Contribution of energy efficiency improvement towards deep decarbonization of Swiss Food and Beverage sector

By

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SCCER EFFICIENCY OF INDUSTRIAL PROCESSES

Odyssee MURE

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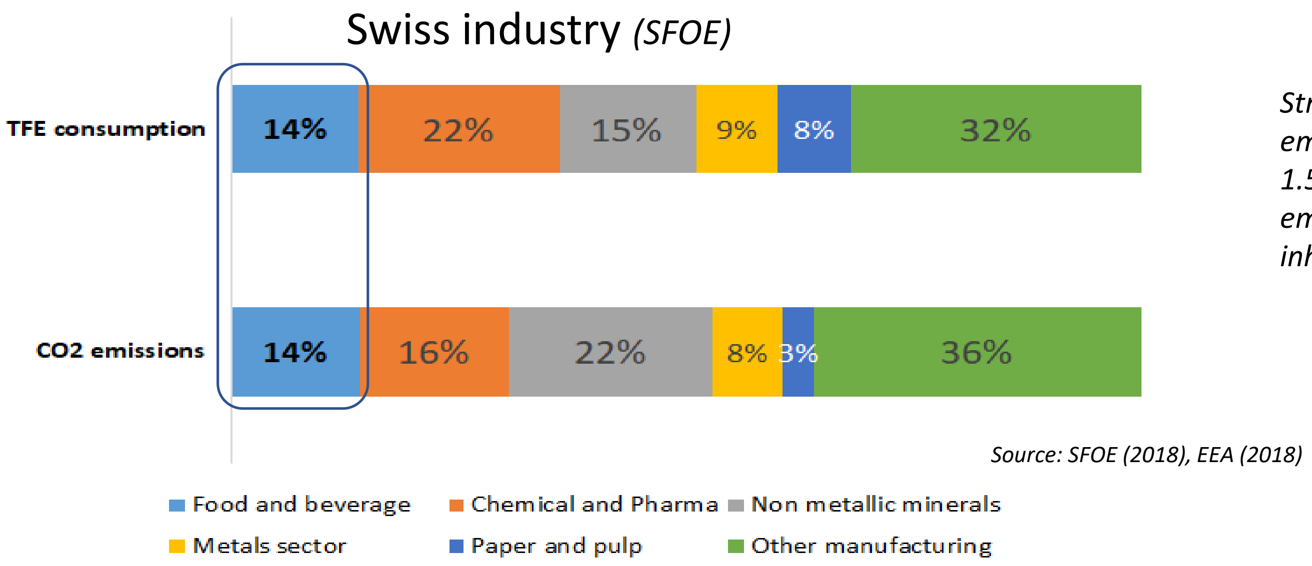
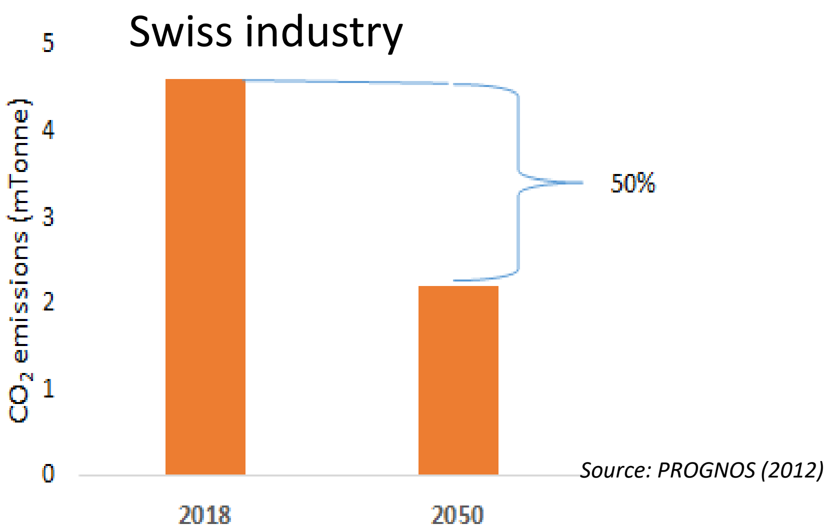
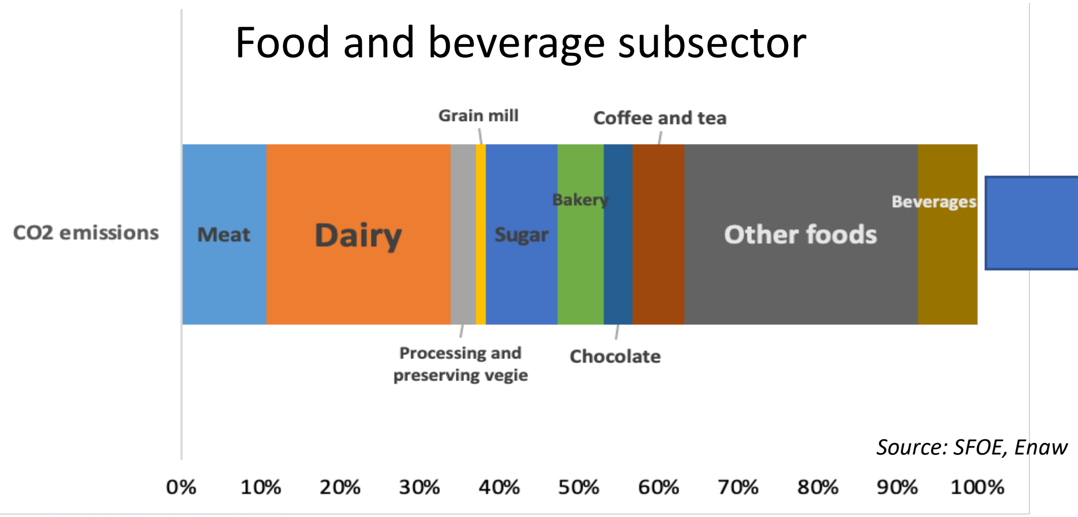
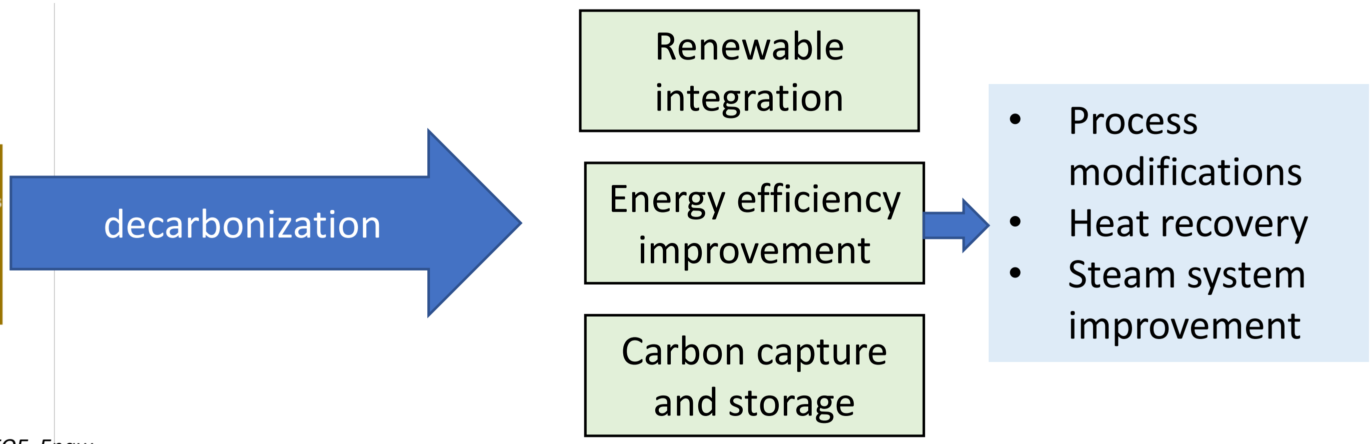
Introduction



