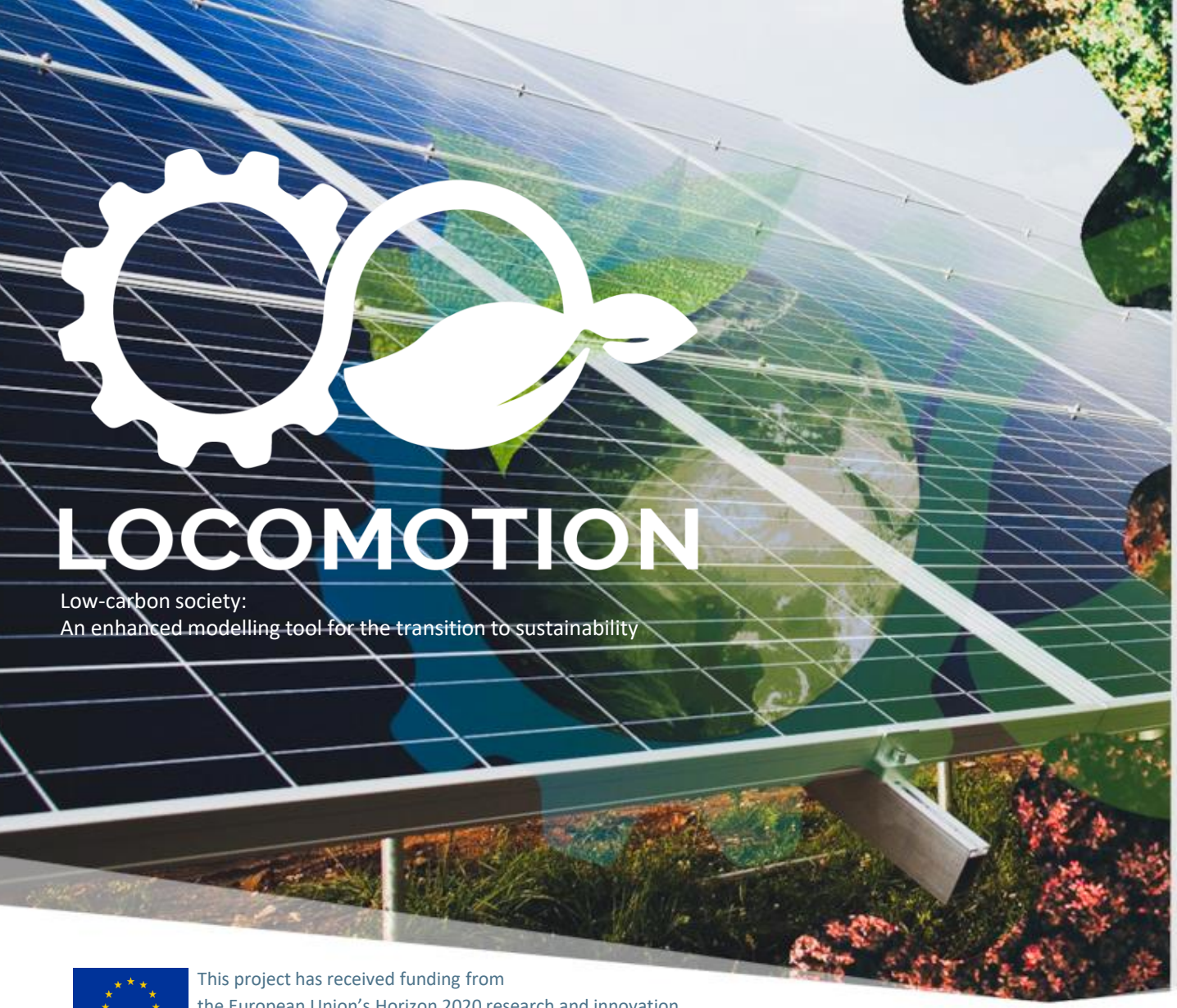


LOCOMOTION

Low-carbon society:
An enhanced modelling tool for the transition to sustainability

WILIAM ENERGY MODULE

A SYSTEM DYNAMICS APPROACH TO ENERGY MODELLING IN A MULTIREGIONAL INTEGRATED ASSESSMENT MODEL

EnInnov, Session A4, Online, 17.2.2022

Lukas Eggler, Martin Baumann

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 821105.

