# *Cost-Effectiveness Analysis (CEA)*

Economic evaluation of industrial projects

# Introduction to CEA

- The CEA methodology can be used if
  - it is not deemed convenient or possible to express the outcomes of the project in monetary values
  - it is possible to determine the costs of the project.
- It is assumed that different solutions can be compared with respect to a *common effect* (*outcome*).

- The outcome against which costs can be measured can be:
  - unique (one effect that is not measured in monetary units)
  - multi-dimensional (different effects, but common to all alternatives).
- Stages of analysis:
  - definition of the project objective
  - identification of the components of effectiveness
  - definition of the measure for each component
  - definition of the level of importance of the component (in the multi-dimensional case).

- If costs are measured in monetary units (C), if non-monetary costs are negligible and there is a common effect (E), for each solution $a_i$:

$$a_i \rightarrow (E_i, C_i)$$

- If all the solutions in the feasible set $\{a_i\}$ offer the same value of effectiveness $E_i$, a *cost-minimisation analysis* can be adopted.

- Having identified for each alternative ($a_i$) the same measure of effectiveness, E(a), one of the following criteria can be used:
  - minimum ratio C(a)/E(a)
  - minimum C(a)/E(a), subject to E(a) $\geq$ E*
  - minimum C(a)/E(a), subject to C(a) $\leq$ C*
  - minimum C(a)/E(a), subject to E(a) $\geq$ E* and C(a) $\leq$ C*
- However, output/input ratio indicators (i.e. E(a)/C(a)) can be adopted with the search for the maximum.

- The definitions of constraints and measures have a certain degree of subjectivity and must be validated by the decision-maker.

# *Example* [AVS]

- An automated ventilation system equipped with adjustable airflow controls will be installed in a steel manufacturing facility, specifically targeting emissions from a 10-ton electric arc furnace.
- The new system is particularly aimed at reducing particulate matter (PM) fugitive emissions.
- Particulate matter concentration is measured by active sampling.
- Five plant solutions satisfy the regulation and standard requirements.
- They have different abatement technologies, layout configurations and monitoring and control systems.

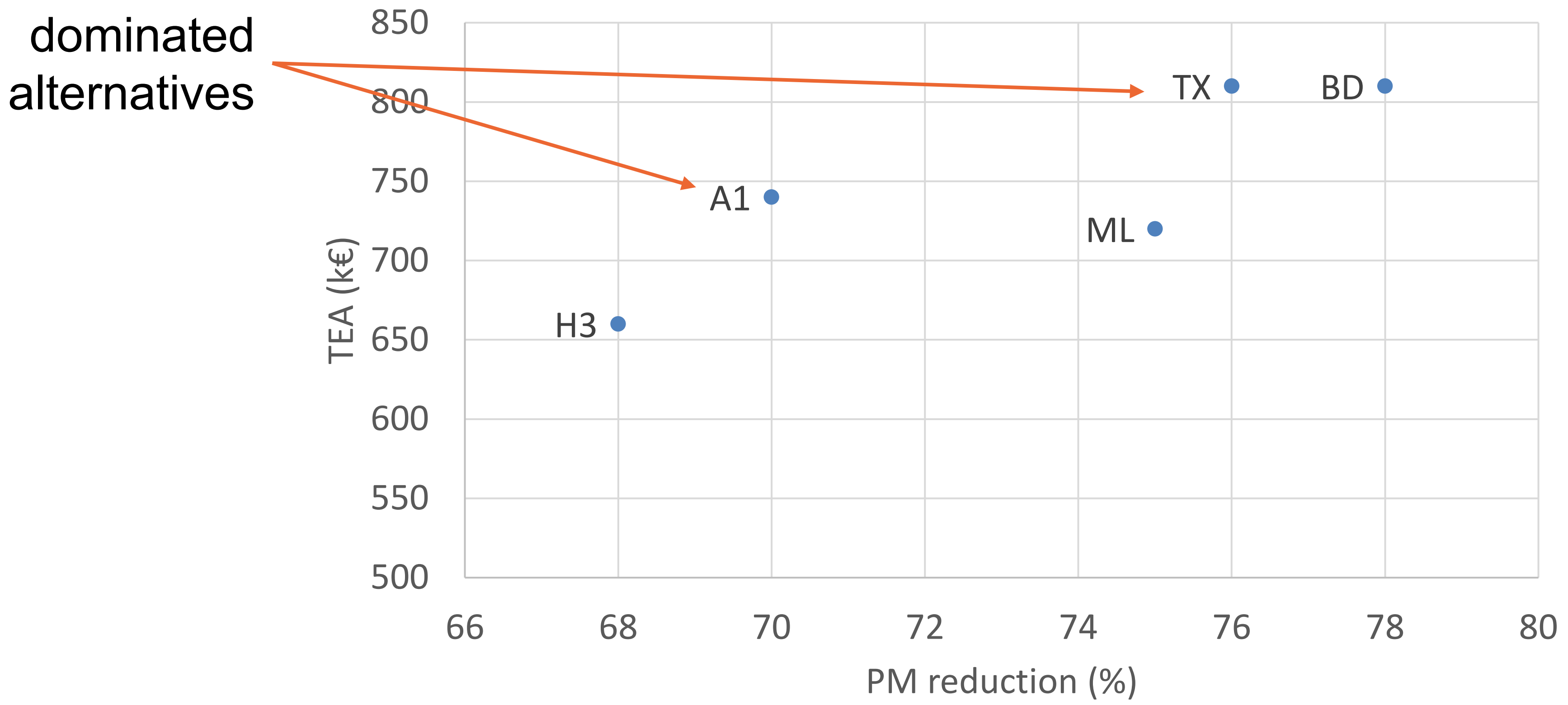
# *Example* [AVS]

