Industry decarbonization through electrification

SWEET

Lunch talk

02.04.2024

This study was conducted by Kevin Pahud as a research project at the E-CUBE Strategy Consultants office in Lausanne in partnership with Prof. Rachid Cherkaoui from EPFL

Kevin PAHUD
Junior Consultant – Lausanne

Energy engineer from EPFL, graduated in 2023, specializing in electrification and energy efficiency

►Principal researcher on the study

Nicolas CHARTON
Director – Lausanne

Founder and Director of the Lausanne office, oversaw more than 250 mandates in Switzerland and across Europe.

►Study steering

Rachid CHERKAOUI
Prof. EPFL – Lausanne

Power systems professor at EPFL, senior member of IEEE

►Scientific partner & reviewer

E-CUBE is the strategy consulting firm dedicated to energy, mobility and climate stakes

Energy & Environment

Renewable energies | Storage | Hydrogen | Biogas - Biofuels | Electricity & gas networks, district heating & cooling | Nuclear | Water & Waste | CCUS | Energy efficiency

Mobility & Infrastructure

Low-carbon transport | Railway & Airport | Smart grids | Urban & regional mobility | Charging infrastructure

Climate strategy & Sustainable innovation

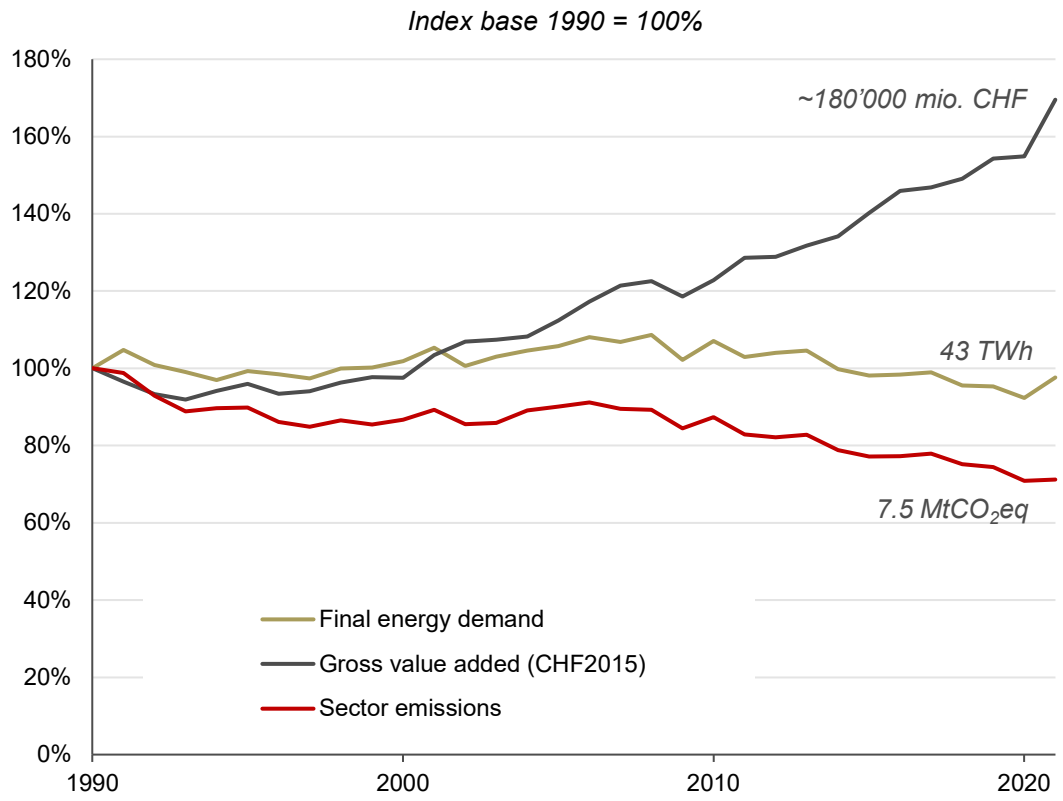
Decarbonation strategy | Industrial ecology | Circular economy | Sustainable business models | Climate risks analysis

Source : E-CUBE Strategy Consultants

Summary

Switzerland's industry consumes around 19% Switzerland's total final energy consumption and represents 21% of the nation's emissions.

Fig. 1 - Evolution of Switzerland's industry's emissions[1], energy consumption[2], and economic output[3] 1990-2021



1 **Industrial sector represents 23% of Switzerland's GDP[3]**

2 **Energy consumption represents 19% of Switzerland's consumption in 2021[2]**

3 **Emissions account for 17% of Switzerland's territorial emissions in 2021[1]**

Sources:

1) Includes energetic and process emissions. Source FOEN NIR 2023
2) SFOE – Global energy statistics 2022
3) FSO – Industry production accounts

The industry sector currently is currently electrified at 41%, and consumes around 15 TWh of fossil fuels

Fig. 2 - Distribution of energy carriers according to end-use demand for Switzerland's industry, 2021

