UNIVERSITÉ DE GENÈVE

Energy (Efficiency) Policy Evaluation

Imane Fouiteh
Francesco Sasso
Martin Patel

Scope and aims

At the end of the session:

- What are the three basic approaches of energy policy?
- How to evaluate energy & climate policy?
- What is Multicriteria Analysis (MCA) and how does it work?

UNIVERSITÉ DE GENÈVE

Contents

- Energy Policy
- Simple Energy Indicators
- Evaluation of Energy Policy
- Multicriteria Analysis (MCA)

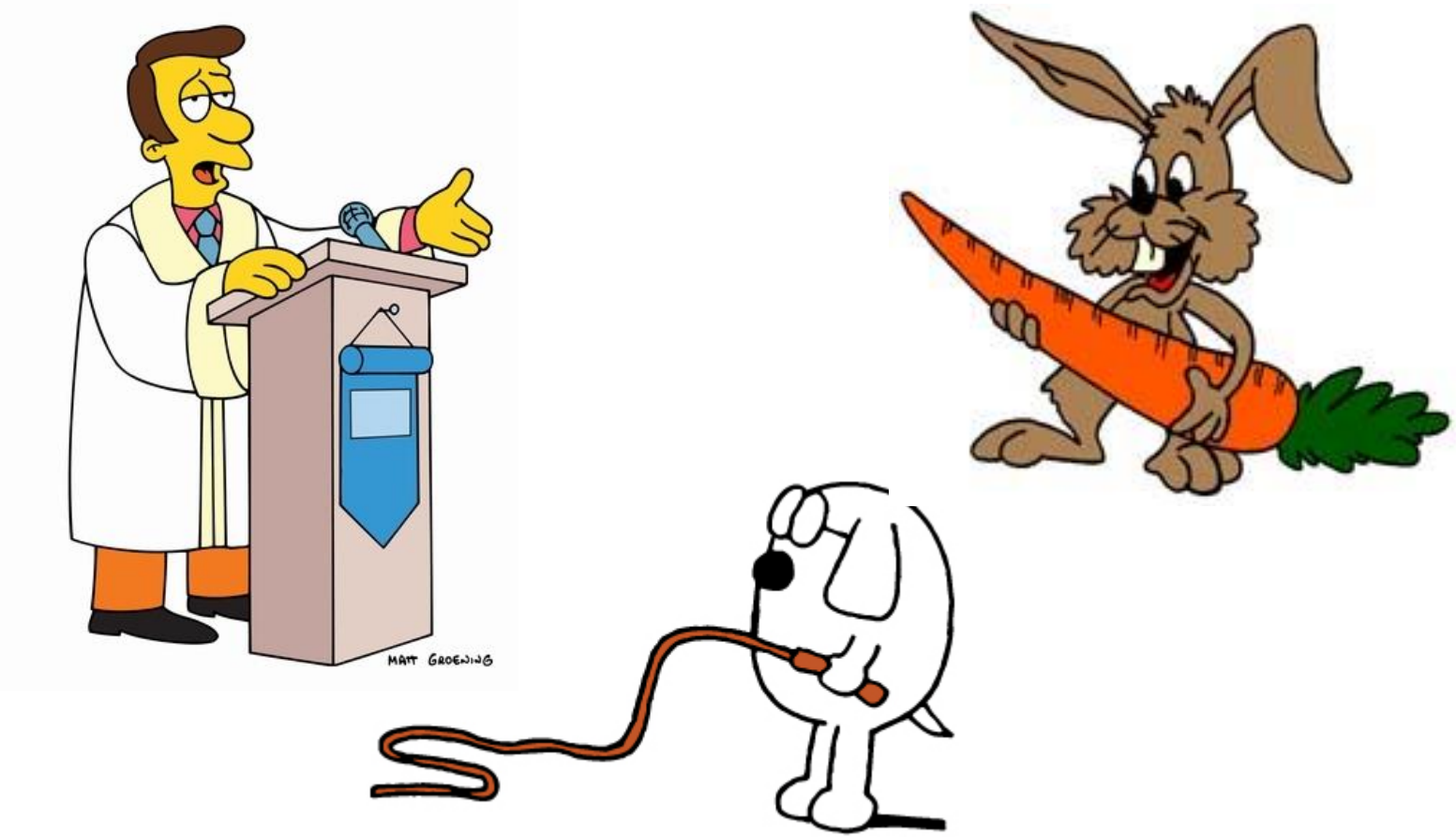
UNIVERSITÉ DE GENÈVE

Contents

- Energy Policy
- Simple Energy Indicators
- Evaluation of Energy Policy
- Multicriteria Analysis (MCA)

Governance options (1/2)

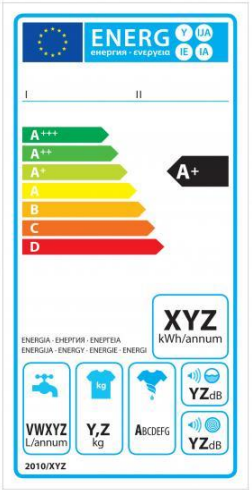
- Leverage the **three basic measures** of energy policy
- Generally valid (not only for energy efficiency)



See e.g. Azevedo, I.; Delarue, E.; Meeus, L.: Mobilizing cities towards a low-carbon future: Tambourines, carrots and sticks? Energy Policy 61 (2013), pp. 894-900

Governance options (2/2)

Basic categories of energy policy measures



- Information/Communication, e.g.:
  - Awareness campaigns, energy advisors
  - Labels
- Economic, e.g.:
  - Subsidies, tax exemption, rebates
  - CO_2 tax, CO_2 levy
  - Bonus-malus
- Coercive (also: normative, command & control), e.g. by
  - Setting minimal thermal performance standards (e.g. bulbs, hoovers)
  - Setting rules for renewable energy use (mandatory solar; banning fossil)
  - Making the use of energy distribution networks mandatory

UNIVERSITÉ DE GENÈVE

Contents

- Energy Policy
- Simple Energy Indicators
- Evaluation of Energy Policy
- Multicriteria Analysis (MCA)

Simple indicators for energy use

UNIVERSITÉ DE GENÈVE

- "…energy consumption can be decoupled from economic growth"

  → (Energy use) / GDP ↓ *Energy intensity* ↓

- (Energy use) / (physical activity) ↓ *Energy efficiency* ↑

$$\text{SEC} = \frac{\text{energy input into a process}}{\text{useful output of a process}}$$

e.g.:
- Buildings: MJ/m^2/yr
- Cars: liters per 100 km
- Refrigerator: kWh/liter/yr
- Steelmaking: GJ/tonne steel

SEC = specific energy consumption

SEC ↓ means energy efficiency ↑ **Do More with Less !**

- Energy use ↓ (it ***may*** mean:) *Energy savings* ↑

Simple indicators for energy use

Attention!

The simple indicators described above typically do not allow us to assess the effectiveness of a policy measure!

- Counterfactual analysis
- Additionality

UNIVERSITÉ DE GENÈVE

Contents

- Energy Policy
- Simple Energy Indicators
- Evaluation of Energy Policy
- Multicriteria Analysis (MCA)

