7th AIEE Energy Symposium

Current and Future Challenges to Energy Security

– the energy crisis, the impact on the transition roadmap –

A cost-benefit analysis on different energy scenarios for Sardinia: methanization versus electrification, renewables, and hydrogen

Linda Cerana, Arturo Lorenzoni

University of Padova

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Università degli Studi di Padova

DIPARTIMENTO DI INGEGNERIA INDUSTRIALE

Scenarios towards the Net Zero 2050

Methanization

- Current plans (since 1990s)
- Studies by **RSE** (Phase 1 & 2, 2020-2021) commissioned by ARERA
- Time horizon: 2020-2040
- LNG supply via “virtual pipeline”

- **Coal-fired power plants** to be **closed by 2025**
- Reactivation of the **aluminium industrial hub in Portovesme?**

Electrification, renewables, and hydrogen

- Joint study by **Politecnico di Milano (POLIMI)** and **Università degli Studi di Padova (UNIPD)** (2021) commissioned by WWF Italia
- Target years: 2030 & 2050

GOAL OF THIS STUDY:

Comparison of two possible alternative scenarios for the evolution of the Sardinian energy system, though a **Cost-Benefit Analysis** (socio-economic analysis)

Methodology

- Definition of **two reference scenarios**, from the **assumptions of RSE and POLIMI respectively**
  → **evolution** of the Sardinian energy system **between 2020 and 2050:**
  - **Final consumption** of energy vectors by sector
  - **Power system**
- **2050**: for both scenarios, **same "decarbonized" configuration** of the energy system developed by POLIMI.
- Both cases of reactivation and absence of the **aluminium supply chain** were taken into account
- Comparison, with time horizon 2020-2050, through:
  - **Cost-Benefit Analysis**
  - Analysis of the **employment effects**

Production site	Process	Energy demand	RSE	POLIMI
Eurallumina	Production of aluminum oxide from bauxite	100 ktep th. HT	**GN**	**Fuel oil / H_2 from 2040**
		200 ktep th. LT (furnaces)	CHP - **GN**	CHP - **H_2**
SiderAlloys (ex Alcoa)	Production of aluminum by electrolysis, from aluminum oxide	2 TWhe		

Final consumption (Civil, Industry & Transport*)

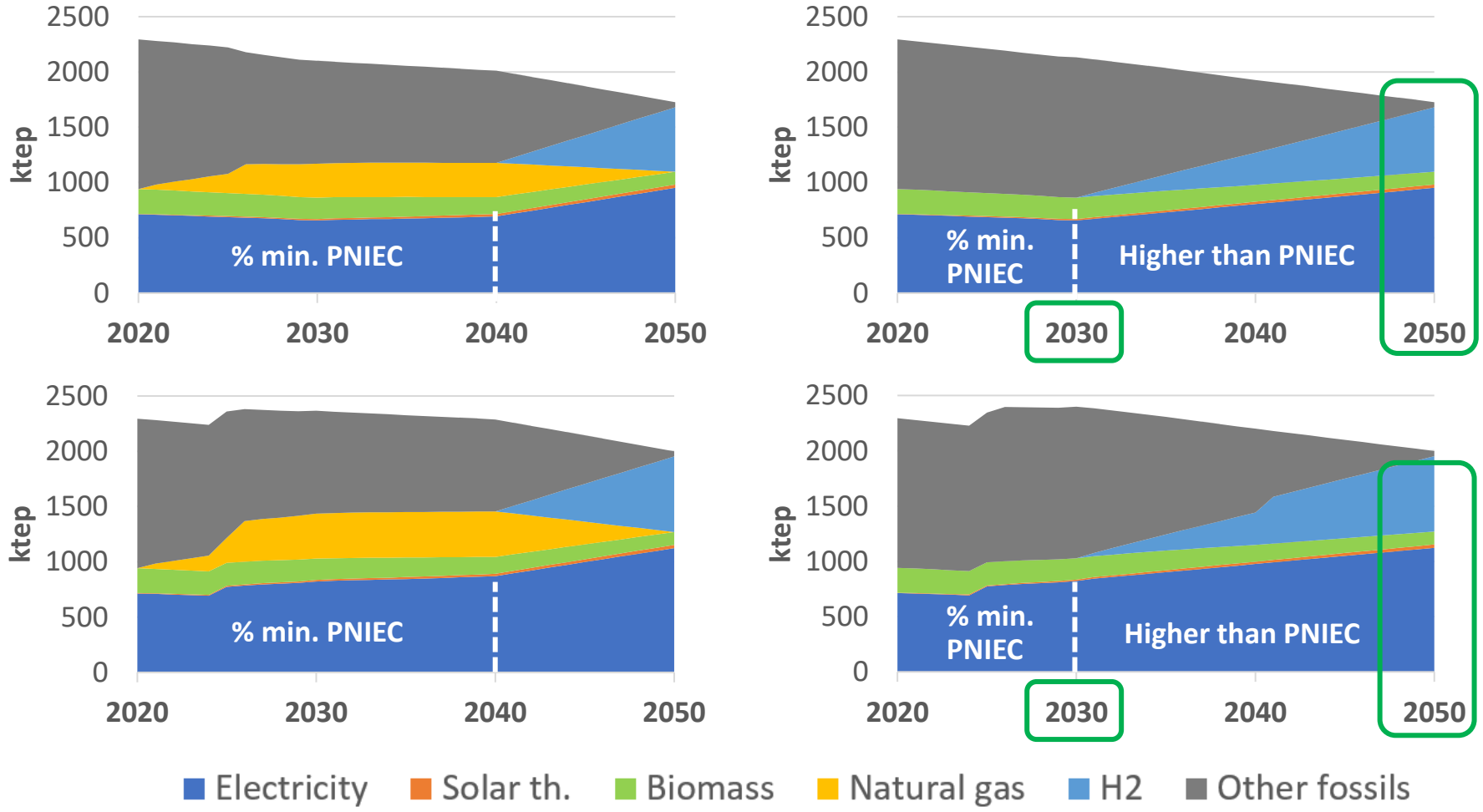
METHANIZATION SCENARIO
(based on RSE, "BASE" configuration Phase 2)