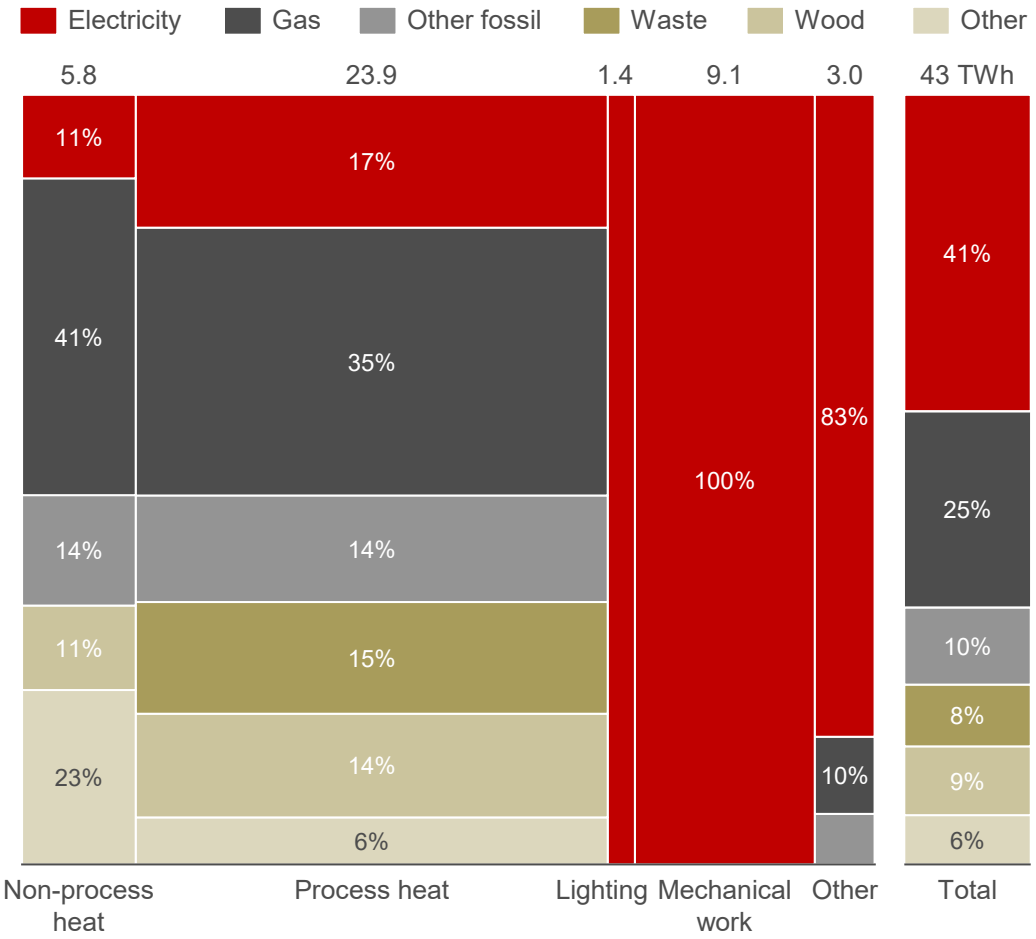
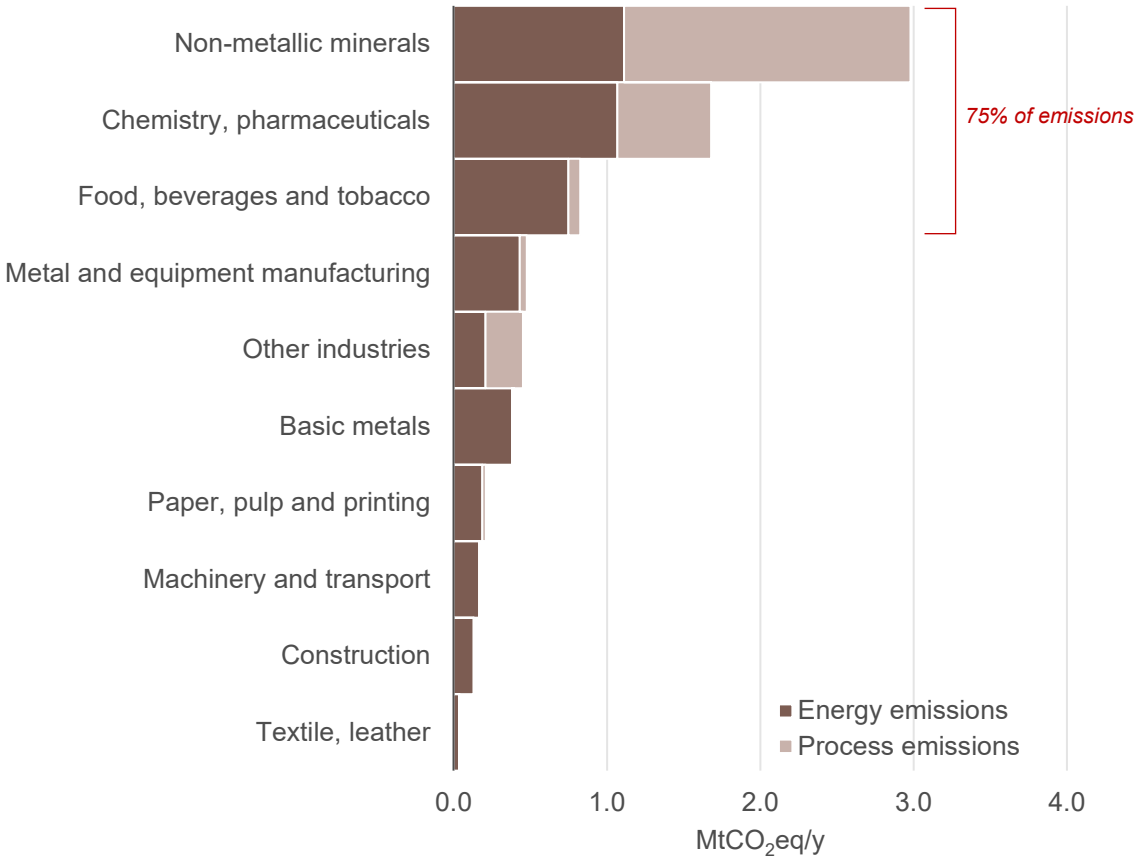
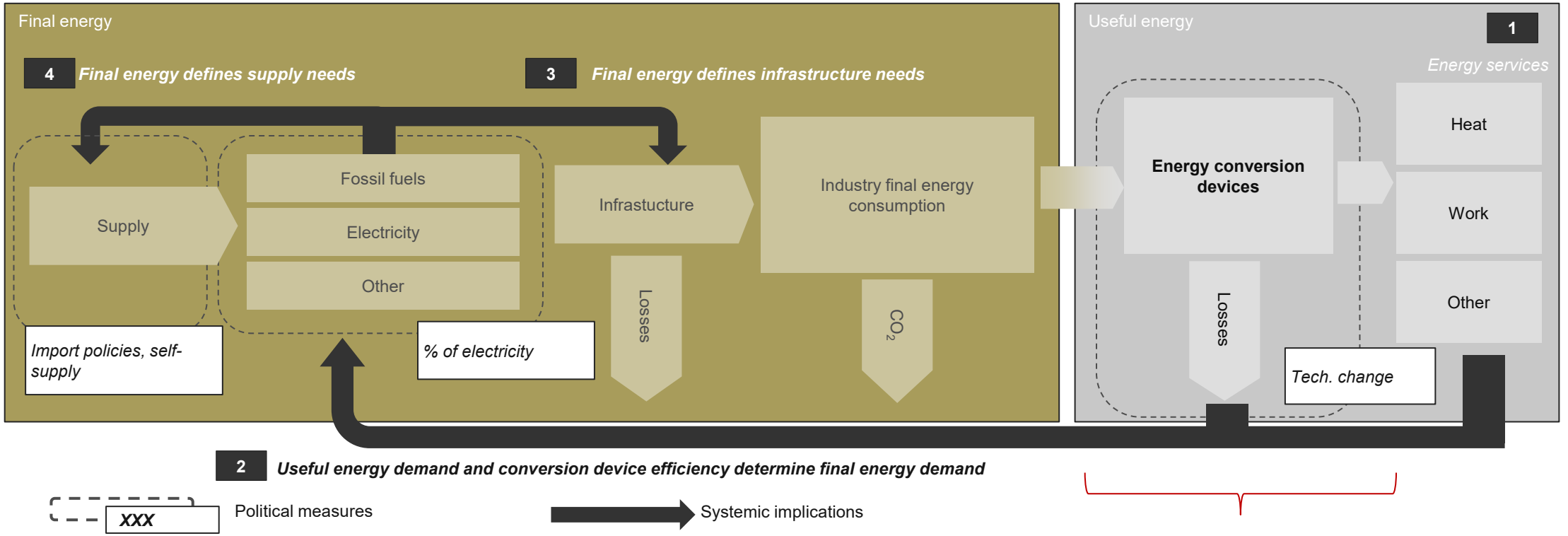


Fig. 3 - Distribution of GHG emissions by type and sector, 2021



Sources:
1) E-CUBE Strategy Consultants Analysis & FOEN NIR 2023
2) E-CUBE Strategy Consultants Analysis & SFOE Analysis of energy consumption by specific use 2023

Electrify end-uses to reduce simultaneously energy consumption, emissions and foreign dependency, as Switzerland's grid is low-carbon and EU's grid is getting cleaner



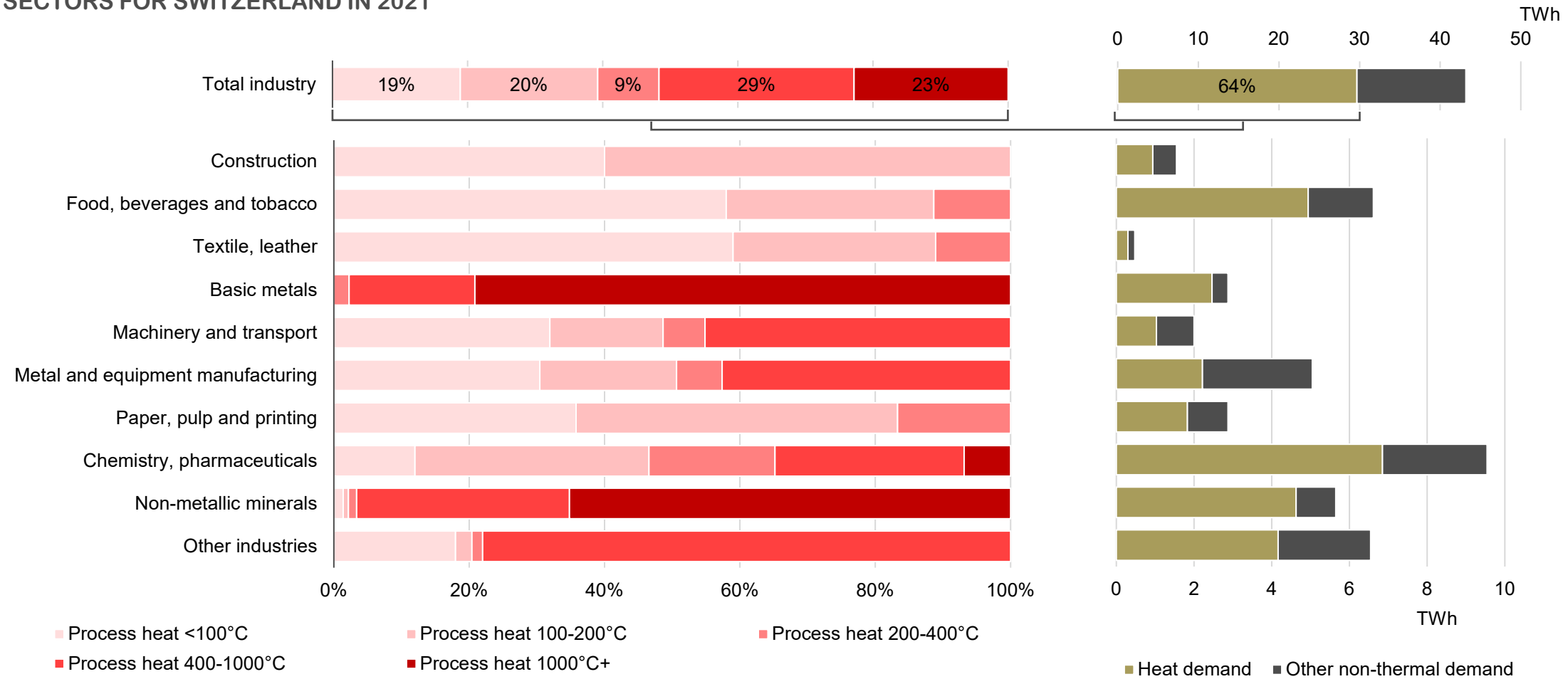
Goal:
Switching to electricity-based devices to provide energy services to Switzerland's industry, and reduce losses

Sources:
1) SFOE – Global energy statistics 2023 & EMBER data

Summary

The highest electrification potential can be found in low temperature sectors such as the food & beverages sector

DISTRIBUTION OF HEAT DEMAND[1)] PER TEMPERATURE LEVEL WITH RESPECT TO TOTAL ENERGY DEMAND ACROSS INDUSTRIAL SECTORS FOR SWITZERLAND IN 2021



1) Includes heating and cooling

Sources: E-CUBE Strategy Consultants Analysis & SFOE Analysis of energy consumption by specific use 2023

Electrification of industry is met by different stages of transformation and is tuned by specific & realistic industry constraints

