The importance of additionality in evaluating the economic viability of motor-related energy efficiency measures

Jibran Zuberi, Martin Patel

Group Energy Efficiency, University of Geneva

6th September, 2017

EEMODS'17, Rome

eemods 2017
10th International Conference on
energy efficiency in motor driven systems
Rome, Italy 6-8 September 2017

SCCER
EFFICIENCY OF INDUSTRIAL PROCESSES
eip

In cooperation with the CTI

Energy funding programme
Swiss Competence Centers for Energy Research

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Commission for Technology and Innovation CTI

Outline

- Introduction
- Materials and methods
  - Cost-effectiveness of EE measures
  - Accounting for additionality
    - *EnAW method*
    - *ProKilowatt method*
    - *EPA metrics*
- Case study: motor retrofit
  - Situation
  - Electricity demand and price
  - Remaining value of the motor
- Results and discussion
- Conclusions

Introduction

- Additionality → the supplementary impact of a measure beyond standard practices and autonomous changes.

- Baseline scenarios for comparison with the energy efficiency scenario.
  E.g. early replacement of an IE2 motor with either IE3 or IE4

- Additionality of EE measure →
  1. additional investment costs and
  2. energy savings due to measure implementation

- Typically lack of methodological clarity for both components in cost-benefit studies on EE available in literature.

Outline

- Introduction
- Materials and methods
  - Cost-effectiveness of EE measures
  - Accounting for additionality
    - *EnAW method*
    - *ProKilowatt method*
    - *EPA metrics*
- Case study: motor retrofit
  - Situation
  - Electricity demand and price
  - Remaining value of the motor
- Results and discussion
- Conclusions

eemods 2017
10th International Conference on energy efficiency in motor driven systems
Rome, Italy 6-8 September 2017

Cost-effectiveness of EE measures

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

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

where;

NPV_y = Net present value of measure *y*

ES_y = Electricity savings of measure *y*

ANF = Annuity factor

$$NPV_y = \sum_{t=2015} CF_t \times (1+r)^{-t+2015}$$

where;

CF_t = Annual cash flow for the year *t*

$$CF_t = I_y + O\&M_y - B_y$$

where;

I_y = Initial investment (CHF) required to achieve the ES_y.

$O\&M_y$ = Operation and maintenance cost (CHF)

B_y = Annual benefits of the measure (CHF), i.e. the annual electricity cost savings

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

where;

r = real discount rate taken as 10.5%

L = Lifetime of the measure

Additionality – EnAW method

- Energy Agency of the Swiss Private Sector (Energie-Agentur der Wirtschaft – EnAW).
- Energy audits for companies and implementation of EE measures with PBP <4 years for industrial processes and <8 years for infrastructure.
- Reimbursement for the CO_2 tax and the network surcharge for renewable power (KEV).

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

where;

TI = Total investment costs (CHF)

EI = Energy relevant investment costs (CHF)

A = Age of the replaced equipment (years)

$$ES_y = ED_{old} - ED_{efficient}$$

where;

ED_{old} = Annual electricity demand by the old equipment (GJ/yr)

$ED_{efficient}$ = Annual electricity demand by the new or more energy efficient equipment (GJ/yr)

Additionality – ProKilowatt method

- ProKilowatt → Sector-wide program initiated by the Swiss Federal Office of Energy (SFOE).
- Subsidizes EE measures that are not economically viable (PBP >5 years for process measures and >9 years for infrastructure).
- Competitive tender call procedure.
- Process of EE measure implementation is monitored.

$$I_y = EI = 40 - 15 \times \left(\frac{A}{0.5 \times L} - 1\right)$$

$$ES_y = (ED_{old} - ED_{efficient}) \times 0.75$$

where 0.75 is the reduction factor correcting for the autonomous technological change in future

Additionality – US EPA metrics

eemods 2017
10th International Conference on
energy efficiency in motor driven systems
Rome, Italy 6-8 September 2017

Simple method:

$$I_y = TI$$

$$ES_y = ED_{old} - ED_{efficient}$$

Advanced method:

$$I_y = EI = PV_{old} + I_{efficient} - I_{standard}$$

where;

PV_{old} = Remaining present value of the old equipment (CHF)

$I_{efficient}$ = Total investment cost of the efficient equipment (CHF)

$I_{standard}$ = Total investment cost of the standard equipment (CHF)

Additionality – EPA metrics

Advanced method

$$ES_{dur} = ED_{old} - ED_{efficient}$$

where;

ES_{dur} = Energy savings by efficient equipment compared to old equipment *during* the remaining lifetime of the old equipment (lifetime 'L' - current age 'A') (GJ/yr).

$$ES_{aft} = ED_{standard} - ED_{efficient}$$

where;

ES_{aft} = Energy savings *after* the remaining lifetime of the old equipment (when the new equipment is considered to replace a standard equipment) (GJ/yr).