Strategic goal for CO_2 emissions → reach 1.5 tonne CO_2 emissions per inhabitant







Characterization of process energy consumption (Top down)

ENERGIE-AGENTUR DER WIRTSCHAFT EnAW

Description of EEMs

Energy mix

Geographic location

Estimating shares of energy consumed by **product groups within EnAW database**

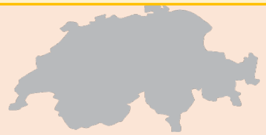
Food and beverage products (EnAW)
Dairy industry, meat industry, fruits and vegetables processing, sugar, chocolate, bakery and beverages

e.g. % TFE consumed by diary

76% coverage

Estimating total final energy consumed by **product groups in at national scale**

Shares of sub-sectoral energy consumption in EnAW in database scaled to National statistics



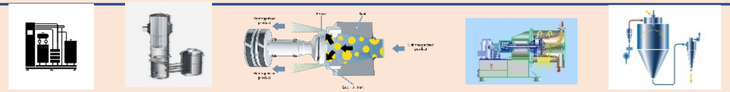
Food and beverage sector (Switzerland)

e.g. Total final energy in TJ consumed by diary

Based on typical energy consumption profiles of each type of establishment

Estimating energy consumed for each **production step/end use**

Food and beverage sector
Pasteurization, evaporation, homogenization, centrifugal separation, drying, cutting and mixing, refrigeration, EMDS



e.g. TFE in TJ consumed by pasteurization

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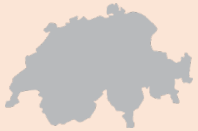
Background | Methodology | Results

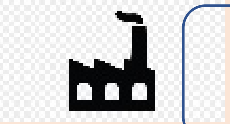
Technical EE improvement potentials in Swiss industry (Bottom-up)



Technical energy saving potential at the **level of entire subsector**

Food and beverage sector

Aggregate saving potential at **establishment and the level of produt groups**



Food and beverage sector
Dairy industry, meat industry, fruits and vegetables processing, sugar, chocolate, bakery and beverages

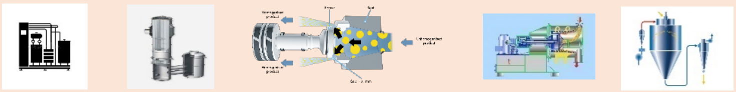
Estimation of technical EE potential at **process level**

SECs of Individual production processes

SECs of best available techniques

TFE consumed by pasteurizer/tonne of milk

Food and beverage sector



Top-down TFE consumption estimates for individual production processes

Production estimates

Description of EEMs in EnAW database or national statistics

Estimation of cost-effective EE improvement potential (Bottom-up)

Levelized cost

EECC → Levelized cost on Y-axis, cumulative annual saving potential in X-axis

$$Levelized\ cost = \frac{I * ANF + OM - B}{ES}\ \text{(CHF/GJ)}$$

OR

$$CO_2\ abatement\ cost = \frac{I * ANF + OM - B}{CS}\ \text{(CHF/t-}CO_2\text{)}$$