STAGES OF ELECTRIFICATION AND ASSOCIATED CONSTRAINTS TO ELECTRIFICATION

Electrification In core processes

Electrification in utilities

1 Stage 1 electrification

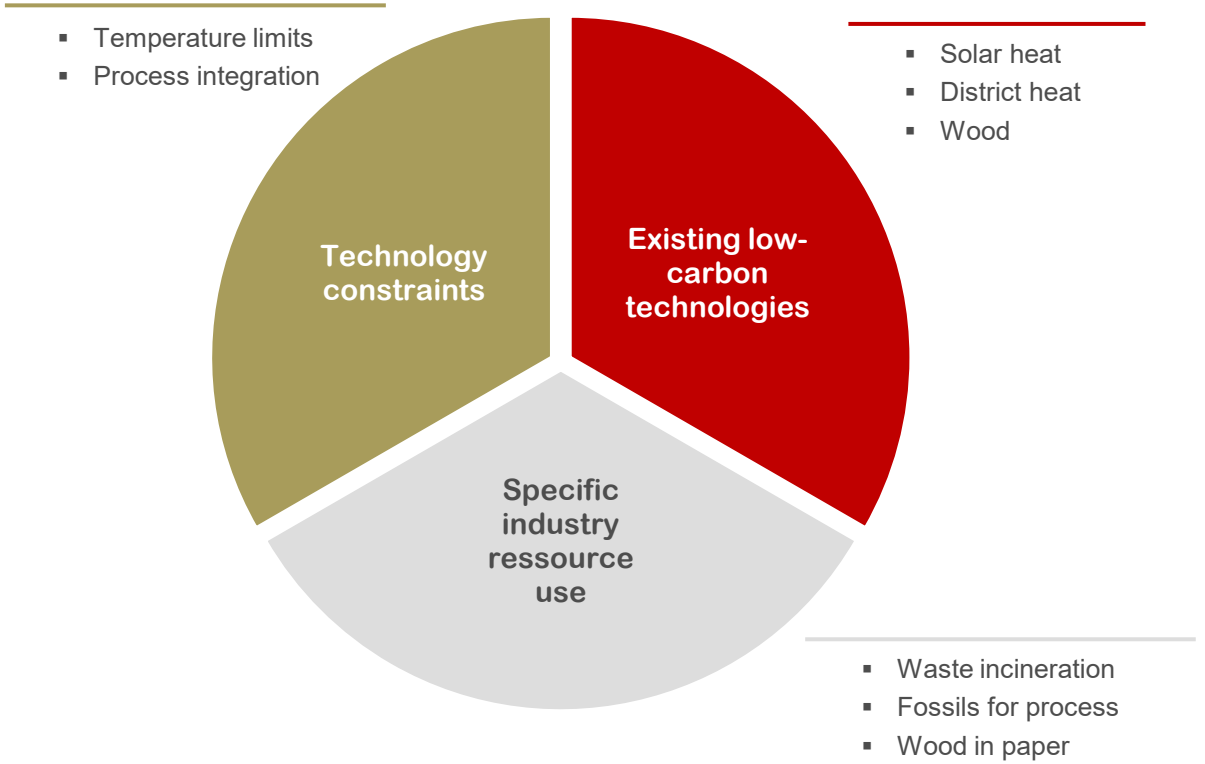
- Entry point electrification of non-process heat
- Space heating & hot water

2 Stage 2 electrification

- Process heat electrification with mature technologies
- Up to process heat < 400°C

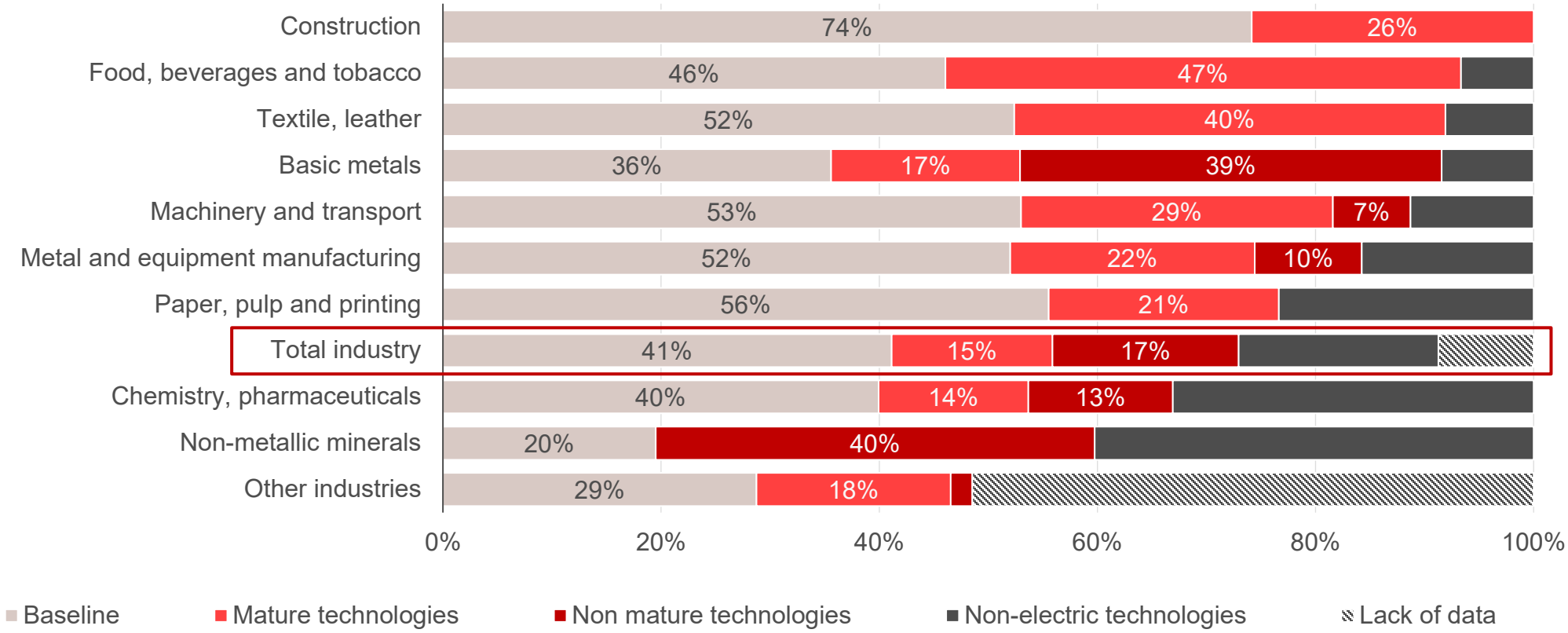
3 Stage 3 electrification

- Maximum electrification potential with technological and cost uncertainty:
- Process heat >400°C



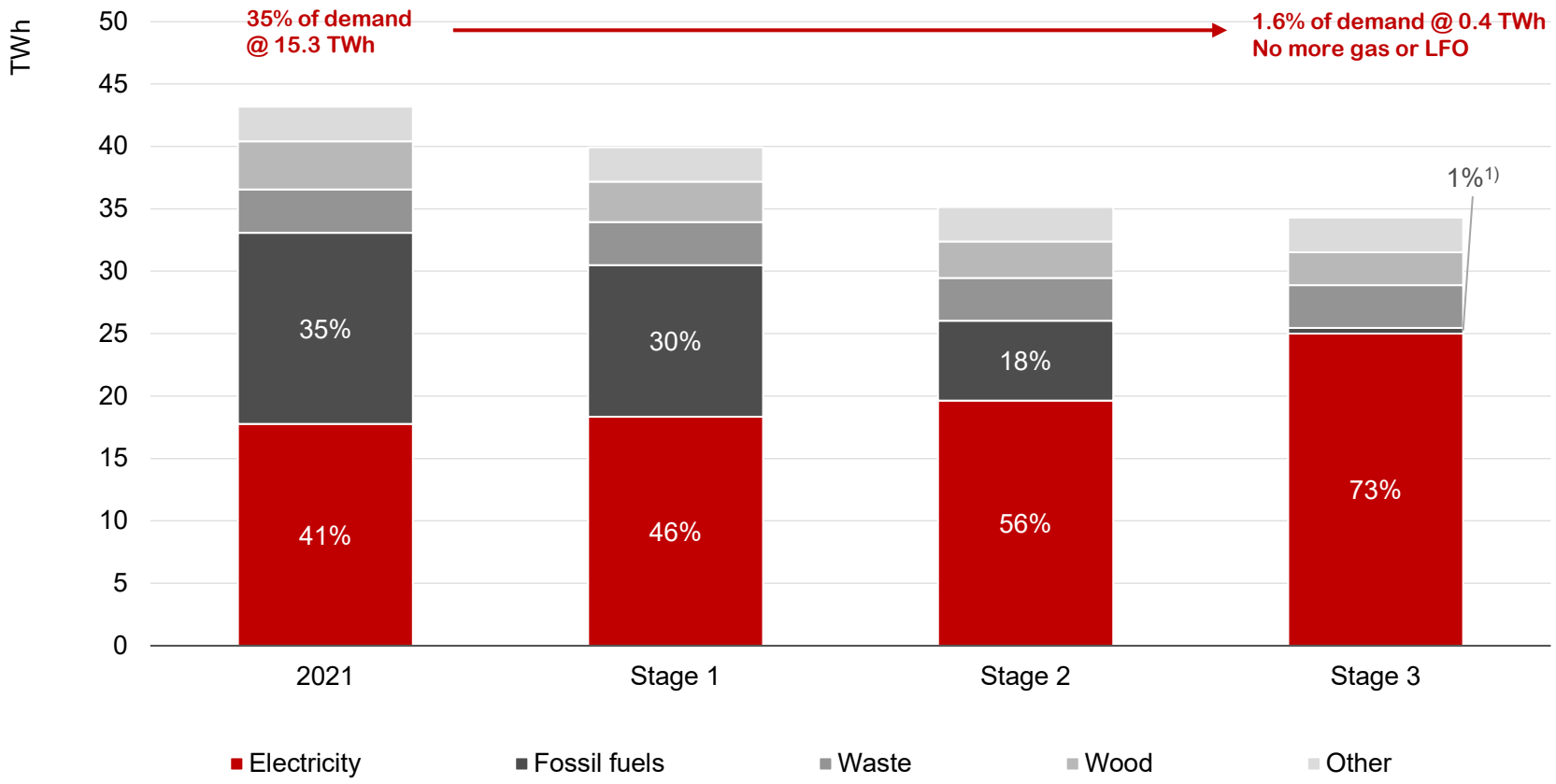
Switzerland's industry can be electrified up to 73%, with half of additions from existing & mature technologies.

