基金会，也通过补贴来支持可再生能源的生产和能效的提高。部分补贴
其中特别包括：

- 一个全国性的 "建筑计划"，为建筑物业主提供直接的财政支持
- 各州、市、县提供直接财政支持
- 为能源和气候相关的改造活动提供资金和减税优惠
- 促进建筑现场的能源生产
- 联邦政府的示范项目计划

根据国家建筑计划[3]，通常约有20%-30%的总投资成本由补助金支付，在工程调试时支付。

“瑞士能源 "计划

"瑞士能源 "国家计划于1991年启动，是瑞士的第一个能源政策工具，目的是通过自愿措施与来自商业和公共部门、教育和科学、环境和消费的合作伙伴一起促进能源和可再生能源的合理利用。
今天，该计划与其他能源和气候政策工具一起，促进了《瑞士2050年能源战略》的实施。
在EnergieSchweiz的保护伞下，一套多样化的自愿措施被实施，以支持瑞士能源和气候战略的目标。
在建筑领域，这包括以网站（www.energieschweiz.ch）的形式为公众和特殊目标群体提供信息和建议，以及一般和深入的信息材料和指南。
该计划还支持能源相关部门专家的培训和进修，并为新技术的市场渗透提供质量保证。通过这些措施，瑞士能源署旨在帮助那些有助于提高燃料、供热和电力部门的能源效率，或有助于可再生能源传播的新技术和概念实现市场突破。

[3] bit.ly/3kDoI93

Green Building Labels in Switzerland

In Switzerland, the most widely used building labels have been developed by the national and can-tonal authorities, together with the building sector stakeholders. This family of building labels is promoted by Swiss Federal Office of Energy according to its vision for the Swiss building stock 2050.
Four different labels are implemented with different priorities and application focus.

Building energy certificate of the cantons (GEAK4):
- Used for existing and new buildings
- Provides information on the performance of a building regarding primary energy use and green-house gas emissions
- Also used a an instrument for accessing financial support, e.g. under the Building Program

MINERGIE 5:
- Includes a family of sublabels with different ambition levels “Basic”, “Plus” (ZEB buildings) 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 provide building users and owners with living comfort, efficiency and value retention.
- High market penetration with approx. 15% of new buildings and 3% of building renovations in Switzerland being MINERGIE labelled.

SNBS 6 (Swiss Standard for Sustainable Buildings):
- Provides a wide reaching set of sustainability criteria for green buildings
- focus on building, its use, and its location (access, location, etc.)
- combines approaches and concepts of sustainable building in Switzerland (Minergie, Minergie-ECO, 2000-Watt-Areale) and brings them together towards holistic planning.
- Builds on established SIA standards.

2000-Watt-Areal 7 (2000 Watt site):
- Provides planning guidelines for net zero emission ready sites
- Instead of looking at the individual buildings, the concept of the 2000-watt sites focuses 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-friendly buildings
- Mobility

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

[4] www.geak.ch
[5] www.minergie.ch
[6] www.snbs-hochbau.ch
[7] www.2000watt.swiss

瑞士的绿色建筑标签

在瑞士，最广泛使用的建筑标签是由国家和地方当局与建筑部门的利益相关者共同开发的。这个建筑标签系列是由瑞士联邦能源办公室根据其对2050年瑞士建筑总量的展望而推广的。
四个不同的标签以不同的优先级和应用重点实施。

各州的建筑能源证书（GEAK4）：
- 用于既有建筑和新建筑
- 提供建筑在一次能源使用和温室气体排放方面的性能信息
- 也被用来作为获得财政支持的工具，例如在建筑计划下。

MINERGIE 5:
- 包括一系列具有不同目标水平的子标签“基本”、“加强”（ZEB建筑）和“生态”（涵盖对健康和建筑生态问题的额外要求）。
- 是一个针对新建筑和建筑改造的规划和认证体系。
- 为整个建筑以及建筑部件提供认证。
- 非常注重质量保证，为建筑用户和业主提供生活舒适度、效率和保值性。
- 市场渗透率高，瑞士约有15%的新建筑和3%的翻新建筑已被贴上MINERGIE标签。