LOCOMOTION

Low-carbon society: An enhanced modelling tool for the transition to sustainability

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 821105

"LOCOMOTION aims to enhance the existing MEDEAS IAMs to provide policy-makers and relevant other stakeholders with and open source, well-documented model to assess the feasibility, effectiveness, costs and impacts of different sustainability policy options"

The project

CONTACT:
Prof. Luis Javier Miguel González
Nathalie Wergles
Energy Economy and System Dynamics Group
University of Valladolid

info@locomotion-h2020.eu

www.locomotion-h2020.eu

- Duration: 1st June 2019 – 31th May 2023
- Coordinator: Universidad de Valladolid (Spain)
- Partners:

UNIPI
SDEWES
AEA
BC3
CESAR
UoI
CRES
FC.ID
UNU-EHS
EEB
CREAF
CARTIF
INN

Agenda

WILIAM – a brief overview

Energy Module

Detail: Energy Transformation chain

Detail: Capacity Expansion Mechanism

Detail: Scarcity Feedback

Outlook & Learnings

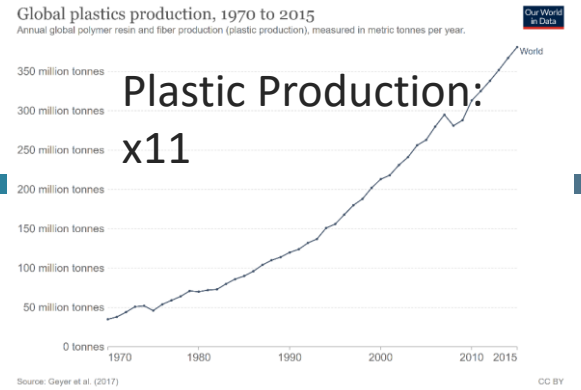
WILIAM

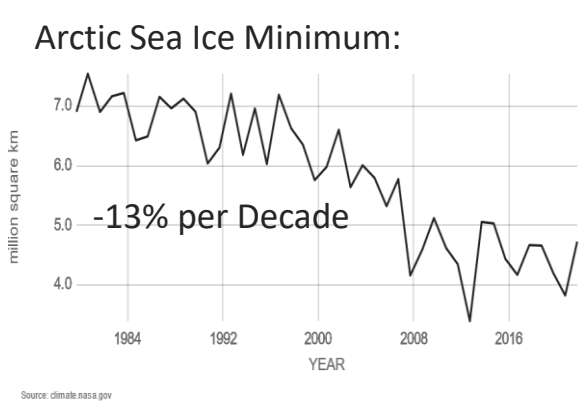
A brief overview

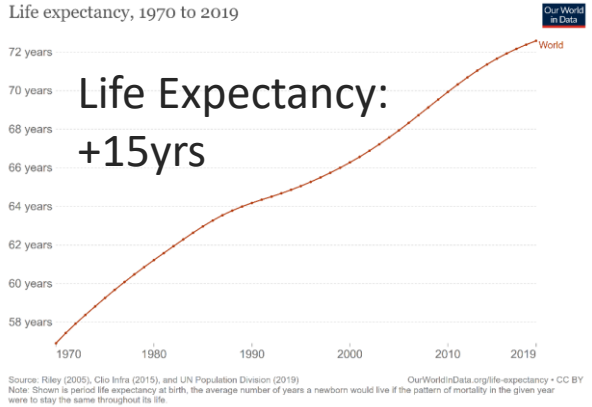
LOCOMOTION

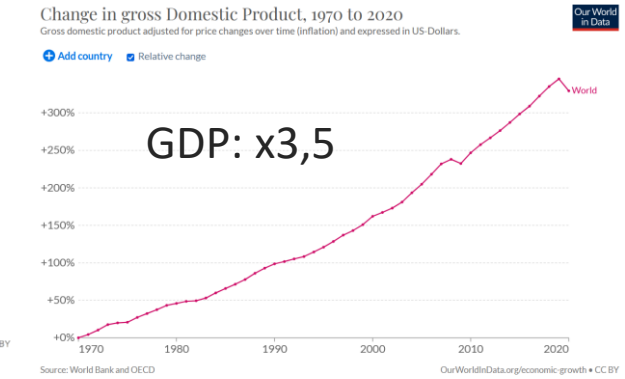
Global developments since 1970

