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AN APPROACH FOR A BETTER EVALUATION OF ENERGY EFFICIENCY TRENDS

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Energy efficiency

- Fundamental for security, competitiveness and sustainability
- There is no consensus on the perspective of efficiency that should be tracked

Energy efficiency= Useful output provided/ Energy input converted to provide it

*i.e. any function, service, or value

Energy efficiency indicators

- Thermodynamic (TEE)
  - 1st and 2nd-law eff. *[TJ /TJ]*
- Physical-Thermodynamic (PTEE)
  - E.g. Fuel eff. *[km /TJ]* or light eff. *[lm /kW]*
- Economic-Thermodynamic (ETEE)
  - Inverse energy intensity *[USD/TJ]*
- Economic (EEE)
  - Output per energy-USD *[USD/USD]*

Energy efficiency evaluation

- Economic-thermodynamic indicators are the most used for monitoring economy-wide trends

- Policy targets at the macro level focus on energy intensity or savings; while actual policy measures focus on technical energy efficiency.

We propose an approach that allows disentangling the technical energy efficiency from the energy intensity.

Energy-related decomposition

- Identifies the driving factors of changes in indicators
- Helps evaluate policy effectiveness, plan measures and forecast future trends
- IDA is preferred for long term historical analysis (also due to data)

Aggregate intensity

Sectoral energy intensity

$$I_A = \sum_i Q_i / Q \times E_i / Q_i = \sum_i S_i \times I_i$$

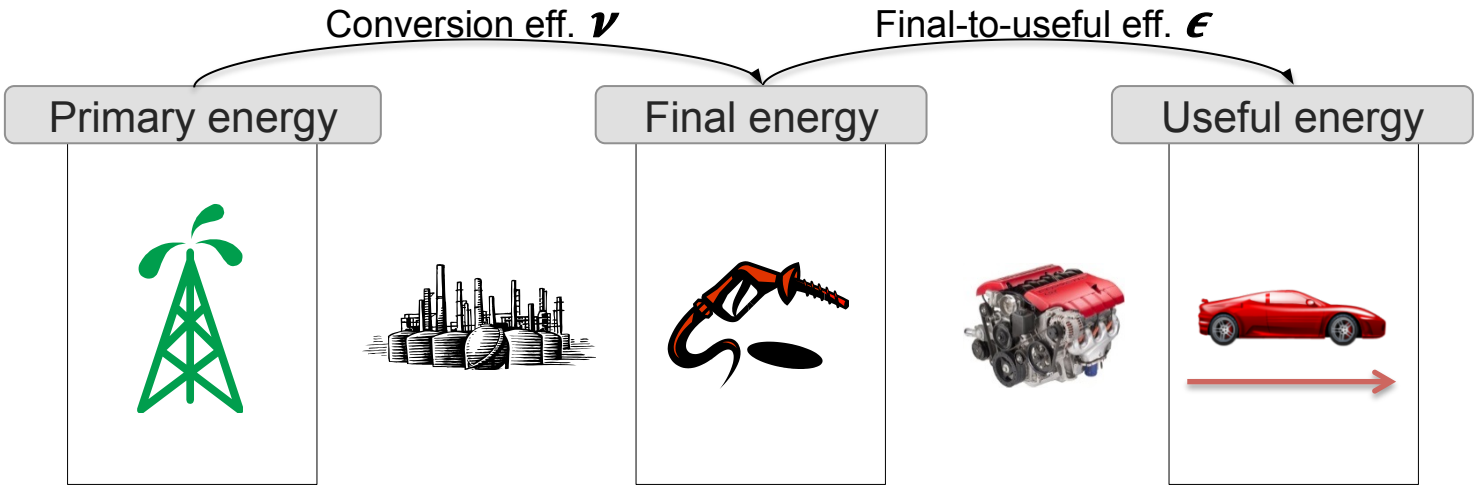
- Decomposition

Activity mix

$$\Delta I_A = I_{A\,t1} - I_{A\,t0} = C_S + C_I$$

Useful energy accounting

- Developed by R. Ayres & B. Warr and lately by others
- UE is in terms of exergy, which measures the quantity and quality of energy carriers
- UE focuses on the productive role instead of on carriers