ELECTRIFICATION POTENTIAL OF SWITZERLAND'S INDUSTRIES ACCORDING TO TECHNOLOGY MATURITY



Electrifying the sector would decrease final energy consumption by 21% yet increase electricity demand by 7 TWh annually.

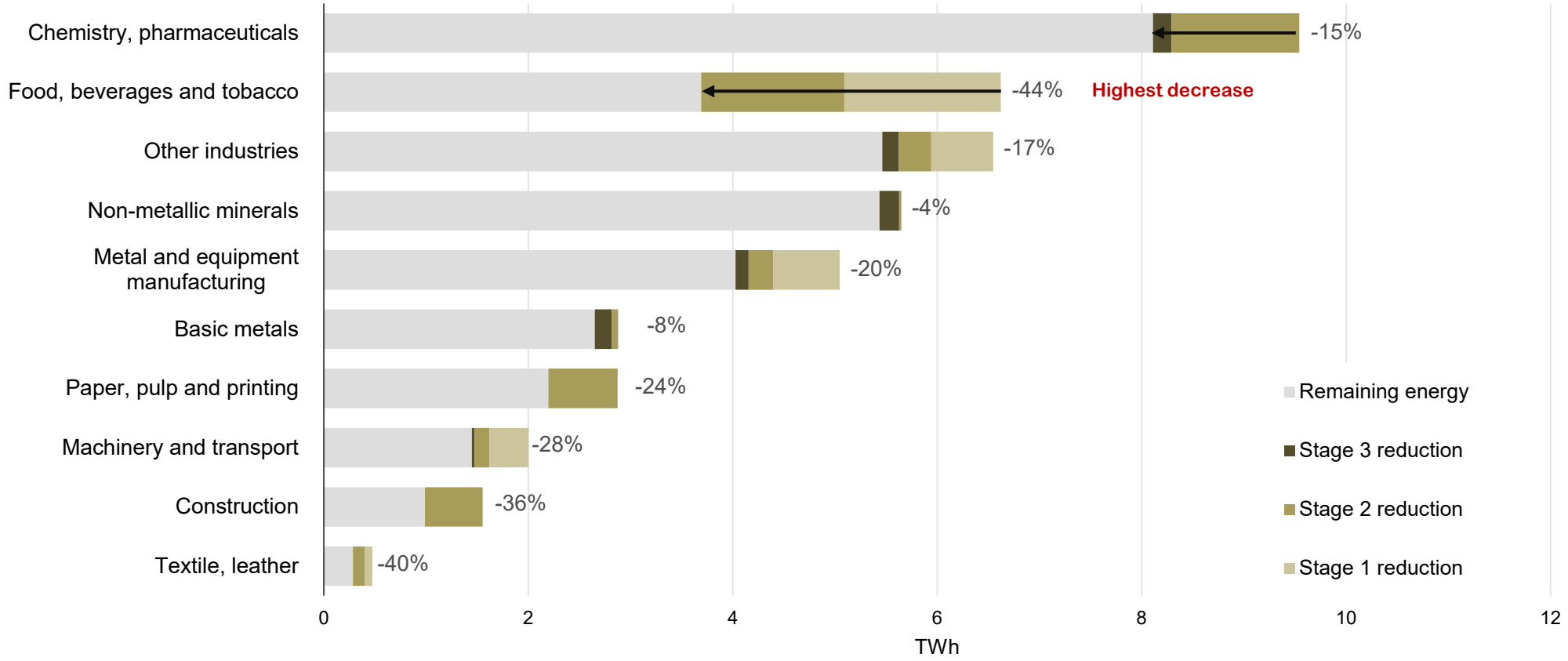
ELECTRICITY COULD ACCOUNT FOR 48% OF NON-PROCESS HEAT AND 57% OF PROCESS HEAT.



1) Concerns the remaining fossil fuel demand for all end-uses, focusing on process-heat only (i.e., the only end-use for which fossil fuels remain), they represent 2% of the demand.

Electrifying the sector would decrease final energy consumption by up to 44% for the food, beverages, and tobvaco sector

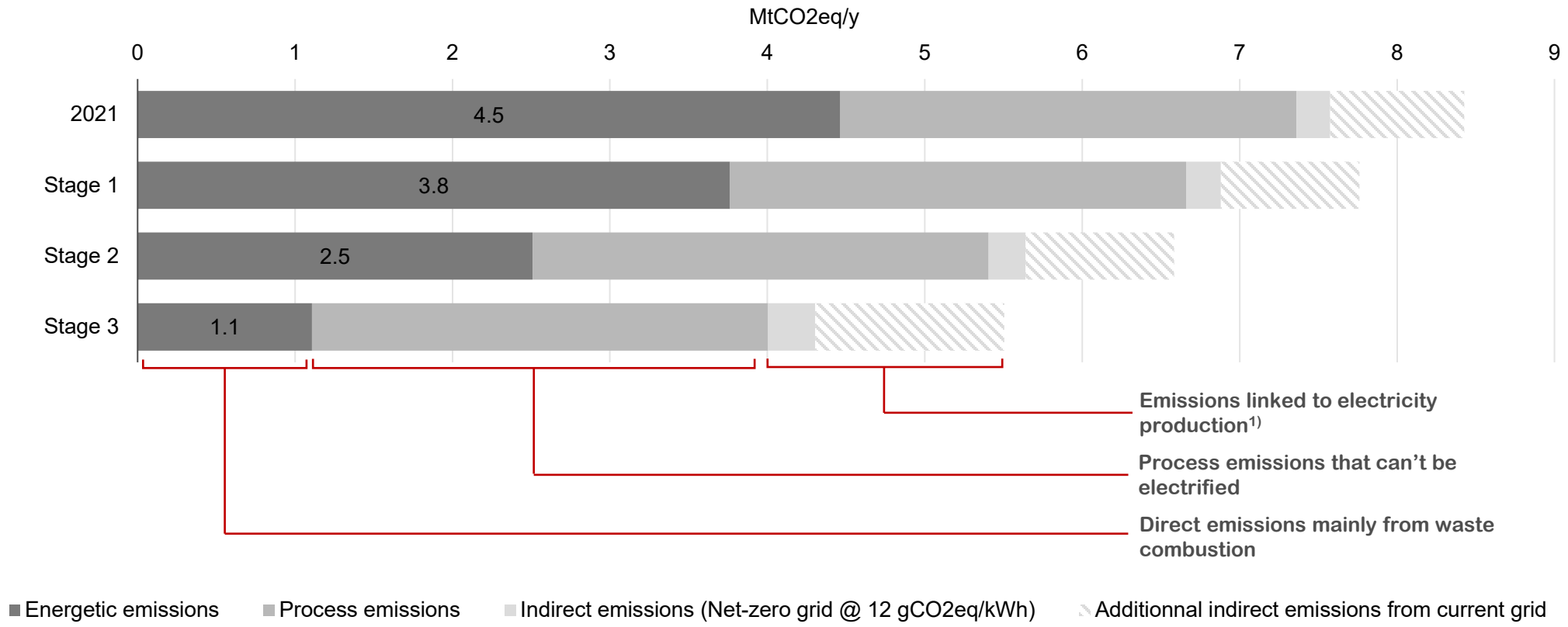
ELECTRIFICATION IMPACT ON FINAL ENERGY CONSUMPTION BY INDUSTRIAL SECTOR.



1) Concerns the remaining fossil fuel demand for all end-uses, focusing on process-heat only (i.e., the only end-use for which fossil fuels remain), they represent 2% of the demand.

Electrifying the sector could quarter energy emissions and reduce them by 45% using only mature technologies.

ELECTRIFICATION IMPACT ON GHG EMISSIONS BY ELECTRIFICATION STAGE.



