Energy efficiency improvement and carbon dioxide abatement potentials for Swiss Food and Beverage sector

By

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SCCER EFFICIENCY OF INDUSTRIAL PROCESSES

Odyssee MUREII

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- Shares of CO_2 emissions
- Past trends and future projections

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  - →Energy, CO_2
- Sensitivity analysis
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  - → CO_2 levy

Conclusions

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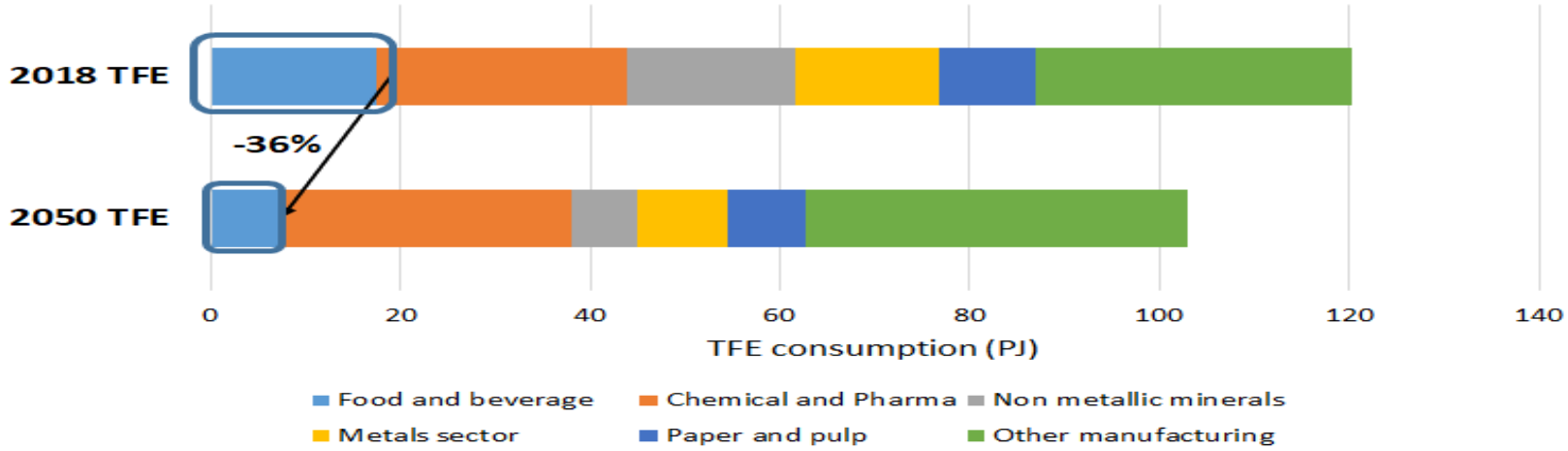
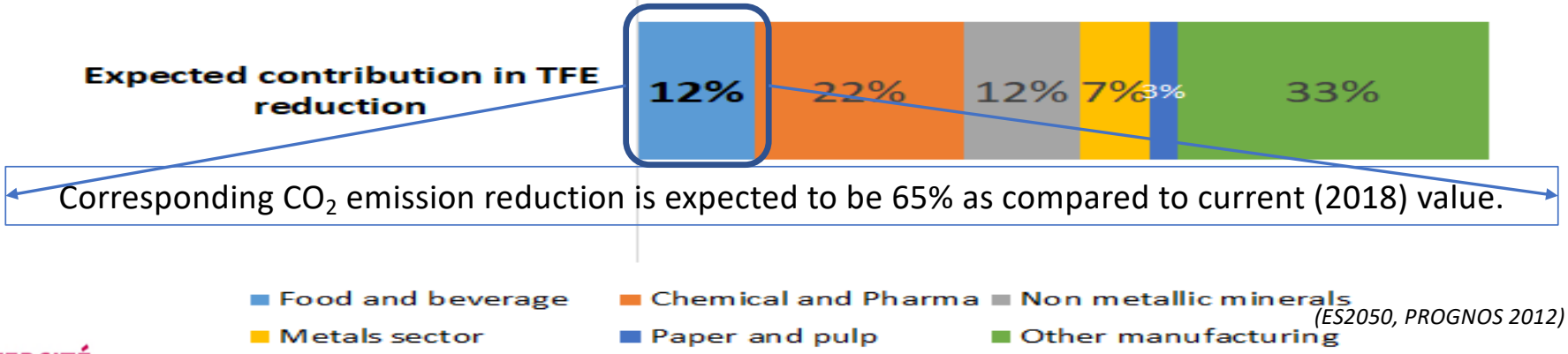
Introduction