→ methanization: only industrial (**300 Mm³ + 121 Mm³ Eurallumina)** and residential (18 areas, **76 Mm³**)

ELECTRIFICATION, RENEWABLES, AND HYDROGEN SCENARIO
(based on POLIMI)

WITHOUT THE ALUMINIUM HUB →

WITH THE ALUMINIUM HUB FROM 2025 →

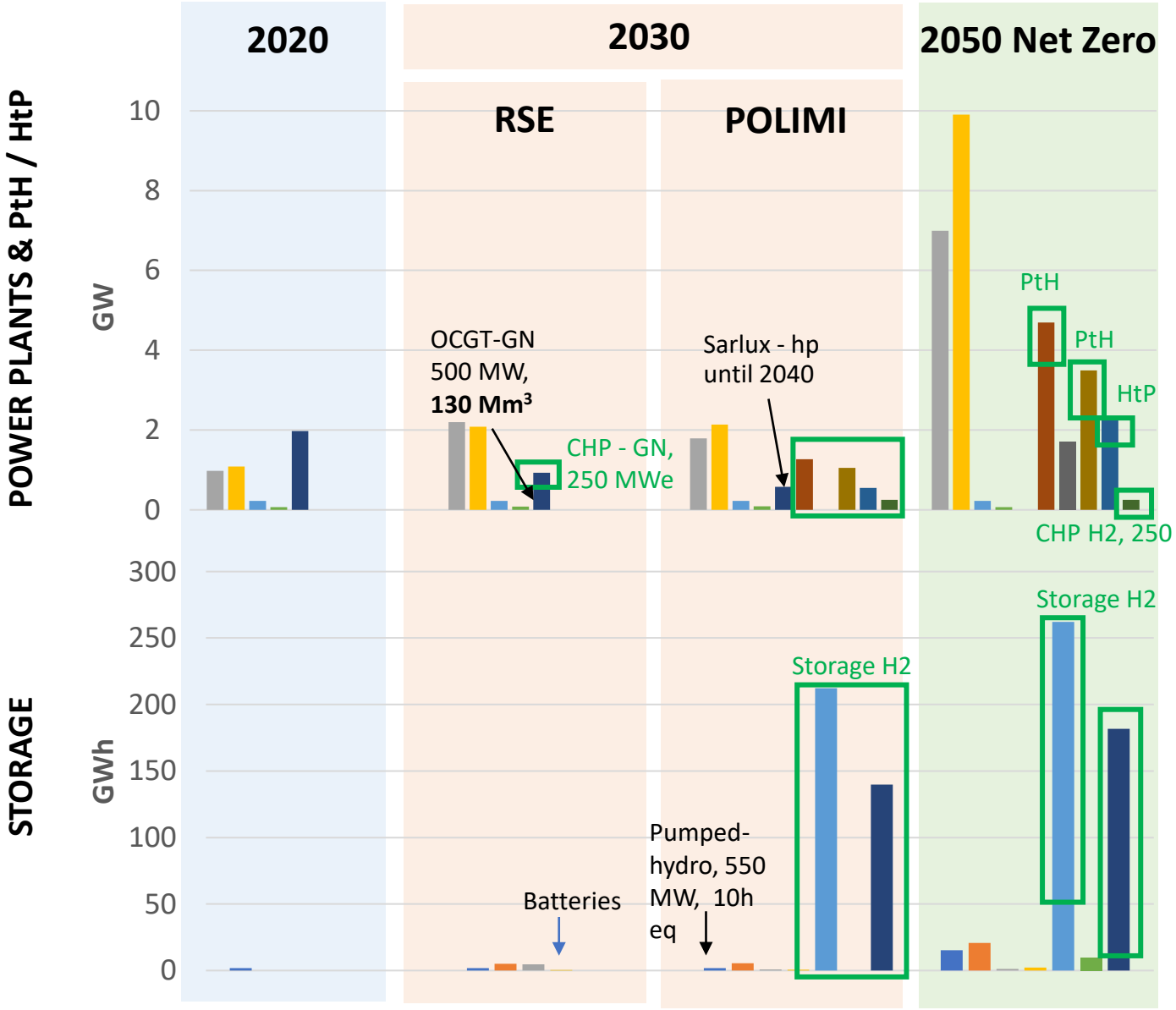


NET ZERO 2050:

- Civil: 100% electricity, biomass & solar thermal
- Industry: 100% electricity & hydrogen + non-replaceable fuels
- Transport: 100% electricity & hydrogen

*Not included: maritime transportation (oil, 159 ktep) and new sectors of agricultural greenhouses and ceramic (22 ktep)

Power system



Until 2030: both scenarios assume the minimum targets for the installation of renewable energy plants derived from PNIEC.

From 2030:

- RSE: GN-power plants still active (at least until 2040)
- POLIMI: higher development of renewables + hydrogen

