17-19 May 2023

HydrogEn Expo 2nd Edition

Piacenza, Italy

MERCOLEDÌ 17 MAGGIO
Quartiere Fieristico di Piacenza Expo
Sala E - Ore 15:00 - 17:30

OPPORTUNITÀ, PROSPETTIVE E FATTORI ABILITANTI PER L'ECONOMIA DELL'IDROGENO

Workshop organizzato da

LEAP FOUNDED IN 2005 BY POLITECNICO DI MILANO

RETE ALTA TECNOLOGIA EMILIA-ROMAGNA HIGH TECHNOLOGY NETWORK

TECNOPOLO PIACENZA

POLITECNICO MILANO 1863

DIPARTIMENTO DI ENERGIA

Fondazione Politecnico di Milano

Hydrogen JRP JOINT RESEARCH PLATFORM

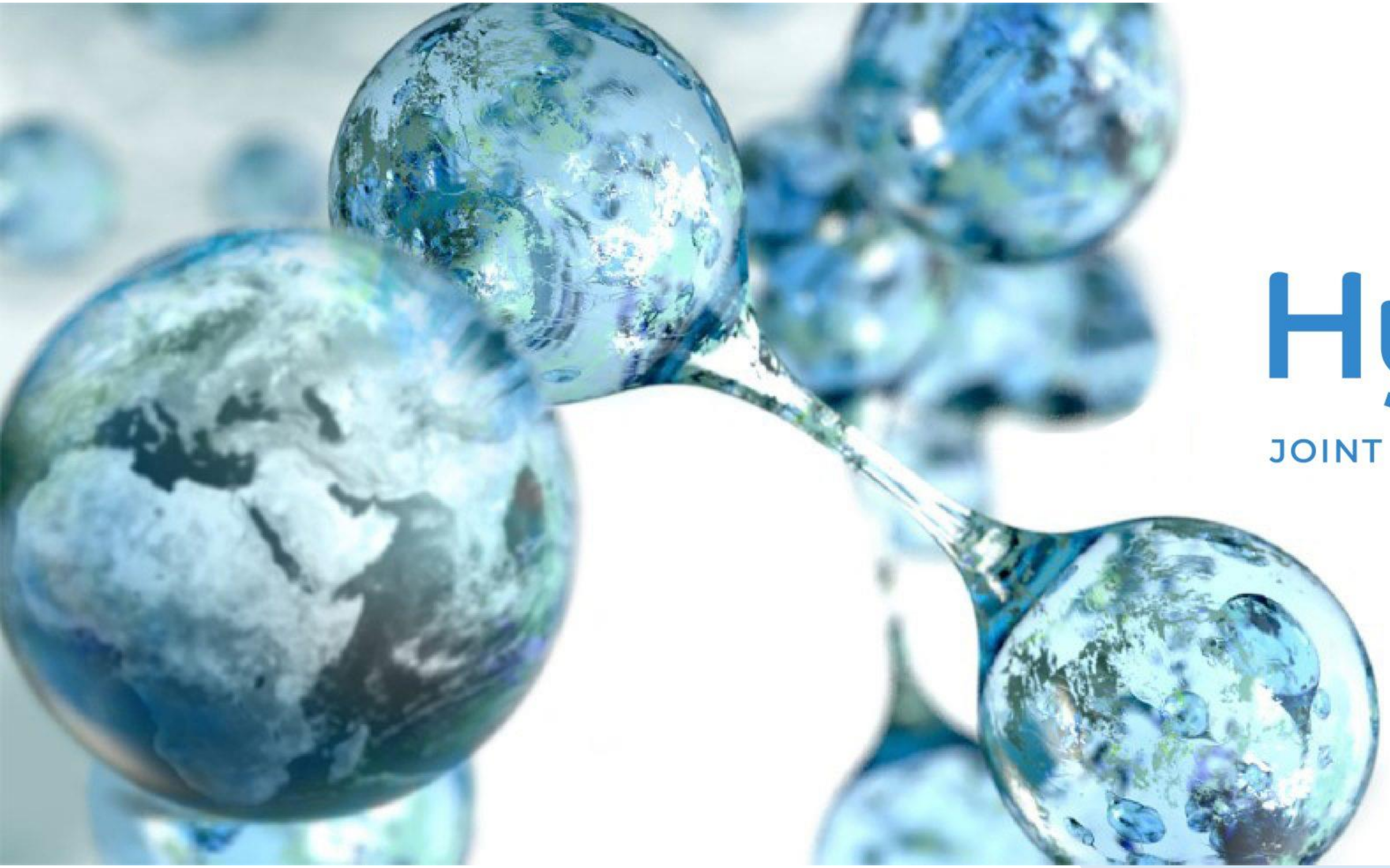
Il ruolo dell'idrogeno per un sistema energetico ad emissioni net-zero

