Processes and tools for Solar Energy Buildings

IEA SHC TASK 66 | SOLAR ENERGY BUILDINGS

Technology Collaboration Programme
by IEA

SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

Processes and tools for Solar Energy Buildings

This is a report from SHC Task 66: Solar Energy Buildings and work performed in Subtask BC: Processes and tools for Solar Energy Buildings

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Solar Heating & Cooling Technology Collaboration Programme (IEA SHC)

The Solar Heating and Cooling Technology Collaboration Programme was founded in 1977 as one of the first multilateral technology initiatives ("Implementing Agreements") of the International Energy Agency.

Our mission is: *"Through multi-disciplinary international collaborative research and knowledge exchange, as well as market and policy recommendations, the IEA SHC will work to increase the deployment rate of solar heating and cooling systems by breaking down the technical and non-technical barriers."*

IEA SHC members carry out cooperative research, development, demonstrations, and exchanges of information through Tasks (projects) on solar heating and cooling components and systems and their application to advance the deployment and research and development activities in the field of solar heating and cooling.

Our focus areas, with the associated Tasks in parenthesis, include:

- Solar Space Heating and Water Heating (Tasks 14, 19, 26, 44, 54, 69)
- Solar Cooling (Tasks 25, 38, 48, 53, 65)
- Solar Heat for Industrial and Agricultural Processes (Tasks 29, 33, 49, 62, 64)
- Solar District Heating (Tasks 7, 45, 55, 68)
- Solar Buildings/Architecture/Urban Planning (Tasks 8, 11, 12, 13, 20, 22, 23, 28, 37, 40, 41, 47, 51, 52, 56, 59, 63, 66)
- Solar Thermal & PV (Tasks 16, 35, 60)
- Daylighting/Lighting (Tasks 21, 31, 50, 61)
- Materials/Components for Solar Heating and Cooling (Tasks 2, 3, 6, 10, 18, 27, 39)
- Standards, Certification, and Test Methods (Tasks 14, 24, 34, 43, 57)
- Resource Assessment (Tasks 1, 4, 5, 9, 17, 36, 46)
- Storage of Solar Heat (Tasks 7, 32, 42, 58, 67)

In addition to our Task work, other activities of the IEA SHC include our:

- SHC Solar Academy
- *Solar Heat Worldwide*, annual statistics report
- SHC International Conference

Our members

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1 Executive Summary

Designing new or converting existing buildings into Solar Energy Buildings or communities involves tools and methods for the different building life cycle phases from cradle to grave.

A survey was conducted to investigate which methods and tools are used and which are missing, including interviews with 46 stakeholders in 4 different countries.

The conducted interviews were 16 in Germany, 18 in China, 8 in Austria, and 4 in Denmark.

Solar Energy Building designs and the technologies used to supply heat, cold and electricity largely depend on the climates where the buildings are operated, building practices, and the energy infrastructure.

For example, in countries with a high share of district heating, centralized renewable energy systems are often applied by the district heating utilities, leading to a better economy for central systems compared to possible decentralized renewable energy systems.

The report presents excerpts of the different countries' energy landscape and the survey results.

European countries are reducing their non-renewable energy production and increasing their renewable energy production. For China, fossil fuel is still the main body of energy consumption and guarantee energy supply security. Meanwhile, China’s energy structure continuously optimizes with the growing proportion of renewable energy installation capacity.

The survey showed that in Germany, POLYSUN is the most popular program followed by TRNSYS, nPro and Hottgenroth Energiberater. In China TRNSYS is the most popular program followed by EnergyPlus and Dymola Modelica. In Austria, Trimble Nova is the most used program followed by Plancal. In Denmark POLYSUN, EnergyPro and Revit are most used.

The survey also revealed that many stakeholders use self-made programs, mainly because of the complexity and costs of the programs/software but also due to limitations in the commercial programs/software.

A high number of the tools and programs are used in the design and planning phase for Solar Energy Buildings. A smaller number of the tools and programs are used in the construction and verification phases and the operation and maintenance phases. No tools and programs are used in the renovation and end-of-life phases.

There are large differences in the tools used from country to country due to differences in national regulations, climate conditions, energy structures, and building traditions.

2 The survey

A questionnaire for stakeholders was prepared and distributed among the participating countries to investigate which processes and tools are used to build new or convert existing buildings into Solar Energy Buildings or communities.

In total, 46 responses are received from 4 countries. The number of conducted interviews was 16 in Germany, 18 in China, 8 in Austria, and 4 in Denmark.

The questionnaire included questions on tools and methods used in the building lifetime phases of Design, Construction and Verification, Operation and Maintenance, and Renovation and End of life.

The questions in the questionnaire are as follows:

Design

- Which procedures/guidelines are used in design phases?

Construction and verification

- Which procedures/guidelines are used in the construction and verification phase?
- Are standard operation procedures (SOP) for the verification of design used?
- Which equipment/tools/instruments are used for verification?
- Is a commissioning checklist followed?
- Are health and safety guidelines followed during construction?
- Are material testing procedures/guidelines followed?
- Are rectification procedures/guidelines for inaccurate construction followed?
- Are project monitoring techniques followed?

Operation and maintenance

- Which procedures/guidelines are used for the operation and maintenance phase?
- Are guarantees for good operation offered?
  - If yes, in how many % of your projects?
  - How is good operation verified?
  - What actions are taken if the guarantee is not fulfilled?
- Are monitoring contracts offered?
  - If yes, in how many % of the projects?
  - How long is the monitoring period?
- Are maintenance contracts offered?
  - If yes, in how many % of the projects?
  - How are the intervals for maintenance determined?
- Are energy performance contracts (EPC) offered?
  - If yes, in how many % of the projects?
- Are there general rules for the lifetime of specific components for economic assessment?
  - If yes, are you in favour of such rules?
  - If yes, and you are not in favour of such rules, why not?

Renovation and end of life

- Which procedures/guidelines are used for the renovation and end of life phase?
- How is the decision taken between renovation and end of life?
  - What is done with the materials at the end of life?

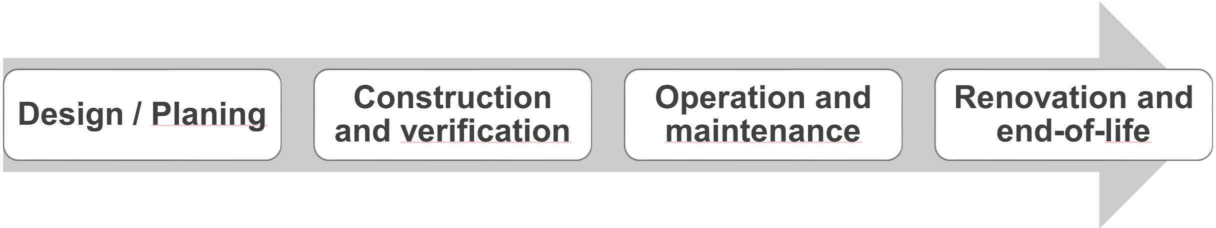
Programs/software

- Are commercial programs used?
  - Which programs/software are used?
  - Are special libraries used?
  - In which phase are the programs/software used?
- Are self-made programs/software used?
  - Which programs/software are used?
  - Can you give a short description of the program/software?

- In which phase are the programs/software used?
- What are the faced limitations of the program/software?
- What are the advantages/disadvantages of the program/software?
- Which programs/software are missing, and which limitation is essential?

3 Typical applied procedures and methodology in the building process

The graphic below describes the typical procedures and methodology applied in the building process throughout the building life cycle.



- recording of rough building concept, successive refinement in compliance with the specifications (e.g. efficiency standard, QNG (Qualitätssiegel Nachhaltige Gebäude) eco-balance class)
- evaluation of energy consumption and system technology, modulation of different reasonable variants; estimation of energy demand based on the energetic calculation
- cost estimation and economic efficiency calculation
- determination of available areas with orientation, shading ….; planning of thermal insulation partly based on 3-D models
- choice of technology according to local conditions.
- use of simulation tools in preliminary phases 1-3 (building simulation), 4 (thermic simulation), sometimes to 5 (controlling strategy) or even 9 (calibration with measured data)

construction supervision by means of detailed planning:

- thermal bridge details
- air tightness concept
- ventilation concept
- heating load and cooling load calculation
- hydraulic balancing
- funding verification

- structured construction support / construction site control - on site or digitally via live camera

- customer instructions
- maintenance plans
- hydraulic and pneumatic calibration
- performance monitoring (setting specifications)

How is the decision taken between renovation or end of life?

- decides the client /owner
- via a life cycle assessment
- economical, ecological decision making, trending to individual decision, competition based
- depends on the status

What is done with the materials?

- databank for selling used building components
- focus in design on dismantling of the same kind
- unkown

Goal:

- recommendation for variants with indication of investment costs and energy costs.
- understanding the concept and convert them into plans / drawings

4 Germany

4.1 Excerpts from the German energy landscape

Germany uses diverse energy sources, including oil, natural gas, coal, renewable energy, electricity, district heating and other energy sources. Renewable sources include solar energy (PV and solar thermal), wind power, hydropower, geothermal energy as well as biomass (gases, liquid and solid).

The use of oil, gas and coal continues to decrease with the government's policy of facing out these energy sources, while renewable energy sources are taking over energy production. The total energy consumption remained stable at around 9,000 PJ until around 2017. Since 2018, there has been an annual decline and the consumption is now at a lower level. (Figure *1*). Energy consumption in Germany is divided into the sectors of mining and manufacturing, private households, as well as traffic, each accounting for 25 - 30%, and trade, commerce and services accounting for around 15%. In addition, consumption can also be split into the areas of electricity and district heating production, heating and cooling and traffic. Here it can be seen that a large proportion is accounted for electricity production. (*Figure* ***3*** and Figure 4)

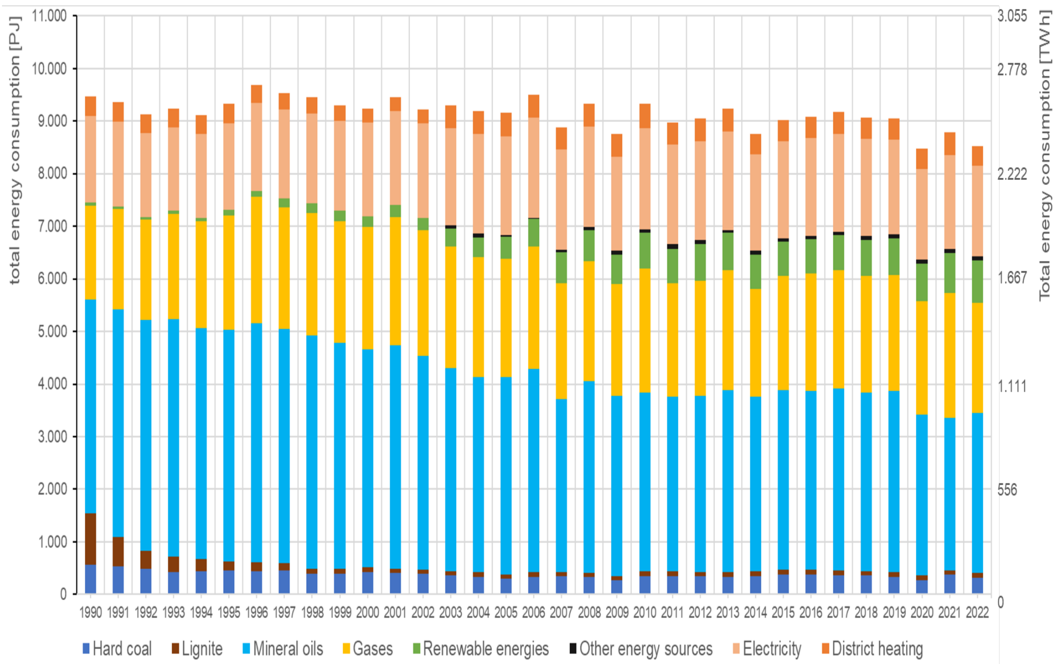


Figure 1: Total energy consumption by fuel in Germany (1990 – 2022) (AGEB - Auswertungstabellen zur Energiebilanz 1990 bis 2022, Stand November 2023)); includes all sectors: Mining and manufacturing, private household, traffic as well as trade, commerce and services

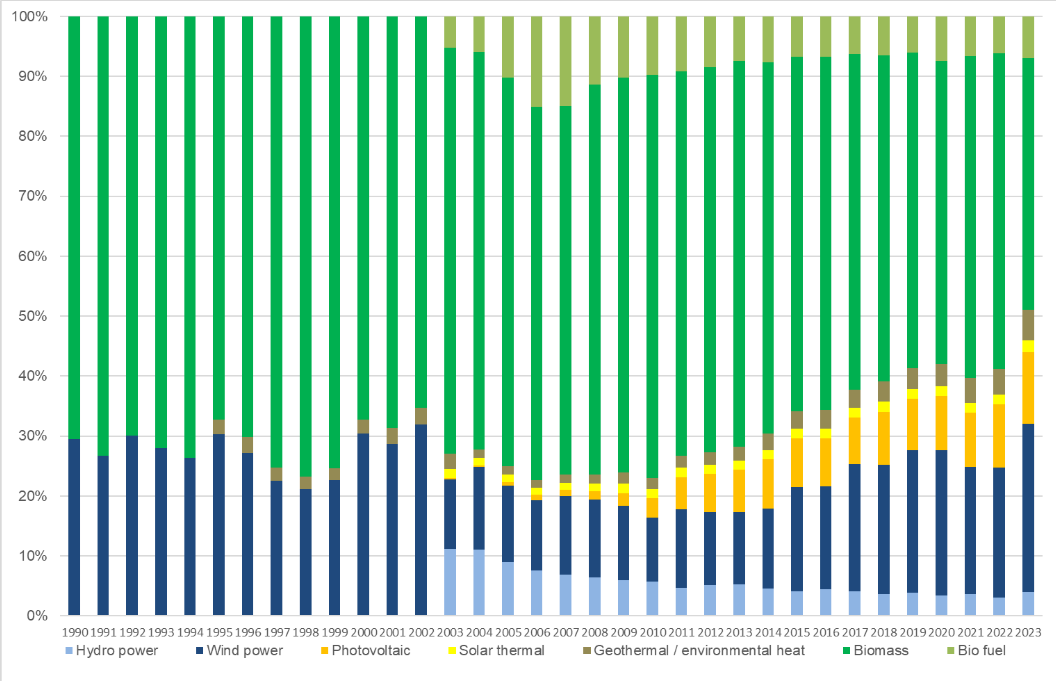


Figure 2: Share of renewable energy (1990 – 2022) (AGEB - Auswertungstabellen zur Energiebilanz 1990 bis 2022, Stand November 2023))