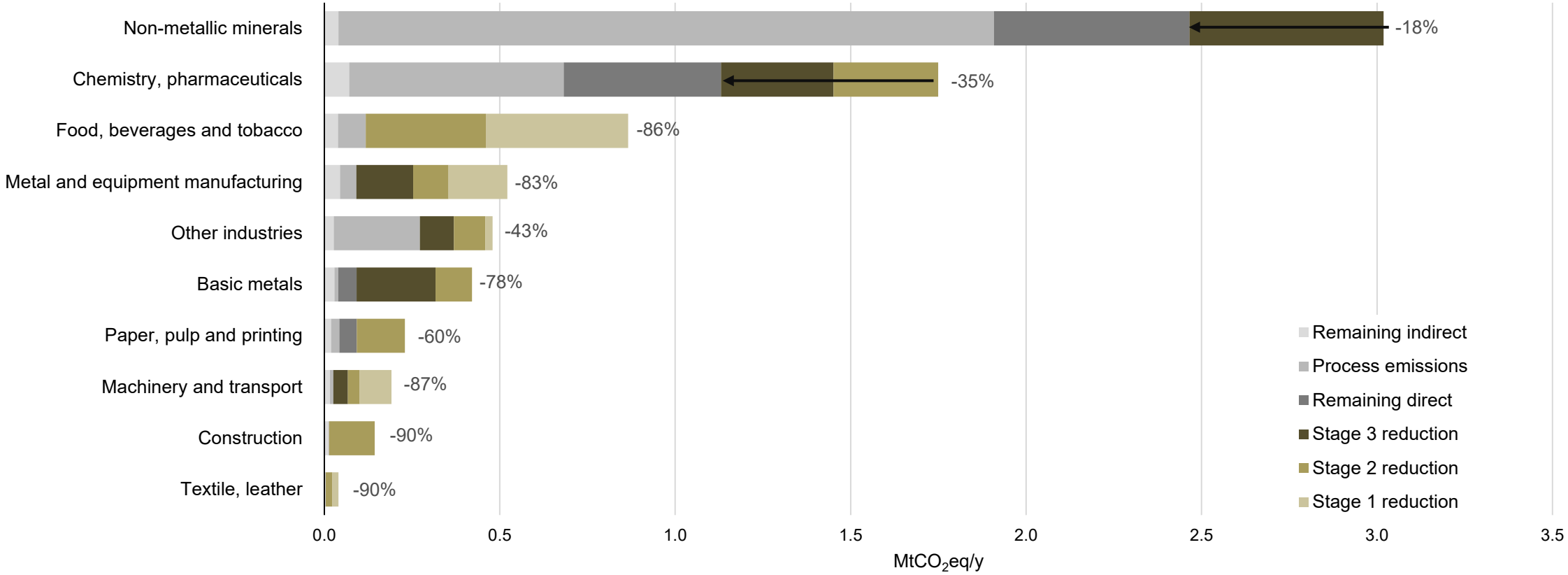
1) Indirect emissions assume a current grid at 60 gCO2eq/kWh for industrial consumers on Switzerland's grid based on direct emissions assumptions as direct and process emissions are extracted from territorial emissions and not on a carbon footprint basis

Sources: OFEV, E-CUBE Strategy Consultants analysis

.

Electrifying the sector could quarter energy emissions and reduce them by 45% using only mature technologies.

ELECTRIFICATION IMPACT ON GHG EMISSIONS BY ELECTRIFICATION STAGE AND INDUSTRIAL SECTOR



1) Indirect emissions assume a current grid at 60 gCO2eq/kWh for industrial consumers on Switzerland's grid based on direct emissions assumptions as direct and process emissions are extracted from territorial emissions and not on a carbon footprint basis

Sources: OFEV, E-CUBE Strategy Consultants analysis

.

Summary

The success of industry electrification is highly dependent on the electricity's competitiveness against alternatives and the cost of CO_2

Fig. Industrial heat pump heating Coefficient of Performance (COP) as a function of required temperature lifts for existing industry projects[1] in Switzerland (CH) and other regions (Other).

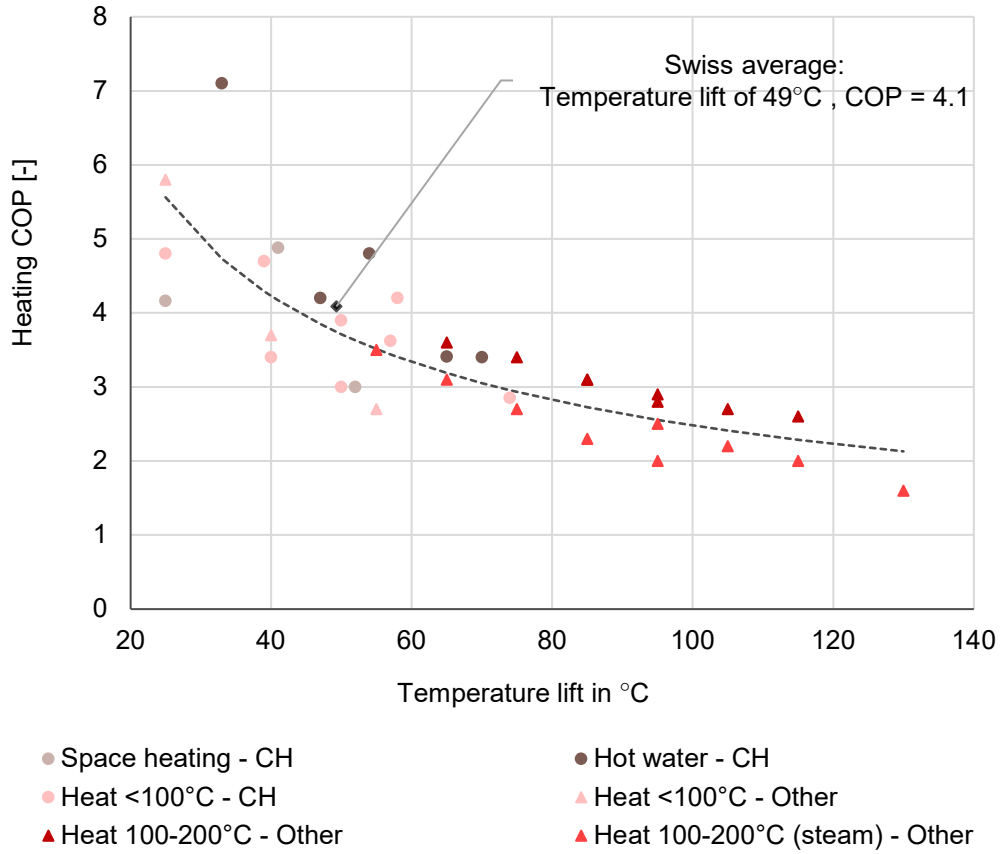
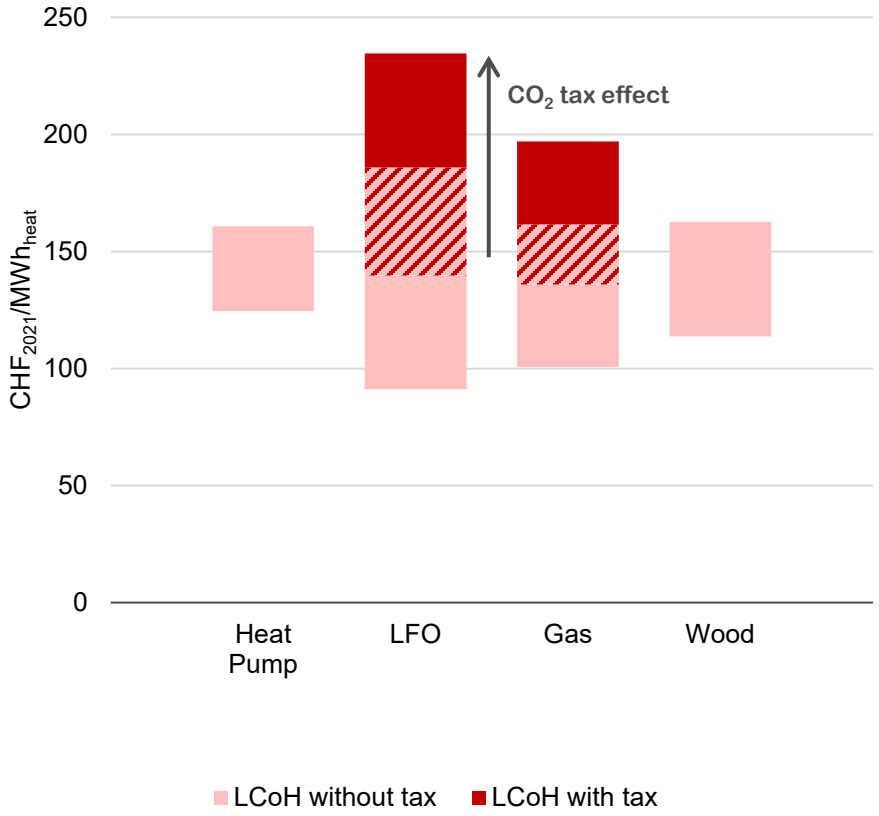