**Source (Blok, 2007)*

$$ANF = \frac{(1+r)^L * r}{(1+r)^L - 1}$$

r= discount rate

L= lifetime of the measure

$$B = ELS_y * P_e + FS_y * P_f + CS_y * P_{CO2}$$

ELS_y and Fs_y = electricity and fuel savings by measure y per year

P_e ,P_f and P_{CO2}= energy and CO_2 prices

$$ES_y = (ELS_y + FS_y) * dr_y$$

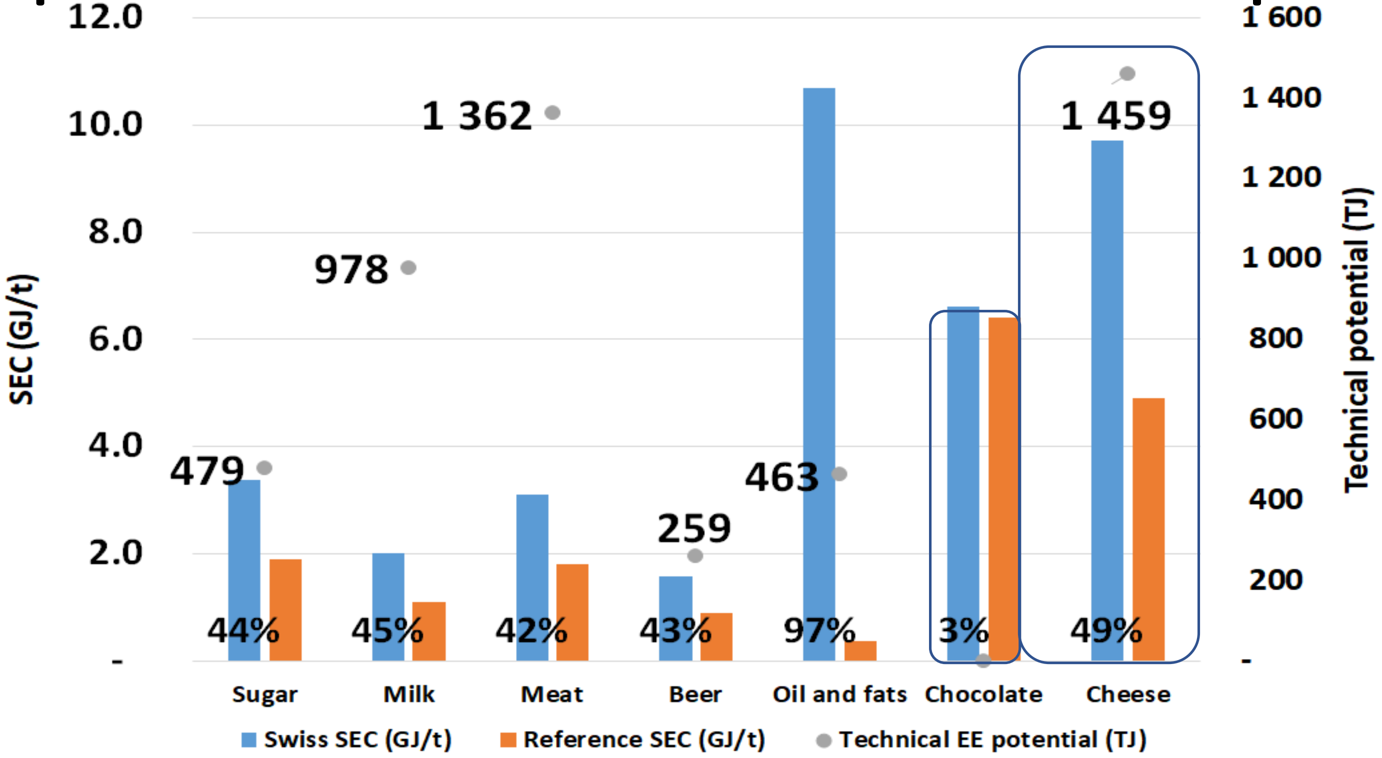
dr_y= remaining diffusion of measure y

$$CS_y = (ES_y) * EF_r$$

EF_r= emission factor for fuel r

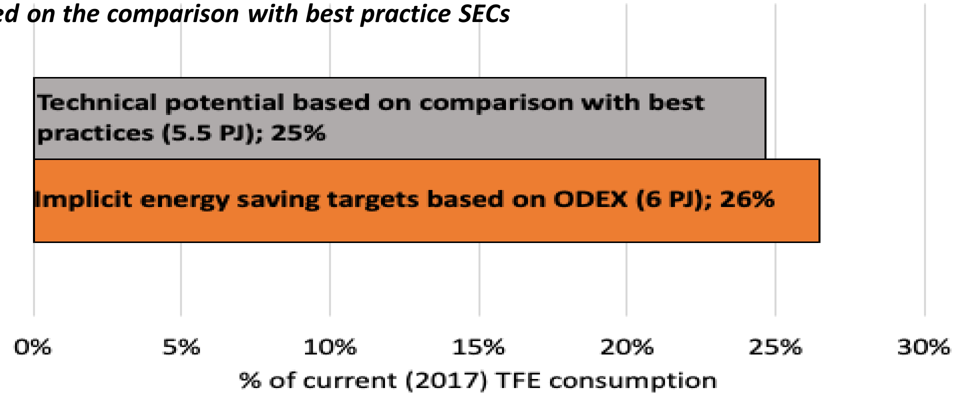
Total 43 EEMs identified

Bottom-up estimates for SEC and technical potential



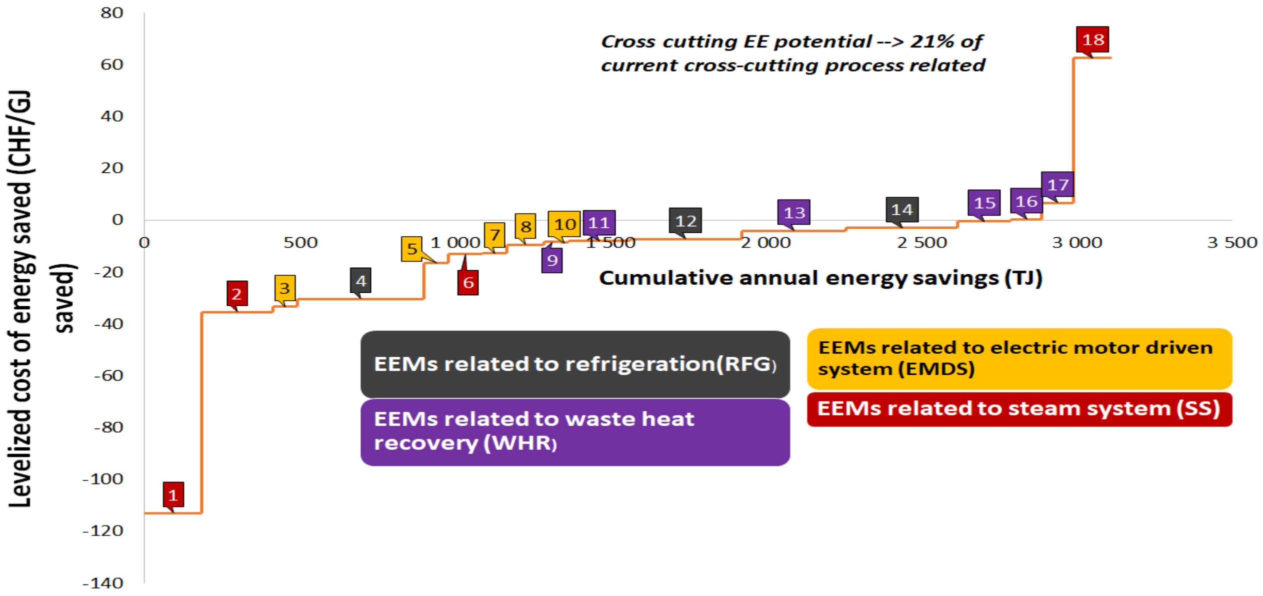
Percentage and absolute technical EE improvement potentials-Based on the comparison with best practice SECs

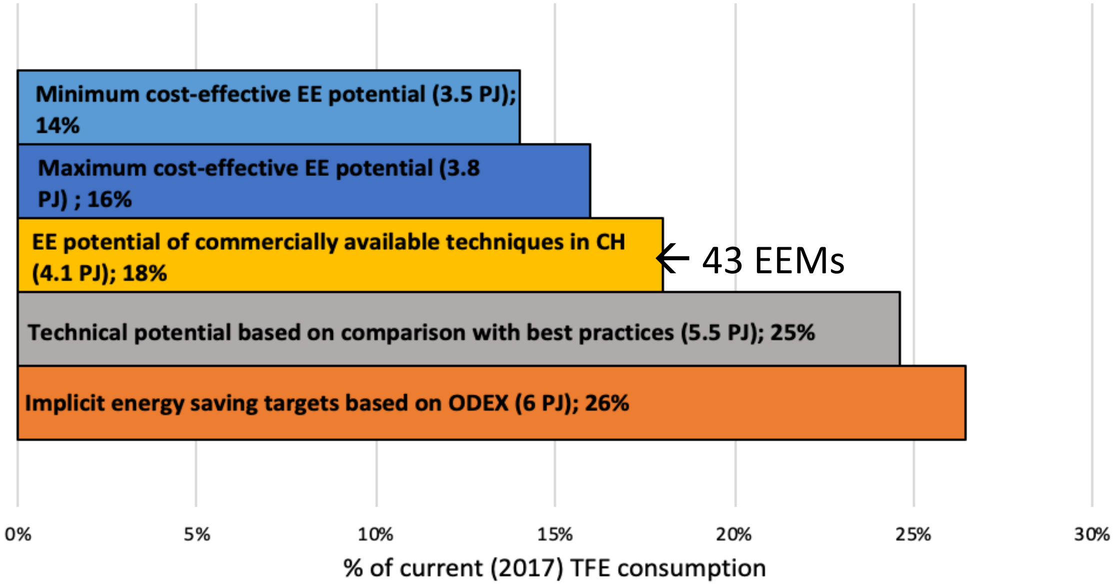
- **Largest share of technical EE improvement →** Cheese manufacturing (26% share).
- **Most efficient →** Cocoa and chocolate production