- Based on the technical specifications and test results provided by the suppliers, the solutions are evaluated using a cost-effectiveness analysis.
- The outcome is the reduction in fugitive PM concentration ($\mu g/Nm^3$) of the new system with respect to the as-is situation.
- To compare the solutions, the percentage reduction of PM concentration with respect to the as-is situation is adopted as the measure of effectiveness.
- The costs are expressed as total equivalent annual cost including:
  - capital cost (turn-key)
  - operating costs (energy, consumables, routine maintenance).

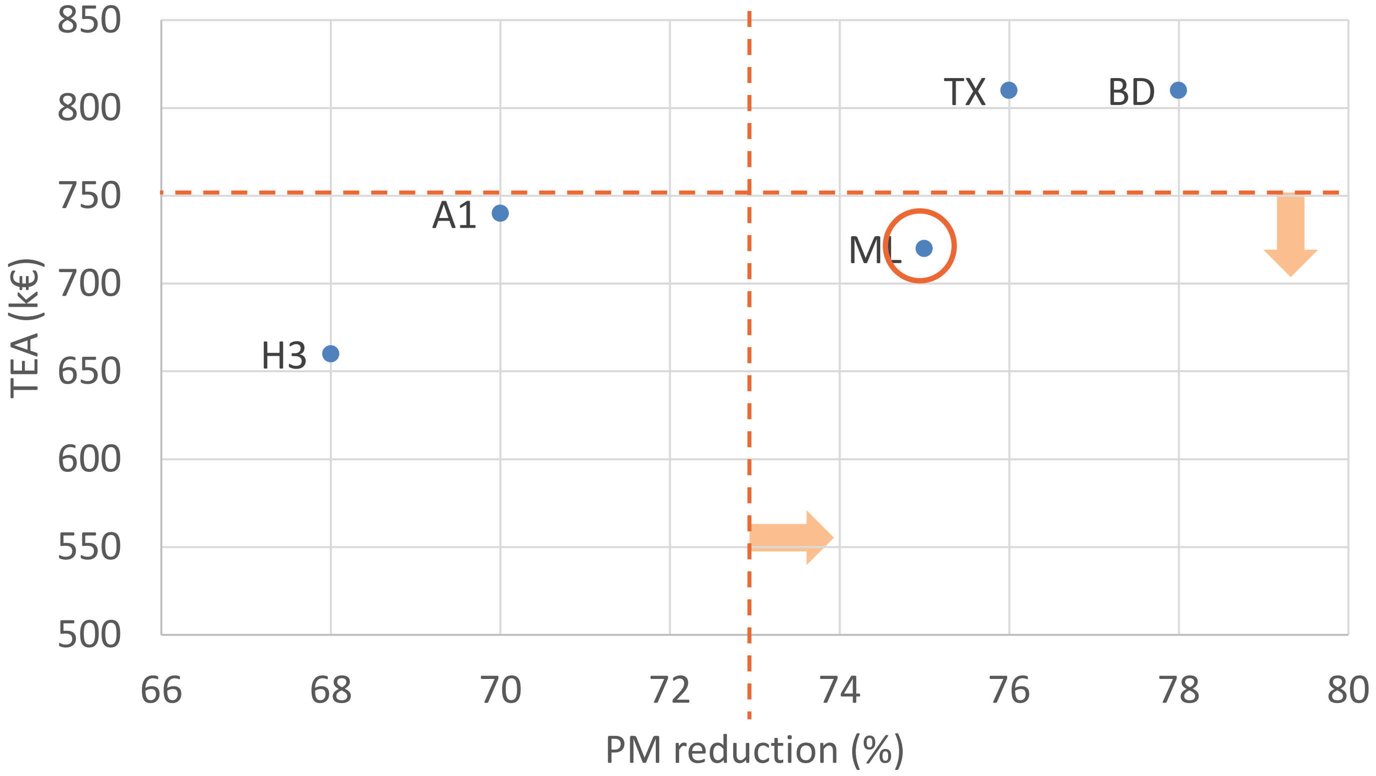
| Technology | C(a): TEA(k€) | E(a): PM red(%) | C/E (k€/U%) |
|---|---|---|---|
| A1 | 740 | 70 | 10.57 |
| BD | 810 | 78 | 10.38 |
| H3 | 660 | 68 | 9.71 |
| ML | 720 | 75 | 9.60 |
| TX | 810 | 76 | 10.66 |

- Adopting, for example, the following criteria we have:
  - minimum ratio C(a)/E(a) $\Rightarrow$ Alt “ML"
  - minimum C(a)/E(a), s.t. E(a) > 75% $\Rightarrow$ Alt “BD"
  - minimum C(a)/E(a), s.t. C(a) $\leq$ 750k€ $\Rightarrow$ Alt “ML”
  - minimum C(a)/E(a), s.t. E(a) $\geq$ 75% and C(a) $\leq$ 750k€ $\Rightarrow$ Alt “ML”

