CO$_2$NSTRUCT

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Modelling the role of circular economy construction value chains for a carbon-neutral Europe

JRC-EU-TIMES Model usage

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EERA Center of Excellence status meeting. Virtual Meeting. 2nd July 2024

HORIZON-CL5-2021-D1-01-02: Modelling the role of the circular economy for climate change mitigation

Expected Outcome:

Project results are expected to contribute to all of the following expected outcomes:

- **Improve existing** European and/or global **climate mitigation models** by **better representation of basic industrial value chains** (including reliable data) and **potential mitigation technologies** including the impact of circular economy
- Improve the **quantification of the impacts and potentials** of the circular economy for climate change mitigation
- Support the **integration of the circular economy into climate action**, policies and their evidence base, including externalities
- Support the **integration of the GHG emission reduction / mitigation in the circular economy criteria**

3 funded projects combining many models: WITCH, MESSAGE, JRC-EU-TIMES, etc.

On the project

CO_2NSTRUCT - Modelling the role of circular economy construction value chains for a carbon-neutral Europe

Project facts

EU funding programme: Horizon Europe

Call: HORIZON-CL5-2021-D1-01: Climate sciences and responses

Topic: HORIZON-CL5-2021-D1-01-02

Type of action: HORIZON Research and Innovation Actions

Start date: 01-06-2022

End date: 31-05-2026

Duration: 4 years

Budget: 5 million Euro

What we will do in CO_2NSTRUCT

To develop a new climate mitigation modelling framework for the construction materials value chain that includes an account for:

- **Circular Economy (CE) feedback loops and other CE tools**
- **their rebound effects**
- **expected citizen engagement and**
- **an evaluation of externalities**

for different CE climate mitigation scenarios

Consortium Partners

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DTU
Construction materials
Circular economy
Sustainability

Rebound effects
Supply and value chains
Circular economy

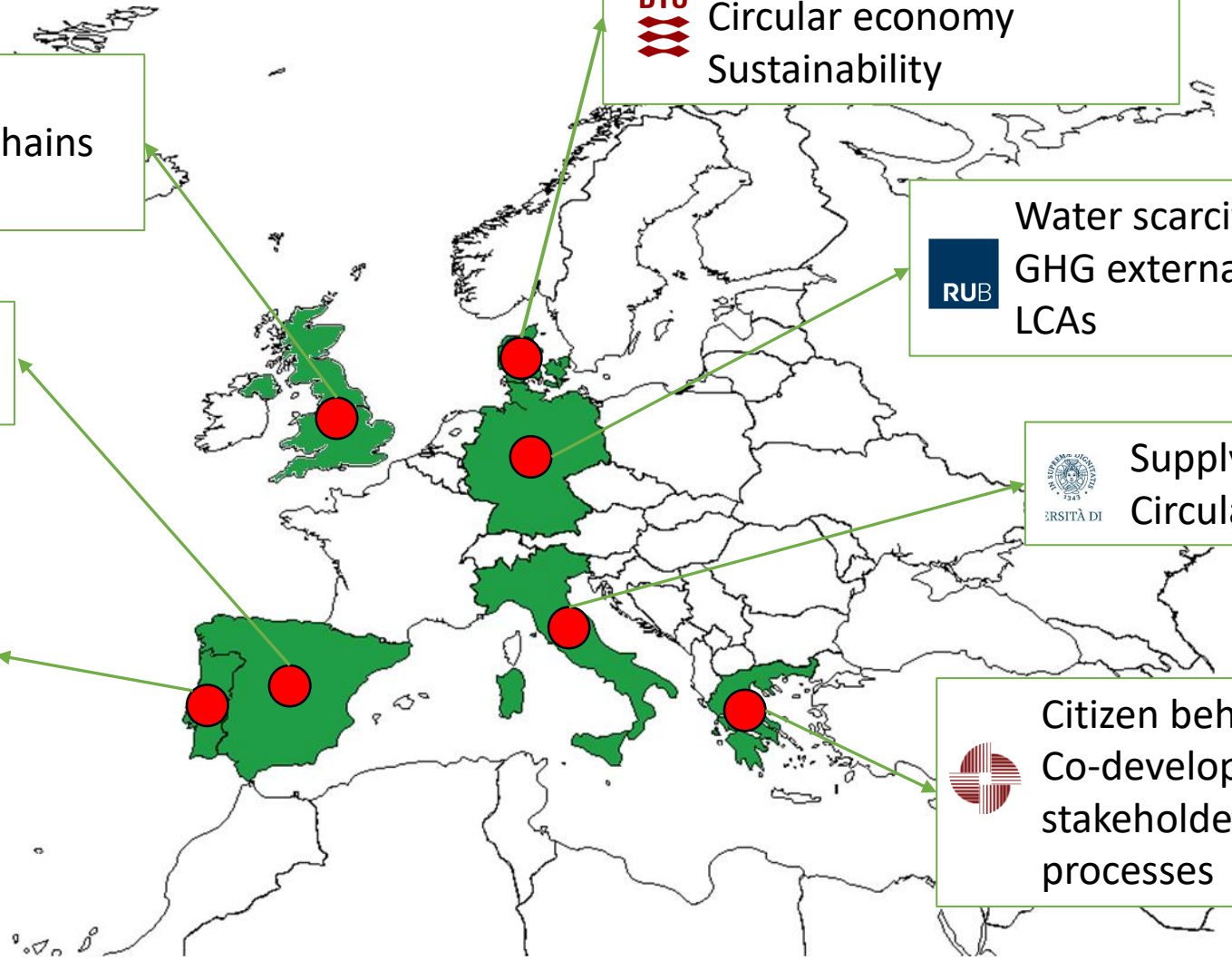
RUB
Water scarcity
GHG externalities
LCAs

Sustainability
LCAs

Supply and value chains
Circular economy

Climate mitigation modelling
GHG externalities
Policy
Energy poverty

Citizen behaviour
Co-development & stakeholder engagement processes



DTU
RUB
Università di Pisa
The University Of Sheffield.
LNEG
Gobierno de España
Ministerio de Ciencia e Innovación
Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas
ΚΑΠΕ CRES

TIMES Vs circular economy (CE)

TIMES models currently represent **linear patterns of economic activity**.