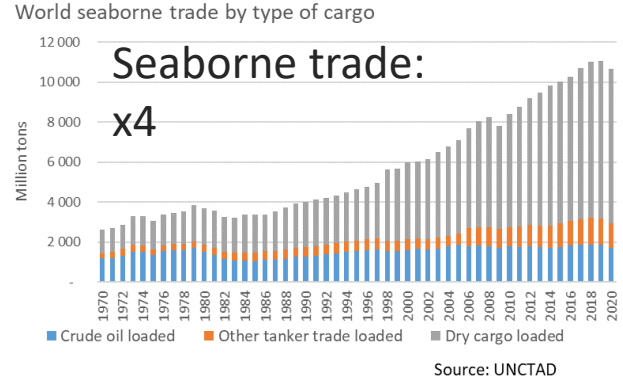
We are facing a multidimensional Crisis

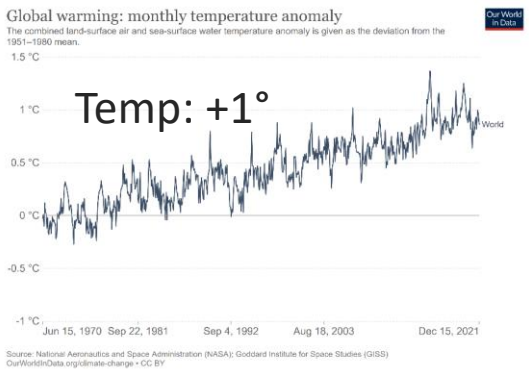


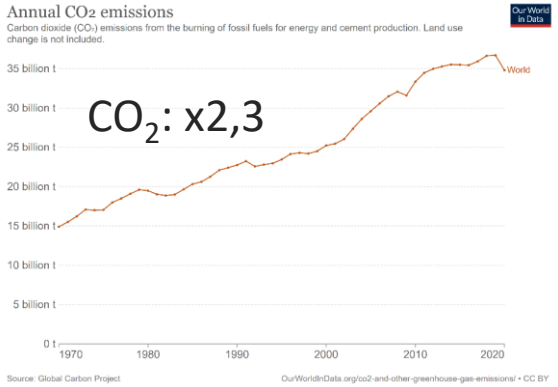


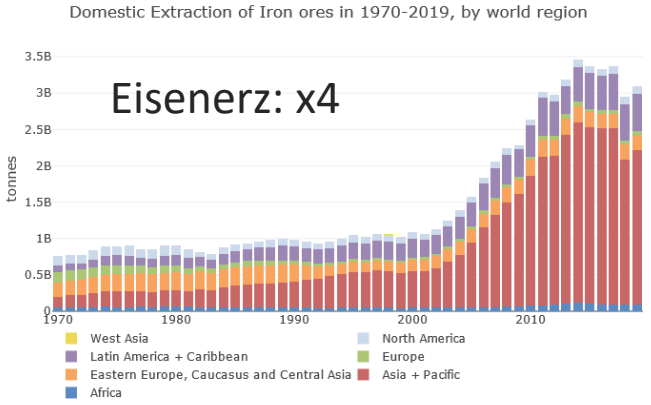


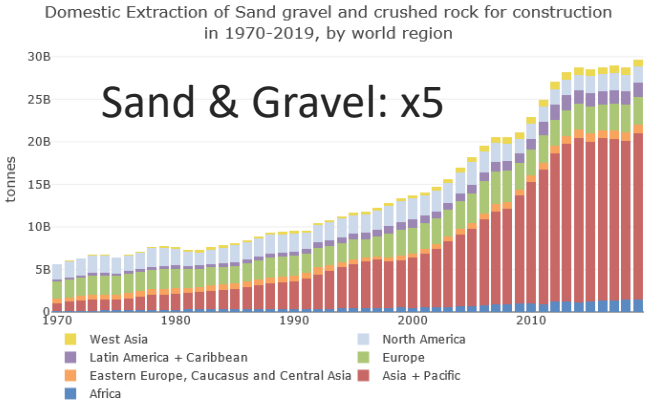












WILIAM

(**WI**thin **L**imits **I**ntegrated **A**ssessment **M**odel)

- Based on predecessor model MEDEAS
- **System dynamics** methodology,
  implemented in VENSIM and translated to Python (OPEN SOURCE)
- **Multiregional** 9 regions + 27 EU countries (35 in total)
- **Annual** timesteps until 2050
- **Modules** currently in development
  - **Economic module** with Input-Output of 62 economic sectors. Higher disaggregation of energy and mining sectors, enabling consistency of monetary and physical flows.
  - **Demographic module** including climate change feedbacks on migration
  - **Environmental module** covering climate, water, land use, agricultural production and diets
  - **Minerals- & Materials module** accounting for the resource requirements our economy from mining to recycling
  - The **Energy Module** determines the demand for primary energy and selects the required transformation technologies.