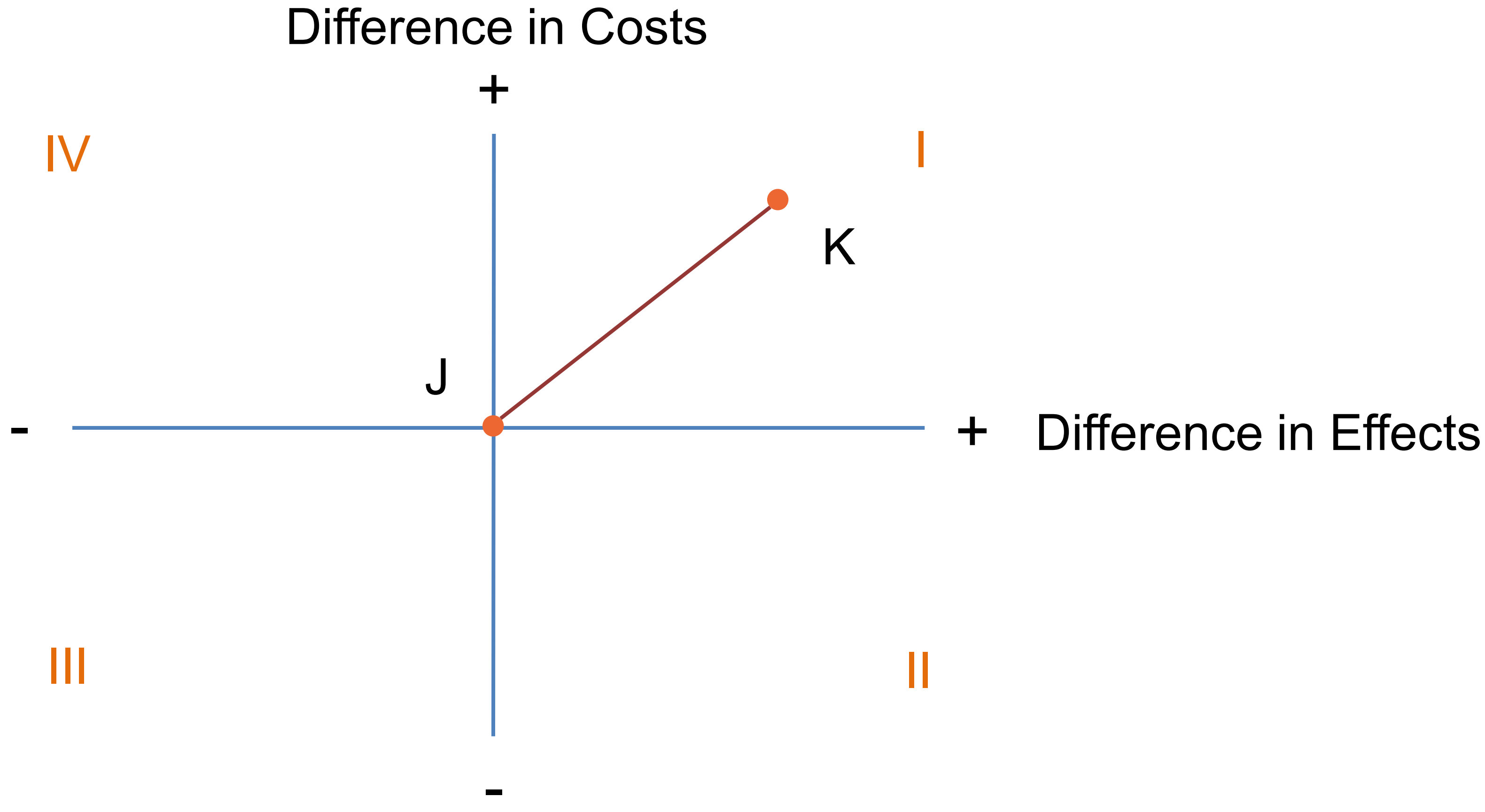
- The alternatives can be represented in the (C,E) graph:



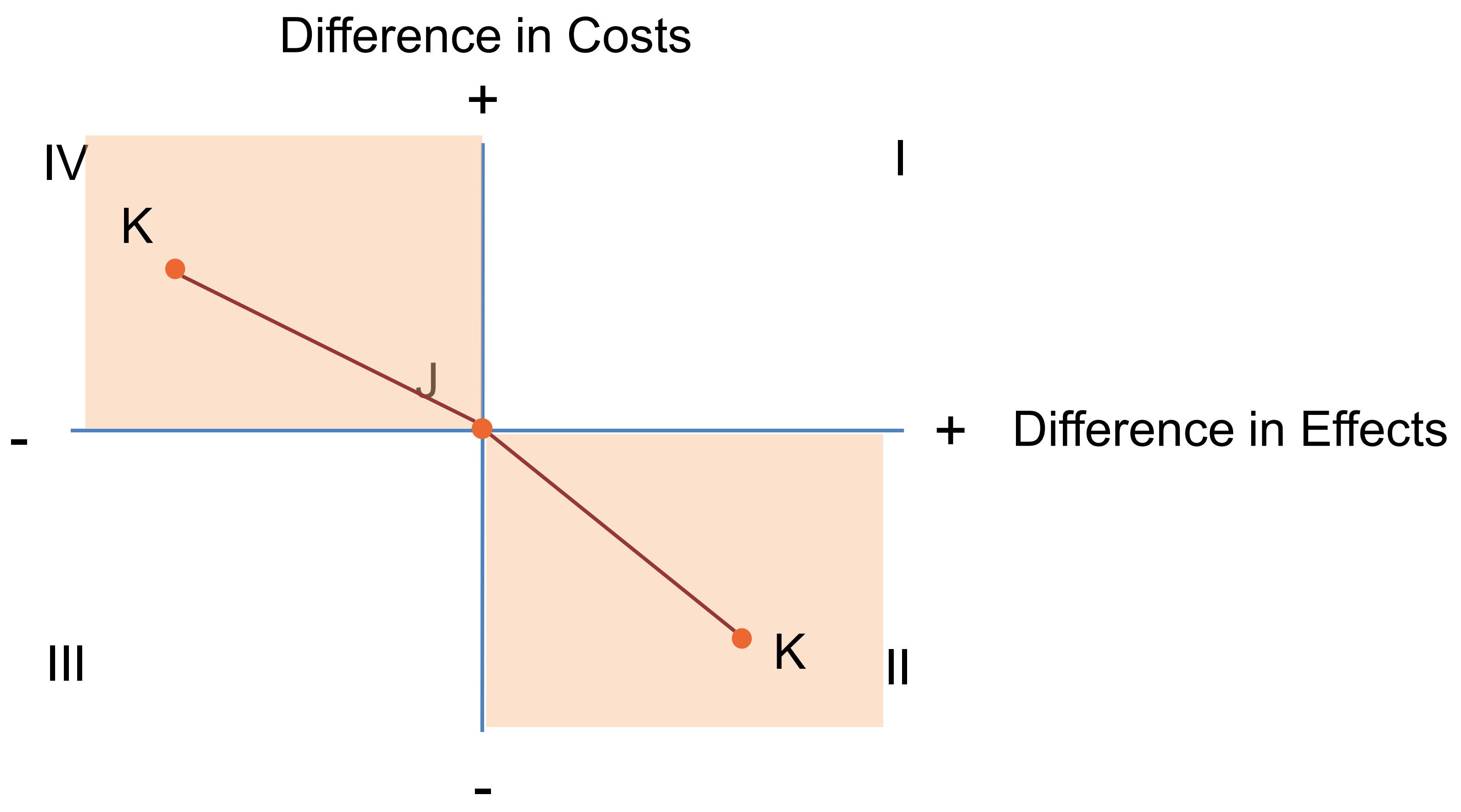
# If we aim to obtain minimum C(a)/E(a), s.t. E(a) ≥ 75% and C(a) ≤ 750k€:



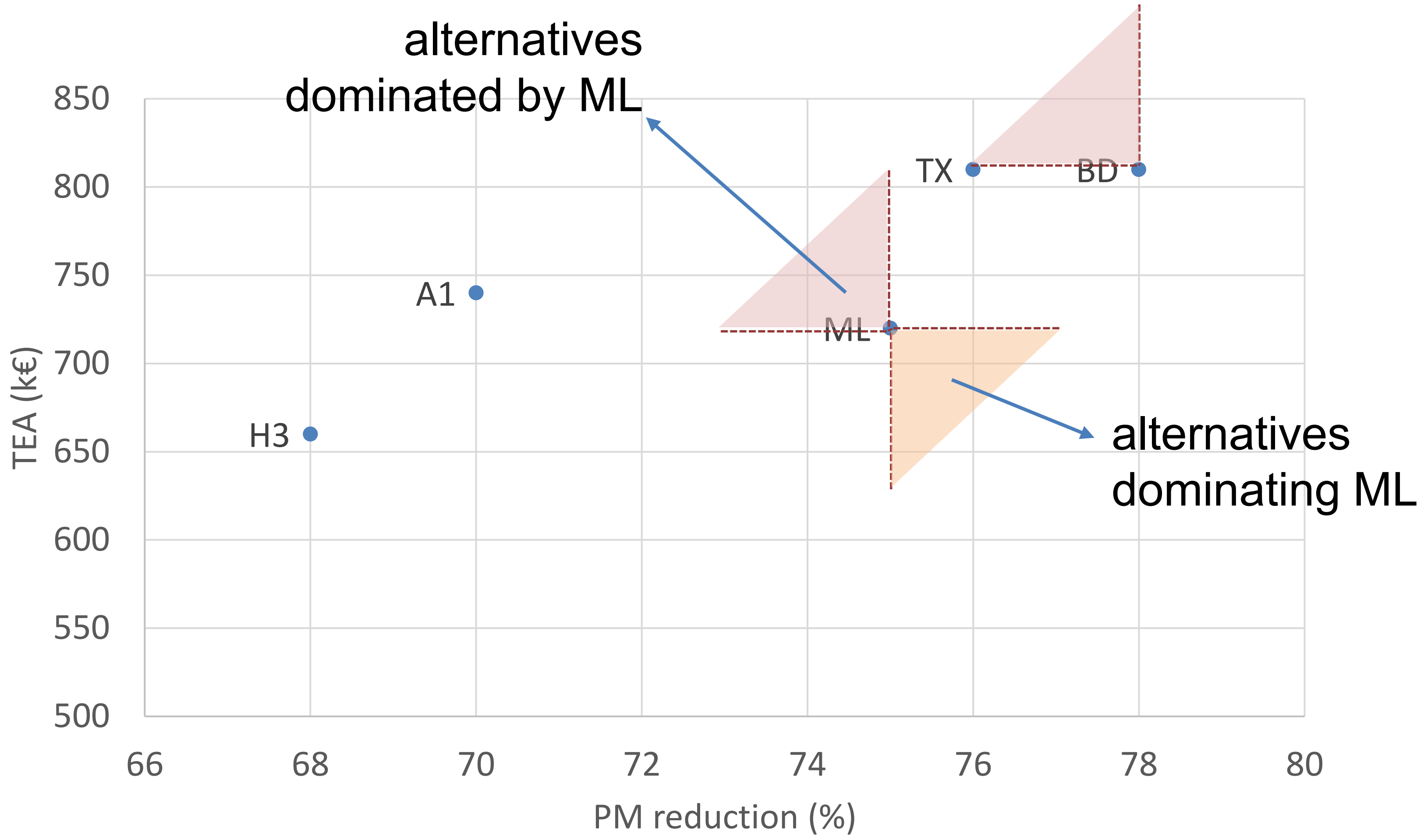
- For incremental analysis, the *cost-effectiveness graph* can be used.
- The costs and effects of one alternative are compared to another (including the current state):



- If K is in quadrant II, J is *dominated* by K (higher effectiveness, lower cost).
- If K is in quadrant IV, K *is dominated* by J (lower effectiveness, higher cost).

