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Integrating multiple impacts and lifecycle assessment in the evaluation of energy efficiency funding programs

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When we evaluate energy efficiency, are we truly capturing its full value?

NO!

But we can make it possible.

WHY THIS TOPIC MATTERS?

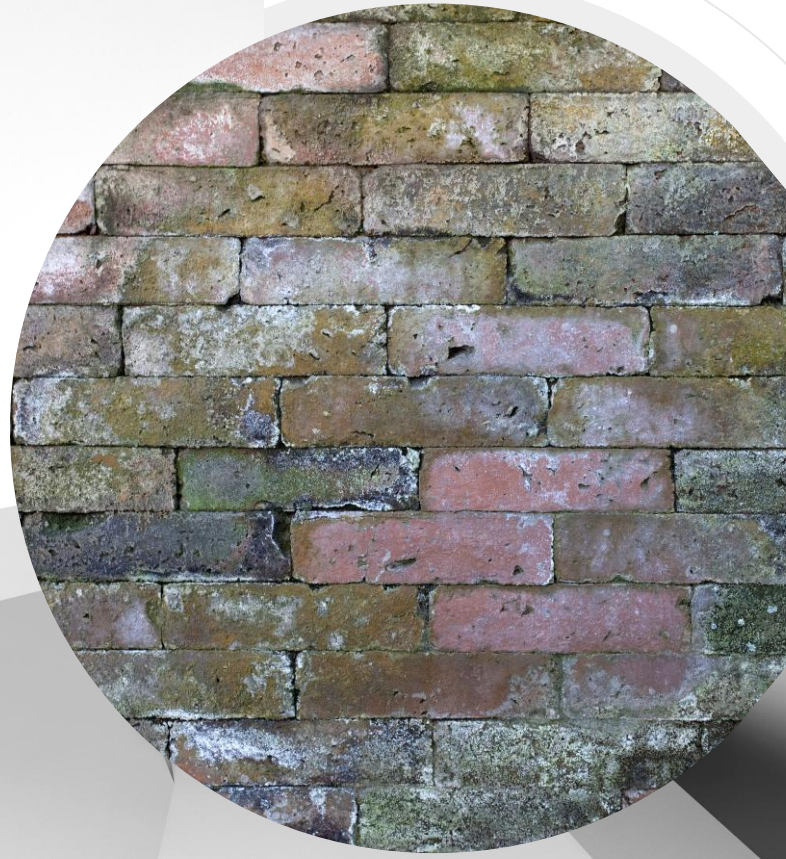
Residential sector

- **EU** Building stock
  - 40% of energy consumption
  - 36% of GHG emissions
  - 75% inefficient
  - 85% in use in 2050
- **Portuguese** building stock is mainly composed by residential buildings
  - Accounts for more than 30% of final energy consumption
  - Two-thirds built before 1990
    - Low energy performance
    - Reduced thermal comfort
    - Increased energy consumption, emissions and energy poverty

WHY THIS TOPIC MATTERS?

The Current Challenge

- EE is a crucial energy resource.
- However there remains a persistent EE gap attributed to :
  - **Financial** (e.g. High upfront costs and lack of access to funding)
  - **Social** (e.g. Lack of public awareness or resistance and skepticism)
  - **Institutional** (e.g. Complex application procedures or misaligned policy objectives)
  - **Technical Barriers** (e.g. Shortage of skilled labor or insufficient support)
  - **Traditional EE evaluations** (assess operational energy and GHG savings, often omitting key lifecycle impacts and benefits).
- Outcome:
  - **Sub-Optimal Decisions**: Risk of funding projects with limited overall value
  - **Undervaluation of long-term societal and environmental benefits** (e.g. Economic growth, job creation, poverty alleviation or reduction of emissions)
  - Renovation rate is only 1–1.5%/year—**well below the 2% target**.
  - Residential sector is **not on track** to achieve full decarbonization