Paolo Colbertaldo – Dipartimento di Energia, Politecnico di Milano

Work group: S. Campanari, M. Catania, P. Colbertaldo, F. Fattori, F. Mezzera, M. Motta, F. Parolin

May 17th, 2023

The H_2 Joint Research Platform at PoliMi

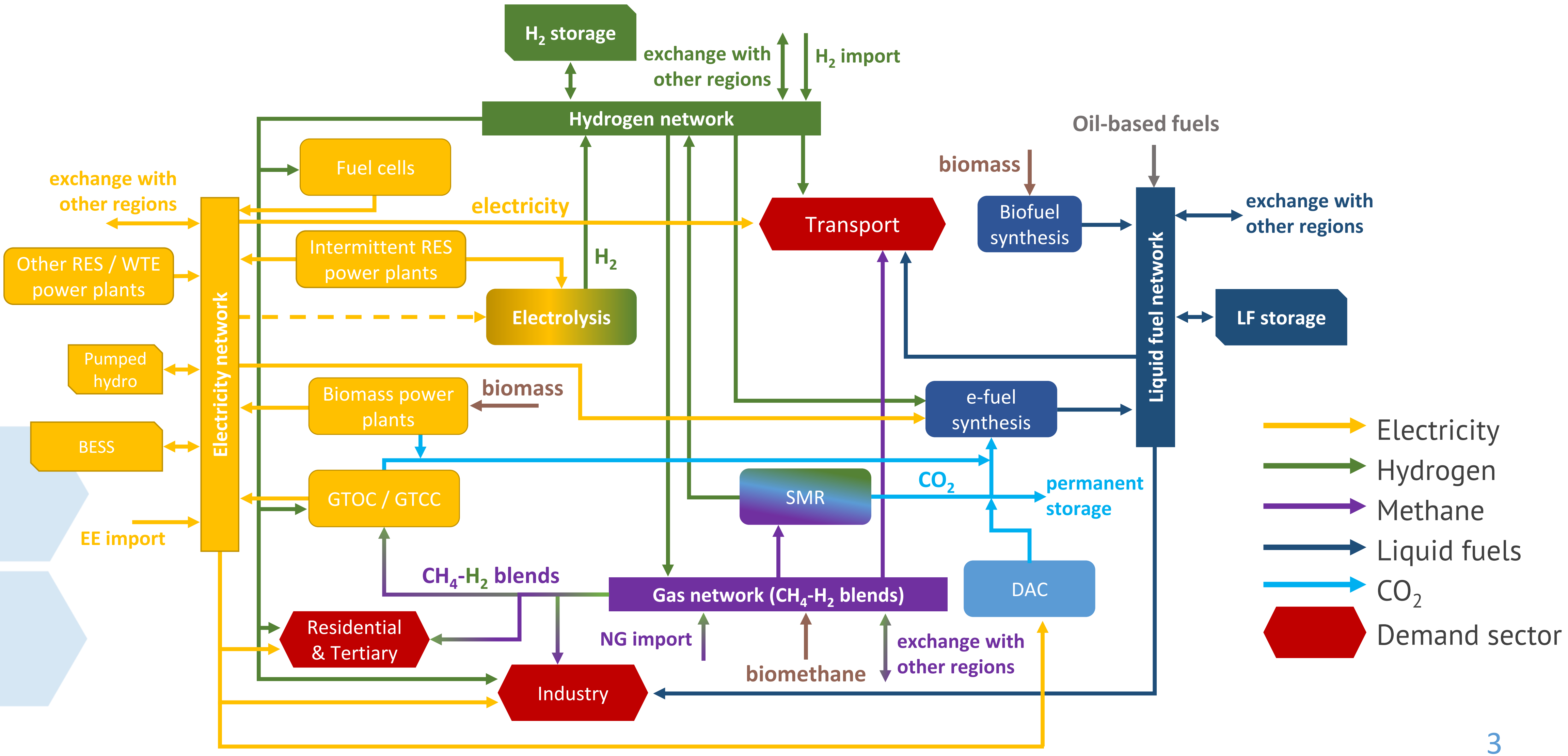


Hydrogen JRP
JOINT RESEARCH PLATFORM

Fondazione Politecnico di Milano
POLITECNICO MILANO 1863
eni
EDISON
a2a
snam
NextChem
Maire Tecnimont for Energy Transition

Integrated energy system modelling

Interwoven energy flows, solved in each region



Integrated energy system modelling

Cost-optimal system under net-zero emission goal

Model objective: minimum Total Annual Cost

- including CAPEX for new plants and revamping, OPEX for O&M, domestic sources, energy vector import, energy vector transport for regional exchange, CCS options for CO_2 balance closure
- subject to energy vector balances in each node *n* (hourly resolution)
- with target of **net-zero CO_2 emissions** → this is a **perspective change** (from «reduce» to «remove»)