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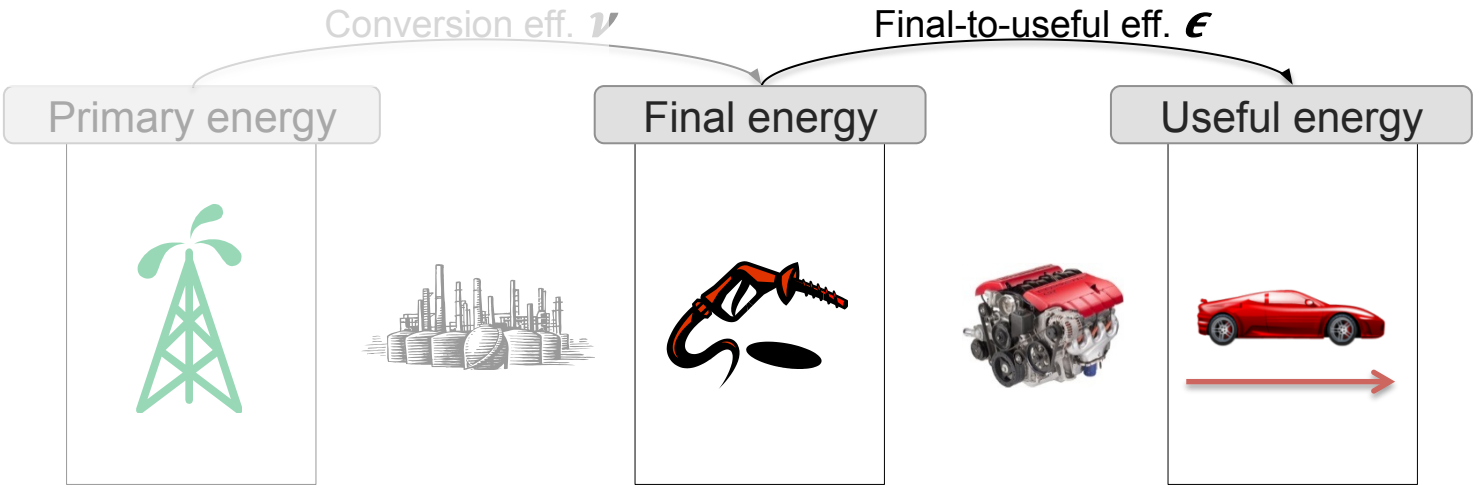


UE: Technical efficiency

- UE analysis disaggregates final energy intensity into a thermodynamic eff. (ϵ) and UE intensity

$$I\downarrow i = E\downarrow i \,/ Q\downarrow i \;=\; 1/\epsilon\,(UE\downarrow i \,/ Q\downarrow i\;)$$

- ϵ means
  - efficiency of the end-use device (single process)
  - aggregate efficiency / *Technical efficiency (*economy)

UE-based IDA

- Our model

Sectoral useful E. intensity

$$I_A = \sum_i Q_i / Q \times 1/\epsilon_i \times UE_i / Q_i = \sum_i S_i \epsilon_i^{-1}$$

