Bottom-up analysis of energy efficiency improvement in motor systems and heat recovery opportunities in Swiss industry

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EFFICIENCY OF INDUSTRIAL PROCESSES

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Background

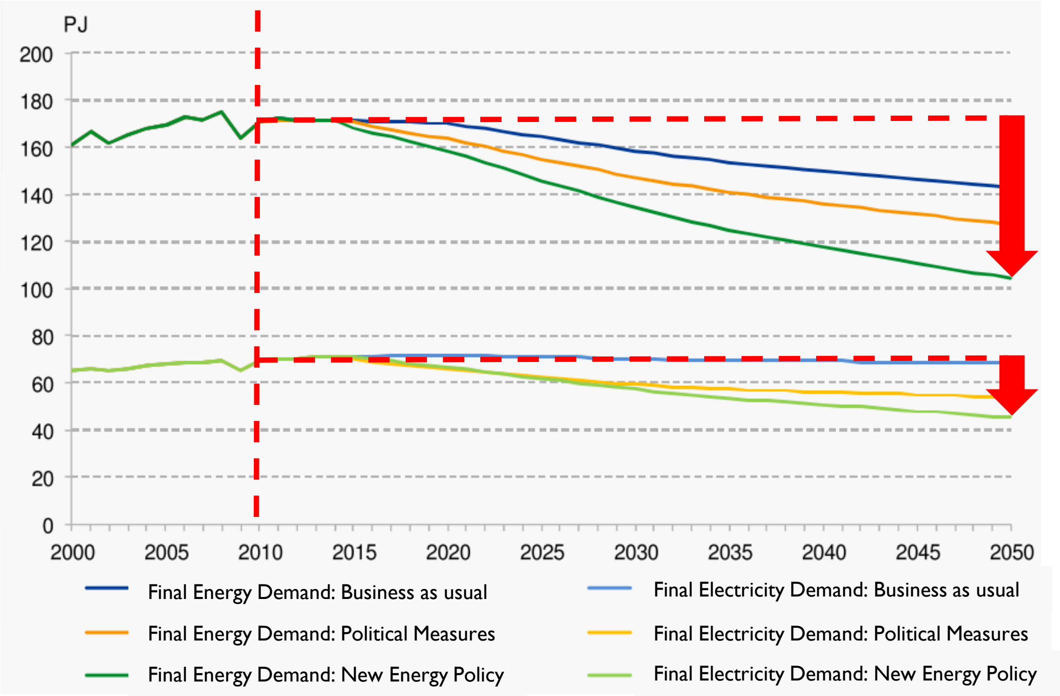
Energy Strategy 2050

- Reduce final energy demand per capita
- Reduce the share of fossil energy
- Withdraw from the use of nuclear energy

Research motivation

- No comparable analyses available for CH in context of its ambitious `ES 2050`
- Lack of data and relevant indicators
- Paucity in literature when it comes to the associated costs of EE improvement potentials

Swiss industrial final energy demand projections up to 2050



Source: Die Energieperspektiven für die Schweiz bis 2050. Basel: Prognos AG/BFE; 2012.

- Reduce final energy demand by **40%** in 2050 from the level in 2010.
- Reduce electricity demand by **35%** in 2050 from the level in 2010.

EE improvement opportunities

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- Industrial EMDS and process heat → approx. **70%** of the total industrial electricity and thermal energy demand as of 2014 respectively.

Data sources (for electricity savings and costs) :

1. Energy Agency of the Swiss Private Sector (EnAW/AEnEC)
2. ProKilowatt – Swiss Federal Office of Energy (SFOE)
3. Services Industriels de Genève (SIG)

- Energy savings by measure implementation
- Total investment cost of measure (TI)
- Energy-relevant cost of measure (EI) calculated by EnAW as follows:

$$EI = TI \times \left(1 - \frac{A}{L}\right)$$

where `A` is the age of the replaced equipment while `L` is the lifetime of the equipment.