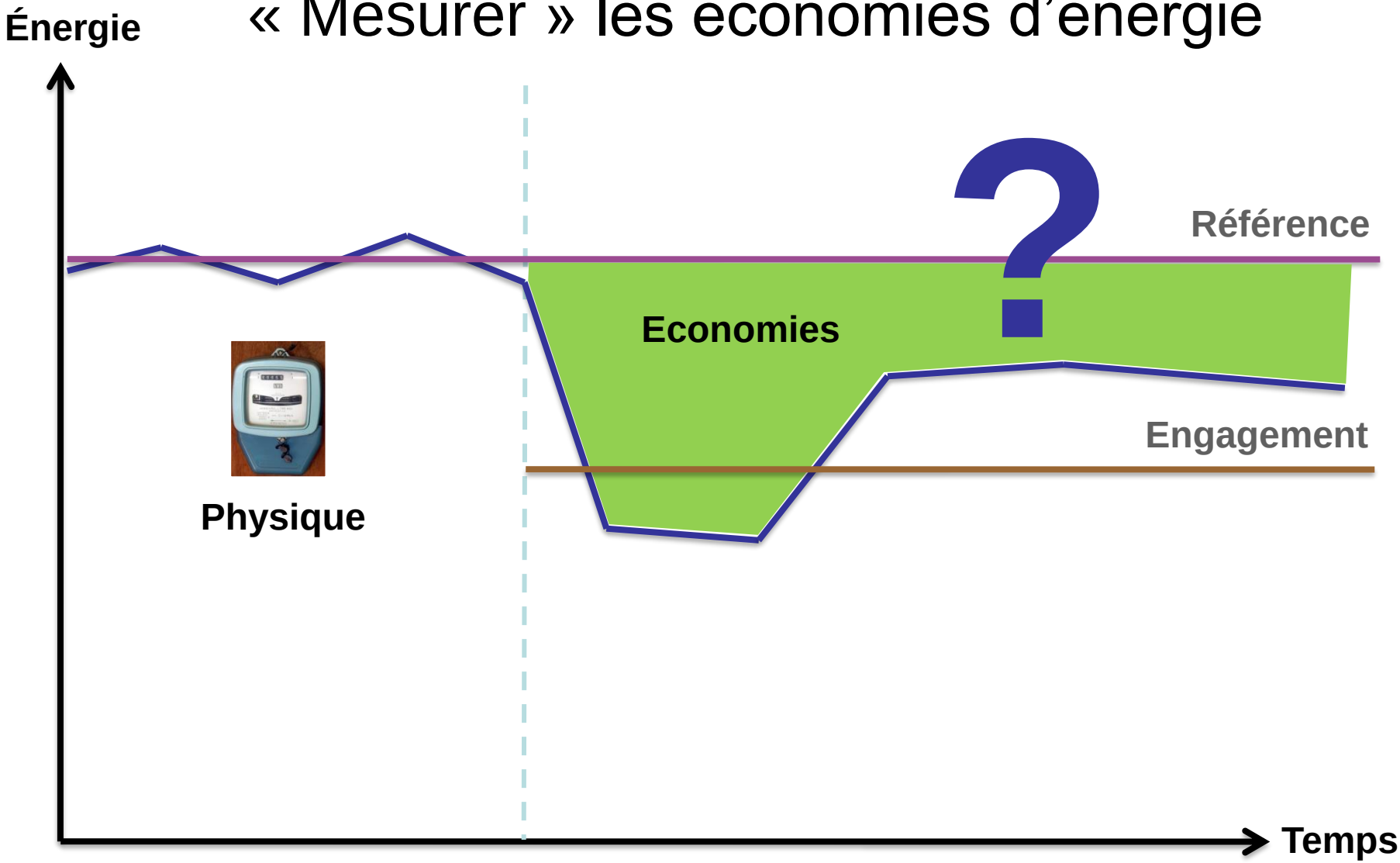
UNIVERSITÉ DE GENÈVE

Contents

- Energy policy
- Simple Energy Indicators
- Evaluation of Energy Policy
  - **Effectiveness: Counterfactual analysis**
  - **Cost-Benefit and Cost-Effectiveness Analysis**
  - Energy Efficiency Cost Curves
- Multicriteria Analysis (MCA)

i. Effectiveness - Counterfactual analysis (1/3)

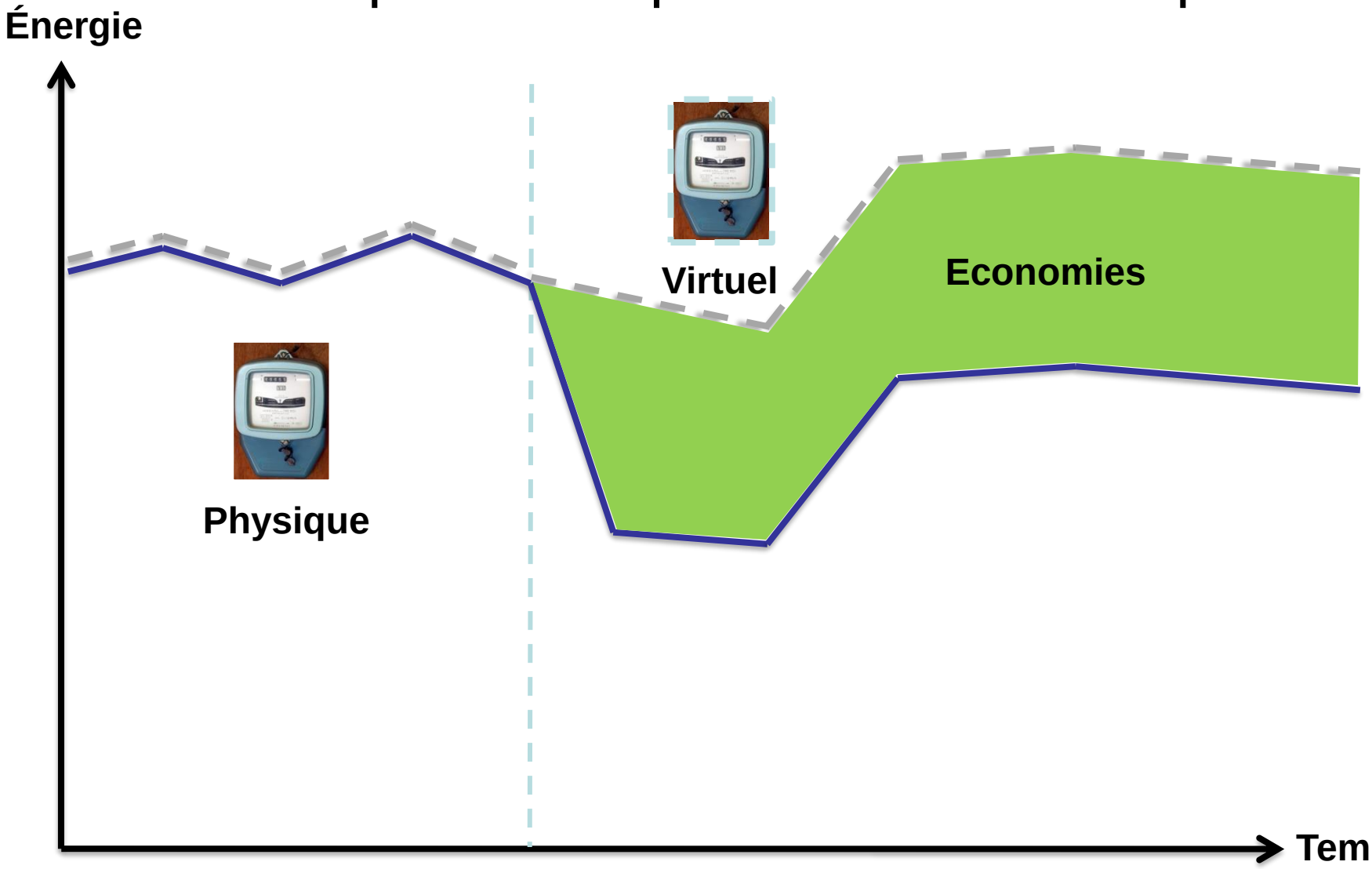
« Mesurer » les économies d'énergie



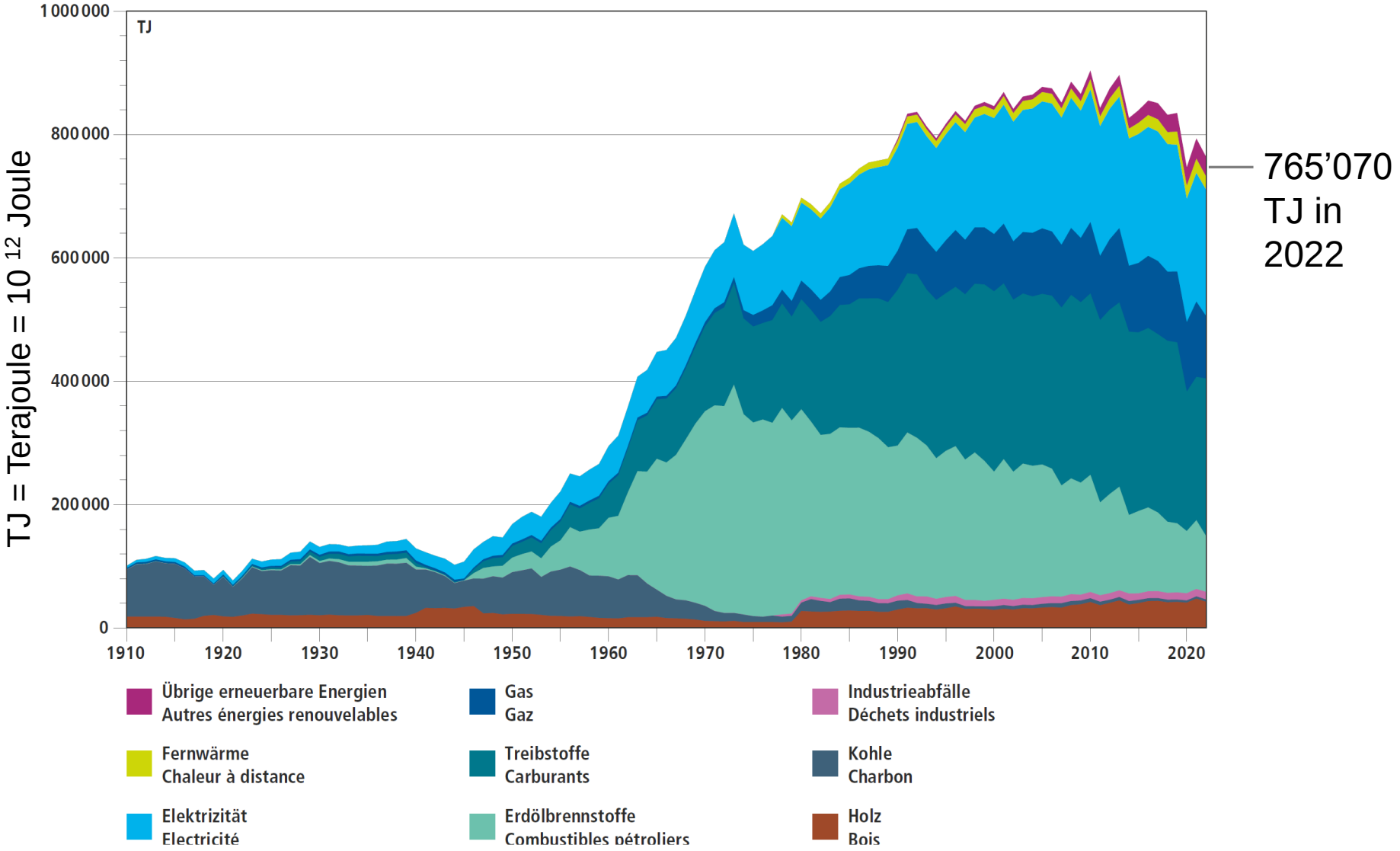
Slide copy – Jean-Marc Zgraggen, SIG

i. Effectiveness - Counterfactual analysis (1/3)