UEI_i

Aggregate intensity

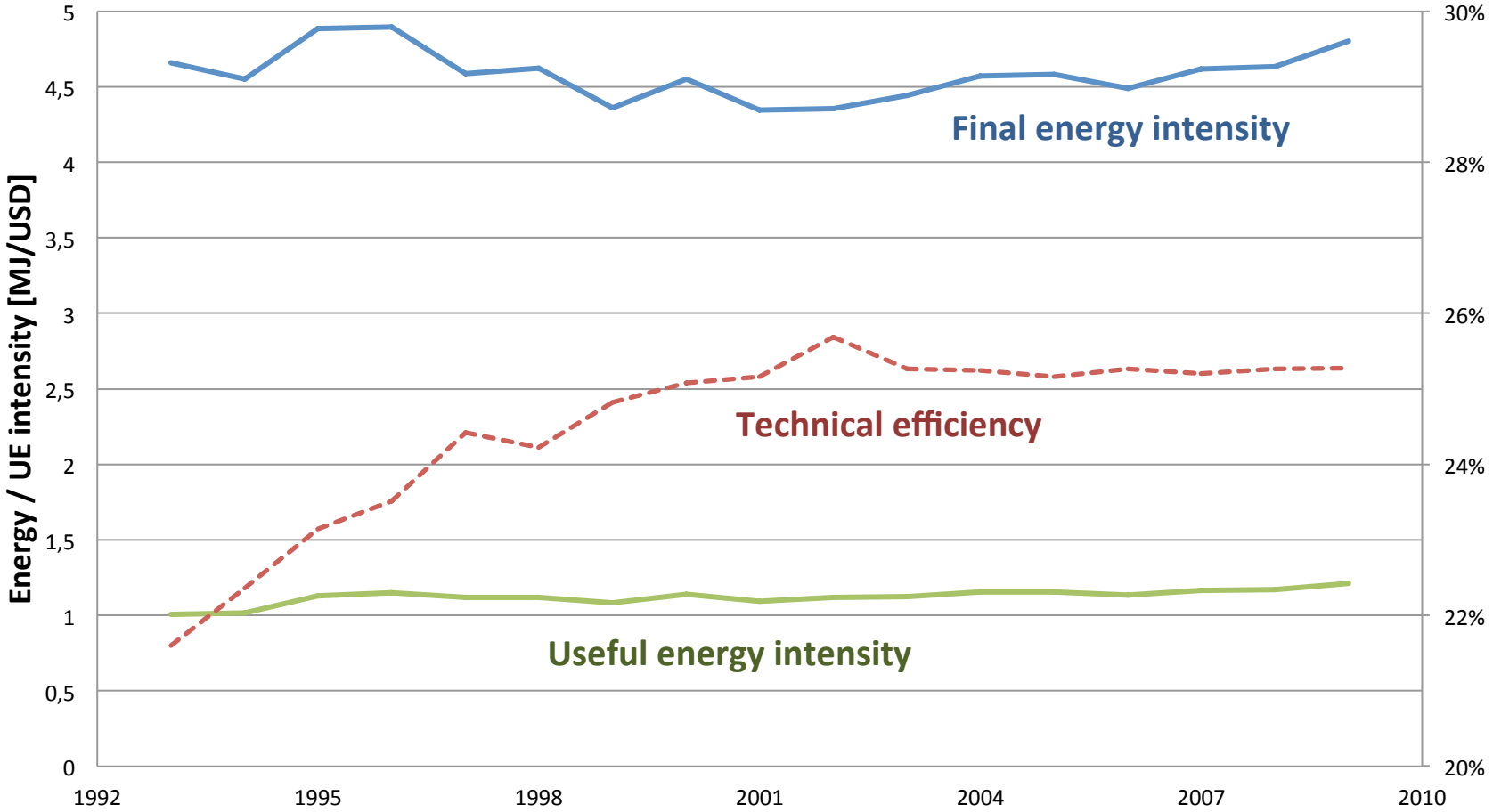
Inverse technical efficiency

- Decomposition

$$\Delta I_A = I_A^{t1} - I_A^{t0} = C_S + C_\epsilon + C_{UEI}$$

- We use the LMDI technique to calculate coefficients

Mexican industrial sector



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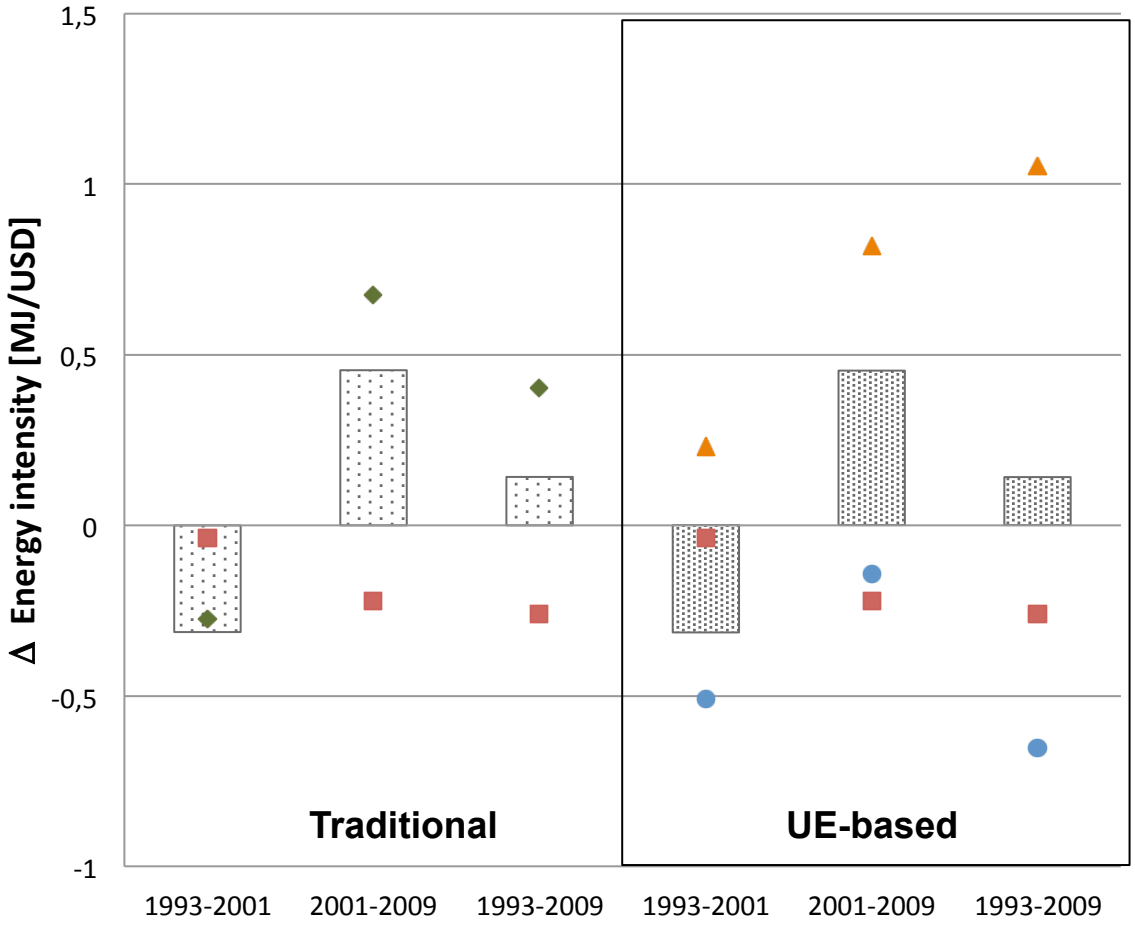
