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A computational model linking EnergyPLAN with Input-Output analysis for evaluating the macroeconomic impact of the transition at regional level

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Rationale of the work (by simplifying)

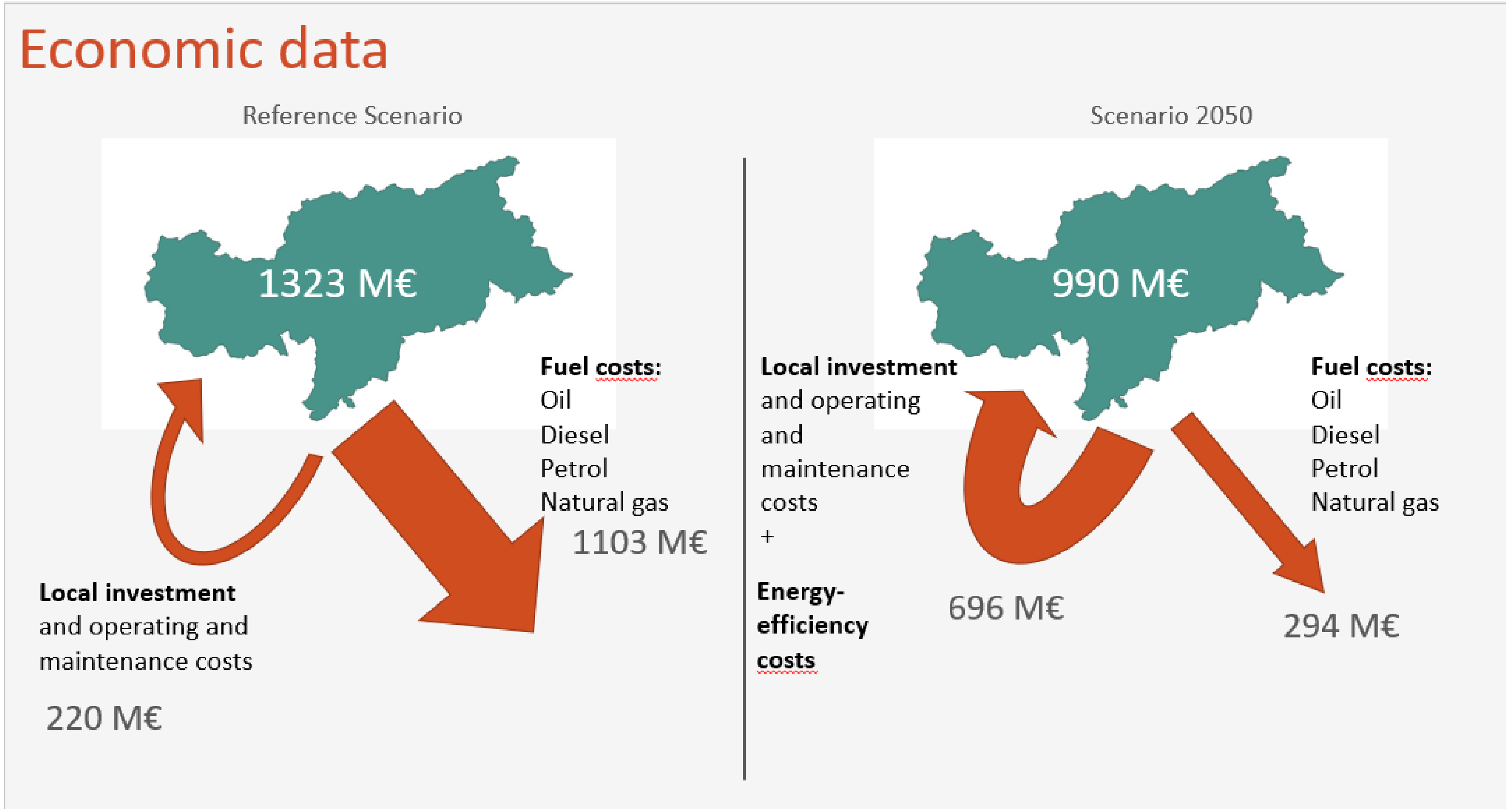
- Energy (bottom up) models lack in addressing macroeconomic aspects (impacts on sectors, GDP, employment)

- Economic (top down) models lack in capturing the complexity of energy systems (particularly flexibility, sizing of storage needs)

- Hybrid models are complex, requires many data and are not diffused at regional level

Objectives

- Extending the economic analysis' capacity of the EPLANopt model (EnergyPLAN's extension by Eurac) beyond investment and O&M costs analysis