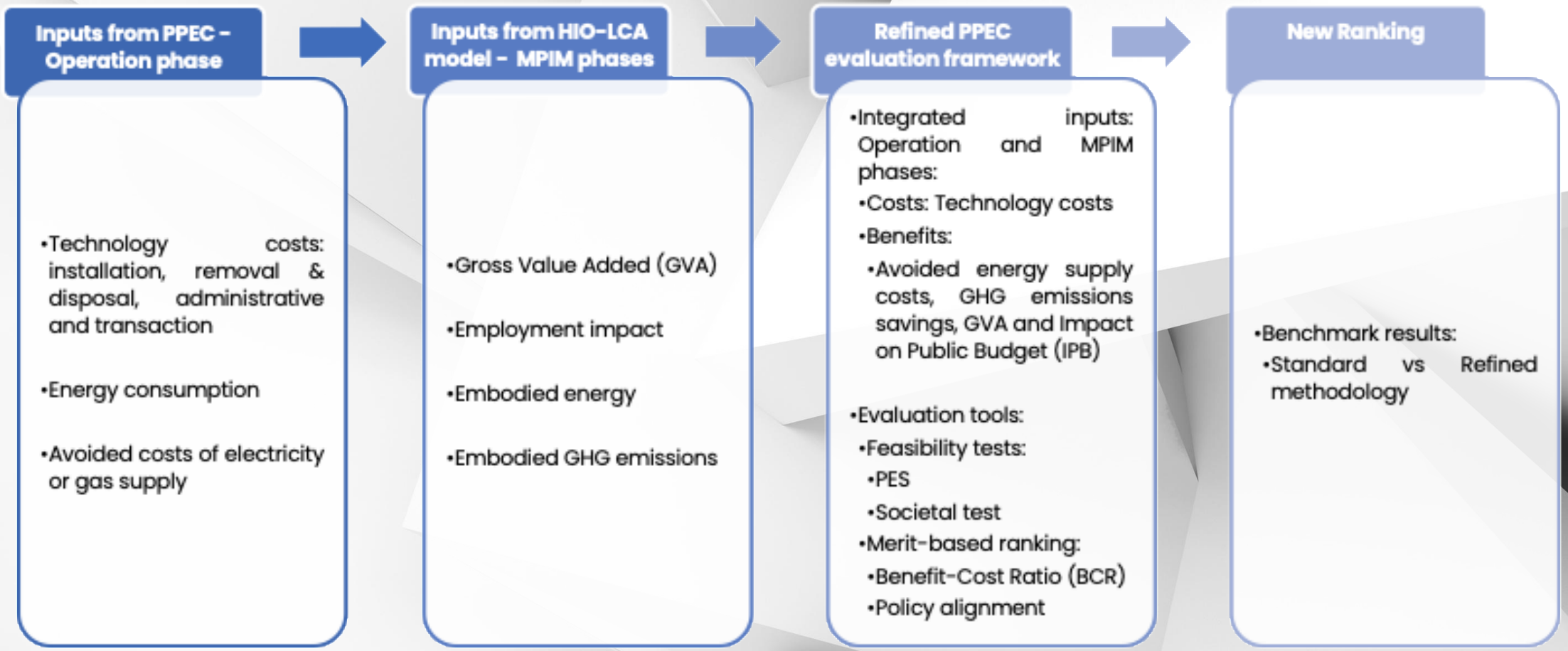
SOLUTION

Objective

- Integrate **Hybrid Input-Output Lifecycle Assessment (HIO-LCA) + Portuguese Energy Consumption Efficiency Promotion Plan (PPEC)**
- Relevance:
  - **Extends** cost-benefit evaluations to capture upstream and systemic socio-economic and environmental effects of EE measures
  - **Refine PPEC evaluation system**
  - **Improves decision-making** and provides a more **accurate reflection of EE investments**' long-term value
  - **Increase attractiveness** of EE measures
  - **Shape** broader national and EU-level energy **policy agendas**

