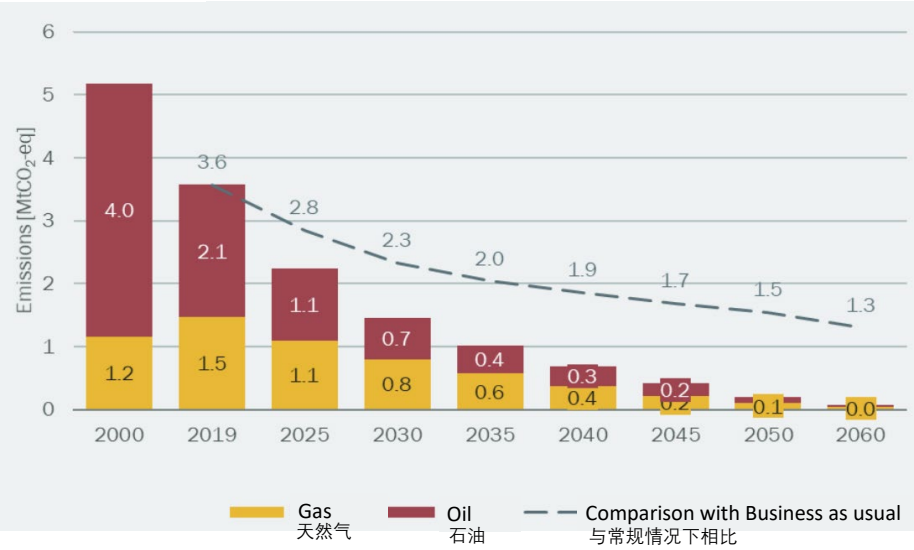
ZERO EMISSION BUILDINGS IN CHINA

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

中国零碳建筑

中瑞合作促进有利气候保护的建筑和社区发展

GHG emissions: 温室气体排放：



The Swiss decarbonization roadmap for 2050
and related policies for the building sector

瑞士 2050 年脱碳路径及建筑行业的相关政策

A project financed by

Implemented by

The generous inner courtyard of Lokstadt in Winterthur, Switzerland will contain lush islands of green.
位于瑞士温特图尔的 Lokstadt 宽敞的内部庭院里有着郁郁葱葱的绿色岛屿
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Version 1.0

The Swiss decarbonization roadmap for 2050 and related policies for the building sector

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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瑞士 2050 年脱碳路径及建筑行业的相关政策

瑞士，苏黎世

本项目由瑞士发展与合作署（简称 SDC，为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: 服务类建筑中与能耗相关温室气体排放的发展状况 (见第 16 页)

中文翻译: 茵态中国团队

01

The Swiss national roadmap to decarbonize the building sector by 2050

“Energy Strategy 2050” for Switzerland

Following the reactor melt down in Fukushima in 2011, the Swiss Federal Council and Parliament decided to phase out Switzerland's use of nuclear energy. This decision, as well as other far-reaching changes in the international energy environment, require a restructuring of the Swiss energy system.

The milestones of the process towards the Energy Strategy 2050[1] were:

- March 2011: As a result of the Fukushima disaster, the Federal Council instructs the Federal Department of the Environment, Transport, Energy and Communications (DETEC) to review the existing energy strategy 2007 and update the existing Energy Perspectives 2035.
- 2012: Adoption of a first package of measures for the Energy Strategy 2050 which aims to increase energy efficiency and promote renewable energies
- 2013: Adoption of the action plan "Coordinated Energy Research Switzerland", a first round of adjustments to Energy Act is decided and proposals for further revision of the energy act are circulated
- 2014-2016: Technical work and parliamentary process for integral revision of the Energy Act
- 2017: Acceptance of revised Energy Act through a public vote
- 2018-2022: Updating of the outdated Energy Perspectives 2035
- 2022: Publication of the Documentation on Energy Perspectives 2050+[2], analysing different scenarios for an energy system that is compatible with the long-term climate goal of net-zero greenhouse gas emissions by 2050 and, at the same time, ensures a secure energy supply.

[1] Source: bit.ly/3VnFAB0

[2] Source: bit.ly/3gBq45P

瑞士 2050 年建筑行业脱碳国家路线图

瑞士的"2050 年能源战略"

2011 年福岛反应堆熔毁后，瑞士联邦委员会和议会决定逐步取消瑞士的核能使用。这一决定以及国际能源环境中其他意义深远的变化，将导致需要对瑞士能源系统进行重建。

瑞士迈向"2050 年能源战略"[3]的里程碑如下：

- 2011 年 3 月：由于福岛核事故，联邦委员会指示联邦环境、运输、能源和通信部（DETEC）审查已有的 2007 年能源战略，并更新已有的 2035 年能源展望
- 2012：通过**《2050 年能源战略》**的第一套措施，旨在提高能源效率和促进可再生能源的发展
- 2013：通过 "瑞士协调能源研究 "行动计划，决定对能源法进行第一轮调整，并分发进一步修订能源法的提案
- 2014-2016：对能源法进行整体修订的技术工作和议会程序
- 2017：修订后的能源法通过了公投程序
- 2018-2022：更新原有的 2035 年能源展望
- 2022：出版**《2050+能源展望》**[4]，分析能源系统的不同发展情景，确保其与 2050 年温室气体净零排放的长期气候目标相一致，同时确保安全的能源供应

[3] 来源: dwz.date/fvP2

[4] 来源: dwz.date/fvP3

The core elements of the Energy Strategy 2050 are as follows:

- Phasing out nuclear energy
- Action plan "Coordinated Energy Research Switzerland" - Swiss Competence Centers for Energy Research
- Innovation promotion:
  - Promotion of pilot, demonstration, and lighthouse projects by the Swiss Federal Office for Energy (SFOE).
  - Support for market introduction of innovative technologies through the action program SwissEnergy
  - Competitive tendering for energy efficient use of electricity.
- Parliamentary initiative 12.400
  - Increase of grid surcharge for promotion of renewable energies to 1.5 Rp./kWh
  - Partial to full reimbursement of grid surcharge for electricity-intensive companies
  - Regulation of self-consumption of Photovoltaic on-site electricity production, providing the right to use on-site produced electricity for self-consumption without attracting grid charges.
- New energy law:
  - Measures to increase energy efficiency
    - Buildings
    - Mobility
    - Industry
    - Appliances
  - Measures to expand renewable energy:
    - Subsidy scheme for promotion of PV systems and replacement of fossil heating system
    - Improvement of legal framework, e.g. providing leaner and faster approval processes
  - Nuclear phase-out:
    - No renewal of general licenses
    - Gradual phase-out of existing nuclear power plants with safety as sole criterion for the shut down-date
  - Measures to adapt the electricity grids to cater for more renewable power production.

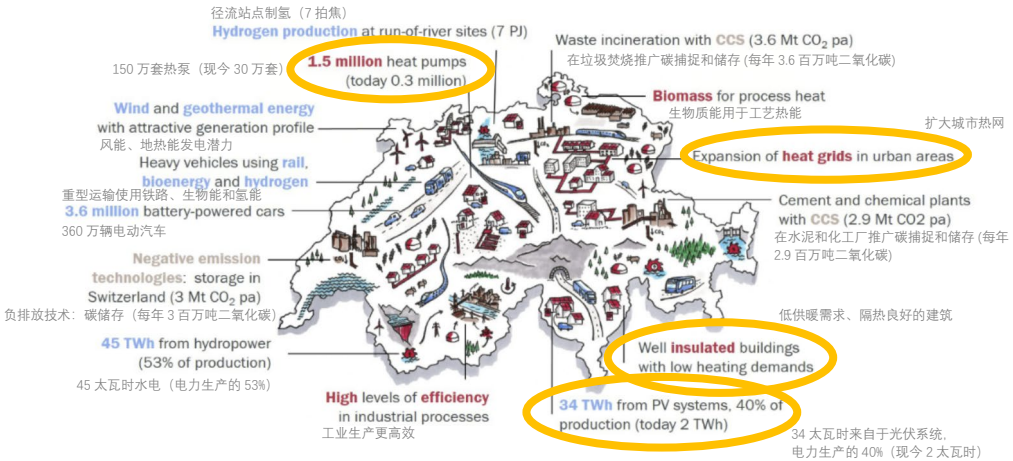

Image: Dina Tschumi. Konsortium Prognos AG, TEP Energy GmbH, Infras AG, Ecoplan AG;
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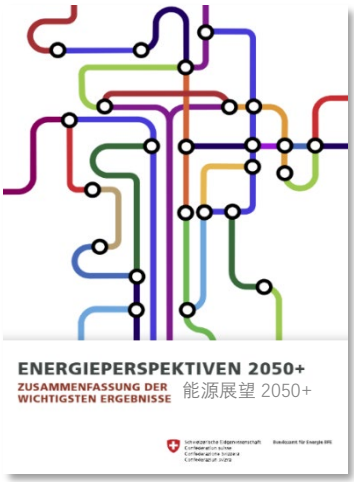
2050 年能源战略的核心内容如下：

- 逐步淘汰核能
- 行动计划 "协调瑞士能源研究" - 瑞士能源研究能力中心
- 促进创新：
  - 由瑞士联邦能源办公室（SFOE）推动试点、示范和灯塔项目
  - 通过行动方案支持创新技术的市场引进
  - 启动能源瑞士计划
  - 为电能的高效利用开展招标竞赛
- 议会倡议 12.400：
  - 为促进可再生能源而将电网附加费提高到 1.5 生丁/千瓦时
  - 为电力密集型公司减免电网附加费
- 规范光伏现场发电自用，允许现场发电自用并免收电网费用
- 新能源法：
  - 引入措施提高以下领域能源效率
    - 建筑
    - 交通
    - 工业
    - 设备
  - 扩大可再生能源的措施：
    - 推广光伏系统和替换化石能源供暖系统的补贴方案
    - 改善法律框架，例如提供更精简和更快速的审批程序
  - 淘汰核电：
    - 不得延长一般许可证
    - 逐步淘汰现有的核电站，将安全作为关闭日期的唯一标准
  - 采取措施调整电网，以提升可再生能源的消纳能力



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© BFE | energy perspectives 2050+: bit.ly/3kF2oMt or dwz.date/fvP3

Long-term scenario "Energy Perspectives 2050+"

Background

The Energy Perspectives represent a central quantitative basis for the energy policy in Switzerland since the 1970ies. They have been completely updated in 2007 and adapted and expanded in 2012 for the Swiss Energy Strategy 2050[5]. In 2020 the most current Energy Perspectives 2050+ (EP2050+) were published, using the latest framework data and technology developments.

The Energy Perspectives 2050+ analyze with different scenarios ("ZERO") how to develop an energy system that is on one hand compatible with net-zero greenhouse gas emissions by 2050 and on the other hand, ensure a secure energy supply. The scenarios are not prophecies, but they show consistent possibilities of how the energy system – i.e. energy demand and supply – could develop under plausible conditions that are assumed to be probable today.

The net-zero scenarios differ in their combination of technologies and the speed of the renewable energy transition in the electricity sector.

However, the variants of the net-zero scenarios do not fundamentally differ in the assumptions applied for the technology types and efficiency measures. The Energy Perspectives 2050+ focus on the scenario "ZERO Basis" as the key variant[6]. While the EP2050+ cover all sectors relevant for the energy domain, our report focuses on the building sector containing buildings of private households as well as the service sector.

We look at the main drivers reducing **energy consumption and greenhouse gas emissions in buildings** according to the EP2050+ including space heating/cooling, warm water heating as well as installations such as ventilation systems, lighting or air conditioning. Moreover, as in the EP2050+ itself, we mainly focus on the "ZERO Basis"[7] scenario for summarizing the main results of the Energy Perspectives 2050+ for the building sector.

[5] The three main pillars of the Swiss Energy Strategy 2050 consist of a nuclear phase-out (following the Fukushima reactor accident in 2011), the expansion of renewable energies and the increase of energy efficiency.

[6] Differences of other net-zero scenarios in comparison to ZERO Basis:
- Scenario ZERO A: more electrification, well thermal networks
- Scenario ZERO B: less electrification and more relevant role of gas (biogas and electricity-based methane
- Scenario ZERO C: less electrification, higher importance of thermal networks, rest with electricity-based fuels

[7] The ZERO Basis variant scenario develops today's foreseeable trends in technological development further into the future. It assumes a high and as early as possible increase in energy efficiency and a significant electrification. Heat grids are gaining importance in urban areas. Synthetic fuels and hydrogen play a subordinate role. Carbon capture and storage is used in waste incineration plants and cement production to reduce fossil CO_2 emissions. Remaining GHG emissions are offset by sinks or by negative emission technologies, which remove CO_2 from the atmosphere and storing it, thereby generating on-balance negative CO_2 emissions. This includes technical removal methods such as the capture and storage of CO_2 from the atmosphere or biomass CCS, but also natural removal methods such as the afforestation of forests.

长期愿景 "能源展望 2050+"

背景

自 1970 年以来，能源展望是瑞士能源政策的核心量化基础。2007 年对其进行了全面更新，并在 2012 年对《2050 年瑞士能源战略》[8] 进行了调整和扩展。2020 年，采用了最新框架数据和技术发展的最新能源展望 2050+（EP2050+）发布。

能源展望 2050+通过不同的规划情景（"零"）分析了如何开发一个能源系统，一方面与 2050 年的温室气体净零排放相适应，另一方面确保安全的能源供应。这些情景不是预言，但它们显示了能源系统——即能源需求和供应——在今天可能出现的合理框架下未来发展的一致可能性。

净零情景在电力部门的技术组合和可再生能源转型速度方面的假设有所不同。然而，在技术类型和能效措施的假设方面，不同路径的净零情景并没有根本的不同。能源展望 2050+作为关键的路径，则重点关注 "零基"方案 [9]。虽然能源展望 2050+涵盖了与能源领域相关的所有部门，但该报告侧重于建筑部门，包括居住建筑以及公共服务建筑。

根据能源展望 2050+，该报告研究了**减少建筑能耗和温室气体排放**的主要驱动因素，包括供暖（冷）、生活热水以及通风系统、照明或空调等设备安装。此外，与能源展望 2050+本身一样，该报告主要关注"零基"[10]方案，以总结能源展望 2050+在建筑领域的主要成果。

[8] 瑞士能源战略 2050 的三大支柱包括逐步淘汰核能（继 2011 年福岛反应堆事故之后），扩大可再生能源和提高能源效率。

[9] 其他净零情景与零基区别:
- 净零情景 A: 更高的电气化水平，良好的供热网络
- 净零情景 B: 电气化水平降低，天然气（沼气和基于电力的甲烷）角色变得更加重要
- 净零情景 C: 电气化水平降低，供热网络重要性提高，其余使用基于电力生产的燃料

[10] 零基情景把可预期的当今技术发展趋势延伸到未来。它假设了尽早且尽可能高水平提高能效和电气化的重要性。热网将在城市领域变得越来越重要。合成燃料和氢气则起到辅助作用。碳捕获和储存措施在垃圾焚烧厂和水泥生产中的推广能减少化石燃料二氧化碳的排放。剩余的温室气体排放则通过碳汇和负排放技术来抵消，这些技术可以从大气中去除二氧化碳并将其储存，从而用来平衡二氧化碳排放。这包括了技术清除法，例如从大气中捕获和储存二氧化碳以及生物质 CCS，也包括自然清除法，如植树造林。

Relevance of the building sector in Switzerland

Buildings are highly relevant in terms of energy demand and greenhouse gas emissions:

- **Final energy consumption**: In 2020, approximately 45% of the final energy consumption in Switzerland took place in the building sector (including space heating, warm water, lighting, building services, ventilation etc.). Only considering space heating – the largest energy consumer in buildings – the final energy demand amounts to 30%.
- Greenhouse gas emissions: In terms of greenhouse gas emissions the building sector accounts for 1/3 of energy related emissions respectively for 1/4 of the total emissions in Switzerland.

Background about electricity in Switzerland

Electricity in Switzerland is mainly generated by hydropower and nuclear power, and with small proportions also with renewable (e.g. PV, wind) and fossil energy sources. Today's electricity mixture is therefore considered nearly free from greenhouse gas emissions. According to the energy strategy 2050 of Switzerland electricity from nuclear power plants will fully be replaced by renewable energies, particularly PV.

Thus, also the future electricity mix will be nearly free from fossil energy sources. Nevertheless, it is still crucial to reduce electricity demand as much as possible through efficiency measures, in order to succeed in the transformation from fossil fuels to electrification of the energy system.