$ED_{standard}$ = Annual energy demand by the standard equipment (GJ/yr)

Outline

- Introduction
- Materials and methods
  - Cost-effectiveness of EE measures
  - Accounting for additionality
    - *EnAW method*
    - *ProKilowatt method*
    - *EPA metrics*
- Case study: motor retrofit
  - Situation
  - Electricity demand and price
  - Remaining value of the motor
- Results and discussion
- Conclusions

Case study – Situation

Motor efficiency class:	45 kW motor of class IE2 installed in 2010.
Hours of operation:	6000 hours per year
Age of motor (A) :	5 years (base year 2015)
Lifetime (L):	15 years
Remaining lifetime:	10 years
EE Measure:	Early replacement of the motor with a motor of efficiency class IE4
Standard motor today:	IE3

Sources:

http://site.cantonigroup.com/en/motors/celma_indukta/series/376/three-phase-squirrel-cage-high-efficiency-motors-2sie-ie2-series/
http://www.kaeser.ca/Products_and_Solutions/Rotary-screw-compressors/standard/with-1-to-1-drive-up-to-500-kW/default.asp

Case study – Elec. demand and price

Energy demand of motor:

$$ED_m = \frac{0.0036\,(SZ \times OP \times LF)}{\eta_m}$$

where;

ED_m = Annual electricity demand by motor 'm' (GJ/yr)

SZ = Performance of motor, i.e. 45 kW

OP = Annual operating hours i.e. 6000 hrs

LF = Load factor which is assumed 75% at or above which motors work efficiently

η_m = Efficiency of motor specific to each class

0.0036 = Conversion factor from kWh to GJ

Table: Annual electricity demand and price of each motor efficiency class

Motor class	Electricity demand (GJ/yr)[1]	Total investment cost (CHF)[2]
IE2 (old)	783	4605
IE3 (standard)	774	5610
IE4 (efficient)	764	6950

[1] Based on efficiencies of electric motors (4-pole) according to the standard IEC 60034-30.
[2] Installation costs are included.

Case study – Remaining present value

Reducing balance depreciation:

$$PV_{old} = I_{old} \times \left(1 - \frac{d}{100}\right)^{A}$$

where;

d = Depreciation rate per annum i.e. 18%, 12% and 4% for the salvage value (SV) of 5%, 15% and 50% respectively at the end of the expected lifetime.

A = Years of depreciation equivalent to the age of the motor being replaced.

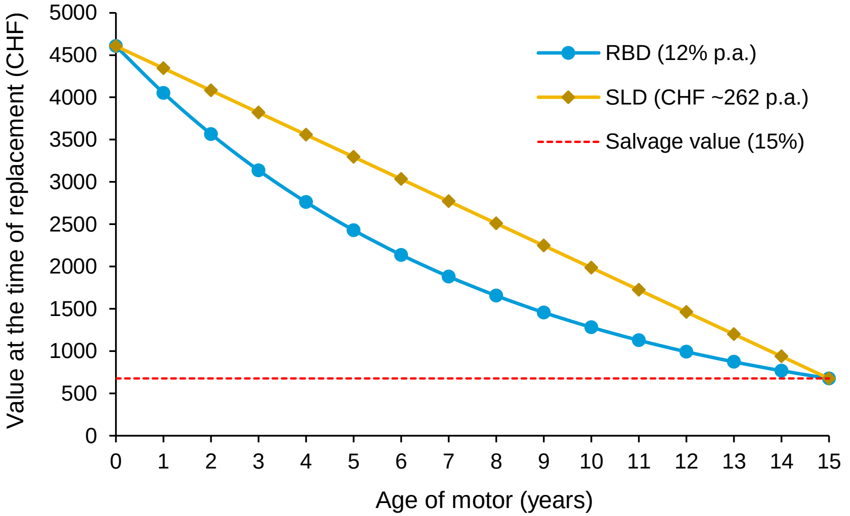


Figure: Depreciated and salvage value of the old IE2 efficiency class motor

Straight line depreciation:

$$PV_{old} = I_{old} - (A \times D)$$

where;