METHODOLOGY

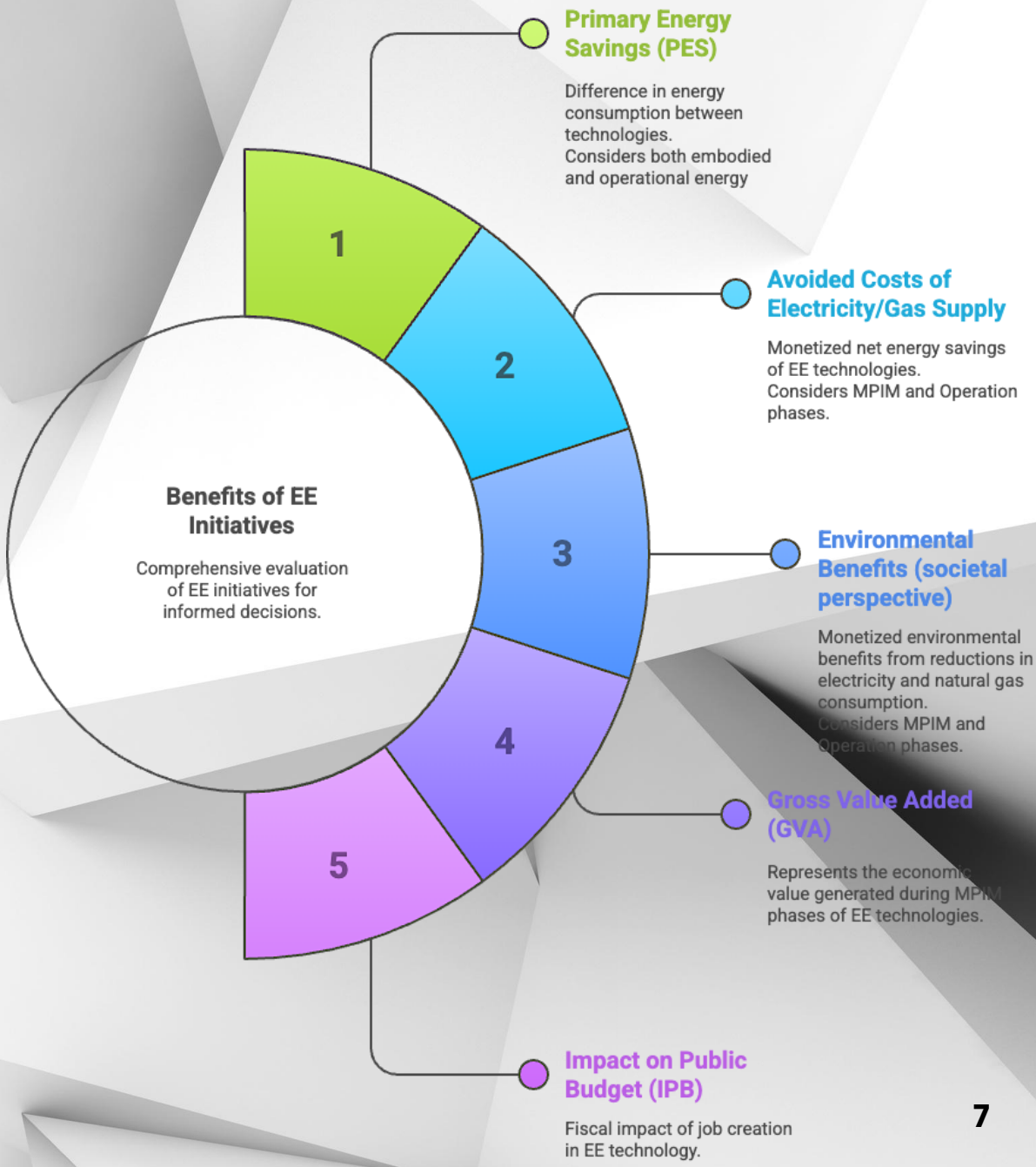
Overview



CASE STUDY

Measures and Benefits

Nomenclature	Measure	Sector
IBD_TR1	Heat Pump + PV	Residential
IBD_TR2	DHW Heat Pump + PV	
PORTGAS_TR1	Efficient Water Heaters	
GOLDENERGY_TR1	Smart Thermostats	
LISGDL_TR1	Condensing Boilers	