Comparer des pommes avec des pommes

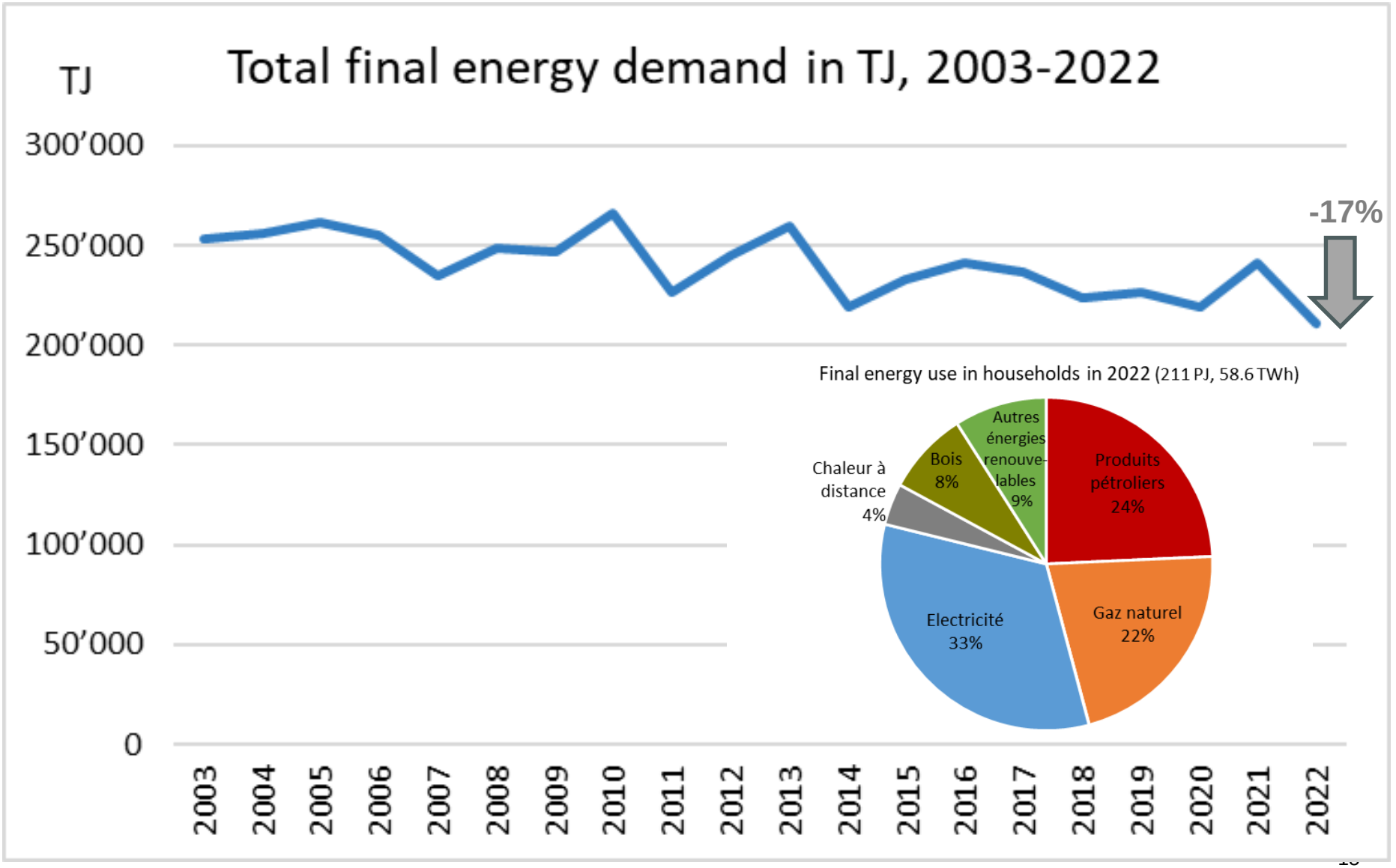


Final energy use in CH



OFEN, Statistique Globale Suisse de l’Energie, 2023

Final energy use in households in CH



OFEN, Statistique Globale Suisse de l'Energie, 2023

i. Effectiveness

Net effect of energy policy measures, i.e. which energy savings?

net impact = gross impact x (1 – free-rider coefficient + multiplier coefficient) x double counting coefficient

Stenqvist et al. (2012) and EMEEES (2009)

- **Free-rider effect** (also known as windfall gains, deadweight effect): Measures would have been implemented also without existence of policy.
- **Multiplier effect:** Also known as **spillover effect**, market transformation effect (example: Minergie building for new townhall → installers and private owners start using same technologies)
- **Double counting:** Overlap with effect generated by other policy measures (e.g. pre-existing policies)

→ Effectiveness of energy policy
(Additionality to what would anyway have been done)

https://partnersinexcellenceblog.com/what-we-do-is-not-complicated/

Cost-Benefit and Cost-Effectiveness analysis

- "Cost-benefit analysis" and "Cost-effectiveness" are often used interchangeably, sometimes also Levelized cost, Annual(ized) cost, …
- Ratio: Costs and the energy savings - Examples:

Let's call this "Levelized cost"

$$\frac{Costs}{Benefits} = \frac{Costs\ of\ Policy\ measure\ (\frac{CHF}{year})}{Energy\ savings\ (\frac{kWh}{year})}$$

Let's call these "Cost-benefit analysis"

$$\frac{Costs}{Benefits} = \frac{Costs\ of\ Policy\ measure\ (\frac{CHF}{year})}{Avoided\ energy\ costs\ (\frac{CHF}{year})}$$

$$\frac{Benefits}{Costs} = \frac{Avoided\ energy\ costs\ (\frac{CHF}{year})}{Costs\ of\ Policy\ measure\ \left(\frac{CHF}{year}\right)}$$

By analogy:

Benefits

= Emission reduction

Or

= Avoided external costs

More below (PCT, PACT, TRC, etc.)

ii. Cost effectiveness

Why we need it – Examples (1/2)

- **Energy law of canton Basel-City (2017):**
  When replacing the **heating system** in existing buildings, a renewable energy system must be chosen, **insofar as this** is technically possible and **does not lead to additional costs**.

- **Proposal for recast of EU Energy Efficiency Directive (2021):**
  "In multi-apartment and multi-purpose buildings with a central heating or central cooling source or supplied from a district heating or district cooling system, **individual meters** shall be installed to measure the consumption of heating, cooling or domestic hot water for each building unit, **where** technically feasible and **cost effective in terms of being proportionate in relation to the potential energy savings**."

Compteur de chaleur

- Art. 7 of Energy law of canton Basel-City (2017), https://www.gesetzessammlung.bs.ch/app/de/texts_of_law/772.100
- EU: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021PC0558

ii. Cost effectiveness

Why we need it – Examples (2/2)

Better Evaluation

Getting started | Frameworks & guides | Methods & approaches | Tools & resources | Community

Home › Evaluation Methods and Approaches › Evaluation Methods › Cost-benefit analysis

Cost-benefit analysis

This method compares the total costs of a programme/project with its benefits, using a common metric (most commonly monetary units), which enables you to calculate the net cost or benefit associated with the programme.

Cost-benefit analysis (CBA) is used most often at the start of a programme or project when different options or courses of action are being appraised and compared, as a method for choosing the best approach. It can also be used to evaluate the overall impact of a programme in quantifiable and monetised terms.