The Cost-Benefit Analysis (CBA)

The energy scenarios are compared using a **Cost-Benefit Analysis**:

- Perimeter: "**Sardinia energy system**"
- Time horizon: **2020-2050**.

System costs and externalities which were evaluated:

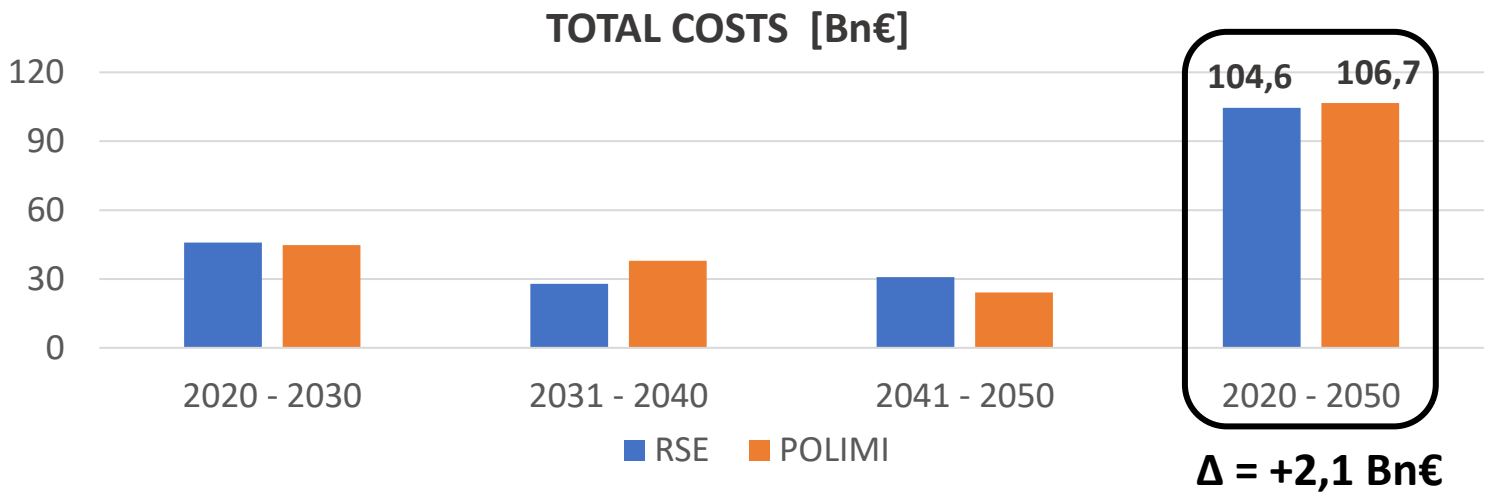
1. costs of purchasing **energy commodities**;
2. costs of **environmental externalities** (CO_{2eq}, SO_2, NO_X, PM_{10}, $PM_{2,5}$ and NMVOC);
3. costs of **CO_2 - ETS** for the thermoelectric and industrial sectors;
4. investment and operational costs for the **technologies of the power systems**;
5. costs of building and operating the **methanization infrastructure** (transport to Sardinia, storage & regasification, transport & distribution);
6. costs **for Sardinian domestic consumers** (heating systems and cooktops).