Operational & MPIM impacts

Operational Impacts (PPEC)

Measures	PES	Costs		Benefits	
		PPEC	Social	Environmental benefits from a societal perspective	Avoided costs of electricity or gas supply
	Toe/year	(€)	(€)	(€)	(€)
IBD_TR1	43.72	112,344	334,798	19,287	488,107
IBD_TR2	13.55	41,098	157,601	5,803	152,227
PORTGAS_TR1	159.28	685,125	940,000	129,026	825,699
GOLDENERGY_TR1	41.18	104,545	150,560	33,360	330,132
LISGDL_TR1	254.26	**799,433**	**1,279,609**	205,965	1,318,074

MPIM impacts (HIO-LCA)

Measures	GVA	Employment	Impact on public budget	Embodied GHG emissions		Embodied energy	
	€	Nº of jobs	€	Tons of CO2eq	€	Toe	€
IBD_TR1	34,315.47	0.96	5,570.26	23.67	299.77	7.06	4,597.31
IBD_TR2	16,740.14	0.50	3,542.66	8.56	127.40	2.93	1,868.94
PORTGAS_TR1	**362,279.42**	**10.25**	**51,686.85**	**310.19**	**3,577.04**	**82.96**	**87,754.63**
GOLDENERGY_TR1	35,180.37	1.16	4,411.62	14.62	224.87	5.03	3,015.95
LISGDL_TR1	282,300.88	7.75	49,651.49	206.83	2,566.60	57.90	65,258.57

KEY RESULTS

Conventional vs New

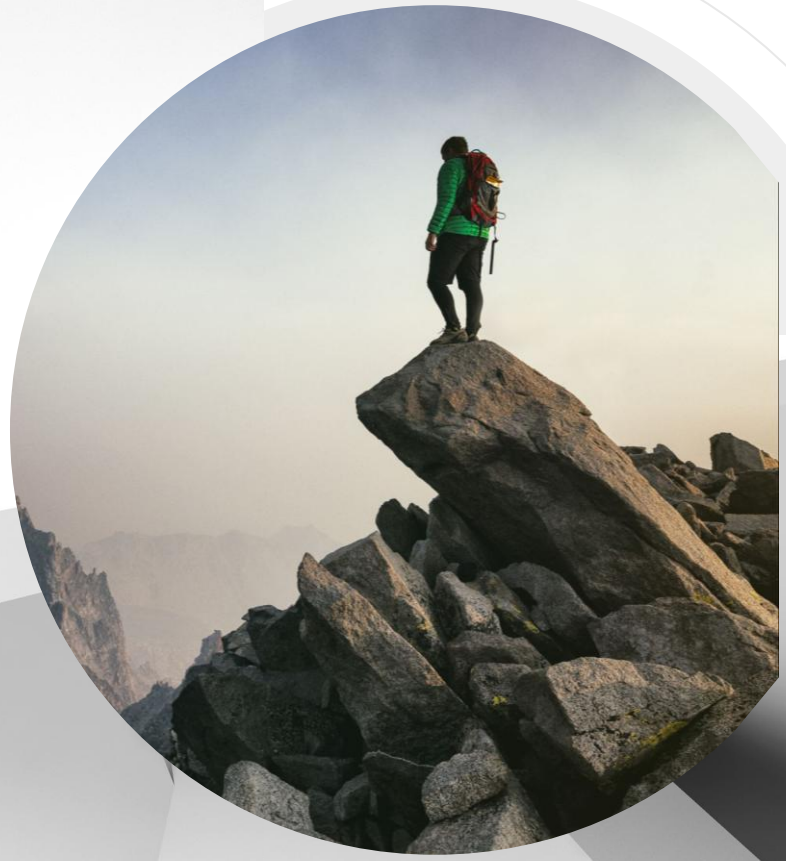
Measures	Old BCR	New BCR	Old PES (toe)	New PES (toe)	Old NPV (€)	New NPV (€)
IBD_TR1	4.52	**4.83**	874.4	**867**	172,595	**207,584**
IBD_TR2	3.85	**4.29**	271	**268**	428	**18,715**
PORTGAS_TR1	1.39	**1.86**	1,911.36	**1,828**	14,724	**337,360**
GOLDENERGY_TR1	3.48	**3.82**	494.16	**489**	212,932	**249,283**
LISGDL_TR1	1.91	**2.24**	3,051.12	**2,993**	244,430.3	**508,557**