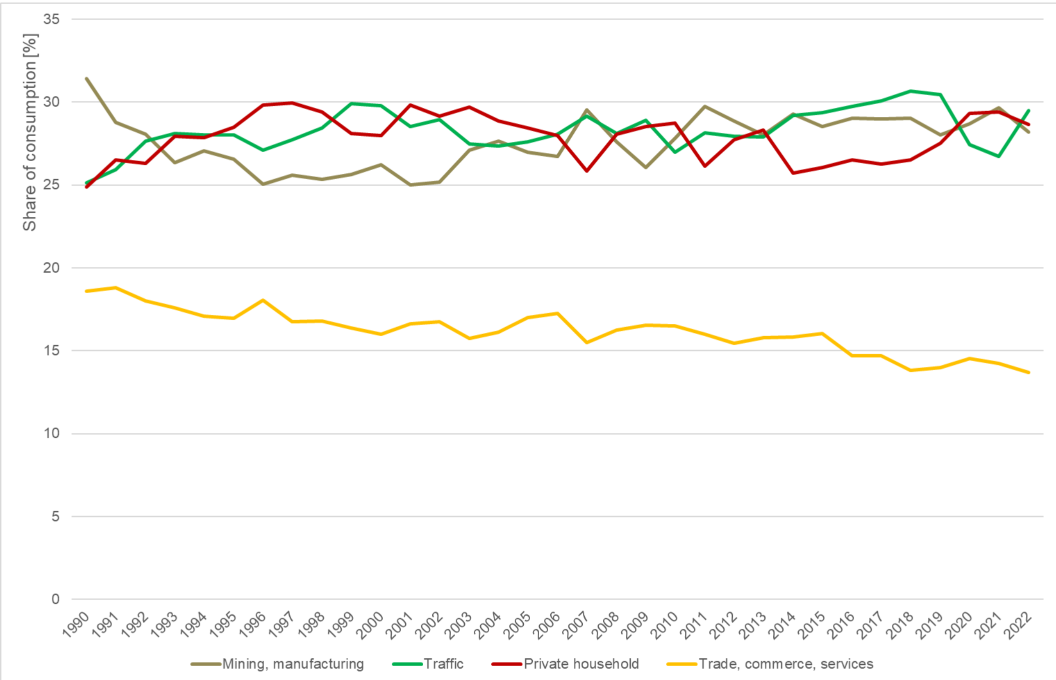


Figure 3: Share of total final energy consumption in different sectors in Germany (1990 – 2022) (AGEB - Auswertungstabellen zur Energiebilanz 1990 bis 2022, 11/ 2023))

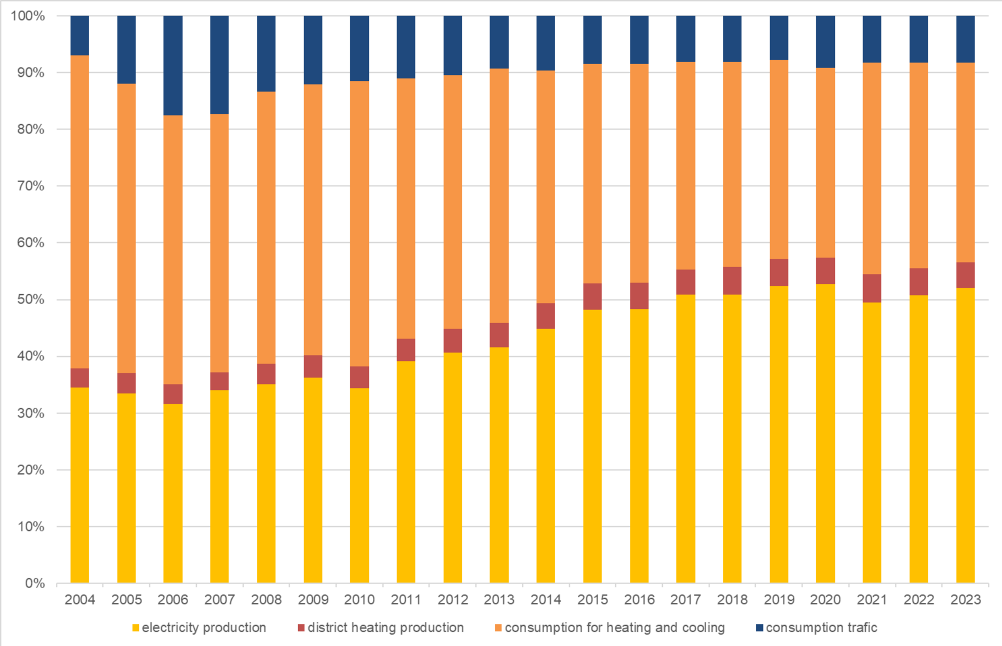


Figure 4: Share of total final energy consumption in Germany (1990 – 2023) (AGEB - Auswertungstabellen zur Energiebilanz 1990 bis 2022, 11/ 2023))

There has been a significant reduction in electricity consumption in Germany since 2011. Due to the shutdown of nuclear power plants, consumption here is approaching zero.

Since 2003, Germany made remarkable progress, it starts with 3% of its total consumption coming from renewables. The share of renewable energies in electricity consumption will increase to 51.8% by 2023, and the heating sector (18.8%) and transport (7.3%) will also slowly move in the direction of renewables. (Figure 7). (Reference only to the sectors: trade, commerce and services, private household as well as traffic sector). Germany has made significant progress in incorporating renewable energy into its electricity grids. Wind power, in particular, plays a crucial role, contributing significantly to the country's electricity generation. Additionally, solar power and biomass contribute to the diverse renewable energy mix in the electric grid. (Figure 6)

The primary contributor is wind power, accounting for 52 % in 2023, followed by photovoltaic (23 % in 2023), bio mass (18 % in 2023), and hydro power (7 % in 2023) (Figure 6 and Table 1Figure 22).

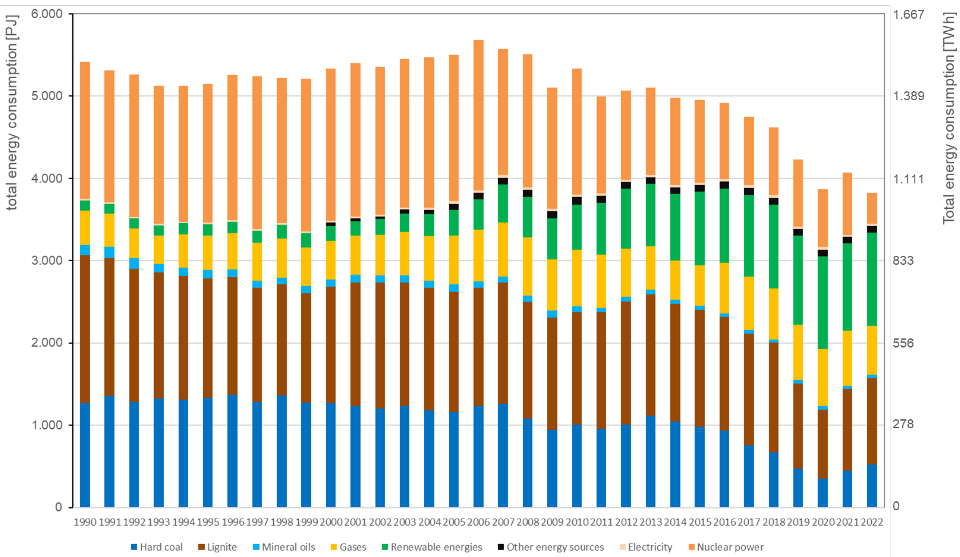


Figure 5: Total electricity consumption by fuel in Germany (1990 – 2022) (AGEB - Auswertungstabellen zur Energiebilanz 1990 bis 2022, 11/2023))

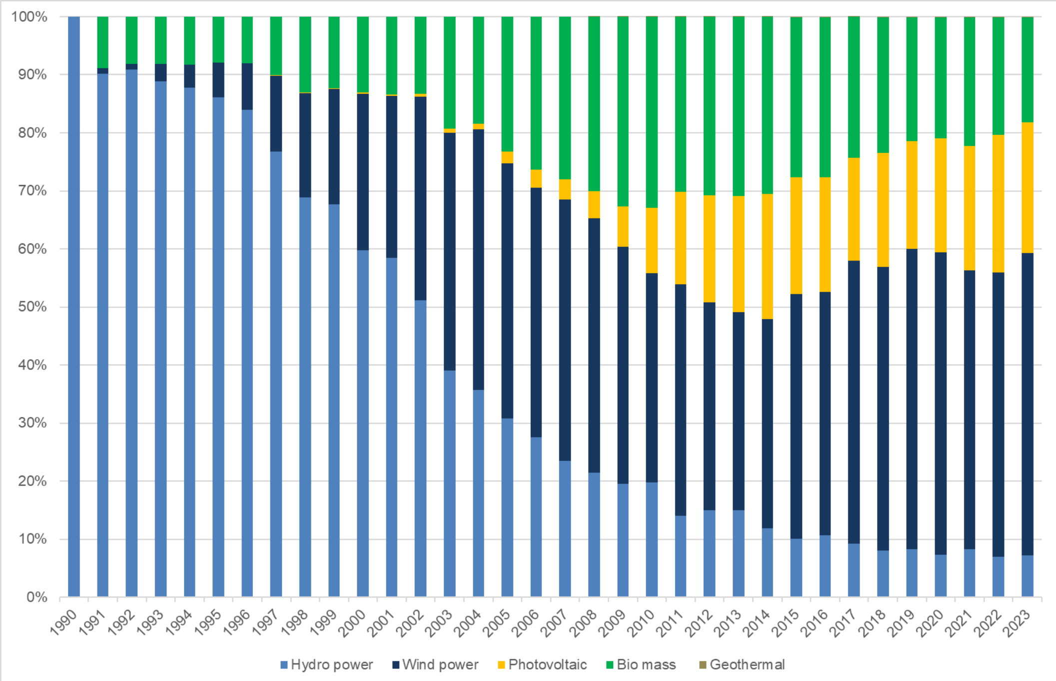


Figure 6: Share of renewable energy on electricity consumption 1990 – 2023 (Arbeitsgruppe Erneuerbare Energien-Statistik (AGEE-Stat)).

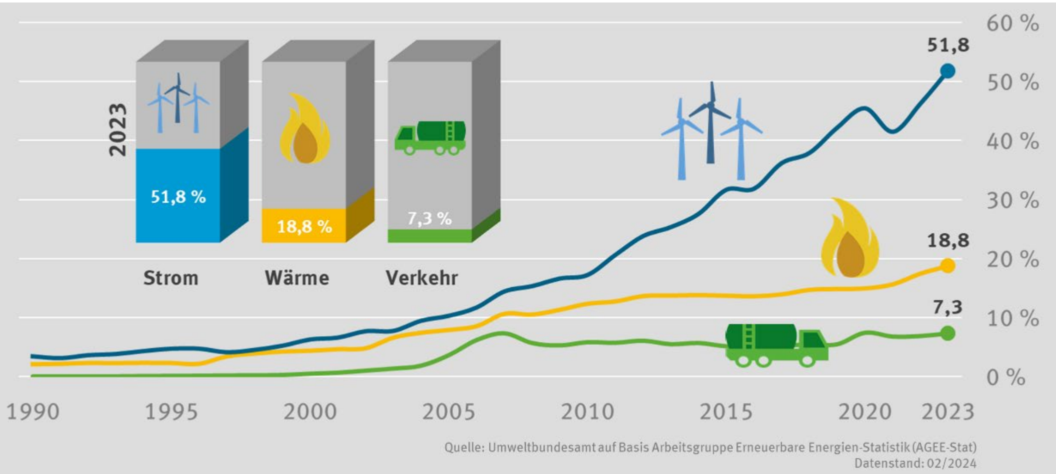


Figure 7: Renewable energies: Shares in the transport, heating and electricity sectors in Germany (1990 – 2023) (Umweltbundesamt)

Energy used in households and heating and cooling

In terms of energy consumption for heating and cooling, given Germany's climate, a considerable portion of energy is dedicated to meeting heating needs, especially during colder months. This requirement extends to residential buildings, commercial spaces, and industrial facilities. While the demand for cooling energy is comparatively lower (not predefined for residential buildings), it is still present, particularly in the warmer seasons.

The private household sector accounts for 25 to 30 % of the total energy consumption in Germany (*Figure 3*). Figure 8 shows the final energy consumption in private households and the different energy sources used to cover the consumption. Energy consumption still relies heavily on non-renewable energy sources. The energy consumption of households is influenced by the weather and a general reduction in energy consumption due to strict building regulations and very high energy costs, especially from 2021. In 2021 and 2022, public buildings were required to keep a maximum temperature of 19 °C, reducing energy consumption considerably (Figure 8).

Around 19% of heating and cooling consumption is covered by renewables. The majority of this, >80%, is covered by biomass. Geothermal energy only covers a share of around 20% and a share of 5% is covered by solar thermal energy.

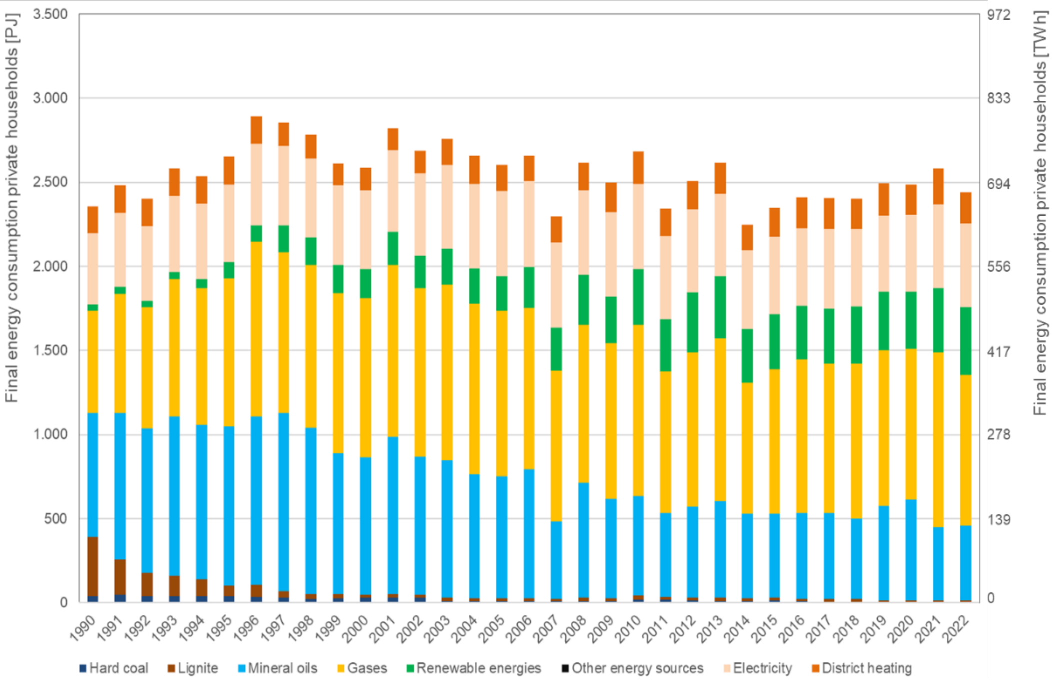


Figure 8: Final energy consumption in private households based on energy source in Germany (1990 - 2022) (AGEB - Auswertungstabellen zur Energiebilanz 1990 bis 2022, 11/ 2023)