CO_2 emissions at **point of use** (*e.g., combustion*) + CO_2 emissions related to **supply chains** + **Incompressible** CO_2 emissions (*e.g., agriculture*) - Net natural **absorption** (*Land Use, Land-Use Change, and Forestry - LULUCF*) - **Stored** CO_2 (CCS on fossil fuel plants and in carbon-negative plants) = **Zero**

Integrated energy system modelling

Model approach «Multi^3»

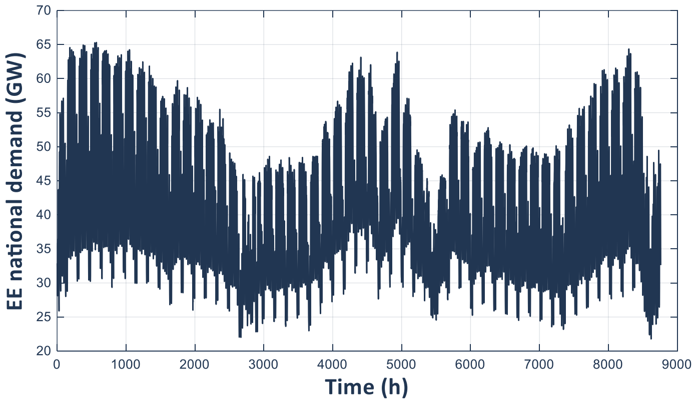
Multi-vector
- Electricity (EE)
- Hydrogen (H_2)
- CH_4-H_2 blends
- Liquid fuels (LF) (including biofuels, e-fuels, conventional)

Multi-node
- Regional description of the country (20 regions)

Multi-sector
- Civil (heating, cooling, end-use electricity)
- Industrial (heating, process, end-use electricity)
- Mobility (road, aviation, navigation)

Time-dependent
- Hourly balances over a year-long time horizon (allows to track RES power generation and storage evolution)

Combination of domestic and imported sources
- Natural gas (imported or domestic)
- Renewable energy to electricity (domestic)
- Biomass (domestic)
- Biogas for biomethane production (domestic)
- Waste-to-Energy (domestic)
- Import of EE, H_2, LF from abroad