Results (1)



Total change $\Delta I \downarrow A$

Effect of factor changes

- Final E intensity $C \downarrow I$
- Useful E intensity $C \downarrow UEI$
- Technical efficiency $C \downarrow \epsilon$
- Activity Mix $C \downarrow S$

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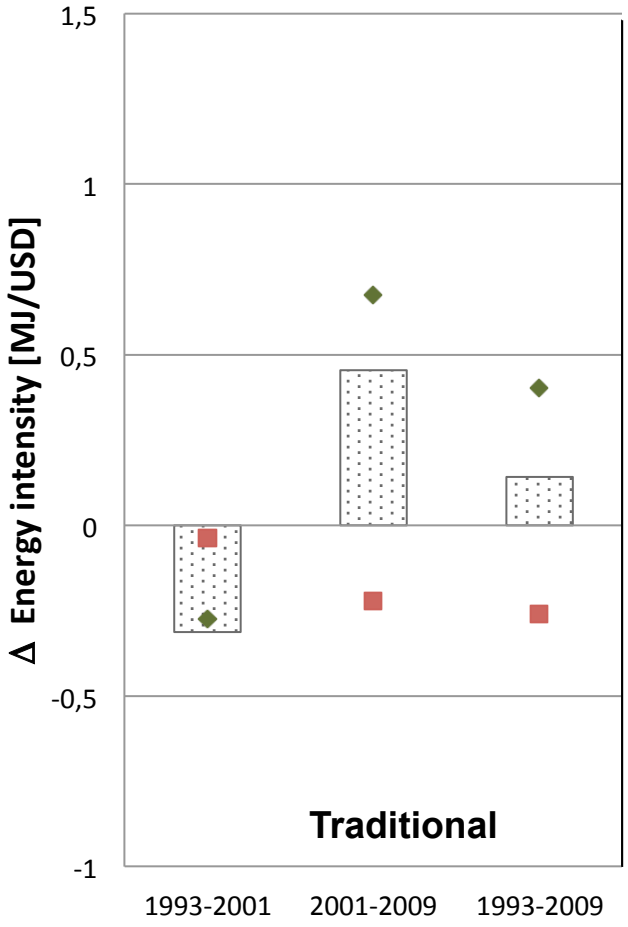
Results (1)