WILIAM alternative storylines

Green Growth

market tools and technological development

economic growth, absolute decoupling, global economic convergence; fast diffusion of low carbon technologies, sector coupling, efficiency improvements

Green Deal

Green Growth complemented with social policies

Features of Green Growth + social inequality reduction; public investments; welfare state; public ownership of energy utilities; job guarantee; public intervention

Post-growth

voluntary downscaling

relocalization, sharing economy, self-organization, commons, conviviality, voluntary behavioural changes; sufficiency; reducing material throughput

WILIAM ENERGY MODULE

LOCOMOTION

Energy Module – design principles

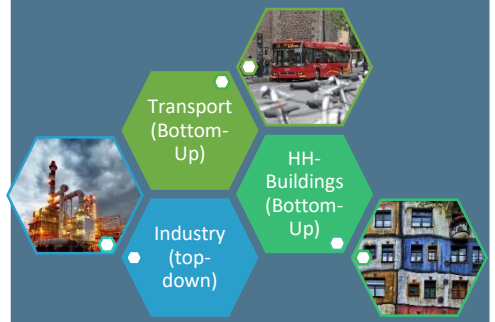
- IEA **Energy Balance Consistency**
- **Adequate representation of technologies** that will likely play increasing role in **sustainable scenarios** (RES, Storage, CCS, DSM, H2…)
- Taking into account **biophysical limitations** via Feedback loops with other modules (e.g. Landuse for PV, biomass, material requirements, fuel scarcities and dynamic price signals)

Energy Module

Economic Demand

Policy Assumptions

Energy End-Use
„converting USD to kWh“



КАПЕ CRES

Universidad de Valladolid

FE demand

Dynamic OPEX

FE Imports/Exports

Energy Transformation
„modelling annual energy balances“

Energy transformation chain

technology utilization allocation

Emissions

PE demand

Max. Biofuel Production

RES Potential
„accounting for land competition“

Universidad de Valladolid

КАПЕ CRES

Biophysical Limitations

Max. RES Capacity by Region

Energy Capacity
„accounting for capacity stocks“

Transformation capacity – Stock- and flow modelling

Transformation Technology Expansion **allocation**

Available transformation Capacity

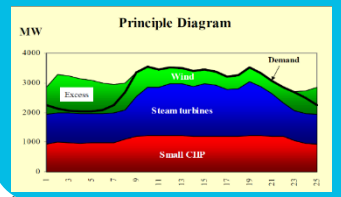
Material- & Land Use

Investments

- Max. vRES production without curtailment
- vRES production with curtailment
- Storage Losses
- Flexible Production Tech. Utilization

- DSM
- Smart Charging
- V2G
- small heatpumps
- …

Energy Variability Management
„impact of intermittent power sources on annual energy balances“