- GHG emissions are **modelled per economic sector and no downstream value chains** are considered
- **upstream value-chains are poorly represented**, **indirect GHG emissions** are mostly not included
- **extending products lifetime**, **sharing models**, and **feedback loops** - generally not considered
- increased resource use for climate mitigation is not addressed

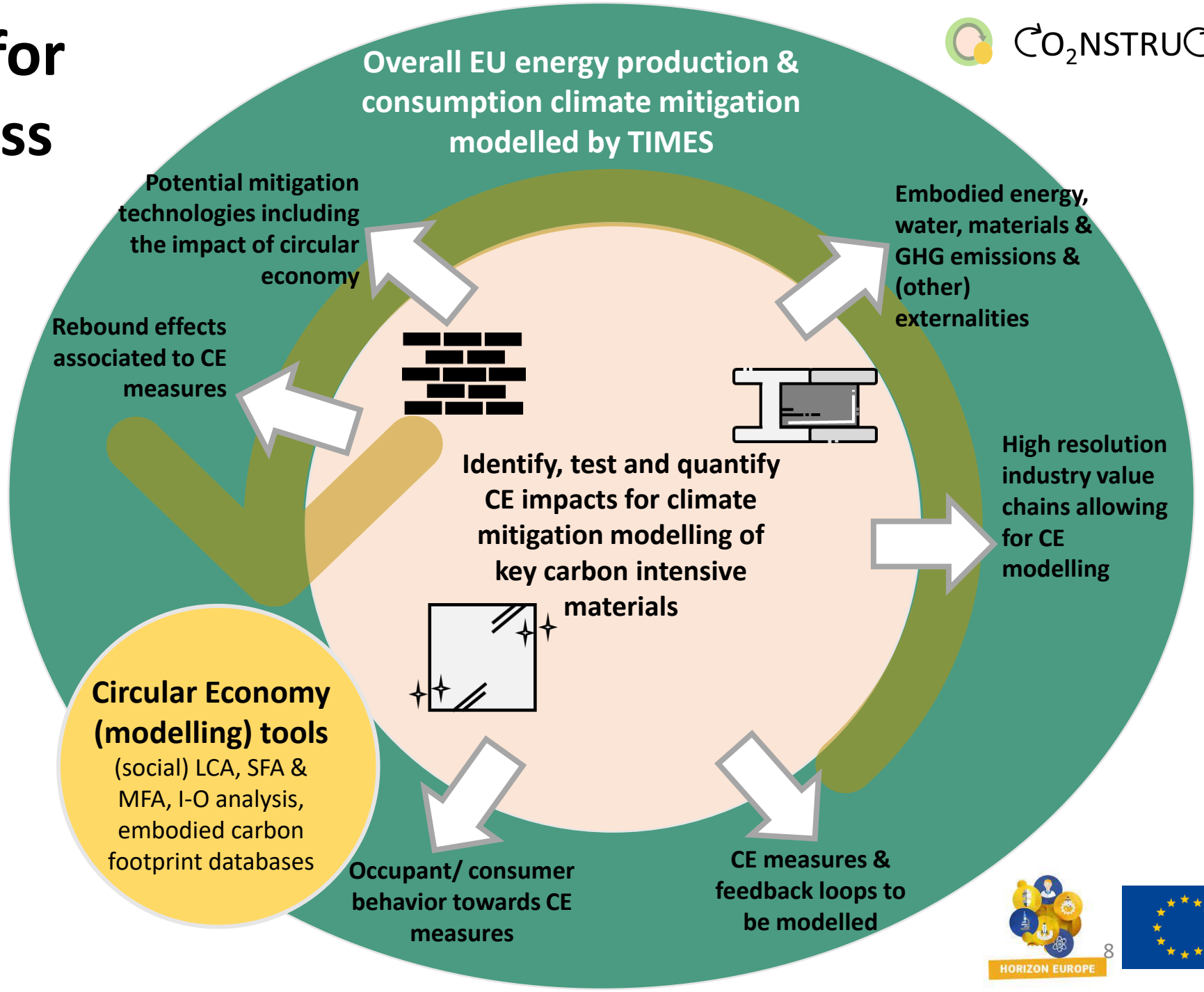
TIMES models cannot account for materials' circularity

there is increased attention to the need to transform linear models into circular models

Bridge the gap between **TIMES** modelling and **CE analytical tools** used for cradle-to-cradle assessments (e.g., LCA-Life Cycle Assessment, MFA-Material Flow Analysis, or value-chain analysis)

TIMES models need a **high level of technical detail** to adequately represent CE measures and to integrate feedback loops characteristic of CE practices

Some elements for making TIMES less linear



SOME OUTPUTS

Policy recommendations
GHG emissions gains
Impacts on GHG abatement and on energy costs
Hotspots for CE measures that impact GHG mitigation

Circular economy options in the project

Raw material extraction

(CE options not considered)

Material manufacturing

(CE options mapping is done! First paper out!)