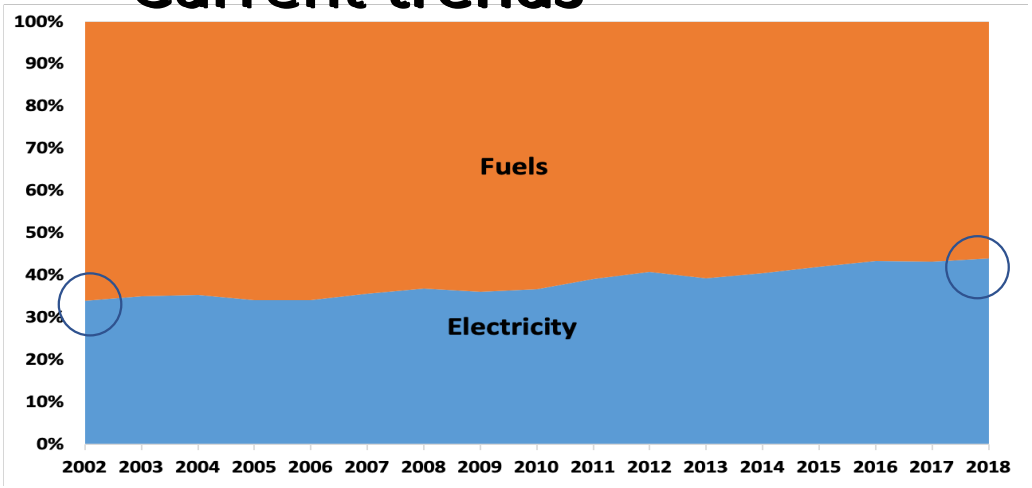


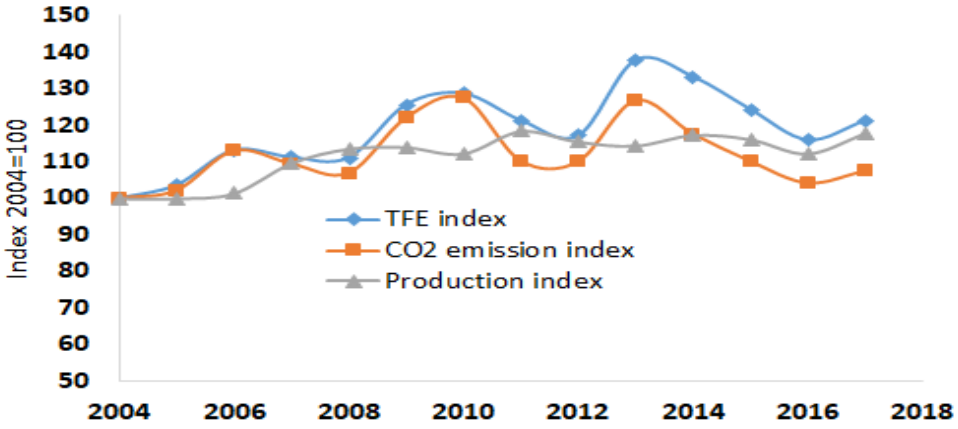
Future (until 2050; based on ES2050)



(ES2050, PROGNOS 2012)

Current trends

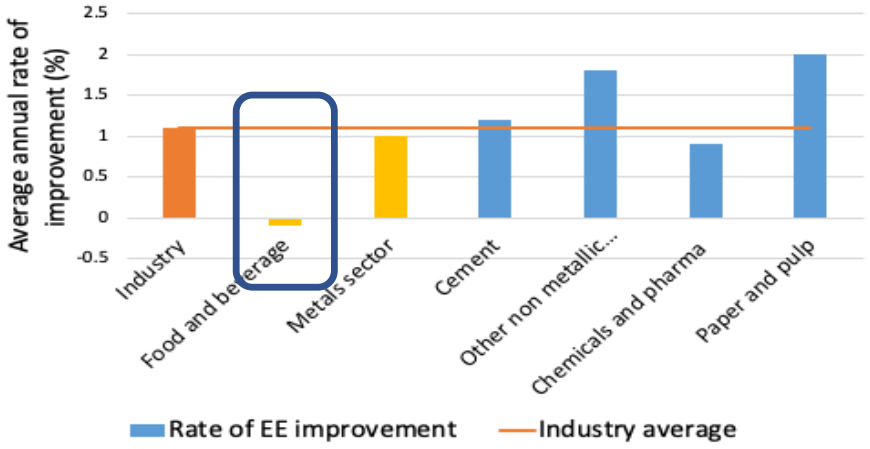




- Gradual electrification → 34% share in 2002 and 44% share in 2018.
- Reduction in CO_2 intensity →at 0.6 % p.a.
- Deterioration of EE →0.2% p.a.

<u>Aim</u>:

- **Identification of technology options and their potential to improve energy efficiency (EE)**
- **Estimation of contribution of EE towards CO_2 emission reduction**.



Average annual rates of physical EE improvement for sub-sectors in Swiss industry (Based on ODEX)

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

76% coverage

e.g. % TFE consumed by diary

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

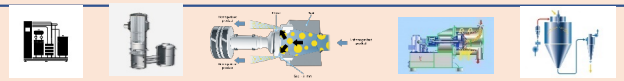
Food and beverage sector (Switzerland)

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

Based on typical energy consumption profiles of each type of establishment

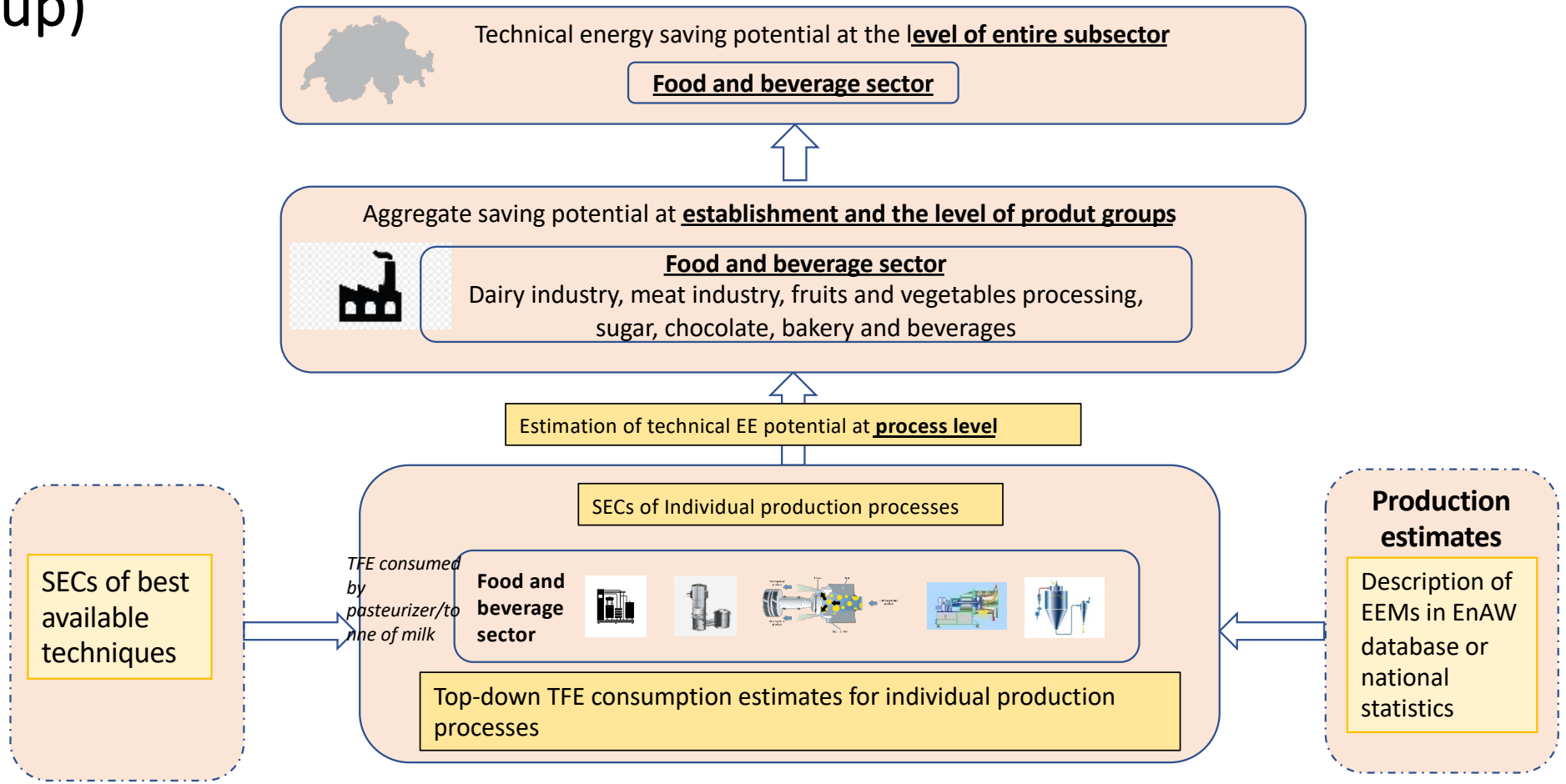
Estimating energy consumed for each **production step/end use**