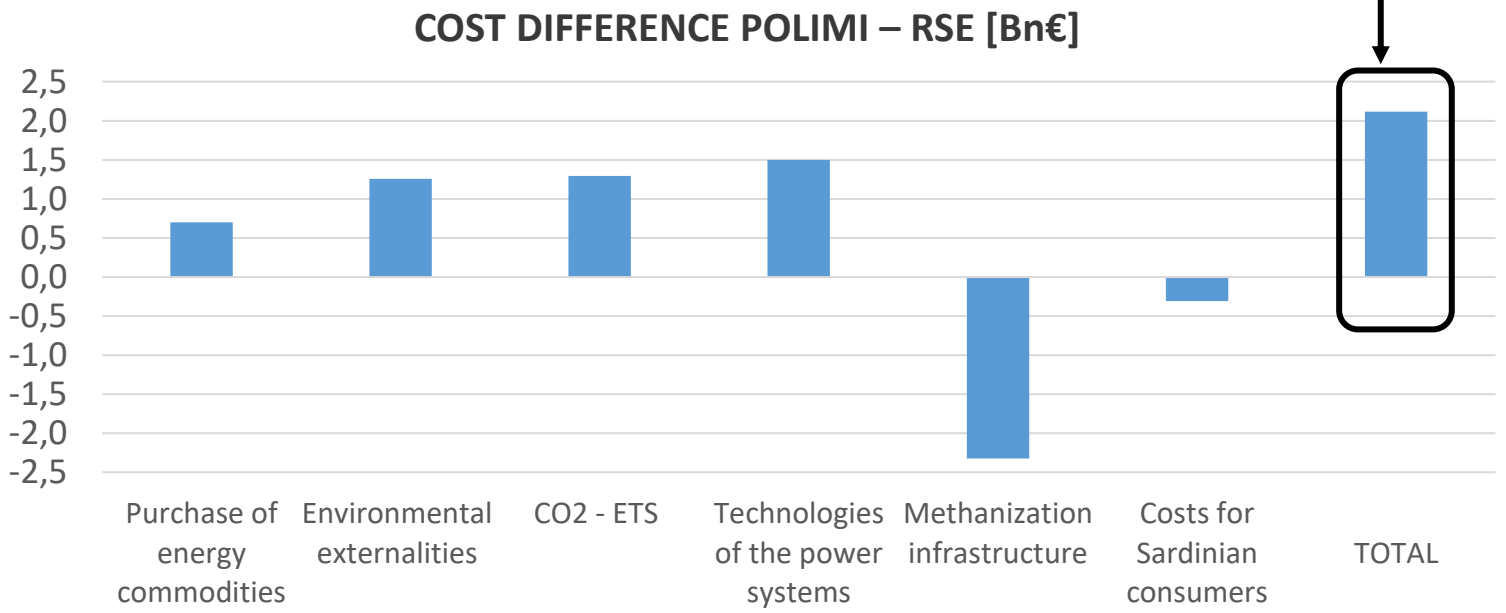
In the “BASE” case, the prices of energy commodities are derived from recent trends and are assumed constant over the analysis period. However, through a **sensitivity analysis** different prices of gas, electricity and ETS have been considered.