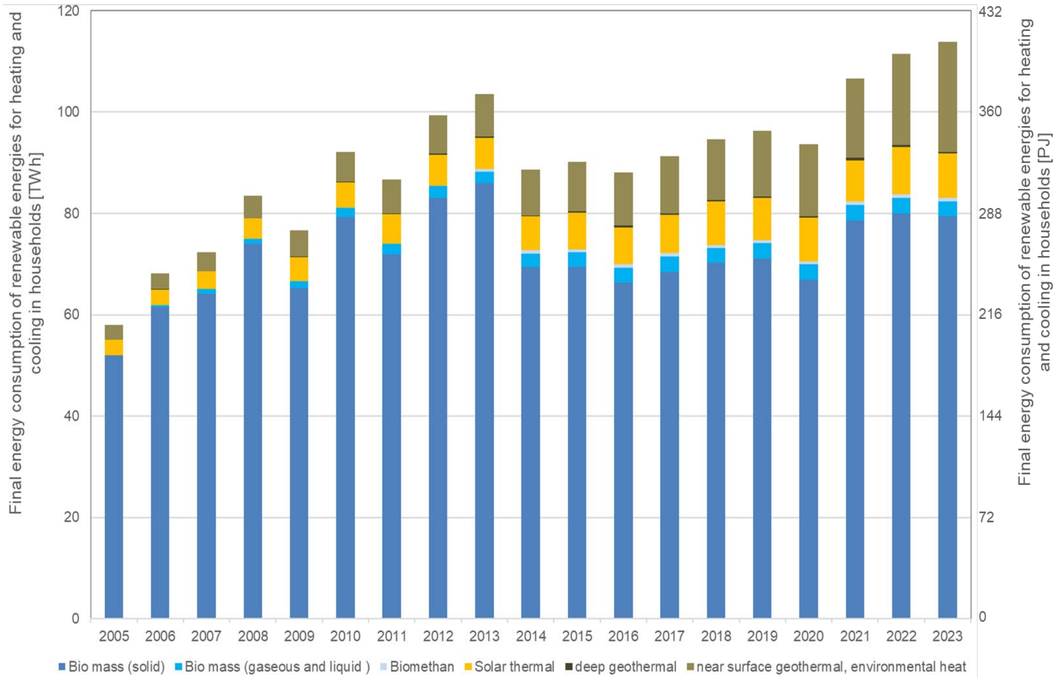


Figure 9: Final energy consumption of renewable energy for heating and cooling in households (2005 – 2023) (Arbeitsgruppe Erneuerbare Energien-Statistik (AGEE-Stat)).

Table 1 shows the renewable share of the final energy and electricity consumption in the German energy supply for 2023. The electricity consumption is about 47 % of the final energy consumption.

Table 1: Renewable share in the German energy supply (Arbeitsgruppe Erneuerbare Energien-Statistik (AGEE-Stat)). Table and values include the sectors: trade, commerce and services, private household as well as traffic sector

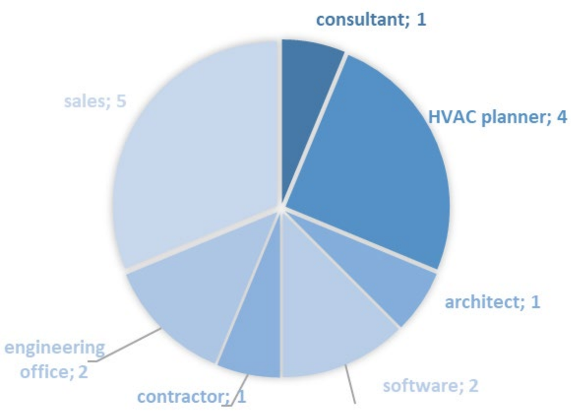
	Renewable energy coverage of final energy consumption	Renewable energy coverage of final electricity consumption
Photovoltaic (PV)	6 %	12 %
Wind	13 %	27 %
Solar thermal	1 % -	-
Geothermal	2 %-	< 0,1 %
Hydro power	2%	4 %
Biomass (gaseous, liquid and solid)	19 %	9 %
Bio fuel	3 %	-

4.2 Questionnaire results

4.2.1 Participants

16 stakeholders in Germany took part in the survey on methods and tools in the SEB planning and construction process. The participants come from different areas of work. The majority of participants work in the sales and planning part of HVAC systems. Other participants work as consultants, architects, software providers, contractors, and in engineering offices (Figure 10).

The activities and commissions of the participants (multiple answers possible) focus during the building process as follows: 35% (12/13 answers) of the activities / processing relate to the design / planning phase as well as the construction and verification phase. In each case, 14% (5 answers) consider or work on the operation and maintenance as well as on renovation and end of life phases as part of their assignments (Figure 10).



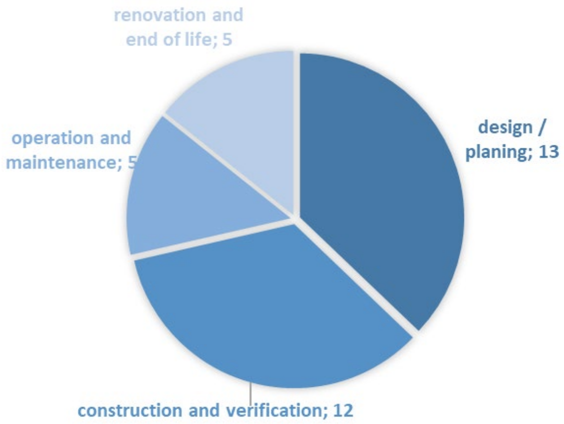


Figure 10: Left: Areas of work of the stakeholders in Germany (number of responses). Right: Performance phases of the processing of stakeholders in Germany (number of responses)

4.2.2 Procedures and guidelines used in different life cycle phases

The survey asked which procedures, guidelines, and regulations are used in the various construction phases. The answers from the participants show that in Germany, only the standard and prescribed procedures and guidelines are used. These are then also applied throughout the entire planning and construction process. Most of the guidelines are listed for the design phase. In the operation and maintenance phase, only two guidelines were mentioned. This may also be due to the fact that hardly any participants work in this area. (see Figure 11)

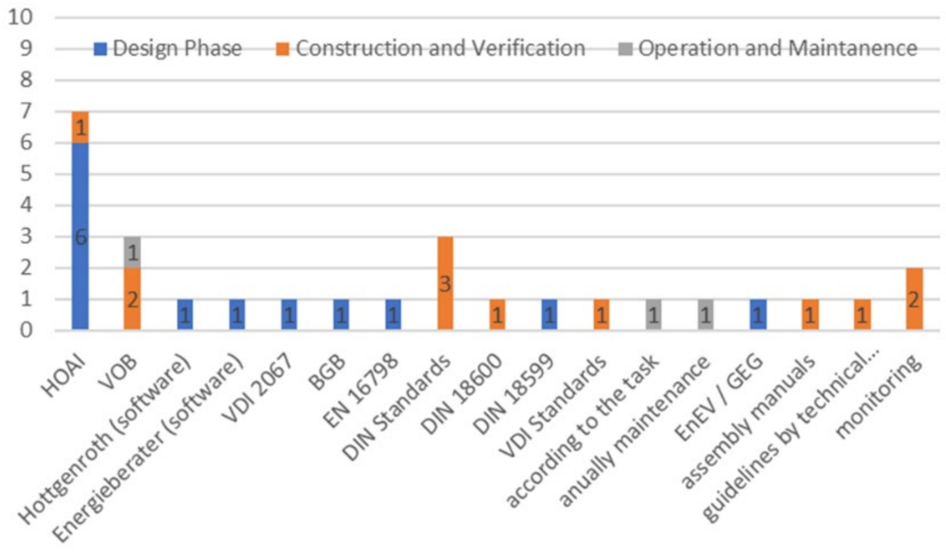


Figure 11: Procedures, guidelines and standards used / applied in the construction process (number of responses)

Indices and abbreviations used in Figure 11 are listed in Table 2.

Table 2: Indices and abbreviations.

BGB	Bürgerliches Gesetzbuch German Civil Code
EnEV / GEG	Energieeinsparverordnung / Gebäude-Energie-Gesetz Energy Saving Ordinance / Building Energy Act
HOAI	Honorarordnung für Architekten und Ingenieure Fee Structure for Architects and Engineers
VOB	Vergabe- und Vertragsordnung für Bauleistungen Contract award and contract regulations for construction work

4.2.3 Operation and maintenance and renovation and end of life

With the increasing complexity of system technology, the focus is increasingly on scheduled system operation and efficient operation.

Figure 12 and Table 3 show different services offered by companies to clients and the interviewee answers to the follow up questions on operation and maintenance.

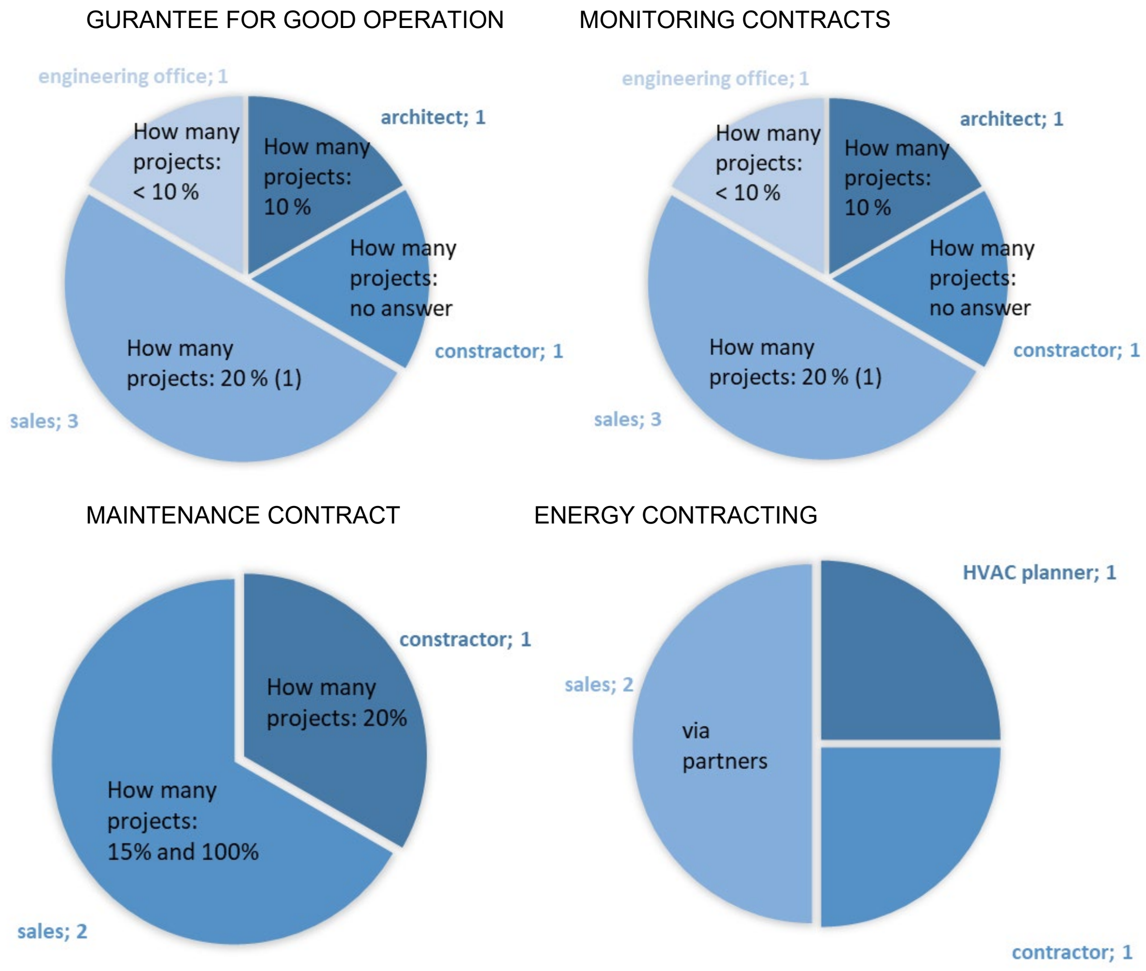


Figure 12: Services offered regarding operation and maintenance in Germany.

Table 3: Operation and maintenance answers from the German interviewee.

Question	Answer
How is good operation verified?	• checks are rarely carried out • if monitoring takes place, this is the case via monitoring and operation tests or online-monitoring by handyman as well as • via suppliers (in the area of public utilities)
What actions are taken if the guarantee is not fulfilled?	• this has not yet been the case and a penalty has been imposed, • penalties are set out in contract law. A contractual penalty is a binding sum of money promised to the other contracting party in the event that the promising debtor fails to fulfill the contractual obligations or fails to do so in the appropriate manner.
How long is the monitoring period?	• 2 years • As long as the maintenance contract runs • 2 to 3 months during the winter and summer periods
How are the intervals for maintenance determined?	• annually maintenance • in consultation with operator and installer/manufacturer • e.g. power plants: lubrication analyses are carried out. • e.g. filter change in ventilation according to DIN 1946-6
Are there general rules for the lifetime of specific components for economic assessment?	• VDI 2067 is fundamentally crucial for the specification and listing of service lifes as well as maintenance and servicing requirements • 25-30 years

	• BNB (Bewertungssystem Nachhaltiges Bauen) useful life - but questionable and very different depending on the type of building/ownership
If yes, are you in favour of such rules?	• -
If yes, and you are not in favour of such rules, why not?	• rules are insufficiently accurate • energy supplier has more knowledge
How is the decision taken between renovation and end of life?	• -
What is done with the materials at the end of life?	• -

5 China

5.1 Excerpts from the Chinese energy landscape

To achieve the “carbon peaking and carbon neutrality” target, establishing a clean, low-carbon, secure and high efficient modern energy system is important.

China remains committed to advance energy revolution. The comprehensive energy production system, which is driven by coal, petroleum, natural gas, electricity, renewable energy, and others, is formed basically. Meanwhile, the exploration and utilization of renewable energy scales up at express speed, and the accumulated installation capacity of hydro power, wind power and photovoltaic power ranks first globally.

As can be seen in Figure 13, in recent years, the energy production is growing steadily, including use of raw coal, raw petroleum, natural gas and electricity.

In 2022, China’s total primary energy production reaches 4.6 gigaton of standard coal. Thereof, raw coal production reaches 4.56 gigaton, the raw petroleum production reaches 204.7 million tons, the natural gas production reaches 22 billion cubic meters, and the electricity production reaches about 8800 terawatt-hour.

Figure 13: Total energy production in China from 2013 – 2022.

Figure 14 shows the power installation capacity and structure from 2013 to 2022 in China, including thermal power, hydropower, wind power, solar power, and nuclear power. As shown in the figure, the power generation and supply capacity continue to improve.