Measures	ERSE – Old score	ERSE – New score	DGEG score	PPEC – Old score	PPEC – New score	Old ranking	New ranking
IBD_TR1	98.53	**98.53**	84.00	91.27	**91.27**	1º	**1º**
IBD_TR2	83.59	**85.07**	84.00	83.80	**84.54**	2º	**2º**
PORTGAS_TR1	45.43	**49.14**	79.00	62.21	**64.07**	**3º**	**4º**
GOLDENERGY_TR1	59.32	**69.27**	64.00	61.66	**66.64**	**4º**	**3º**
LISGDL_TR1	52.98	**54.83**	64.00	58.49	**59.42**	5º	**5º**

Conclusions

Key Takeaways

- **EE** remains a top EU priority for the cost-effective meeting of energy and environmental goals.
- Conventional evaluations **undervalue EE** measures
- Study introduces an **enhanced methodology**:
  - Integrating multiple benefits **changes cost-effectiveness and rankings**
  - Covers **additional life cycle phases** beyond operational
  - Assess **national impacts** and ensures **scalability**
  - Provides robust, equitable, transparent basis for **funding decisions**
  - Establishes **HIO-LCA as a valuable instrument** to enhance the evaluation mechanisms of EE funding programs



Conclusions

Future Work

- Extend analysis to cover industry and agriculture
- Integrate end-of-life impacts
- Consider other impacts
- Extend the application to other programs promoting EE
  - E.g., **Portuguese Environmental Fund** could be enhanced with this comprehensive approach

Thank you!

Any questions?

You can find me at

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Portuguese Energy Consumption Efficiency Promotion Plan - PPEC

- Scope:
  - Tangible measures (e.g., efficient equipment)
    - **Residential**, commercial & services, and industrial & agricultural sectors.
  - Intangible measures (e.g., awareness campaigns)
- **Evaluation Criteria for Funding** -Tangible measures
  - **PES Test:** Reduction in primary energy use (toe). ✓
  - **Social Test:** NPV of societal benefits and total costs of EE measure. ✓
  - **Ranking System** (100 Points Total):
    - **ERSE (Economic Assessment) - 50%:**
      - **BCR tests** (75 points):
        - **Societal benefits** - Avoided costs of electricity or gas supply, GHG emissions, impacts on public health, resource-use impacts, and investments in infrastructure.
        - **PPEC costs** - Installation, removal and disposal of the replaced equipment, administrative and transaction costs.
      - Share of **equipment investment** in total measure cost (25 points)
    - **DGEG (national relevance, policy alignment, and program coordination) - 50%**

Hybrid Input-Output Lifecycle Assessment - HIO-LCA

- HIO-LCA integrates conventional LCA with IO models
- Key stages in HIO-LCA:
  1. System Boundary Definition
     - Define reference and EE technologies.
     - Selection of LC phases
       - Manufacturing, Packaging, Installation and Maintenance (MPIM)
  2. Cost estimation
     - Investment, installation, and maintenance costs
  3. Domestic output calculation
     - EE-related expenditures are disaggregated into components and activities across MPIM phases
  4. Assess direct & indirect effects