Main drivers of reducing greenhouse gas emissions in the building sector

According to the energy perspectives 2050+ the following three main measures will lead to a reduction of greenhouse gas emissions up to net zero by 2050 in the building sector:

- Increase of energy efficiency (electrical appliances, installations and building envelope)
- Strong electrification of the heating system with decentralized electric heat pumps
- Expansion of thermal networks

While the first measure contributes to a **reduction of energy consumption**, the other two measures include the use of renewable energy sources leading to the **decarbonization of the HVAC system.**

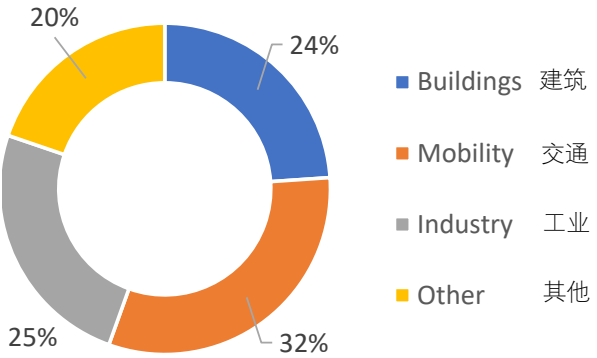
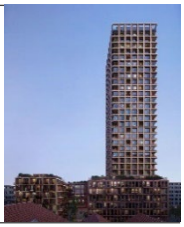


Figure 1: Breakdown of CO_2 emissions in Switzerland
图 1：瑞士各部门的二氧化碳排放量明细表
© Graph by INFRAS. Source: BAFU 2022 | Emissionen von Treibhausgasen nach CO_2-Gesetz und Kyoto-Protokoll, 2. Verpflichtungsperiode (2013–2020), Table 8: bit.ly/3XuIPbK or dwz.date/fvP4

"the three main drivers of reducing greenhouse gas emissions in the building sector are: increase of energy efficiency, electrification of the heating system, expansion of thermal networks."
"建筑领域三个减少温室气体排放的驱动器是：提高能效，供热系统电气化，扩大热网。"



右图: 瑞士温特图尔住宅区的火箭楼是当前世界上规划的最高的木结构住宅楼。

瑞士建筑行业的相关性

建筑行业占总能源需求和温室气体排放的比例较高：

- **终端能源消耗：** 2020 年，瑞士约 45%的终端能源消耗发生在建筑行业（包括供暖、生活热水、照明、建筑服务、通风等）。仅供暖能耗（建筑中最大的能源消耗），就占了终端能源需求的 30%。
- **温室气体排放：** 在温室气体排放方面，建筑行业占能源相关排放的 1/3，占瑞士总排放量的 1/4。

瑞士电力的背景信息

瑞士的电力主要来自于水电和核电，也有小部分来自于可再生能源（如光伏、风能）和化石能源。因此，今天的电力结构被认为几乎不存在温室气体排放。根据瑞士 2050 年的能源战略，来自核电站的电力将完全被可再生能源取代，尤其是光伏。因此，未来的电力结构也将几乎不含化石能源。然而，为了成功实现从化石燃料到能源系统电气化的转变，通过高能效的措施来尽可能地减少电力需求仍然是至关重要的。

减少建筑行业温室气体排放的主要措施

根据能源展望 2050+，以下三项主要措施将使建筑行业的温室气体排放量在 2050 年前减少到净零。

- 提高能源效率（电器、装置和建筑围护结构）
- 利用分布式电热泵实现供暖系统的高度电气化
- 扩大热力网络

第一项措施有助于**减少能源消耗**，其他两项措施包括使用**可再生能源**，进而实现**暖通空调系统脱碳**。

Energy efficiency: Reduction of energy consumption

Space heating accounts for approximately 30% of the final energy consumption of Switzerland and for about 70% of the energy consumption in buildings. In future, the space heating consumption will be reduced due to different measures consisting of energy-saving renovations of existing buildings, replacement of old buildings to new ones, construction of new buildings with high energy efficiency and last but not least more efficient heating systems. The development of efficiency of building envelopes is thus mainly determined by:

- rates of energy-saving renovations of existing buildings
- quality of energy-saving renovations of existing buildings
- standards of new buildings

Today, the **renovation rates** range from 0.8-1% per year. The EP2050+ assume that they will in-crease in future, reaching a peak of about 1.3% in 2040 and steadily decreasing again to below 1%. Limiting factors for a sharp scaling up of renovation rates are the amount of investment required, the natural investment cycles (avoidance of stranded investments) and the limited availability of skilled work force. On the other side, technological and economic progress is expected for the building and insulation materials leading to a higher **renovation quality**.

Therefore, the thermal conductivity of the used building components is reduced by time (U-values = Heat transfer coefficient) and thus, the energy consumption of renovated buildings decreases (Figure 2a). For example, thermal insulation materials with current U-values of 0.35-0.4 W/m^{2}K are expected to be improved in future to about 0.1-0.05 W/m^{2}K. Window glazing (today's U-values mostly around 1 W/m^{2}K) will more and more reach U-values of 0.5 W/m^{2}K thanks to triple glazing with coated glasses and inert gas filling. The energy standards applied in the EP2050+ for renovated and new buildings are derived from the MuKEn 2014. For **new buildings** the standards are based on the norm SIA 380/1. According to the MuKEn 2014 the limit for the heating requirement of renovations is about 50% higher than the requirements for new buildings. Figure 2b shows the expected development of specific heating requirement after full renovation[11] and of newly constructed residential buildings. For the average specific space heat consumption of building stock of service sector buildings a similar dynamic is expected, but at a lower consumption level if compared to residential buildings.

Moreover, in Switzerland space-heating demand will be reduced due to fewer heating degree days caused by climate change. In hot climate regions such as China but also in Switzerland, this will result in increasing cooling demand.

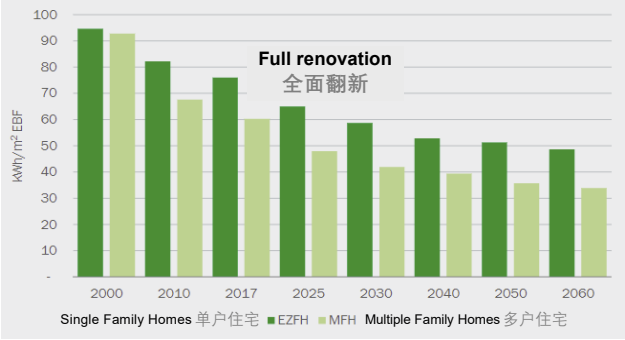


Figure 2a: Evolution of specific heating demand of residential buildings (Scenario ZERO Basis) – full renovation; Values are in kWh per square meter of energy reference area (EBF) /
图 2a：住宅建筑单位面积供暖需求的演变（零基情景）- 全面翻新；单位为每平方米（用能面积）千瓦时

[11] From a technical point of view, it would be possible to achieve lower consumption values than those shown in Figures 2a and 2b. However, this would result in higher material investment costs.

能源效率：降低能耗

建筑供暖约占瑞士终端能源消耗的 30%，约占建筑能源消耗的 70%。未来，由于采取不同的措施，包括对现有建筑进行节能改造，建造高能效的新建筑以及安装高能效的供暖系统等，供暖能耗将会降低。因此，建筑围护结构效率的发展主要取决于：

- 既有建筑的节能改造率
- 既有建筑节能改造的质量
- 新建建筑的标准

如今，瑞士每年的建筑**翻新率**在 0.8-1%之间。能源展望 2050+假设未来这个数值将会增加，并在 2040 年达到约 1.3%的峰值，然后再稳步下降到 1%以下。限制翻新率大幅扩大的因素包括所需的投资额、自然投资周期（避免搁浅的投资）和熟练技术工人数量的不足。此外，建造和绝热材料的技术和经济性能的提高预计将促进建筑达到更高的**翻新质量**。

因此，所使用的建筑构件的传热系数（U 值）随时间的变化会逐步降低，从而降低翻新建筑的能耗（图 2a）。目前 U 值为 0.35-0.4 W/m^2K 的保温材料，未来有望提高到约 0.1-0.05 W/m^2K。窗户玻璃（今天的 U 值大多在 1 W/m^2K 左右）将会越来越多地达到 0.5 W/m^2K，这得益于带涂层玻璃和惰性气体填充的三层玻璃的推广。能源展望 2050+中用于翻新和新建建筑的能源标准源自 MuKEn 2014。对**新建筑**的标准则基于 SIA 380/1 规范。根据 MuKEn 2014 的规定，对翻新建筑供暖要求的限值比新建筑的要求高 50%左右。图 2b 显示了全面翻新后的建筑[12]和新建住宅建筑单位面积供热需求的预期发展情况。公共服务建筑的单位面积供暖能耗，预计会有类似的发展趋势，但如果与住宅建筑相比，其能耗水平则较低。

此外，在瑞士，由于气候变化导致的采暖度日数减少，供暖需求也将降低。但在中国和瑞士的炎热气候区，气候变化将导致未来供冷需求的增加。

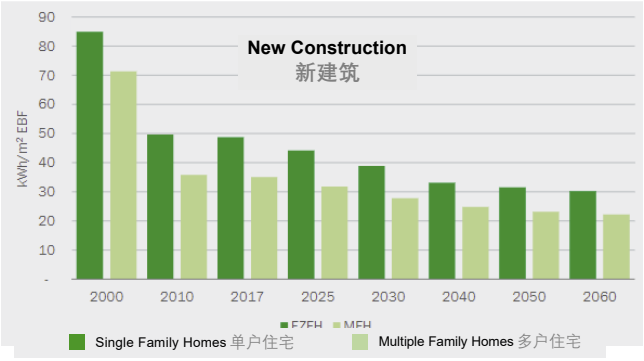


Figure 2b: Evolution of specific heating demand of residential buildings (Scenario ZERO Basis) – new constructions; Values are in kWh per square meter of energy reference area (EBF) /
图 2b：住宅建筑单位面积供暖需求的演变（零基情景）- 新建筑；单位为每平方米（用能面积）千瓦时

[12]从技术角度来看，可以实现比图 2a 和 2b 所示更低的消耗值。然而，这将导致更高的材料投资成本。

"(…) the decarbonization of the heating system is a key area for transforming the building sector towards net zero greenhouse gas emissions."
"(…)供热系统脱碳是建筑行业走向净零温室气体排放的关键点"

On the left: the interior of the innovative wooden construction of the Rocket tower.
左图：瑞士温特图尔市火箭楼的室内创新木构造
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Overall, the energy consumption for space heating in buildings will decrease over time (in total and per capita). Besides space heating, buildings contain other energy consumers:

- **Warm water**: Energy for the heating of water is expected to decrease by about 10% until 2050. In most buildings warm water will be provided over the central heating system becoming more efficient with the increased use of heat pumps. Furthermore, water saving installations will more often be applied.
- **Lighting**: Energy for lighting is expected to decrease by 70% until 2050 thanks to increased efficiency and installation of LED.
- **Air conditioning, ventilation and building services**: While ventilation and building services get more efficient, the demand for cooling in summer will increase. The number of ventilation systems will increase which will be compensated by technical development and increased share of heat recovery. Overall, this leads to a small reduction of energy consumption until 2050.

Decarbonization of the heating system: Heat pumps and thermal networks

Besides the efficiency of a building envelope, the decarbonization of the heating system is a key area for transforming the building sector towards net zero greenhouse gas emissions. According to the EP2050+ the most relevant technologies comprise of heat pumps as well as thermal networks.

The heating structure of the building stock arises from installed heating systems in new buildings and from heating replacements in existing buildings. In 2017 about 80% and 10% of the in-stalled heating systems in new residential buildings were heat pumps and thermal networks, respectively. According to the scenario ZERO Basis gas and oil heating systems are no longer in-stalled in new residential buildings after 2025. In future, newly installed heating systems will al-most only consist of heat pumps (about 70%) and thermal networks (about 30%) (Figure 3).
Also for the heating replacements in existing residential buildings heat pumps and thermal networks will become the most important technologies. Moreover, a small proportion of solar heat will be used as complementary measure to other heating systems and especially for the heating of warm water. While oil heating systems will not be replaced by oil anymore from 2025-2030 on, one to one replacements of gas heating systems will gradually decrease, reaching below 5% after 2040. In the remaining gas heating systems biogas will be used. As the building sector requires relatively low temperatures compared to the industry sector, wood will mainly be applied to produce process heat in industry. For some buildings that cannot be connected to thermal networks (e.g. due to insulation restrictions) heating with wood will also be used in the long-term.

总的来说，建筑供暖的能源消耗（总量和人均）将随着时间的推移而减少。除了供暖，建筑还有其他能源消耗：

- **热水**：到 2050 年，用于生产热水的能源消耗预计将减少约 10%。在大多数建筑中，热水将通过中央供暖系统提供，而随着热泵使用的增加，效率会越来越高。此外，更多的节水装置也将被使用。
- **照明**：由于 LED 灯具广泛的应用和效率的提高和安装，照明的能源消耗预计在 2050 年前预计将减少 70%。
- **空调、通风和建筑服务**：虽然通风效率和建筑服务变得更加高效，但夏季的制冷需求将会增加。技术的和热回收比例的增加可以抵消通风系统数量增加导致的能耗变化。总的来说，这将导致 2050 年之前能源消耗的小幅下降。

建筑行业的供暖体系意味着在新建筑中安装供暖系统和更换既有建筑的供暖系统。2017 年，新建住宅建筑中安装的供暖系统中，约 80%和 10%分别来自于热泵和热网。根据 "零基 "方案，2025 年后，**新建住宅建筑**将不再安装天然气和燃油供暖系统。未来，新安装的供暖系统几乎只包括热泵（约 70%）和热网（约 30%）（图 3）。同时，对于**既有住宅建筑供暖系统的替换**，热泵和热网也将成为最重要的技术。此外，一小部分太阳能供热将作为其他供热系统的补充措施，特别是用于提供热水。从 2025-2030 年开始，燃油供暖系统将禁止一对一替换，且天然气供暖系统的一对一替换也将逐渐减少，2040 年后将达到 5%以下。剩余的燃气供暖系统将使用沼气。建筑部门与工业部门相比需要相对较低的供热温度，木材将主要被用于工业生产过程。对于一些不能连接到热力网络的建筑（例如受保温的限制），将长期使用木材进行供暖。

供暖系统的去碳化：热泵和热网

除了建筑围护结构的效率外，供热系统的脱碳也是建筑行业向温室气体净零排放转变的一个关键领域。根据能源展望 2050+，最相关的技术包括热泵和热网。

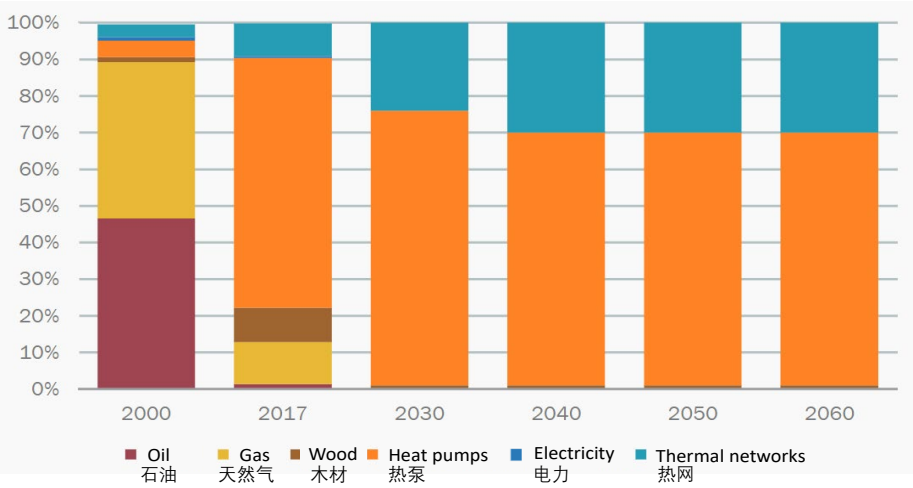


Figure 3: Share of heating systems in newly built Multiple Family Homes (Scenario ZERO Basis)
图 3：新建的多户家庭住宅中供暖系统的比例（零基情景）

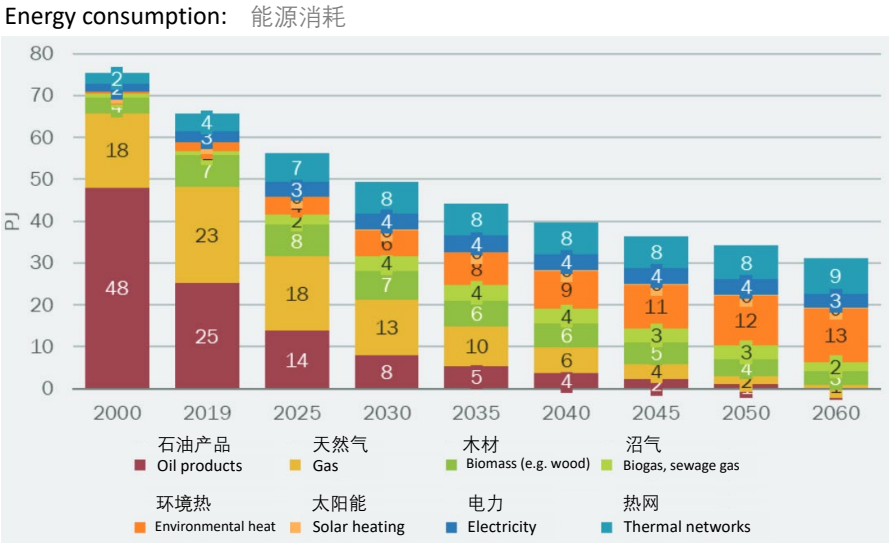


Figure 4a: Development of space heating consumption by energy source in service buildings (Scenario ZERO Basis); Environmental heat and Electricity are used in heat pumps /
图 4a：公共服务类建筑用于供暖的不同能源类型的发展趋势（零基情景）； 用于热泵的环境能和电力

With an annual rate of about 1.3% of the existing floor area the share of new residential buildings is low in relation to the total stock[13]. In combination with the assumed lifetime of 25 years for gas and oil heating systems the **heating structure for the building stock** is only changing slowly (Figure 4a). The combination of efficiency measures (reduction of heat energy consumption) and decarbonization of the heating system leads to the greenhouse gas emission reduction pathway to nearly zero by 2050 in residential buildings (Figure 4b).