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



e.g. TFE in TJ consumed by pasteurization

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



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

$$CO_2\ abatement\ cost = \frac{I*ANF+OM-B}{CA}\ \text{(CHF/t-CO}_2\text{)}$$

Where, I = Initial investment

ANF = Annuity factor

OM = Annual operation and maintenance cost

B = Annual benefits

ES= Energy savings

CA=Total annual CO_2 abatement (t-CO_2/yr)

**Source (Blok, 2007)*

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

r= discount rate

L= lifetime of the measure

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

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

Total 43 EEMs identified

$$dr = \left(\frac{(EC_x - ED_{yEnAW})}{EC_x}\right) * Pt_x$$

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 = $(SEC_{CHx} - SEC_{wx})/SEC_{CHx}$

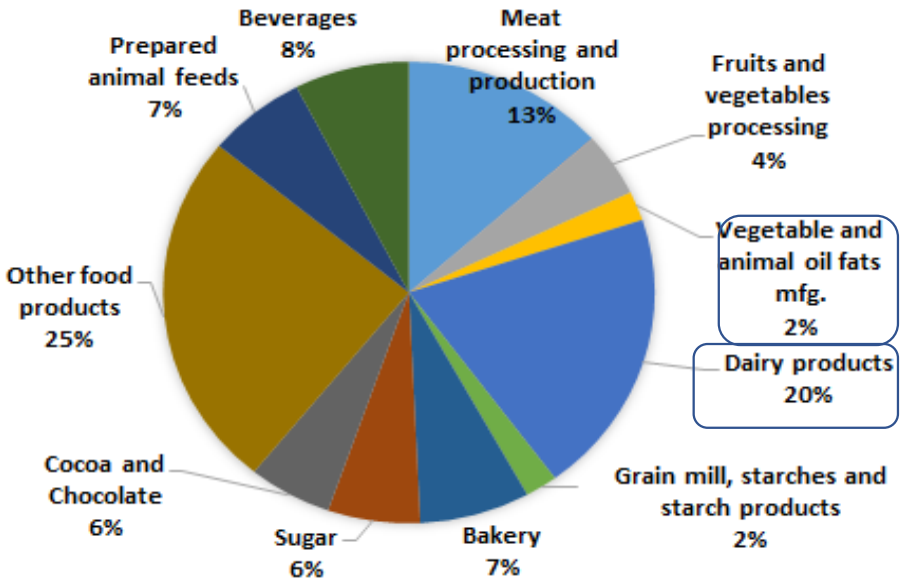
→E.g. ECx for evaporation = 1193 TJ

→Edyenaw = 144 TJ

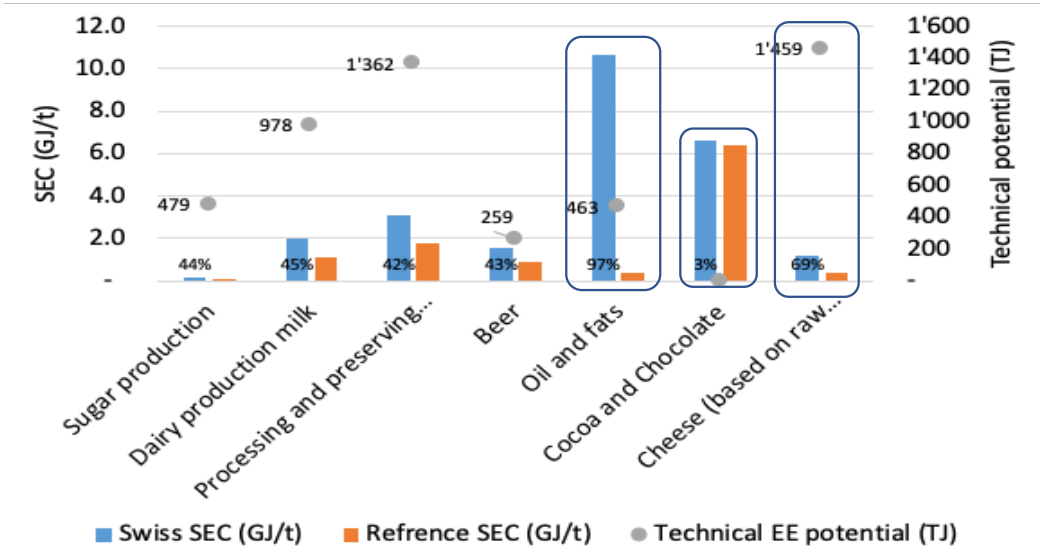
→Ptx = 60% → 40% of energy demand cannot be further reduced

→dr = 52% for vapor recompression in evaporation

Bottom-up technical EE improvement potential

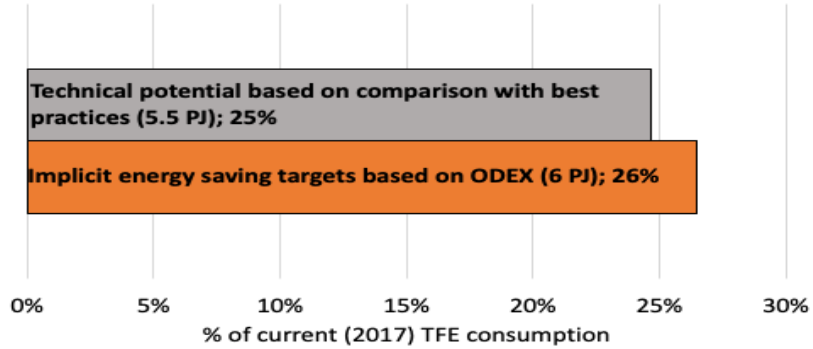


Shares of product groups in TFE of Swiss F&B sector (Based on EnAW)