Ref. Bhadbhade et al., 2020

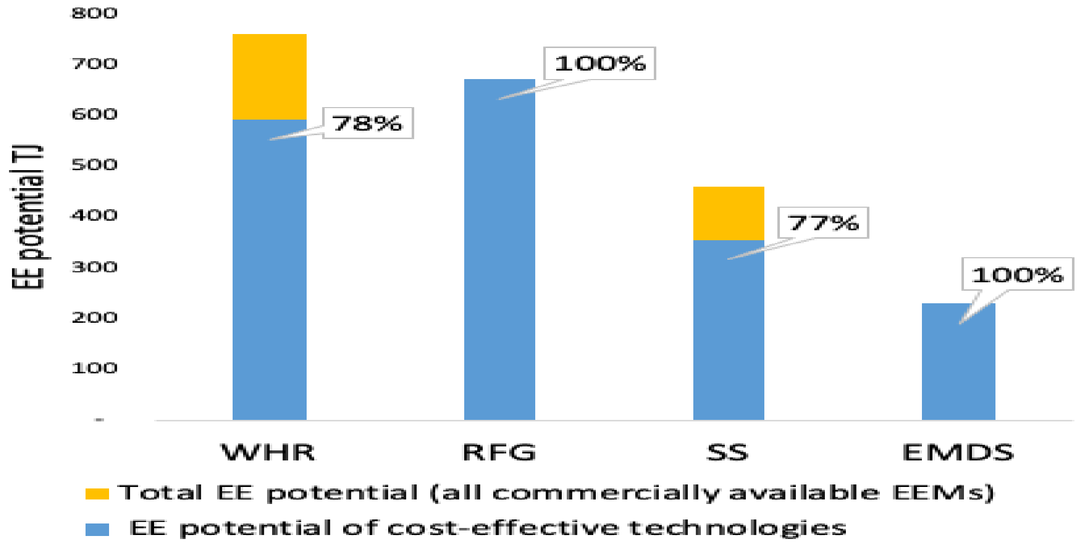
Energy efficiency cost curves





Various levels of potential for food and beverage subsector

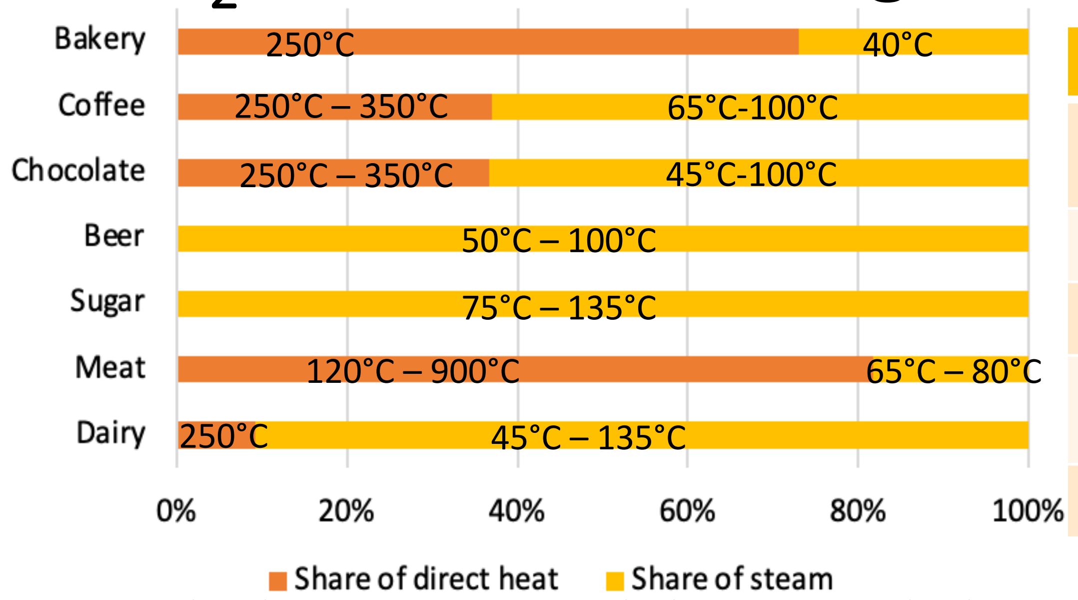
- **Core processes related EEMs→** 30% EE improvement potential.
- **Largest share of EE potential→** Dairy production related EEMs *(Reverse osmosis instead of evaporation).*
- **Cross-cutting processes EEMs→** 70% EE improvement potential.
- **Largest share of cross-cutting EE potential →** WHR related measures *(Process heat integration).*



Total technical and cost-effective EE potential by product groups and cross-cutting technology groups

Ref. Bhadbhade et al., 2020

CO_2 abatement through waste heat recovery



Sources: Shares based on EnAW, Temperature levels: BREF, Lorenz et al, J. Klemens

CO_2 abatement potentials for heat pumps

Product group	CO2 emission reduction potential[1]	Typical scheme
Meat	14% to 28%	Refrigeration to thermal storage
Bakery	10% to 14%	Refrigeration to thermal storage
Chocolate	11% to 52%	Refrigeration to hot water network
Confectionery	23%	Refrigeration to thermal storage

CO_2 abatement potentials for process heat integration

Product group	CO2 emission reduction potential[1]	Typical scheme
Sugar	5%-10%	Evaporation to extraction/ Drying to extraction
Bakery	16% to 30%	Flue gas to thermal storage
Chocolate	11%	Roaster heat integration
Beer	11%-21%	Brewhouse integration
Dairy	4%-13%	Dryer preheating, pasterurized preheating, CIP thermal demand

[1] Percentages estimated relative to total CO_2 emissions generated from particular establishment (Source; EnAW)