By the end of 2022, the total power installation reaches nearly 2500 GW. Hereof, the thermal power installation reaches 1330 GW, including 1120 GW of coal power while renewable energy power installation reaches 1213 GW, and accounts for nearly 50% of total power installation.

From the past decade historical data, it can be seen that the proportion of installation of non-fossil fuel has increased significantly, mainly the solar power, but also that continues progress was made in the green transformation of power installation in China.

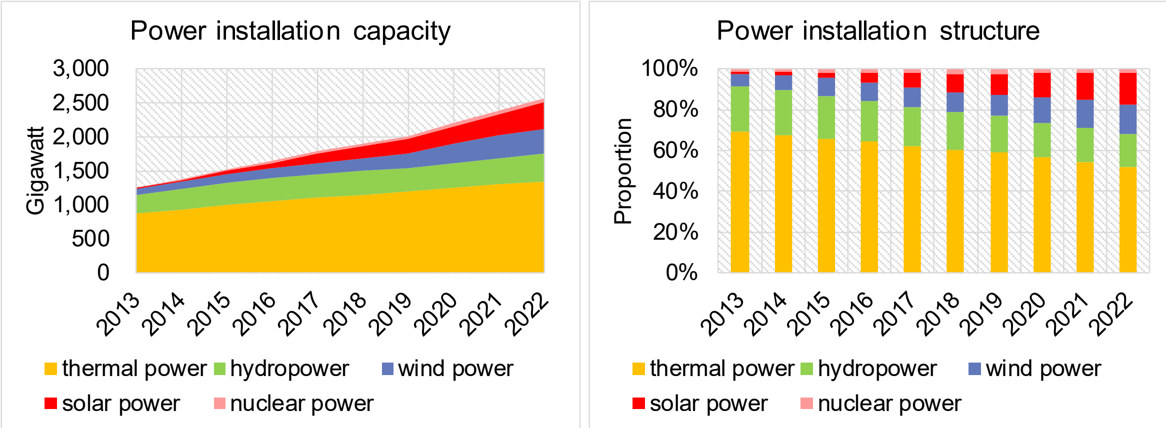


Figure 14: Development of national power installation capacity and structure from 2013 – 2022.

In 2022, the national power generation reaches nearly 8800 TWh. The thermal power is still the main body of energy supply in China, and it accounts for 66% of the national electricity production (Figure 15).

The power generation of renewable energy reaches nearly 2700 TWh, accounting for 31.6% of social electricity consumption. Thereof, the power generation of wind and photovoltaic reaches nearly 1200 TWh, which is close to the national urban and rural residents living electricity consumption.

In China, the renewable energy is playing an increasingly important role in securing energy supplies.

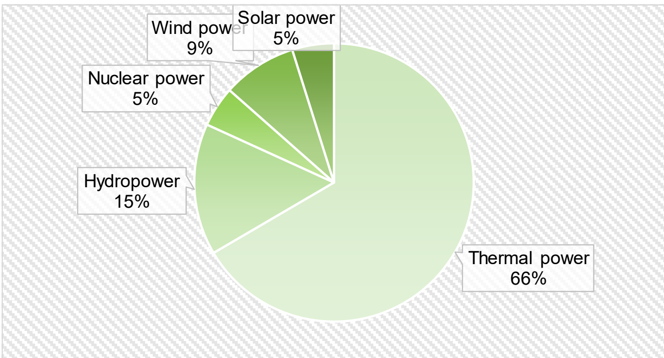
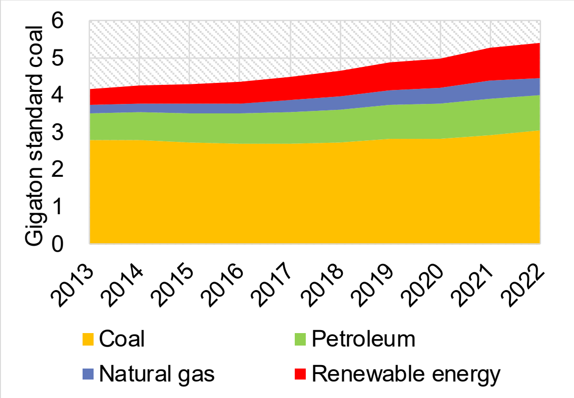


Figure 15: Power generation in 2022.

In 2022, the total energy consumption reaches 5.41 gigaton of standard coal. The energy consumption is still dominated by traditional fossil fuels, such as coal and petroleum. But the proportion of clean energy consumption continuous to increase (Figure 16). China's energy consumption structure is continuously changed with an increasing number of non-fossil energy production systems.



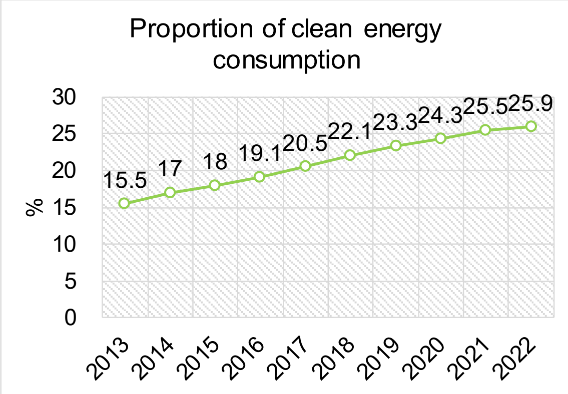


Figure 16: Energy consumption 2013 – 2022.

The share of renewable energy in the Chinese energy supply is listed in Table 4 for 2022.

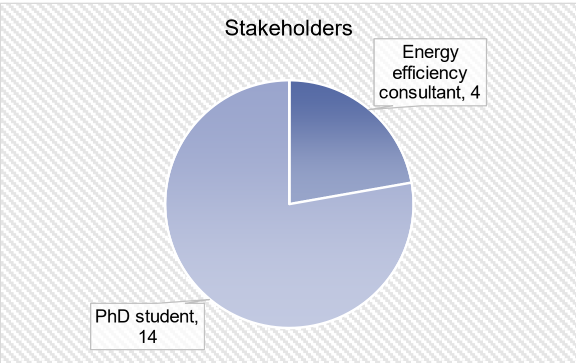
Table 4: Renewable share in the Chinese energy supply.

2022	Renewable energy coverage of final energy consumption	Renewable energy coverage of final electricity consumption
Photovoltaic, PV	2.4 %	5 %
Wind	4.3 %	8.8 %
Solar thermal	0.01 %	0.01 %
Hydro power	7.6 %	15.6 %
Biomass	1 %	2.1 %
Nuclear	2.3 %	4.8 %

5.2 Questionnaire results

5.2.1 Participants

18 Chinese stakeholders took part in the survey on methods and tools used in the process of designing new or converting existing buildings into Solar Energy Building communities. The stakeholders are from different areas of work (Figure 17).



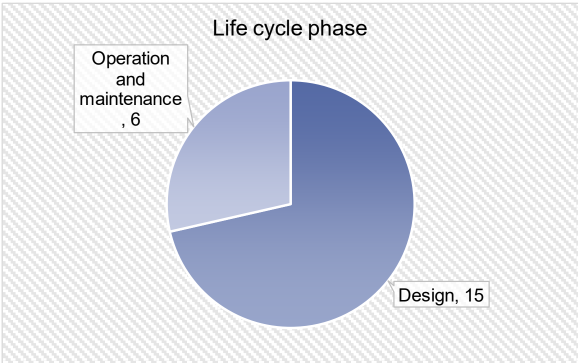


Figure 17: Chinese stakeholders.

5.2.2 Procedures and guidelines used in different life cycle phases

In Figure 18, procedures/guidelines used in different building life phases are shown. The phases are Design and Operation and maintenance.

The national standards used in the two life cycle phases of the buildings are listed here and in Figure 18 the number of stakeholders applying the national standards are shown:

- GB 55015-2021, General code for energy efficiency and renewable energy application in buildings
- GB 50176-2016, Thermal design code for civil building
- GB 50736-2012, Design code for heating, ventilation, and air conditioning of civil buildings
- GB 55016-2021, General code for building environment
- Technical standard for zero carbon buildings (Exposure draft)
- GB 50189, Design standard for energy efficiency of public buildings (under revision)
- GB 50495-2019, Technical standard for solar heating system
- GB/T 51350-2019, Technical standard for nearly zero energy buildings
- GB 55022-2011, General code for maintenance and renovation of existing buildings

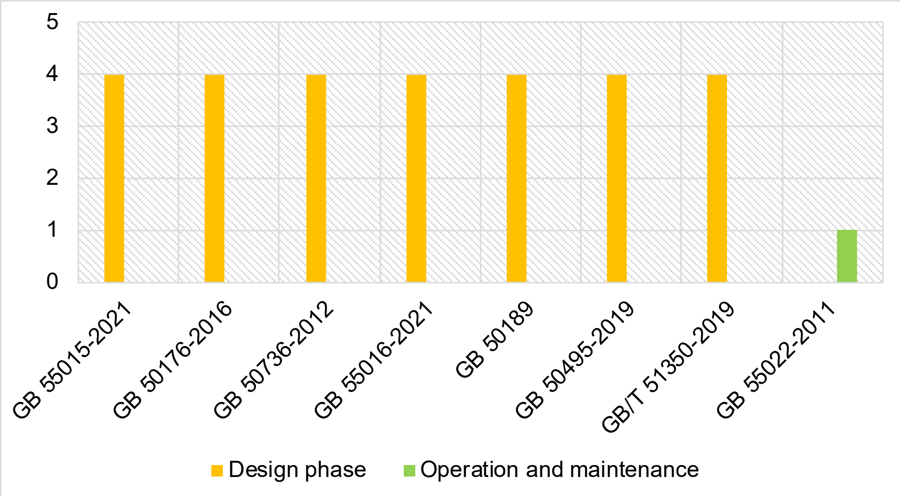


Figure 18: Procedures / guidelines used in different phases.

5.2.3 Operation and maintenance and renovation and end of life

Table 5: Operation and maintenance questions.

Question	Answer
How is good operation verified?	▪ Regularly inspection for checking the building situation, including appearance, equipment operation situation, maintenance situation, etc., to identify potential problems. ▪ Applying sensors and testing equipment to inspect the operation parameters of buildings. ▪ Benchmarking the operation data with design parameters and simulation results. ▪ Collecting opinions of the users by questionnaire or interview
What actions are taken if the guarantee is not fulfilled?	▪ Writing detailed technical analysis report to analyze the cause. ▪ Improving the efficiency of the system by using high performance equipment, updating control software, etc. ▪ Establishing an effective supervision mechanism, and punishing when a violation occurs
How long is the monitoring period?	▪ -

How are the intervals for maintenance determined?	▪ -
Are there general rules for the lifetime of specific components for economic assessment?	▪ -
If yes, are you in favour of such rules?	▪ -
If yes, and you are not in favour of such rules, why not?	▪ -
How is the decision taken between renovation and end of life?	▪ -
What is done with the materials at the end of life?	▪ -

6 Austria

6.1 Excerpts from the Austrian energy landscape

The Austrian government set the goal to reach climate neutrality by 2040. [1] To achieve this goal, significant efforts towards decarbonization are crucial across all energy sectors. A key milestone in this journey is Austria's aim to have 100% renewable electricity by 2030, as outlined in the national balance. In 2018, Austria made remarkable progress, with 77% of its electricity coming from renewables, making it the third-largest share among IEA countries [1]. The country relies on hydroelectric power, wind energy, biomass, and solar power as primary energy sources. While natural gas and oil are still in the mix, Austria actively works on reducing its dependence on non-renewable sources.

Energy generation

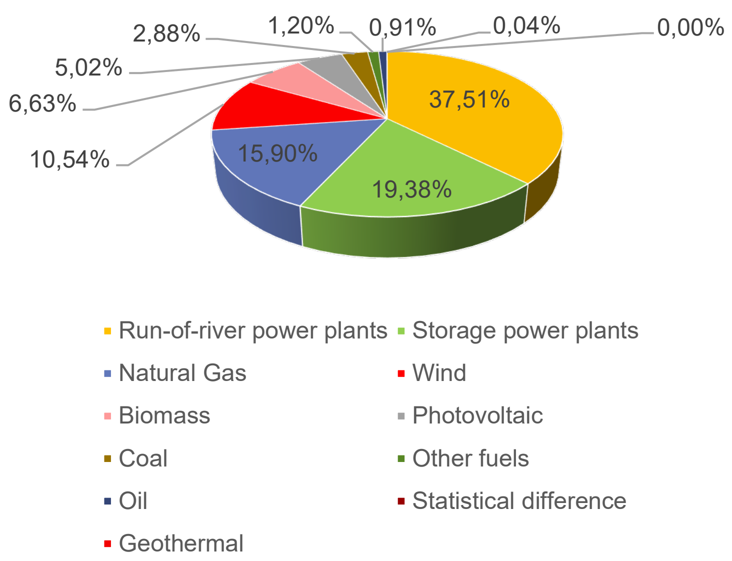


Figure 19: Gross electricity generation in Austria in 2022. Source: Osterreichs Energie (https://oesterreichsenergie.at/en/our-electricity-system/overview)

Energy supply

When assessing the energy supply, we take into account both production and imports, excluding exports. Despite the continuous growth of renewable energies such as wind and solar energy in the Austrian energy supply, the predominant contributors remain oil and natural gas, with approximately 450,696 and 283,504 TJ in 2022, respectively. It's noteworthy that biofuels and waste have experienced substantial growth since 2004, reaching 265,510 TJ in 2022, a value closely comparable to that of natural gas [1].