CBA adds up the total costs of a programme or activity and compares it against its total benefits. The technique assumes that a monetary value can be placed on all the costs and benefits of a programme, including tangible and intangible returns to other people and organisations in addition to those immediately impacted. As such, a major advantage of cost-benefit analysis lies in forcing people to explicitly and systematically consider the various factors which should influence strategic choice.

https://www.betterevaluation.org/methods-approaches/methods/cost-benefit-analysis

ii. Cost effectiveness

UNIVERSITÉ DE GENÈVE

Cost-Benefit and Cost-Effectiveness analysis

- "Cost-benefit analysis" and "Cost-effectiveness" are often used interchangeably, sometimes also Levelized cost, Annual(ized) cost, …
- Ratio: Costs and the energy savings - Examples:

Let's call this "Levelized cost"

$$\frac{Costs}{Benefits} = \frac{Costs\ of\ Policy\ measure\ (\frac{CHF}{year})}{Energy\ savings\ (\frac{kWh}{year})}$$

Let's call these "Cost-benefit analysis"

$$\frac{Costs}{Benefits} = \frac{Costs\ of\ Policy\ measure\ (\frac{CHF}{year})}{Avoided\ energy\ costs\ (\frac{CHF}{year})}$$

$$\frac{Benefits}{Costs} = \frac{Avoided\ energy\ costs\ (\frac{CHF}{year})}{Costs\ of\ Policy\ measure\ \left(\frac{CHF}{year}\right)}$$

By analogy:

Benefits

= Emission reduction

Or

= Avoided external costs

More below (PCT, PACT, TRC, etc.)

ii. Cost effectiveness

A) For individual technical measures

UNIVERSITÉ DE GENÈVE

Table 4-5. Defining Costs and Impacts of Energy Efficiency Measures

	Type of Measure	Measure Cost ($/Unit)	Impact Measurement (kWh/Unit and kW/Unit)
1.)	**New** New construction Lost opportunity	Cost of efficient device **minus** cost of standard device *(Incremental)*	Consumption of standard device **minus** consumption of efficient device
2.)	**Replacement** Failure replacement Natural replacement Replace on burnout	Cost of efficient device **minus** cost of standard device *(Incremental)*	Consumption of standard device **minus** consumption of efficient device
3.)	**Retrofit** Early replacement *(Simple)*	Cost of efficient device **plus** installation costs *(Full)*	Consumption of old device **minus** consumption of efficient device
4.)	**Retrofit** Early replacement *(Advanced)**	Cost of efficient device **minus** cost of standard device **plus** remaining present value	*During remaining life of old device:* Consumption of old device **minus** consumption of efficient device *After remaining life of old device:* Consumption of standard device **minus** consumption of efficient device
5.)	**Retire**	Cost of removing old device	Consumption of old device

* The advanced retrofit case is essentially a combination of the simple retrofit treatment (for the time period during which the existing measure would have otherwise remained in service) and the failure replacement treatment for the years after the existing device would have been replaced. "Present Value" indicates that the early replacement costs should be discounted to reflect the time value of money associated with the installation of the efficient device compared to the installation of the standard device that would have occurred at a later date.

US-EPA, Understanding Cost-Effectiveness of Energy Efficiency Programs, 2008, http://www2.epa.gov/sites/production/files/2015-08/documents/cost-effectiveness.pdf

ii. Cost effectiveness

B) For an energy (efficiency) policy

Test	Benefits	Costs
PCT	*Benefits and costs from the perspective of the customer installing the measure*	
Partici-pant cost test	▪ Incentive payments ▪ Bill savings ▪ Applicable tax credits or incentives	▪ Incremental equipment costs ▪ Incremental installation costs
PACT	*Perspective of utility, government agency, or third party implementing the program*	
Program Admini-strator cost test	▪ Energy-related costs avoided by the utility ▪ Capacity-related costs avoided by the utility, including generation, transmission, and distribution	▪ Program overhead costs ▪ Utility/program administrator incentive costs ▪ Utility/program administrator installation costs
SCT	*Benefits and costs to all in the utility service territory, state, or nation as a whole*	
Societal cost test	▪ Energy-related costs avoided by the utility ▪ Capacity-related costs avoided by the utility, including generation, transmission, and distribution ▪ Additional resource savings (i.e., gas and water if utility is electric) ▪ Non-monetized benefits (and costs) such as cleaner air or health impacts	▪ Program overhead costs ▪ Program installation costs ▪ Incremental measure costs (whether paid by the customer or utility)

US-EPA, Understanding Cost-Effectiveness of Energy Efficiency Programs, 2008, http://www2.epa.gov/sites/production/files/2015-08/documents/cost-effectiveness.pdf

ii. Cost effectiveness

UNIVERSITÉ DE GENÈVE

Annuity method (1/2)

Calculation of Levelized Costs (LC)

$$LC = \underbrace{\alpha * I}_{k} + C_{yearly} - B_{yearly}$$

Examples:

- **without B_{yearly}:** PV plant on open field: to be compared with average prod. price
- **with B_{yearly}:** PV panels on residential building. B_{yearly} = avoided purchase of grid electricity

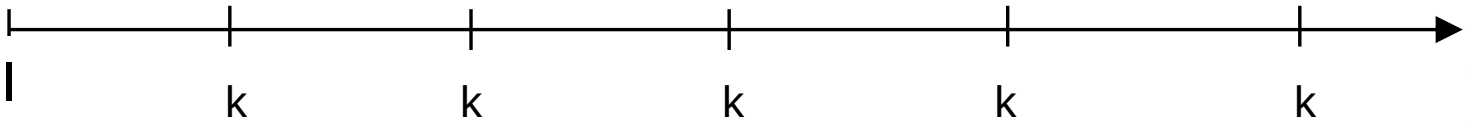
k = annualized investment costs (per year)

$$\alpha = \frac{r}{1 - (1 + r)^{-n}}$$

I = investment, in million CHF
k = annualized investment (costs), in CHF per year
r = interest rate (discount rate), in %
n = (economic) lifetime of the investment, in years (= period of depreciation)
α = annuity factor, in %

ii. Cost effectiveness

Annuity method (2/2)



$$I = \frac{k}{(1+r)} + \frac{k}{(1+r)^2} + \frac{k}{(1+r)^3} + \dots$$

$$I = \frac{k}{(1+r)} * \left[1 + \frac{1}{(1+r)} + \frac{1}{(1+r)^2} + \dots \right]$$

$$I = \frac{k}{(1+r)} * \left[1 + q + q^2 + \right]$$

$$I = \frac{k}{(1+r)} * \left[\frac{q^n - 1}{q - 1} \right]$$

$$I = k * \frac{(1+r)^n - 1}{(1+r)^n * r}$$

$1/\alpha$

k: yearly investment cost
I: Investment (capital expenditure)
α: Annuity factor
r: Interest rate
L: Lifetime or period of depreciation

ii. Cost effectiveness

UNIVERSITÉ DE GENÈVE

Different stakeholder perspectives (see exercise)

- Private perspective
  ('textbook' discount rate: e.g. 10-15% p.a. ←→ until recently: ~ 5-10% p.a.)
- Social perspective
  ('textbook' discount rate: e.g. 4-6% p.a. ←→ until recently: ~ 0-2% p.a.)

Annuity method

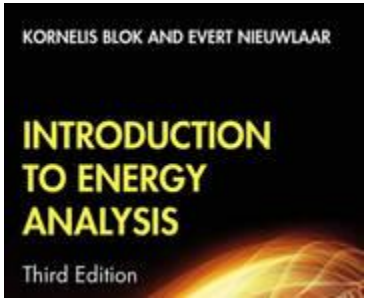
Investment costs k (per year)

$$k = \alpha * I$$

$$\alpha = \frac{r}{1 - (1 + r)^{-n}}$$

r = interest rate (discount rate)
n = (economic) lifetime of the investment
(= period of depreciation)
α = annuity factor

Discount rate Depreciation period (years)	4%	5%	10%	15%	20%	25%
5	22.5%	23.1%	26.4%	29.8%	33.4%	37.2%
10	12.3%	13.0%	16.3%	19.9%	23.9%	28.0%
15	9.0%	9.6%	13.1%	17.1%	21.4%	25.9%
20	7.4%	8.0%	11.7%	16.0%	20.5%	25.3%
25	6.4%	7.1%	11.0%	15.5%	20.2%	25.1%
30	5.8%	6.5%	10.6%	15.2%	20.1%	25.0%
50	4.7%	5.5%	10.1%	15.0%	20.0%	25.0%



Example: Levelized cost of a policy measure – How to calculate? (1/2)

1. Sum all government costs (I)
2. Calculate annual(ized) costs (α*I)

   Depreciate the expenditure over the economic lifetime of the energy saving measure using a discount rate of e.g. 4%

   α = annuity factor
3. Divide the annual costs by the additional energy savings of the instrument (α*I/ΔE)

Example: Levelized cost of a policy measure – How to calculate? (2/2)

- Total expenditure (I): 11 MEuro
  - Subsidies: 10 MEuro
  - Programme cost or Policy cost: 1 MEuro
- Annual cost (α*I) = 0.13*11 = 1.4 MEuro
- E.g. additional savings: 300 TJ per year
- Levelized cost = Cost-effectiveness
  = $1.4*10^6/300*10^3$
  = 4.7 Euro/GJ

ii. Cost effectiveness – More indicators

UNIVERSITÉ DE GENÈVE

- Elasticity:
  - Price elasticity of demand
  - Price elasticity of supply
  - Income elasticity of demand

$$e_p = \frac{dQ/Q}{dP/P} = \frac{\frac{Q_2 - Q_1}{Q_1}}{\frac{P_2 - P_1}{P_1}}$$

% change in quantity
% change in price

→ perfectly elastic if = -1

- Simple payback period (PBP):

$$PBP = \frac{I}{B-C} = \frac{I}{Profit+Depreciation}$$

I = investment
B = annual benefits, revenue
C = annual costs

- Internal Rate of Return (IRR):

$$IRR = Discount\ rate\ at\ which\ NPV = 0$$

Valeur actuelle nette (VAN)