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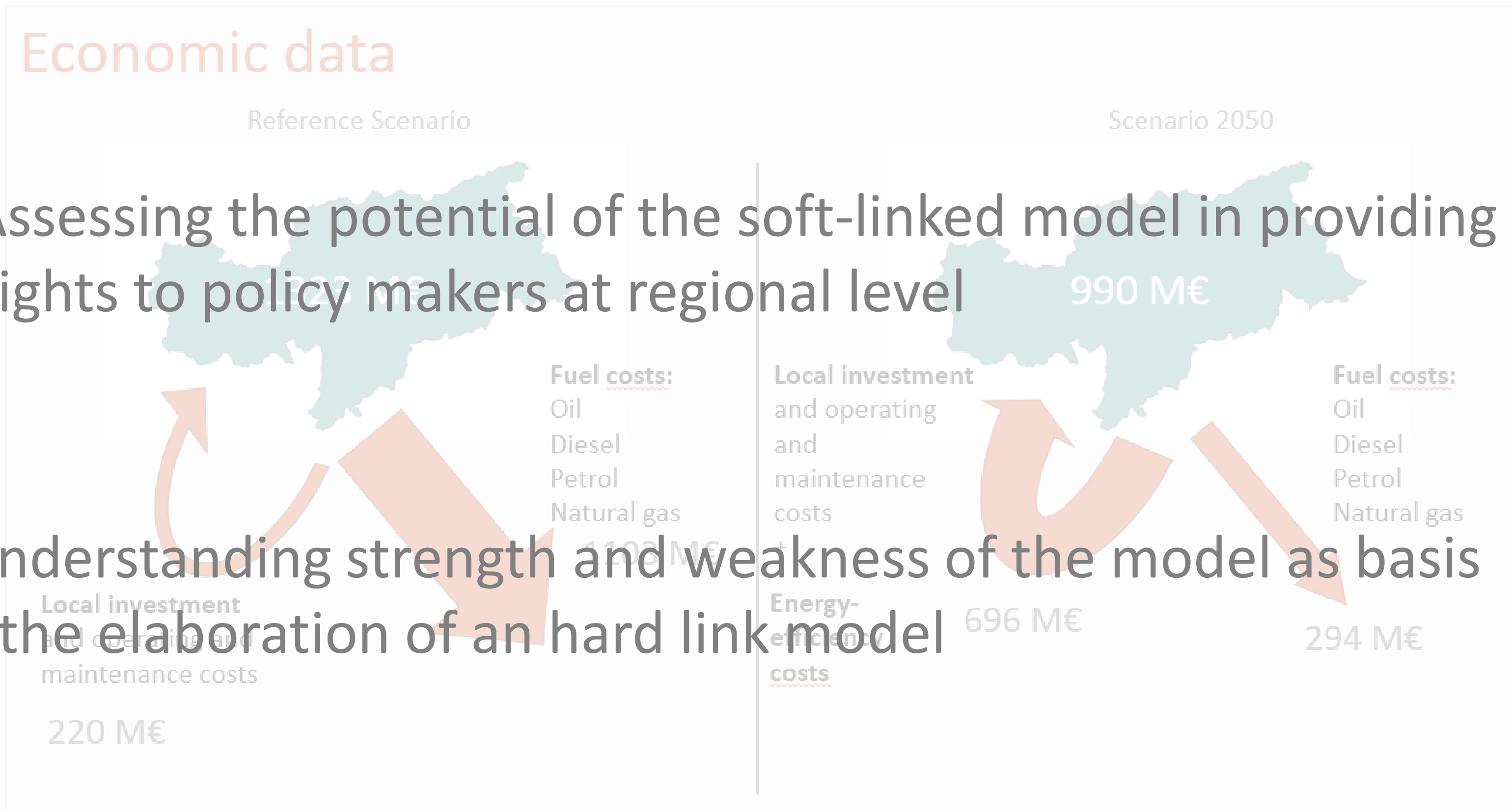


- Assessing the potential of the soft-linked model in providing insights to policy makers at regional level

- Understanding strength and weakness of the model as basis for the elaboration of an hard link model

Novelty of the work

- First soft-link between EPLANopt and an Input-Output (IO) model

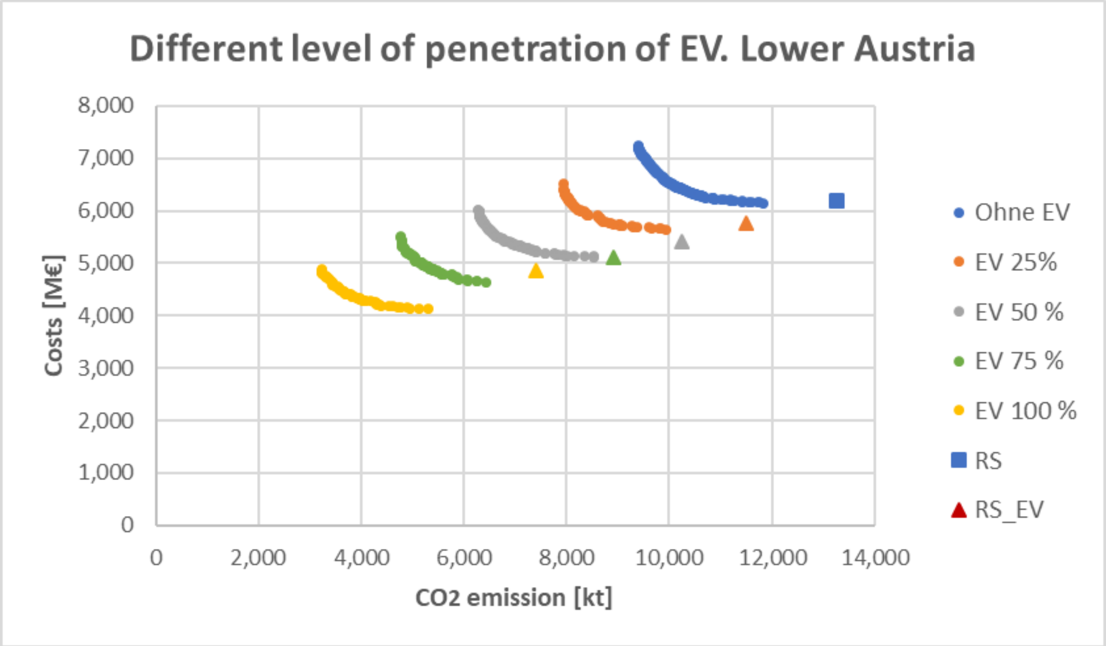
- Input-Output model is defined in mixed units, enabling:
  * energy balance check (validation procedure)
  * direct physical (and monetary) inputs from energy model (allows directly assessing the effect of energy changes)

- The soft-linked model is applied at regional level - South Tyrol (IT) - with high time and space resolutions

EPLANopt

EPLANopt is a software, developed in Python by Eurac, to run a genetic optimization for the EnergyPLAN software
https://gitlab.inf.unibz.it/URS/EPLANopt