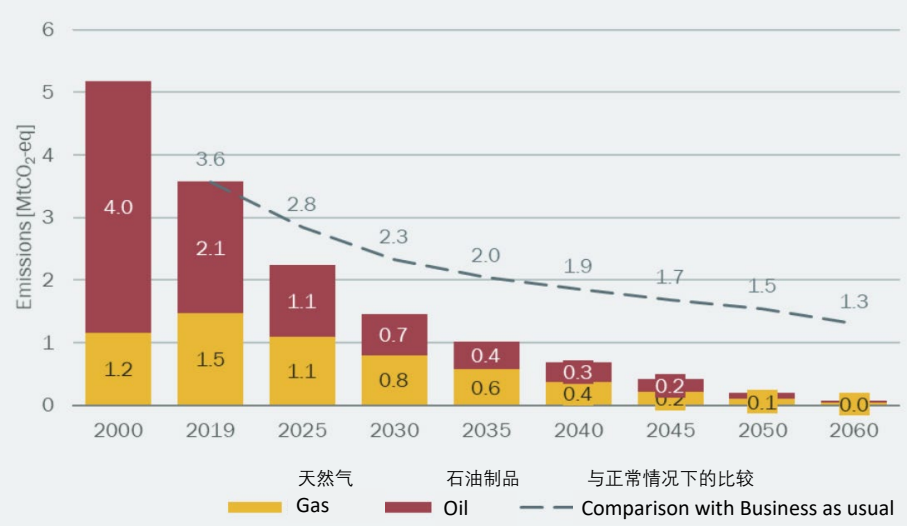
Specific information and comparison with service buildings

The trends described for residential buildings apply for service buildings as well. These trends basically contain:

- **Decarbonization of heating system**: analogous to residential buildings the key technologies used for the heating of service buildings will be heat pumps and thermal networks. However, for service buildings thermal networks, wood biomass and gas/biogas heating systems are of relatively higher importance than for residential buildings (Figure 4a).
- **Improved building efficiency**: like in residential buildings, the renovation of service buildings will lead to a lower heating demand. However, the renovation rates and replacements of service buildings are expected to continue to be higher than in residential buildings. Moreover, the widespread use of ventilation systems increases the energy efficiency of heating. Both factors are leading to a stronger reduction of heat energy demand. According to the EP2050+ the specific heat demand in service buildings will be halved by 2050 (Figure 5).

[13] In 2017 new buildings comprised 1.3% of the building stock. In the long-term the proportion will become smaller (below 1%).

GHG emissions: 温室气体排放



GHG = greenhouse gases 温室气体

Figure 4b: Development of GHG emissions by energy source in service buildings (Scenario ZERO Basis)
图 4b：公共服务类建筑不同能源类型温室气体排放的发展趋势（零基情形）

新建住宅楼的年增长率约为既有建筑面积的 1.3%，相对于总的建筑存量来说比例是很低的[14]。假定燃气和燃油供热系统的使用周期为 25 年，既有**建筑存量的供热结构只**会缓慢变化（图 4a）。如果将高能效改造措施（减少热能消耗）和供热系统的脱碳相结合，到 2050 年可使住宅建筑的温室气体排放达到几乎为零（图 4b）。

具体信息和与公共服务类建筑的比较

住宅建筑呈现的趋势也适用于公共服务类建筑。这些趋势大体包括：

- **供暖系统的脱碳：**与住宅建筑类似，公共服务建筑供暖的关键技术将是热泵和热网。然而，对于公共服务类建筑来说，热网、基于木材的生物质燃料和燃气/沼气供热系统的重要性相对高于住宅建筑（图 4a）。
- **提高建筑效率：**与住宅建筑一样，公共服务建筑的改造将促进供暖需求降低，且公共服务类建筑的翻新率和替代率预计将持续高于住宅建筑。此外，通风系统的广泛使用提高了供暖的能源效率。这两个因素都将导致了用于供暖的能源需求的大幅下降。根据能源展望 2050+，到 2050 年，公共服务类建筑的供暖需求将减少一半（图 5）。

[14] 2017 年新建建筑占建筑存量的 1.3%。长远来看这个占比会减小（低于 1%）。

Decentralized electric heat pumps

Already from 2025 on decentralized heat pumps (air/water, brine/water, and groundwater) will become the most important heating system to produce space heat in buildings. The number of installed heat pumps will increase by a factor of five from today to 2050.
Furthermore, the heat **efficiency of heat pumps** will increase by time due to higher source temperatures (e.g. regeneration of geothermal probes), lower supply temperatures needed in new and renovated buildings as well as improved power system efficiency of the heat pump itself. Depending on the energy source used, the heat efficiency of heat pumps is expected to increase from about 2.8 – 4 (in 2020) to 3.5 – 6 (in 2050).

Thermal networks for heating and cooling at district level

Thermal networks that use renewable energy sources and provide heating (and cooling) to buildings are also a key technology for a comprehensive greenhouse gas reduction in the building sector. Especially in dense settlement areas they will play a significant role, as buildings there can often only be supplied with renewable energies by means of thermal networks. Thermal networks are particularly important for larger apartment houses (covering about 30% of the heating systems in 2050 compared to 10% in single family houses) as well as service buildings. According to the EP2050+ the demand for district heating systems in residential and service buildings will double from 2019 to 2050.

The **energy sources used in thermal networks** today mainly consist of heat from waste incineration plants, industrial waste heat, wood and gas. In future, large heat pumps (mainly use of groundwater, lakes and rivers), but also geothermal energy and biogas will gain of importance for the generation of district heating (Figure 6).

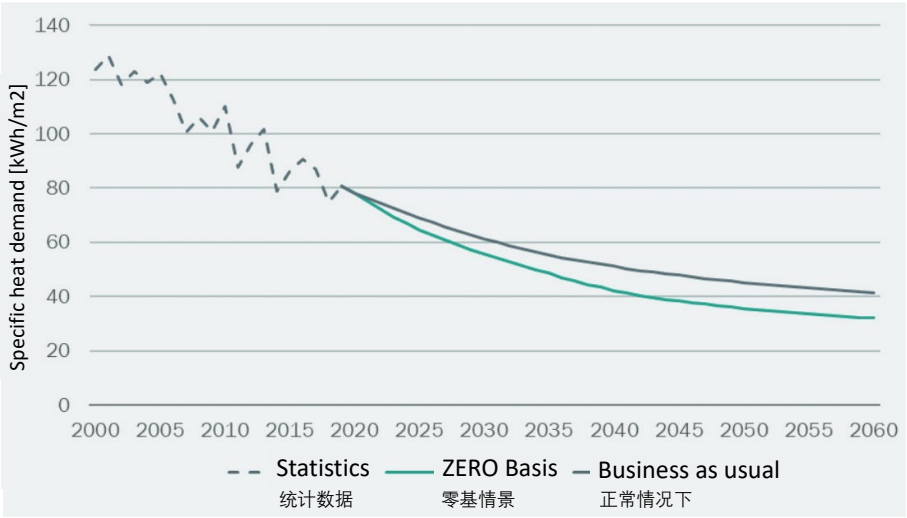


Figure 5: Evolution of specific heating demand of service buildings; values are in kWh per square meter of energy reference area
图 5：公共服务类建筑单位面积采暖需求的趋势图；单位为每平方米（用能面积）千瓦时
© Prognos AG, TEP Energy GmbH, INFRAS AG. Source: BFE | energy perspectives 2050+: bit.ly/3kF2oMt or dwz.date/fvP3

分散式电热泵

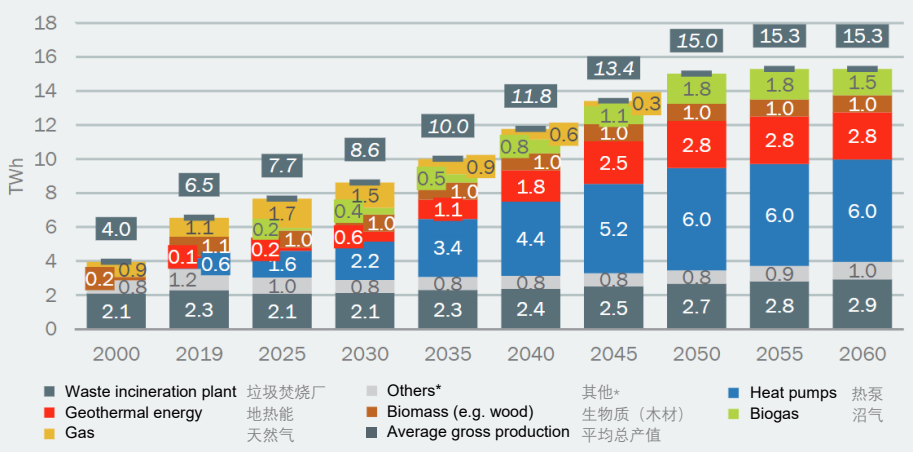
从 2025 年开始，分散式热泵（空气源、水源、地源热泵）将成为建筑行业最重要的供暖系统。从今天到 2050 年，热泵的安装数量将增加五倍。

此外，由于热源温度的提高（如地源热泵技术的革新），新建和翻新的建筑所需的供应温度降低，以及热泵本身电力系统效率的提高，**热泵的效率**将随着时间的推移而提高。根据热源的不同，热泵的热效率预计将从大约 2.8-4（2020 年）增加到 3.5-6（2050 年）。

区域供暖及供冷管网

使用可再生能源并为建筑供暖（冷）的热网也是使建筑全面减少温室气体排放的一项关键技术。特别是在人口密集的居住区，它们将发挥重要作用，因为那里的建筑往往只能通过热力网络来获得可再生能源的供应。热网对于大型公寓住宅（2050 年覆盖约 30%的供暖系统，而单户住宅为 10%）以及公共服务类建筑尤为重要。根据能源展望 2050+，从 2019 年到 2050 年，住宅和公共服务建筑对区域供暖系统的需求将增加一倍。

目前，**热网使用的能源**主要来自垃圾焚烧厂的余热、工业废热、木材和天然气。未来，大型热泵（主要利用地下水、湖泊和河流），以及地热能和沼气将在区域供热中占有重要地位（图 6）。



*others = nuclear energy, waste heat, other renewable energies
*其他 = 核能、废热、其他可再生能源

Figure 6: Thermal networks: Development of energy sources used in thermal networks (Scenario ZERO Basis)
图 6：热网：热网中不同能源供应量趋势图（零基方案）

Conclusion from the EP2050+

According to the EP2050+ it is possible to reach nearly net zero greenhouse gas emissions by 2050 in the building sector. All the necessary technologies are already available today. The biggest challenge lies with scaling up the NET. Scaling up of the markets and research will lead to technical progress and innovation.

Residual emissions come from few remaining gas heating systems. The EP2050+ apply **robust technologies – i.e. mainly heat pumps and heat grids** – that exist already and will be further improved and become more efficient. Electric heat pumps become the most relevant system for the generation of space heat in buildings, while district heating systems are an important supplement, particularly in densely built-up areas and for larger buildings. Electricity-based energy sources (e.g. power-to-gas) are not applied in the building sector.

Moreover, **efficiency measures** in buildings play a crucial role. These consist of increased energy efficiency for electrical devices, equipment and building envelope. Overall, the energy consumption and space heating in buildings will decrease over time (in total and per capita). Electricity consumption will stay constant in total respectively slightly decrease per capita (more electricity is needed for the heat pumps, however, this is nearly compensated with the increased efficiency of the heating systems and the building envelope).

The principal trends of used technologies and efficiency increase also applies for service buildings. In contrast to residential buildings, service buildings will use more thermal networks and biomass and the efficiency of their building envelopes are expected to increase faster.

"(…) it is possible to reach nearly net zero greenhouse gas emissions by 2050"

"(…)2050 年达到近净零温室气体排放是可能的"

On the left: the timber structure of the Rocket tower.
左图：瑞士温特图尔市火箭楼的木结构
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结论

根据能源展望 2050+，到 2050 年，建筑行业的温室气体排放量有可能几乎净零。所有必要的技术如今都已经存在。最大的挑战在于扩大净零排放的规模。市场和研究的扩大将促进技术的进步和创新。

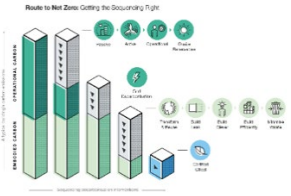
剩余的排放将来自于少数的燃气供热系统。能源展望 2050+应用了**性能稳定的技术（主要是热泵和热网）**，其已经存在，并将进一步改进，变得更加高效。电热泵成为建筑供暖最普遍的系统，而区域供热系统是一个重要的补充，特别是对于高密度开发的区域和大型建筑。在能源展望 2050+中，基于电力的能源（如电转气）并没有应用于建筑领域。

此外，建筑的**节能策略**也发挥了关键作用。这些措施包括提高电气设备、暖通设备和建筑围护结构的能源效率。总的来说，建筑的能源消耗和空间供暖将随着时间的推移而减少（总量和人均）。电力消耗将保持不变，人均消耗将略有下降（热泵需要更多的电力，然而，这几乎被供暖系统和建筑围护结构的效率提高所补偿）。

所用技术和效率提高的主要趋势也适用于公共服务类建筑。与住宅建筑相比，公共服务类建筑将使用更多的热力管网和生物质能，其建筑围护结构的效率预计将更快地提高。

"(…) it is possible to reach nearly net zero greenhouse gas emissions by 2050"
"(…)2050 年达到近净零温室气体排放是可能的"

On the right: decarbonization pathway
右图：脱碳路径



Building related key features of the Swiss CO_2 act 2021

In 2020 the Swiss Parliament agreed on a revised Federal Act on the Reduction of Greenhouse Gas Emissions (hereafter CO_2 act) which would have strengthened the Swiss climate policy and brought the policy instruments in line with the international commitments of the Paris Agreement. However, the act was put under a public referendum and was rejected by the Swiss electorate in the public vote on 13 June 2021. As the planned elements in the proposed act still can be of interest for the Chinese counterparts, a summary is given below. The focus is on the building sector related instruments.

Instrument	Description	Relevance for sector
Mandatory CO_2 limits for buildings (new)	New buildings may no longer emit CO_2 from fossil fuels, which is already standard today. Existing buildings are allowed to continue to emit CO_2 unless the heating system is replaced. In this case an upper limit of 20 kg of CO_2 emissions per square meter of living space per year has to be respected from. The value is reduced by five kg of CO_2 in five-year steps.	The instrument includes a mandatory upper limit for CO_2-emissions of existing buildings which becomes effective, whenever the heating system is replaced. In well insulated buildings or buildings with renewable based heating systems, the upper limit is anyhow respected. In all other cases, efficiency measures or conversion to a renewable based heating system or connection to a district heating system is required. If measures such as the installation of a heat pump are required for compliance, the owners can apply for financial support from the climate fund.
National CO_2 tax (continued and strengthened)	Since 2008, the federal government levies a CO_2 tax on fossil fuels such as heating oil, natural gas and coal in form of an incentive tax. Those who cause an above-average amount of CO_2 pay more, others less. With the revised law the Federal Counsel would have been authorized to raise the levy to a maximum of 210 CHF per tonne of CO_2 (approx. 0.5 CHF per litre of heating oil, approx. 0.042 CHF per kWh of natural gas). However, an increase from today's tax level of 120 CHF per tonne only is made if CO_2 emissions do not decrease sufficiently. Two thirds of the money is being distributed back to the population and the economy. The rest flows into the climate fund for financing climate mitigation actions.	The levy makes it financially worthwhile for building owners and tenants to use less heating oil or to heat with a heat pump, wood or solar energy. Households that do not heat with oil or natural gas pay no CO_2 tax at all.