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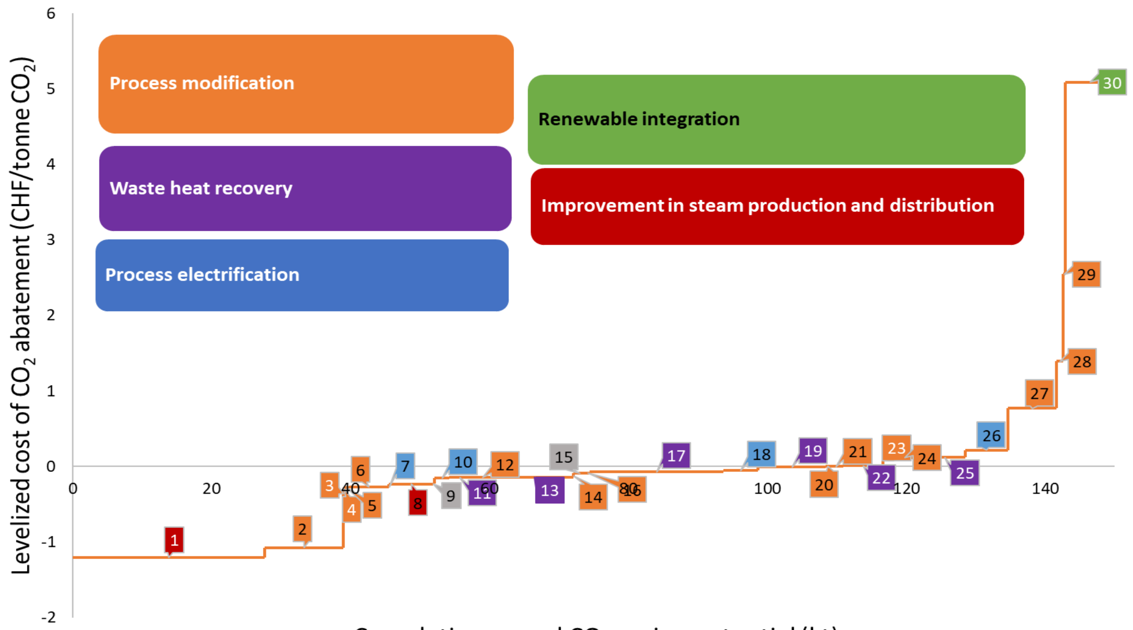
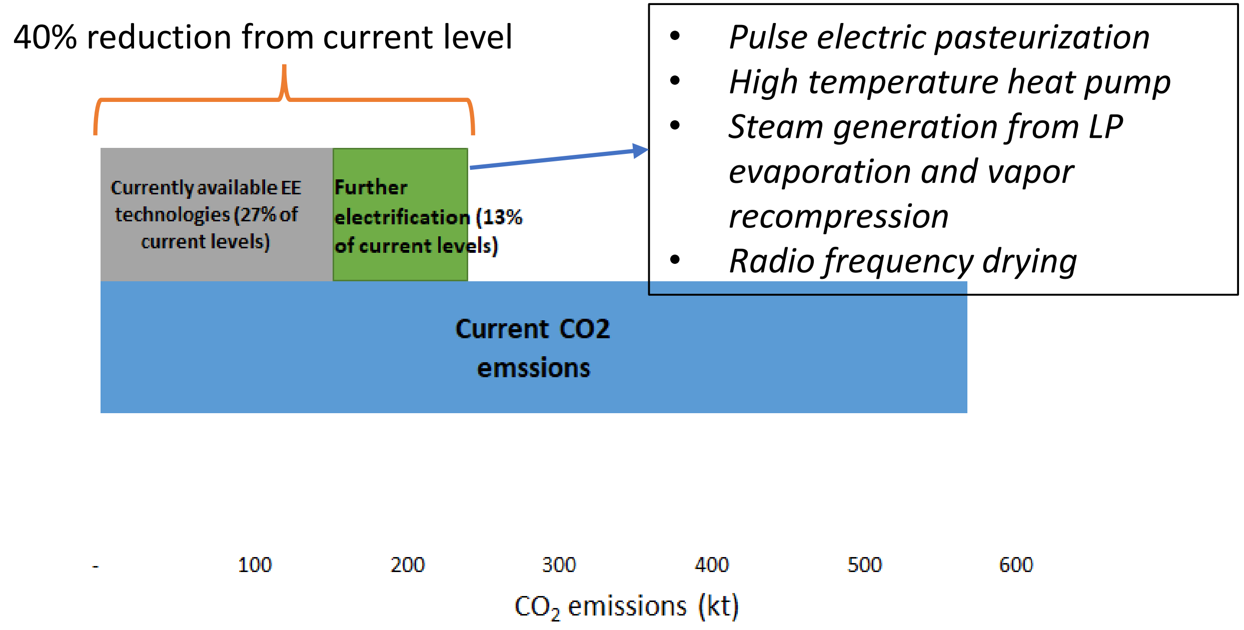
CO_2 abatement cost curves

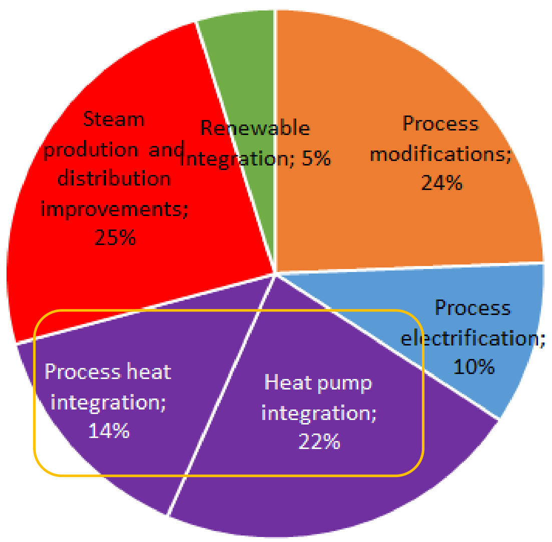


CO_2 mitigation cost curve



CO_2 abatement projections and available levels

- **Largest share of CO_2 abatement potential in current EE technologies →**waste heat recovery EEMs.
- **Most cost-effective way to reduce CO_2 emissions→** Steam system improvements.



Shares of technology groups in CO_2 abatement potential

Sensitivity analysis

		Higher values		Lower values	
Exogenous variables	**Base case values**	**Significance**	**Effect**	**Significance**	**Effect**
Discount rate	21%	Companies with stringent economic criterion	Capital intensive EEMs become economically unattractive (e.g. plant wide heat integration, purchasing efficient process equipment)	Companies with less stringent economic criterion	Less sensitivity of cost-effectiveness to any changes
Energy prices	Fuel: 13.6 CHF/GJ Electricity 43.3 CHF/GJ (*IEA, 2018*)	Future projected energy prices	On average EEMs become more economically attractive	Energy prices for large consumers (sometimes negotiated)	Measures related to EMDS and WHR become economically unattractive
CO_2 levy	96 CHF/tonne CO2	Future projected values (upto 250 CHF/tonne CO2)	WHR and electrification (MVR or membrane technology instead of evaporation) become economically viable	Current value	

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Background | Methodology | Results

Conclusions

EE potential (process related):

- **Large scope for the expansion of implementation of currently available technologies**→25% of subsector's TFE reduction**.**
- **High potential for emerging technologies** → 18% of subsector's TFE reduction.
- **Most of the available EE improvement technologies are found to be cost-effective** → 16% subsector's TFE reduction.