Integrated energy system modelling: Networks

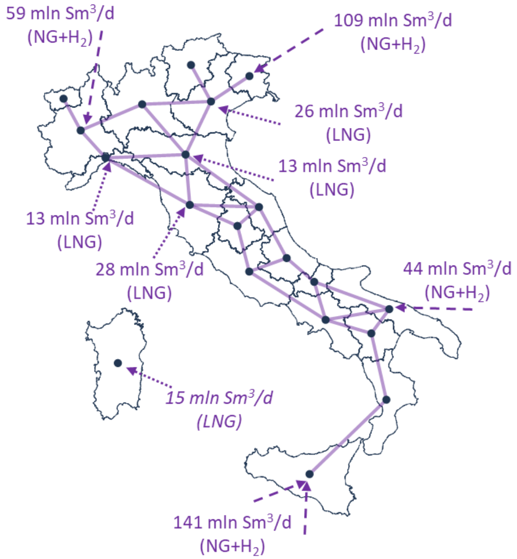
Simplified networks for each energy vector

- Allows assessing the prospective requirements of cross-border and inter-regional exchange

Electricity

Including future expansion projections

CH_4-H_2 blend

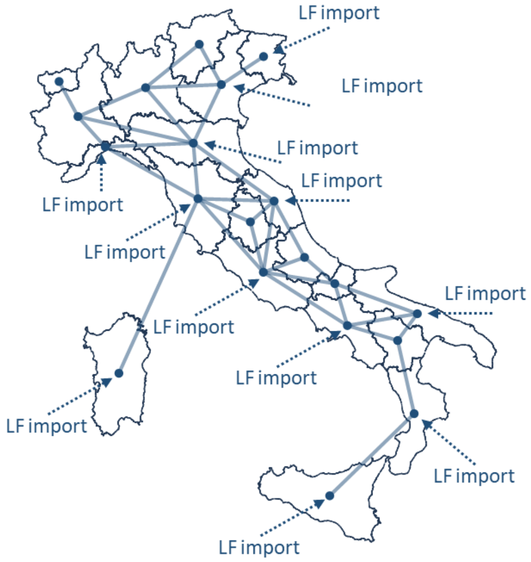


Including future expansion projections and repurposing

Hydrogen

Including generic connections, which might be via pipe, truck, ship.

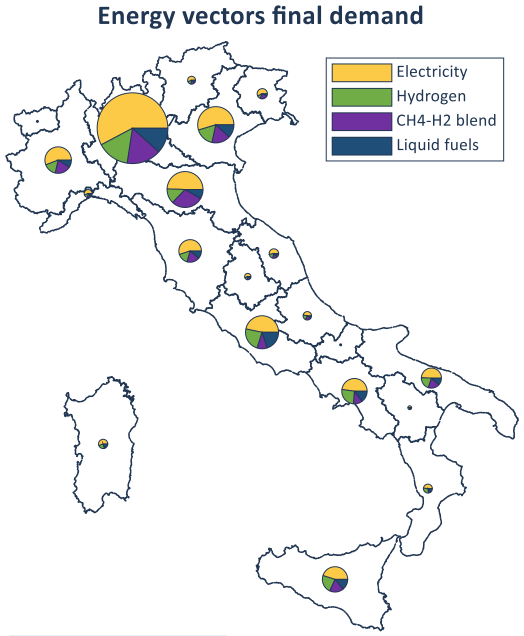
Liquid fuels



Including biofuels, e-fuels, conventional fuels.