2021 年瑞士二氧化碳法案中与建筑相关的主要特点

2020 年，瑞士议会就修订后的《联邦减少温室气体排放法》（以下简称《二氧化碳法案》）达成一致，该法案将加强瑞士的气候政策，使政策工具与《巴黎协定》的国际承诺保持一致。然而，该法案在 2021 年 6 月 13 日的公众投票中被瑞士选民拒绝。由于拟议法案中的计划内容仍能引起中国同仁的兴趣，下文将重点对与建筑行业有关的工具进行总结。

工具	描述	行业相关性
对建筑采取强制性的二氧化碳排放限制(新)	现有的标准是：新建建筑不得再因使用化石燃料而排放二氧化碳，而既有建筑则允许继续排放二氧化碳，除非更换了供暖系统。在这种情况下，也必须遵守每平方米每年 20 公斤二氧化碳的排放上限。该值将以每五年为时间单位，每次减少 5 公斤的二氧化碳排放。	该文件包括对既有建筑二氧化碳排放的强制上限，只要其更换了供暖系统则即刻生效。对于隔热性能良好的建筑或采用可再生供暖系统的建筑，无论如何都要遵守该上限。在所有其他情况下，需要采取能效措施或转换为可再生的供热系统或连接到区域供热系统。如果需要安装热泵等措施，业主可以向气候基金申请资金支持。
国家二氧化碳税法(继续并强化)	自 2008 年以来，联邦政府以税收的形式对取暖燃油、天然气和煤炭等化石燃料征收二氧化碳税。超过平均二氧化碳排放量的人要支付更多的钱，而其他人则少付。根据修订后的法律，联邦委员会将被授权将征税额度提高到每吨二氧化碳最高 210 瑞士法郎（每升取暖燃油约 0.5 瑞士法郎，每千瓦时天然气约 0.042 瑞士法郎）。然而，只有在二氧化碳排放量没有充分减少的情况下，才会从现在每吨 120 瑞士法郎的税收基础上增加。三分之二的税收重新分配给人民和用于经济，其余的则分配给气候补贴，用于资助缓解气候变化的活动。	征税使业主和租户减少使用燃油取暖，进而使用热泵、木材或太阳能取暖，这在经济性方面是有益的。不使用石油或天然气取暖的家庭基本上不需要支付二氧化碳税。

Climate fund (new, encompassing also various existing instruments)	The proposed climate fund promotes climate-friendly investments such as financing of district heating networks or charging stations for electric cars or the procurement of electric buses. In the case of buildings, the fund was to support building refurbishment for lowering energy consumption and installation of CO_2-free heating systems.	The Climate Fund ensured the continuation of the tried and tested federal and cantonal buildings programme and the existing technology fund. The Swiss buildings programme is today a major driver in the market for building refurbishment and renewable energy based retrofit of heating systems. The subsidy granted is typically between 20 to 50% of the total investment cost. (www.dasgebaeudeprogramm.ch).
Compensation obligation of fuel importers (continued and strengthened)	Importers of petrol and diesel must offset part of the CO_2 emissions of the imported fuels with climate mitigation measures. From 2025, at least 20 percent of CO_2 emissions must be offset by projects in Switzerland. The rule set for the offset projects is similar to the rules for projects under the Clean Development Mechanism (CDM) under the Montreal Protocol. The revised law sets an upper limit for the surcharge to consumers which would have been raised from 0.05 CHF per liter of petrol or diesel today to a maximum of 0.12 CHF per liter.	In the building sector, existing offset projects and programmes under the compensation obligation provide finance for e.g. replacement of existing fossil fuel based heating system with renewable based ones, the setup or extension of district heating systems, end user efficiency measures such as efficient water taps, or intelligent controllers for heating systems. The subsidy granted is typically between 20 to 60% of the total investment cost.

Table 1: Instruments of Swiss CO_2 act related to the building sector (Status 2021)

气候补贴 (新，也包括各种现有的工具)	拟议的气候补贴是为了促进气候友好型投资，如资助区域供热网络或电动汽车的充电站或采购电动巴士。就建筑而言，该补贴是为了支持建筑翻新以降低能源消耗和安装无二氧化碳排放的供热系统。	气候补贴确保继续执行经过试验和测试的联邦和州层面的建筑项目，以及现有的技术型补贴。如今，瑞士的建筑项目已经成为市场上进行建筑翻新和实施基于可再生能源的供暖系统改造的主要驱动力。所提供的补贴通常为总投资成本的 20%至 50%。 (www.dasgebaeudeprogramm.ch)
燃料进口商的补偿义务 (继续并强化)	汽油和柴油的进口商必须用气候减缓措施抵消部分进口燃料引发的二氧化碳排放。从 2025 年起，至少有 20%的二氧化碳排放必须由瑞士的项目来抵消。为抵消项目设定的规则与《蒙特利尔议定书》框架下的清洁发展机制（CDM）的项目规则类似。修订后的法律为消费者的附加费设定了上限，将从现在每升汽油或柴油 0.05 瑞士法郎提高到最高每升 0.12 瑞士法郎。	在建筑部门，根据补偿义务为现有的抵消项目和方案提供资金，例如用可再生的供暖系统替换现有的化石能源供暖系统，建立或扩大区域供暖系统，提高终端用户的能源效率，如高效水龙头，供暖系统的智能控制等。给予的补贴通常在总投资成本的 20-60%之间。

表 1：瑞士二氧化碳法案中与建筑行业相关的工具（2021 年状况）

02

The Swiss legal, economic, educational and information instruments for the implementation of the energy strategy in the building sector

National level

Legal

The national level is of lesser importance regarding legal requirements for energy in buildings. In Switzerland, this is mainly the responsibility of the Cantonal (State) level.

Instrument	Regulator	Summary
Constitution	n.a.	Art 89 BV, Abs. 4 delegates regulation for energy consumption of buildings to the Cantons
Minimum Energy Performance Standards and energy labels for electrical devices and technical installations in buildings[15]	SFOE	MEPS and energy labels for a wide range of applications (e.g. lights, household appliances, electronic equipment, electrical machines) MEPS for water heaters, hot water storage appliances, ventilation systems
Compensation obligation for importers of fossil transport fuels[16]	SFOE	A certain share if the emissions from burning imported fossil transport fuels has to be compensated through projects implemented in Switzerland. This also includes building efficiency measures and heating system retrofit.

Table 2: Legal instruments at national level
© Table INFRAS. Source: various sub-pages of SFOE and FOEN | Web: bit.ly/3OvrJq6 (SFOE) and bit.ly/3V3VIb8 (FOEN)

[15] Source: dwz.date/fvP9
[16] Source: dwz.date/fvPA

瑞士实施建筑领域能源战略的法律、经济、教育和信息方面的工具

国家层面

法律

在瑞士，国家层面上的建筑能源相关法律要求的重要性比较低，这主要是地方上，如各联邦（州）层面的责任。

工具	监管机构	总结
宪法	n.a.	第 89.4 条将建筑能源消耗的规定下放给各州。
建筑内电气设备和技术安装的最低能效标准及能源标签 [17]	瑞士联邦能源办公室	最低能效标准和能源标签的应用范围很广（如灯、家用电器、电子设备、电机）。 用于热水器、热水储存设备、通风系统的最低能效标准。
对化石运输燃料进口商的补偿义务 [18]	瑞士联邦能源办公室	如果是燃烧进口化石运输燃料所产生的排放量，必须在瑞士实施的项目予以补偿（见 2.1.2 节中的补偿项目）。这一要求也包括在建筑能效措施和供暖系统改造中。

表 2：国家层面上的法律工具
© Table INFRAS. Source 资料来源: various sub-pages of SFOE and FOEN | Web: dwz.date/fvP8 (SFOE) and dwz.date/fvP7 (FOEN)

[17] 来源：dwz.date/fvP9
[18] 来源：dwz.date/fvPA

Economic

In Switzerland, the national level is important when it comes to financing of energy and climate related activities for buildings. The reason being that levies and taxes on energy are regulated at the national level. There are Cantons which collect additional taxes on electricity (e.g. Basel-Stadt). One share of the funds is redistributed to the households and industries, the other share is used for investment support to renewable heating systems and efficiency measures in buildings.

Instrument	Implementer	Summary
CO_2 levy[19]	FOEN	CO_2-intensitiy related levy on fossil heating fuels. At date, the levy is at 120 CHF per Tonne of CO_2eq.
Building subsidy program[20]	FOEN / Cantons	Subsidies for efficiency improvement and renewable heating systems. In 2020, the equivalent amount of 40 CHF per capita was paid out. The funding is through the CO_2 tax and the Cantons.
Compensation projects[21]	FOEN	Performance based funding system for project reducing GHG emissions in Switzerland. There is a wide range of applicable project types. The methodology used is closely related to approach for Clean Development Mechanism (CDM) projects, with adaptation and simplification for the Swiss compensation market.
Grid surcharge for the promotion of electricity from renewable energies[22]	SFOE / Pronovo	A levy of 0.023 CHF / kWh is applied on electricity. The funds are used for promoting renewable electricity generation.
One-off investment grant for Photovoltaic systems[23]	SFOE / Pronovo	For PV systems on buildings a one-off payment is granted, covering up to 30% of total investment cost. Funding source is the national grid surcharge (see above).
Program ProKilowatt[24]	SFOE / ProKilowatt	For uneconomical electricity saving projects or programs, a grant is given which covers up to 30% of total investment cost. Every year there are three to four competitive auctioning rounds where projects /programs can apply. Selection of projects / programs is based on the requested funding level in CHF per kWh of savings. Funding source is the national grid surcharge (see above).

Table 3: Economic instruments at national level
© Table INFRAS. Source: various sub-pages of SFOE and FOEN | Web: bit.ly/3OvrJq6 (SFOE) and bit.ly/3V3VIb8 (FOEN)

[19] Source: dwz.date/fvPB
[20] Source: dwz.date/fvPC
[21] Source: dwz.date/fvPD
[22] Source: pronovo.ch/de/foerderung/evs/herkunft-foerdergelder/
[23] Source: pronovo.ch/de/foerderung/einmalverguetung-eiv/
[24] Source: www.prokw.ch/de/

经济

对于瑞士而言，国家在建筑领域的能源和气候相关活动的融资起着非常重要的作用。因为能源方面的征税和纳税是由国家层面进行管理的，其中有些州对电力征收附加税（如巴塞尔州）。税收所得的一部分资金被重新分配给家庭和工业，另一部分则用于投资支持可再生能源供暖系统和建筑的节能措施。

工具	执行机构	总结
征收二氧化碳税 [25]	瑞士联邦环境署（FOEN）	对化石供热燃料征收与二氧化碳强度相关的税。目前，每吨 CO_2 当量征收 120 瑞士法郎。
建筑补贴项目 [26]	瑞士联邦和州环境署（FOEN / Cantons）	为提高建筑能源效率和推广可再生能源供暖系统提供补贴。2020 年，人均支付了相当于 40 瑞士法郎的金额。该资金是通过二氧化碳税和各州提供的。
补偿项目 [27]	瑞士联邦环境署（FOEN）	对瑞士减少温室气体排放的项目实行基于绩效的资助制度。适用的项目类型很广泛。使用的方法与清洁发展机制（CDM）项目的方法密切相关，并针对瑞士的补偿市场进行了调整和简化。
为促进可再生能源发电而征收的电网附加费 [28]	瑞士联邦能源办公室（SFOE）/ Pronovo (Pronovo 是被认证的机构，负责处理联邦政府的可再生能源支持计划。)	对电力征收 0.023 瑞士法郎/千瓦时的税。这些资金将用于促进可再生能源发电。
光伏系统的一次性投资补助 [29]	瑞士联邦能源办公室（SFOE）/ Pronovo	对建筑用光伏系统给予一次性补贴，最高可覆盖总投资成本的 30%。资金来源是电网附加费（见上文）。
“每千瓦”项目 [30]	瑞士联邦能源办公室/“每千瓦”项目组（SFOE / ProKilowatt）	对于经济性较差的节能项目或计划，给予补贴，最高可涵盖总投资成本的 30%。每年有三到四轮项目竞赛，项目/计划可以申请。项目/计划的选择是基于节电每千瓦时所需的资金水平，以瑞士法郎计算。资金来源是电网附加费（见上文）。

表 3: 国家层面的经济工具

[25] 来源：dwz.date/fvPB
[26] 来源：dwz.date/fvPC
[27] 来源：dwz.date/fvPD
[28] 来源：pronovo.ch/de/foerderung/evs/herkunft-foerdergelder/
[29] 来源：pronovo.ch/de/foerderung/einmalverguetung-eiv/
[30] 来源：www.prokw.ch/de/

Education and information

The development of the entire energy sector is proceeding rapidly and there is also a great need for building renovation. These challenges require a sufficient number of competent specialists who are actively involved in this dynamic field. High quality and easily accessible primary and continued vocational training are therefore of paramount importance for reaching a zero-emission building stock. The national program SwissEnergy integrates, coordinates and partly funds the sector-wide activities. Experience has shown, that for achieving a relevant impact the activities need to be well coordinated and integrated with activities of other relevant stakeholders in the sector like trade and professional associations, lobbying groups or training institutions. Only a multi-stakeholder approach can ensure that the know-how reaches down to the level of construction and renovation of buildings and efforts of the different levels are in line and form synergies.

As energy use in buildings highly depends on the individual behaviour of the building users and investment decisions are ultimately made by the building owners, information and awareness raising for the public and specifically for the building owners has a high relevance. In Switzerland these activities are also supported by the program "SwissEnergy".

Instrument	Implementer	Summary
National information website on primary and continued vocational training in the building sector[31]	SwissEnergy, SFOE	Provides links to training opportunities for building specialists and professionals.
Program "Education campaign for buildings"[32]	SwissEnergy, SFOE	In order to successfully implement the energy and climate strategy in the building sector, more competent specialists are needed. With the education campaign, the industry wants to ensure that sufficient qualified specialists will be available in the future. In a broad stakeholder dialogue together with the industry and educational institutions a roadmap and specific measures to be implemented was developed.
Program "Renewable Heating"[33]	SwissEnergy, SFOE	Platform for information on heating retrofit. As part of the program a free of cost on-site consultancy is provided to building owners. The consultancy provides a broad overview on available technology options and costs as well as an optimized integral approach for building retrofit, based on the object specific situation.
School teaching aids [34]	SwissEnergy, SFOE	Provision of school level teaching aids and information on energy and climate as a teaching topic.
National energy newspaper, fact sheets and success stories on energy use in buildings[35]	SwissEnergy, SFOE	The program Swiss Energy provides a wide range of information material for building owners and tenants. This also includes a printed newspaper with information and success stories which twice a year is sent to all building owners in Switzerland.
Coordination of building labels on energy and environmental (Zero emission buildings)[36]	SwissEnergy, SFOE	Institutions for green building labels receive funding through SwissEnergy. The Swiss Federal office of Energy is coordinating the different labels available at the national scale. The label family includes differentiated labels with focus on energy and climate, indoor quality and integral sustainability.

Table 4: Educational and information instruments at national level (non-exhaustive)
© Table INFRAS. Source: various sub-pages of SFOE | Web: bit.ly/3OvrJq6

[31] Source: www.energieschweiz.ch/bildung/weiterbildungsangebote/
[32] Source: www.energieschweiz.ch/bildung/bildungsoffensive-gebaeude/
[33] Source: erneuerbarheizen.ch/
[34] Source: www.energieschweiz.ch/bildung/unterrichtsthema/
[35] Source: www.energieschweiz.ch/pub/
[36] Source: www.energieschweiz.ch/gebaeude/gebaeudelabels/

教育和信息

整个能源行业正在迅速发展，并对建筑的翻新有很大的需求。这些挑战需要有足够数量的、有专业能力的人员积极参与到这个充满活力的领域中。因此，高质量的、容易获得的初级和持续的职业培训对于实现建筑领域的零排放是至关重要的。国家项目 SwissEnergy（瑞士能源）旨在整合、协调并部分资助整个行业的活动。经验表明，为了实现对整个行业的影响，这些活动需要与该行业的其他利益相关方（如贸易和专业协会、游说团体、培训机构）的活动进行充分协调和整合。只有一个多利益相关方的模式才能确保技术知识深入到建筑的建造和翻新过程中，不同层面的奋斗目标是一致的，且可以形成协同效应。

由于建筑的能源使用在很大程度上取决于建筑使用者的个人行为，且投资决定最终是由建筑所有者提出，因此对公众，特别是对建筑所有者的信息和意识的提高具有很大的意义。在瑞士，这些活动也得到了 "SwissEnergy "项目的支持。

工具	执行机构	总结
关于建筑行业初级和继续职业培训的国家信息网站 [37]	瑞士能源，瑞士联邦能源办公室	为建筑专家和专业人士提供培训机会的平台。
"建筑教育倡议"项目 [38]	瑞士能源，瑞士联邦能源办公室	为了在建筑领域成功实施能源和气候战略，需要更多有能力的专家。通过教育倡议项目，行业希望确保在未来有足够的合格专家。在与工业界和教育机构一起进行的广泛的利益相关方对话中，制定了路线图和要实施的具体措施。
"可再生能源供暖 "项目 [39]	瑞士能源，瑞士联邦能源办公室	供暖改造的信息平台。作为该计划的一部分，向建筑业主提供免费的现场咨询。该咨询提供了关于可用技术选择和成本的广泛概述，以及根据业主的具体情况，为建筑改造提供优化的整体方案。
学校教育协助 [40]	瑞士能源，瑞士联邦能源办公室	提供学校层面的教具和信息，将能源和气候作为一个教学主题。
国家能源报纸，关于建筑能源使用的概况介绍和成功案例 [41]	瑞士能源，瑞士联邦能源办公室	瑞士能源项目为建筑业主和租户提供了广泛的信息材料。这也包括一份印有信息和成功案例的报纸，每年两次寄给瑞士的所有建筑业主。
协调能源和环境方面的建筑标签（零排放建筑）[42]	瑞士能源，瑞士联邦能源办公室	绿色建筑标签的机构通过 SwissEnergy 获得资金。瑞士联邦能源办公室正在协调全国范围内的不同标签。该系列标签包括专注于能源和气候、室内质量和整体可持续性的差异化标签。

表 4：国家层面的教育和信息措工具（待完善）

[37] 来源：www.energieschweiz.ch/bildung/weiterbildungsangebote/
[38] 来源：www.energieschweiz.ch/bildung/bildungsoffensive-gebaeude/
[39] 来源：erneuerbarheizen.ch/
[40] 来源：www.energieschweiz.ch/bildung/unterrichtsthema/
[41] 来源：www.energieschweiz.ch/pub/
[42] 来源：www.energieschweiz.ch/gebaeude/gebaeudelabels/

Cantonal level

Legal

In Switzerland, regulation and enforcement of building construction lies mainly with the Cantons.