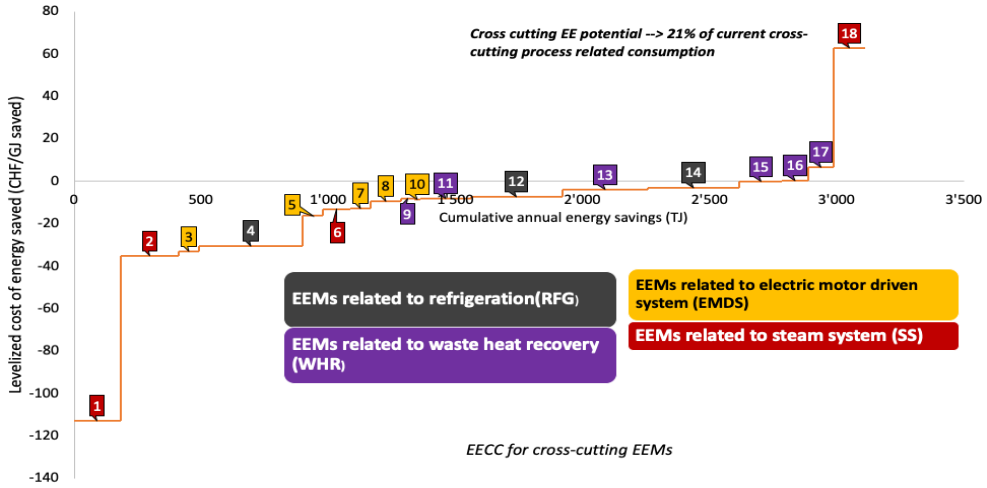
Percentage and absolute technical EE improvement potentials

- **Largest share of technical EE improvement** → Cheese manufacturing (26% share).
- **Large relative technical EE potential** → Vegetable and animal oils and fats manufacturing
- **Most efficient** → Cocoa and chocolate production

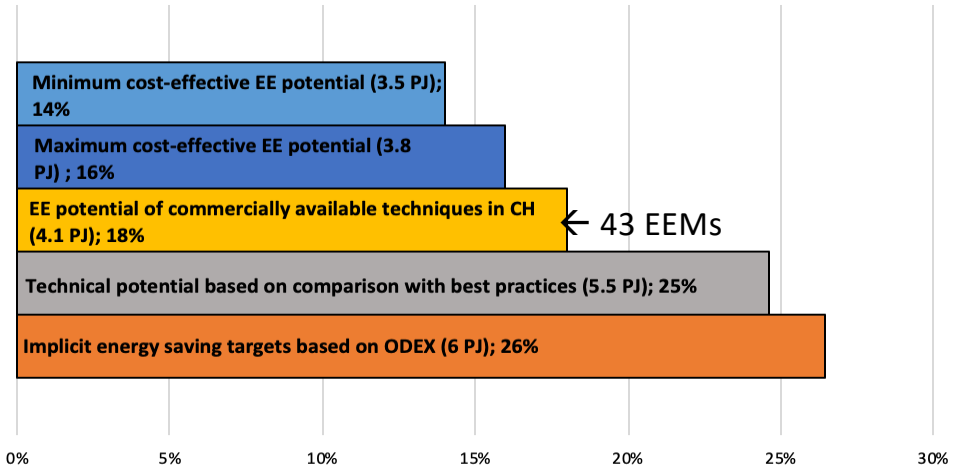


Ref. Bhadbhade et al., 2020

Energy efficiency cost curves

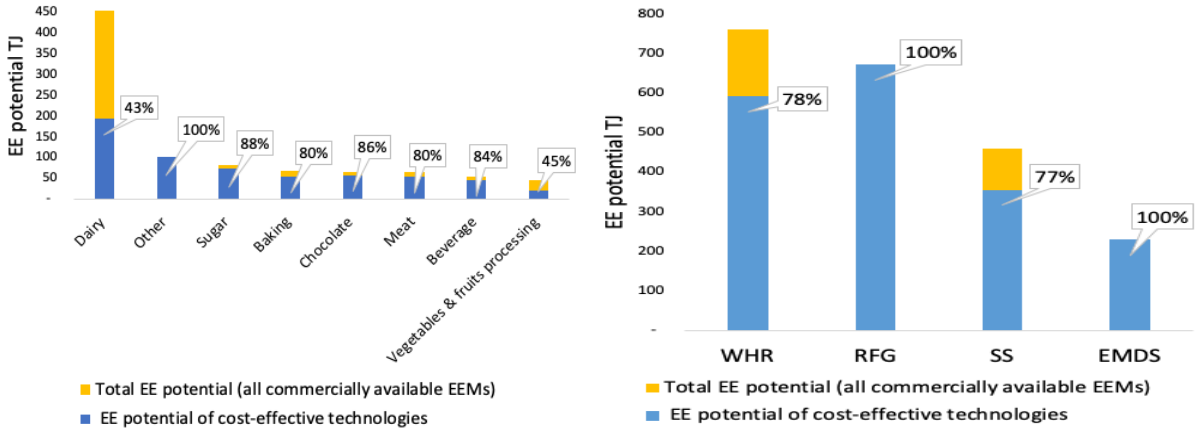


EECC for cross-cutting EEMs



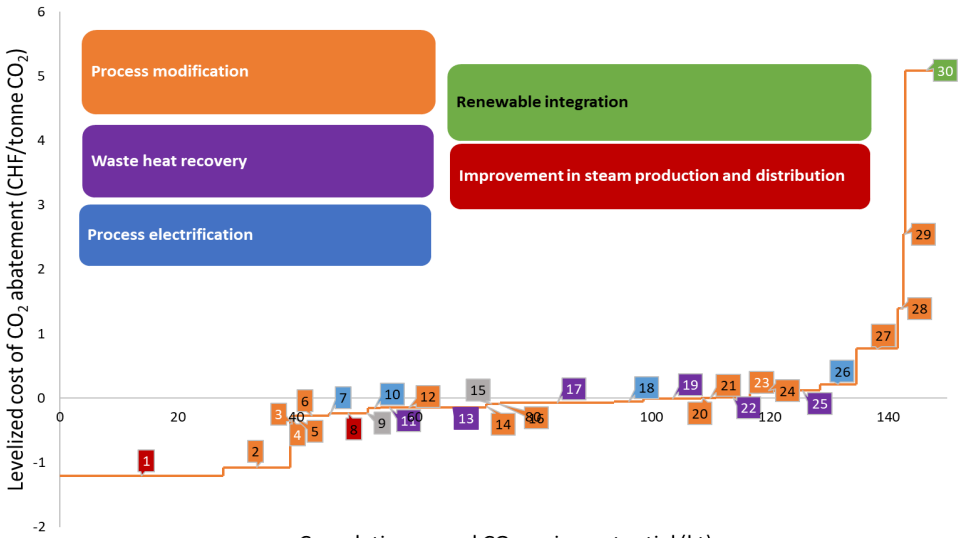
Various levels of potential for food and beverage subsector