Results of the CBA – "BASE" case without the aluminium

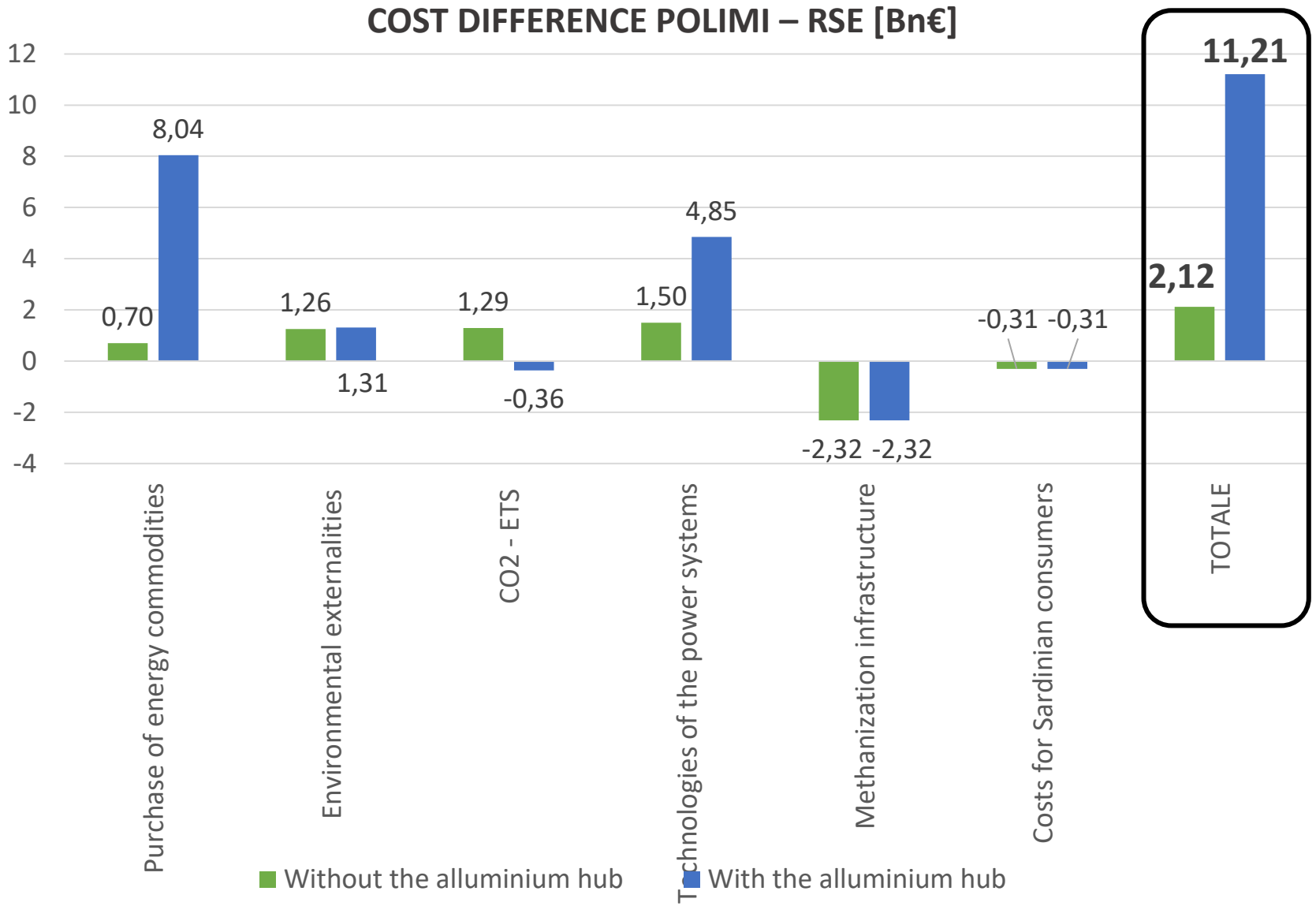
Price values (constant over the analysis period 2020):

- **Natural gas: 20 €/MWh**
- **Electricity** traded with other Italian market areas at the PUN value of **55 €/MWh**
- **ETS-CO_2: 83 €/ton**





Results of the CBA – Without & with the aluminium hub



The cost difference between the two scenarios rises to **+11.21 Bn€**, primarily due to:

- costs for the **technologies of the power systems** (+4.85 Bn€) → increased development of the **hydrogen** supply chain for the aluminium hub;
- purchase of energy vectors (+8.04 Bn€) → larger import of **electricity** required to power electrolyzers.