SNBS 6（瑞士可持续建筑标准）：
- 为绿色建筑提供了一套广泛的可持续性标准
- 关注建筑物、其用途和其位置（交通、位置等）。
- 结合了瑞士可持续建筑的方法和方案（Minergie, Minergie-ECO, 2000-Watt-Areale），并将它们结合起来，实现整体规划。
- 建立在既定的SIA标准之上。

2000-Watt-Areal 7（2000瓦社区）。
- 为准备就绪的净零排放社区提供规划指南
- 2000瓦特社区的概念不是着眼于单个建筑，而是把社区和人作为一个单位来关注。
- 包括六个重点领域的标准和要求。
- 透明的管理制度
- 参与式交流
- 社区功能多样化
- 可持续的供应和废弃（能源、水、废弃物）
- 经济型、资源节约型和气候友好型建筑
- 交通流动性

除了这些国家标签，一些国际绿色建筑标签，如BREEAM、LEED、DGNB在瑞士得到使用。这主要是因为对国际客户的项目而言，他们有自己的企业标准。对大型项目中通常会实施国际和瑞士标签双认证。

[4] www.geak.ch
[5] www.minergie.ch
[6] www.snbs-hochbau.ch
[7] www.2000watt.swiss

03

Swiss Stakeholder landscape for ZEB

Energy act and act on CO_2 emissions

Table 2 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.

Stakeholder	Role
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 individual TER ▪ coordinate development of national labels for green buildings ▪ communication and awareness activities ▪ support for light house projects ▪ finance national research 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 CO_2 emissions
Cantons	▪ regulatory body for technical regulation in the building sector ▪ subsidy programs for decarbonisation and efficiency improvement of buildings (partly funded by national CO_2-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 developers and owners (especially in cities) ▪ for some: “topping up” subsidies (in addition to Canton)

三

瑞士ZEB的利益相关者情况

能源法和二氧化碳排放法

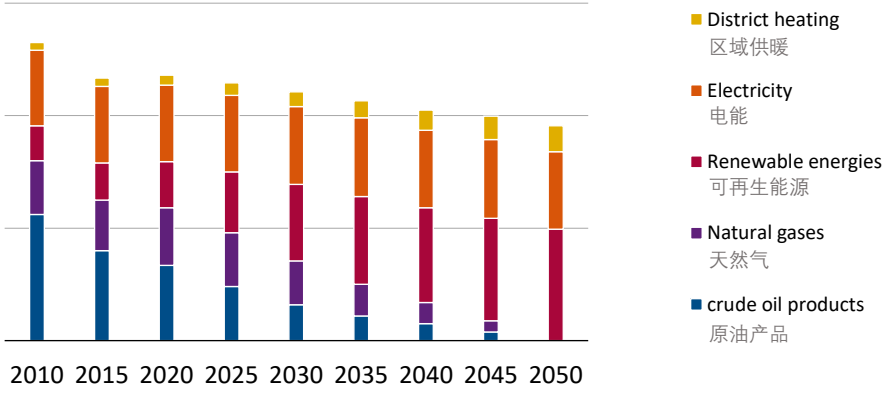
表2提供了瑞士利益相关者的概况。表中只列出了与推动建筑业实现零排放最直接的利益相关者。

值得一提的是，无论是以前还是现在，瑞士在建筑行业向ZEB过渡方面的进展是由不同利益相关者层面的有效互动所推动的。

利益相关者	角色
政府行政/政策层面	
瑞士联邦能源办公室 SFOE	▪ 国家能源使用监管机构 ▪ 支持方案和培训指南 ▪ 为各州提供指导，使其拥有独立的TER政策 ▪ 协调国家绿色建筑标签的发展 ▪ 交流和宣传活动 ▪ 支持示范项目 ▪ 资助国家研究项目
联邦环境办公室（FOEN）	▪ 缓解和适应气候变化活动的国家监管机构 ▪ 通过国家对二氧化碳排放征税，为建筑领域的脱碳和提高能效提供资金。
各州政府	▪ 建筑部门的技术监管机构 ▪ 建筑物脱碳和提高能效的补贴计划（部分资金来自国家二氧化碳税） ▪ 为贸易和建筑业主提供关于TER实施的培训和信息 ▪ 通过自己的项目发挥表率作用
市政当局	▪ 以身作则，推动州一级的工作使其更加积极主动 ▪ 建筑领域技术法规的执行情况 ▪ 为建筑开发商和业主(特别是城市)提供“产品独立”基础咨询和信息 ▪ 提供一些"额外"补贴（除州外）