Building design

(CE options mapping is ongoing)

Building construction

(CE options mapping is ongoing)

Building use

(CE options mapping is ongoing)

Building end-use

(CE options mapping is ongoing)

Offshore turbine design

(CE options mapping is starting - design)

Offshore construction

(CE options mapping is ongoing)

Offshore use

(CE options mapping is starting)

Offshore end-use

(CE options mapping is starting)

APPROACHES TO INTEGRATE CIRCULAR ECONOMY IN TIMES

1. Consider changes in demand for energy services due to modifications in consumption patterns (e.g. due to sharing spaces)
2. Change allocation of emission across economic sectors (e.g. emissions are allocated to cement users not cement producers)
3. Include impacts of CE as externalities (e.g. land-use) as “costs”
4. **Disaggregate sectors as construction and waste management**
5. **Model sectors in more detail with mass balances (currently mostly done for steel, cement, glass and paper)**
6. **Include explicitly feedback loops (& value-chain) between material producers and consumers**

Being applied to:

- **Buildings (energy use in commercial & residential buildings)**
- **Construction (renovating, demolishing and building new)**
- **Offshore power**
- **Cement production**
- **Glass production**
- **Steel production**
- **Other industry (insulation, soda ash,…)**
- **…**

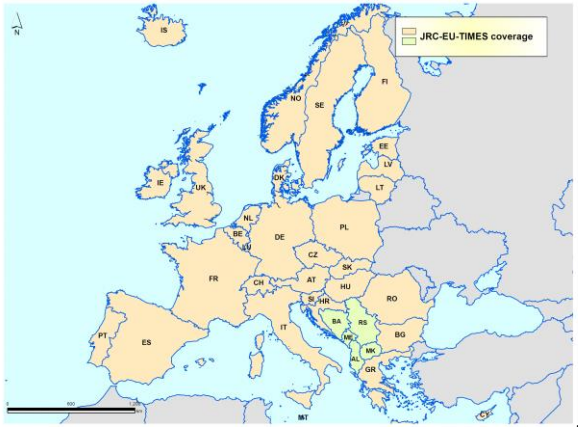
On the modelling
(sorry, not really results yet)

JRC-EU-TIMES model

JRC-EU-TIMES energy system model for EU+ developed at JRC

- Optimization model for overall EU energy system
- Detailed technology databased for energy production, transport/distribution and end-use
- Each EU country modelled in detail
- 2015 till 2070 (?)
- Open and documented
- Part of the widely used TIMES family of models developed by ETSAP IEA

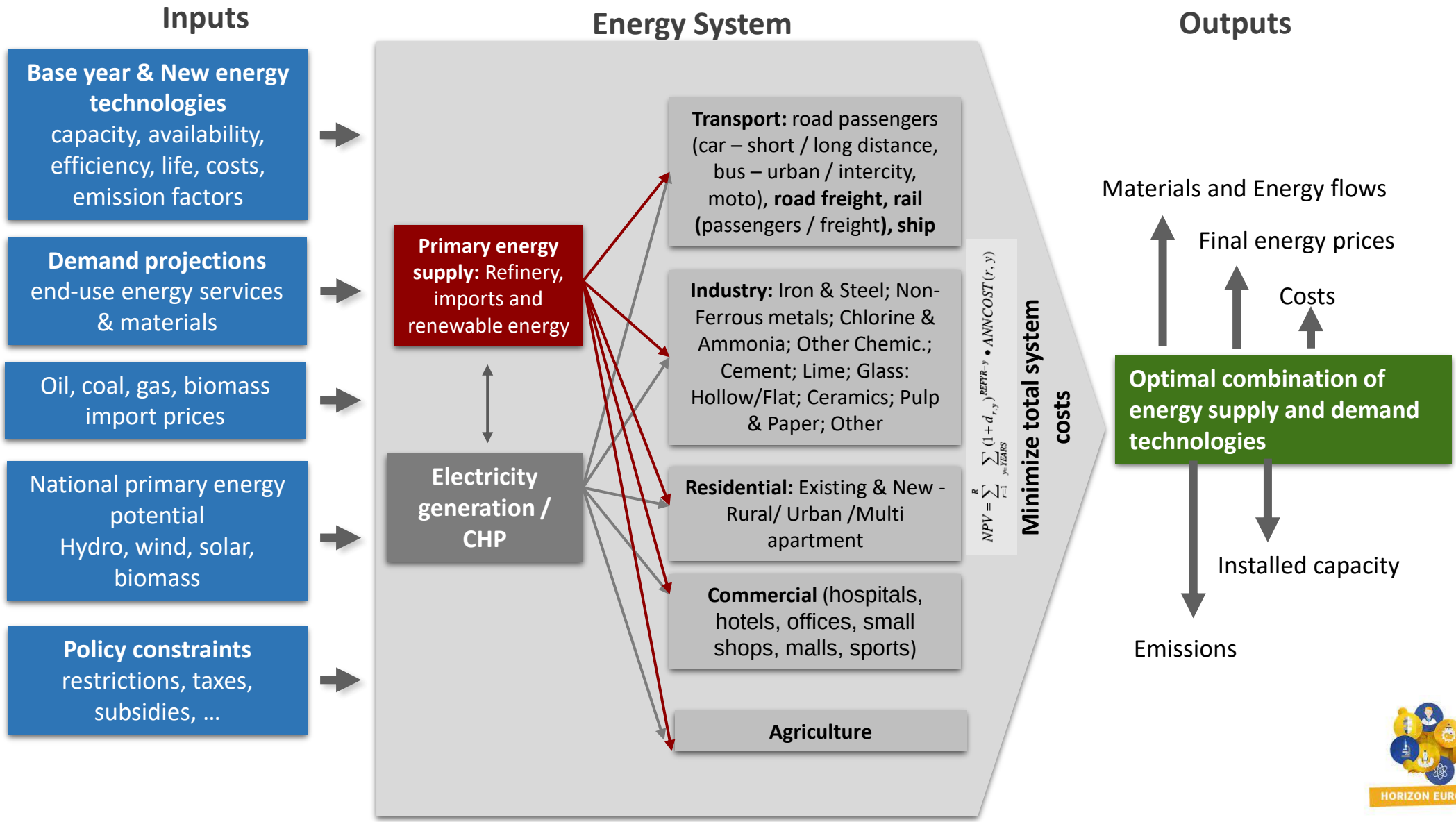
What is the combination of energy technologies that allows satisfying the demand for energy services at the lowest cost, while ensuring carbon neutrality goals?