CO_2 emission reduction potential:

- **Further electrification and renewable integration to reach expected reduction levels** → 27% of CO_2 emissions reduction potential by current technologies + 13% by emerging technologies
- **Waste heat recovery technologies represent the largest share of current CO_2 emissions reduction potential**→ 36% potential of currently available technologies
  →HPs represent relatively larger CO_2 abatement potentials at establishment level
- **Improvements in steam generation can reduce CO_2 emissions in the most cost-effective manner**

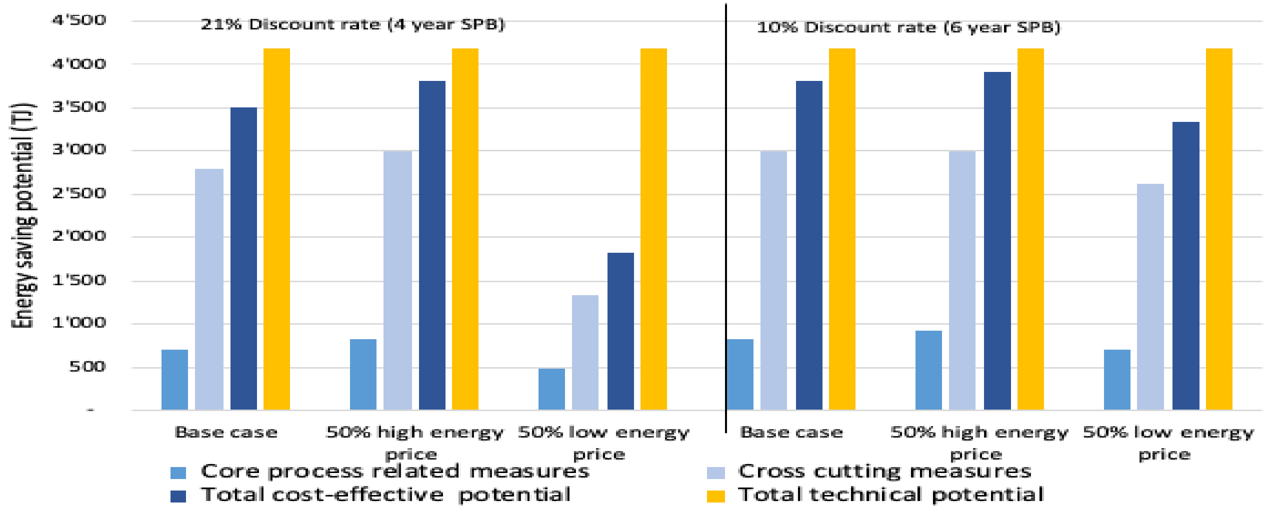
Sensitivity analysis of cost-effective potential

- **Higher CO_2 levy favorable for adoption of WHR and capital-intensive measures**→ Heat integration projects and electrification of production steps become cost-effective.

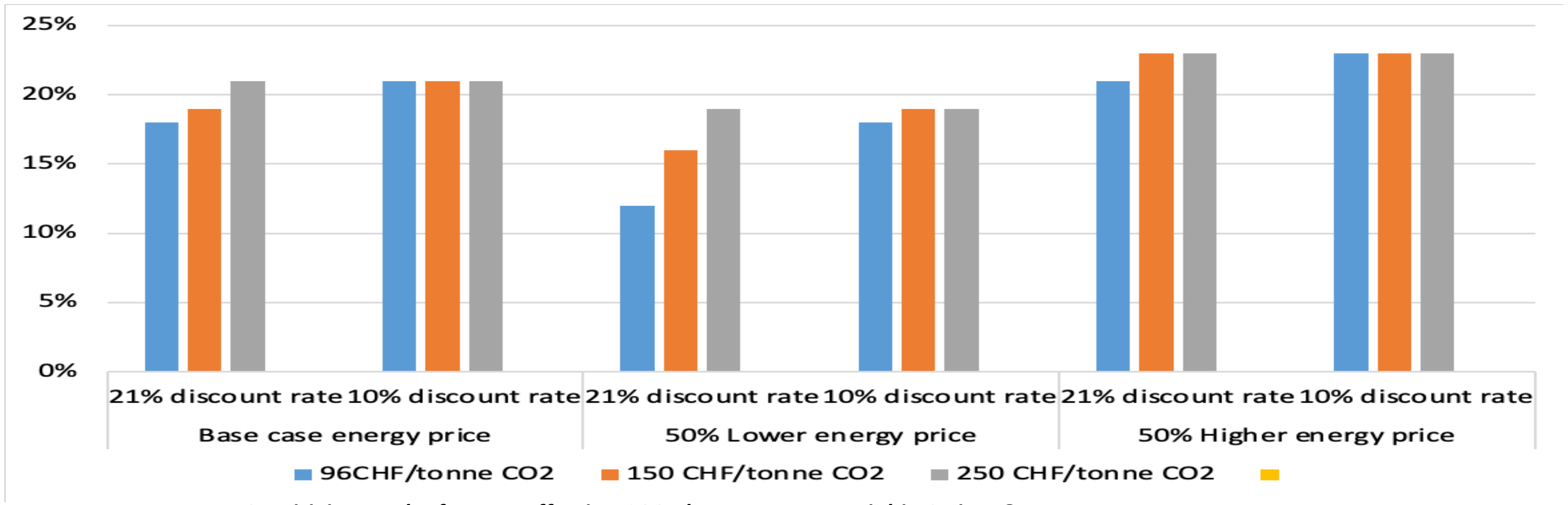
Thank you!