H_2 role in the Italian system towards net-zero CO_2

Expected total consumption and demand @ 2050 Net Zero CO2



Values include all sectors included in the model

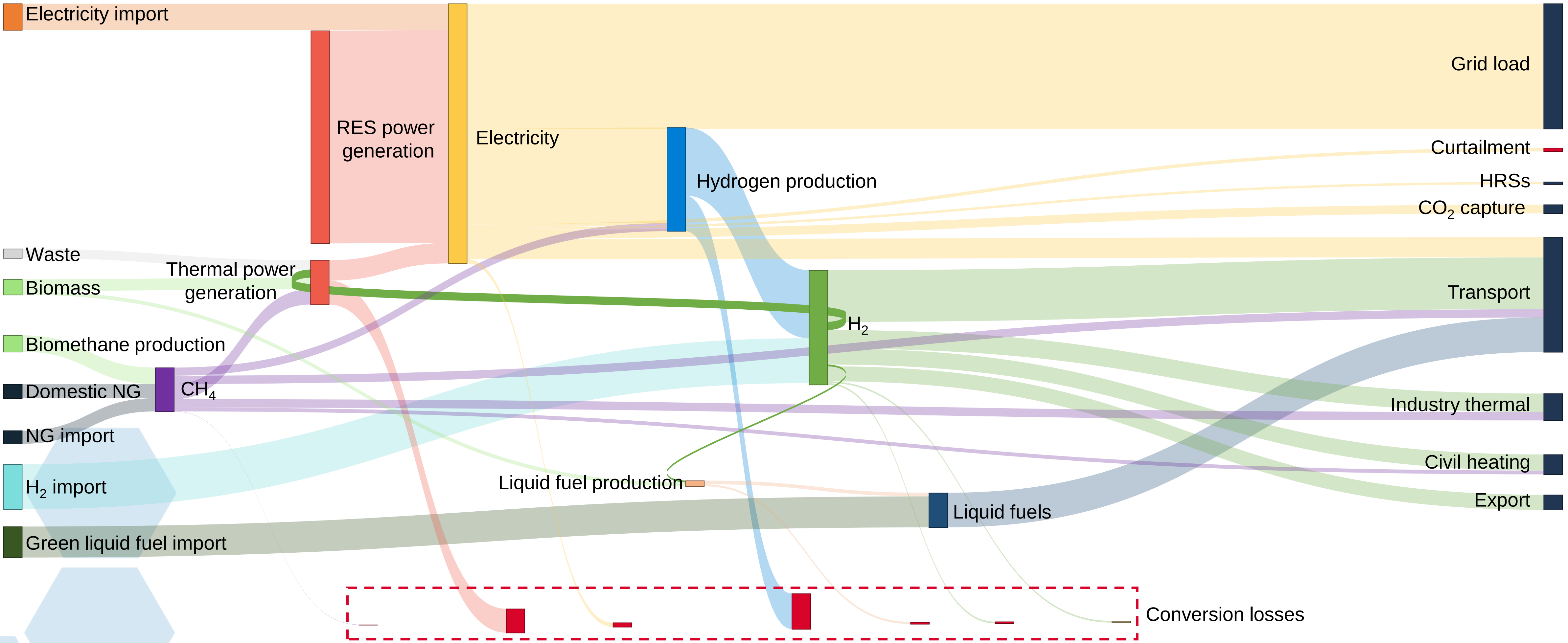
EXPECTED FINAL CONSUMPTIONS (= quantities to be managed within the system)

Energy vector	Annual consumption (final uses + conversion)	Uses	Variation from 2020
Electricity (production RES + thermoelectric +import)	~ 900 TWh_e/y	*Direct final demand (~450 TWh_e/y) + electrolysis + CO_2 capture units*	3x
H_2 (domestic electrolysis or SMR + import)	~ 300 TWh_{LHV}/y (~ 10 Mt_{H2}/y)	*Direct final demand for mobility + industrial feedstock + thermoelectric power generation + civil heating and industry*	New vector
CH_4 (1) (domestic biomethane + domestic NG + import NG)	~ 73 TWh_{LHV}/y (~ 8 mld Sm^3/y)	*Civil heating, industry, thermoelectric power generation, H_2 production via SMR+CCS*	-90%
Liquid fuels (2)	~ 180 TWh_{LHV}/y	*Mobility and industrial feedstock*	-80%

(1) Distributed as NG or in blend with H_2 (H_2 share optimized by the model)
(2) Including grey and green options