Stakeholder	Role
Associations, Industry, Trade	
MINERGIE	▪ Building label with high market penetration ▪ Driver of innovation by providing forerunners in the market visibility and quality control instruments
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	▪ Development of technical standards and guidelines
Trade Associations	▪ Provide trade specific information and training on ZEB related issues ▪ Ensure acceptance of TER with the trade ▪ Promote sustainable practices in the trade
Science and 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	▪ Education and professional training of architects and engineers
Vocational training institutes	▪ Providing the market with adequate number of skilled professionals ▪ Ensuring the specific skills for ZEB in the trade ▪ Ensuring field level implementation of TER
Building owners and investors / Developers	
Investors and building owners	▪ leading by example with lighthouse projects ▪ anchor leading edge approaches through corporate policies for own building portfolio

Development of energy consumption for residential buildings:
居住建筑的能耗发展:



Source: Energy Perspectives 2050+: bit.ly/3kF2oMt

"The progress in Switzerland towards ZEB historically and today is driven by the fruitful interaction of the different stakeholder levels."

Zero Emission Building retrofit, "La Cigale", Geneva
零排放建筑改建工程，"La Cigale"，热内瓦
Source: Solaragentur Schweiz: bit.ly/3LJgurV
出处：瑞士太阳能办事处

"瑞士过去和今天的在零碳建筑方面取得的进展是由不同利益相关方层面富有成效的互动所推动的。"

Prime Tower in the city of Zurich
苏黎世的Prime Tower大厦
Source: www.video-drohne.ch

利益相关者	角色
协会，工业，贸易界	
MINERGIE	▪ 具有高市场渗透率的建筑标签 ▪ 通过提供市场上的可视性和质量控制仪器的先驱者，推动创新
2000瓦社会	▪ 为建筑部门制定长期愿景和概念 ▪ 提供规划和监测准则 ▪ 促进社会和技术向净零排放过渡
SIA	▪ 制定技术标准和指南
贸易协会	▪ 提供关于ZEB相关问题的具体贸易信息和培训 ▪ 确保接受与贸易有关的TER ▪ 促进贸易中的可持续做法
科学和大学 / 研究机构	
国家研究计划和网络	▪ 能源技术、社会经济方面、社会影响、行为科学、转型途径等领域的基础研究。
大学	▪ 建筑师和工程师的教育和专业培训
职业培训机构	▪ 为市场提供足够数量的熟练专业人员 ▪ 确保ZEB的具体实施 ▪ 确保TER的实地实施
建筑物业主和投资者/开发商	
投资者和楼宇业主	▪ 以身作则的示范项目 ▪ 通过为自己的建筑组合制定公司政策来确定优先手段

04

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 consensus, 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 technical energy regulations in buildings (Project EnTeR). 8 The purpose of the project was to assess the role of technical regulations in the trans-formation 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 limits.

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 "grey9 energy" and “grey emissions”
iii. increase the share of renewable energies
iv. close the "performance gap" 10
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 CO_2-free by 2050. To achieve the CO_2 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 CO_2 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 understand 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.

[8] NFP 71 - Concept for next generation of technical energy regulations in building: bit.ly/39oRXdq
[9] the term “grey” is used in this document for embodied energy consumption or emissions which do not occur directly at the building site during operation, but indirectly and at a global scale through the input or output of material to the building site.
[10] the performance gap is the difference between the predicted performance values in design stage and measured in occupancy stage of a building.