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Final E intensity $C \downarrow I$

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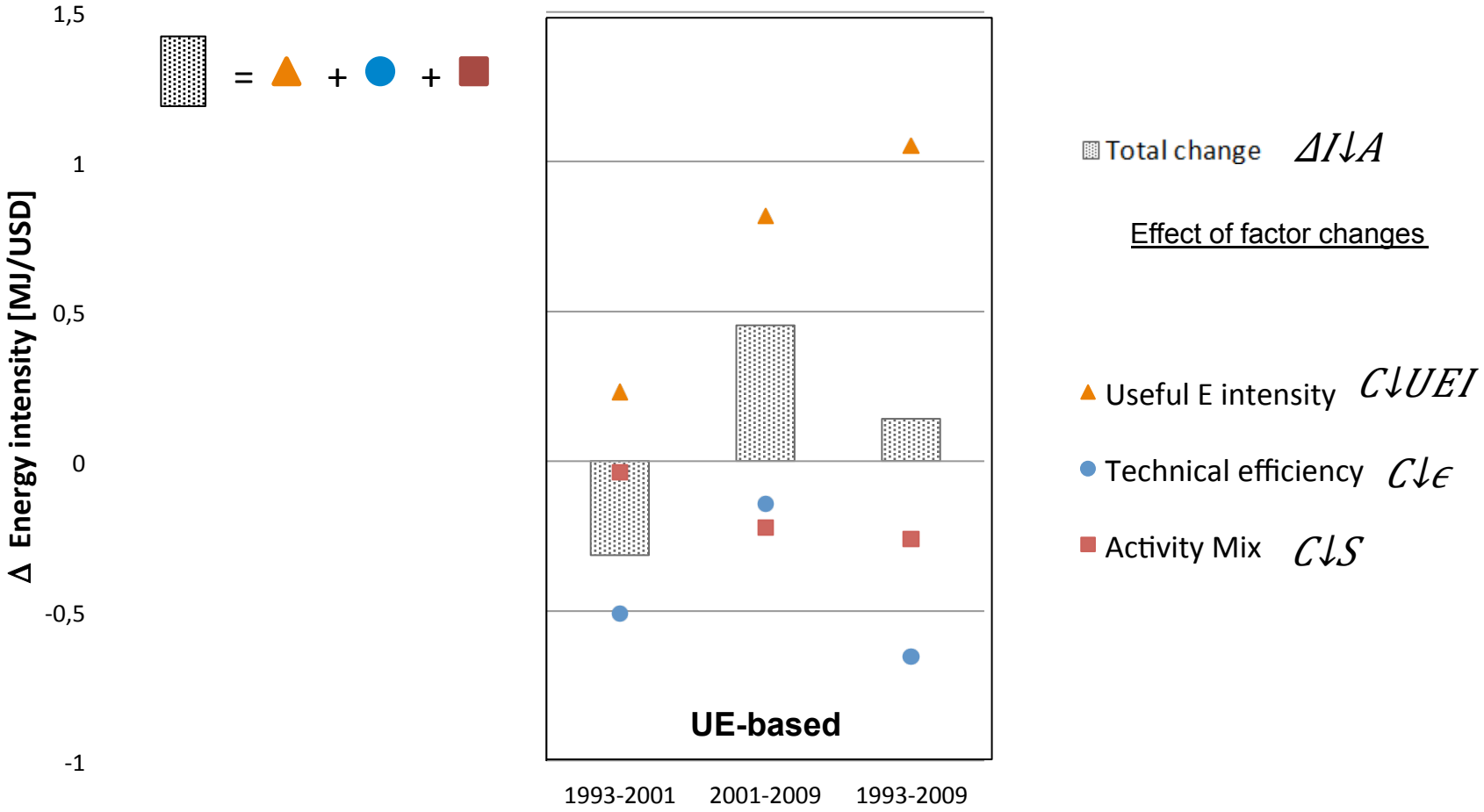
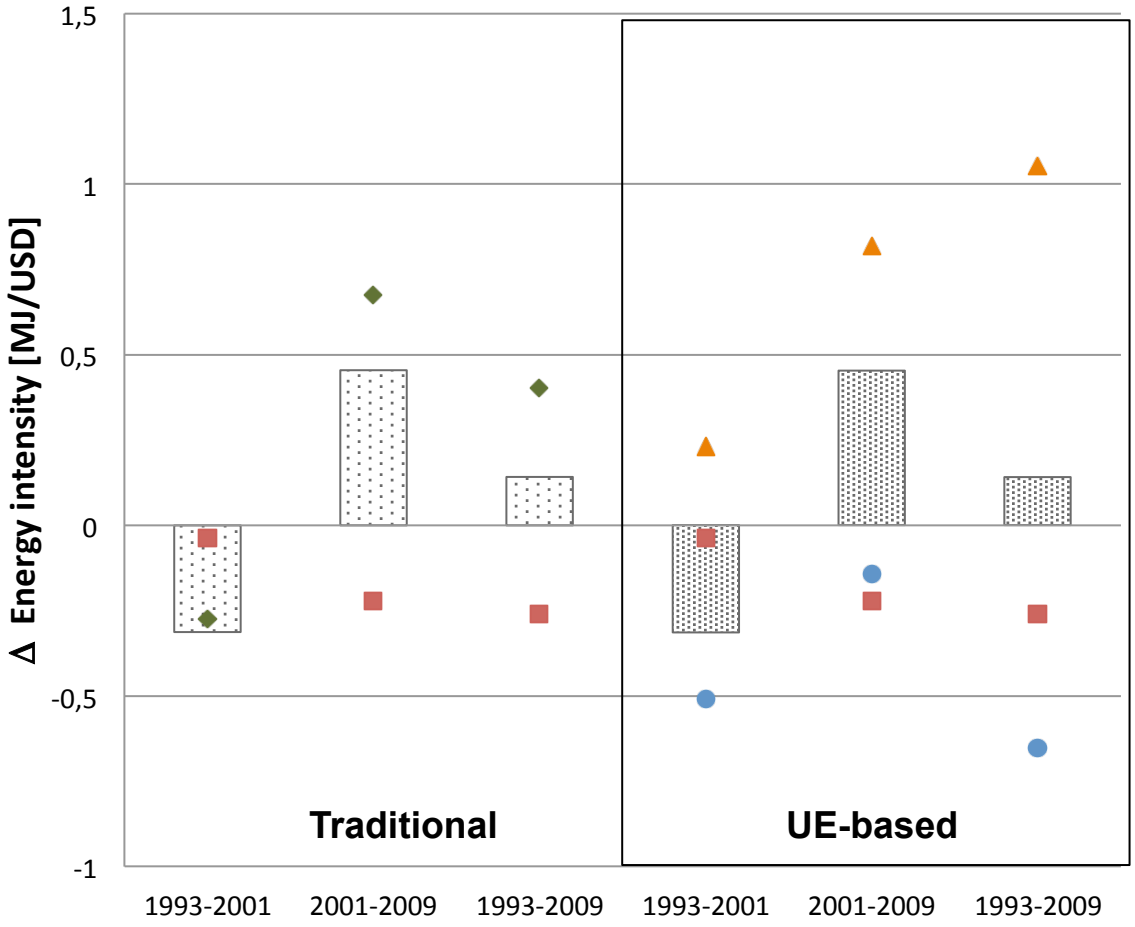
Results (1)


1,5
1
0,5
0
-0,5
-1
Δ Energy intensity [MJ/USD]
=
+
+
UE-based
1993-2001
2001-2009
1993-2009
Total change ΔI↓A
Effect of factor changes
Useful E intensity C↓UEI
Technical efficiency C↓ϵ
Activity Mix C↓S

Results (1)