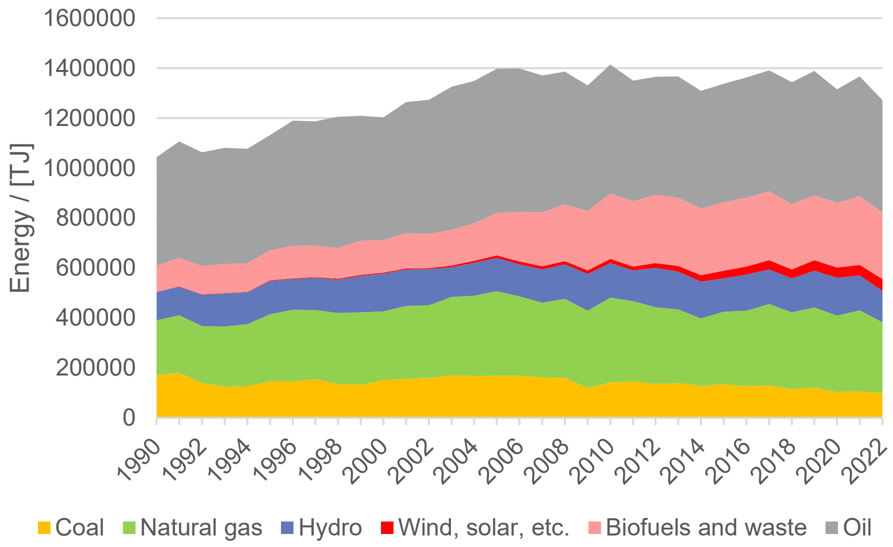


Figure 20: Total energy supply in Austria (1990 – 2022). Source: IEA (https://www.iea.org/countries/austria)

Useful energy

Useful energy is distributed to various end-users in Austria through different means, with diesel accounting for 23% and electricity for 22%, as depicted in Figure 21 [3]

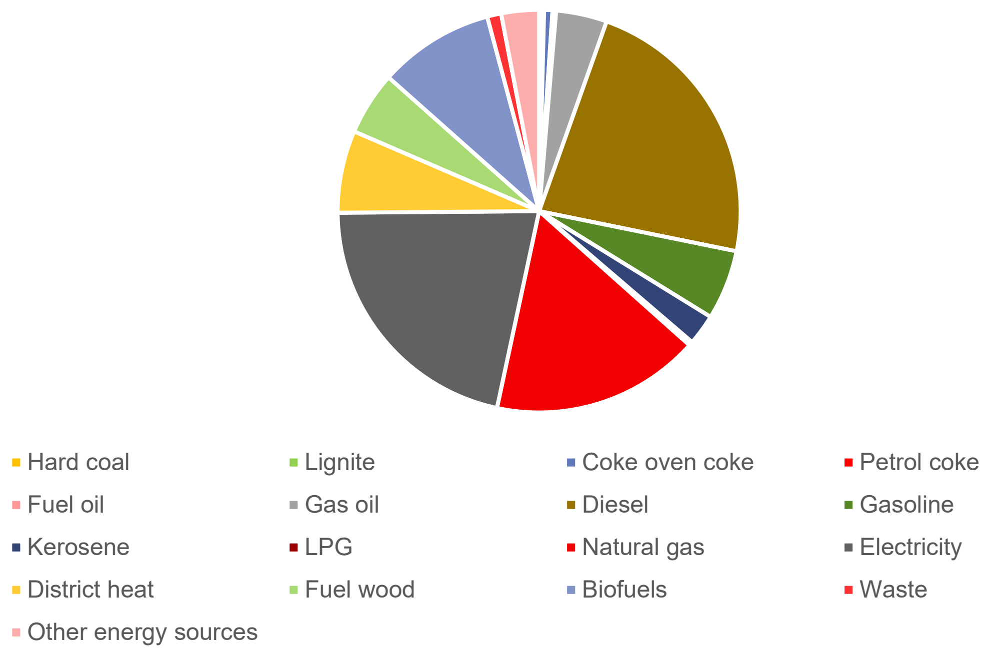


Figure 21: Useful energy in Austria (2022). Source: Statistic Austria (https://www.statistik.at/en/statistics/energy-and-environment/energy/useful-energy-analysis)

Renewable energy

Austria has made significant progress in incorporating renewable energy into its electricity grids. Hydropower, in particular, plays a crucial role, contributing significantly to the country's electricity generation. Additionally, wind and solar power contribute to the diverse renewable energy mix in the electric grid. In district heating systems, biomass and geothermal energy are commonly employed, promoting a more sustainable and environmentally friendly approach to providing heat to residential and commercial areas.

The distribution of sources in the Austrian electricity mix aligns with the trends observed in energy production. The primary contributor is hydropower, accounting for 39,221 GWh in 2022, followed by natural gas (10,880 GWh in 2022), wind (7,245 GWh in 2022), biofuels (4,336 GWh in 2022), and solar PV (3,792 GWh in 2022) (Figure 22) [1].

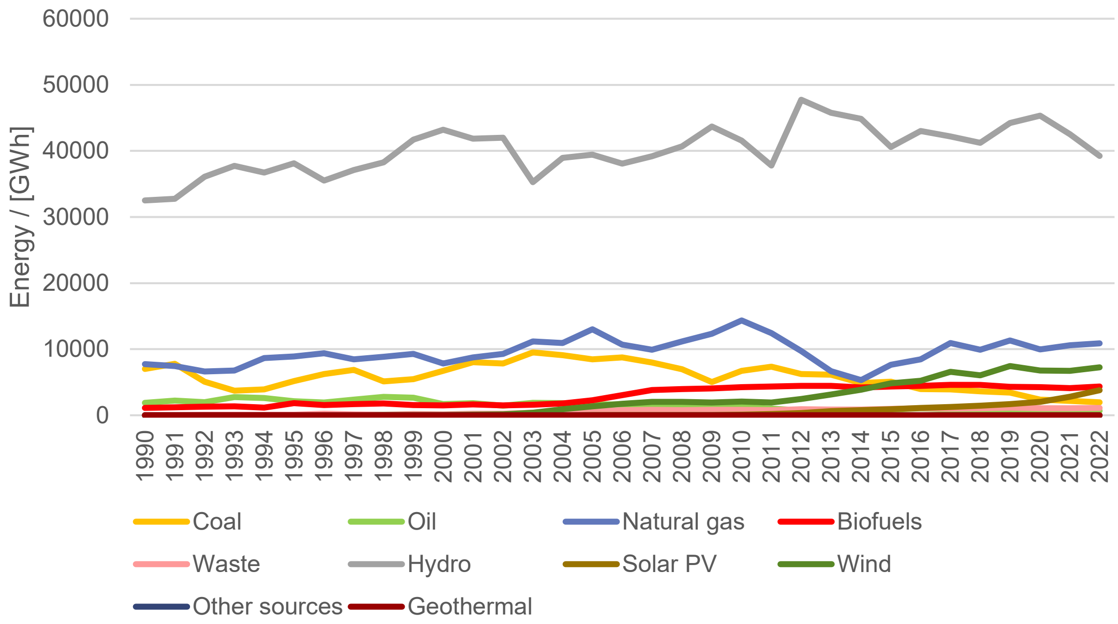


Figure 22: Electricity generation by source in Austria (1990-2022). Source: IEA (https://www.iea.org/countries/austria)

Furthermore, district heating plays a significant role in the Austrian energy system, with approximately 25% of Austrian apartments being heated through district heating, and this number continues to rise, particularly in urban areas. Currently, there are over 2,000 heating networks in Austria [4].

Energy used for heating and cooling

In terms of energy consumption for heating and cooling, given Austria's climate, a considerable portion of energy is dedicated to meeting heating needs, especially during colder months. This requirement extends to residential buildings, commercial spaces, and industrial facilities. While the demand for cooling energy is comparatively lower, it is still present, particularly in the warmer seasons.

The heating and cooling sector accounts for 35% of the total energy consumption in Austria, representing the highest share among all sectors (Figure 23). There are notable variations among different sectors. In the manufacturing industries sector, space heating and air conditioning represent 18% of the total energy consumption, whereas in the commercial and residential sectors, these values increase to 63% and 86%, respectively, of the total required energy [3].

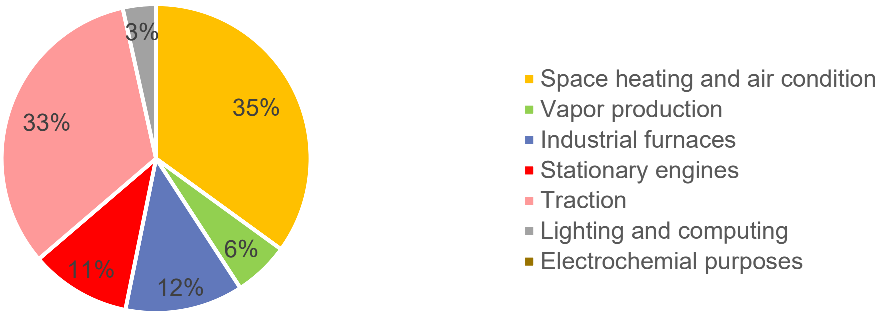


Figure 23: End of use of energy in Austria (2022). Source: Statistic Austria (https://www.statistik.at/en/statistics/energy-and-environment/energy/useful-energy-analysis)

The share of renewable energy in the Austrian energy supply is listed in Table 6 for YYYY.

Table 6: Renewable share in the Austrian energy supply.

YYYY	Renewable energy coverage of final energy consumption	Renewable energy coverage of final electricity consumption
Photovoltaic, PV	1.2 %	5.5 %
Wind	2.3 %	10.5 %
Solar thermal	2.6 %	0 %
Hydro power	12.2 %	56.7 %
Biomass & Biofuels	27 %	23 %

Useful sources

Useful websites to check Austria energy data divided in several categories (e.g. energy production and energy use) and for several years until 2022:

- https://www.iea.org/countries/austria
- https://oesterreichsenergie.at/en/facts-figures/graphics

References

[1] IEA International Energy Agency, https://www.iea.org/countries/austria

[2] Osterreichs Energie, https://oesterreichsenergie.at/en/our-electricity-system/overview

[3] Statistik Austria, The Information Manager, https://www.statistik.at/en

[4] IEA Research Cooperation, EA District Heating and Cooling (DHC TCP)
https://nachhaltigwirtschaften.at/en/iea/technologyprogrammes/dhc/

6.2 Questionnaire results

6.2.1 Participants

Interviews have been conducted with 8 Austrian stakeholders to answer the questions (Figure 24). The stakeholders are from different areas of work.

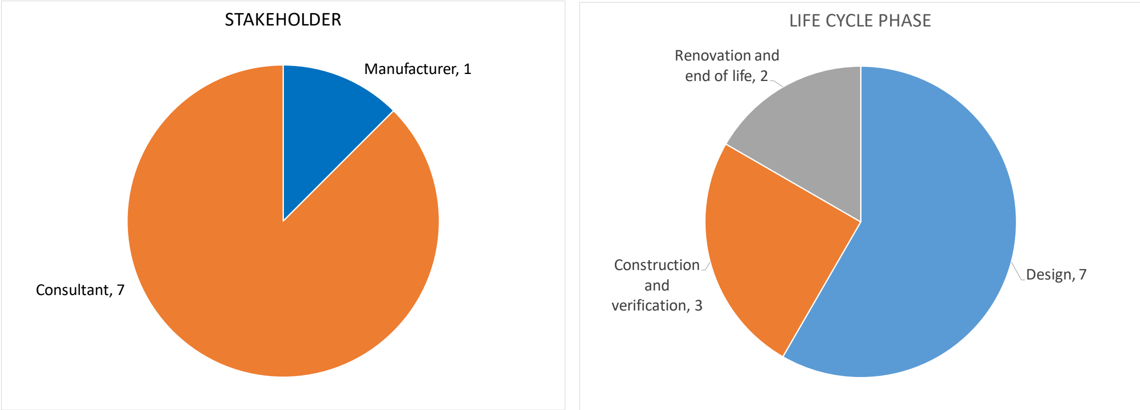


Figure 24: Left: Areas of work of the stakeholders in Austria. Right: Performance phases of the processing of stakeholders in Austria

No Austrian answers were given to the questions on methods used for design, operation and maintenance, or renovation and end of life.

7 Denmark

7.1 Excerpts from the Danish energy landscape

Denmark uses diverse energy sources, including oil, natural gas, coal, and coke, non-biodegradable waste (just under half of the waste), renewable energy, electricity, district heating, and town gas.

Renewable sources include solar energy, wind power, hydropower, geothermal energy, biomass (Straw, wood chips, firewood, pellets, wood waste, biodegradable waste (just over half of the waste)), biodiesel, bio-oil, biogas, and heat pumps. Renewable energy in the form of biomass and biofuels is also imported (note that the import in 2022 is estimated due to a lack of data at the time).

The use of oil, gas, coal, and coke continues to decrease with the government's policy of facing out these energy sources, while renewable energy sources are taking over energy production. The total energy consumption decreases yearly, and the total share of the electricity consumption remains stable at around 20%. Renewable sources, mainly biomass, produce the largest part of district heating (Figure 25).

Figure 26 shows the renewable energy production by source and import.

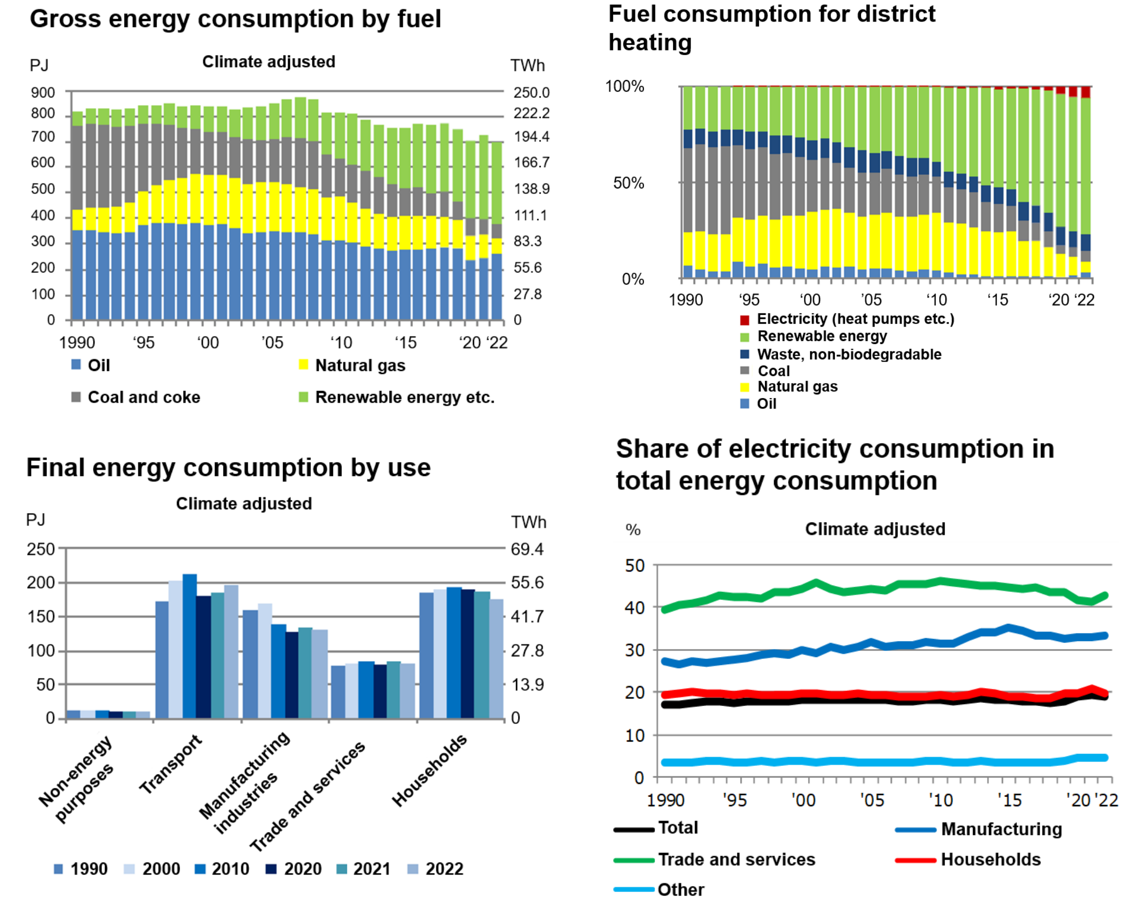


Figure 25: Energy consumption (Energistatistik 2022_dansk.pdf (ens.dk)).