四

对瑞士下一代符合ZEB标准的建筑的TER进行展望

到目前为止，瑞士还没有就建筑技术法规的长期发展方案做出决定。这个问题仍在研究之中。人们一致认为，任何适合净零排放世界的TER都必须采用纵观全局的方法，必须涵盖整个建筑的生命周期，而不仅仅只看是运营阶段。
国家研究计划 “能源消耗管理” （NRP71，2020）研究了能源战略变化的社会、经济和监管方面，从而研究了如何促使私人和公共行为者有效利用能源。其中一项子研究是为下一代建筑能源技术法规制定一个方案（EnTeR项目）。[8] 该项目的目的是评估技术法规在建筑存量的转型和融入未来能源系统中的作用。
从这项研究中得出以下结论。

■ 国际分析显示，尽管TER在提高建筑能源效率方面曾经取得过成功，但似乎已经达到其经济极限。

特别是当它涉及到建筑领域的脱碳问题。因此，文献中列出了以下五个挑战。

i. 进一步提高能源效率
ii. 考虑 "灰色[9]能源 "和 "灰色排放"
iii. 增加可再生能源的份额
iv. 缩小 “业绩差距 “[10]
v. 加快翻新率

■MuKEn在将瑞士建筑业转变为到2050年几乎无二氧化碳的行业过程中发挥着关键作用。为了实现二氧化碳目标，必须在新的能源税中加入更多或更严格的规定，特别是适用于更换燃油和燃气加热系统的规定。目前MuKEn 2014对既有和新建筑的建筑围护结构的要求被认为是足够的。

■ 为了实现建筑领域的长期二氧化碳目标，实施工作必须达到非常高的效率水平。为此，TER必须非常容易理解和简单应用，而且必须对可接受的技术解决方案给予高度的灵活性。

■ 在城市中，带有热力网络的区域解决方案适用于50-80%的地区，在人口更稠密或工业化的城市群，适用于高达50%的街区。这种区域解决方案的投资成本比独立的建筑解决方案低20-25%。

■ 为了提供最佳的监管环境，鼓励建筑业向预定方向发展，我们提出了一个基于生命周期思维的TER方案。生命周期的观点允许在物业的三个主要阶段（建设、运营和拆除）制定有效措施。这种分离使TER能够具体地与特定阶段的相关行动者保持一致。

[8] NFP 71 - 下一代建筑能源技术法规的概念: bit.ly/39oRXdq
[9] 本文件中的 "灰色 "一词是指在运行过程中不直接在建筑工地发生，而是通过向建筑工地输入或输出材料间接地在全球范围内发生的能源消耗或排放。
[10] 性能差距是指建筑物在设计阶段的预测性能值与在使用阶段的测量值之间的差异。

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

Planning and 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 maximum / 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 advantage 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 optimization. The single parameter also makes compliance checking for the authorities extremely simple.

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 CO_2-emissions per floor area.

The actor can comply with the CO_2 limits by reducing his consumption, choosing CO_2 or CO_2-free energy products and/or increasing his own energy production at the building site (e.g. photovoltaics, combined heat and power generation, etc.).

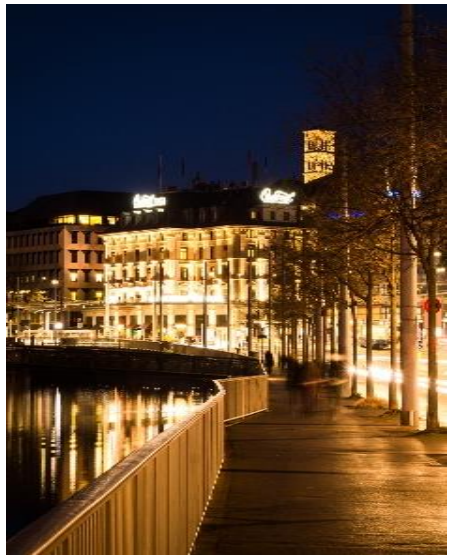
Decommissioning phase:
The share of non-operating emissions from building materials can account for as much as 40% of total emissions over the lifetime of a building and more. To avoid loss of resources from decommissioning of buildings and make maximum use of the embodied emissions contained in the 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.