Instrument	Regulator	Summary
Technical regulation on energy use and CO_2-emissions of buildings	Building departments of the cantonal administration	Each Canton is responsible for issuing its technical regulation on energy and emissions. A wide reaching but not full harmonization is achieved through the "Sample regulations of the Cantons on energy in buildings" (MuKEn[43]) which are issued by the assembly of the energy directors of the Cantons (EnDK[44]).
Accreditation of private building control staff	Cantons	Some cantons make use of accredited private sector staff for design and construction compliance checks. The persons must be accredited by the cantonal building authority.

Table 5: Legal instruments at cantonal level
© Table INFRAS. Source: | Web : bit.ly/3Ynf4Kd

[43] Source: www.endk.ch/de/energiepolitik-der-kantone/muken
[44] Source: www.endk.ch/de

联邦州层面

法律

在瑞士，建筑施工的监管和执法工作主要由各州负责。

工具	监管机构	总结
建筑能源使用和二氧化碳排放的技术法规	各州政府的建筑部门	各州政府的建筑部门负责发布其能源和排放的技术法规。通过各州能源主管部门(EnDK[45])发布的 "各州建筑能源条例样本"(MuKEn[46])，实现了各州之间广泛但不完全的协调统一。
建筑质量监控人员的认证	联邦州	一些联邦州利用经认证的企业人员进行设计和施工的检查。这些人员必须得到州建筑当局的认可。

表 5：州层面上的法律工具

[45] 来源：www.endk.ch/de/energiepolitik-der-kantone/muken

[46] 来源：www.endk.ch/de

Economic

In co-ordination and co-financing with the national government, all twenty-six Cantons in Switzerland implement tax discounts for investments in energy performance of buildings as well as subsidy schemes for energy efficient and low carbon emission buildings. The subsidy mainly addresses retrofit of existing buildings, as new buildings are adequately covered through the technical regulation and the available labels which provide market incentives.

The financial support provides strong incentives to building owners to go beyond the legally required and market standard ambition level for making their building energy efficient and low emission. The level of subsidy provided is typically in the order of 20 – 50% of the total investment cost, depending on the Canton and the specific measure.

Instrument	Implementer	Summary
Building subsidy program[47]	Cantons / FOEN	Subsidies for efficiency improvement and renewable heating systems. In 2020, the equivalent amount of 40 CHF per capita was paid out. The Cantons are responsible for administering the subsidies. The funding is through the national CO_2 tax and the Cantons. Each Canton puts an individual focus for the supported measures depending on their local priorities. Some Cantons provide additional funding for measures which are not supported at the national level.
Tax discounts on investments for energy performance of buildings	Cantons / National Tax Authority	In most Cantons, investments related to decarbonization and energy efficiency of buildings benefit from a tax discount. The tax rules allow to deduct the investment amount from the income on annual basis. Recently, efforts have started to revise the tax rules, so that it will be possible to spread deduction of the investments from a specific year to multiple tax periods. This will ensure that also large investments (higher than the total annual income of the investor) still receive the full incentive.

Table 6: Economic instruments at cantonal level

[47] Source: www.dasgebaeudeprogramm.ch/

经济

在与中央政府的协同和共同资助下，瑞士 26 个联邦州都对建筑能效投资以及节能和低碳排放建筑的补贴计划实施税收优惠制度。补贴主要针对既有建筑的改造，因为新建筑通过技术法规和提供市场激励的可用标签已充分覆盖。财政支持有力地激励建筑业主实现高于法律要求和市场标准的能效水平，使建筑更加节能，更加低碳。提供的补贴通常为总投资成本的 20-50%，具体取决于所在州和措施本身。

工具	执行机构	总结
建筑补贴计划 [48]	瑞士联邦及州环境署	为提高建筑效率和可再生能源供暖系统提供补贴。2020 年，人均补贴额度为 40 瑞士法郎。各州负责管理这些补贴，资金来源于国家二氧化碳税和各州。每个州都会根据当地的优先事项，重点支持若干措施。此外，一些州会为那些没有得到国家支持的措施提供额外的补贴。
建筑能源性能投资的税收折扣	国家和州税务局	在大多数州，与建筑脱碳和节能有关的投资可以享受税收优惠。税收政策允许每年从收入中扣除投资金额。最近，税收规则已经开始修改，以便能够将投资的扣除从一个特定的年份扩展到多个税收期。这将确保大额投资（高于投资者的年收入总额）也能得到充分的激励。

表 6：州层面上的法律工具
© Table INFRAS. Source: INFRAS

[48] 来源：www.dasgebaeudeprogramm.ch/

Education and information

The Cantons play an important role in informing building owners and the public on energy issues in buildings. This is primarily through targeted energy consultancy, information along the building approval process, after work information events and specific training courses on technical issues and correct implementation of standards.

Instrument	Implementer	Summary
Vocational training schools	Various	Vocational training schools are operated by the Cantons to provide primary and continued vocational training in various fields related to buildings and renewable energies.
Public energy consultancy	Cantons	Each Canton has an energy office or energy agency which provides basic information and low level and industry independent consultancy for building owners.
Large range of different information and awareness event	Various	The Cantons run different formats for providing energy and sustainability related information to building owners and building sector specialists.

Table 7: Educational and information instruments at cantonal level (non-exhaustive)

教育与信息

各州在向建筑业主和公众宣传建筑能源问题方面发挥了重要作用。这主要是通过有针对性的能源咨询，建筑审批过程中的信息，工作后的信息活动以及在技术方面和标准执行层面具体的培训课程。

工具	执行机构	总结
职业培训学校	多方	职业培训学校由各州开办，针对建筑和可再生能源有关的各个领域提供初级和继续职业培训。
公共能源咨询	州	每个州都有一个能源办公室或能源机构，为建筑业主提供基本信息和基本的、独立的行业咨询。
大范围的信息和宣传活动	多方	各州以不同的形式向建筑业主和建筑行业专家提供能源和可持续发展的相关信息。

表 7：国家层面的教育和信息措施（待完善）

03

The Swiss key stakeholders for the implementation of the energy strategy in the building sector

National level

Stakeholders at the national level include Government Authorities as well as private organizations. The key stakeholders and their respective role are summarized in table 8.

There is close interaction between the national, cantonal (State), municipal level as well as with the private sector stakeholders.

瑞士在建筑领域实施能源战略的主要利益相关方

国家层面

国家层面的利益相关方包括政府主管部门和私营组织。主要的利益相关方和他们各自的作用如下表 8 总结所示

国家、联邦（州）、城市层面与私营领域利益相关方之间存在着密切的互动。

Stakeholder	Role
Swiss Federal Office for Energy[49] SFOE	• Energy related acts and ordinances • National support program Energie Schweiz (Energy Switzerland) • Statistical data and reporting on energy use and production • Public information related to e.g. energy in buildings • Coordination of building related national research programs • Coordination of international activities, e.g. with International Energy Agency IEA • Long-term energy scenarios (e.g. EP2050+) • Studies on specific energy related topics • Coordination of building labels • Coordination of subsidy programs for buildings (in co-operation with FOEN).
Federal Office for Environment[50] FOEN	• Climate related acts and ordinances • Statistical data and reporting on greenhouse gas emissions • Studies on specific climate related topics • Emission related energy taxes
Association "Energiestadt"[51] (Energy Cities)	• Competence center for local energy and climate policy in Switzerland, bringing together Swiss municipalities, from large cities to small mountain villages for information sharing and collective action through continuous commitment. • Continuous development and administration of the Label "Energy City" [52] • Information, practical guidelines and support to activities at city and municipal level
Coordination office "2000-Watt-Society" [53]	• Methodological work on methodologies and tools for long-term sustainability • continuous development and administration of the Label "2000-Watt-District" • Program Smart Cities • Program "Sustainable Energy Regions"
Association MINERGIE[54]	• Development and certification of the Label family MINERGIE • The different ambition levels of the MINERGIE label cover operational energy and embodied emissions of buildings as well as comfort and indoor climate aspects for near-zero and zero emission buildings.
Sustainable Construction Network Switzerland[55] (NNBS)	• Development and certification of the Label SNBS (Standard Sustainable Building Switzerland) • The SNBS label integrates not only energy and climate related criteria, but covers sustainability in an integrative form and provides guidance for near-zero and zero emission buildings

Table 8: Key stakeholder at national level

[49] Source: www.bfe.admin.ch/bfe/en/home.html
[50] Source: www.bafu.admin.ch/bafu/en/home.html
[51] Source: www.energiestadt.ch/de/startseite-2.html
[52] see also Sino-Swiss project capaCITIES: www.econcept.ch/media/projects/downloads/2018/01/Brochure_Dec2016.pdf
[53] Source: www.local-energy.swiss/programme/2000-watt-gesellschaft.html#/
[54] Source: www.minergie.com/
[55] Source: www.nnbs.ch/uber-uns

利益相关方	角色
瑞士联邦能源办公室 [56]	• 与能源相关的法案和条例 • 国家支持计划"Energie Schweiz" (能源瑞士) • 关于能源消费和生产的统计数据和报告 • 与建筑能源有关的公共信息 • 协调与建筑有关的国家研究计划 • 协调国际活动，例如与国际能源署 IEA 的活动 • 长期能源发展情景（如能源展望 2050+） • 与能源有关的具体议题的研究 • 协调建筑认证 • 协调建筑的补贴计划（与 FOEN 合作）
瑞士联邦环境署 [57]	• 与气候有关的法案和条例 • 温室气体排放的统计数据和报告 • 与气候有关的具体议题的研究 • 与排放有关的能源税
"能源城市"协会 [58]	• 瑞士地方能源和气候政策的能力中心，汇集了瑞士各市镇，从大城市到小山村，通过持续的努力，分享信息和集体行动 • 持续发展和管理 "能源城市 "[59]标签 • 为城市和市镇级的活动提供信息、实用指南和支持
"2000 瓦社会 "协调办公室 [60]	• 为实现长期可持续性进行的方法学和工具方面的工作 • 持续发展和管理 "2000 瓦社区 "标签 • 智慧城市计划 • "可持续能源区域 "计划
MINERGIE 协会 [61]	• MINERGIE 标签的开发和认证 • MINERGIE 认证体系的不同级别涵盖了近零和零排放建筑的运行能耗、隐含碳排放，以及建筑的舒适度和室内气候等方面的要求
瑞士可持续建筑网络（NNBS）[62]	• 开发和认证 SNBS 标签（瑞士可持续建筑标准） • SNBS 标签不仅整合了能源和气候相关的标准，而且以综合的形式涵盖了可持续性，并为近零和零排放建筑提供了指导

表 8：国家层面的主要利益相关方

[56] 来源：www.bfe.admin.ch/bfe/en/home.html
[57] 来源：www.bafu.admin.ch/bafu/en/home.html
[58] 来源：www.energiestadt.ch/de/startseite-2.html
[59] 参见中瑞项目 capaCITIES: www.econcept.ch/media/projects/downloads/2018/01/Brochure_Dec2016.pdf
[60] 来源：www.local-energy.swiss/programme/2000-watt-gesellschaft.html#/
[61] 来源：www.minergie.com/
[62] 来源：www.nnbs.ch/uber-uns

Cantonal level

As mentioned above, in Switzerland the cantonal level (could be compared to State level in China) is of high importance for the building sector as the regulatory power for energy use in buildings is with the 26 Cantons. Each of the cantons operates it's own Energy Office (Energiefachstelle). Table 9 lists the most relevant stakeholders at the cantonal level.

Municipal / local level

In Switzerland the importance of the municipal level depends on the Canton. In some Cantons the authority for building approvals and compliance checking is delegated to the municipal level, in others it is with cantonal authorities. The municipal and local level is important because there is continuous (not only building related) interaction between the Municipality and/or local stakeholders such as the Utilities and the building owners. The geographical proximity provides a good entry point for information and target oriented interaction with building owners.

Stakeholder	Role
Energy Office[63]	• Technical design of regulation on energy use and production in buildings • Enforcement of the technical regulation on energy use and production in buildings at the cantonal level (building approval) • Monitoring and evaluation of enforcement quality • Tools and forms for building design and approval • Coordination of building approval processes at cantonal or municipal level • Energy related consultancy and information for building sector professionals and the public • Education and training of building sector professionals
Energy Agencies	• Some Cantons operate separate energy agencies which deal with information, consultancy and education. The regulatory tasks remain with the Energy Office while the day to day routine work is sourced out to the Energy Agency.
Building Owners Associations[64] HEV	• Energy related information to private sector building owners • Advocacy and political lobbying for interests of building owners • Legal and administrative support for building operation and building transactions • Lists of local and regional building professionals and service providers

Table 9: Key stakeholder at cantonal level

[63] Source: www.endk.ch/de/endk/die-energiefachstellenkonferenz-enfk
[64] Source: www.hev-schweiz.ch/

Stakeholder	Role
building authority of the municipality	• Enforcement of the technical regulation on energy use and production in buildings (if delegate to the municipal level), building approval and compliance checking • Information and consultancy to building owners. Very often, the technical know-how and staff capacity at the municipal level is however restricted and the municipal authority acts merely as an intermediary for linking to the right addresses.
Utilities (Electricity, Gas)	• Customer support and information • Technical Consultancy on heating systems and building efficiency measures • Some Utilities operate municipal level subsidy schemes for energy efficiency and GHG mitigation
Heating System Suppliers	• Typically, they are the first contact and information point for building owners for replacement of heating system. Therefore, it is of highest importance that they are trained and motivated to promote sustainable technologies and not just the well-known “fossile” technologies.

Tablel 10: Key stakeholder at municipal / local level

联邦州层面

如上所述，在瑞士，州一级（可与中国的省级相比较）的管理对建筑行业非常重要，因为建筑能源使用的监管权属于 26 个联邦州。每个州都有自己的能源办公室（Energiefachstelle）。表 9 列出了各州最相关的利益相关方。

城市层面/地方层面

在瑞士，市镇一级的重要性取决于各州。在一些州，建筑审批和合规性检查的权力被下放至市级，而在其他州，则由州政府负责。因为市政当局和/或地方利益相关方，如公共事业部门和建筑业主之间有持续的（不仅仅是建筑有关的）互动，所以市政和地方层面非常重要。地理上的接近为信息提供了一个很好的切入点，也为与建筑业主进行目标导向的互动提供了机会。

利益相关方	角色
能源办公室 [65]	• 建筑能源使用和生产条例的技术设计 • 在州一级执行有关建筑能源使用和生产的技术法规（建筑审批） • 对执法质量的监测和评估 • 建筑设计和审批的工具和表格 • 协调州或市一级的建筑审批程序 • 为建筑行业的专业人士和公众提供与能源有关的咨询和信息 • 建筑部门专业人员的教育和培训
能源机构	• 一些州设有独立的能源机构，负责提供信息、咨询和教育工作。监管任务仍由能源办公室负责，而日常工作则由能源机构负责
建筑业主协会 [66]	• 向私营部门的建筑业主提供能源相关信息 • 为建筑业主的利益进行宣传和政治游说 • 为建筑运营和建筑交易提供法律和行政支持 • 地方和区域建筑专业人员和服务供应商的名单

表 9：州层面的主要利益相关方

[65] 来源：www.endk.ch/de/endk/die-energiefachstellenkonferenz-enfk

[66] 来源：www.hev-schweiz.ch/

利益相关方	角色
城市层面的建筑部门	• 执行关于建筑能源使用和生产的技术法规（如果授权给城市层面），建筑审批和合规性检查 • 为建筑业主提供信息和咨询。然而，城市层面的技术知识和人员能力往往是有限的，市级机构往往作为一个联系沟通的桥梁
城市管理服务行业（电、气）	• 客户支持和提供信息 • 供暖系统和建筑节能措施的技术咨询 • 一些城市管理服务行业的单位为提高能源效率和减少温室气体排放实施城市层面的补贴计划
供暖系统的供应商	• 通常情况下，他们是建筑业主更换供暖系统的第一个联系人和信息点。因此，对他们进行培训并激励他们推广可持续技术而不仅仅是众所周知的传统技术，是最重要的

表 10：城市层面/地方层面上的主要利益相关方

Professional Associations

In the Swiss building sector, a number of professional associations are active. Associations are highly relevant in providing the market with the required number of qualified professionals which can drive the building sector towards zero emissions. Associations do not only provide basic technical information and practical guidelines; they also offer basic and advanced education courses in their specific fields of profession.