- it allows to calculate the Pareto front of optimal multi-objective solutions



- Electric vehicles penetration is an exogenous variable

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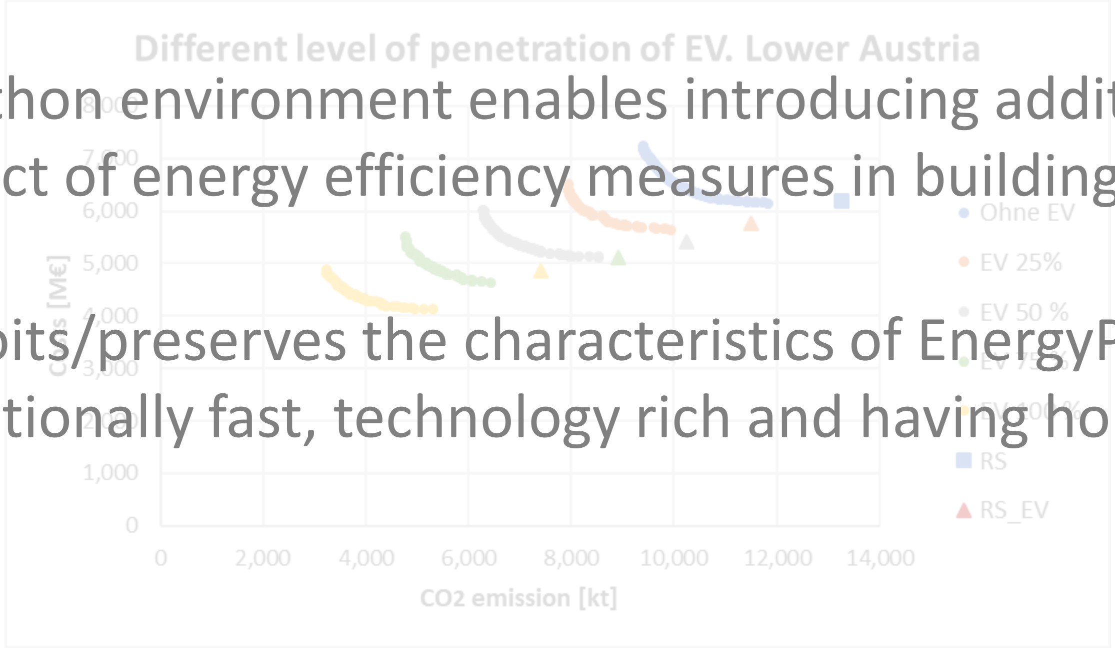


- the Python environment enables introducing additional features (e.g. effect of energy efficiency measures in buildings)

- it exploits/preserves the characteristics of EnergyPLAN of being: computationally fast, technology rich and having hourly resolution

Input Output models

- Based on standardised table and on the application of the Leontief model: $x = (I-A)^{-1} f$

XX	Dati 2011	Agricoltura, silvicoltura	Pesca	Estrazione di minerali da cave e miniere	Industrie alimentari delle bavande e	Industrie tessili, abbigliamento, pelli e	Industria del legno	Carta, stampa e registrazione	Fabbricazione di coke e prodotti petroliferi	Fabbricazione di prodotti chimici	Fabbricazione di prodotti farmaceutic	Fabbricazione di articoli in gomma e materie	Altri prodotti della lavorazione	Metallurgia; fabbricazione di prodotti in	Fabbric ne di comput prodott
XX	Categorie	AA	AB	B	CA	CB	CCA	CCB	CD	CE	CF	22	23	CH	
AA	Agricoltura, silvicoltura	93.9	0.0	0.0	349.7	2.4	13.6	0.5	0.0	0.4	0.0	1.3	0.1	1.3	
AB	Pesca	0.0	0.0	-	1.5	0.0	-	-	-	0.0	0.0	-	-	-	
B	Estrazione di minerali da cave e miniere	0.1	0.0	2.6	0.7	0.0	0.3	0.1	10.0	0.5	0.0	0.1	11.0	1.0	
CA	Industrie alimentari delle bavande e del tabacco	62.6	0.0	0.1	249.4	1.1	0.4	0.5	0.0	4.1	0.3	1.0	0.3	0.8	
CB	Industrie tessili, abbigliamento, pelli e accessori	1.1	0.0	0.0	0.6	19.8	1.9	0.2	0.0	0.8	0.1	1.7	0.3	1.6	
CCA	Industria del legno	0.9	0.0	0.3	6.9	0.3	185.5	0.6	0.0	2.0	0.1	2.7	1.8	6.6	
CCB	Carta, stampa e registrazione	0.2	0.0	0.1	10.4	0.6	2.7	17.8	0.0	2.5	0.2	1.6	0.9	3.4	
CD	Fabbricazione di coke e prodotti petroliferi raffinati	8.6	0.0	0.7	2.1	0.2	1.5	0.2	1.0	1.8	0.1	0.3	1.9	1.9	
CE	Fabbricazione di prodotti chimici	6.4	0.0	0.3	8.5	2.1	3.5	2.2	0.2	21.6	1.6	15.9	2.3	3.6	
CF	Fabbricazione di prodotti farmaceutici di base e di preparati farmaceutici	0.4	0.0	0.0	0.6	0.1	0.2	0.1	0.0	1.4	0.1	1.1	0.1	0.2	
22	Fabbricazione di articoli in gomma e materie plastiche	1.1	0.0	0.3	10.2	0.9	2.3	0.9	0.1	3.9	0.2	17.5	1.3	5.6	
23	Altri prodotti della lavorazione di minerali non metalliferi	1.7	0.0	2.7	12.4	0.2	3.1	0.1	1.0	2.6	0.2	0.6	17.9	4.3	
CH	Metallurgia; fabbricazione di prodotti in metallo	2.0	0.0	0.4	10.4	0.7	18.2	1.0	0.1	3.4	0.2	6.2	3.6	185.4	
CI	Fabbricazione di computer e prodotti di elettronica e ottica	0.1	0.0	0.1	1.1	0.1	0.4	0.1	0.0	0.2	0.0	0.3	0.2	1.8	
CJ	Fabbricazione di apparecchiature elettriche	0.4	0.0	0.1	2.2	0.2	1.5	0.5	0.1	1.5	0.1	1.9	0.6	10.0	
CK	Fabbricazione di macchinari ed apparecchiature n.c.a.	0.4	0.0	1.1	9.3	1.0	3.6	1.0	0.1	1.6	0.1	2.8	2.0	15.4	
CL	Fabbricazione di mezzi di trasporto	1.3	0.0	0.1	0.4	0.1	0.4	0.0	0.0	0.2	0.0	1.2	0.2	2.6	
CM	Altre industrie manifatturiere	0.5	0.0	0.1	3.8	0.6	3.4	0.8	0.1	1.0	0.1	1.0	0.9	5.9	
D	Fornitura di energia elettrica, gas, vapore e aria condizionata	15.0	0.0	1.9	39.9	4.0	12.4	2.4	0.3	7.0	0.5	8.2	13.2	13.6	
E	Fornitura di acqua; reti fognarie, attività di gestione dei rifiuti e risanamento	1.7	0.0	0.2	4.4	0.4	1.4	0.3	0.0	0.8	0.1	0.9	1.5	1.5	