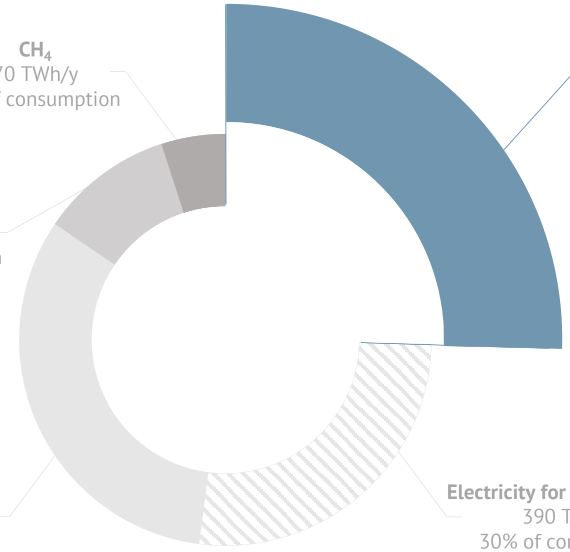
- Electricity consumption islarger than final demand (+80%), due to electrolysis, storage and CCS
- H_2 is largely adopted to decarbonize uses that currently rely on natural gas, making its consumption nearly double than the final demand for mobility and industrial feedstocks
- Nearly 75% of CH_4 consumption is covered by biomethane

Sankey diagram of energy vectors flows



H_2 role in the Italian system towards net-zero CO_2

H_2 share* in the energy system



**Shares refer to the total energy vectors 'moving' through the national infrastructures (excluding 50 TWh_{LHV} of H_2 flowing South-to-North for export)*

Avoided CO_2 emissions from H_2 direct final use

9 Mt_{CO2}/y avoided in **power generation**

9 Mt_{CO2}/y avoided in **light mobility**

32 Mt_{CO2}/y avoided in **HD mobility**

6 Mt_{CO2}/y avoided in **aviation**

1 Mt_{CO2}/y avoided in **navigation**

1 Mt_{CO2}/y avoided in **civil heating**

26 Mt_{CO2}/y avoided in **industry**

- 19 Mt_{CO2}/y avoided replacing fossil fuels in process heat generation
- 3 Mt_{CO2}/y avoided replacing fossil feedstocks in the chemical industry
- 4 Mt_{CO2}/y replacing coal in primary steelmaking

Trends and impacts

- A high degree of **energy self-sufficiency** and **CO_2 emissions cut** is difficult to achieve
  - The system needs import of green vectors

- **RES power generation** and direct electric use is favoured – when temporally matched
  - Low cost, high potential, low impact on direct CO_2 emissions

- **Power generation from H_2** is strongly dependent upon economics and conversion efficiency
  - Gas turbine-based plants are favoured over fuel cell systems (very high efficiency and moderate revamping investment)

- Use of **biogenic sources** (biomass and biomethane) is **essential** for net-zero CO_2 emissions
  - **Limited available quantities** cause **competition** between sectors

- **Blend CH_4-H_2**
  - Shifts towards **high H_2 shares** ($68\%_{LHV}$ or $89\%_{vol}$) in the gas grid
  - Hydrogen is used to replace CH_4 - **prioritizing** applications where CO_2 capture is not possible

- Hydrogen-based **e-fuels** become relevant **if the import of green liquid fuels is constrained**
  - Need for additional RES power generation and electrolysis capacity
  - Require a relevant increase of H_2 import and need for neutral CO_2 (via DAC)
  - May be avoided with a further (yet unlikely) switch in the mobility sector (vehicle reduction, electricity, hydrogen)

Il ruolo dell'idrogeno per un sistema energetico ad emissioni net-zero

Grazie per l'attenzione

Paolo Colbertaldo
paolo.colbertaldo@polimi.it

POLITECNICO MILANO 1863
DIPARTIMENTO DI ENERGIA

Fondazione Politecnico di Milano

May 17th, 2023 – Hydrogen Expo