Total change $\Delta I \downarrow A$

Effect of factor changes

- Final E intensity $C \downarrow I$
- Useful E intensity $C \downarrow UEI$
- Technical efficiency $C \downarrow \epsilon$
- Activity Mix $C \downarrow S$

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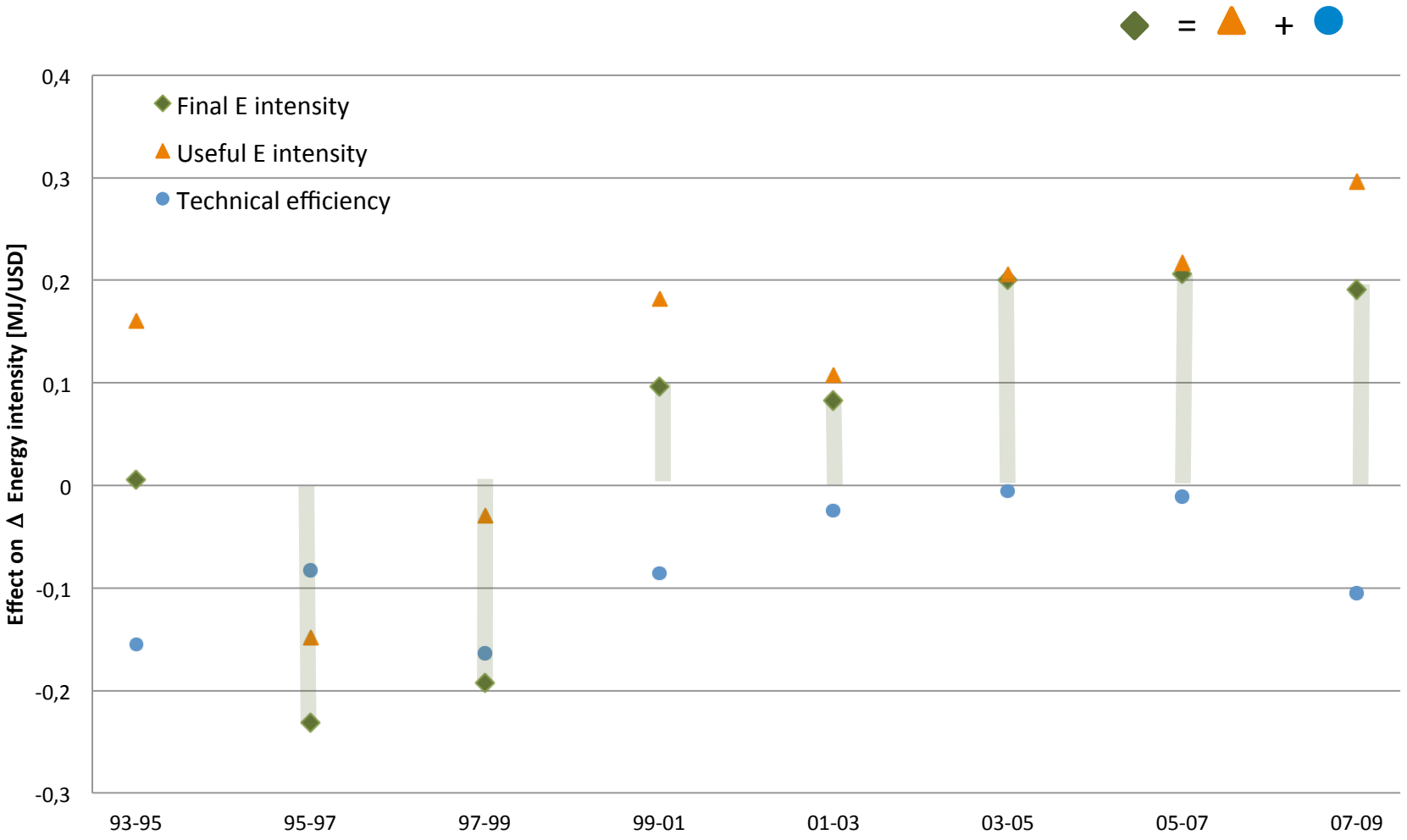
Results (2)