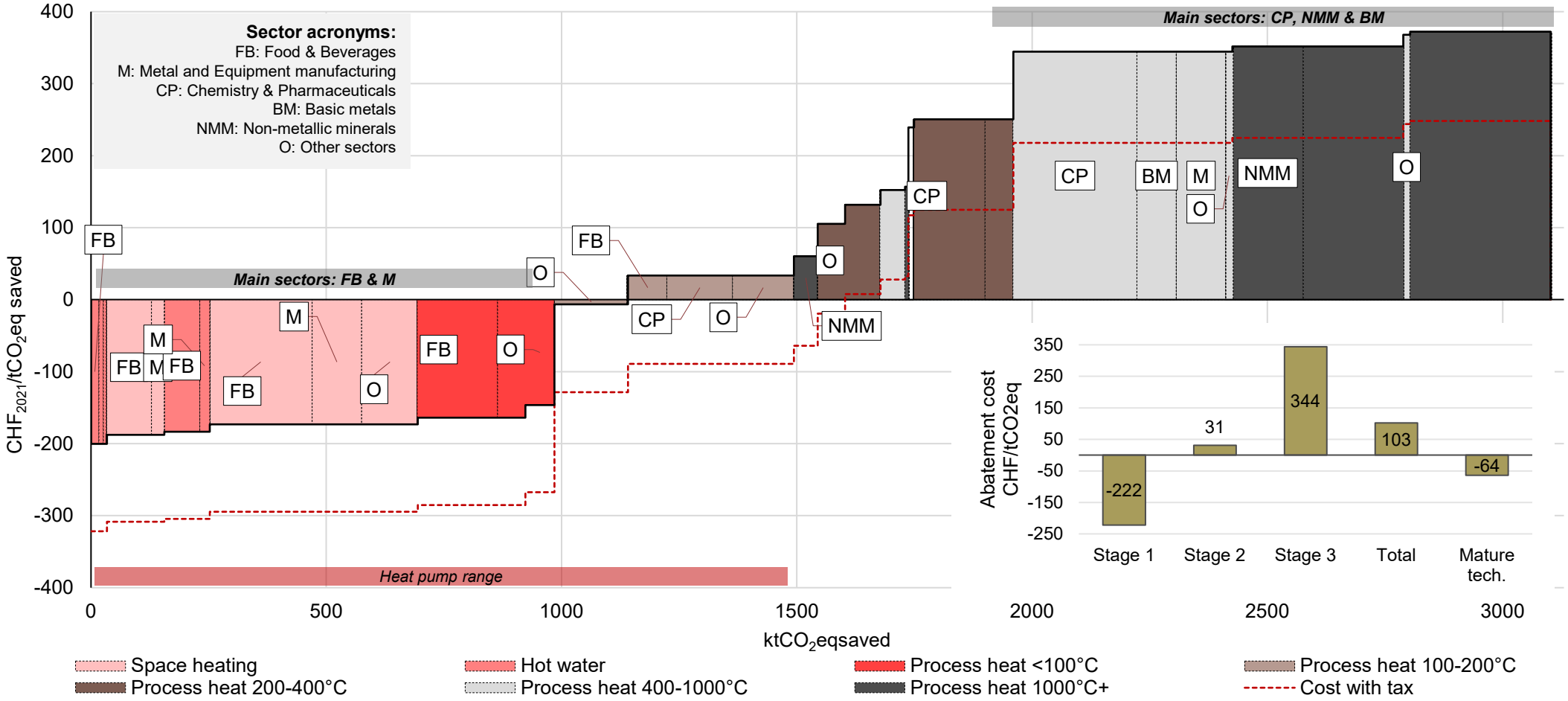
Fig. Levelized Cost of Heat[2], (LCoH) with, and without a CO2 tax of 120 CHF/tCO_2eq, for brownfield process heat generation at 100-200°C operating ranges.



Sources:
1) Industrial heat pumps Switzerland, SFOE; Market analysis, E-CUBE Strategy Consultants analysis
2) Hypotheses for energy input costs defined as historical price spreads for industry consumers from FSO: Gas 68-110 CHF/MWh; LFO 58 - 120 CHF/MWh; Wood 70 – 108 CHF/MWh, Electricity 160-170 CHF/MWh

A significant share of electrification can be profitably achieved with mature technologies, boasting an average abatement cost of -64 CHF/tCO2eq.

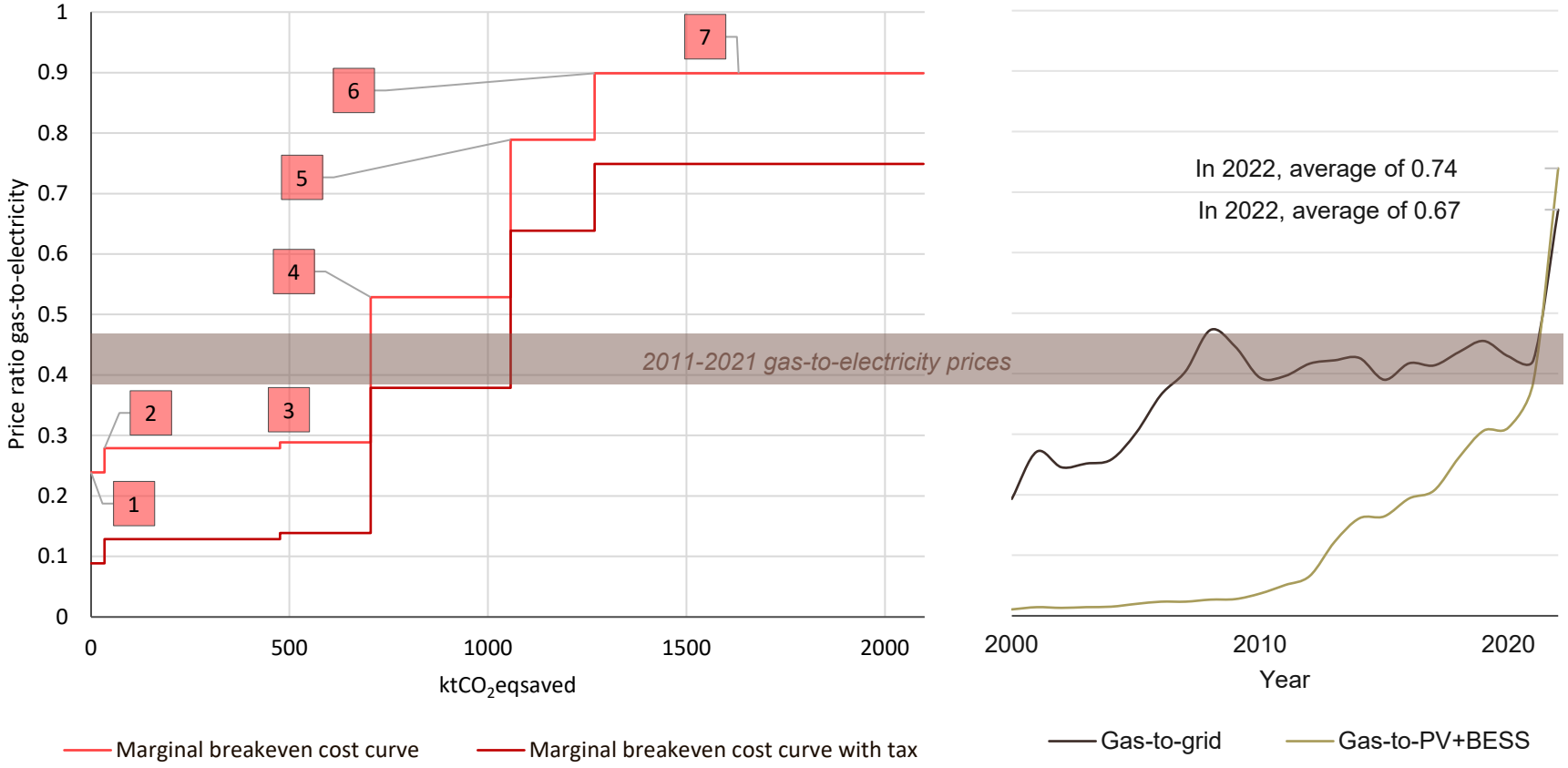
MARGINAL ABATEMENT COST CURVE[1] FOR EMISSIONS, BY FUEL SWITCH, SECTOR, AND END-USE.



Sources:
1) Hypotheses for energy input costs defined as historical price spreads for industry consumers from FSO: Gas 68-110 CHF/MWh; LFO 58 - 120 CHF/MWh; Wood 70 – 108 CHF/MWh, Electricity 160-170 CHF/MWh

Fuel-to-electricity price ratios are key for cost-effectiveness, with electrification for heat <100°C being competitive regardless of historical gas & electricity prices

MARGINAL BREAKEVEN COST ANALYSIS (WITH AND WITHOUT CO2 TAX OF 120 CHF/TCO$_2$EQ) FOR ELECTRIFICATION TECHNOLOGIES (ONSITE PRODUCTION[1)] AND GRID ELECTRICITY) AGAINST GAS HISTORICAL PRICE RATIOS 2000-2022