CBA – Sensitivity for different NG, electricity and ETS prices

5 scenarios were analysed, assuming the following prices:

- natural gas at 45 €/MWh or 80 €/MWh;
- electricity at 100 €/MWh or 150 €/MWh, or valued at Sardinia's average cost of generation
- ETS at 83 €/ton or increasing linearly from 83 €/ton today to 145 €/ton in 2050.

COST DIFFERENCE [Bn€] between the electrification-based scenario (POLIMI) and the methanization scenario (RSE) WITHOUT THE ALUMINIUM HUB

Cost	**BASE CASE** NG: 20 €/MWh EE: 55 €/MWh CO2: 83 €/t	**CASE 1** NG: 80 €/MWh EE: 100 €/MWh CO2: 83 €/t	**CASE 2** NG: 80 €/MWh EE: 150 €/MWh CO2: 83 €/t	**CASE 3** NG: 80 €/MWh EE: cost of generation CO2: 83 €/t	**CASE 4** NG: 80 €/MWh EE: cost of generation CO2: increasing 83 €/t - 145 €/t	**CASE 5** NG: 45 €/MWh EE: cost of generation CO2: increasing 83 €/t - 145 €/t
Purchase of energy commodities, of which:	0,70	-2,86	0,37	-5,75	-5,75	-2,21
Civil sector	0,38	-0,55	-0,55	-0,55	-0,55	-0,01
Transport sector	-2,89	-2,89	-2,89	-2,89	-2,89	-2,89
Industry sector	0,55	-3,05	-3,05	-3,05	-3,05	-0,95
Power generation	-0,88	-2,82	-2,82	-2,82	-2,82	-1,69
Δimport/export/excess	3,55	6,45	9,68	3,56	3,56	3,33
CO_2 - ETS	1,29	1,29	1,29	1,29	1,55	1,55
Environmental externalities	1,26	1,26	1,26	1,26	1,26	1,26
Technologies of the power systems	1,50	1,50	1,50	1,50	1,50	1,50
Methanization infrastructure	-2,32	-2,32	-2,32	-2,32	-2,32	-2,32
Costs for Sardinian consumers	-0,31	-0,31	-0,31	-0,31	-0,31	-0,31
TOTAL	**2,12**	**-1,45**	**1,78**	**-4,34**	**-4,08**	**-0,54**