- **Core processes related EEMs**→ 30% EE improvement potential.
- **Cross-cutting processes EEMs**→ 70% EE improvement potential.
- **Cost-effective EEMs**→ 85% potential.
- **Largest share of core process EE potential**→ Dairy production related EEMs *(Reverse osmosis intead of evaporation).*
- **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*

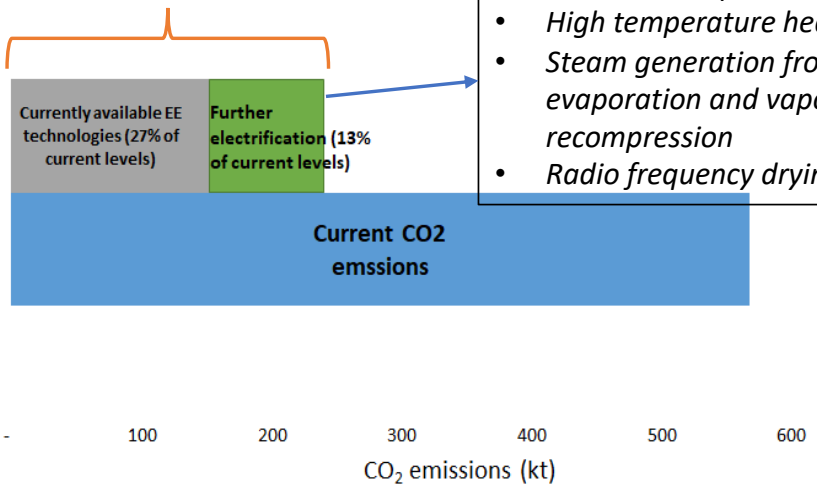
CO_2 abatement cost curves



CO_2 mitigation cost curve

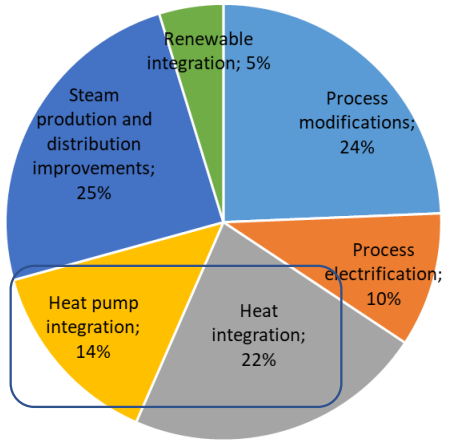
- **Largest share of CO_2 abatement potential in current EE technologies** →waste heat recovery EEMs.
- **Most cost-effective as well as the EEM with the largest CO_2 abatement share** → substitution of fuel oil by natural gas steam system.
- **Most expensive EEM**→ Solar thermal integration

40% reduction from current level



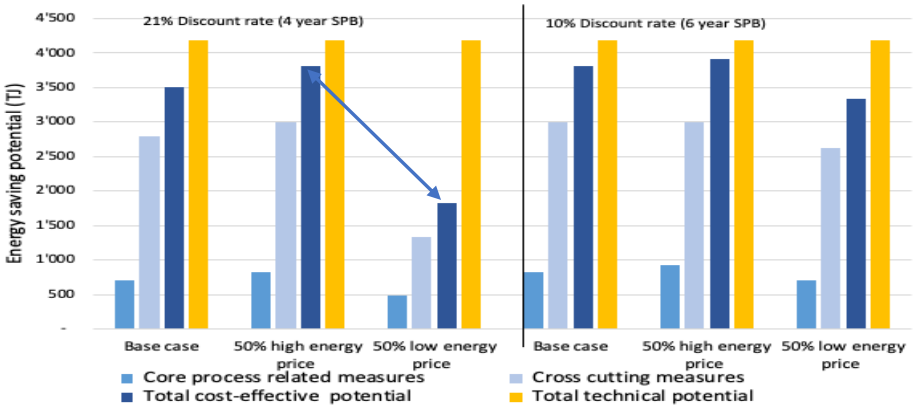
- *Pulse electric pasteurization*
- *High temperature heat pump*
- *Steam generation from LP evaporation and vapor recompression*
- *Radio frequency drying*

CO_2 abatement projections and available levels

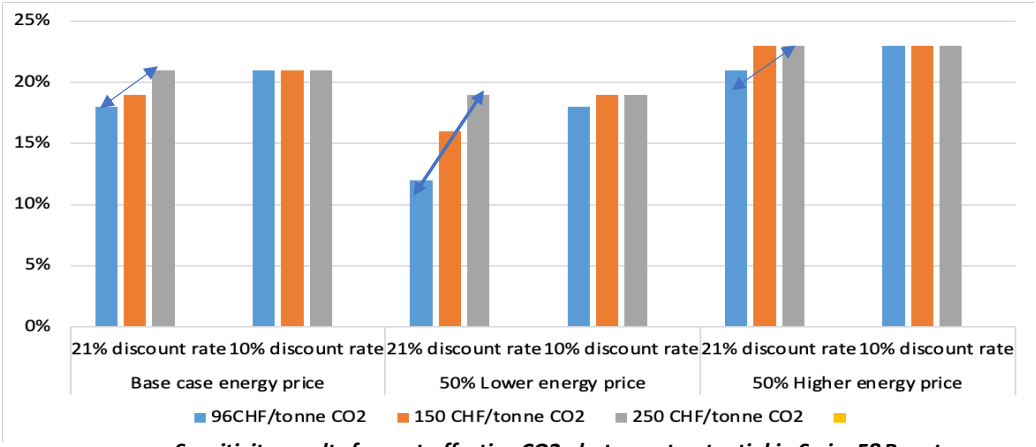


Shares of technology groups in CO_2 abatement potential

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

		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	Future projected values	WHR and electrification (MVR or membrane technology instead of evaporation) become economically viable	Current value	