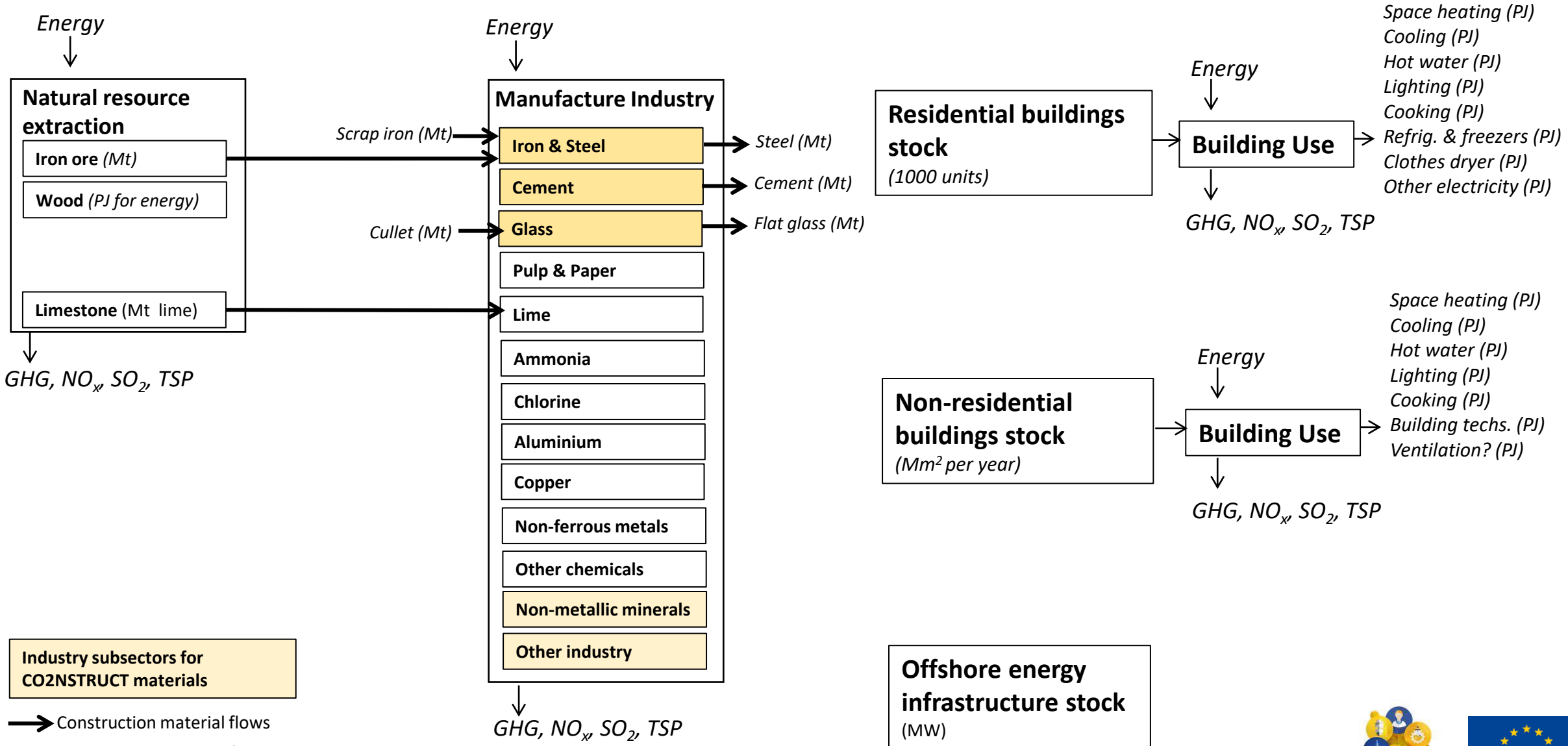
More on JRC-EU-TIMES [here](#) and [here](#)

- **Supply sector** description (fuel mining, primary and secondary production, import and export)
- **Electricity multi-grid model** (high, medium and low voltage grid), tracking demand-supply via 12+ time slices (4 seasons, 3 diurnal periods), and gas across 4 seasons
- **Country specific differences** for characterisation of the conversion and end-use technologies
- **Renewable potential** (onshore wind, offshore wind, geothermal, biomass, biogas, hydro)
- **Cross-border and Endogenous (EU) Trade**