CBA – Sensitivity for different NG, electricity and ETS prices

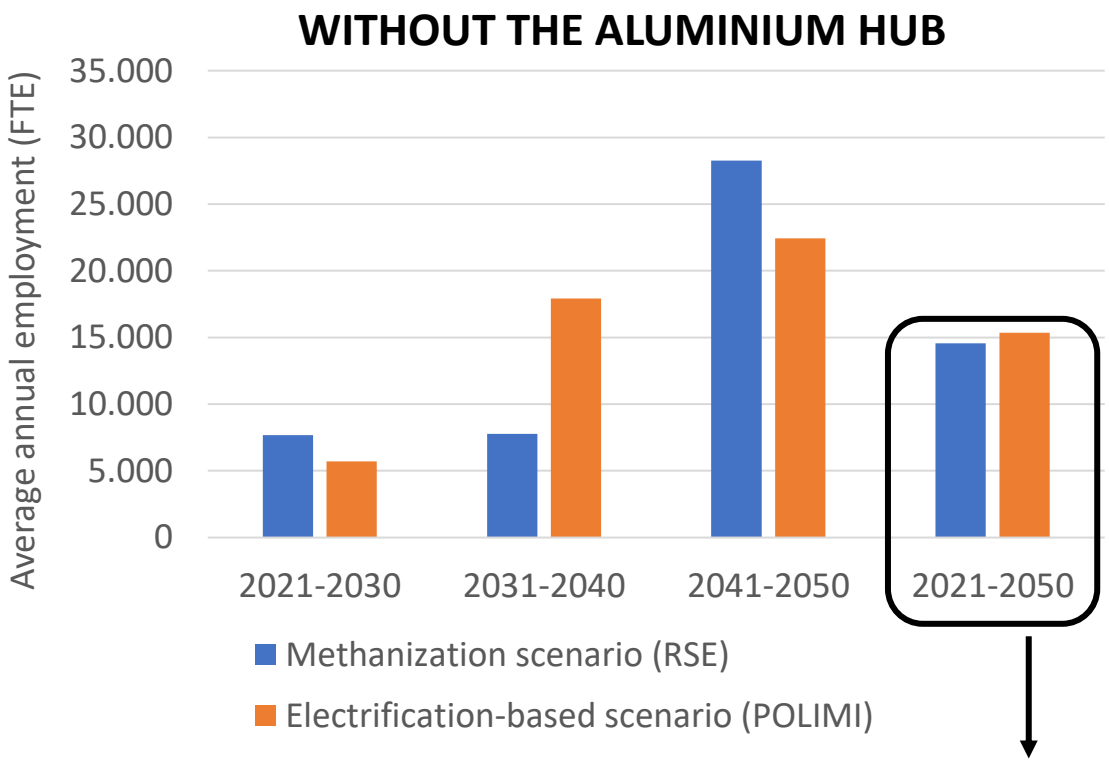
COST DIFFERENCE [Bn€] between the electrification-based scenario (POLIMI) and the methanization scenario (RSE) WITH THE ALUMINIUM HUB.

Cost	**BASE CASE** NG: 20 €/MWh EE: 55 €/MWh CO2: 83 €/t	**CASE 1** NG: 80 €/MWh EE: 100 €/MWh CO2: 83 €/t	**CASE 2** NG: 80 €/MWh EE: 150 €/MWh CO2: 83 €/t	**CASE 3** NG: 80 €/MWh EE: cost of generation CO2: 83 €/t	**CASE 4** NG: 80 €/MWh EE: cost of generation CO2: increasing 83 €/t - 145 €/t	**CASE 5** NG: 45 €/MWh EE: cost of generation CO2: increasing 83 €/t - 145 €/t
Purchase of energy commodities, of which:	8,04	4,69	16,11	-2,74	-2,47	4,86
Civil sector	0,38	-0,55	-0,55	-0,55	-0,55	-0,01
Transport sector	-2,89	-2,89	-2,89	-2,89	-2,89	-2,89
Industry sector	0,80	-4,19	-4,19	-4,19	-4,19	-1,28
Power generation	-2,80	-10,49	-10,49	-10,49	-10,49	-6,01
Δimport/export/excess	12,55	22,82	34,23	15,39	15,66	15,05
CO2 - ETS	-0,36	-0,36	-0,36	-0,36	-0,64	-0,64
Environmental externalities	1,31	1,31	1,31	1,31	1,31	1,31
Technologies of the power systems	4,85	4,85	4,85	4,85	4,85	4,85
Methanization infrastructure	-2,32	-2,32	-2,32	-2,32	-2,32	-2,32
Costs for Sardinian consumers	-0,31	-0,31	-0,31	-0,31	-0,31	-0,31
TOTAL	**11,21**	**7,86**	**19,27**	**0,43**	**0,43**	**7,75**