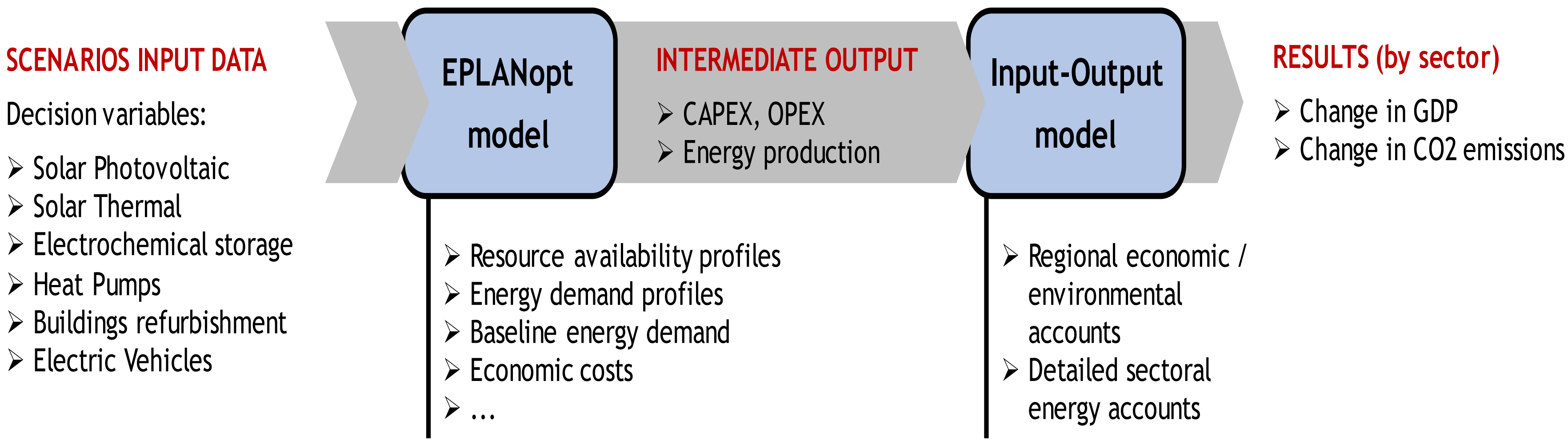
Input Output models

- Based on standardised table and on the application of the Leontief model: $x = (I-A)^{-1} f$
- Versatile in use (macroeconomic, environmental and material use analysis)
- Computational fast (linear algebra calculations) and limited data request (given the availability of the IO tables)
- Present limits to be aware of: e.g. constant returns to scale, resources supply is infinite and perfectly elastic, constant technology coefficients

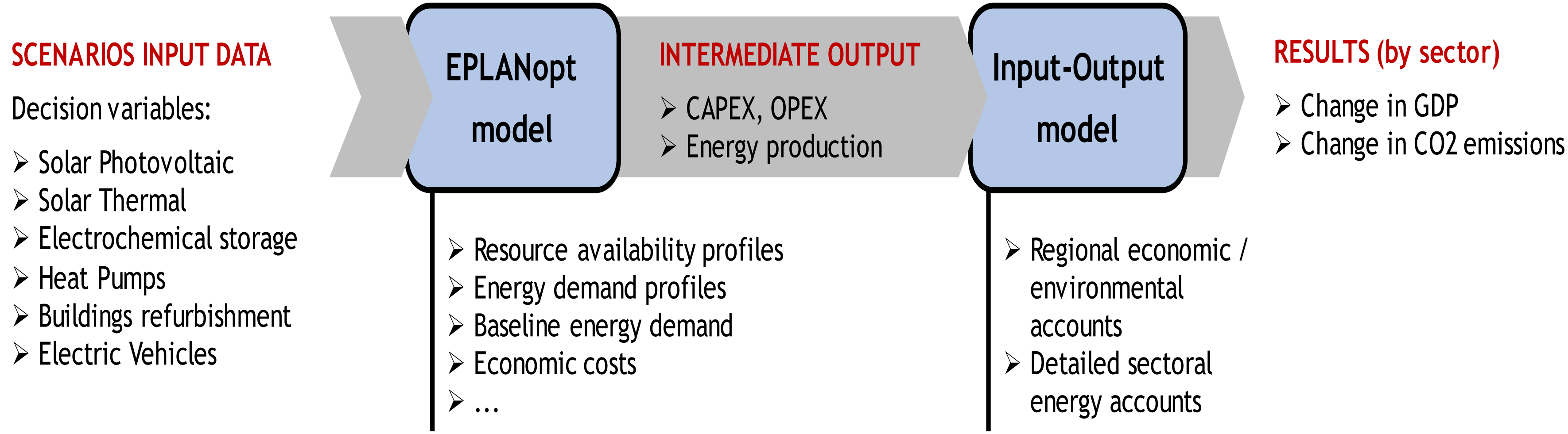
Soft-linked model

Information and data exchange between the models is provided and controlled by the user

- It has been set up in Python (and excel)