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Conclusions

- Our approach
  - calculates the effect of technical energy efficiency
  - provides results aligned with historical structural transitions
  - clarifies that UE intensive does not necessarily mean less efficient
  - is suitable to evaluate the effectiveness of energy policies
  - emphasizes the need of measures to reduce UE intensity

- The traditional approach could sometimes lead to misinterpretation of efficiency trends
- A drawback of our approach is the limited availability of sectoral UE data

Questions

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Energy efficiency categories

Category	Advantages	Disadvantages
Thermodynamic (TEE)	Based on and limited by physical principles Objectively measured hence convergent	Of limited for macro-level analysis Unable to include end use services
Physical-Thermodynamic (PTEE)	Adequately reflect end use services Objectively measured hence convergent	Too specific Cannot be compared between services Unable to be generalize
Economic-Thermodynamic (ETEE)	Applicable to different aggregation levels Can be compared btw sectors and countries	Cannot accurately measure tech. efficiency It is influenced by other economic variables
Economic (EEE)	Include the value of energy commodities	Same as ETEE

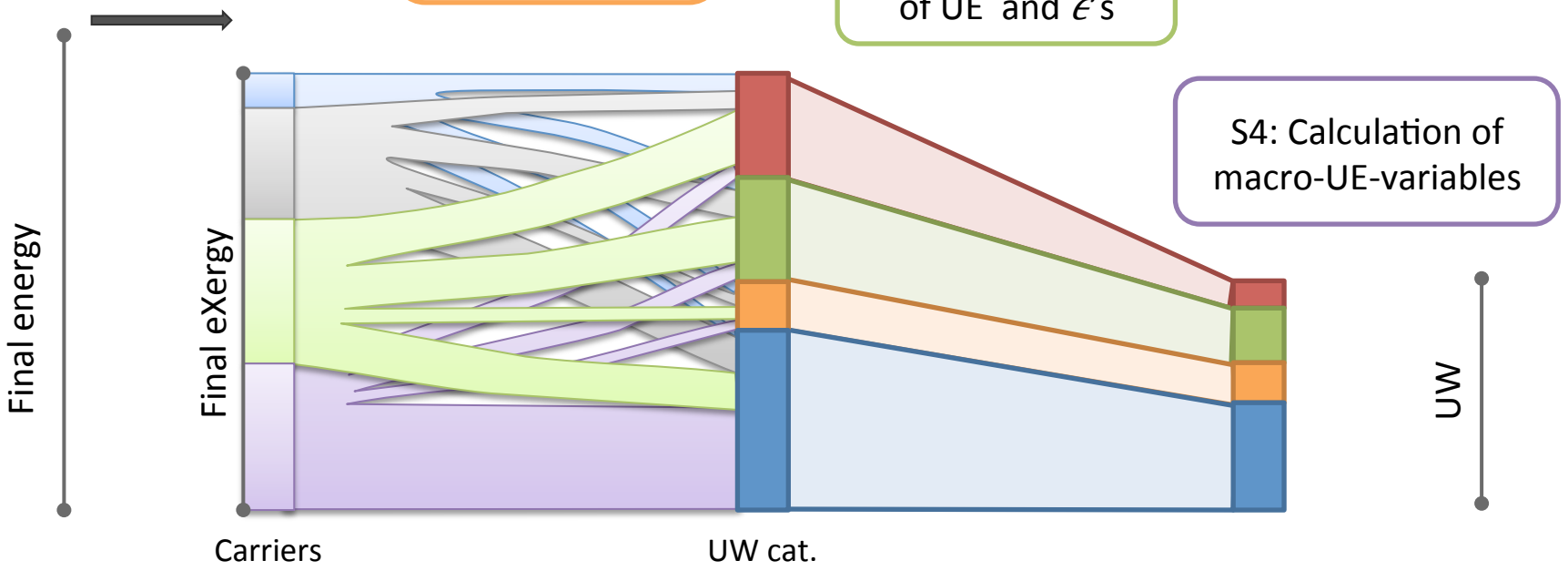
UEA: Steps

S1: Conversion of energy to exergy values

S2: Allocation of final exergy to UE categories

S3: Computation of UE and ϵ's

S4: Calculation of macro-UE-variables



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