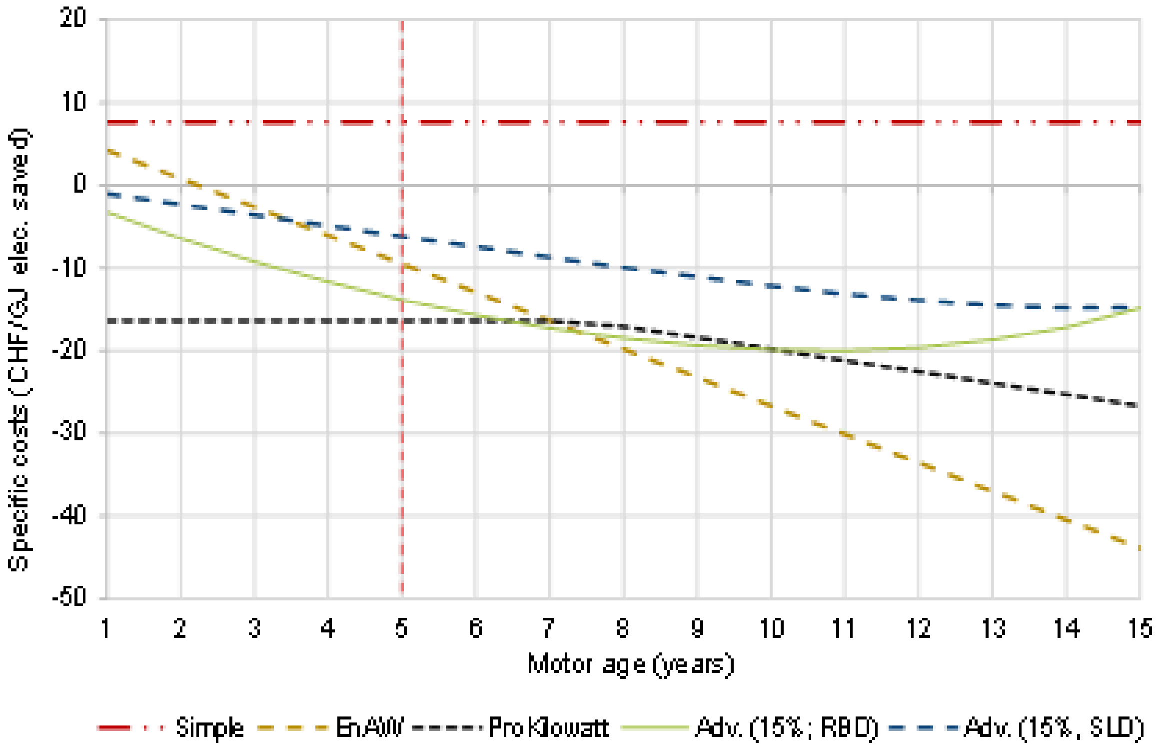
D = Fixed amount depreciation per year which is calculated by the following equation.

$$D = \frac{I_{old}}{L} \times \left(1 - \frac{SV}{100}\right)$$

Outline

- Introduction
- Materials and methods
  - Cost-effectiveness of EE measures
  - Accounting for additionality
    - *EnAW method*
    - *ProKilowatt method*
    - *EPA metrics*
- Case study: motor retrofit
  - Situation
  - Electricity demand and price
  - Remaining value of the motor
- Results and discussion
- Conclusions

Results and discussion



Specific costs of motor retrofit measure calculated by different approaches (IE2 motor is replaced by IE4 motor after X years of lifetime)

- Simple method → underestimates cost-effectiveness
- If advanced method is considered ideal, then:
  - EnAW method overestimates the cost-effectiveness for high ages.
  - Slight bias towards high cost-effectiveness for ProKilowatt method.

Results and discussion

eemods 2017
10th International Conference on
energy efficiency in motor driven systems
Rome, Italy 6-8 September 2017