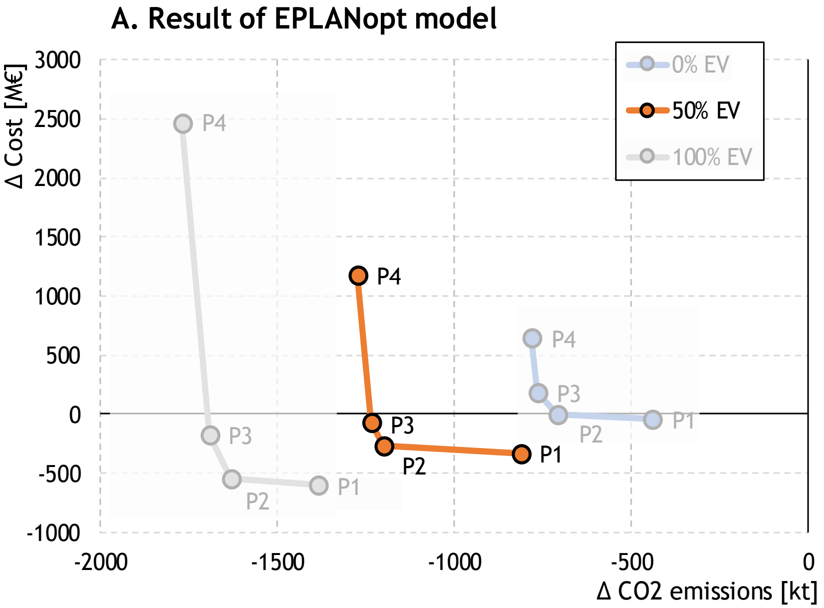


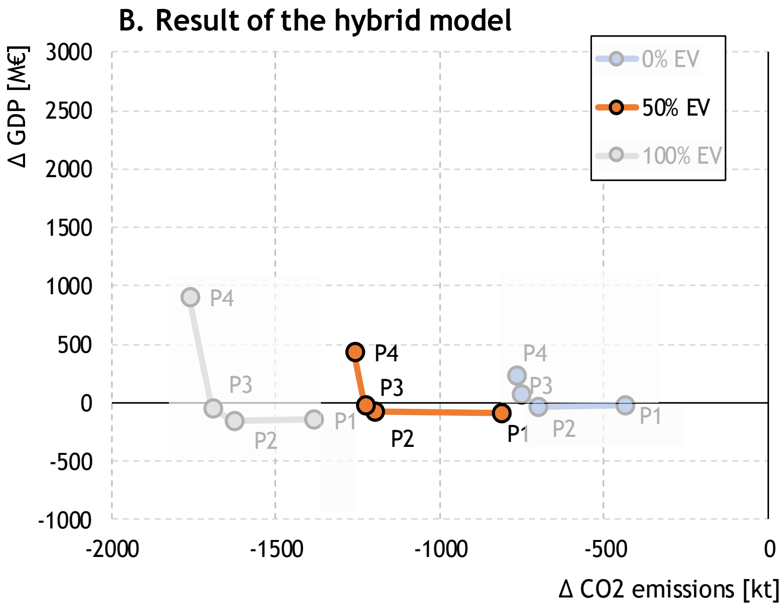
Soft-linked model



- Decision variables → range of variation (EV exogenous)
- Other parameters and input data for the EPLANopt model
- Results for selected points (4 for each front) are transformed to be inserted in the IO model → e.g. CAPEX and OPEX divided among demands sectors on the base of literature review
- Original IO table pre-processed and transformed into mixed units IO table to directly include results from EPLANopt.
- Results: 34 economic and 7 energy sectors. Aggregated in 6 and 3

Results: EPLANopt vs hybrid model



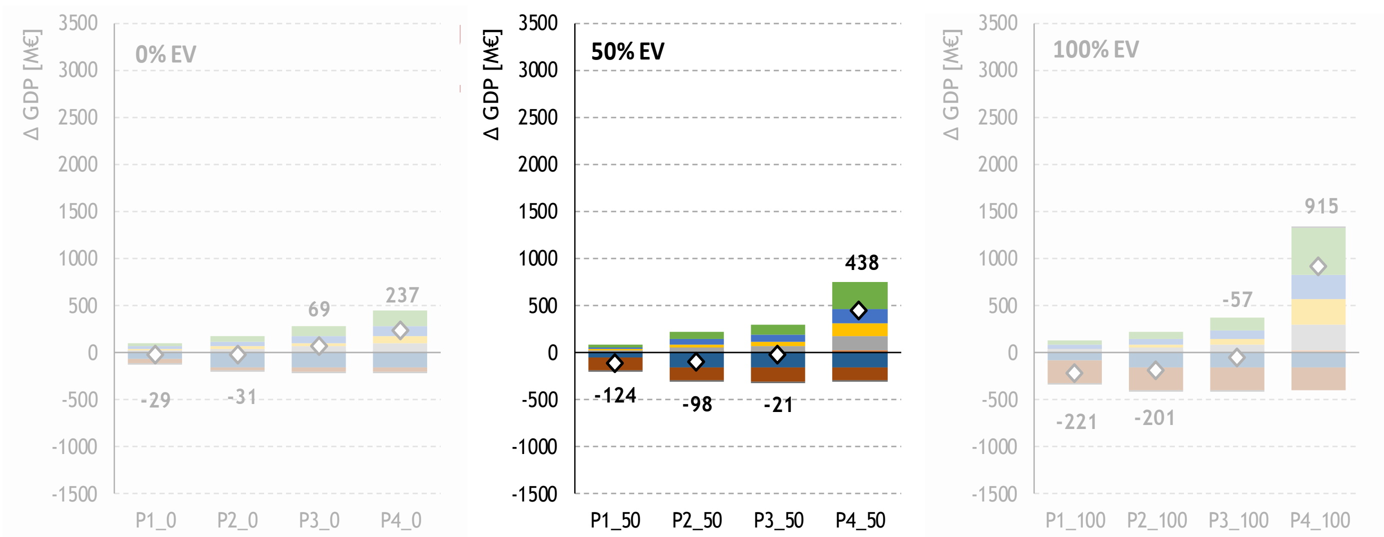


- Points from 1 to 4 : Increasing technologies → increasing costs and decreasing CO_2 emissions
- CO_2 emissions almost coincident → verification of hybrid model
- Economic impact dimension: cost vs Gross Domestic Product (GDP)
- Net worth potentially generated in local context is recognized as a relevant information for policymakers.