Durée d'amortissement
= Durée du retour sur investissement

Taux de rentabilité interne

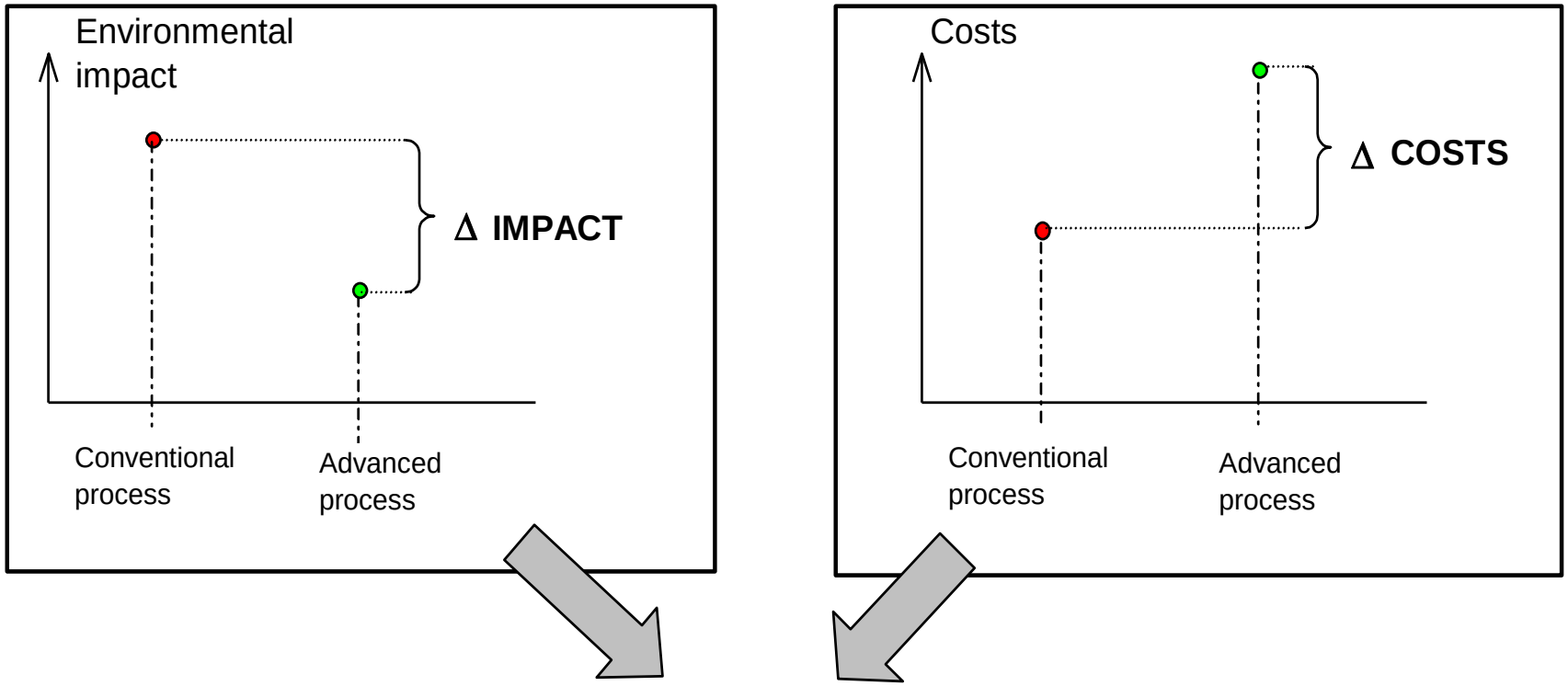
$$NPV = -I + \sum_{i=1}^{n} \frac{B-C}{(1+r)^i} = -I + \frac{B-C}{\alpha}$$

$$\alpha = \frac{r}{1-(1+r)^{-n}}$$

I = initial investment
B = annual benefits
C = annual costs (excluding capital costs)
α = the capital recovery factor
r = the discount rate
n = the life time or depreciation period of the equipment

UNIVERSITÉ DE GENÈVE

Specific mitigation costs

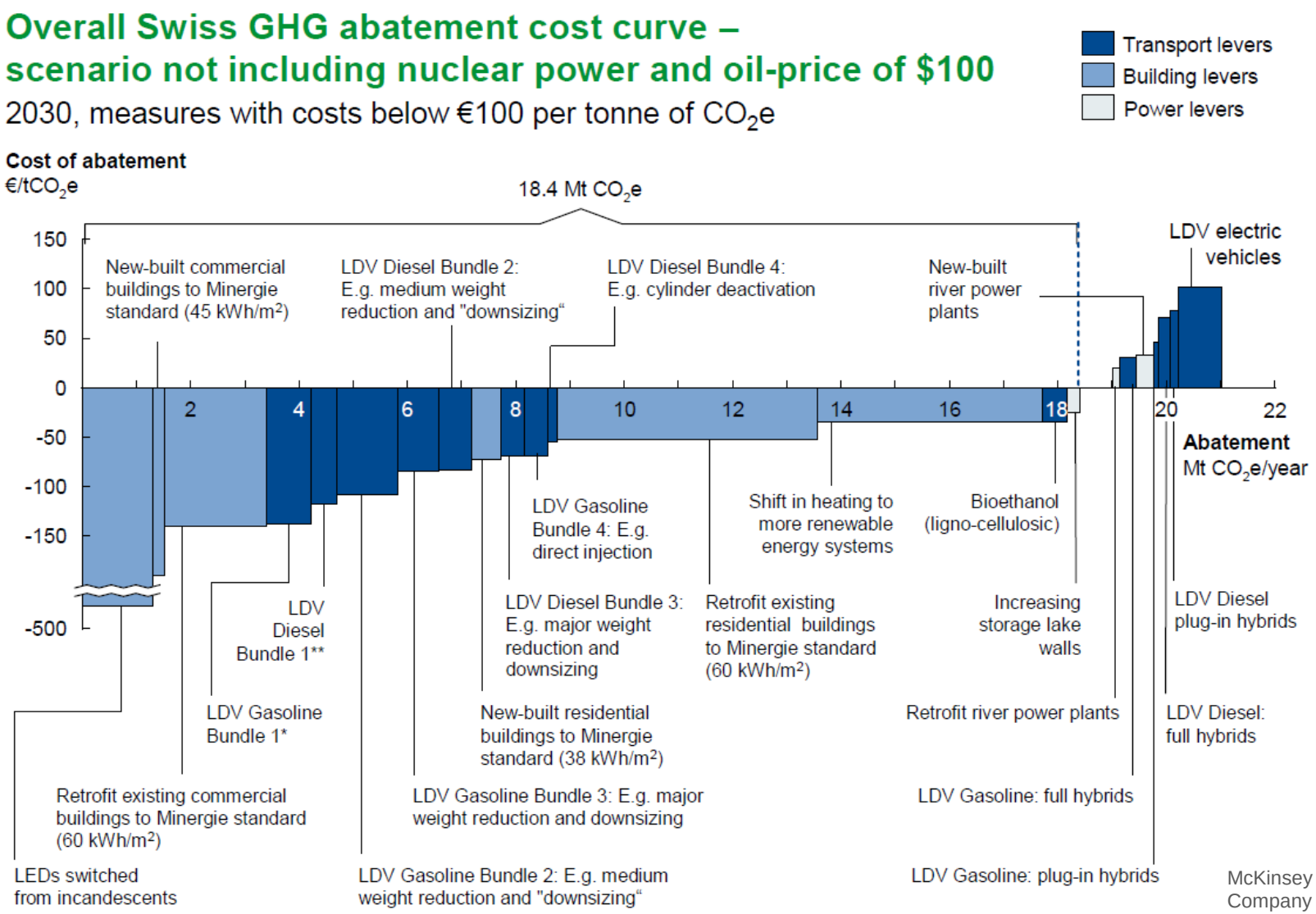


$$\frac{\Delta \text{ COSTS}}{\Delta \text{ IMPACT}}$$

Spec. mitigation costs

iii. Energy efficiency cost curves

= Graphical representation of cost-effectiveness of technical measures



LDV Light-duty vehicles

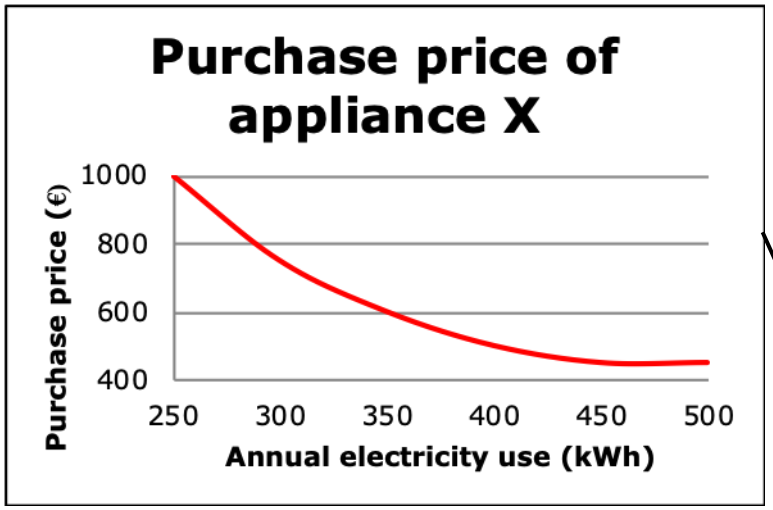
* LDV Gasoline Bundle 1: Including variable valve control, engine friction reduction (mild), low rolling resistance tires, tire pressure control system, mild weight reduction
** LDV Diesel Bundle 1: Including Torque oriented boost, engine friction reduction, low rolling resistance tires, tire pressure control system, mild weight reduction