Additional slides

Sensitivity analysis

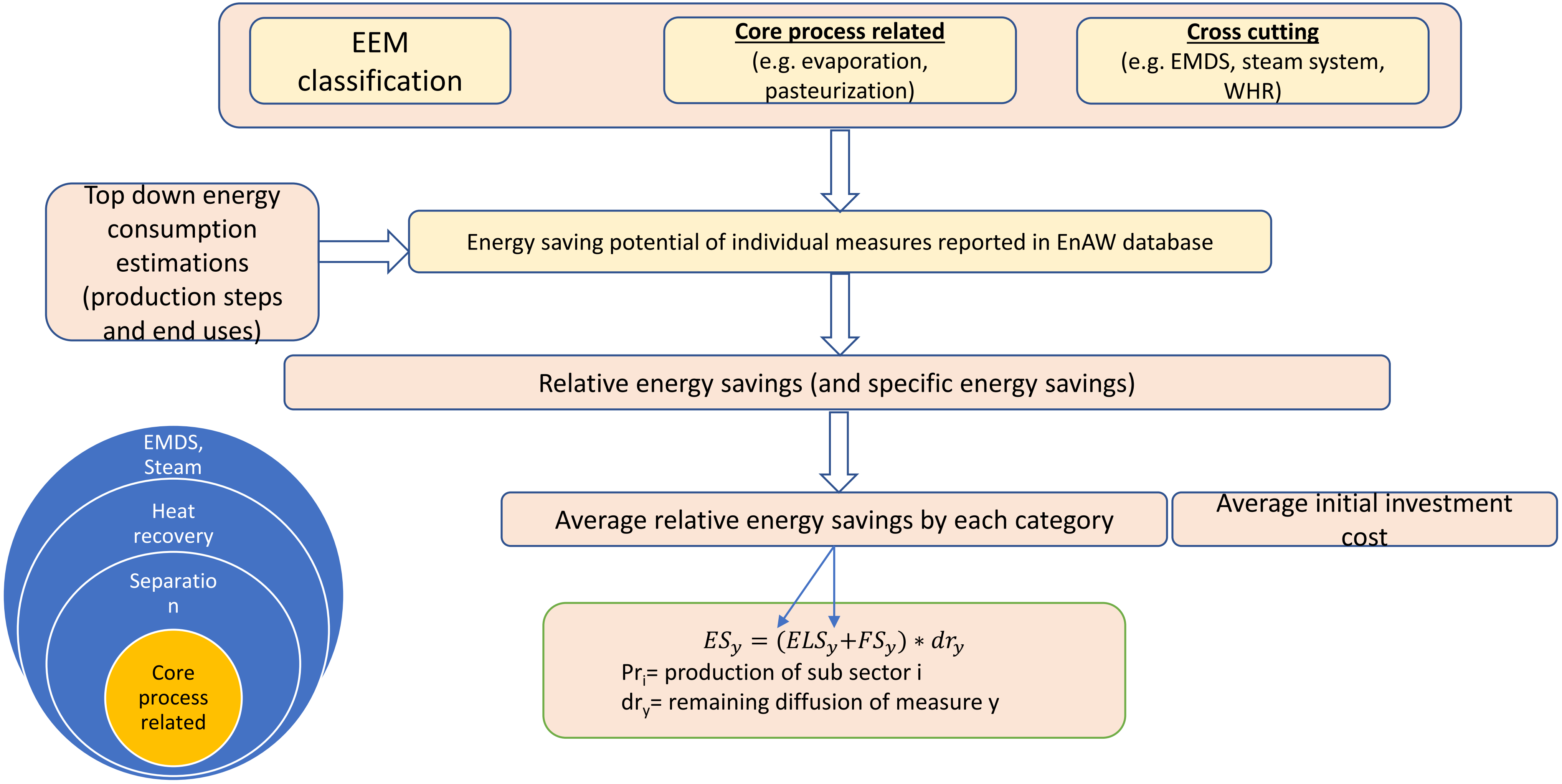


Sensitivity results for cost-effective EE potential in Swiss F&B sector



Sensitivity results for cost-effective CO2 abatement potential in Swiss F&B sector

Categorization of techno-economic data for energy efficiency measures



ODEX methodology – Energy efficiency improvement trend and energy savings

Global ODEX

$$ODEX_{global,t} = \sum_i ODEX_{i,t} \times ES_{i,t}$$

For entire country

Aggregation based on shares of each **main sector** in country's TFE (ESi)

Main sector ODEX

$$ODEX_{i,t} = s \times \left({}^{I_{i,t}}/_{I_{i,t-1}}\right)$$

With $s = \begin{cases} 100, & t = t_0 \\ ODEX_{t-1}, & t > t_0 \end{cases}$ and t = t_0, t_1, t_2

…

$${}^{I_{i,t-1}}/_{I_{i,t}} = \sum_j \left(\frac{UC_{j,t}}{UC_{j,t-1}} \times ES_{j,t}\right)$$

-->*Unit consumption index*

At main sector level (i) e.g. ***Industry***, Transport, Households, Services

Aggregation based on share of each **subsector** (ESj) in main sector's TFE

Unit consumption (UC)

$$UC_{j,t} = {}^{(EC_{j,t})}/_{(A_{j,t})}$$

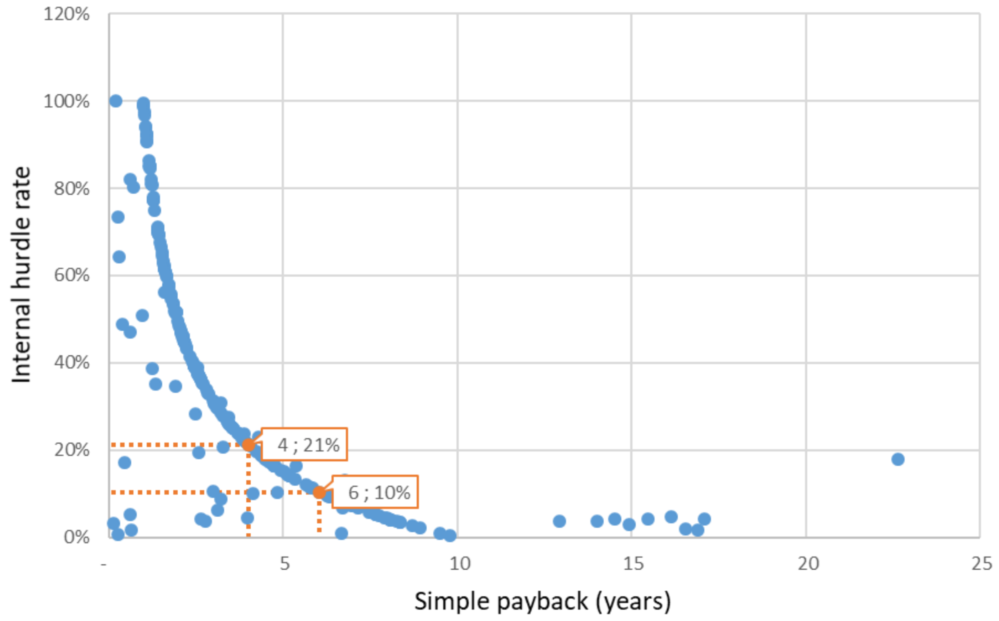
$UC_{j,t}$= Unit consumption index for subsector j and year t
$EC_{j,t}$ = Final Energy demand of subsector j,
$A_{j,t}$ = Activity of subsector j, for year t

At subsector level (j) e.g. ***Metals production and fabrication, and food***

ODEX → EE indiator developed in the framework of ODYSSEE-MURE project to evaluate EE trends at the level main sectors and entire country based on subsectoral physical EE indicators. *Ref. Bhadbhade et al 2019, Odyssee methodology*