So they are key stakeholders for the transition process for reaching the net-zero emission target.

However, they also must represent the interest of their members. These are often not in favour of a rapid transition as this puts their traditional field of know-how and commerce at risk (e.g. oil-based heating systems). Therefore, the opposition of associations to policy processes can also form a substantial barrier for needed transformation of the sector.

Stakeholder	Role
Swiss society of Engineers and Architects[67] SIA	• Switzerland's leading professional association for construction, technology and environment specialists. With over 16'000 members from the fields of engineering and architecture, the SIA is a professional and interdisciplinary network whose central aim is to promote sustainable and high-quality design of the built environment in Switzerland • Develop, update and publish standards, regulations, guidelines, recommendations and documentation, which is of vital importance for the Swiss construction industry • Typically, the technical regulation by the cantonal and national Authorities makes reference to SIA standards
Building Envelope Switzerland [68](Gebäudehülle Schweiz)	• Basic and advanced training courses in all aspects of the building envelope professions • Develop innovative, forward-looking solutions and products in cooperation with product manufacturers, specialists in the building envelope, science, research, technology as well as architecture and planning
Building Services Association[69] (Suissetec)	• High-quality services for manufacturers/suppliers, planners and installers in the heating, ventilation, sanitary, water, gas and plumbing sectors • Education, networking, political lobbying
Swiss Association for Refrigeration [70] SVK	• Trade association for commercial refrigeration, industrial refrigeration, air conditioning and heat pumps • Provide information and training aids • Basic and advanced education • Guidelines and policy development for the cooling sector in cooperation with FOEN
Schweizerischer Verein von Wärme- und Klima-Ingenieuren[71] SWKI	• Network of building technology professionals • Education, training, guidelines
Swiss Real Estate Association[72] SVIT	• Education, networking, political commitment, know-how and innovative services for the real estate industry

Table 11: Shortlist of professional associations
© Table INFRAS. Source: INFRAS

[67] Source: www.sia.ch/en/the-sia/
[68] Source: xn--gebudehlle-s5a60a.swiss/
[69] Source: suissetec.ch/de/home.html
[70] Source: www.svk.ch/de/
[71] Source: die-planer.ch/
[72] Source: www.svit.ch/de

专业协会

在瑞士建筑行业，有许多活跃的专业协会。这些协会在为市场提供所需数量的合格专业人士方面有很大的作用，这一贡献可以推动建筑行业实现零排放。专业协会不仅能提供基本的技术信息和实用指南；他们还提供其特定专业领域的基础和高级培训课程。因此，可以说专业协会是实现净零排放转型过程中的关键利益相关方。

与此同时，专业协会也必须代表其成员的利益，而相关人群通常不赞成快速转型，因为这会使他们的传统专业知识和商业领域面临风险（例如燃油供暖系统）。因此，专业协会对政策进程的反对也可能构成该领域实施转型的重大障碍。

利益相关方	角色
瑞士工程师和建筑师协会（SIA）[73]	• SIA 是瑞士最具权威性的建筑、技术和环境专家专业协会。 SIA 拥有来自工程和建筑领域的 16,000 多名成员，是一个专业的跨学科网络，其核心目标是促进瑞士建筑环境的可持续和高质量设计 • 制定、发布和更新标准、法规、指南、建议和文件，对瑞士建筑业起到了至关重要的作用 • 通常，在编制国家和州层面的技术法规时会参考 SIA 标准
瑞士建筑围护结构协会[74]	• 提供建筑围护结构专业各个方面的基础和高级培训课程 • 与产品制造商以及建筑围护结构相关的科学、研究、技术以及建筑和规划方面的专家合作，开发创新、前瞻性的解决方案和产品
建筑服务协会（Suissetec）[75]	• 为供暖、通风、卫生、水、燃气和管道行业的制造商/供应商、规划师和安装人员提供高质量的服务 • 教育、网络、政治游说
瑞士制冷协会（SVK）[76]	• 商业制冷、工业制冷、空调和热泵行业协会 • 提供信息和培训 • 基础教育和高等教育 • 与 FOEN 合作，为制冷部门制定指导方针和政策
瑞士热能和气候工程师协会（SWKI）[77]	• 建筑技术专业人员网络 • 教育、培训、指导方针
瑞士房地产协会[78]	• 房地产行业的教育、网络、政策参与、专业知识和创新服务

表 11：专业协会名单表

[73] 来源：www.sia.ch/en/the-sia/
[74] 来源：xn--gebudehlle-s5a60a.swiss/
[75] 来源：suissetec.ch/de/home.html
[76] 来源：www.svk.ch/de/
[77] 来源：die-planer.ch/
[78] 来源：www.svit.ch/de

04

The role of Research Institutes and data for drafting concepts for regulations of the next generation

As per Art. 89 Abs. 4 of the Swiss Constitution, the development of technical regulations in the building sector is within the responsibility of the 26 Cantons (i.e. State level). As an overarching framework, the model regulations of the Cantons on energy use in buildings (MuKEn) define "building blocks" for the regulations at the cantonal level in form of mandatory and voluntary modules. The MuKEn are periodically (each 4-5 years) updated (see also ZEB China 2022 for more details) and coordinated with activities and GHG emission targets at the national level.

Any revision of the MuKEn integrates latest research findings, field data, technical and economic progress since last revision, and political priorities. The availability of representative and up to date data is of utmost importance for updating the regulations. While research can inter alia provide technical sound and economically optimal solution as well as behavioral economic theory models, the design of the legislation also must be effective "on the ground". This includes effective enforcement system, financial support schemes and much more. The basis of effective policy design is evidence-based decisions. This requires specific and up to date data. Some of the main sources of data for building sector policy design in Switzerland include:

- Periodic field monitoring of performance of buildings (sample based, e.g. to identify performance gaps between design performance and field performance)
- Sample based evaluation of effectiveness of construction permit processes (e.g. quality of private controls of energy related building permit applications)
- Cost data gathered from subsidy programs (e.g. for monitoring cost of technologies)
- Surveys and interviews with building owners (e.g. on barriers for implementation of measures)
- Information gathered from energy consulting activities for building owners (e.g. on decision processes and information sources of building owners).
- Comparison and analysis of international experience and practices (e.g. technical concepts for building codes).

四

研究机构和数据在起草下一代法规方案中的作用

根据《瑞士宪法》第 89 条第 4 款的规定，建筑领域技术法规的制定由 26 个州（即州一级）负责。作为一个总体框架，各州制定的建筑能源使用的示范条例（MuKEn）以强制性和自愿性模块的形式为各州层面的法规奠定了"基石"。 示范条例会定期更新（每 4-5 年）（更多细节见 ZEB China），并与国家层面的活动和温室气体排放目标相协调。

MuKEn 的修订整合了最新的研究成果、现场数据、自上次修订以来的技术和经济进展以及政治优先事项。具有代表性和最新数据的可用性对于更新法规来说至关重要。虽然研究可以提供技术上合理且经济上最优的解决方案以及行为经济理论模型，但立法的设计也必须 “在真实场景中” 有效。这包括有效的执法系统、财政支持计划等。有效政策设计的基础是循证决策。这需要特定的和最新的数据。瑞士建筑行业政策设计的主要数据来源包括:

- 建筑性能的定期现场监测（基于样本，例如，确定设计性能和实际性能之间的差距）
- 基于样本的建筑许可程序有效性评估（例如，对建筑能源相关进行质量控制的私人许可申请）
- 从补贴计划中收集的成本数据（例如，用于监测技术成本）
- 对业主的调查和访谈（例如关于实施措施的障碍）
- 从建筑业主的能源咨询活动中收集的信息（例如关于建筑业主的决策过程和信息来源）
- 国际经验和实践的比较与分析（例如建筑规范的技术概念）

In Switzerland different institutions and networks are active in research for the building sector. In the following a non-exhaustive list is provided:

Institution / Network	focus of activities related to buildings
National Research Program Buildings and Cities[79]	• Sustainability strategies for sites and districts, Optimised interaction of production of energy, storage, distribution and consumption • Buildings and sites as energy service providers long-term reduction of the energy consumption of old buildings • BIM in life cycle assessment • Embodied energy, minimisation of material flows, use of energy, material and building data at planning and operation stages • Cooling in view of the future climate • Building automation, monitoring and system optimisation • Heating systems with low CO_2 emissions and low electricity consumption in the winter. • Research on Consumers, market, policy • Feedback systems • Incentive systems for sufficiency • Acceptance of building automation solutions: influence of privacy and security, flexibility of use, user interfaces.
Swiss Federal Laboratories for Materials Science and Technology (EMPA)[80]	• Sustainable built Environment (Materials & Processes, Structures & Systems, Integration & Demonstration, Circular Economy, Data Science) • Energy (Energy Supply, Conversion and Storage, Energy Demand, System Integration) • Resources and Pollutants (raw materials availability and criticality, resilient supply chains, reduction of greenhouse gas emissions, circular economy and recycling of building materials)
Swiss Competence Centers for Energy Research (SCCERs)[81]	• Future Energy-Efficient Buildings & Districts (SCCER FEEB&D) • Heat & Electricity Storage (SCCER HaE) • Competence Centre for Research in Energy, Society, and Transition (SCCER CREST)
Federal Institutes of Technology (ETH) Zurich and Lausanne, Universities of Applied Sciences[82] (HSLU, ZHAW, FHNW, OST, BFH)	• Wide range of activities
Private sector Consultants	• Regulatory design, socio-economic research, behavioural economics, subsidy programs, policy evaluation, etc.

Table 12: Building related research institutions and networks (non-exhaustive)

[79] Source: dwz.date/fvPE
[80] Source: www.empa.ch/web/empa/
[81] Source: dwz.date/fvPF
[82] Source: dwz.date/fvPG

在瑞士，不同的机构和网络都在积极参与建筑行业的研究。以下是部分清单：

研究机构/网络	与建筑有关的活动重点
国家建筑与城市研究项目 [83]	• 社区和城区的可持续发展战略，优化协调能源生产、储存、分配和消费 • 作为能源服务提供者的建筑和场地，长期降低老旧建筑的能源消耗 • 生命周期评估中运用 BIM • 规划和运营阶段的隐含能耗，物质流最小化，能源、材料和建筑数据的使用 • 考虑到未来气候变化的的建筑制冷 • 楼宇自动化、监控和系统优化 • 低二氧化碳排放和冬季低耗电量的供暖系统 • 消费者、市场、政策研究 • 反馈机制 • 充足的激励制度 • 建筑自动化解决方案的接受度：隐私和安全性、使用灵活性、用户界面的影响
瑞士联邦材料科学与技术实验室 [84]	• 可持续建筑环境（材料与工艺、结构与系统、集成与示范、循环经济、数据科学） • 能源（能源供应、转换和储存、能源需求、系统集成） • 资源和污染物（原材料的可用性和重要性、弹性供应链、减少温室气体排放、循环经济和建筑材料的回收利用）
瑞士能源研究中心 [85]	• 未来的节能建筑和区域节能 (SCCER FEEB&D) • 热量和电力储存 (SCCER HaE) • 能源、社会和转型研究能力中心 (SCCER CREST)
苏黎世联邦理工学院，洛桑联邦理工学院，应用科学大学 [86](HSLU, ZHAW, FHNW, OST, BFH)	• 多方面的活动
私营咨询部门	• 监管设计、社会经济研究、行为经济学、补贴计划、政策评估等

表 12：建筑相关的研究机构和关系网络（待完善）

[83] 来源：dwz.date/fvPE
[84] 来源：www.empa.ch/web/empa/
[85] 来源：dwz.date/fvPF
[86] 来源：dwz.date/fvPG

05

Next generation of technical regulation for buildings

Introduction

Energy demand and carbon emission from buildings can be drastically reduced by applying today's best practice and emerging technologies [Ürge-Vorsatz et al., 2012]. However, many of these opportunities are not realized, although being already cost-effective, due to specific market and behavioural failures. Literature has long recognized that implementing policies— individually tailored in form, magnitude and timed to address these failures — can help to close this so-called "energy efficiency gap" [Schwarz et al., 2020; Mowery et al., 2010]. Most effectively the variety of instruments (e.g. control and regulatory mechanisms, economic and market-based instruments, fiscal instruments and incentives, and support, information and voluntary action) work in synergy in a so-called policy mix [Kern et al., 2017; Rogge, K. S., Reichardt, K., 2016].

In addition, policies from outside the energy domain often have a significant impact on the building stock transformation [Ivalin et al., 2021]. Nevertheless, Technical Energy Regulations (TERs[87]) - control and regulatory mechanisms that traditionally set minimum requirements for energy use and generation in buildings - are seen as one of the most cost-effective policies for closing the energy efficiency gap [Lucon et al., 2014], and are thus an essential part of such a policy mix.

In the following, we first outline the state-of-the-art of TERs based on an international review and derive policy design principles for next-generation TERs. Second, we outline the challenges and propose three TERs ideas. The last section provides a brief outlook for embedding TERs in a comprehensive regulatory framework.

[87] also referred to as Building Energy Codes (BEC) in literature: bit.ly/3i5oGc7

五

下一代建筑技术法规

介绍

通过应用当今最佳的实践和新兴的技术，建筑的能源需求和碳排放可以大幅减少[Ürge-Vorsatz et al., 2012]。然而，由于特定的市场和行动失误，许多机会在已有的成本效益下仍没有实现。通过研究了解到，政策实施——在形式、规模和时间上针对这些问题进行个性化定制，有助于缩小这种所谓的"能源效率差距"[Schwarz et al., 2020; Mowery et al., 2010]。最有效的是，各种工具（例如控制和监管机制、经济和基于市场的工具、财政工具和激励措施，以及支持、信息和自愿行动）在所谓的政策组合中协同工作[Kern et al., 2017; Rogge, K. S., Reichardt, K., 2016]。

此外，能源领域以外的政策往往对建筑领域的转型有重大影响[Ivalin et al., 2021]。尽管如此，能源技术法规 (TERs[88]) - 传统上为建筑中的能源使用和发电设定最低要求的控制和监管机制 - 被视为缩小能源效率差距的最具成本效益的政策之一 [Lucon et al., 2014]，因此被视为政策组合的重要组成部分。

下文首先根据国际审查概述了制定建筑技术法规的最新技术，归纳了下一代建筑技术法规设计原则。其次，概述了可能遇到的挑战并提出了三个关于建筑技术法规的想法。最后一节则简要介绍将建筑技术法规嵌入综合监管框架的前景。

[88] 文献中也称作建筑能源规范(BEC): dwz.date/fvPH

International Overview

Historically, TERs have proven effective and efficient for advancing building decarbonization. However, researchers increasingly recognize the limitations of prevalent TER designs and have thus begun to discuss the development and implementation of TERs that overcome these limitations. Schwarz et al. (2020) provide a detailed overview of the state-of-the-art, leverage points, and innovative approaches in TERs, and derive policy design principles from five European case studies (i.e., Denmark, France, England, Switzerland, Sweden).

The following five challenges of current TER design or leverage points have been outlined in literature: (i) further increase in energy efficiency, (ii) consider "embodied energy", (iii) increase the share of renewable energies, (iv) close the "performance gap", and (v) accelerate the renovation rate. Besides considering embodied energy, all of the outlined leverage points above have been considered in status quo TERs of the selected five European countries albeit to various decrees. The table below presents an overview on the state-of-the-art of the TERs in each of the five identified countries, and sketches the status of the five most important leverage-points.

		Denmark	France	England	Switzer-land	Sweden
Energy Efficiency	Performance	Yes	Yes	Yes	Yes	Yes
	Prescriptive	Yes	Yes	Yes	Yes	Yes
	Capacity	-	-	-	Yes	Yes
Embodied Energy & Carbon	Performance	-	Yes (pilot)	-	-	-
Renewable Energy	Performance	Yes	Yes	Yes	Yes	-
	Prescriptive (direct)	Yes	Yes	-	Yes	-
	Prescriptive (indirect)	Yes	-	Yes	-	-
	Prescriptive (ban)	Yes	-	-	Yes	-
Performance Gap	Compliance Check	Yes	Yes	Yes	Yes	Yes
Accelerate Retrofit	Requirements when retrofitting	Yes	Yes	Yes	Yes	Yes
	Requirements to retrofit	-	Yes	-	-	-

Performance requirements define a metric on a systemic (i.e. building) level (e.g. kWh/m^2 or CO_2/m^2), prescriptive requirements in contrast define specific metrics for individual building parts (e.g. U-Value in kW/m^2K) or renewable heating systems for heating re-placements, capacity requirements define maximal allowed peak values (e.g. W/m^2 for heating demand).