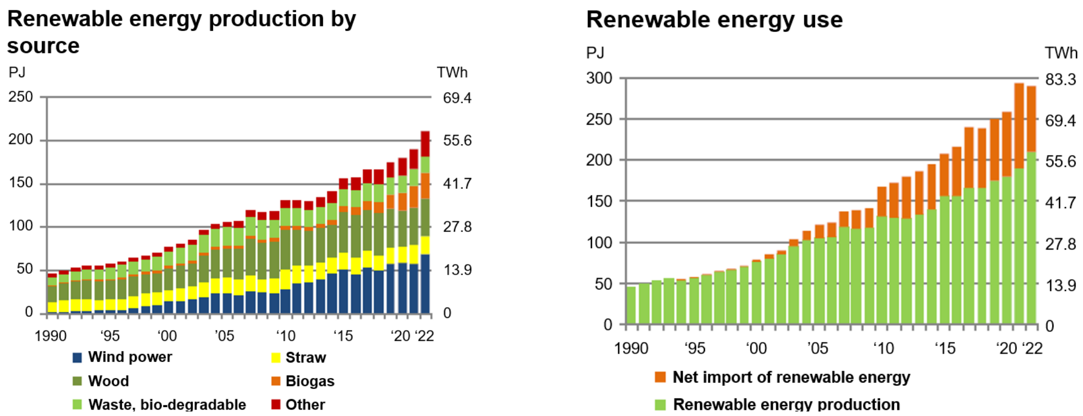


Figure 26: Renewable energy production and import (Energistatistik 2022_dansk.pdf (ens.dk)).

Renewable energy is mainly used to produces electricity and district heating (Figure 27).

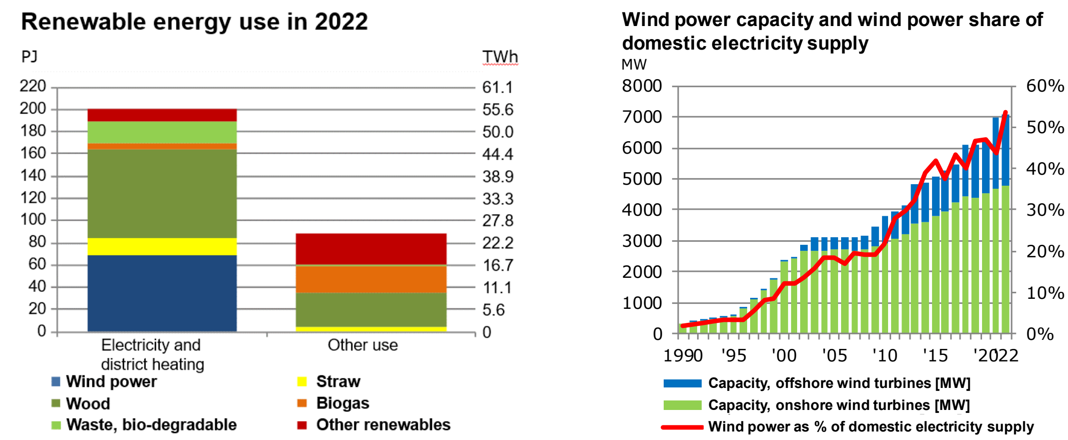


Figure 27: Renewable energy use in 2022 and wind turbines' share of renewable electricity from 1990-2022 (Energistatistik 2022_dansk.pdf (ens.dk)).

The energy consumption of households is influenced by the weather and a general reduction in energy consumption due to strict building regulations and very high energy costs, especially from 2021. In 2022, public buildings were required to keep a maximum temperature of 19 °C, reducing energy consumption considerably (Figure 28).

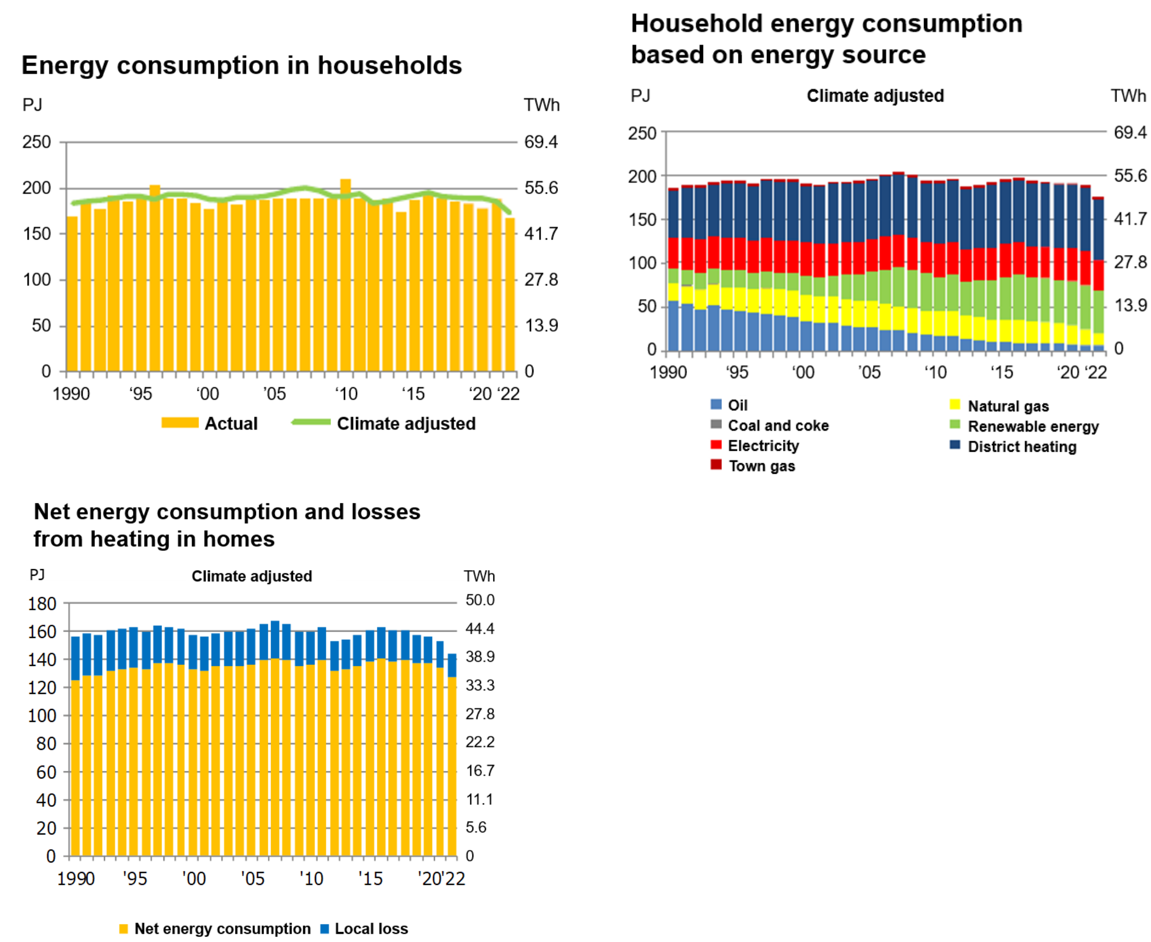


Figure 28: Energy consumption in households (Energistatistik 2022_dansk.pdf (ens.dk)).

The energy consumption per household for heating continues to decrease as the building envelopes become more energy efficient (Figure 29). This decrease is not as strong in Figure 28 as in Figure 29 because Figure 28 shows the total household energy consumption, and the heated area of households is increasing. The rate of newly built homes is about 1.3% per year in 2020, 2021, and 2022.

Figure 29 also shows that the share of households connected to district heating increases year by year.

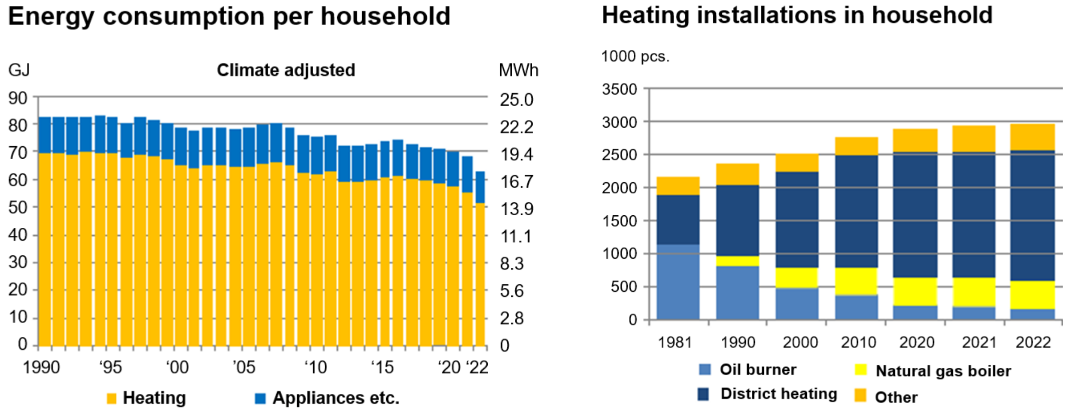


Figure 29: Energy consumption in households (Energistatistik 2022_dansk.pdf (ens.dk)).

The electricity consumption for household appliances has increased, but not as much as the amount of household appliances has increased. The explanation is a significant drop in electricity consumption of new household appliances (Figure 31). The share of total electricity consumption per household has been stable since 1990 (Figure 25), even though the private consumption economic value has increased by about 60% (Figure 30). This shows that people are becoming more prosperous and using their money for things other than household energy. With the intense focus on electrifying everything, electricity consumption is expected to increase significantly in the future. This development is still in its early stages.

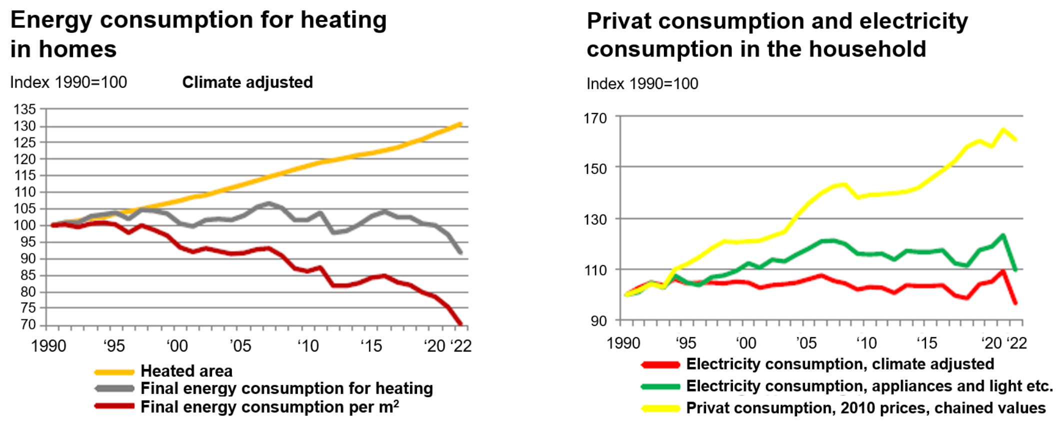


Figure 30: Relative energy consumption for heating and electricity (Energistatistik 2022_dansk.pdf (ens.dk)).

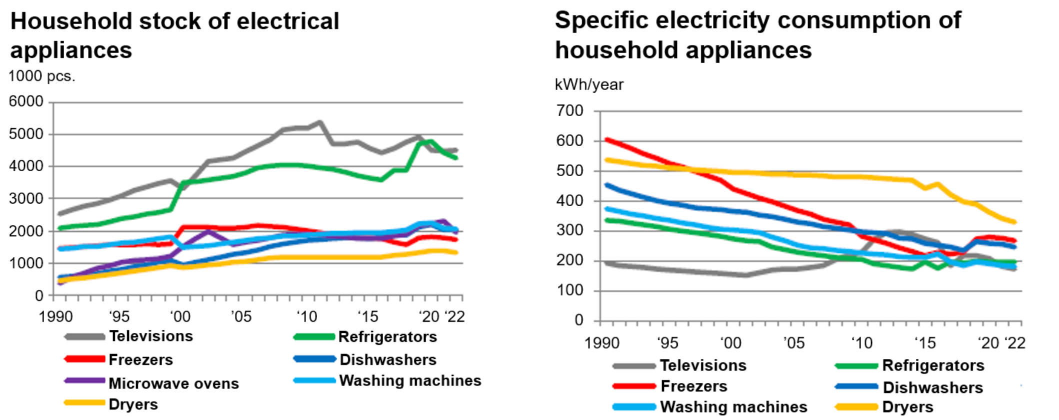


Figure 31: Number of electric appliances and their electricity consumption (Energistatistik 2022_dansk.pdf (ens.dk)).

Table 7 shows the final energy consumption in single- and multi-family households and the different energy sources used to cover the consumption, and Table 8 shows the renewable share in the energy system. Energy consumption still relies heavily on non-renewable energy sources.

Table 8 shows the renewable share of the final energy and electricity consumption in the Danish energy supply for 2023. The electricity consumption is about 20% of the final energy consumption (Figure 25).

Table 7: Final energy consumption in households in 2022 (https://ens.dk/service/statistik-data-noegletal-og-kort/maanedlig-og-aarlig-energistatistik).

2022	Single-family homes (TJ / % of final energy consumption)	Multi-family homes (TJ / % of final energy consumption)
Final energy consumption (TJ)	120 615 / 100	47 918 / 100
LPG	626 / 0.5	261 / 0.5
Motor gasoline	523 / 0.4	-
Kerosene	-	2 / 0
Gas/diesel	4673 / 3.9	698 / 1.5
Fuelolie	-	23 / 0.1
Natural gas (incl. LNG)	10973 / 9.1	2076 / 4.3
Solar energy	428 / 0.4	92 / 0.2
Straw	2944 / 2.4	-
Wood chips	82 / 0.1	-
Firewood	13761 / 11.4	-
Pellets	10652 / 8.8	-
Bio natural gas	5355 / 4.4	1013 / 2.1
Heat pumps	13006 / 10.8	-
Electricity	24841 / 20.7	9433 / 19.7
District heating	32590 / 27	34185 / 71.3
Town gas	161 / 0.1	135 / 0.3

Table 8: Renewable share in the Danish energy supply, 2023.

2023	Renewable energy coverage of final energy consumption	Renewable energy coverage of final electricity consumption
Photovoltaic, PV	2 %	9 %
Wind	10 %	54 %
Solar thermal	1 %	-
Biomass	27 %	23 %
Biogas	3 %	2 %

Households use about 30% of the total final energy consumption. About 66% of all buildings are connected to district heating grids, which cover about 40% of energy consumption in single- and multifamily homes.