这里，就生命周期三个阶段的实施路径总结如下。

规划和建设阶段：
调节能源系统的最大可输送热功率输出（单位：瓦/平方米建筑面积），而不是像今天的TER那样直接调节能源需求。采暖或制冷系统的最大可输送热功率输出被用作建筑能源效率的代表。一个设计良好的系统的热功率等级被设定为在一年中的最高/最低室外温度下为相应的建筑提供足够的舒适度。
如果TER提供的是功率限制而不是能量限制，设计者必须确保建筑效率足以应对限制的功率水平。这样做的好处是，设计过程必须确保符合单一的关键参数。在设计的细节方面，有很大的灵活性和优化空间。单一参数也使当局的合规性检查变得非常简单。

Photo previous page: planning and construction phase;
前一页照片：建筑规划和建造阶段；
© Chantier RTS | EPFL: bit.ly/3vGKFu8
Photo bottom: operating phase;
下方照片：运营阶段；
© Daniel Lerps | Flickr: bit.ly/3vDvu4X
Photo top: decommissioning phase;
上方照片：废弃阶段；
© Wolfgang Staudt | Flickr: bit.ly/3s9tZJX



运行阶段：
虽然能源需求是由设计决定的（见上文），但在运行阶段唯一需要限制的参数是能源组合。这可以通过设定每层建筑面积（单位面积）的二氧化碳排放量限值来实现。
行为人可以通过减少消费、选择二氧化碳或无二氧化碳的能源产品和/或在建筑场地内增加自己的能源生产（如光伏发电、热电联产等）来遵守二氧化碳限制。

拆除阶段：
建筑材料的隐含碳排放份额可占到建筑物生命周期内总排放量的40%，甚至更高。为了避免建筑退役带来的资源损失，并最大限度地利用即将退役的建筑材料中所包含的隐含碳排放，建议在建筑材料的循环经济中，根据 "隐含碳排放 "对建筑材料征收前期回收费用。通过对建筑材料征收含碳量相关的费用，业主将有动力回收他的材料，行业将发展回收过程，这在未来是完全脱碳的。这是一个基于市场的经济手段，将鼓励创新并影响设计过程。

这一仍在进行的研究的下一阶段用于制定有效和高效的监管，其具体内容、门槛和执行。

05

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 efficient and decarbonised build-ings. 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, planners, and technology providers

The more ambitious the TER is, the more important it is for all stakeholders in the building 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 investment.

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 physical “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.

五

向ZEB过渡的瑞士经验的九点启示

以下是成功过渡到零排放建筑群的九个假设。这些假设是基于对瑞士长期以来在政策制定和技术监管方面的成功经验的学习，以实现高效和低碳化的建筑。从长远来看，它可以为中国向零排放建筑群的过渡提供重要借鉴。

1. 只有一个目标明确的政策框架，具有明确和长期的减排路径，并逐步增加TER，才能为投资者、规划者和技术提供者提供必要的可预测性。

TER的目标越高，建筑行业的所有利益相关者就越需要有明确的长期方向和可预测性。经济科学表明，如果所有相关实体对他们的活动和技术路径有一个明确的规划基础，并且可以单独决定他们是否要预测下一步TER的严格程度，那么对深远的过渡的接受程度会更高。
这可以在市场上为他们提供即时和长期的经济激励，为他们提供以身作则的可能性，并确保投资的可持续性。

2. ZEB政策的成功实施需要一个多样化的措施生态系统，有三个主要支柱

- 一个成功的政策环境建立在三个主要支柱之上：
- 规范、立法和执法
- 教育和能力建设
- 激励措施、领导和激励

然而，零排放建筑的目标只能通过一系列不同的工具的积极耦合来实现。
例如，如果没有强有力的沟通和能力建设的支持，一个强有力的、意义深远的立法将有可能失败。如果执行层面的资源和能力不足，它也不会成功。
成功的唯一基准是在物理 "现场现实 "中实现的变化水平。成功的转型需要一套平衡的政策工具，包括 "推 "和 "拉 "的要素、领导力、行动的一致性和所有利益相关者层面的强大同行群体。这将为建筑部门的快速和广泛的转型提供必要的动力。