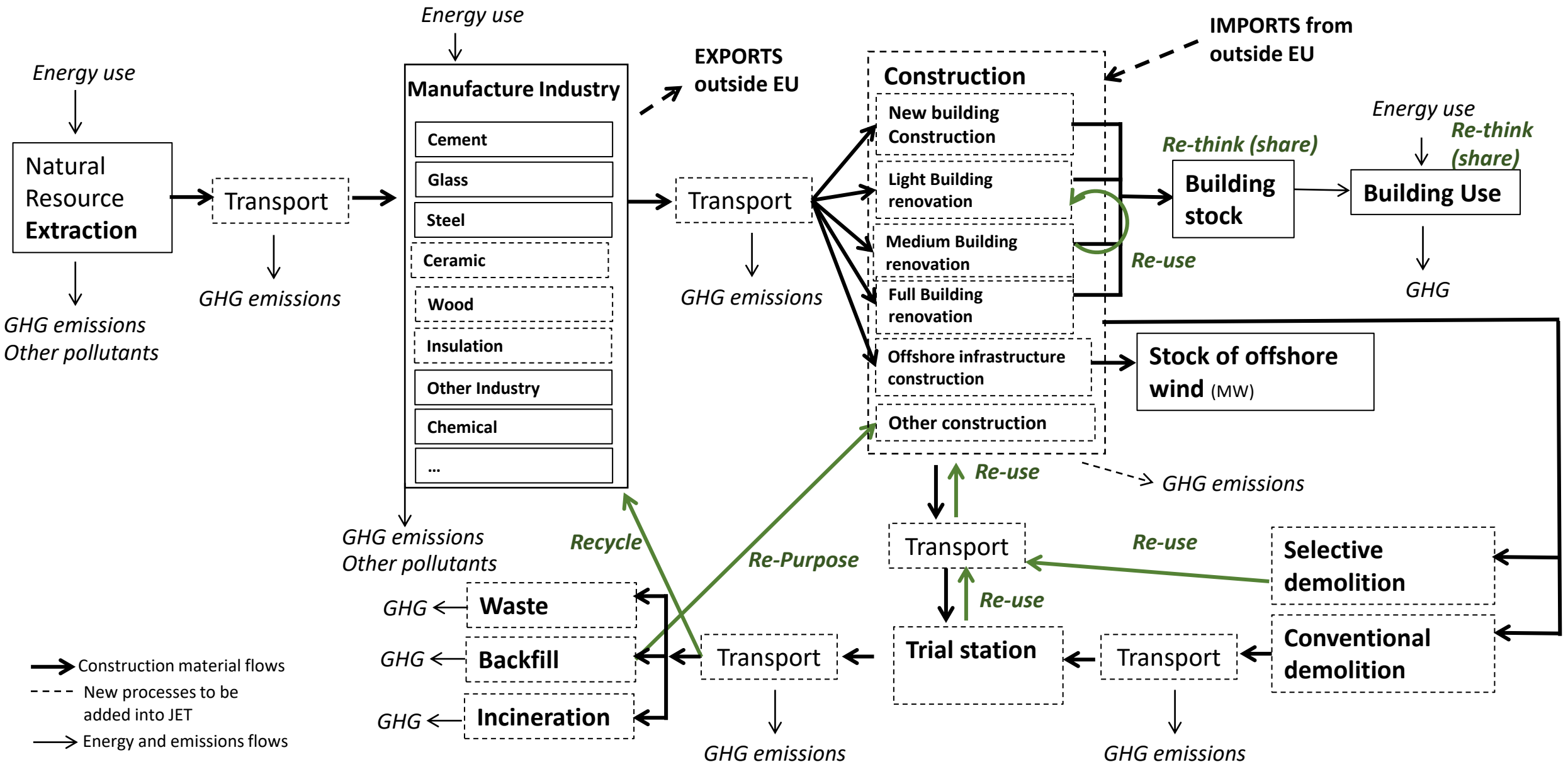
JRC-EU-TIMES model



This is how construction materials are currently in the JRC-EU-TIMES model



The more circular JET model being built



It was necessary to develop a new methodology to estimate material, energy flows and emission associated to buildings construction value chains

At annual level for each country in EU28+

WHY? Because this is the level that GHG emissions policies work

(resource/LCA community work at lifetime scale: embodied carbon)

Methods (simplified)

Energy consumption per energy carrier (TJ) *[Eurostat "Mining and quarrying"]*

Extraction of raw materials (mineral ores, sand and gravel, …) from Material Flow Accounts (kt) *[Eurostat]*

Combustion EF ($ktCO_2/TJ$) *[UK DEFRA & USA EPA]*

Raw material extraction (metal ores and other)

Country specific % construction relevant materials over total minerals extracted
% of annual extracted volumes to be used in construction *[EUROSTAT]*
81% of total energy consumption in construction assumed to be for buildings GAV *[EUROSTAT]*
Country specific Multiplier for EUROSTAT energy consumption "Mining of Metal Ores" for buildings

Raw material transport

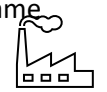
Annual production (Mt) *[National Inventory Reports to UNFCCC]*

Raw Materials sold production, exports and imports (kt) *[PRODCOM Eurostat]*

Carbon intensity per material ($ktCO_2/Mt$) *[National Inventory Reports to UNFCCC]*