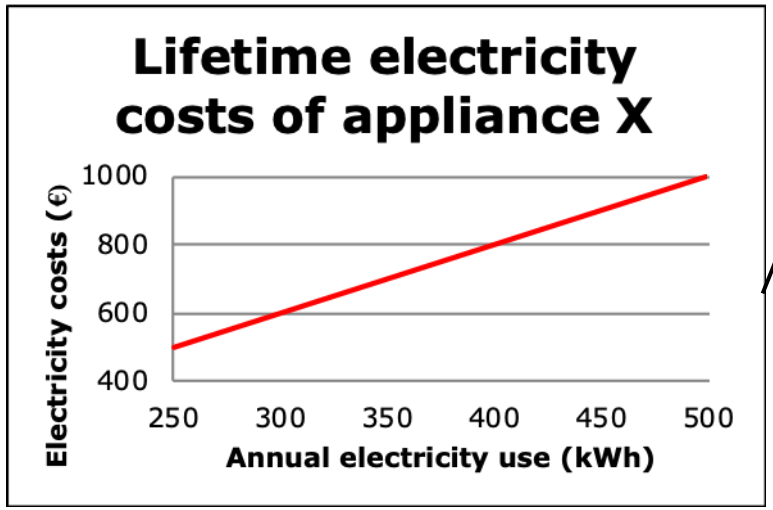
McKinsey & Company 2009: Swiss GHG Abatement Cost Curve.

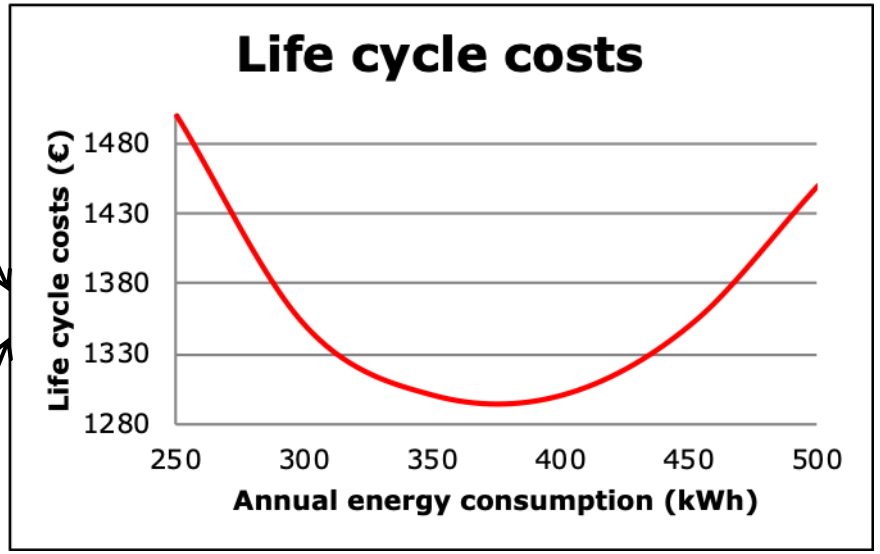
iv. Levelized cost for comparison of alternative appliances (or devices, houses, cars etc.)

- **Levelized cost**, sometimes also referred to as
  - Cost-effectiveness
  - Annual(ized) cost
  - Life Cycle Cost (LCC)
  - **Total Cost of Ownership**
- Costs include:
  - Acquisition costs (or design and development costs).
  - Operating costs:
    - Cost of failures/Downtime costs/Loss of production
    - Cost of repairs/spares
  - Maintenance costs:
    - Cost of corrective/preventive/predictive maintenance
  - **Disposal costs**.

iv. Levelized cost for comparison of alternative appliances - Minimization of costs







Slide copy Maarten Cuijpers, M.Sc. Thesis, 2011

UNIVERSITÉ DE GENÈVE

Levelized cost = coût actualisé

UNIVERSITÉ DE GENÈVE

Contents

- Energy Policy
- Simple Energy Indicators
- Evaluation of Energy Policy
- Multicriteria Analysis (MCA)

UNIVERSITÉ DE GENÈVE

Interpreting multidimensional results

1. Multicriteria Analysis (MCA) for dimensionless assessment

(2. Monetary methods (e.g. social/external costs))

UNIVERSITÉ DE GENÈVE

Weighted summation

1. Identify the options and criteria and construct effect table
2. Normalize scores for each criterion (0-1)
3. Assign weights of the criteria (total: 100%)
4. Calculate final score for each alternative
5. Determine ranking

UNIVERSITÉ DE GENÈVE

Effect table – Road improvement

	C or B	Unit	Broade-ning	Two-lane	Motorway
Costs	C	million euro	40.00	60.00	80.00
Saved travel time	B	minutes	25.00	30.00	20.00
Lost nat. reserve	C	hectares	2.00	1.50	1.75
Less accidents	B	number/yr	4.00	5.00	10.00

Evaluatiemethoden ex ante, J.C Hellendoorn (red), 2001

UNIVERSITÉ DE GENÈVE

Weighted summation

1. Identify the options and criteria and construct effect table
2. Normalize scores for each criterion (0-1)
3. Assign weights of the criteria (total: 100%)
4. Calculate final score for each alternative
5. Determine ranking

UNIVERSITÉ DE GENÈVE

Normalization of scores

Normalize between 0 and 1

The higher the normalized value is, the better the option scores.

- Linear-scale transf.: **maximum**, interval or goal
- Non-linear: convex & concave, S-form, other

For Benefits: score_normalized = score/score_max

For Costs: score_normalized = 1 – score/score_max

Evaluatiemethoden ex ante, J.C Hellendoorn (red), 2001

UNIVERSITÉ DE GENÈVE

Weighted summation

1. Identify the options and criteria and construct effect table
2. Normalize scores for each criterion (0-1)
3. Assign weights of the criteria (total: 100%)
4. Calculate final score for each alternative
5. Determine ranking

Multi-criteria analysis

UNIVERSITÉ DE GENÈVE

Normalized effect table and calculations – Maximum normalization

	C or B	Unit	Broad-ening	Two-lane	Motorway	Weight
Costs	C	million euro	40.00	60.00	80.00	
		normalized	*0.5*	*0.25*	*0.00*	0.40
Travel time saved	B	minutes	25.00	30.00	20.0	
		normalized	*0.83*	*1.00*	*0.67*	0.20
Lost natural reserve	C	hectares	2.00	1.50	1.75	
		normalized	*0.00*	*0.25*	*0.13*	0.10
Less accidents	B	number/yr	4.00	5.00	10.00	
		normalized	*0.40*	*0.50*	*1.00*	0.30