1 – Space Heating

2 – Hot water

3 – Process heat <100°C

4 – Process heat 100-200°C

5 – Process heat 200-400°C

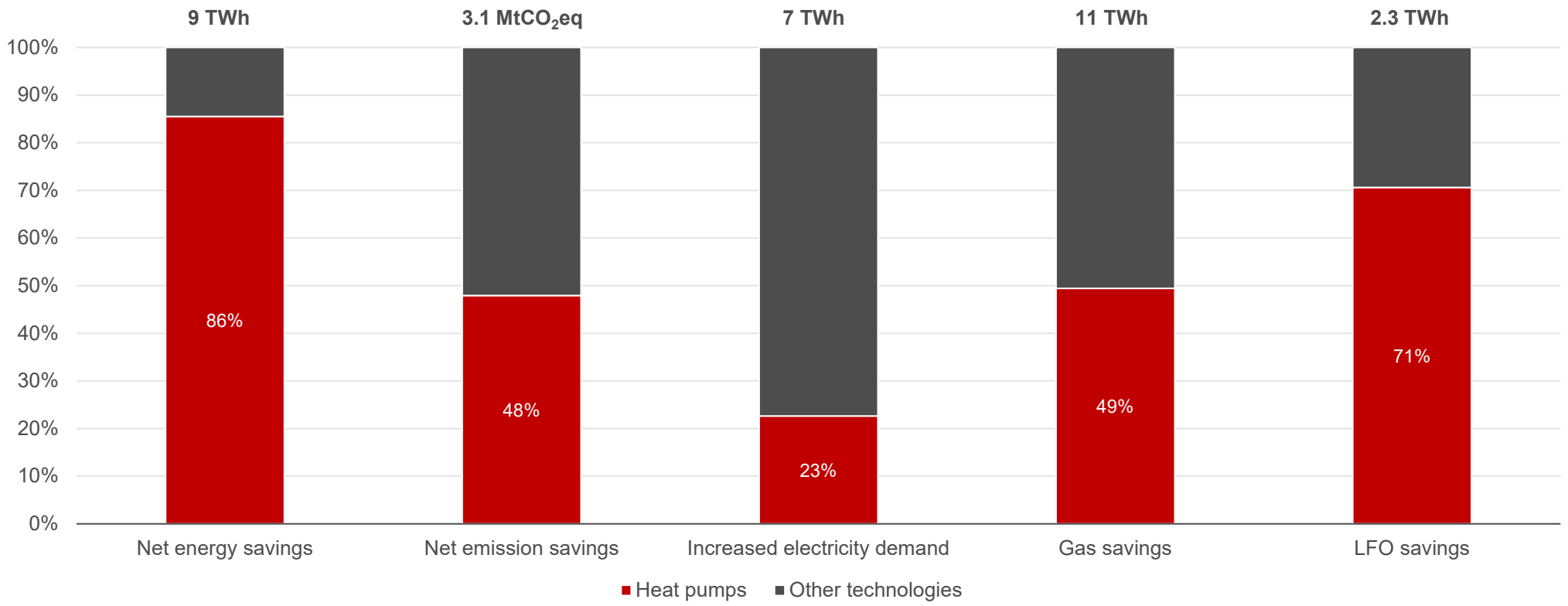
6 – Process heat 400-1000°C

7 – Process heat 1000°C+

1) Onsite production generation assumed as PV system coupled with Li-ion stationary batteries at an average system cost of ~150 CHF/MWh in 2022. Historical cost data based on battery and PV learning curves.
Sources: SFOE, E-CUBE Strategy Consultants analysis

Industrial heat pumps, the backbone of electrification, could profitably save 5.3 TWh of gas and 1.7 TWh of LFO, with an increase of 1.7 TWh in electricity demand

HEAT PUMP INTEGRATION IMPACT SHARE IN INDUSTRY ELECTRIFICATION



1) The marginal energy abatement cost curve is not shown in full as some electrification technologies reach up to 2'000 CHF/MWh of abatement cost, hence hindering the core message regarding heat pumps. Red dash line shows the same graph without taxes.

2) Hypotheses for energy input costs defined as average historical price spreads for industry consumers: Gas 68-110 CHF/MWh; LFO 58 - 120 CHF/MWh; Electricity 160-170 CHF/MWh. CO2 tax is set at 120 CHF/tCO2eq.

Sources: E-CUBE Strategy Consultants analysis

Cost-competitiveness of industrial heat pumps hinges on fuel-to-electricity price ratios and temperature lift requirements.

MARGINAL BREAKEVEN COST CURVES (WITH AND WITHOUT CO_2 TAX OF 120 CHF/TCO$_2$EQ) FOR HEAT PUMPS AGAINST GAS BOILERS[1] AS A FUNCTION OF FUEL-TO-ELECTRICITY PRICE RATIOS[2] AND REQUIRED TEMPERATURE LIFTS.

Fig. Process heat <100°C

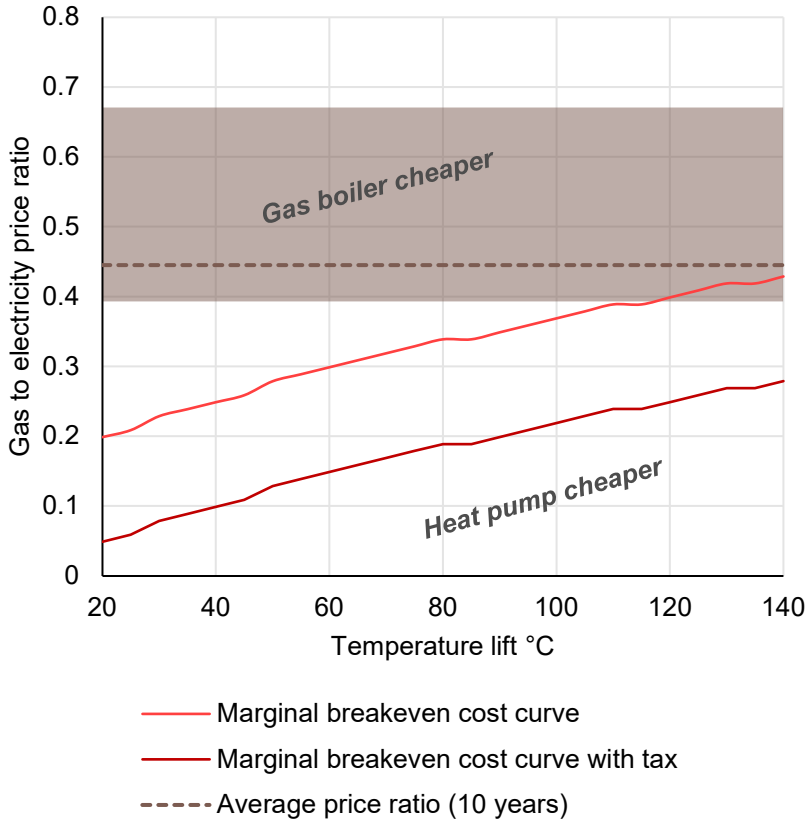
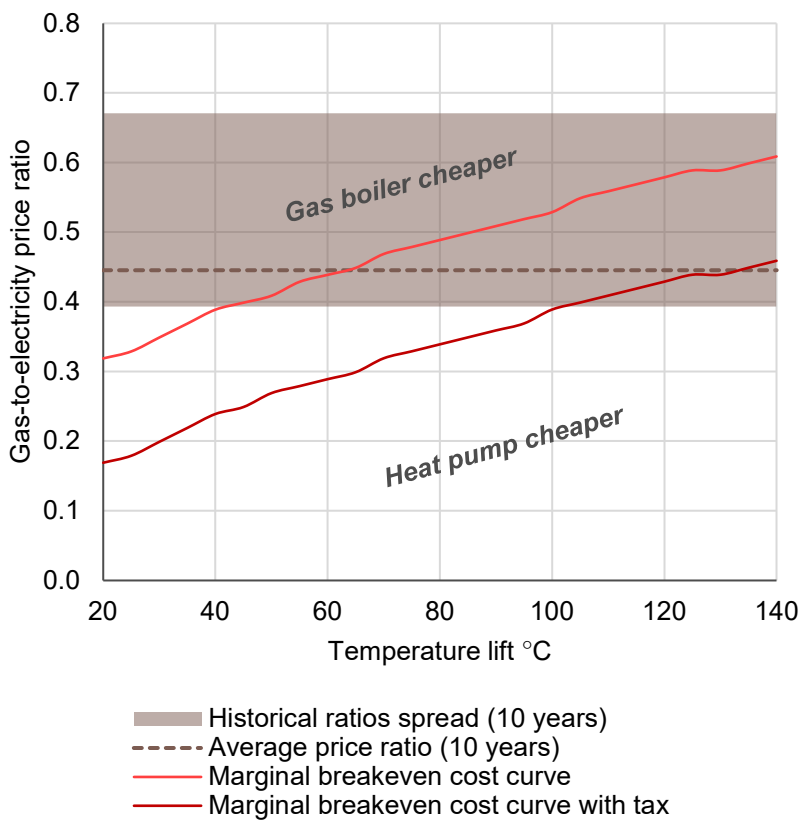