Table 13: Overview of key leverage points for building decarbonization and related BEC design options

国际概况

从历史上看，建筑技术法规在推进建筑脱碳方面已被证明是有效且高效的。然而，研究人员越来越意识到当前存在的建筑技术法规设计上的局限性，因此开始讨论克服这些局限性的建筑技术法规的发展和实施。Schwarz 等人（2020 年）详细概述了建筑技术法规的最新技术、杠杆点和创新方法，并从五个欧洲案例研究（即丹麦、法国、英国、瑞士、瑞典）中得出了政策设计原则。文献中概述了目前 TER 设计的五个挑战或关键点：（1）进一步提高能源效率，（2）考虑 "隐含能源"，（3）增加可再生能源的份额，（4）缩小 "性能差距"，以及（5）加快翻新率。除了隐含能源外，上述所有的挑战都在上述五个欧洲国家现行的建筑技术法规中得到了考虑，尽管分布在不同的法规中。表 13 列出了这五个国家的建筑技术法规的最新情况，并概述了五个最重要方面的情况。

		丹麦	法国	英国	瑞士	瑞典
能效	性能	有	有	有	有	有
	规范	有	有	有	有	有
	容量	-	-	-	有	有
隐含能源和隐含碳	性能	-	有 (示范)	-	-	-
可再生能源	性能	有	有	有	有	-
	规范（直接）	有	有	-	有	-
	规范（间接）	有	-	有	-	-
	规范（禁止）	有	-	-	有	-
性能差距	合规性检查	有	有	有	有	有
加快建筑改造	改造过程中的要求	有	有	有	有	有
	对于改造的要求	-	有	-	-	-

性能要求定义了整个系统（即建筑）层面的指标要求（例如 kWh/m² 或 CO_2/m^2），规定性要求则定义了单个建筑部件的特定指标（例如 U 值，以 kW/m²K 为单位）或用于更换的可再生供暖系统，容量要求定义了最大允许值（例如供暖需求的峰值 W/m²）。

表 13：建筑脱碳和相关建筑能源法规设计方案的关键杠杆点概述
© 来源：建筑脱碳建筑能源法规的创新设计及其实施挑战；M.Schwarz 等人/清洁生产杂志 248（2020）；链接：https://dwz.date/fwrZ

Below we outline the status quo and innovative examples addressing these leverage points.

i) All countries shifted towards performance metrics for the entire building's energy use to further increase energy efficiency but retained prescriptive requirements for envelope efficiency or individual building technologies. As an innovative example, Denmark increased energy efficiency by introducing voluntary low-energy classes and announcing far in advance when they would become mandatory, thus providing long-term targets for the construction industry.

ii) Despite the increasing importance of embodied impacts, historical and current TERs, however, concentrate on energy use during the operational phase, and do not set requirements for embodied energy. However, France will begin to reduce embodied energy by taking a lifecycle perspective for performance metrics and adopting requirements for the construction phase in the next update of its thermal regulations for building.

iii) In contrast to the historic TER setting, the current status quo increasingly regulates renewable energy in buildings, through more stringent performance-based renewable requirements and specific prescriptive regulations or bans of certain technologies. England, in addition, introduced carbon emissions as the key performance metric in its building regulation. Switzerland in contrast adopted two prescriptive requirements that aim to increase renewable energy in buildings. First, they stipulate that new buildings must produce a certain amount of electricity on-site. Second, they require the 1.1 million Swiss buildings that have an oil or gas boiler to install a heating system based on at least 10% renewable energy in case of a boiler replacement or achieve an at least equivalent amount of energy efficiency gains.

iv) the performance gap - the difference between calculated and measured energy use - is only addressed in most current TERs, through compliance checks of planning and construction. In contrast to the status quo, the Swedish building regulation aims to close the performance gap by checking compliance based on measured building performance.

v) To address a notoriously low retrofitting rate most analyzed countries distinguish between regulations for new buildings and retrofits and for example allow the latter to comply with purely prescriptive requirements only. France is trying to accelerate the building stock transformation through retrofit obligations addressing the most energy-demanding buildings.

The MuKEn:2014 takes a key role in Switzerland's transition towards a carbon-free building sector. It is a state-of-the-art regulation and beyond that takes a pioneering role through mandatory on-site electricity generation and renewables for heating. However, the successor of the MuKEn:2014 could learn from innovative approaches of TERs of other frontrunner countries. In the following, we transfer the insights we gained from analysing international and innovative TER to Switzerland.

i) To increase energy efficiency, the next TER could reduce the number of individual regulations and instead focus on two central performance metrics, namely the total energy demand and the primary energy demand including on-site electricity production.

ii) To consider embodied energy, taking a lifecycle perspective and, first, include additional energy and carbon sources in the performance metric or, second, add a new performance metric for embodied energy only would be potential ways forward.

iii) To increase the share of renewables, a MuKEn:20XX could, first, accelerate the phase-out of oil and gas boilers in buildings and, second, extend the system boundaries of energy regulations from buildings to neighbourhoods. A CO_2 emission performance metric would be another potential way to increase the share of renewables in the building sector.

iv) To close the performance gap, the next TER in Switzerland could, first, adjust the current compliance check or, second, switch to a compliance check based on measured data.

v) To accelerate retrofits, Switzerland could follow the French example and include requirements that enforce the retrofitting of low energy-efficiency buildings.

接下来，报告概述了解决这些挑战的现有方法和创新案例。

i) 所有国家都在采用了用于规范整个建筑能源使用的性能指标，以进一步提高能源效率，但保留了对围护结构或个别建筑技术的规范性要求。其中一个创新的例子是，丹麦通过引入自愿的低能耗等级并提前宣布何时成为强制性标准，来提高能源效率，这一举措为建筑行业提供了长期目标。

ii) 尽管 "隐含能源" 的影响越来越大，但是过去和当前的建筑技术法规仅着眼于运营阶段的能源使用，并没有对隐含能源设定要求。法国将开始通过从生命周期的角度来衡量建筑性能指标，并在其建筑热工性能法规的下一次更新中对施工阶段提出要求，以此来减少隐含能耗。

iii) 与过去的建筑技术法规相比，目前的现状是通过更严格的基于性能的可再生要求和具体的规范性规定或禁止某些技术，对建筑领域的可再生能源应用进行越来越多的监管。此外，英国在其建筑法规中引入了碳排放作为关键的性能指标。相比之下，瑞士采取了两项规范性要求，旨在增加建筑领域的可再生能源份额。首先，规定新建筑必须现场生产一定数量的可再生电力。其次，瑞士要求 110 万拥有燃油或燃气锅炉的建筑，在更换锅炉时，必须安装使用至少 10%可再生能源的供热系统，或实现至少同等数量的能源效率提升。

iv) 性能差距 - 计算的能源使用量和测量的能源使用量之间的差异 - 在目前大多数的建筑技术法规中只通过规划和施工的合规性检查来解决。与之相反，瑞典的建筑法规旨在通过检查基于测量的建筑性能的合规性来缩小性能差距。

v) 为了解决众所周知的低改造率问题，大多数被分析的国家对新建筑和建筑改造的法规进行了区分，例如，允许后者只遵守纯粹的规范性要求。法国正试图通过为能源需求较高的建筑设定改造义务来加速既有建筑的节能改造。

MuKEn: 2014 在瑞士建筑行业向零碳转型过渡中发挥了关键作用。可以说，它是一项最先进的法规，通过强制现场可再生发电和可再生能源供暖，发挥了引领作用。但 MuKEn: 2014 的后续更新版本仍可以从其他领先国家的建筑技术法规的创新方法中学习。接下来，该报告将从分析国际上创新的建筑技术法规中获得的见解引入到瑞士。

i) 为了提高能源效率，可以减少对于独立指标数量的要求，转而专注于两个核心绩效指标，即总能源需求和包括现场电力生产在内的一次能源需求。

ii) 从生命周期的角度考虑隐含能源。首先，在性能指标中添加额外的能源消耗和碳排放指标，其次，为隐含能源添加一个新的性能指标要求。

iii) 为了增加可再生能源的份额，MuKEn: 20XX 可以首先加速淘汰建筑中的燃油和燃气锅炉，其次将能源法规的系统边界从建筑扩展到社区。二氧化碳排放性能指标将是增加可再生能源在建筑行业份额的另一种潜在方式。

iv) 为了缩小性能差距，瑞士的下一个建筑技术法规可以首先调整当前的合规性检查，或者基于测量数据调整合规性检查。

v) 为加快建筑改造，瑞士可以效仿法国的做法，如强制改造高能耗建筑。

By synthesizing the implementation challenges for the innovative examples across our five case studies, we derive six policy design principles for TERs. These are generally applicable and ensure TERs function effectively – thus often separating the successful TER implementations from the failures. We recommend that policymakers apply these principles when implementing innovative TER designs to ensure broad acceptance across all actors in the construction sector – particularly important in view of TERs mandatory nature. Table 14 provides an overview of our six TER design principles and outlines examples illustrating how to follow them.

TER design principle	TER design examples
Keep additional burdens for building owners light	• Include technical feasibility and cost-effectiveness tests • Combine TERs with additional policies such as zero-interest financing to lighten the burden of upfront investment
Create long-term regulatory certainty	• Align TERs with national energy and climate targets • Pre-announce upcoming TERs • Integrate continuous improvement processes
Beware technology-specific requirements	• Ensure that multiple technology options are available
Anticipate the impact of new regulations on smaller actors	• Support small firms by reducing unnecessary soft costs • Help small authorities by removing the burden of capacity-intensive compliance control
Promote knowledge of innovative design	• Pre-announce upcoming TERs • Conduct test programs • Build upon voluntary labels • Learn from frontrunner legislation
Integrate TERs in the local context	• Leverage the existing infrastructure • Consider the level and pace of ongoing grid decarbonisation • Leverage domestic resources • Consider the quality of the domestic construction industry • Check political feasibility

Table 14: Overview of BEC design principles and design examples

通过综合分析五个案例中的创新措施的实施挑战，报告得出了六个关于建筑技术法规的政策设计原则。这些原则是普遍适用的，并且能够确保建筑技术法规的有效运转，因此，建议政策制定者在实施创新的建筑技术法规设计时考虑这些原则，并确保建筑行业的所有利益相关方广泛参与进来，鉴于建筑技术法规的强制性，这一点尤为重要。表 14 概述了这六项建筑技术法规设计原则，并概括说明了如何遵循这些原则。

建筑技术法规设计原则	建筑技术法规设计示例
减轻业主的额外负担	• 包括技术可行性和成本效益测试 • 将建筑技术法规与零息融资等附加政策相结合，以减轻前期投资的负担
创造长期监管的确定性	• 使建筑技术法规与国家能源和气候目标保持一致 • 预先宣布即将到来的建筑能源法规 • 整合持续改进流程
注意特定技术的要求	• 确保有多种技术可供选择
预测新法规对小规模参与者的影响	• 通过减少不必要的软成本来支持小公司 • 通过消除能力密集型合规控制的负担来帮助小机构
推广创新设计知识	• 提前公示之后的建筑能源法规 • 开展试点项目 • 开发自愿获取的标签 • 向先进的法规学习
根据当地环境整合建筑能源法规	• 充分利用现有的基础设施 • 考虑正在进行的电网去碳化的水平和速度 • 充分利用国内资源 • 考虑到国内建筑行业的质量 • 检查政治可行性

表 14：建筑能源法规设计原则和设计示例概述
©来源：建筑脱碳建筑能源法规的创新设计及其实施挑战；M.Schwarz 等人/清洁生产杂志 248（2020）；链接：https://dwz.date/fwrZ

Challenges of new TER

According to the international comparison, MuKEN:2014 is a state-of-the-art TER. However, impact analysis confirms that even if the MuKEn:2014 is fully implemented all over Switzerland, the Swiss CO_2 target of net-zero will still fall short by approximately 30% [DOI: 10.13140/RG.2.2.12307.22568].

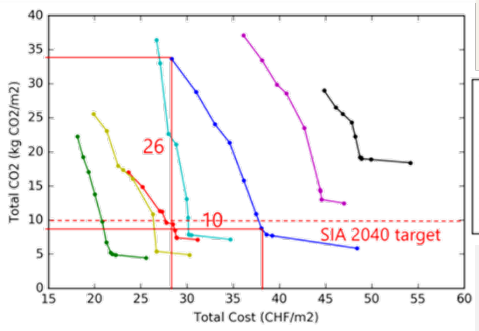
Through techno-economic optimization, retrofit solutions for the Swiss building stock could be identified which achieve specific CO_2 emissions below 10 $kgCO_2/m^2$ - typically at CO_2 avoidance costs of 200-400 CHF/tCO_2 compared to cost-optimal solutions. The technically and economically optimized solutions are characterized by three measures at the building level:

i) partially improve the building envelope in terms of energy efficiency,

ii) replace oil and gas heating systems as far as possible with renewable heating systems and

iii) use photovoltaics and, where appropriate, install battery storage systems.

Analyzing the Pareto fronts in more detail, the ideal retrofit measures and system selection are trade-offs along the multicriteria optimization. A retrofit option and a heating system are selected and, if applicable, a solar system is defined. Since a heating system is already installed in the building, the optimisation process can either keep the existing system (oil or gas-fired boilers, biomass, electric or district heating) or select a new and more efficient system (air source heat pump, ground source heat pump, biomass, cogeneration heat and power system or gas boiler). Figures 7 and 8 show the optimal combination of building envelope and systems for all single and multiple family dwellings archetypes. The size of the individual markers represents the relevant building floor area in m^2. The graphic shows that roof renovations are the most frequently performed upgrade in single-family houses since this usually represents the most cost-effective action. The most promising heating systems are wood pellet systems or air source heat pumps. In certain cases, the optimisation shows that electric heating systems may be retained after renovation, though this occurs in less than 5% of all optimised solutions for single family houses.



Example CO2-avoidance price SFH
= Cost-increase / CO2-Emission reduction
= 10 CHF/m^2 / 26 $kgCO_2/m^2$ * 1000 $kgCO_2$ / tCO_2

例如：二氧化碳减排成本（单户住宅）
= 增加的成本/二氧化碳排放减少量
= 10 瑞郎/平方米/26 公斤二氧化碳/平方米*1000 公斤二氧化碳/吨二氧化碳

Figure 7: Average Pareto front for single family, multi-family and non-residential buildings, representing the Swiss building stock. The life-cycle emissions represent annualized CO2 emissions over the lifetime of the components used and their operation.
图 7：单户住宅、多户住宅以及代表瑞士建筑存量的非住宅建筑类型的平均帕累托最优的集合。生命周期排放量是指所用组件及其运行生命周期内的年二氧化碳排放量。
© Source: Optimal transformation strategies for buildings, neighbourhoods and districts to reach CO2 emission reduction targets, Energy and Buildings, Portia Murray et al., Volume 207, 2020; Link: bit.ly/3Zca2QS
©来源：为实现二氧化碳减排目标，建筑物、街区和地区的最佳改造策略，《能源与建筑》，Portia Murray 等人，第 207 卷，2020 年；链接：dwz.date/fwsb

新建筑能源法规面临的挑战

通过与国际相关法规进行比较，MuKEN: 2014 是一个相对而言最先进的建筑技术法规。然而，影响性的分析证实，即使 MuKEn: 2014 在瑞士各地得到全面实施，离瑞士的二氧化碳净零排放目标仍相差约 30%[DOI: 10.13140/RG.2.2.12307.22568]。

通过技术经济优化，可以确定瑞士建筑行业的改造方案，通过这些方案可以实现低于 10kgCO_2/m^2 排放量。与成本最优方案相比，通常的 CO_2 减排成本为 200-400 瑞士法郎 /tCO_2。技术上和经济上最优化的解决方案是在建筑层面采取以下三项措施：

i)在能效方面，部分改善建筑围护结构

ii)尽可能用可再生供暖系统取代燃油和燃气供暖系统

iii)使用光伏，并在适当情况下安装电池存储系统

通过更详细地分析帕累托最优曲线，理想的改造措施和系统选择是多准则优化的权衡。选择一个改造方案和一个加热系统，如果适用的话，还可以考虑太阳能系统。对于已有供热系统，在优化过程可以保留现有系统（燃油或燃气锅炉、生物质、电力或区域供热）或选择新的更有效的系统（如：空气源热泵、地源热泵、生物质、热电联供系统或燃气锅炉）。图 7 和 图 8 显示了所有单户和多户住宅原型的建筑围护结构和系统的最佳组合。各个图标的大小代表相关的建筑面积，以平方米为单位。该图显示，屋顶翻新是单户住宅中最常见的改造措施，这通常也是最具成本效益的措施。最有前景的供暖系统是木制颗粒燃烧系统或空气源热泵。在某些情况下，优化方案显示电加热系统在翻新后可能会保留，但这种情况在所有针对单户住宅的优化解决方案中占比不到 5%。

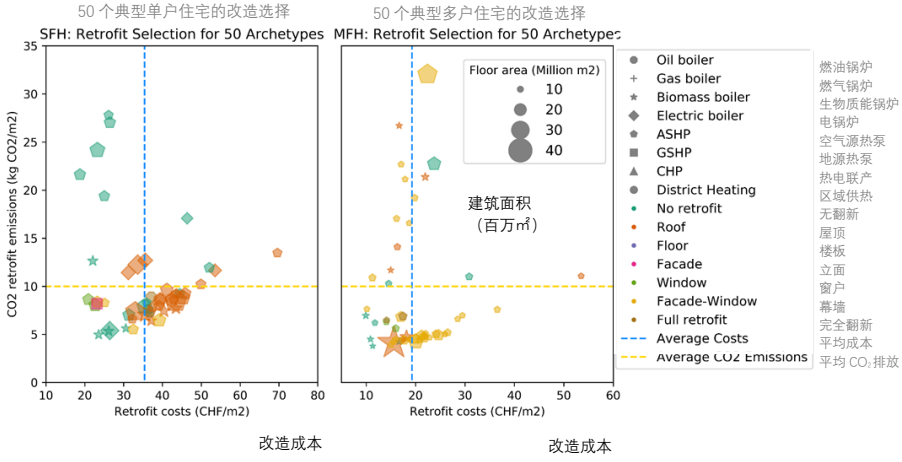


Figure 8: Comparison of deterministic Pareto front with multiple stochastic Pareto fronts resulting from the Robustness analysis.
图 8：确定性帕累托最优与鲁棒性分析得出的多个随机帕累托最优的比较。
© Source: Optimal transformation strategies for buildings, neighbourhoods and districts to reach CO2 emission reduction targets, Energy and Buildings, Portia Murray et al., Volume 207, 2020; Link: bit.ly/3Zca2QS
©来源：为实现二氧化碳减排目标，建筑物、街区和地区的最佳改造策略，《能源与建筑》，Portia Murray 等人，第 207 卷，2020 年；链接：dwz.date/fwsb

Generally speaking, to reach the target of <10 $kgCO_2/m^2$ both a partial retrofit of the building envelope and a change of the heating system are recommended. Replacing fossil-fuelled heating systems is mandatory for nearly all buildings to reach the net-zero goal.