Construction materials manufacturing

Country specific % for steel, glass, % cement, % bricks produced/year assumed as used in same year for buildings *[based on GAV statistical information]*
Adjust total glass production with values from PRODCOM for Flat glass production



Energy consumption per energy carrier(TJ) *[Eurostat "Road freight transport")*

EF freight road vehicles ($ktCO_2/km$) *[ICCT]*

Transport of construction materials

Assumed same quantities as in previous step are transported
Assumed **material specific + average travelled distance per country** for road freight transport *[RUB and Eurostat]*

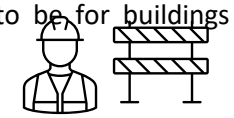
- Average annual CO_2 emissions (kt)

Energy consumption per energy carrier(TJ) *[Eurostat "Construction" & "Building Construction")*

Combustion EF ($ktCO_2/TJ$) *[UK DEFRA & USA EPA]*

Construction (includes renovation/maintenance)

Country specific % of total energy consumption for construction assumed to be for buildings *[Eurostat] - GAV*
Values need to be refined



Energy consumption per energy carrier(TJ) *[Eurostat "Construction")*

Combustion EF ($ktCO_2/TJ$) *[UK DEFRA & USA EPA]*

Demolition

5% total construction energy consumption assumed to be used for buildings *[ECORYS]*

- Average annual CO_2 emissions (kt)
- kt CO_2 / construction Gross Added Value (M€)
- kt CO_2 / built area *per capita*

Energy consumption per energy carrier(TJ) *[Eurostat "Road freight transport")*

FE freight road vehicles ($ktCO_2/km$) *[ICCT]*

Waste transport (and management)

Mt construction and demolition waste transported for disposal *[Eurostat]*
Assumed **average travelled distance per country** for road freight transport *[Eurostat]]*

Annual average (2017-2021) for each member state of European Union and for EU as a whole

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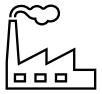
EF - emission factors

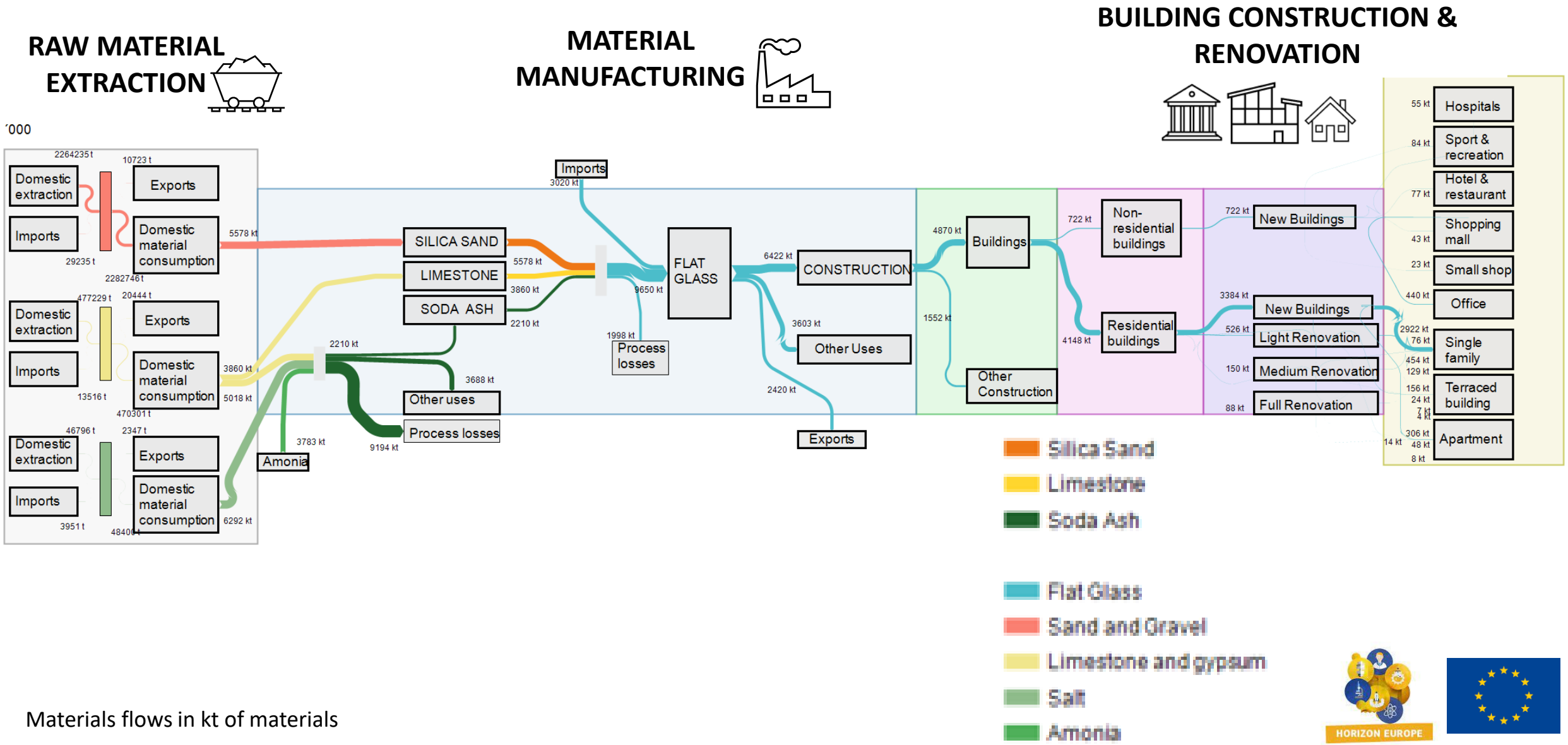
Mass flows

For 2019 (per country in kton)