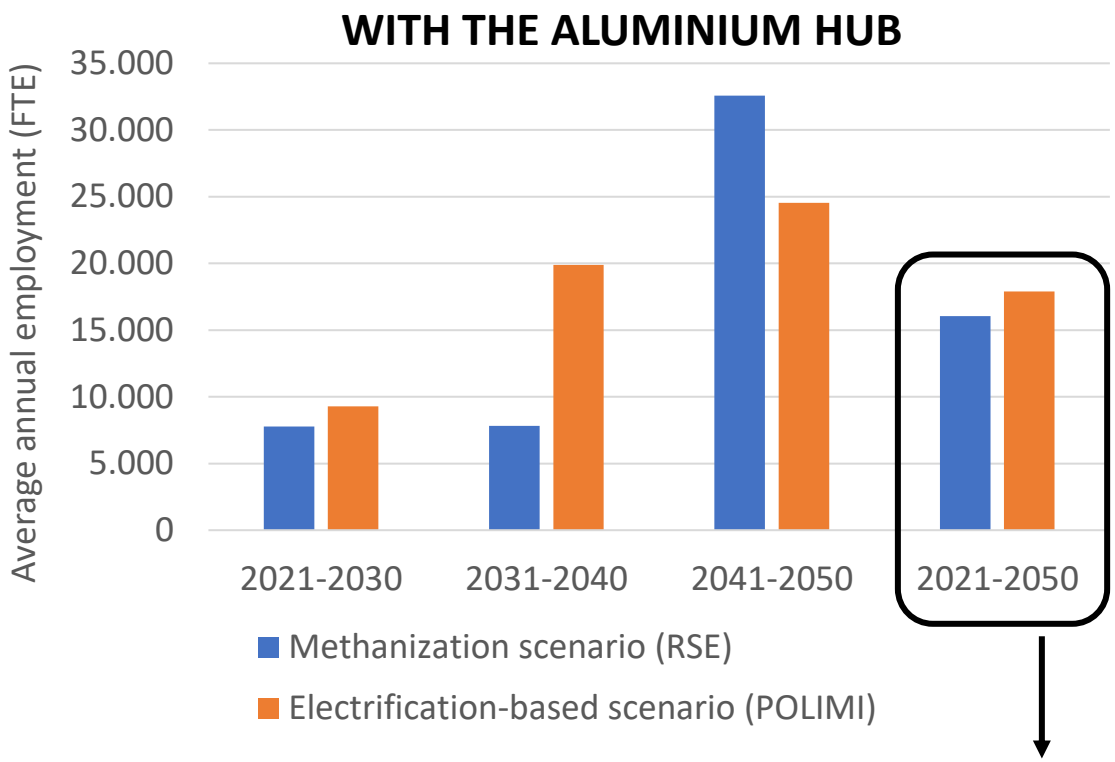
Employment

Methodology: **Employment Factor Approach (EFA)**

→ **Direct, net employment**



+ 788 jobs/year



+ 1.847 jobs/year

Employment

DIFFERENCE IN THE NUMBER OF JOBS [average annual FTE] between the electrification-based scenario (POLIMI) and the methanization scenario (RSE)

Technology	ΔPOLIMI-RSE, TOT. 2021-2050	
	Without the aluminium hub	With the aluminium hub
Solar PV	191	191
Wind	161	161
Hydro – run-of-river & reservoir	0	0
Bioenergy	-3	-3
TOTAL – Renewable energy systems	349	349
Coal	0	0
Refinery residues (Sarlux)	48	48
Petroleum products	0	0
Natural gas	-135	-205
TOTAL – Fossil fuel power plants	-87	-157
Batteries (small-scale)	143	143
Batteries (utility-scale)	-247	-247
Pumped-hydro	127	127
TOTAL – Electrical storage	23	23
Electrolyzers	385	860
Fuel cells	92	203
CHP – H2-fueled	0	25
Hydrogen storage	26	543
TOTAL – Hydrogen supply chain	503	1.632
TOTAL	788	1.847

Type of activity	ΔPOLIMI-RSE, TOT. 2021-2050	
	Without the aluminium hub	With the aluminium hub
Manufacturing	-109	-136
Construction & Installation (C&I)	-65	-138
Operation & Maintenance (O&M)	971	2.152
Fuel	-12	-25
Decommissioning	2	-6
Total	788	1.847

Final considerations & future work

- For the 6 cases with different GN, electricity, and ETS prices:
  - In the absence of the aluminium hub, only 2 cases are in favour of the methanization scenario;
  - In the presence of the aluminium hub, the electrification and hydrogen-based scenario turns out to be more costly in all cases, mainly due to the costs of the dedicated hydrogen supply chain
- Updates need to include:
  - New predictions on the **evolution of energy prices**
  - Eventuality of **reactivation of the aluminium hub**
- Possible **integrations of macro-economic effects**: indirect and induced employment, GDP, ..
- Update according to **new policy targets**:
  - **More challenging targets for electrification, renewables, & hydrogen** → new scenarios of the DDS 2022 from Terna & Snam
  - Possible limitation of the **development of the natural gas demand**

Thank you for the attention

Linda Cerana, Arturo Lorenzoni

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