Reference

[7.1] Danish energy statistics 2022, Energistatistik 2022_dansk.pdf (ens.dk)

[7.2] Danish energy statistics 2022, https://ens.dk/service/statistik-data-noegletal-og-kort/maanedlig-og-aarlig-energistatistik.

7.2 Questionnaire results

7.2.1 Participants

Interviews have been conducted with 4 Danish stakeholders to answer the questions (Figure 32). The stakeholders are from different areas of work.

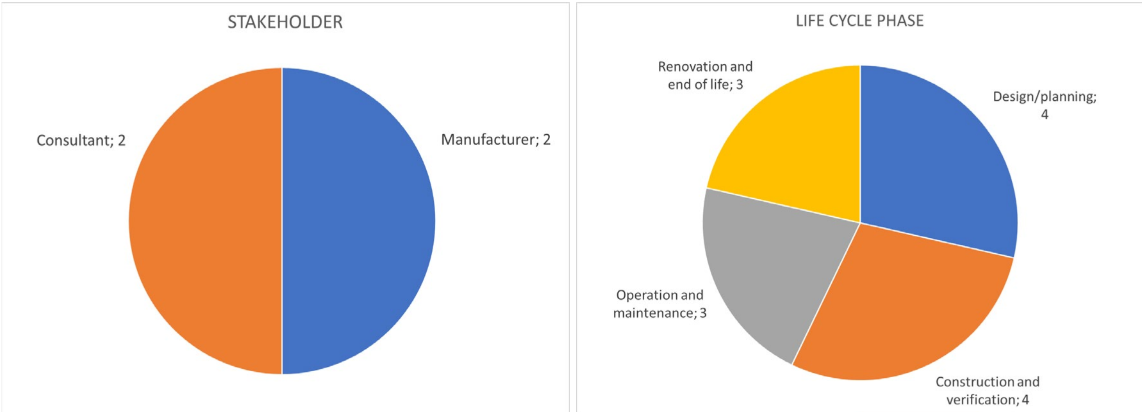


Figure 32: Danish stakeholders.

7.2.2 Procedure and guidelines used in different life cycle phases

In Figure 33, procedures/guidelines used in the different building life phases are shown.

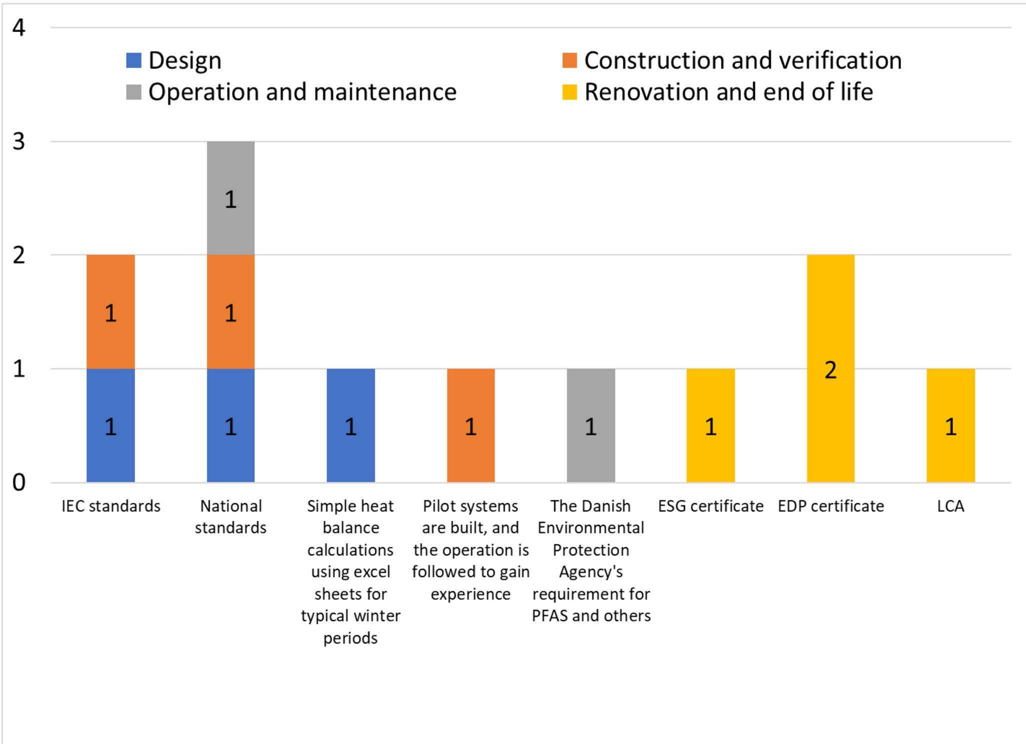


Figure 33: Procedures/guidelines used in different building life phases.

7.2.3 Operation and maintenance and renovation and end of life

In Figure 34 and Table 9, different services offered by companies to clients are show.

Figure 34: Services offered regarding operation and maintenance.

Table 9: Operation and maintenance questions.

Question	Answer
How is good operation verified?	▪ Customer complains
What are the actions to take if the guarantee is not fulfilled?	▪ Repairs to the plant
How long is the monitoring period?	▪ Mostly 5 years ▪ Sometimes 30 years
How are the time intervals for maintenance determined?	▪ Customer wishes
Are there general rules for the lifetime of components?	▪ 25 years for PV ▪ 30 years for glass
If yes, are you in favour of such rules?	▪ -
If yes, and you are not in favour of such rules, why not?	▪ -
How is the decision taken between renovation and end of life?	▪ -
What is done with the materials at the end of life?	▪ Solar panels remain as a building element after the end of life ▪ Thrown out

8 Commercial and self-made programs/software used in different life cycle phases

Various commercial tools and programs are often used to plan and implement projects, but also self-made programs are used (Table 14). The main reasons for using self-made programs are limitations, costs and complexity of commercial programs.

Table 10: Use of commercial and self-made programs/software.

Country	Use of commercial programs [%]	Use of self-made programs [%]
Germany	94	56
China	100	67
Austria	67	33
Denmark	75	50

8.1 Commercial programs/software

Table 11 lists the commercial programs used in the different countries.

In Germany most respondents use Polysun, which is also used in all the design/planning and construction and verification phases. Overall, most of the commercial software mentioned is used in design and planning phase. A total of 13 different programs were named.

In China, a total 5 different commercial software were listed. The commercial software is commonly used in building design and planning phase according to the interview. And sometimes, commercial software, such as TRNSYS, may be used in operation and maintenance phase for optimizing the HVAC system operation strategy. From the practical engineering perspective, TRNSYS and EnergyPlus are more popular among building energy efficiency consultant. Particularly, Designbuilder is development based on the Energyplus computing engine with friendly visualization interface, so it has better promotion and application prospects. But for complex system establishing and simulating, the TRNSYS may be more suitable

In Austria, 13 different commercial programs are used in the design/planning phase of which 3 programs are used in the construction and verification phase.

In Denmark, 9 different commercial programs are used in the design/planning phase and operation and maintenance phase.

Table 11: Used commercial programs/software in the different countries.

Number of answers given	Program/software	Performance Phase		
		Design / planning	Construction and verification	Operation and maintenance
Germany				
6	POLYSUN	X	X	
2	Hottgenroth Energieb.	X		
2	nPro	X		
2	TRNSYS	X		
1	EnergyPro	X		
1	ENVEBI	X	X	
1	GetSolar		X	
1	Noca Rimble	X		
1	Revit	X		
1	SOLAR-COMPUTER	X		

1	TESS libaries	X		
1	Trimble Connect	X		
1	T*SOL	X		
1	PV*SOL	X		
China				
1	DesignBuilder	X		
1	OpenStudio	X		
9	TRNSYS	X		X
7	EnergyPlus	X		
4	Dymola Modelica	X		X
Austria				
3	Trimble Nova	X	X	
2	Plancal	X		
1	Plant 3D	X		
1	E3D	X		
1	Navisworks	X		
1	TRNSYS	X		
1	IDA ICE	X		
1	BricsCAD	X		
1	POLYSUN	X		
1	PV*SOL	X		
1	Allplan	X	X	
1	Vektorworks	X	X	
1	AutoCAD	X		
Denmark				
2	POLYSUN	X		X
1	PV*SOL	X		
1	PVSYST	X		X
2	Revit	X		X
1	IDA ICE	X		X
2	EnergyPro	X		X
1	TRNSYS	X		X
1	TESS library	X		X
1	Leanheat	X		X

8.1.1 Barriers and limitations in the used programs/software

The survey focused on the barriers and limitations of the programs and software.

A major point of criticism was the complexity and costs, but also limitations in the ability to simulate complex structures and controls. In addition, individual programs have various weaknesses, e.g. programming gaps.

The Danish comments are related to specific programs/software, while the comments from the other countries are more general.

Table 12 Summarizes the answers given from all interviewees.

Table 12: General limitations in the used programs/software in the different countries.

Technical limitations	Data/Options limitations	Other limitations
Germany		
• Too complex, interface • Not enough server capacity /calculation times too long • Internal program problems (programming gaps/weaknesses)	• Missing data (e.g., new heat pump data) • Simulation restrictions (e.g., ice storage, seasonal storage, system combination) •	• Costs • “Many”
China		
• Complex system modelling process is difficult • Simulation function is incomplete • Model modification is difficult • The simulation speed of complex system is slow	• Detailed simulation results, such as hourly load of different parts, cannot be derived	• Input and output interface • Professional knowledge
Austria		
• Only static calculations possible • No cooling ceiling available as model • Only simulations based on normative regulations • Manual transfer of simulation results to other programs • No dynamic simulation for heating load	• Missing reference data for building physics	• Programming skills needed
Denmark		
• EnergyPRO is limited in the sense that it doesn't make detailed thermal energy calculations and it is not easy to tailor to a specific project		• TRNSYS is a bit long to set up for a new kind of project/application, so it takes time to make it ready for calculations

8.1.2 Advantages and disadvantages of the used commercial programs/software

Table 13 summarizes the answers given on the reported advantages and disadvantages of the individual programs/software.

Table 13: Reported advantages / disadvantages of the used commercial tools / programs

Tool / program	Advantages	Disadvantages
nPRO 2 users	▪ Very easy to use ▪ Analyses for quarters and buildings with very little work/time input ▪ Integrated graphical processing of results	▪ Complex hydraulic interconnections not representable
POLYSUN 7 users	▪ Fast and easy simulations ▪ Hydraulic and electric aspects simultaneously calculatable ▪ Before created schemes dan be used again, less time needed	▪ Too much data, therefore not user friendly → much training necessary ▪ Too complicated to display certain sup points

	▪ No big differences between simulation and reel monitoring → therefore huge credibility by the customer ▪	▪ Not logically how the numbers add up (e.g at PVT source not included, therefore generated heat not included) ▪ Only used in the company ▪ Poor user manual
Get Solar by Hottgenroth 1 user	▪ Easy handling, user friendly	▪ Water and heat are different profiles
TRNSYS 3 users	▪ Flexible, customizable, easy handling with predefinition ▪ Less errors, faster and more efficient simulations ▪ Already integrated in design ▪ Sometimes open source ▪ Fast to run and easy to set up, Possibility to import data/time series easily, Integrated result interface and built-in operation cost optimization tool	▪ Too complex, not user friendly, difficult controlling ▪ Only used in the company, much training necessary ▪ Takes time to set up ▪ Not very user-friendly interface ▪ Required an experienced user
CAD program 1 user		▪ Bad performance ▪ No communication with other programs
ENVEBI 1 user	▪ DIN18599 calculation core is validated (quality association) ▪ life cycle assessment is validated (BBSR) ▪ renovation roadmaps is validated (dena/BAFA)	
Excel, BKI Energieplaner 8 users		▪ Calculation program always lags very significantly behind the progress ▪ The crediting of battery storage is in most cases exactly 0 → wrong results
Own building control system 1 user		▪ Acceptance by customer
EnergyPlus 7 users	▪ Free and open source, which allows users to develop personalized modules ▪ EnergyPlus is known for its accuracy in simulating building energy performance. It uses detailed physics-based models to account for heat transfer, airflows, an other factors, resulting in precise results ▪ It is a versatile tool that can model a wide range of building types, HVAC systems, and energy efficiency measures. This flexibility makes it suitable for various architectural projects ▪ EnergyPlus provides detailed and comprehensive output data, allowing users to analyze energy consumption, thermal comfort, indoor air quality, HVAC system performance, and more ▪ It complies with industry standards like ASHRAE and is often used for building energy code compliance and LEED) certification ▪ EnergyPlus can be integrated with other software tools and interfaces,	▪ The interface is not intuitive, which is unfriendly to beginners. The ASCII format of input and output mode has a high requirement of specialty for users ▪ It's difficult to describe the model accurately with a large number of input parameters ▪ There is a requirement for professional knowledge in the modeling process, especially for complicated systems ▪ The automatic optimization cannot be realized ▪ The simulation results are sensitive to input parameters. Small errors or inaccuracies in data input can lead to misleading results. Users need to be diligent in validating and verifying input information ▪ While EnergyPlus can simulate the dynamic behavior of building systems, it may not fully capture complex control strategies and interactions in some cases, particularly for advanced control systems ▪ EnergyPlus may not be suitable for long-term climate change analysis or simulations spanning several decades due to limitations in the available weather data

	allowing for customized workflows and expanding its capabilities ▪ It's suitable for modeling complex HVAC systems and controls accurately for having extensive HVAC library. ▪	▪ EnergyPlus primarily focuses on energy performance, and its built-in cost analysis features are limited. Additional tools may be needed to assess the economic aspects of design decisions ▪ Simulations with EnergyPlus can be computationally intensive and time-consuming, especially for large and complex building models. This can limit the ability to explore design alternatives quickly ▪ EnergyPlus provides basic visualization capabilities, but more advanced and user-friendly graphical output often requires third-party software ▪ The occupant behavior impacts on energy consumption. More advanced occupant behavior models may need to be integrated separately.
DesignBuilder 1 user	▪ High visualization of modeling process, which is friendly to users ▪ Optimization function for optimizing design parameters automatically ▪ Multiple simulation models for meeting the different needs of users	▪ The HVAC system cannot be established strictly corresponds to the practical projects ▪ The simulation modules of elevator, socket and other non-HVAC systems is still missing ▪ No Chinese language support.
OpenStudio 1 user	▪ Free to obtain ▪ The interface is visualization ▪ The simulation process is steady ▪ The simulation speed is fast ▪ Results are reasonable.	▪ Some HVAC systems, such as GSHP, ASHP etc. cannot be established ▪ The SHGC (Solar Heat Gain Coefficient) value cannot be set differently for transparent envelop according to different seasons ▪ The daylighting simulation is not supported ▪ The modification process of model is difficult ▪ Some simulation results, such as hourly load for building envelopes isn't available ▪ The complex models are difficult to establish ▪ The debugging process is difficult. ▪
TRNSYS 9 users	▪ The professional simulation of HVAC system can be conducted by specialized modules ▪ Having a wide range of application, include building load, building energy consumption, renewable energy generation, HVAC system and etc. ▪ The individual modules can be developed by users based on the source code ▪ The utilization of the modules is easy for having relatively simple rules ▪ The result is steady.	▪ The professional requirement for mastering the software is high ▪ The shading effects cannot be considered in photovoltaic generation simulation ▪ Other methods or software may be needed to realize complex control of system ▪ No Chinese language support. ▪
Dymola Modelica 4 users	▪ It can basically meet the requirements for the description of building thermal process and energy system ▪ The simulation can cover the whole equipment from heating and cooling source to terminal, and all kinds of operation conditions	▪ Dymola is difficult to use, and there is a lack of guidance and training content ▪ The component library lacks variety ▪ The equipment module is different from the real system ▪ The simulation speed in the system simulation process is slow.