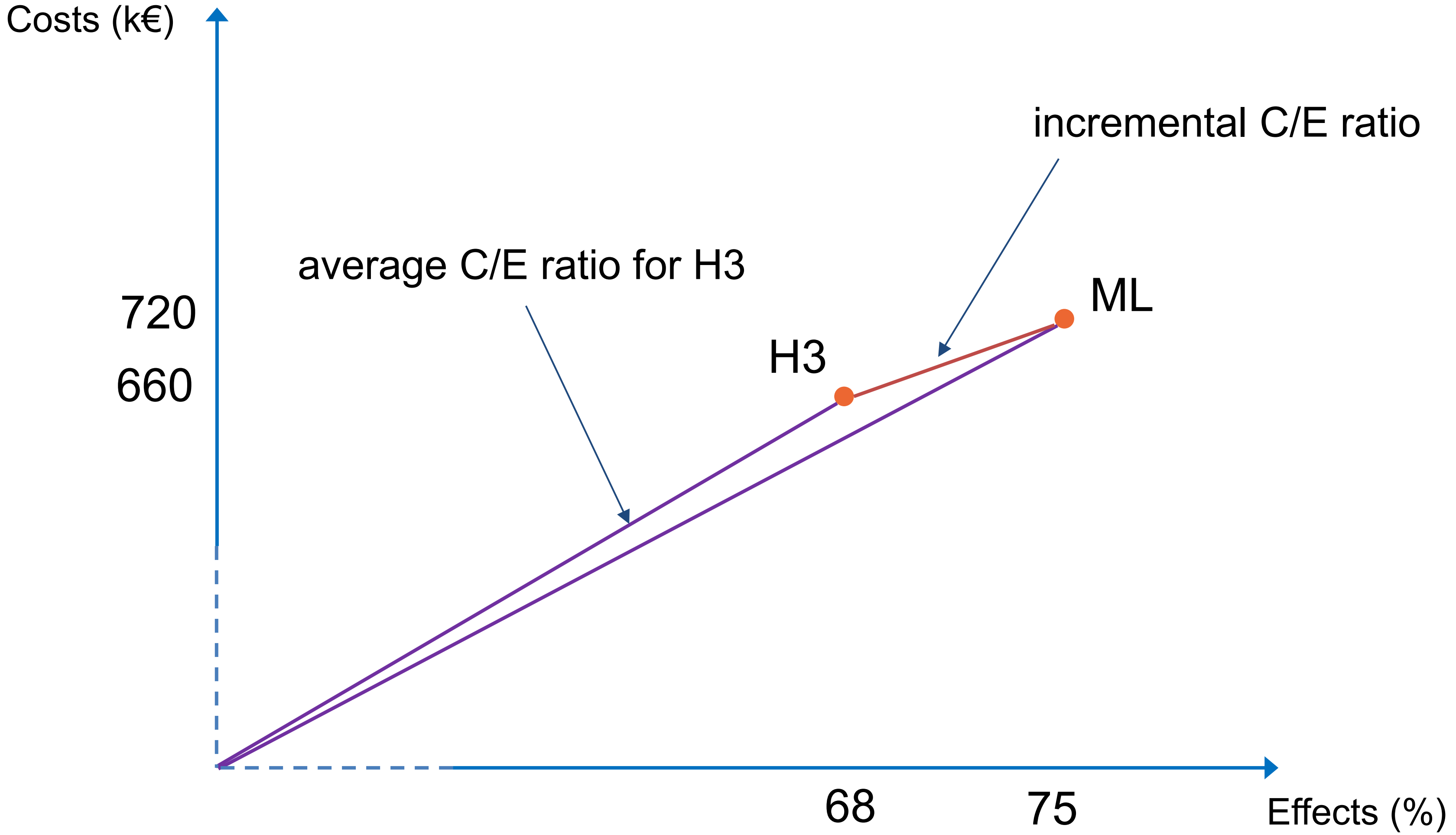


- In quadrants I and III, there is no dominance.
- The choice depends on the maximum cost-effectiveness value that the decision-maker is willing to accept.
- The slope of segment JK represents the *incremental cost-effectiveness* of K (moving from J).




A1 is dominated by ML
TX is dominated by BD

- Example [AVS]: Average C/E and incremental C/E



- The mean C/Es are the segments measured from the origin.
- Average C/E is here the average cost per unit percent (U%) of PM reduction compared to the base alternative.
- In the case of H3 and ML we have:
  - H3: 9.71 (k€/U%)
  - ML: 9.60 (k€/U%).
- These values have significance with respect to the as-is situation (base): ML is on average more efficient than H3.