Conclusions

EE potential (process related) *:*

- **Swiss F&B production is relatively energy inefficient** →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
- **Waste heat recovery technologies represent the largest share of current CO_2 emissions reduction potential**→ 36% potential of currently available technologies
- **Improvements in steam generation can reduce CO_2 emissions in the most cost-effective manner**

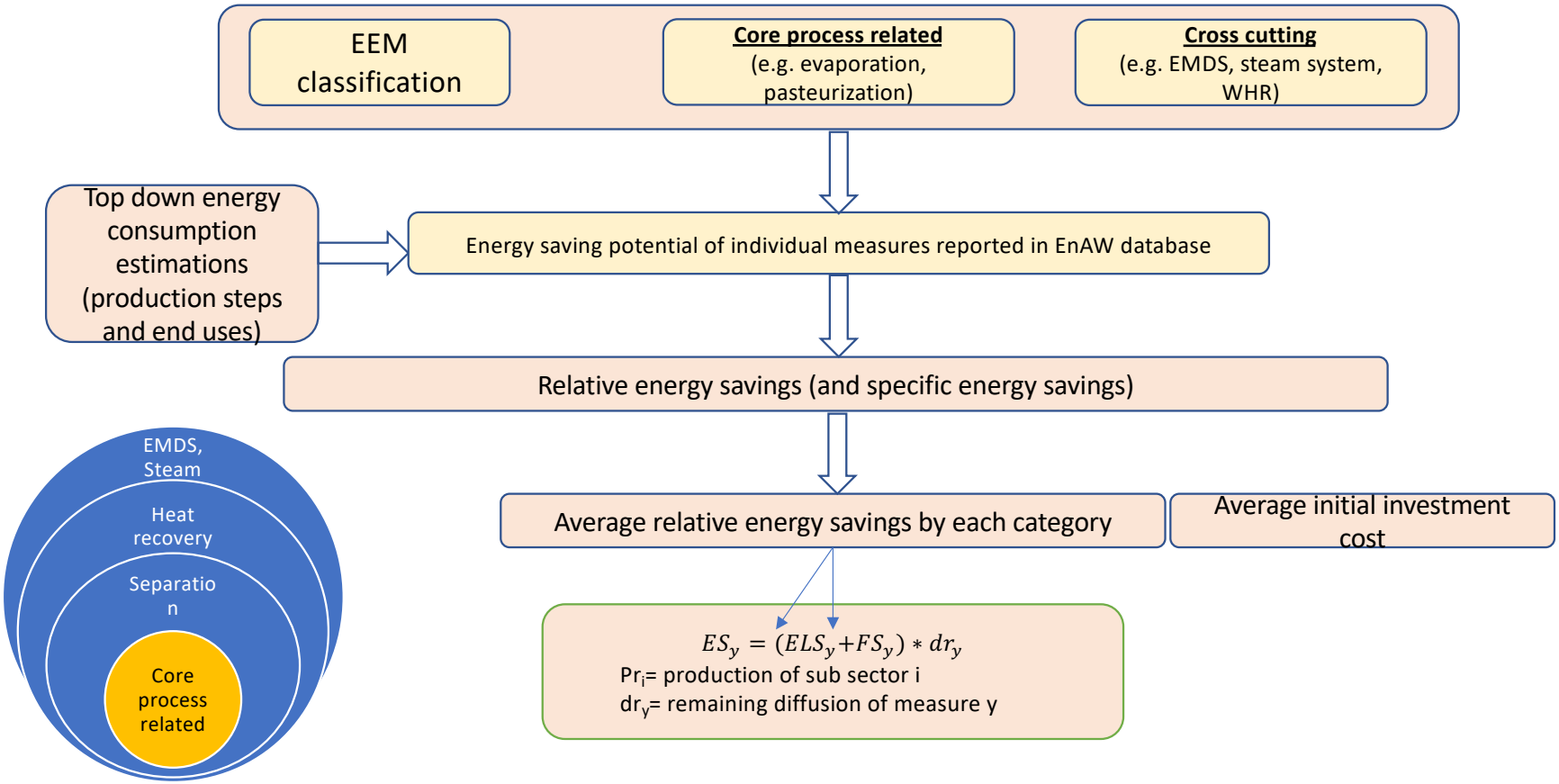
Sensitivity analysis of cost-effective potential

- **Lower energy prices are not favorable for companies with stringent economic criterion** → Cost-effective potential drops from 16% to 7% .
- **Higher CO_2 levy favorable for adoption of capital-intensive measures**→ Plant wide heat integration projects and electrification of production steps become cost-effective.

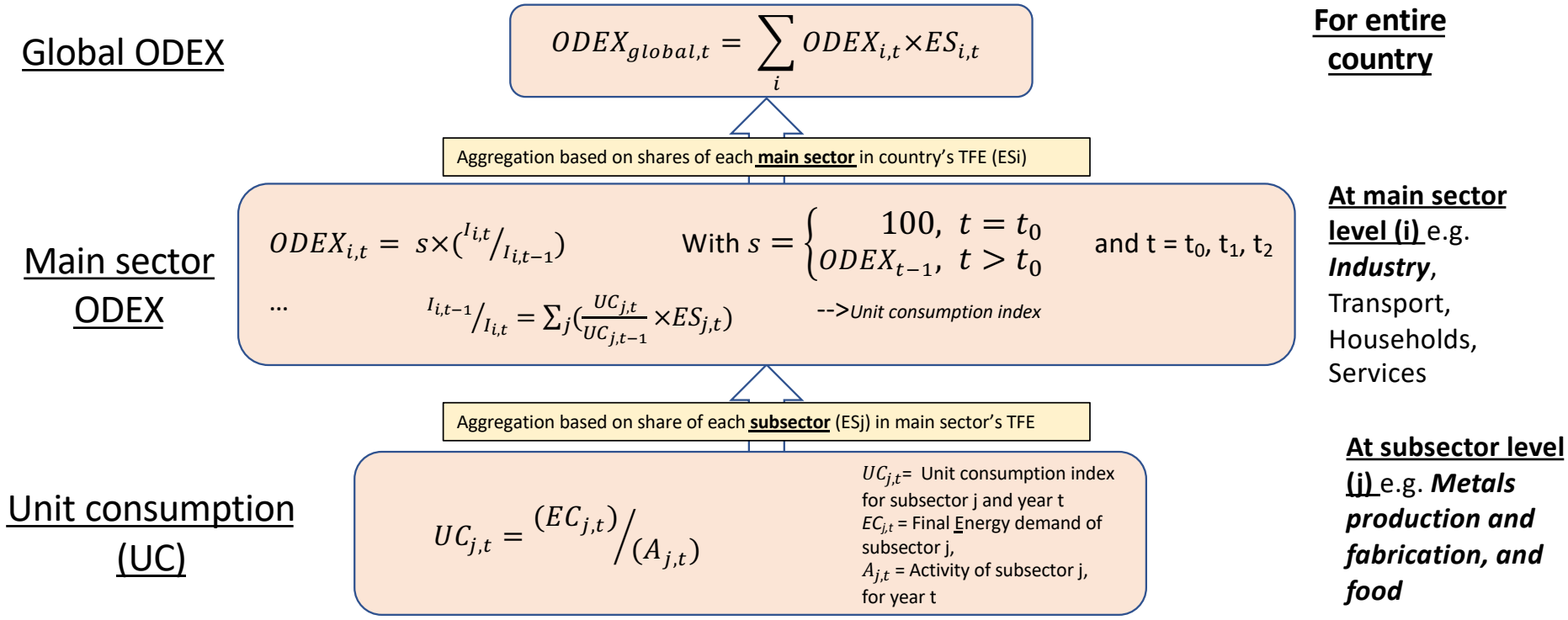
Thank you!