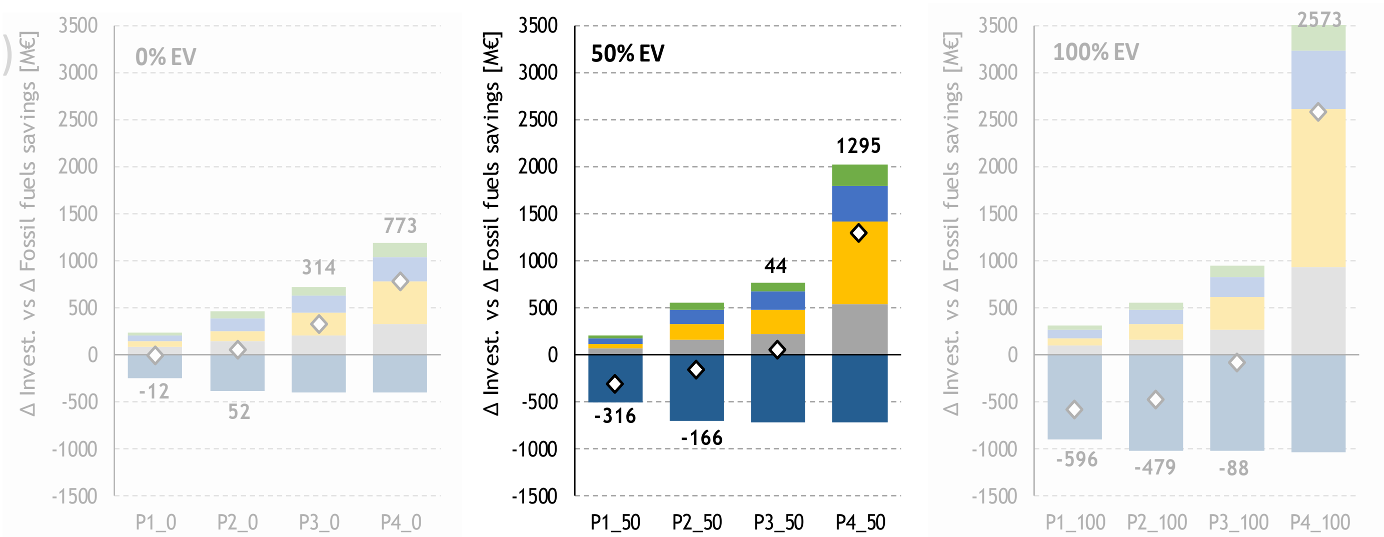
Results

- Results are numerous and complex
  - GDP decreases due to reduced fossil fuel consumption (excise)
  - GDP losses offset by increasing (from P1 to P4) new technologies and buildings refurbishment
  - Main investments: Electronic equipment, Heavy manufacturing
  - Graphs comparison provide relevant insights

Δ GDP [M€]



Δ Investments vs Δ fossil fuel savings [M€]

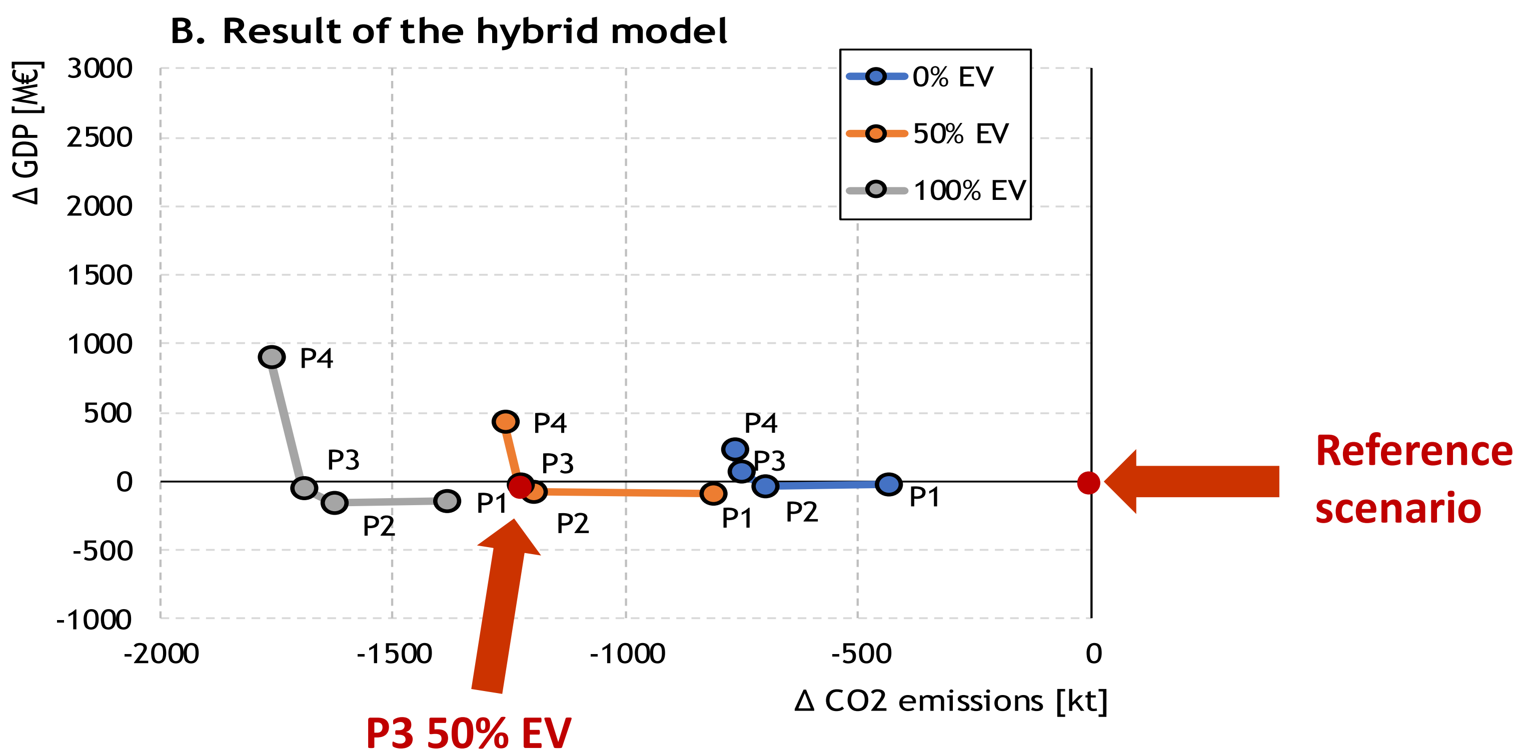


◊ Diamonds represent net values (shown in graphs)