→ **Broadening (A1): 0.5*0.4 + 0.83*0.2 + 0.00*0.1+ 0.40*0.3 = 0.486**

→ **Two-lane (A2): = 0.475**

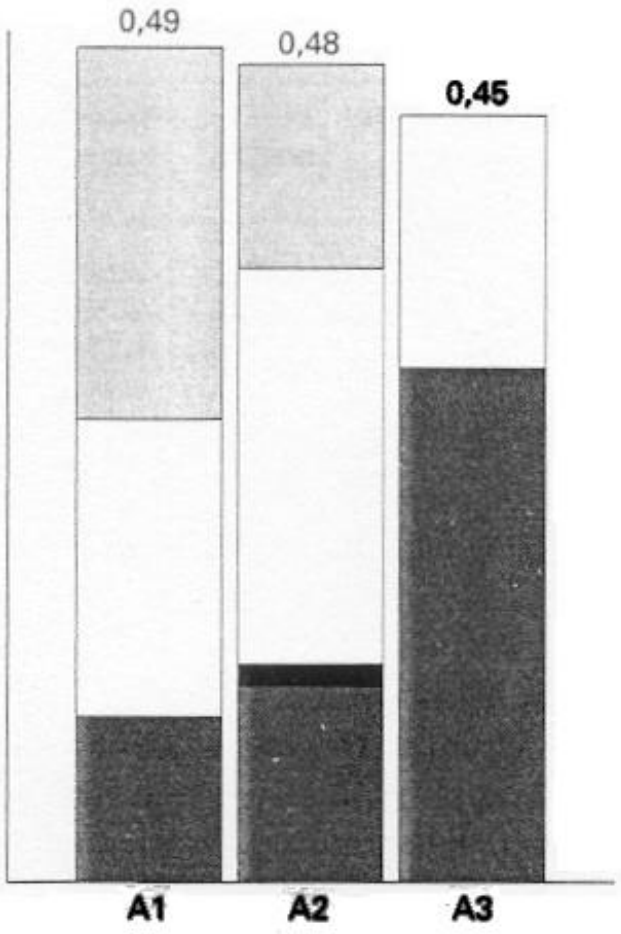
→ **Motorway (A3): = 0.447**

Evaluatiemethoden ex ante, J.C Hellendoorn (red), 2001

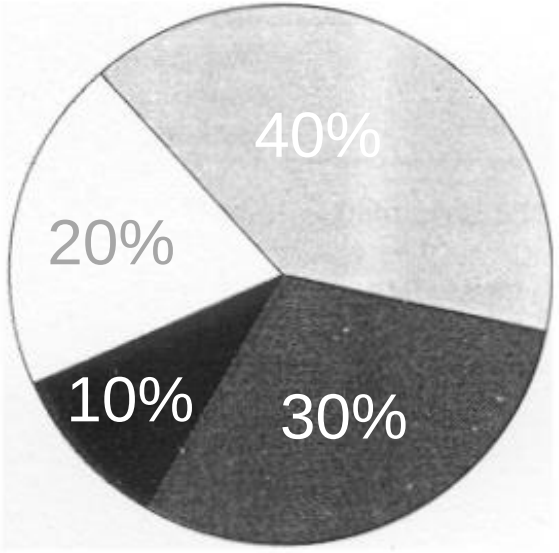
Multi-criteria analysis

Overview of scores – Maximum normalization

Results



Weighting



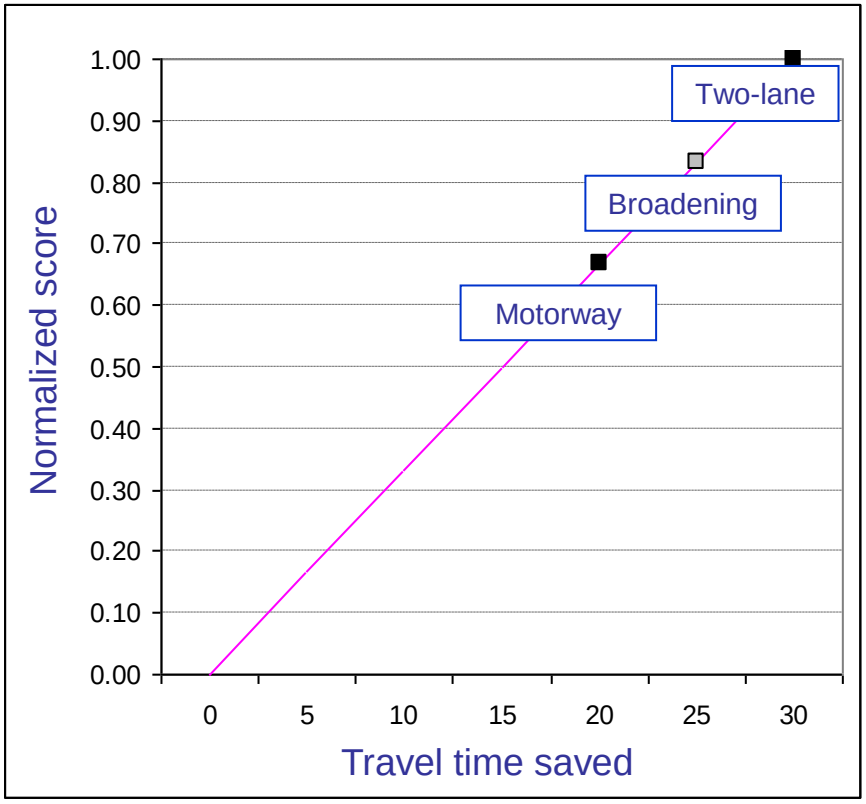
- Costs
- Travel time saved
- Lost nature conservation areas
- Less accidents

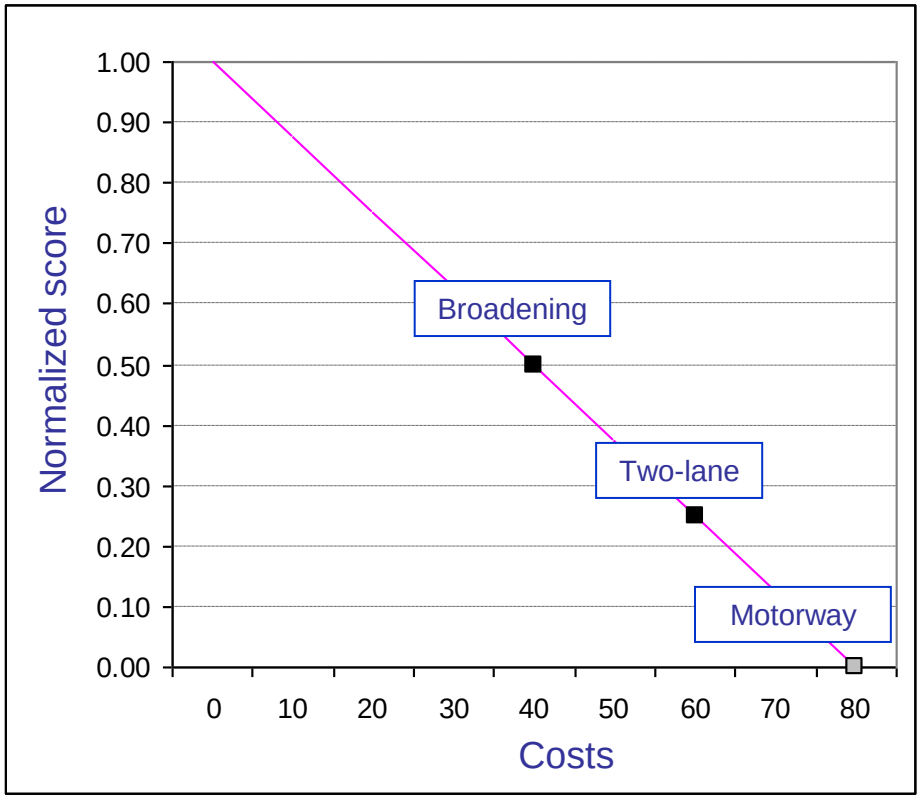
Evaluatiemethoden ex ante, J.C Hellendoorn (red), 2001

Multi-criteria analysis

UNIVERSITÉ DE GENÈVE

Overview of scores – Maximum normalization



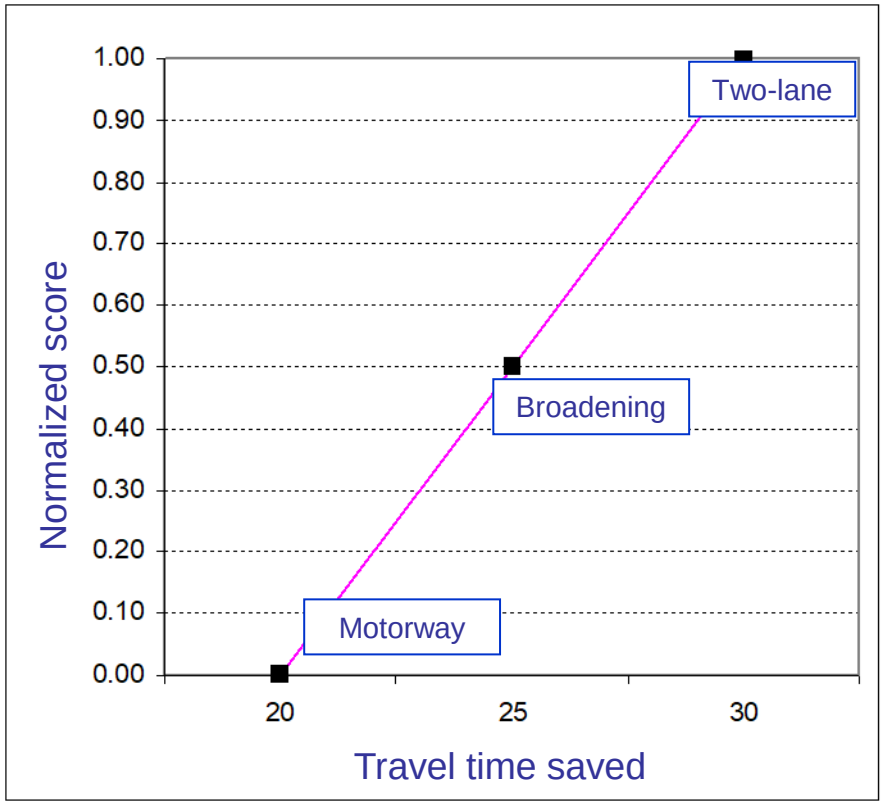


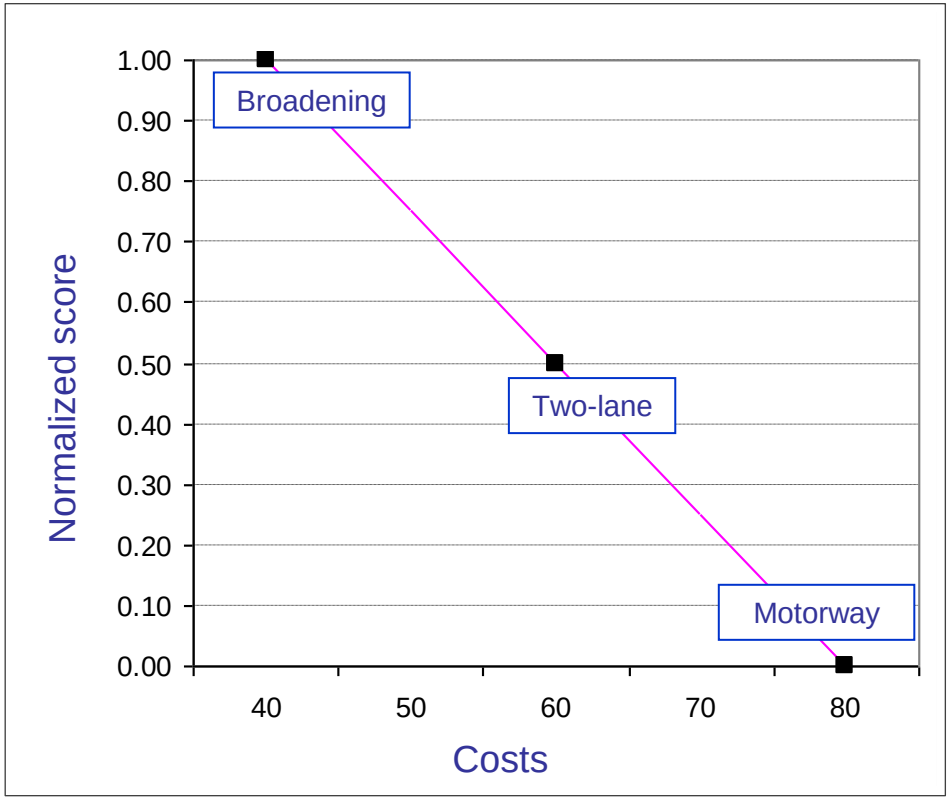
Evaluatiemethoden ex ante, J.C Hellendoorn (red), 2001