3. Effective TER must be simple and easy to apply and must be supported by practical guide-lines

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 there-fore has proved to be very successful to “translate” the complex system-wide requirements in simple to understand prescriptive (sample) solutions. By applying adequate safety margins, it is ensured that the performance of buildings designed on basis of prescriptive requirements is equivalent to system-wide optimized buildings. The “sample solutions” in Swiss TER and the relat-ed 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 successful im-plementation

In Switzerland, periodic field evaluation of the “real-life” success of policy implementation 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 behav-ior. In other words: The regulation does not fully achieve its goal.
The more stringent the building standards are, the higher is the observed variance against the design energy demand. Typically, the variance is much larger in direction of excess energy demand than towards inferior energy demand. This performance gap is a major challenge for the effectiveness of any TER for zero emis-sion buildings and must be addressed adequately in the TER, e.g. by mandatory performance mon-itoring and optimization of buildings in their operation phase.

5. Flexibility in the enforcement organization helps to achieve effective implementation

In Switzerland, the principle of private performance controls in execution of building projects is implemented, which also could be interesting for China. The private controllers are accredited with the building related enforcement authorities for approving designs 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 enforcement capacity and power in all Cantons, includ-ing 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 embodied energy and emissions of the construction and minimize resource loss and emissions in decommissioning of buildings.

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

For reaching at a net-zero emission building stock, the todays approach of TER with optimization at the level of individual buildings will be inadequate. The potential for optimum solutions often requires solutions at a district scale, such as district heating, district level energy storage solutions or resource optimized balancing of energy production at building sites. The TER must be open to district level optimization in future. Special 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 adequate provisions to maintain robust performance of the buildings.

3. 有效的TER必须简单易行，必须有实用的指导原则支持。

大多数国家（包括瑞士）的建筑TER非常复杂。由于所涉及问题的复杂性，只有全系统的优化才能带来经济上最佳的高性能建筑。非专业人士通常无法理解详细的法规在整个系统基础上的后果，从而无法做出选择。因此，在瑞士，将复杂的全系统要求 "转化 "为简单易懂的规范性（样本）解决方案是非常成功的。通过应用足够的安全系数，可以确保根据规范性要求设计的建筑的性能等同于全系统的优化建筑。瑞士TER中的 "样本解决方案 "和相关的实践指南被广泛使用和接受。它们是瑞士在建筑领域有效执行政策的一个关键因素。

4. 现实生活中的绩效评估和实地评估是成功实施的关键因素。

在瑞士，对建筑行业政策实施的“实际”成功进行定期实地评估，是十多年来行之有效的工具。通过这些基于样本的实地研究，人们发现在许多情况下，建筑的设计性能和实际生活性能之间存在着差距，但这取决于个人用户的行为。换句话说，规章制度并没有完全实现其目标。
建筑标准越严格，观察到的与设计能源需求的差异就越大。 通常情况下，超额能源需求的差异比劣质能源需求的差异大得多。这种性能差距是对任何零排放建筑的TER有效性的主要挑战，必须在TER中充分解决，例如在运行阶段对建筑进行强制性性能监测和优化。

5. 执法组织的灵活性有助于法规有效执行

在瑞士，私密性原则在建筑项目的执行过程中实施绩效控制，这对中国来说也是很有意义的。私人控制者得到了与建筑有关的执法部门的认可，负责批准设计和检查执行过程中对TER的遵守情况。通过这种方式，他们协助并加强执法部门。这只允许在所有的城市建立必要的执法能力和权力，包括那些财政和人力资源能力较弱的城市。