EROI/ESOI
Estimate the Energy Return on Energy Invested of the System

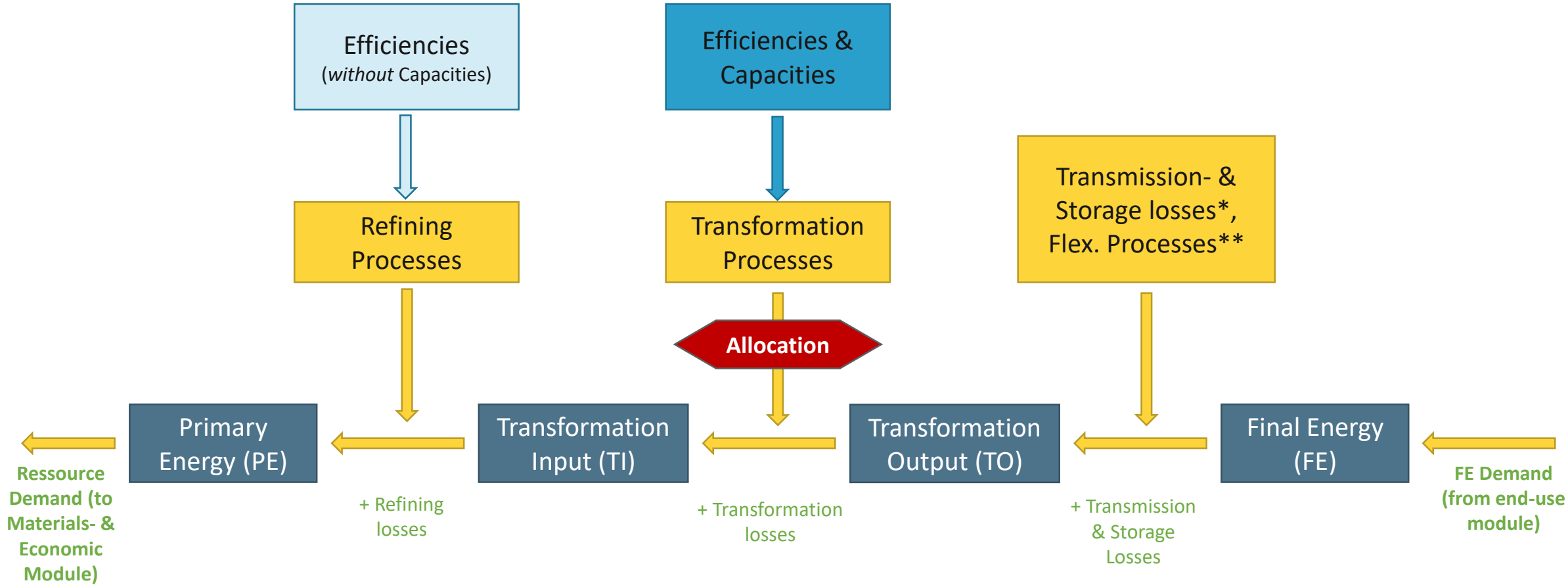
Universidad de Valladolid

Universidad de Valladolid

sdewes

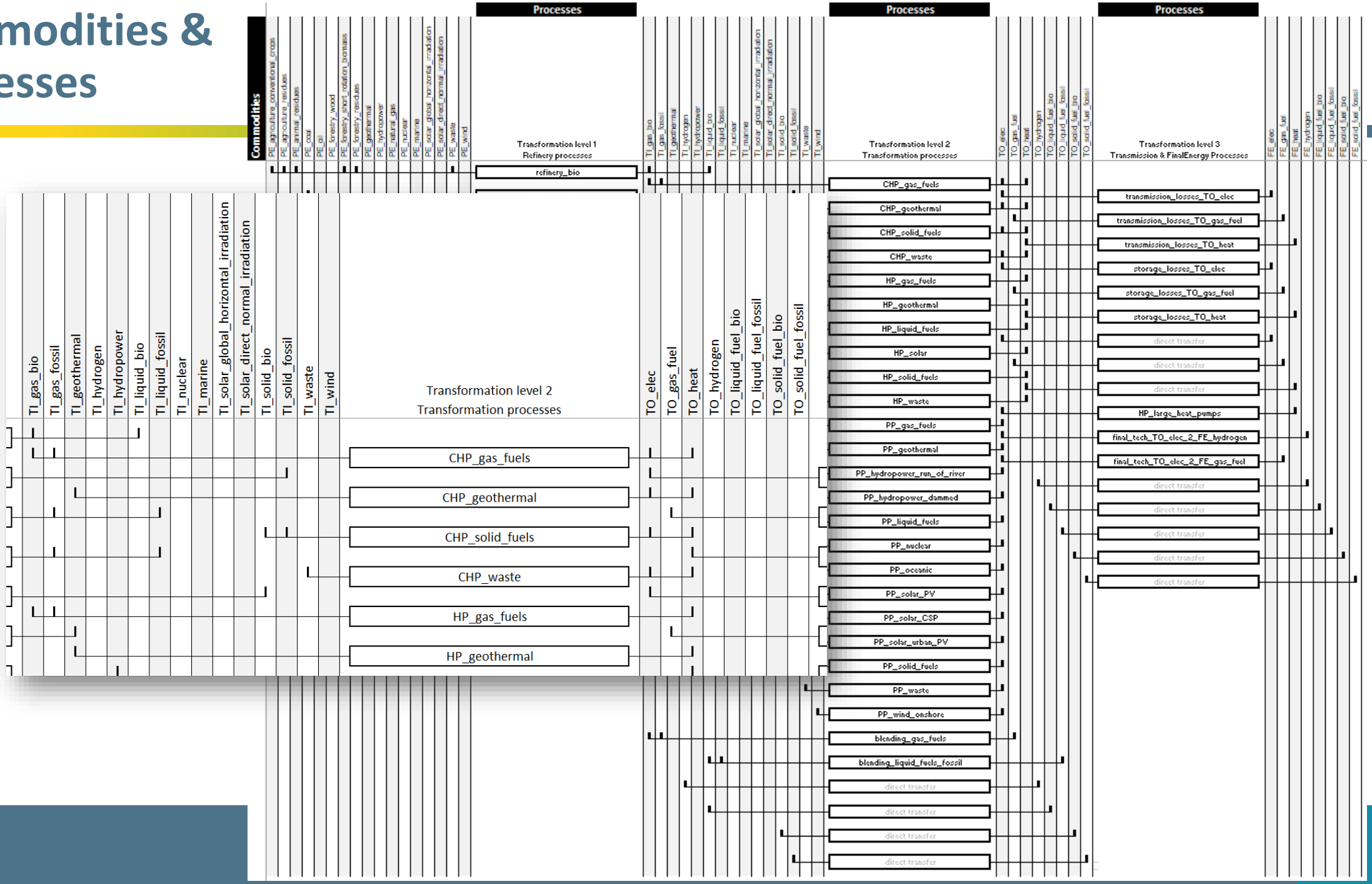
Energy Module – simplified representation of most important interrelations; Source: AEA