Multi-criteria analysis

UNIVERSITÉ DE GENÈVE

Overview of scores – Interval normalization



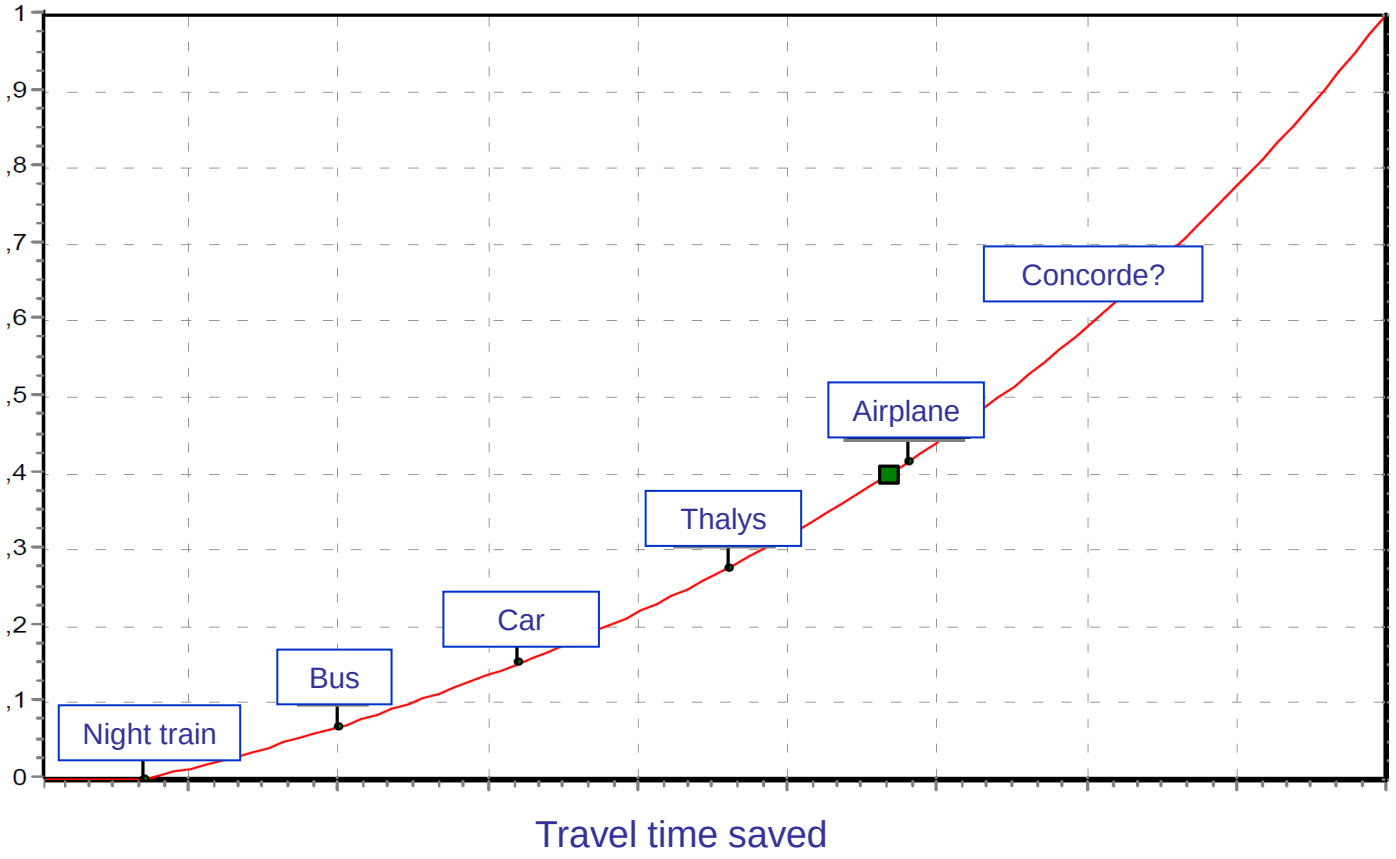


Evaluatiemethoden ex ante, J.C Hellendoorn (red), 2001

Multi-criteria analysis

UNIVERSITÉ DE GENÈVE

Other types of normalisation: Convex



- With increasing benefit (travel time saved), the advantage increases overproportionally.
- Careful: Subjectivity may be involved.

Adapted versiion of graph from R. Hoefnagel, Utrecht University; original source: DEFINITE

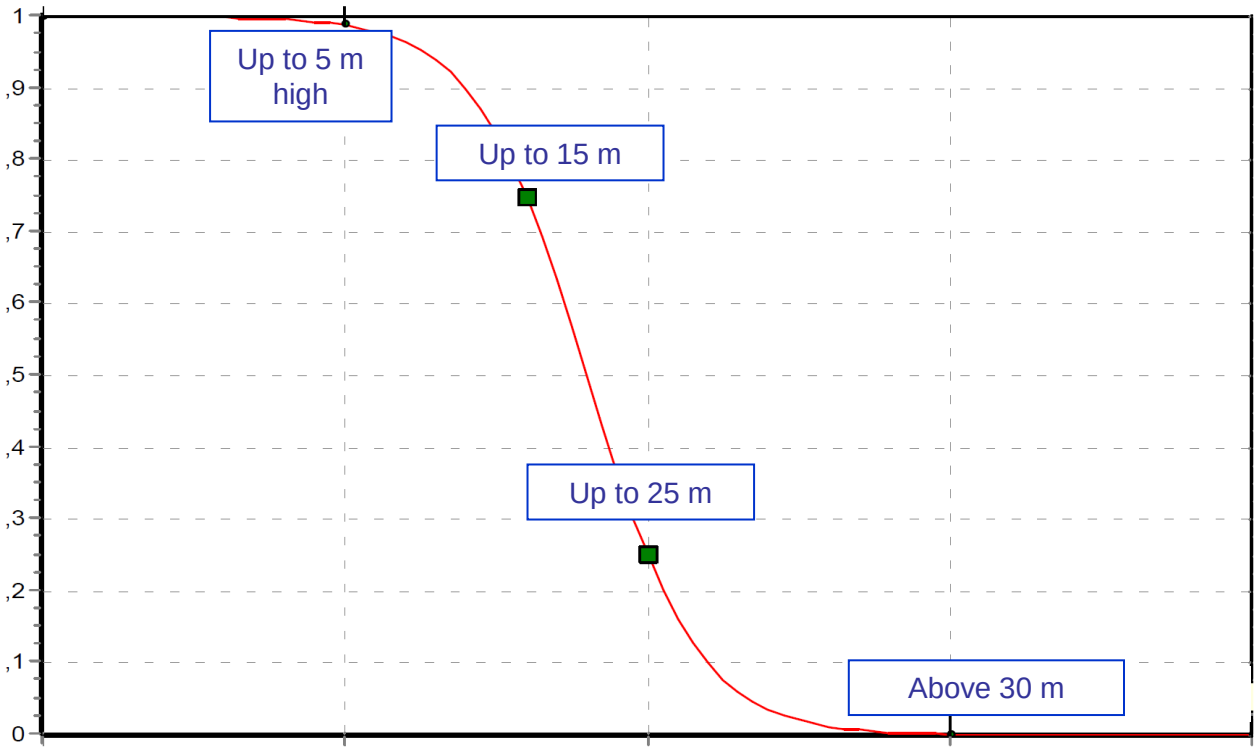
Multi-criteria analysis

Concorde?

Thalys

UNIVERSITÉ DE GENÈVE

Other types of normalisation: S-shape



Visual obtrusion (e.g. by windmill or silo)

- Beyond a certain threshold the impact becomes very large (or vice versa).
- Careful: Background research required; subjectivity may be involved; context specific; with or without moving parts etc.

Adapted version of graph from R. Hoefnagel, Utrecht University; original source: DEFINITE

Scope and aims

At the end of the session:

- What are the three basic measures of energy policy?
- How to evaluate energy & climate policy?
- What is Multicriteria Analysis (MCA) and how does it work?