Trimble Nova 3 users	▪ Powerful tool ▪ Quick mass investigation	▪ Complicated ▪ Rumors about non-continuation
Plancal 2 users	▪ Simple visualization possible ▪ Quick heating load calculation	▪ No TABS design possible ▪ No borehole heat exchangers available
Excel 2 users	▪ Flexible	▪ Time consuming to set up tools
EnergyPro 1 user	▪ Fast to run and easy to set up, Possibility to import data/time series easily, Integrated result interface and built-in operation cost optimization tool	▪ No detailed/physical calculations ▪ not very customizable ▪

8.2 Self-made programs/software

Table 13 shows the used self-made programs in the different countries in the different life cycle phases.

In Germany most use their own Excel tools. These are also used in the design/planning and the construction and verification phase phases. The “BKI-Energieplaner”, “Heat load calculator” and the "Trimvble nova" program are also used in these phases. No information on the phase was provided for the PVT calculation tool.

In China, self-made software is used less. Relatively, the IBE building simulation tool and Excel tool are mostly used in the design and planning phase. The IBE building simulation tool matches the national standard ”Technical standard for nearly zero energy buildings”. It can rapidly calculate relevant quantitative evaluation indicators of ultra-low energy building, nearly zero energy building, and zero energy building. Phyton and Matlab are used more in research in the operation and maintenance phase to optimize system configuration and operation strategy. And it is rarely used in practical projects.

Planners in Austria might use Excel tools over commercially available software because they offer customization for specific project needs and can be tailored to unique calculations and workflows. Often these sheets use standard formulas and tables to determine the appropriate dimensioning for duct and pipe sizes for given demands in HVAC installations. Additionally, Excel tools are cost-effective and accessible, allowing planners to create, modify, and update tools without the need for expensive software licenses or specialized training.

In Denmark, the self-made tools are designed to predict the performance of PV systems with batteries and optimize a control strategy based on weather and electricity price forecasts in the design/planning phase and the operation and maintenance phase.

Table 14: Used self-made programs/software.

Number of answers given	Program/software	Performance phase		
		Design / planning	Construction and verification	Operation and maintenance
Germany				
7	Excel tool	X	X	
1	BKI Energiplaner	X	X	
1	CAD program		X	
1	Calculation tool for PVT			
1	Heat load calculator	X	X	
1	Own building control system		X	
1	Trimvble nova	X	X	
China				
1	IBE building simulation tool	X		
1	Excel tool	X		

1	Python script	X		X
3	Matlab code	X		X
Austria				
2	Excel tool	X		
1	Matlab			X
1	Plancal	X		
1	Trimble Nova	X		
1	ABK	X		
Denmark				
1	Excel tool for PV performance, price and construction	X		
1	PV-Bat (Excel-tool) for smart control based on weather and electricity price forecasts for the performance of PV and batteries	X		X

8.3 Which programs/software are missing, and which limitation is essential?

The stakeholders missed programs and experienced software shortcomings (Table 15).

Table 15: Experienced shortcommings in existing commercial programs.

What can currently not be simulated?	What is missing in terms of user-friendliness?	Other points
Germany		
• Cooling • Heat pump • PVT • Piping design with 3D	• Web based, user friendly interface (TRNSYS) • Standardized results (TRNSYS) • Integrate larger systems (POLYSUN) • Integrate data from other systems (POLYSUN) • Connection to ökobaudat-database • Automatic component register	• Software for the customer for first estimate • A program that can do everything for the construction/planning and monitoring industry in the future.
China		
• Total building energy consumption calculating function, including elevator, equipment, and other systems • Modelling method for irregular shaped buildings • Interaction with programming software, such as Matlab, Python, and others • Comparison and optimization function	• User friendly interface (EnergyPlus, TRNSYS, OpenStudio) • Simulation results (DesignBuilder) • Automatically optimization function (EnergyPlus, TRNSYS, OpenStudio)	

Austria		
• Design of Thermally Activated Building Systems (TABS) • Dimensioning of borehole heat exchangers • Simulations based on dynamic weather/temperatures • Simulation of a whole building and system	• Too expensive (Revit)	
Denmark		
• Program for determining optimal control strategies and monitoring of PV and PVT/HP systems, inclusive of electric batteries based on a forecast for weather and electricity prices • Program for determining optimal control strategies and monitoring of PV and PVT/HP systems, including electric batteries based on the forecast for weather, electricity costs, and energy consumption, including electricity for EVs. The program must be suitable for larger consumers, e.g., social housing companies, and should additionally give grid frequency stabilization solutions		• Easy-to-use program for heat storage and thermal stratification

9 Summary and conclusion

The excerpts from the energy landscape in the different countries show that while the European countries are reducing their non-renewable energy production and increasing their renewable energy production, China is still increasing the non-renewable energy production along with increasing the renewable energy production.

The Climate Protection Act (Klimaschutzgesetz (08/2021)) describes the German goal. The goal of greenhouse gas neutrality by 2045 is anchored in this. Emissions are to be reduced by 65% by 2030 compared to 1990. A reduction target of at least 88% applies for the year 2040. After 2050, the German government is aiming for negative emissions. This means that Germany will have to sequester more greenhouse gases in natural sinks than it emits. Since 2008, the share of renewable energy on energy consumption has slowly increased, especially the use of coal and gas has decreased. The main producers on the renewable side are biomass, wind power, and photovoltaic.

China is by far the world's largest emitter of CO2. To ensure energy supplies, China's energy structure is still dominated by fossil fuel, such as coal and natural gas, and the non-renewable energy consumption is increasing. Meanwhile, China is making steady progress in energy revolution, and the structure of energy production and consumption has been continuously improved. Up to 2023, the national installed capacity of renewable energy generation accounts for more than 50% of total installed power generation capacity, and the renewable energy power generation accounts for more than 1/3 of the society's total electricity consumption. The goal is to be climate neutral before 2060, and the greenhouse gas emission must peak by 2030. Apart from increasingly optimizing the national energy system, great efforts will also be put into developing carbon sequestration technologies in multi-field

The Austrian goal is to be climate neutral in 2040 and covering electricity by 100% renewable by 2030. The predominant energy contribution is from oil and gas. The total amount of energy supply has been stable since 2004 and the use of coal has decreased while the use of renewable energy such as wind, solar, etc. and biofuels and waste have increased.

The Danish goal is to be climate neutral in 2050 and to reduce greenhouse gas emissions by 2030 by 70% compared to the 1990 level. Since 2008, the gross energy consumption has decreased, especially the use of coal and gas has decreased, while the use of renewable energy has increased, especially biomass.

The state of renewable energy coverage in the different countries is listed in Table 16.

Table 16: Renewable share of final energy consumption.

	Renewable energy coverage of final energy consumption	Renewable energy coverage of final electricity consumption
Germany2023		
Photovoltaic (PV)	6 %	12 %
Wind	13 %	27 %
Solar thermal	1 %	-
Geothermal	2 %	< 0.1 %
Hydro power	2 %	4 %
Biomass (gaseous, liquid and solid)	19 %	9 %
Bio fuel	3 %	-
China, 2022		
Photovoltaic, PV	2.4 %	5 %
Wind	4.3 %	8.8 %
Solar thermal	0.01 %	0.01 %
Hydropower	7.6 %	15.6 %
Biomass	1 %	2.1 %
Nuclear	2.3 %	4.8 %
Austria, YYYY		
Photovoltaic, PV	1.2 %	5.5 %
Wind	2.3 %	10.5 %
Solar thermal	2.6 %	0 %
Hydropower	12.2 %	56.7 %
Biomass & Biofuels	27 %	23 %
Denmark, 2023		
Photovoltaic, PV	2 %	9.4 %
Wind	10 %	53.7 %
Solar thermal	1 %	-
Biomass	27 %	
Biogas	3 %	2 %

Mainly local/national standards and procedures are used for designing new or converting existing buildings into Solar Energy Buildings.

The number of projects in which a guarantee for good operation, monitoring, and maintenance contracts are offered ranges from not offered to always offered. Energy performance contracts are rarely offered.

Figure 35 show which commercial programs/software are used in the different countries. In Germany, POLYSUN is most popular followed by TRNSYS, nPro and Hottgenroth Energiberater. In China TRNSYS is most popular followed by EnergyPlus and Dymola Modelica. In Austria, Trimble Nova is most popular followed by Plancal. In Denmark POLYSUN, EnergyPro and Revit are most popular.

Figure 36 shows the distribution of commercial programs/software in all countries where the survey was conducted. In all countries, TRNSYS has the most users followed by POLYSUN and EnergyPlus. In total 71 commercial programs are used.

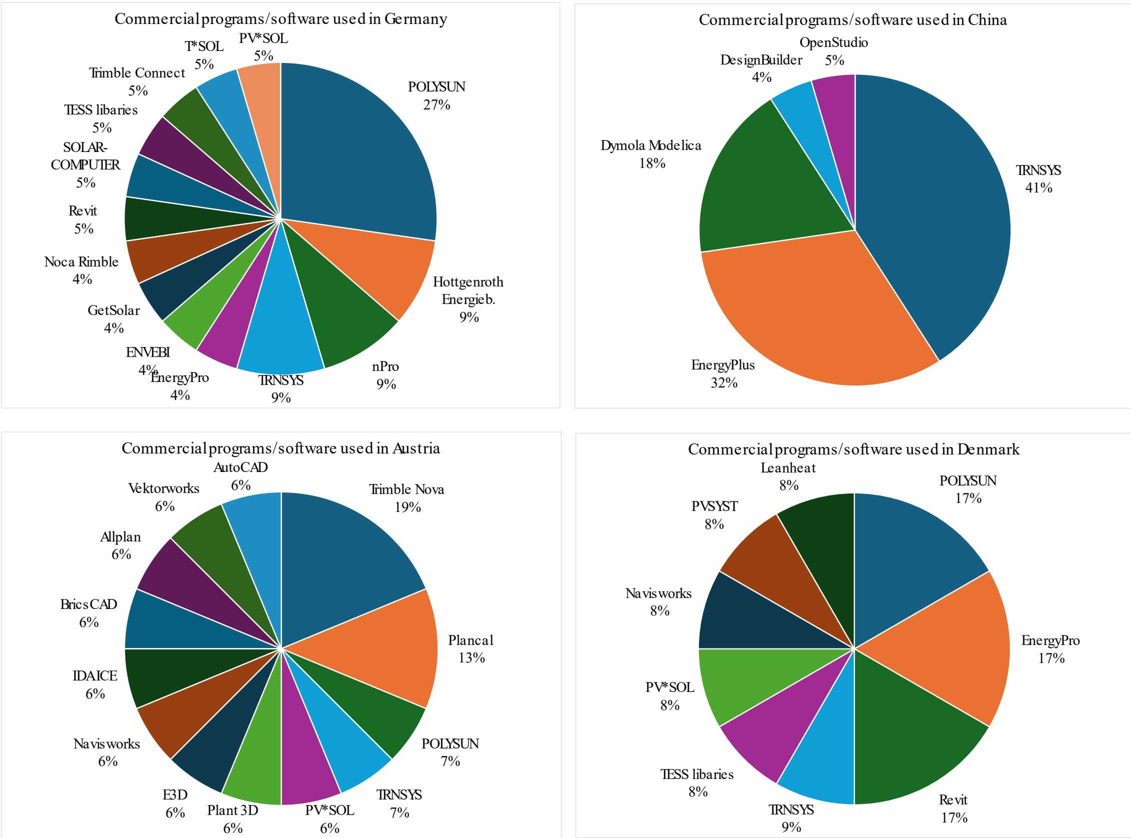


Figure 35: Commercial programs/software used in different countries.

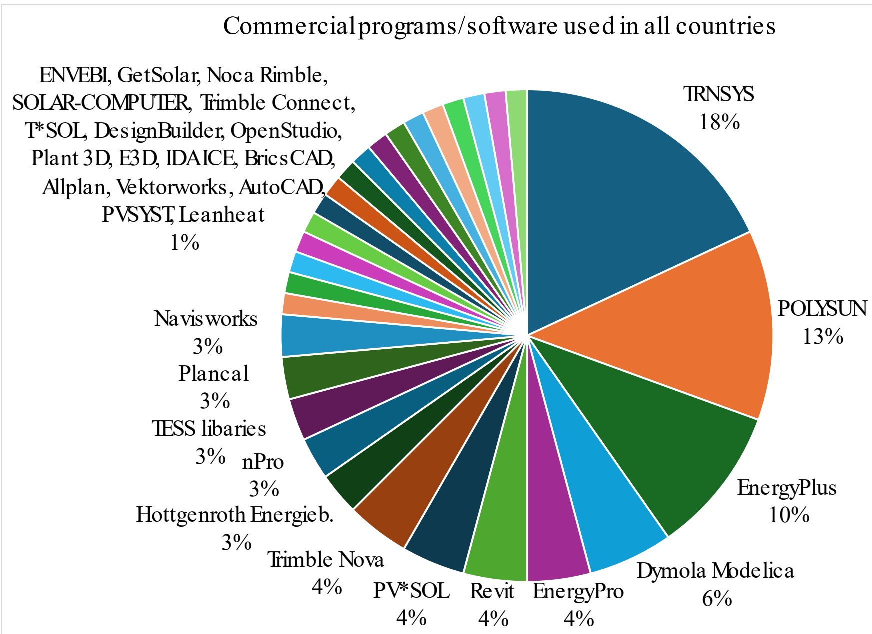


Figure 36: Commercial programs/software used in all countries.

The survey revealed that many stakeholders use self-made programs, mainly because of the complexity and costs but also due to commercial programs/software limitations.

A high number of the tools and programs are used in the design and planning phase for Solar Energy Buildings. A smaller number of the tools and programs are used in the construction and verification phase, as well as in the operation and maintenance phase. No tools and programs are used in the renovation and end of life phase.

There are large differences in the tools used from country to country due to differences in national regulations, climate conditions, energy structures, and building traditions.

The Chinese respondents wish for programs that can simulate irregularly shaped buildings, including elevators and equipment, and better interaction with programming software. The Austrian and German respondents wish for commercial programs/software that can simulate advanced cooling systems, e.g., cooled ceilings. The Danish respondents wish for programs/software that can help determine the best control strategy for systems, including electric batteries and forecast of consumption, weather, and electricity prices.