Additional slides

Categorization of techno-economic data for energy efficiency measures



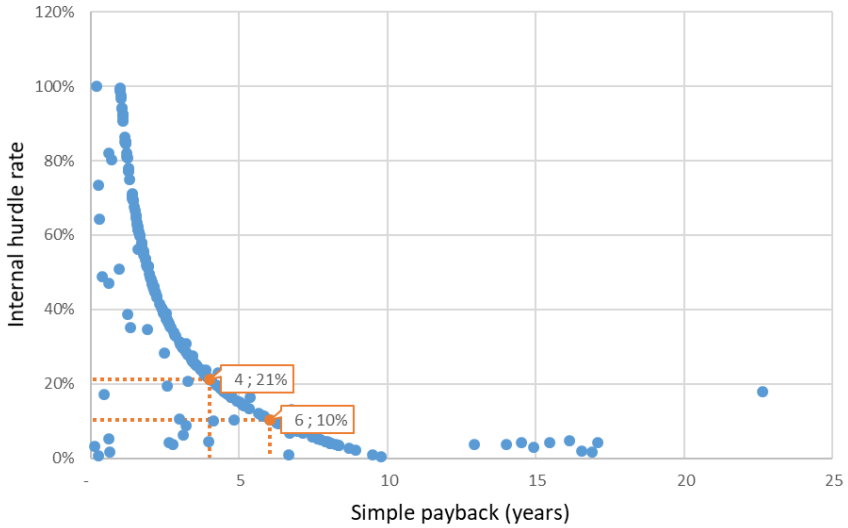
ODEX methodology – Energy efficiency improvement trend and energy savings



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*

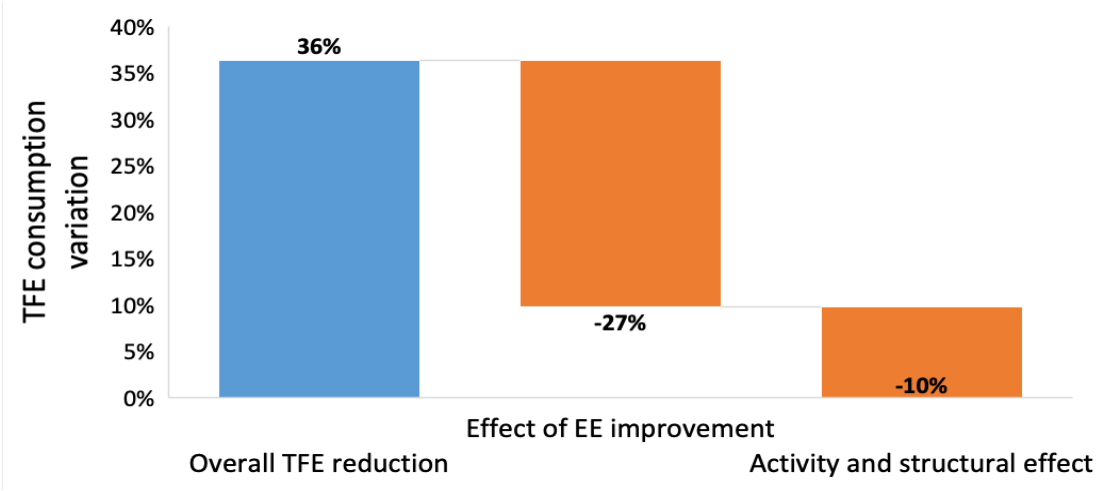
Discount rate

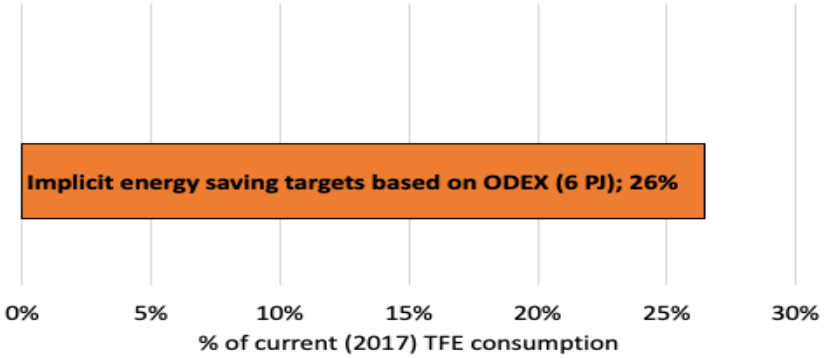
- Discount rates: used to discount future cash flows to present value in order to reflect both the **time value of money and perceived risk .**
- Typically industry prefers the economic criterion of simple payback time (SPB).
- Target agreement: for exemption from CO_2 tax in CH, all measures with **SPB 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)