Legend (positive values, main sectors):
Service sector **Construction**
Electronic equipment **Heavy manufacturing**

Legend (negative values):
GDP graph: **CH4**, **liquid fossil fuels**
Investments graph: **fossil fuels savings**

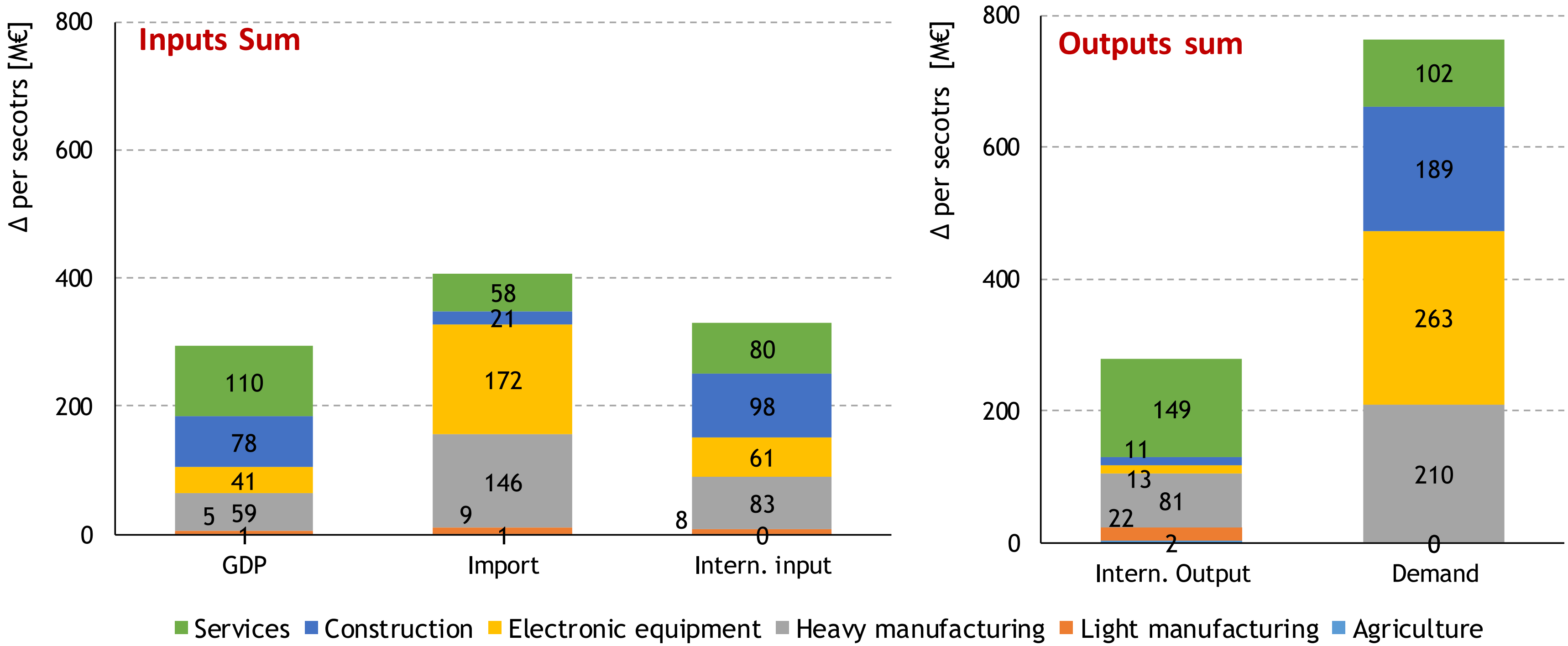
Results for the single point P3 50% EV



- Point chosen because it presents:

- almost the same total cost of the refence scenario (point 0,0)
- both an achievable share of EV (50%) and a wide diffusion of other technologies.