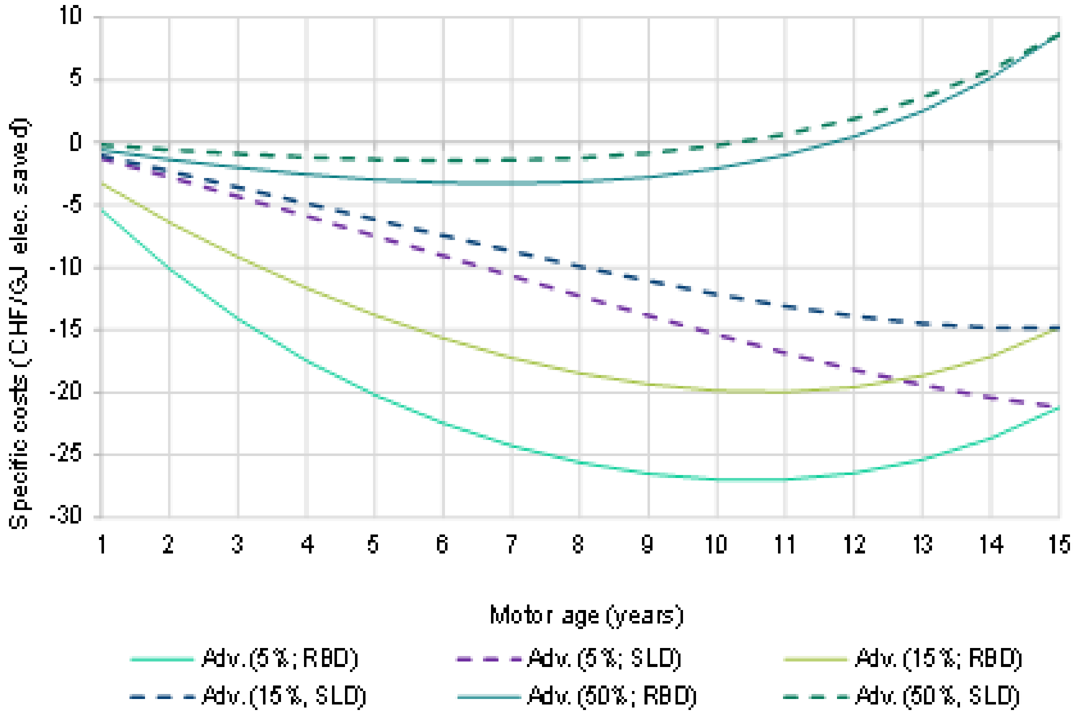


Figure: Comparing specific costs of the motor retrofit measure calculated by advanced EPA method with different salvage values i.e. 5%, 15% (base case) and 50%

- Effect of different salvage values on the measure specific costs.
- Financial value of the manufacturing plant equipment depreciates quickly in the early years as compared to the term closer to the end of lifetime (RBD).
- Specific costs decrease until a certain level is reached, after which the costs start increasing.

Results and discussion

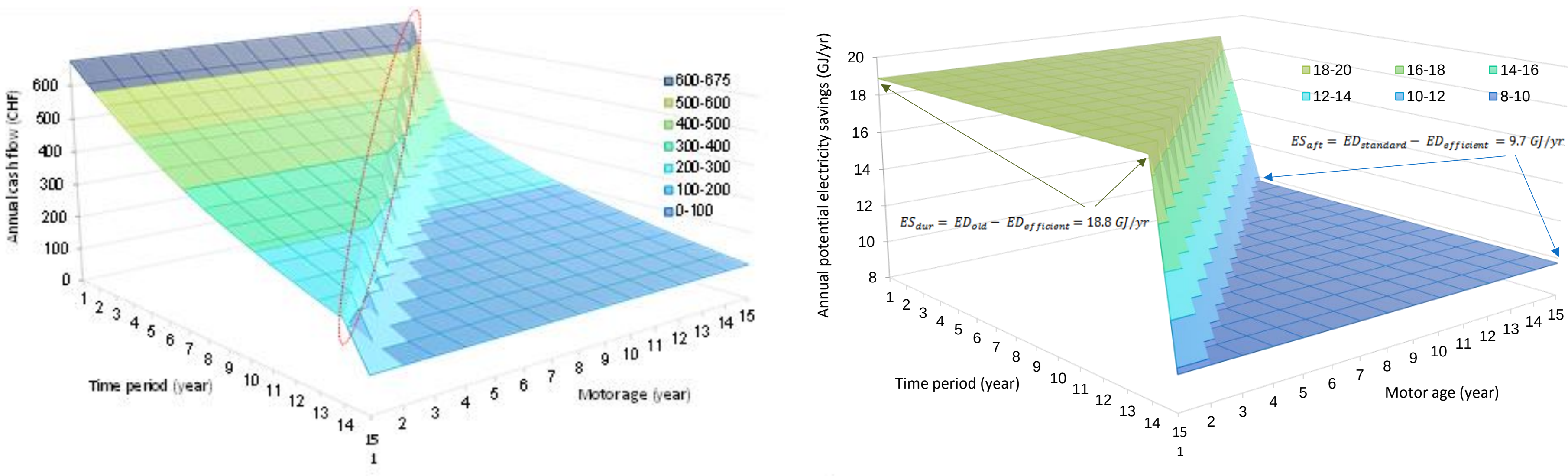


Figure: Annual discounted cash flows (left) and annual electricity savings (right) over the years for different levels of old motor (IE2 in this particular case) age at the time of replacement

Outline

- Introduction
- Materials and methods
  - Cost-effectiveness of EE measures
  - Accounting for additionality
    - *EnAW method*
    - *ProKilowatt method*
    - *EPA metrics*
- Case study: motor retrofit
  - Situation
  - Electricity demand and price
  - Remaining value of the motor
- Results and discussion
- Conclusions

Conclusions

- Advanced EPA approach is recommended.
- Cost-benefit analysis based on total investments leads to underestimation of the economic potential → Additionality should be considered!
- The additionality approach based on age tends to overestimate the cost-effectiveness.
- Replacing old motor with a more energy efficient one is most profitable before the end of the old motor lifetime.
- Several constraints associated with adv. EPA approach → e.g. the definition of reference standard technology for diverse systems, lack of detailed data, complexity etc.

THANK YOU!!!