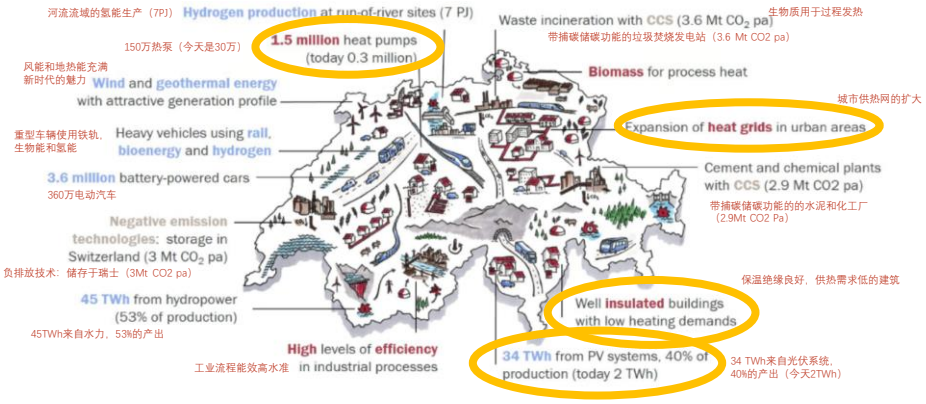
6. 有效的ZEB规范和条例需要参考一次能源需求和生命周期排放。

对于一个净零排放的世界来说，前提条件是TER不仅要规范运行期间的排放，而且必须涵盖建筑的整个生命周期的排放。因此，有必要解决运行期间的一次能源需求、建筑的内含能源和排放问题，并尽量减少拆除建筑时的资源损失和排放。

7. 需要在地区范围内应用和优化强有力的技术，以有效地提高ZEB的市场覆盖率。

为了达到净零排放的建筑总量，今天在单个建筑层面上优化TER的方法将是不够的。
最佳解决方案的潜力往往需要在地区范围内的解决方案，如地区供暖、地区级储能解决方案或建筑工地的能源生产资源优化平衡。TER在未来必须对地区级的优化开放。还必须特别强调技术上过于复杂和不可靠的系统的性能风险。对于许多高科技解决方案，用户甚至没有足够的信息来评估他的系统是否有性能问题。因此，在许多情况下，会有持续的性能不足。这可以通过定期的性能检查和优化来解决。相反，如果设计得当，被动技术是强大的、可靠的、通常具有成本效益的解决方案。一个例子是，外部可移动的遮阳系统与固定的结构性遮阳元件。TER应该包括足够的条款来保持建筑的强大性能。

Climate-neutral goal 2050 of Switzerland



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8. The fast decarbonization of the energy sources of heating systems is becoming a priority 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 heating 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 envelope 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 countries 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 decades, 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, administration and private sector need to be convinced about the urgency of immediate action also for the existing building stock. This requires ramping up the rate of ZEB compliance building renovations as well as planning for replacement of low-performance buildings which cannot be transformed to zero emission buildings at reasonable cost.

8. 供热系统能源的快速去碳化正成为现在实现碳排放目标的优先事项

虽然从整体上看，建筑业去碳化的资源优化战略首先要解决的是建筑的效率潜力，尽量减少损失，其次才是用基于可再生能源的系统取代基于化石燃料的供热系统（这时的等级较低），但当过渡速度变得至关重要时，这可能是不合适的。更换供热系统是一个简单的、具有成本效益的建筑运行阶段的去碳化方式，无论是新建筑还是现有建筑中因寿命终止而更换的现有供热系统。另一方面，改善建筑围护结构在经济上也是可行的，但它是投资密集型的，技术上更加复杂，而且往往会对建筑用户产生暂时的负面影响。
建筑围护结构的技术寿命也明显长于供热系统。因此，在经济上，后者的优化更换率更高。因此，政治上应优先考虑立即实现供热系统的去碳化。

9. 只有在较高的翻新率和优化的替换建筑比例的情况下，才能实现净零排放的建筑总量。

在中国，由于建筑业的高度发展，目前的焦点主要集中在新建筑的能源效率上而瑞士和其他西方国家的例子表明，为了实现净零排放目标，必须在早期阶段解决现有建筑的脱碳问题。考虑到气候变化行动的紧迫性和建筑几十年的技术寿命，对现有建筑的任何重大干预都将产生长期的影响。如果今天的目标水平，例如更换供暖系统的目标定得太低，那么明天就会成为实现目标的障碍。如果现有建筑不符合ZEB的要求，那么从长远来看，所有用于维护现有建筑的投资都有可能被搁浅。需要让政治、行政和私营部门的决策者相信，对现有建筑存量立即采取行动的紧迫性。这需要加快符合ZEB要求的建筑改造速度，并计划替换那些不能以合理成本转变为零排放的低性能建筑。