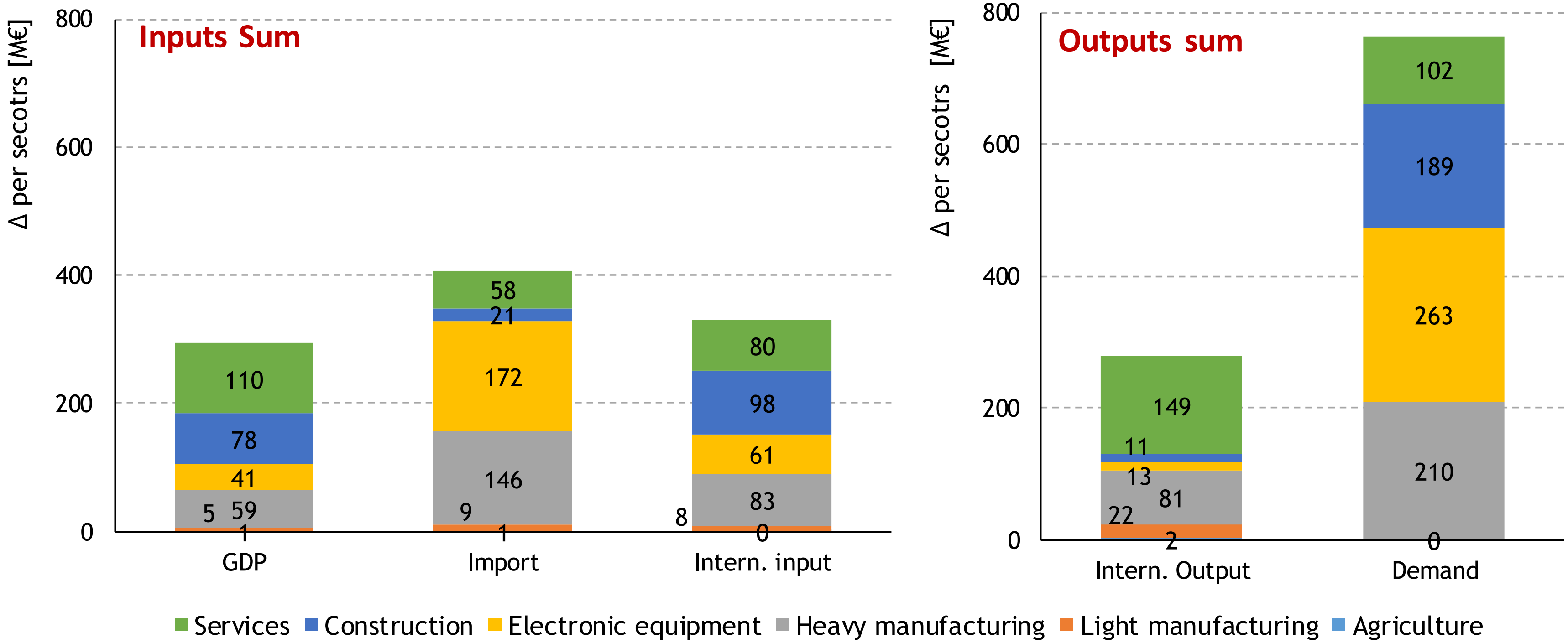
Δ [M€] per sector per indicator, for point P3



- IO table are symmetric* → for each sector | sum of inputs = sum of outputs
- Internal inputs → contribution **from** the other local sectors of the economy
- Internal outputs → contribution **to** the other local sectors of the economy

* disclaimer: not always true and mixed units IO table alter the sums

Δ [M€] per sector per indicator, for point P3



- Main results. (Sectors are aggregated, possible to have results for 34 economic sectors)

- **Service:** highest contributions to other sectors (**OS**), highest GDP

- **Construction:** high demand, low contribution to OS, highest input from OS, high GDP, low import

- **Electronic equipment:** highest demand, low contribution to OS, highest imports

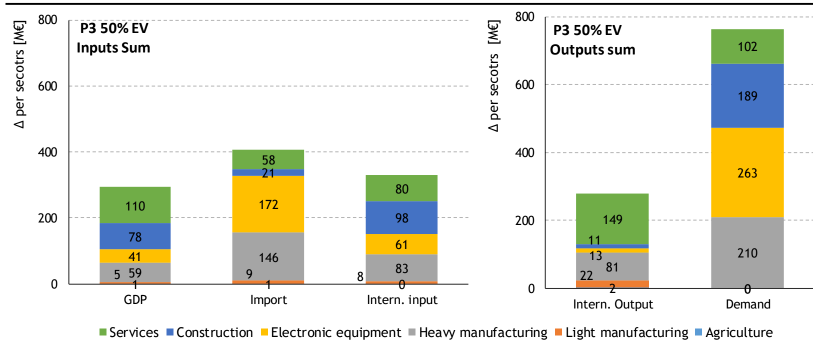
Results for the single point P3 50% EV

The tables show how much a specific value has changed in comparison to the correspondent reference scenario value

- In the “Outputs sum” table, the “Total “Output” variation is also given. It indicates of how much that sector should increment its output to sustain the transition
- The service sector displays relevant absolute variations but limited relative variations. Suggesting that it could face the transition without major structural change or growth
- Conversely the electronic equipment and constructions sectors presents the highest relative variations → highest impact on the local economy

Outputs sum	Internal Output	Demand	Total Output
Agriculture [M€]	0.3%	0.0%	0.1%
Light manufacturing [M€]	1.4%	0.0%	0.5%
Heavy manufacturing [M€]	4.1%	4.7%	4.5%
Electronic equipment [M€]	4.5%	41.2%	29.9%
Construction [M€]	2.3%	7.4%	6.5%
Services [M€]	1.7%	0.6%	1.0%

Inputs Sum	GDP	Import	Internal Input
Agriculture [M€]	0.1%	0.1%	0.1%
Light manufacturing [M€]	0.7%	0.5%	0.5%
Heavy manufacturing [M€]	5.4%	4.1%	4.8%
Electronic equipment [M€]	30.8%	28.9%	32.7%
Construction [M€]	6.5%	6.5%	6.5%
Services [M€]	0.8%	1.5%	1.0%



Results

- The approach allows the identification and quantification of which sectors are affected by the Value-Added generation and to which extent, in which sectors investments occurs and which sectors resort the most on imports or on the other sectors of the economy.
- This means that potential local GDP creation and expansion of relevant sectors for the transition are identified.

  Potential because of IO limits (i.e. infinite supply). GDP and internal inputs and outputs results do not consider capacity of real economy to sustain it (size and number of companies) → need to integrated with study on actual size and expansion potential of companies

- To be effectively capitalized within the boundaries of the South Tyrol economy the increases in local Value-Added and in internal activity should be intercepted by proactively promoted, wherever possible, the reinforcement of the interested sectors

Conclusion

By recalling the objectives:

- the EPLANopt model has been extend with relatively low extra data requirements and complexity. The computational speed and characteristic of the single analysis with EnergyPLAN is preserved.

- insights for policy maker at regional level are provided. Useful in exploring economic relationships and identifying priorities in the development of local policies.

- limits and strengths identified → requirements for integrative studies, to deepen the understanding of information contained in the IO table, addressing limits of IO models, compare results with other methodologies (e.g. CGE).

Thank you
for your attention

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