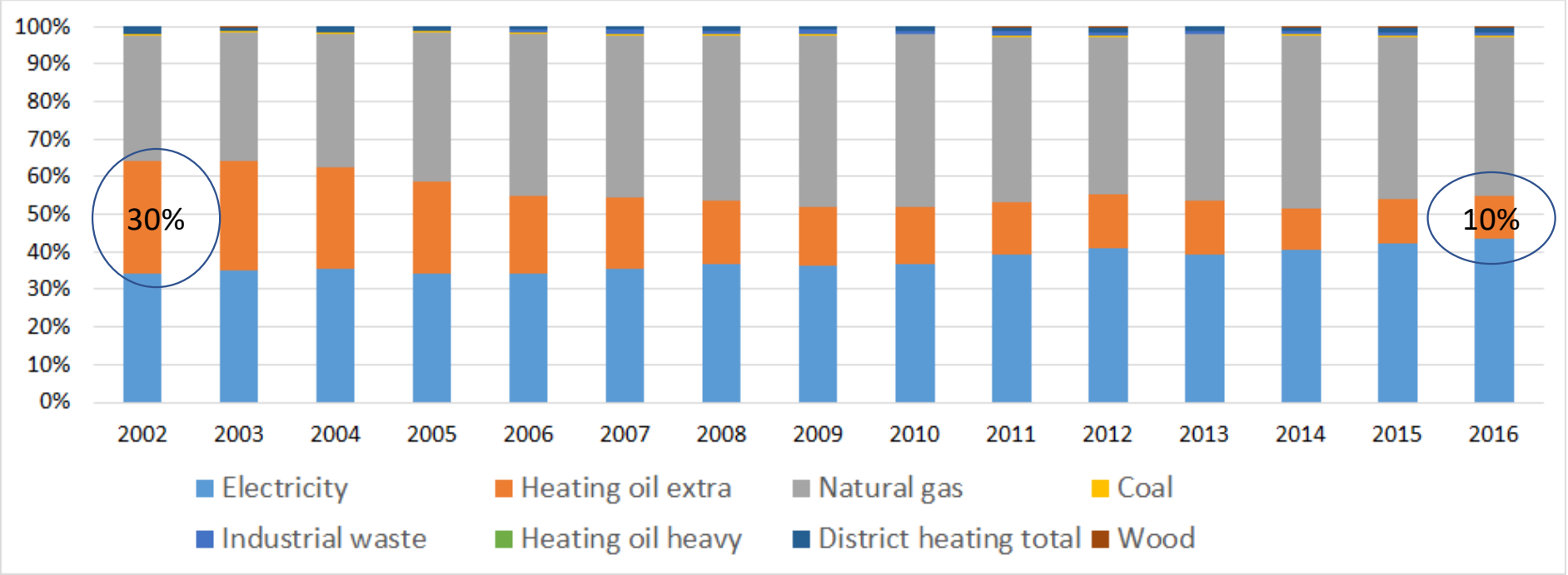
Decomposition analysis – Projections and targets



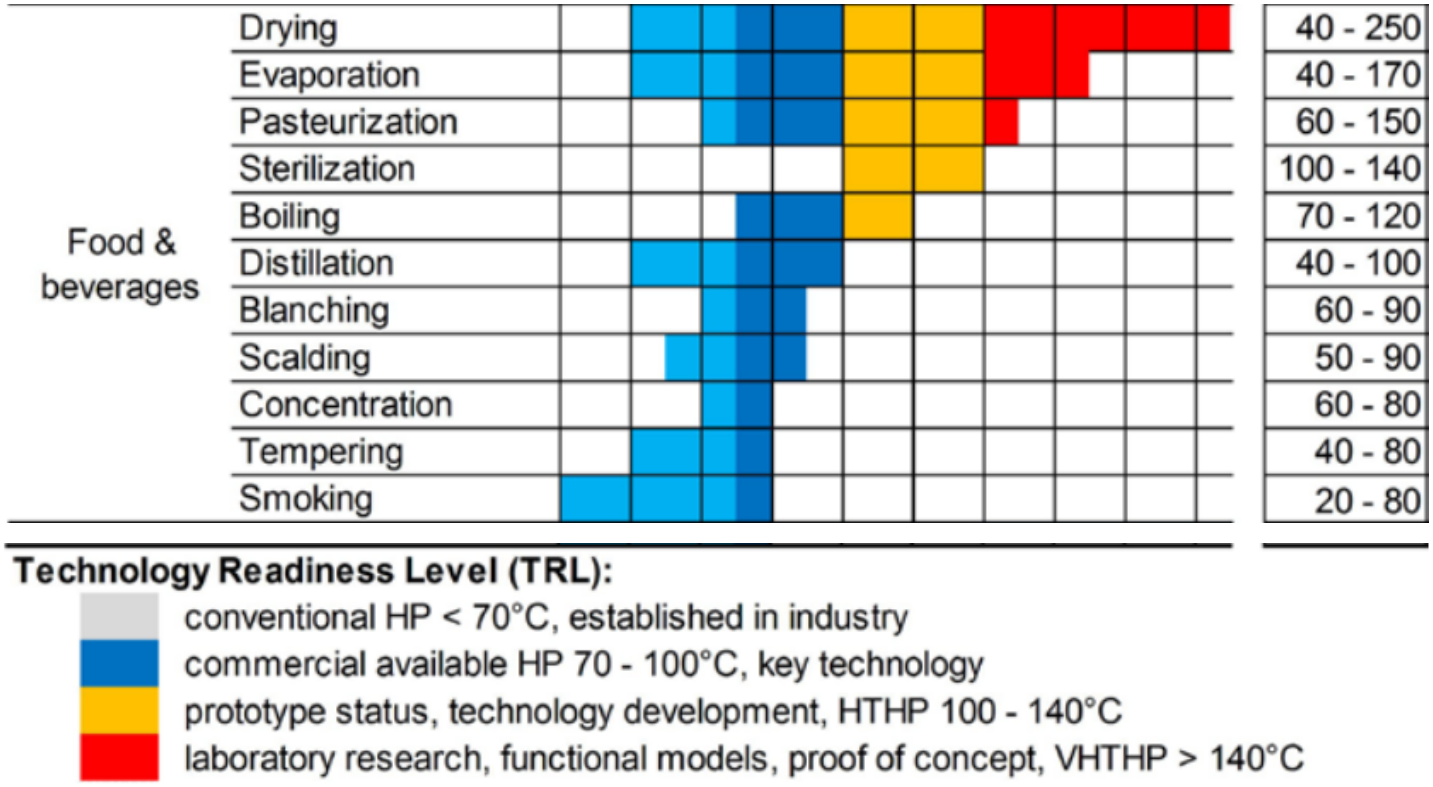


F&B sector: EE improvement is expected to reduce 26% of TFE reduction until 2050 → Energy saving target 6 PJ

Trends of fuel demand in F&B sector



HTHP potentials processes and TRL



Adopted from Arpagaus et al, 2017