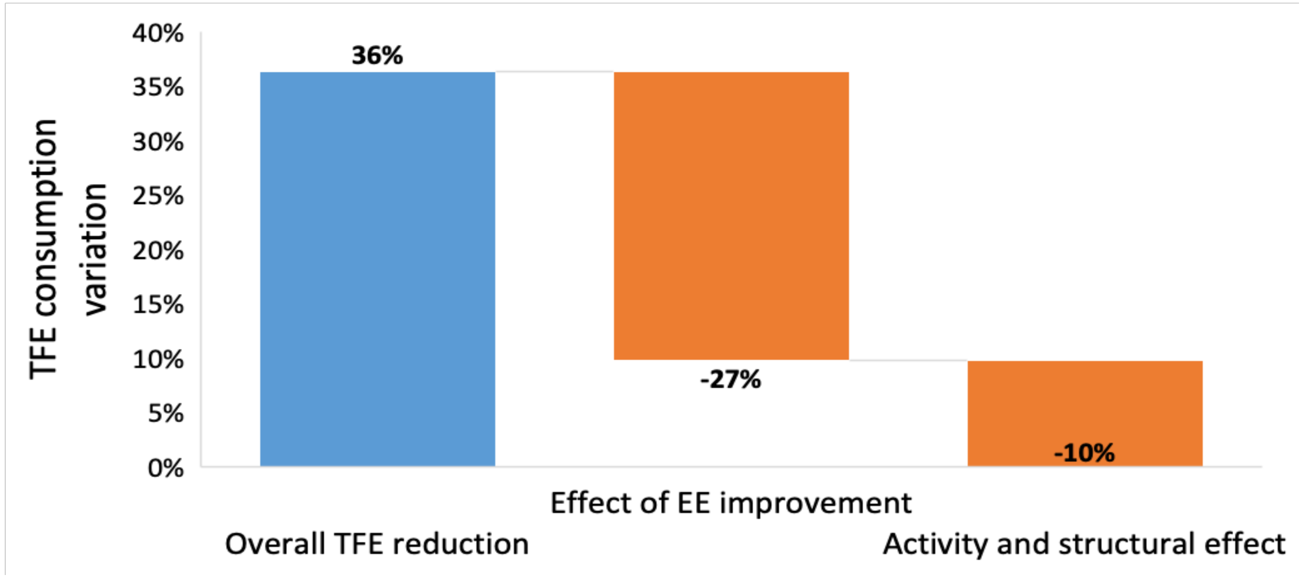
Discount rate

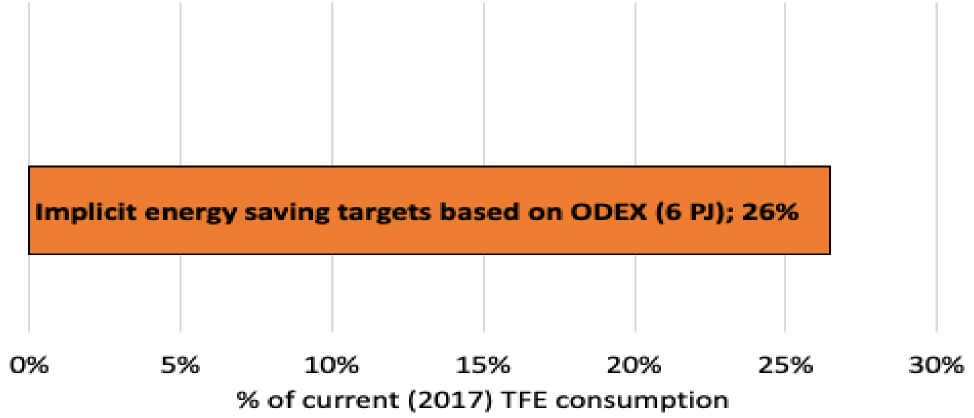
- Discount rates: used to discount future cash flows to present value in order to reflect both the **time value of money and perceived risk .**
- Typically industry prefers the economic criterion of simple payback time (SPB).
- Target agreement: for exemption from CO_2 tax in CH, all measures with **SPB up to 4 years must be implemented** (for process related measures).
- Techno-economic data presented in the EnAW database allows the estimation of internal hurdle rates (or IRR) as well as SPB for each investment.
- The economic criterion of **4 years SPB implies the discount rate of at least 21%** for Swiss F&B establishments.
- In order to **reflect the firm level decision criteria**, 21% was chosen as discount rate for base case cost-effectiveness analysis.



Correlation between Internal hurdle rates (implicit discount rates) and Simple payback period for Swiss F&B industry (Based on EnAW database)

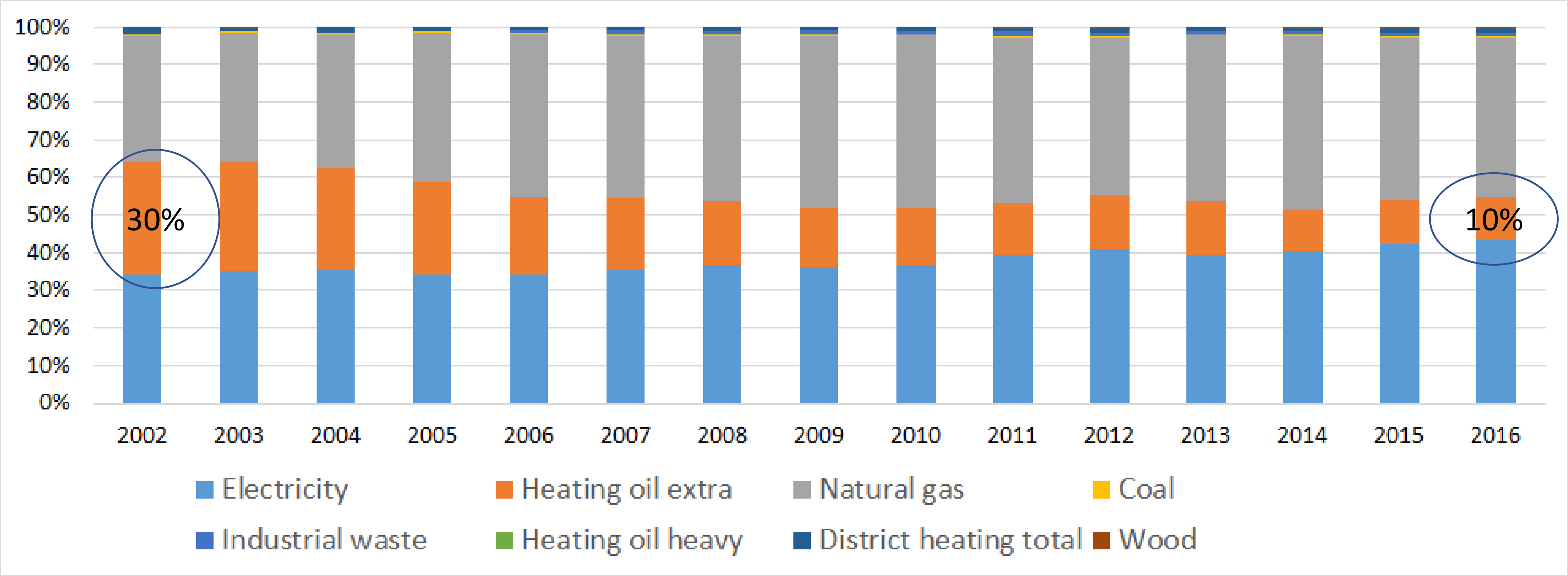
Decomposition analysis – Projections and targets





F&B sector: EE improvement is expected to reduce 26% of TFE reduction until 2050 → Energy saving target 6 PJ

Trends of fuel demand in F&B sector



Remaining diffusion estimates

- $dr = \left(\frac{(EC_x - ED_{yEnAW})}{EC_x}\right) * Pt_x$
- EC_x= Energy consumption of process x
- ED_{yEnAW} = Energy demand to which measure y refers implemented in EnAW database
- Pt_x = technical potential for the process x = $(SEC_{CHx} - SEC_{wx}) / SEC_{CHx}$

→*E.g. ECx for evaporation = 1193 TJ*
→*Edyenaw = 144 TJ*
→*Ptx = 60%*→*40% of energy demand cannot be further reduced*
→*dr = 52% for vapor recompression in evaporation*