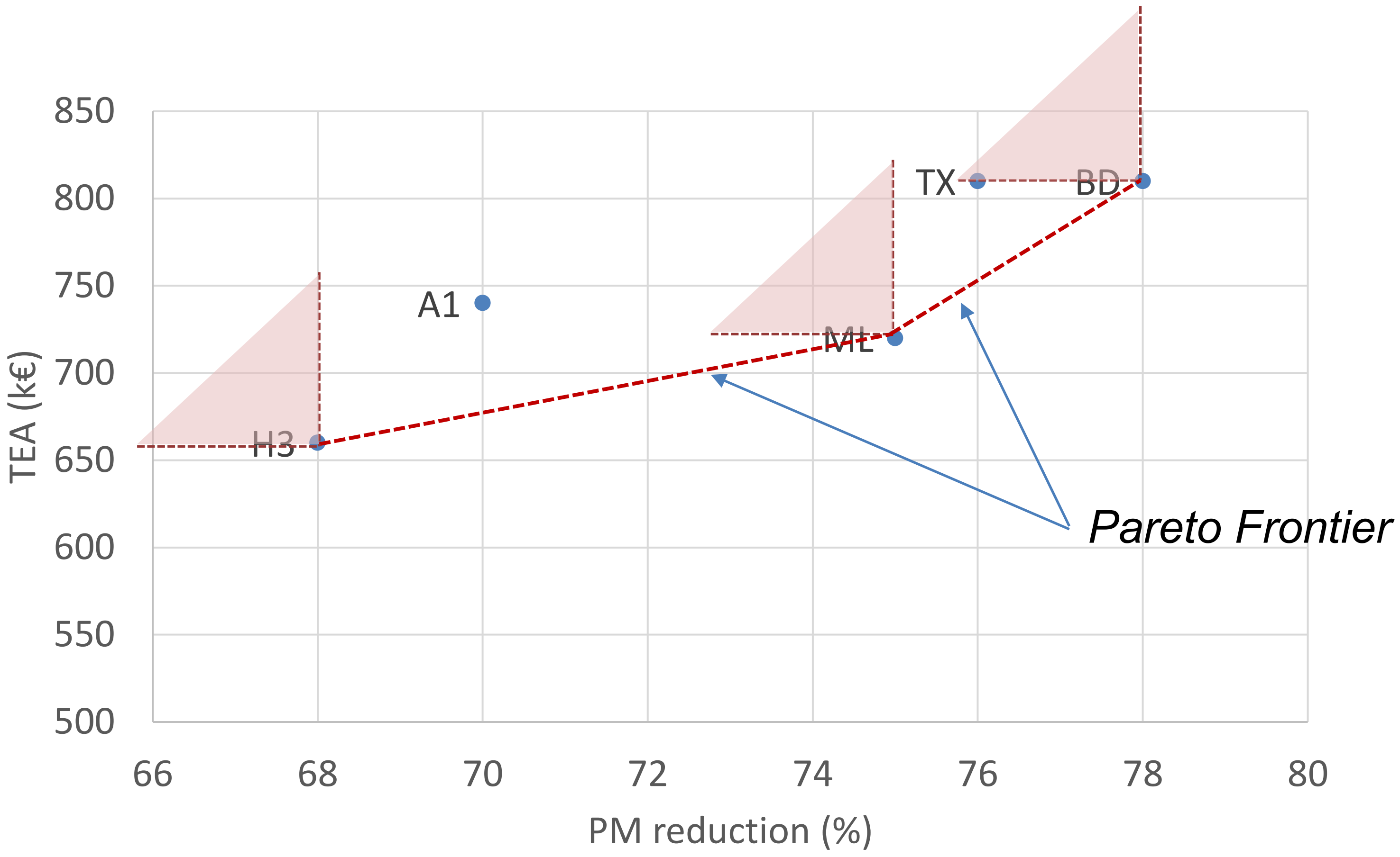
- However, a “new” alternative must be compared with the best available alternative.
- The relative comparison between non-dominated alternatives uses the *incremental cost-effectiveness ratio* (ICER).
- In this way, the decision maker judges if the cost increase, required by the new alternative to achieve an additional unit of effectiveness, is acceptable.

- In the example [AVS], the ICER going from the cheaper non-dominated alternative H3 to the more expensive ML is:

$$ICER_{ML-H3} = \frac{C_{ML} - C_{H3}}{E_{ML} - E_{H3}} = \frac{720 - 660}{75 - 68} \simeq 8.57\ (k€ / U\%)$$

- For each additional % unit of PM reduction, alternative ML costs 8.57k€ more than alternative H3.
- If the decision maker is willing to pay this value (or more) to achieve greater effectiveness in the abatement of PM, alternative ML will be chosen.

- The non-dominated alternatives identify a *Pareto* or *efficient frontier* (*PF*).
- Solutions $a_i \in PF$ are not dominated by others $a_k \in PF$.
- In order to switch from one $a_k$ to one $a_j$ ($a_k$ ,$a_j \in PF$), a *trade-off* between cost and effectiveness must be accepted.


850
800
750
700
650
600
550
500
TEA (k€)
66
68
70
72
74
76
78
80
PM reduction (%)
H3
A1
ML
TX
BD
Pareto Frontier