Raw Materials	Construction Materials	Main uses	In Construction	Buildings Typologies
• Sand • Limestone • Clay • Iron ore • (…)	• Flat Glass • Cement • Steel • Bricks	• Construction • Other uses (Non-construction)	• Buildings • Other construction	• **Residential** (apartments, detac hed houses, semi-detached houses) • **Non-residential** (hospit als, hotels, offices, small shops, malls, sports)

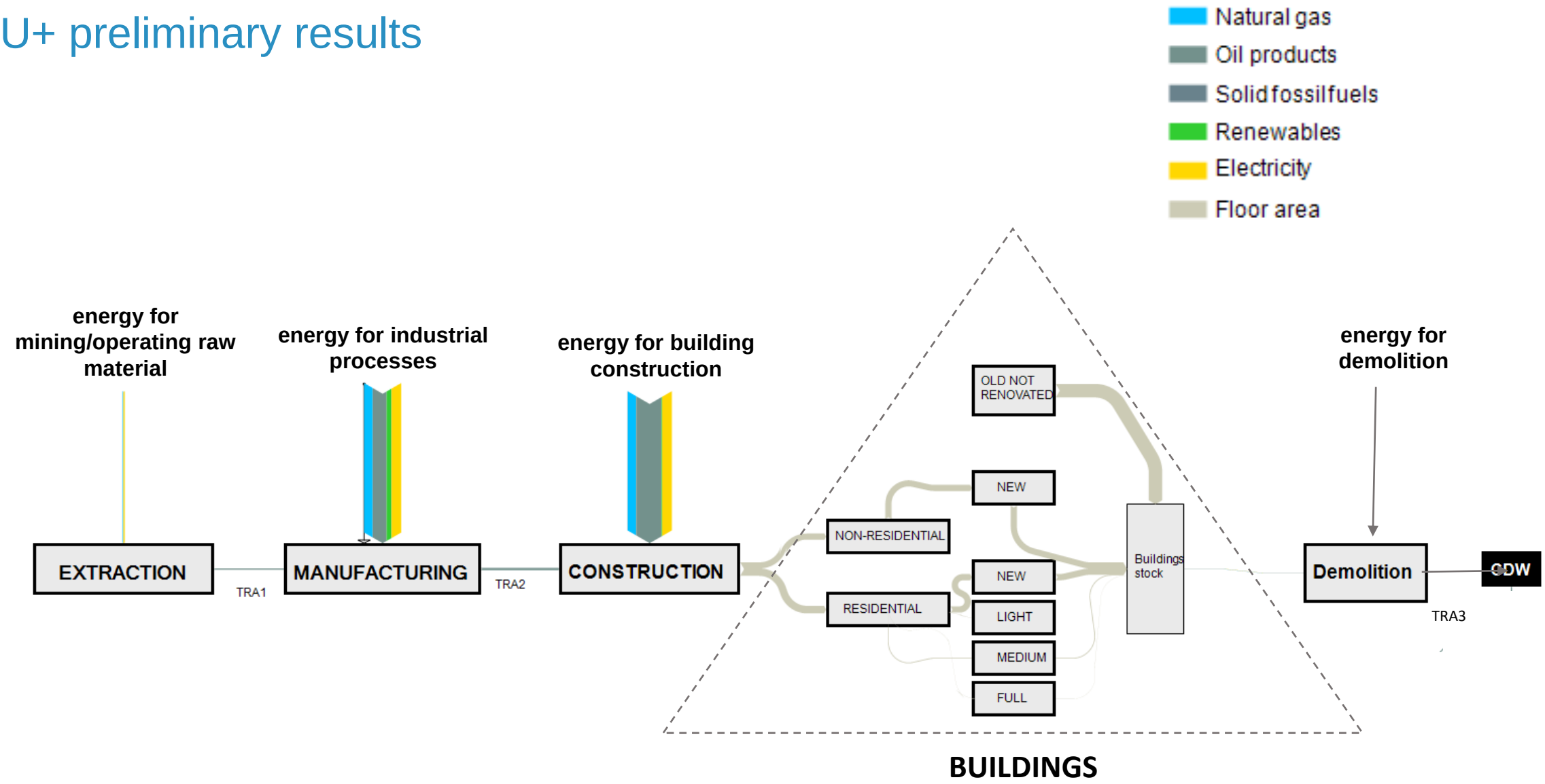
Material flows for flat glass for construction
EU27 (2019)