General methodology

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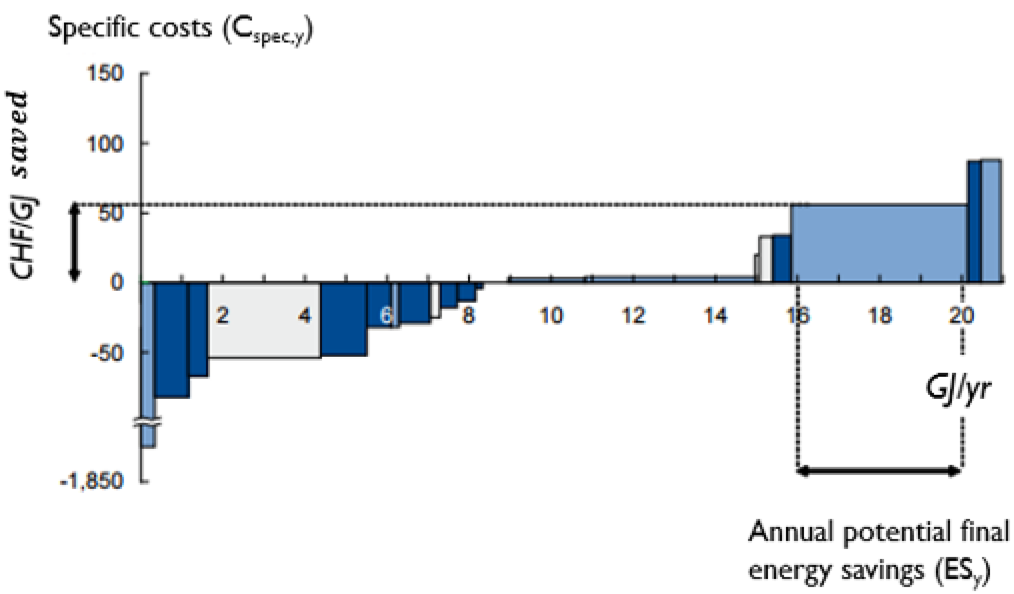
Energy efficiency supply curves



Levelized/ Specific cost ($C_{spec,y}$):

$$C_{spec,y} = \frac{Annualized\ cost}{ES_y}$$

$$C_{spec,y} = \frac{ANF \times NPV_y}{ES_y}$$

where;

NPV_y = Net present value of measure `y` for the base year

ANF = Annuity factor

ES_y = Annual potential final energy savings of measure `y`

Electric motor driven systems

Measures categorization and sample size

System	Compressed air	Pump	Fan	All others [1]
No. of measures	291	210	59	36
No. of companies	205	62	35	31
Measure categories	More efficient compressor (≤ 90 kW) More efficient compressor (> 90 kW) [2] Installing variable frequency drive Efficient control system Optimized hours of operation Process optimization Leak repair Pressure reduction Waste heat recovery	More efficient pump [2] More efficient vacuum pump [2] Installing variable frequency drive Efficient control system Optimized hours of operation Process optimization	More efficient fan [2] Installing variable frequency drive Efficient control system Optimized hours of operation Process optimization	More efficient motor Installing variable frequency drive

[1] EMDS other than compressed air, pump and fan systems include cooling compressors, conveyors, rotating machines, industrial elevators etc. which will be called `other` systems from now onwards.
[2] More efficient motors are only rarely installed as separate measure for compressed air, pump and fan systems which are typically replaced as complete equipment. In contrast, motor replacement is more common in the case of `other` systems (e.g., conveyor belts).

Electric motor driven systems

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Electricity efficiency supply curve for major EMDS (no. of measures = 482)

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Comparing cost-effectiveness of measures implemented by EnAW and ProKilowatt (Total investment)

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Comparing cost-effectiveness of measures implemented by EnAW for both total investment and energy-relevant investment

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Some major conclusions

- Economic potential for electricity savings in Swiss industrial EMDS: ~17% (based on energy-relevant investment; in compliance with SFOE, 2006: 15%).
- Cost-benefit analysis is most sensitive to electricity price > discount rate.
- Economic potential is 25% larger for electricity price paid by small enterprises and 5% lower for electricity price paid by large enterprises.
- More attention to be given to motor systems with high power requirements and high operating hours (Class I) → among the most cost-effective options (in combination with process optimization).
- Unless justified by co-benefits: early replacement of motor systems of smaller scale and/or with lower operating hours may be avoided.

Sources:

Bolla OE et al.. Massnahmen zum Stromsparen bei elektrischen Antrieben - Marktanalyse in der Industrie - Schlussbericht. Zurich: BFE; 2006.
Lang T, Eggimann U, Werner C. Elektrizitätsbedarf für die Druckluft in der Schweiz. Zurich: Energie Schweiz; 2014.

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Some major conclusions

- Cost-benefit analysis based on total investments leads to underestimation of the potential.
- Additionality according to table below would be more accurate.