WILIAMs Energy Transformation Chain



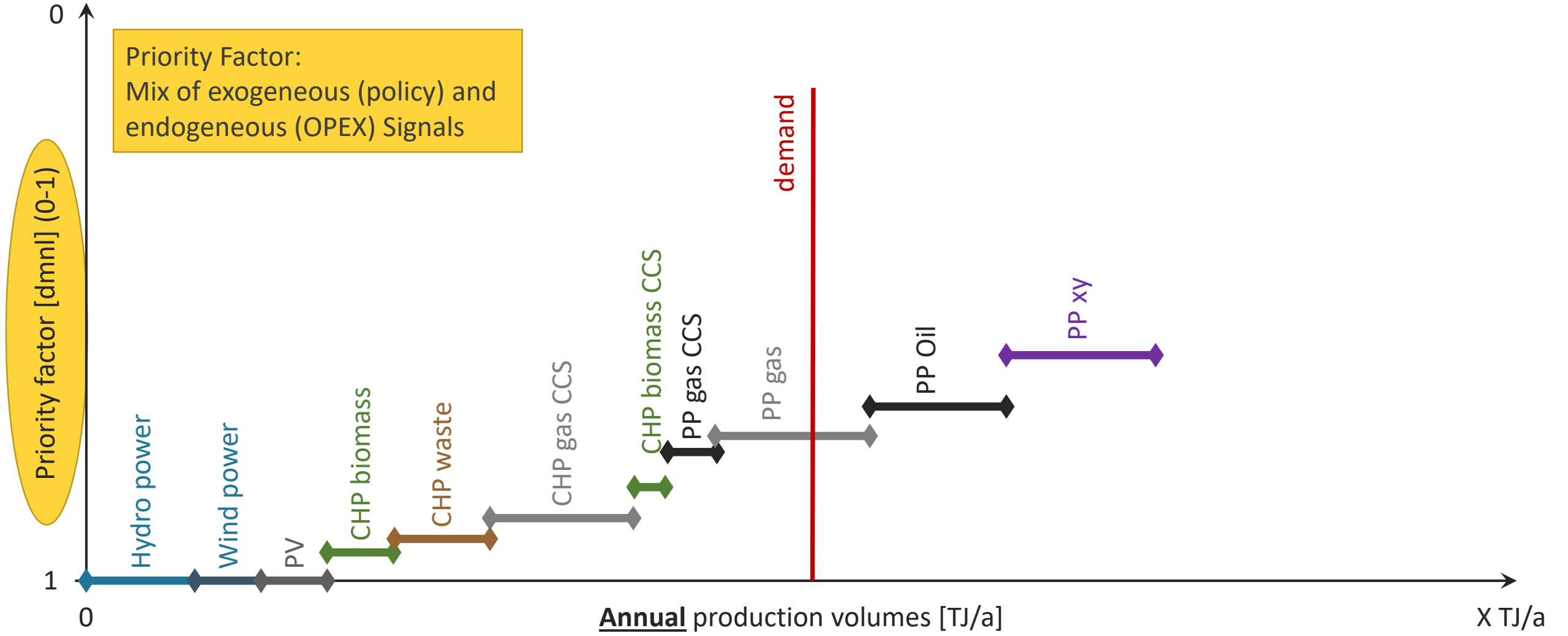
*Storage capacities & -losses are modelled in the intermittency Sub-Module
** Power2Heat and Power2Hydrogen