Materials flows in kt of materials

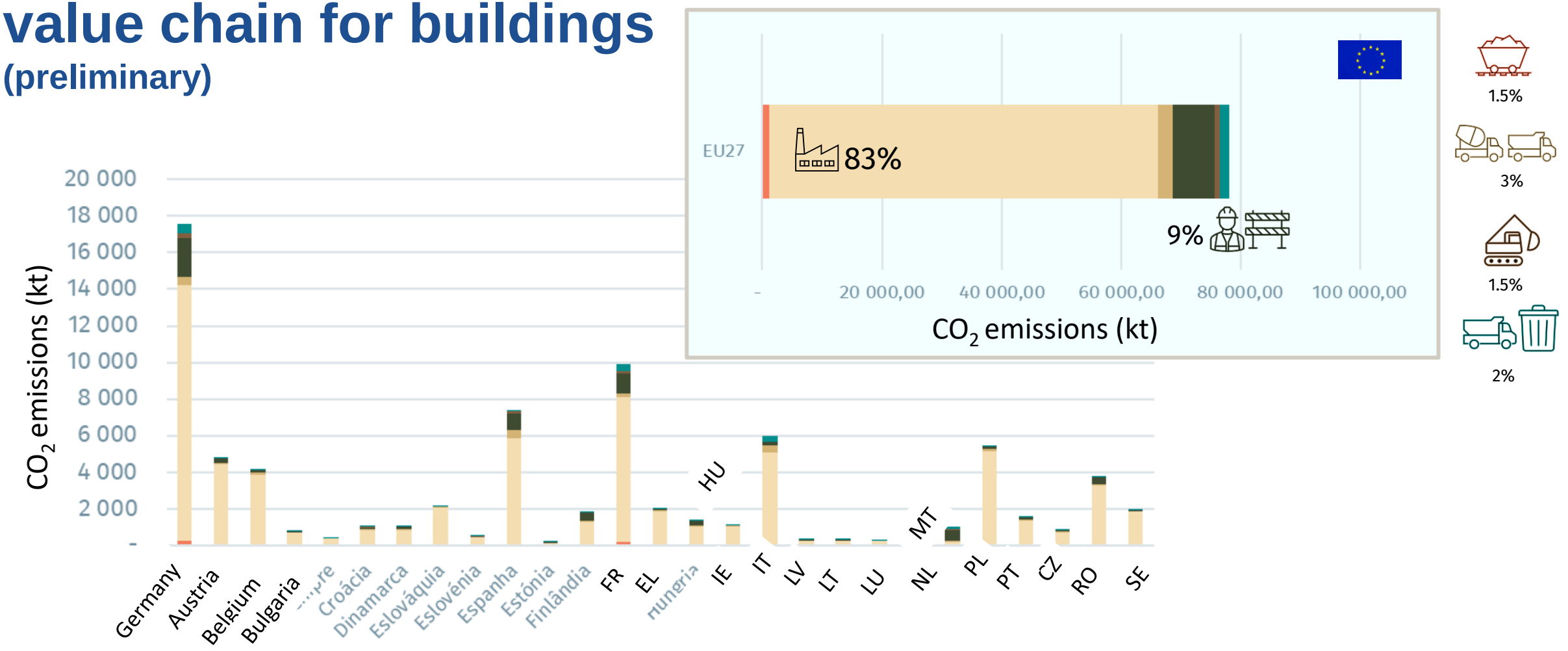
Annual energy flow along the construction value chain

EU+ preliminary results



Annual CO_2 emissions from construction material value chain for buildings

(preliminary)



Some very preliminary insights learnt when modelling Circular Economy in TIMES
(previous exercises from Fortes et al.)

>In general CE contributes to a reduction of energy consumption and have **positive effects in GHG emissions reduction** in the evaluated cases;

>Benefits are **not straightforward**:

Recover and recycling processes may lead to a lower availability and higher prices of some sub-products - its scarcity may conduct to further substitutions that may not be optimal from a climate mitigation perspective.

Extension of technologies life-time conduct to a reduction of energy efficiency.

> **Limitations**:

Highly **uncertain** assumptions;

TIMES is mostly focused on the **energy system**, representing in a roughly way other material/services flows that may have a crucial role in CE.

On scenarios

Co-developed with a User Board

DG ENV
DG CLIMA
EUROFER
Tiles & Bricks Europe
Glass for Europe
CEMBUREAU
Wienerberger
Saint Gobain Glass
ACS Glass
…

Insights from consumer preferences survey
(+1200 consumer replies)

What about Circular Mitigation Scenarios?

We are looking for the synergies between circular economy and climate mitigation in EU+ until 2070 - We will need to use **scenarios**.

Our scenarios will not focus on aspects as population, economic development or levels of GHG emission abatement. We will align with EU socio-economic scenarios and with SSPs (Shared Socio-Economic Pathways).

Instead, we are interested in scenarios on which CE measures will be considered in modelling EU circular climate mitigation pathways towards carbon neutrality. In all scenarios carbon neutrality is a given!

Initially we planned to use only 2 axes along which Circular Mitigation scenarios were going to be developed:

- Axis (a) referring to the scope of CE measures (**which measures?)**
- Axis (b) referring to their coverage (**where and when are they implemented?**).

We need to get the full set of assumptions used on PRIMES on materials demand per country…

Approach for circular mitigations scenarios

BLOCK 1 Evolution of infrastructure (buildings/offshore)

- **Life-time** (demolition rate, construction rate, renovation rate)
- **Material intensity** modifications (product design)
- Demand for **floor area per capita / sufficiency**
- Evolution of **energy services and materials demand** (this is the traditional scenario variable in TIMES model exercises)

BLOCK 3 CE options

- **Types** of CE practices being implemented (having sharing or not)
- **Level of implementation** of the CE practice (recycle all flat glass or just 90%)
- Capacity to recover materials from buildings/offshore
- **Cost** of CE options

SSPs

BLOCK 2 Materials market dynamics

- Change ratio of **CE implementation vs raw material extraction** (might not be that just by more CE you mine less - depends on global steel market dynamics)
- Global materials dynamics and **imports / exports**

BLOCK 4 Transport

- **Location** of factories and waste recovery routes
- Change of transport **modes**
- Improvement in **Logistics**
- …

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