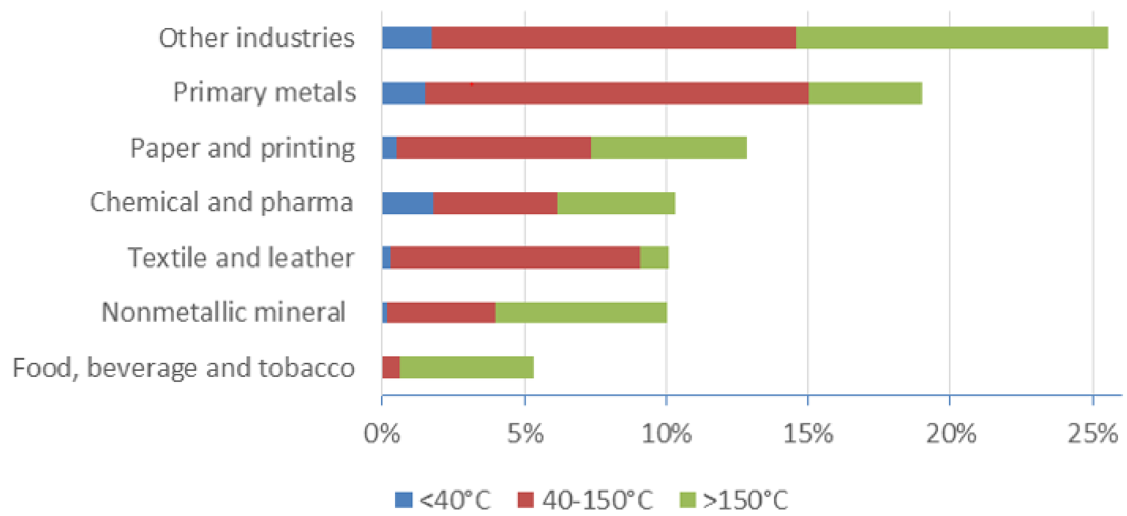
  Bottleneck: Data on age of old equipment and difference in energy efficiency and cost between standard and new equipment.

Method	Measure cost (CHF/unit)	Impact measurement (GJ/unit)
Advanced method	Cost of efficient device minus cost of standard device plus remaining discounted present value $\Delta I = PV_{old} + I_{efficient} - I_{standard}$	*During remaining life of old device*: Consumption of old device minus consumption of efficient device $ES_{dur} = E_{m,old} - E_{m,efficient}$ *After remaining life of old device*: Consumption of standard device minus consumption of efficient device $ES_{aft} = E_{m,standard} - E_{m,efficient}$

Source: Understanding Cost-Effectiveness of Energy Efficiency Programs: Best Practices, Technical Methods, and Emerging Issues for Policy-Makers. US-EPA; 2008.

Process heat recovery

Final energy savings potentials by sector and by temperature level



- *Other industries include plastics, rubber, machinery and metal products*
- *Based on the estimates for US industry.*

Process heat recovery

Measures categorization and sample size

Sr. no.	Measure classification	No. of measures	% of total no. of measures	Temp. Levels[1]	Typical sources[2]	Typical uses[2]
HR1	Process heat integration	87	26%	LM, HM, H	key process equipment, process streams, reactors, dryers, stacks	combustion air preheating, hot water, drying, cooling
HR2	Load preheating	44	13%	LM, HM, H	columns, dryers, cooling/waste waters, stacks	inlet stream preheating
HR3	Condensate recovery	29	9%	LM	steam network	combustion air preheating, hot water
HR4	HR for steam generation	5	1%	HM, H	furnaces, ovens, stacks	steam/power generation
HR5	HR for district heating	33	10%	L, LM	cooling/waste water, stacks, process equipment	space heating, domestic hot water
HR6	Heat pumps	22	6%	L, LM	process equipment	space heating, hot water
HR7	HR from cooling machines	26	8%	L, LM	refrigeration units	space heating, hot water
HR8	HR from ventilation systems	33	10%	L, LM	ventilation systems	space heating, hot water
HR9	HR from air compressors	61	18%	L, LM	air compressors	space heating, hot water
	Total	340	100%			

[1] *Recovery measure is applicable to waste heat at typical temperature levels specified in this column.*

[2] *Based on both EnAW data analysis and literature review.*

Process heat recovery

Thermal energy efficiency supply curve for heat recovery (no. of measures = 340)

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Process heat recovery

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Some major conclusions

- Economic potential for process heat recovery: 14% of the total final energy demand; consistent with the potentials estimated for other regions (Enova, 2009; Berthou & Bory, 2012; US DOE, 2008 etc.).
- Measures related to process heat integration and high temperature heat recovery offer large final energy saving potentials.
- Nearly 55% of the process waste heat is estimated at temperature <150°C (low or low-medium).
- Low temp. heat can be recovered by e.g. heat pumps if a suitable end use is available and economically viable.
- ORC can also be an attractive option for low-medium temp. heat recovery if sufficient heat quantities are available.

Source:
Enova. Utnyttelse av spillvarme fra norsk industri - en potensialstudie. 2009.
Berthou M, Bory D. Overview of waste heat in the industry in France, Arnhem, the Netherlands: 2012.
US DOE. Waste Heat Recovery: Technology and Opportunities in U.S. Industry. 2008.

Process heat recovery

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Some major conclusions

- Thermal energy savings potentials may be exploited with a slow rate due to several barriers associated with some of the measures including:
  - Long payback times
  - High initial investment
  - Space, transportability and process specific issues

THANK YOU!!!