Further results indicate that a district solution with thermal networks in cities would be appropriate for 50-80% of more densely populated neighbourhoods. The investment costs of such district solutions are between 20 and 25% lower than standalone building solutions [Murray, P. et al, 2020].

By scaling the technically and economically optimal solutions to the entire building stock, CO_2 emissions could be reduced by up to 80%. The remaining 20% CO_2 direct emission of the Swiss building stock must be solved at the regional or national level. Transforming the energy supply infrastructure (electricity and gas) into a carbon-free system is a prerequisite for achieving the net-zero target. The above analysis shows that achieving the net-zero target for the Swiss building stock is technically and economically feasible.

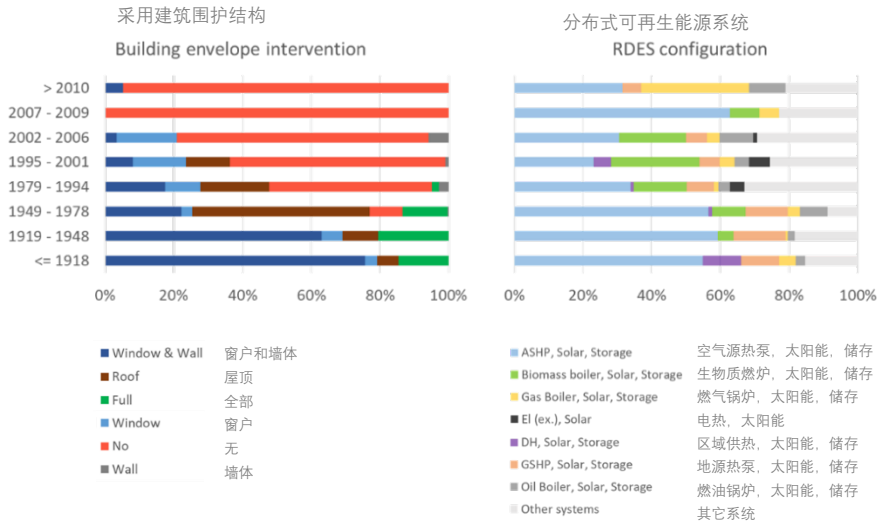


Figure 9: Typical solutions under 10 kg $CO_{2,eq}/m^2$ annually, ranked in by building age (Photovoltaics are the most popular choice in the solar system category.

图 9：每年 10 kg CO_2/m^2 以下的典型解决方案，按建筑建成年份排名，光伏是最常用的太阳能利用方式

一般来说，要达到碳排放小于 10 $kgCO_2/m^2$ 的目标，需要对建筑围护结构进行部分改造，同时升级供暖系统。几乎所有建筑都必须更换化石燃料供暖系统才能达到净零排放目标。

进一步的结果表明，在城市中采用热力网络的区域解决方案适用于 50-80% 的人口密集社区，这种区域解决方案的投资成本比单户建筑解决方案低 20% 到 25% [Murray, P. et al, 2020]

通过将技术上和经济上的最佳解决方案推广到整个建筑行业，二氧化碳排放量可减少 80%。瑞士建筑行业剩余的 20%的二氧化碳直接排放需要在地区或国家层面解决。将能源供应基础设施（电力和天然气）转变为无碳系统是实现净零排放目标的先决条件。综上所述，实现瑞士建筑行业的净零排放目标在技术上和经济上是可行的。

一般来说，要达到碳排放小于 10 kgCO2/m2 的目标，需要对建筑围护结构进行部分改造，同时升级供暖系统
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Next generation of TER

To provide the best possible regulatory environment for encouraging stakeholders to develop the building stock in the intended direction, the following TER ideas have been developed to discuss the next generation of TER. New TERs should be built on performance criteria, which directly address targets, e.g. CO_2 emissions. Prescriptive regulations which describe constructions, e.g. wall insulation and hope of CO_2 reductions, are neither effective nor straightforward in their application. Because of this, we propose three performance criteria: Capacity limits, share of renewable energy and embodied CO_2 emissions.

Regulation of Capacity Limits

The «Capacity Limit» TER targets the design and construction phase of a building. The evaluation of the building energy calculations showed that the maximum system capacity could represent the energy efficiency of a building in a marginally worse way than the advanced calculation of the annual energy demand. However, with a TER "Capacity Limit", the certification can be simplified and the impact extended:

i) Simplification: The calculation of the system capacity is based exclusively on the chosen construction and the selection of materials and equipment. Operational assumptions such as solar gains, internal loads, occupancy, etc. can be neglected.

Implementing such a TER can be performed similarly to the predecessor by verifying compliance with limit values during the planning phase. Or easier during the construction phase by inspecting the capacity data of the installed systems.

ii) Extension: The switch to renewable energy sources (see also below) is a major challenge for the electricity, gas and heat infrastructures. Their magnitude and their corresponding supply capacity are limited by the installed networks. By limiting the capacity of a building, the TER influences infrastructure requirements directly by regulating the necessary network and reserve capacities and incentivising storage capacities at the building level.

Regulation of the Renewable Share

The «Energy Mix» TER targets the operation phase of a building. Energy consumption and greenhouse gas emissions are significantly impacted during building usage. The proposed TER limits the amount of caused CO_2 emissions by the supplied energy. The building owner or tenant can comply with the CO_2 limits by reducing his consumption, choosing low- or zero-CO_2 energy products and/or increasing its on-site renewable energy production. (e.g. photovoltaics, biomass boilers, etc.). The enforcement of such a TER could be performed by Smart Meters and Digital Data Platforms.

New TERs should be built on performance criteria, which directly address targets, e.g. CO2 emissions.
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新一代建筑技术法规

为了提供最佳的监管环境，鼓励利益相关方按照预期方向开发建筑，报告为新建建筑技术法规提出了如下建议。新的建筑技术法规应以性能目标为导向，例如二氧化碳排放量。建筑的规定性指标，例如墙体保温参数和二氧化碳减少的程度，在实际应用过程中既不有效也不够直截了当。因此，报告提出了三个性能指标：容量限制、可再生能源利用率和隐含碳排放。

容量限制的规定

技术法规中"容量限制"针对的是建筑的设计和施工阶段。对建筑能源计算的评估表明，最大的系统容量可以代表建筑的能源效率，其精准度略差于全年能源需求的详细计算方式，但是，使用"容量限制"，可以简化认证并扩大影响：

i) 简化：系统容量的计算完全基于所选结构、材料和设备。太阳能收益、内部负荷、入住率等因素可以忽略不计。

实施这样的建筑设计法规与之前的法规类似，在规划阶段验证是否满足极限值，或者在施工阶段，通过检查已安装系统的容量数据进行验证。

ii）扩展：向可再生能源的转换（另见下文）是电力、天然气和热力基础设施面临的主要挑战。它们的规模和相应的供应能力都受到现有网络的限制。通过限制建筑的容量，建筑技术法规通过调节必要的网络和储备容量以及激励建筑行业的存储容量来直接影响基础设施的要求。

可再生能源利用率的规定

技术法规中"能源结构"针对的是建筑的运行阶段。建筑使用过程中的能源消耗和温室气体排放影响巨大。这里建议的技术法规中限制了化石能源的比例。建筑业主或租户可以通过减少消费、选择低二氧化碳或零二氧化碳排放的能源产品和/或增加可再生能源生产来遵守二氧化碳的限制(例如，光伏发电、生物质锅炉等）。该法规的执行可以通过智能电表和数字数据平台来实现。

新的技术法规应建立在能直接确定目标的性能标准之上，如碳排放量等 。
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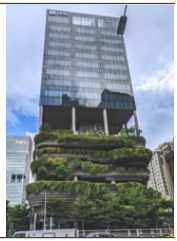


Regulations of the Embodied Emissions

The «Embodied Emissions» TER targets the design phases and upstream material production of the building industry. An increasing proportion of the environmental impact in Switzerland's building stock no longer comes from the use phase, but from the "ecological rucksack" that building materials bring with them, i.e., from the emissions that occur during the production phase (embodied emissions). Approximately half of those emissions will come from new buildings while the other half originates from retrofitting the existing building stock, while the impact from demolition and decommissioning only accounts for a minor share [89]. Therefore it is critical to investigate and implement the solutions aimed at reducing such embodied impacts. Circular economy provides a framework of how to reduce environmental impacts arising throughout the life cycle of materials through various circular strategies (e.g. rethink, reduce, refurbish, recycle) [Potting, J. et al., 2017]. Implementing such circular strategies in the building industry comes with a set of specific challenges due to the unique layout of the construction sector.

i) The current material flows in the construction sector are highly imbalanced as the input flows are much higher than potential secondary resources coming out of the system.

ii) Long and very diverse lifetimes in the building sector make business models dealing with secondary resources from buildings complex.

iii) The broad diversity and increasing complexity of materials require different circular strategies depending on the various materials used.

iv) Construction projects are highly customized and the multitude of stakeholders involved complicates standard solutions.

v) Besides some promising pilots, a large knowledge gap about which materials are in the building stock, and when will they come out where, and in which quality, exists. In sum, these aspects also affect how future TER could address incorporating embodied emissions in their regulations. Labels, material passports, building material databases and pilot projects for individual materials as well as for entire buildings are promising signs of the industry moving into this direction. However, given the large uncertainty about which circular strategies will be most effective, current regulations largely concentrate on prescriptive requirements regarding the deconstruction phase and waste disposal.

The new TERs also allow the technical and economic potentials of larger-scale solutions to be exploited. The suggested performance-based measures for buildings, namely “Capacity Limiting” and “Energy Mix”, can also be applied analogously at the neighbourhood and district scale. Spatial planning, including energy planning, could create supplementary incentives to emphasise larger-scale solutions.

A further consideration for an effective TER could be binding reduction paths for limits or target values. The legislature thereby commits itself over the long-term and constrains its negotiating scope while enabling building owners to prepare themselves for the upcoming limits and allowing them to choose the optimal time to conduct renovation work. At the same time, the building industry gains security for its product and service development since these would comply with future regulations, thereby encouraging innovation.

[89] Source: onlinelibrary.wiley.com/doi/10.1111/jiec.12739

隐含碳排放的规定

技术法规中"隐含碳排放"针对建筑的设计阶段和上游材料生产。瑞士建筑行业越来越多的环境影响评价不再仅仅关注使用阶段，同时也关注生产建筑材料带来的 "生态负担"，即来自于建材生产阶段的排放（隐含排放）。这些排放中约有一半来自新建建筑，另一半来自既有建筑改造，而拆除和退役的影响只占很小一部分[90]。因此，调查和实施旨在减少这种隐含碳排放的解决方案是至关重要的。循环经济提供了一个说明如何通过各种循环策略（例如重新思考、减少、翻新、回收）来减少材料整个生命周期中产生的环境影响的框架。由于建筑行业的独特布局，在建筑行业实施这种循环战略会带来一系列具体挑战。

i) 由于新输入流量远高于来自系统本身的潜在二次资源，建筑部门当前的材料流量高度不平衡。

ii) 建筑漫长而多样的生命周期使得处理来自建筑行业的二次资源的商业模式变得复杂。

iii) 材料的多样性和日益复杂的材料需要不同的循环策略，具体取决于所使用的各种材料。

iv) 建设项目是高度定制化的，众多利益相关方使标准解决方案变得复杂。

v) 除了一些有前景的试点之外，在存量建筑中哪些材料可以得到利用以及它们何时可以被利用以及材料质量如何等方面都存在巨大的知识差距。这些方面也会影响未来的建筑技术法规如何将隐含碳排放纳入进来。标签、材料通行证、建筑材料数据库以及针对个别材料和整个建筑的试点项目都是行业向这个方向发展的良好迹象，但针对哪种循环策略最有效仍存在很大的不确定性。目前的法规主要集中在关于拆除阶段和废物处理的规范要求上。

新的建筑法规还应允许探索更大规模的解决方案的技术和经济潜力。建议对采取以性能为导向的措施，即"热功率限值"和"能源结构限值"，也可以将其应用在社区和城区层面。空间规划，包括能源规划，可以提供一些补充激励措施，以促进更大规模的解决方案。

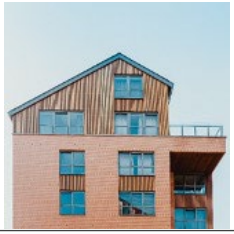
关于有效的建筑技术法规的另一个考虑是如何减少限制或目标值的约束性。立法机构应为此做出长期承诺，并限制其谈判范围，使建筑业主能够为即将到来的限制做好准备，允许他们选择最佳时间进行翻新工作。此外，因为这些产品和服务符合未来的法规，建筑行业产品和服务的发展也获得了保障，进一步鼓励了创新。

[90] 来源: onlinelibrary.wiley.com/doi/10.1111/jiec.12739

Outlook on future TER

The proposed TERs affect the entire life cycle (construction, operation and decommissioning) of a building. By subdividing the complex CO_2 regulation problem of buildings into interrelated but consistent measures, a regulation framework can be built which consist of transparent and comprehensible parts that can be easily and effectively enforced. Moreover, each TER, which covers a particular part of the framework, will target the relevant decision-makers, e.g. TER ‚capacity limit' influence the work of architects, TER ‚renewable share' influences the behaviour of the owner and TER ‚embodied emissions' can be reduced by the building material industry. Such tailored TERs, coordinated by the framework, could achieve the greatest impact of reducing CO_2 emissions.

The presented work focuses on technical energy regulations, which have increased energy efficiency in the past and will effectively decrease CO_2 emissions in the future. However, we acknowledge that such control and regulatory instruments work best if embedded and coordinated in a more comprehensive policy mix [Rogge, K. S., & Reichardt, K., 2016; Kern et al. 2017], as no single TER can address all the market and behavioural failures [Lee, W. L., Yik, F. W. H., 2004]. The coordination with other policy instruments, either economic and market-based (e.g. subsidies) or fiscal (i.e. taxes) instruments, or support, information and voluntary action, although not the focus of this work, will be essential to achieve the most significant possible impact. Furthermore, determining income and policy cost effects of the various mixes of regulatory instruments should also be examined and, if necessary, coordinated. This will establish holistic conditions for achieving the national objectives, like the net-zero goals of Switzerland.



TER set a minimum allowable standard for the energy performance of a building and measure them based on the yearly CO2-emissions. ©Unsplash | Web: bit.ly/3ilx3uk or dwz.date/fwpd

对未来建筑技术法规的展望

拟议的建筑技术法规应贯穿建筑的整个生命周期（建造、运营和停用）。通过将复杂的建筑二氧化碳监管问题细分为相互关联且一致的措施，可以建立一个由透明且易于理解的内容组成的监管框架，这些内容可以轻松有效地执行。此外，法规的每一个框架中特定部分都会针对相关的决策者，如“热功率极限”影响建筑师的工作，“可再生能源占比”影响业主的行为，“隐含碳排放”可以通过建筑材料行业来减少。这种多方面协调，“量身定制”的法规 可以实现最程度的减排。

该报告所展示的工作侧重于技术性能源法规，这些法规在过去提高了能源效率，并将在未来有效减少二氧化碳排放。如果将这种控制和监管手段嵌入到更全面的政策组合中并与之合作，则效果最佳[Rogge, K. S., & Reichardt, K., 2016; Kern et al. 2017]，因为没有一个单一的技术规范可以解决所有的市场和行为失误 [Lee, W. L., Yik, F. W. H., 2004]。虽然与其他政策工具，如经济和基于市场的（例如补贴）或财政（例如税收）工具，以及支持信息和自愿行动等的协调不是本项工作的重点，但这可能起到非常重要的影响。此外，应检查各种组合监管工具对收入和政策成本的影响，并在必要时进行协调。这些举措将为实现国家目标，例如瑞士的净零排放目标，创造整体条件。

技术法规为建筑能耗确定一个最低标准并用年碳排放量来进行测量。
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