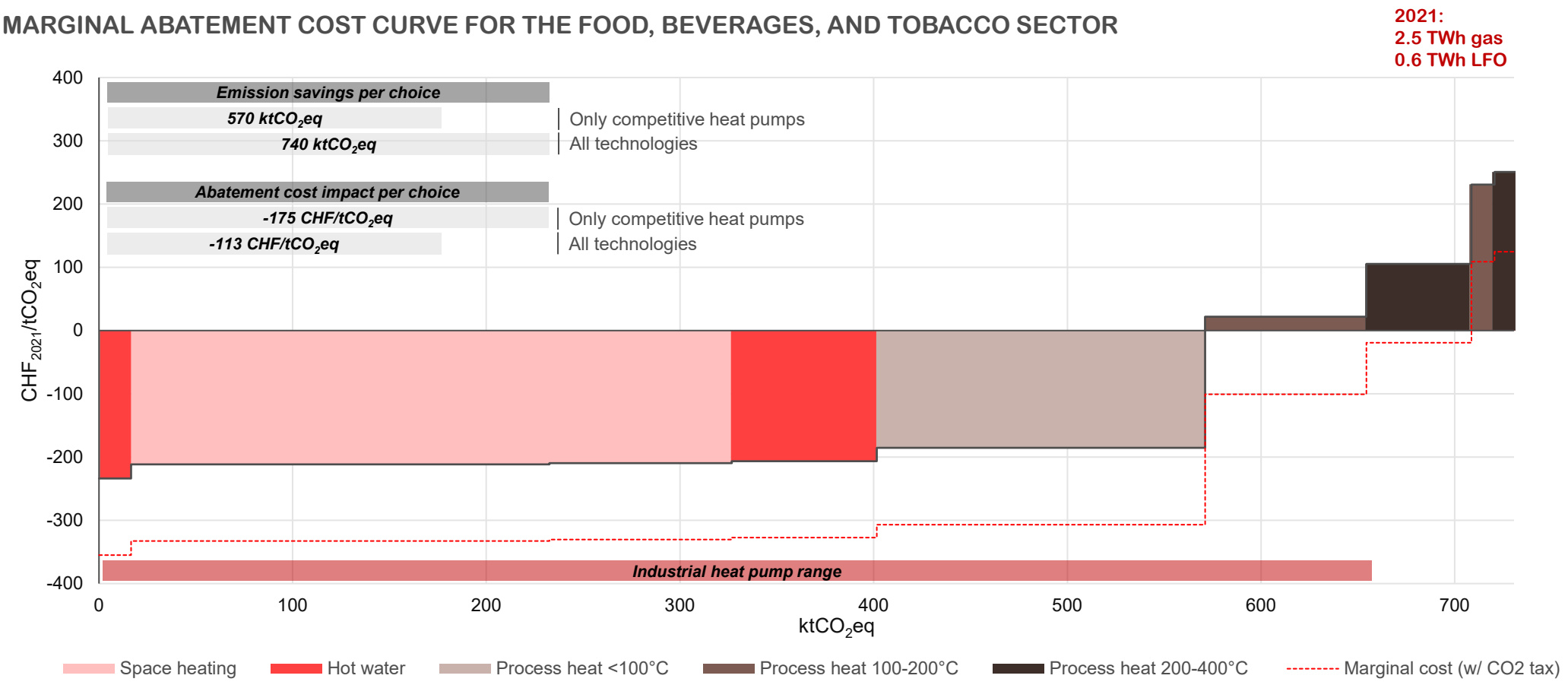
Fig. Process heat 100-200°C (including steam generation)



1) The analysis is only shown for gas boilers as it is the dominant source of heat for steam in Switzerland, LFO boilers are however within the same range of breakeven
2) Onsite production generation assumed as PV system coupled with Li-ion stationary batteries at an average system cost of ~150 CHF/MWh in 2022. Historical cost data based on battery and PV learning curves.
Sources: SFOE, E-CUBE Strategy Consultants analysis

Food, beverages, and tobacco can be fully decarbonized with net savings for the whole sector given its low temperature requirements at an average abatement cost of -113 CHF/tCO_2eq

MARGINAL ABATEMENT COST CURVE FOR THE FOOD, BEVERAGES, AND TOBACCO SECTOR



Challenges hinder the fast deployment of electrification, spanning technical, regulatory, and economic dimensions

Fig. Specific investment costs[1)] of heating technologies in Switzerland, 2021

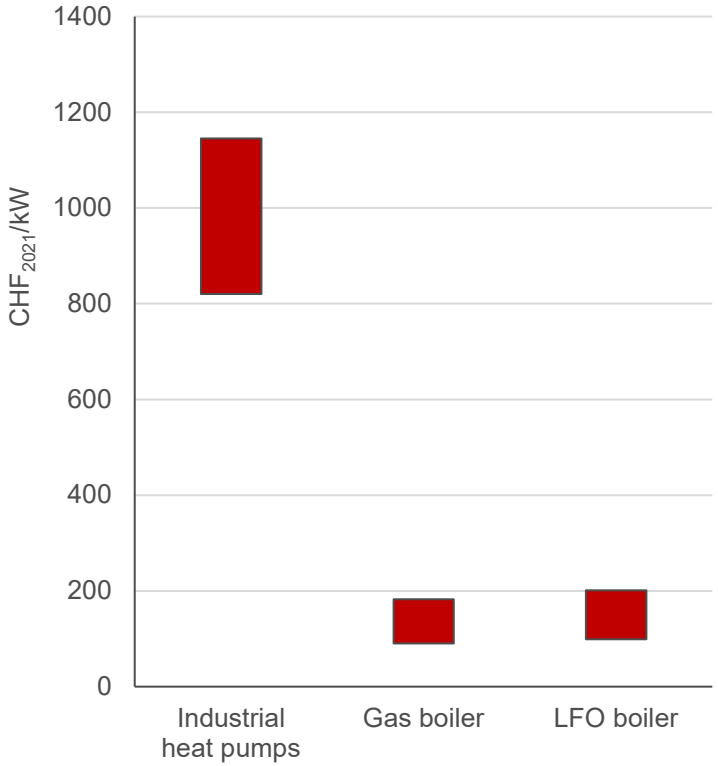
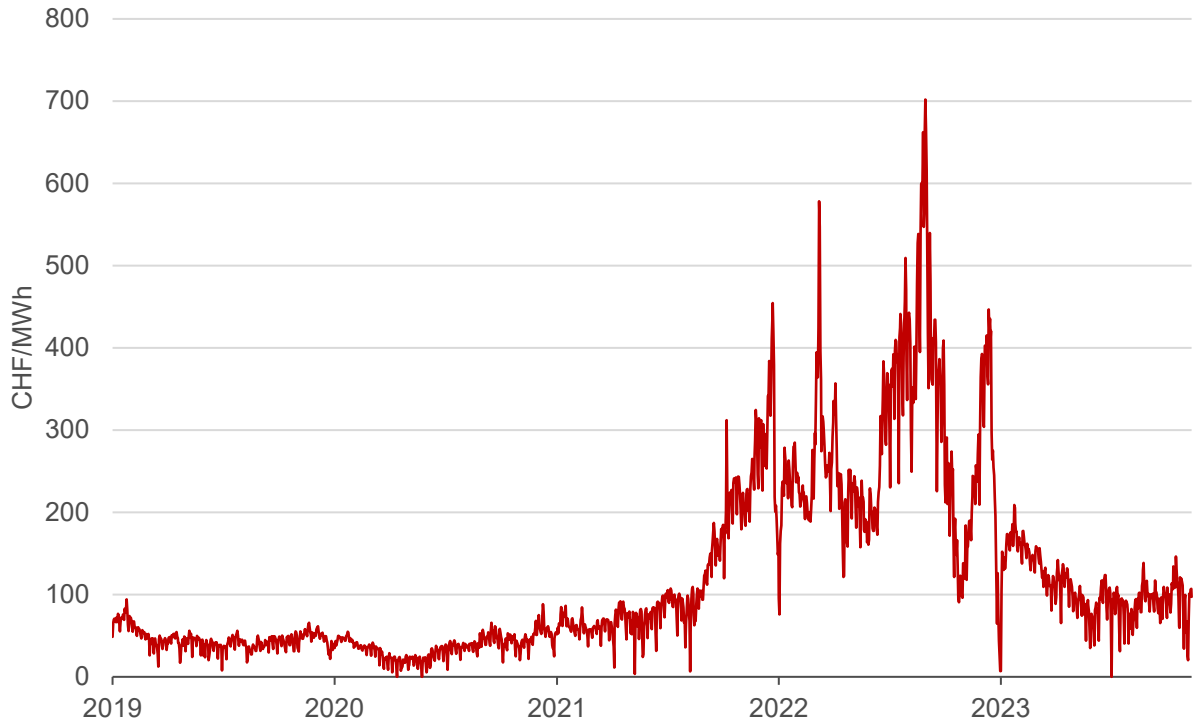


Fig. Electricity prices on the "Day Ahead" spot market Swiss base, 2019-2023



1) Investment costs for heat pumps covering 100-200°C process heat (incl. steam generation) are not listed here as they are not present in the Swiss market. Investment costs cover equipment cost as well as installation costs.

Sources: SFOE, EPEX SPOT, E-CUBE Strategy Consultants analysis

Electrification is a pivotal cost-effective strategy in the decarbonization of Switzerland's industrial sector

1. Switzerland's industry can be electrified up to 73%, with 56% from existing & mature technologies
2. Electrification of the sector would lead to a 21% decrease in final energy consumption and halves the sector emissions
3. Electrification of the sector comes at an abatement cost of ~100 CHF/tCO_2eq, heavily skewed by non-mature technologies
4. With current mature technologies, the cost of emission abatement is at -64 CHF/tCO_2eq and could decrease emission by 31%
5. Industrial heat pumps are the main powerhouse of electrification, and could save 5.3 TWh of gas, 1.7 TWh of LFO with net savings
6. Industry electrification's success will be highly dependent on the competitiveness of electricity against alternatives
7. Food, beverages, and tobacco would benefit the most from electrification, by reducing its emissions by 86%, with an abatement cost of -113 CHF/tCO_2eq

→ Integrate electrification is global energy system modelling, collaborate with industry stakeholders to promote electrification and acquire better data

Any questions?