Commodities & Processes



LOCOMOTION

Endogenize “technology utilization allocation” (Illustrative, mock-data)



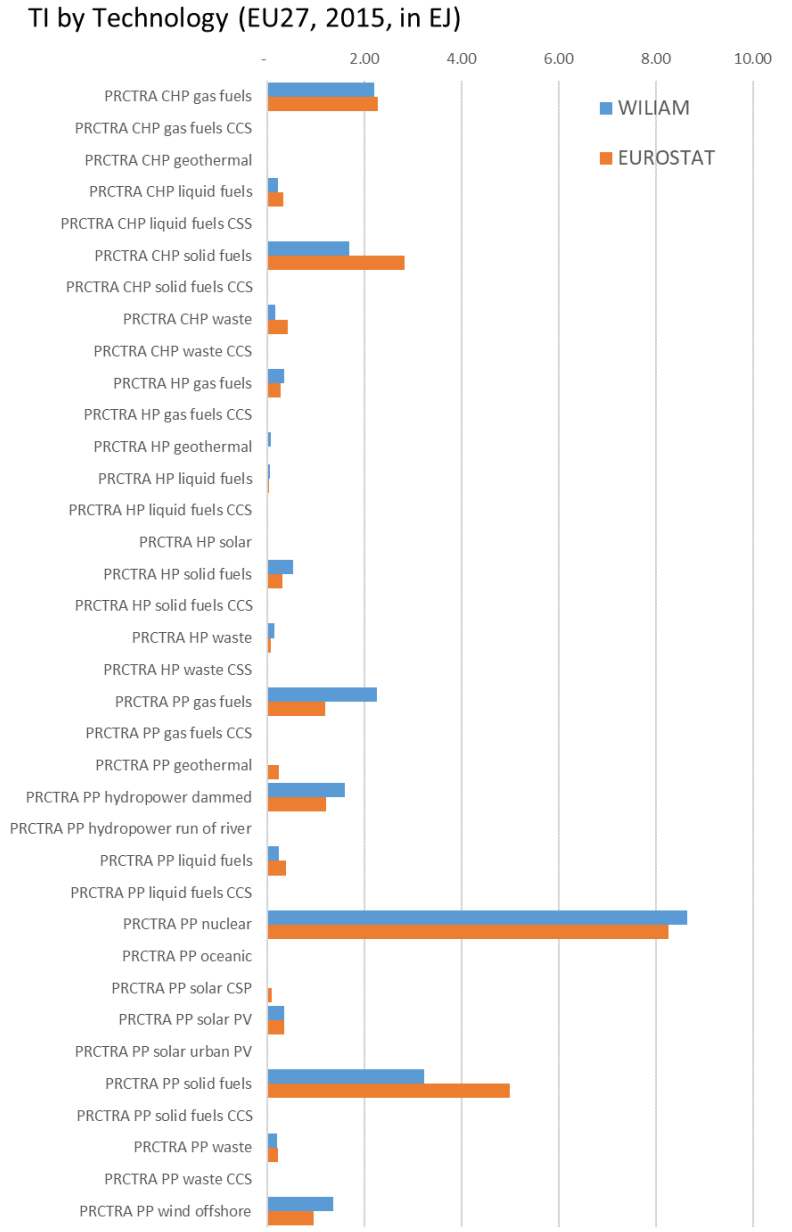
Comparison: EUROSTAT vs. WILIAM 2015

Main Flows	EUROSTAT 2015 (EJ)	WILIAM 2015 (EJ)	Δ (EJ)	Δ (%)
Final Energy	38.1	37.7	0.35	1%
Transformation Output	41.9	41.2	0.67	2%
Transformation Input	54.6	52.0	2.55	5%
Primary Energy	57.0	54.0	3.00	5%

Calculation flow

Energy Transformation

5% Error

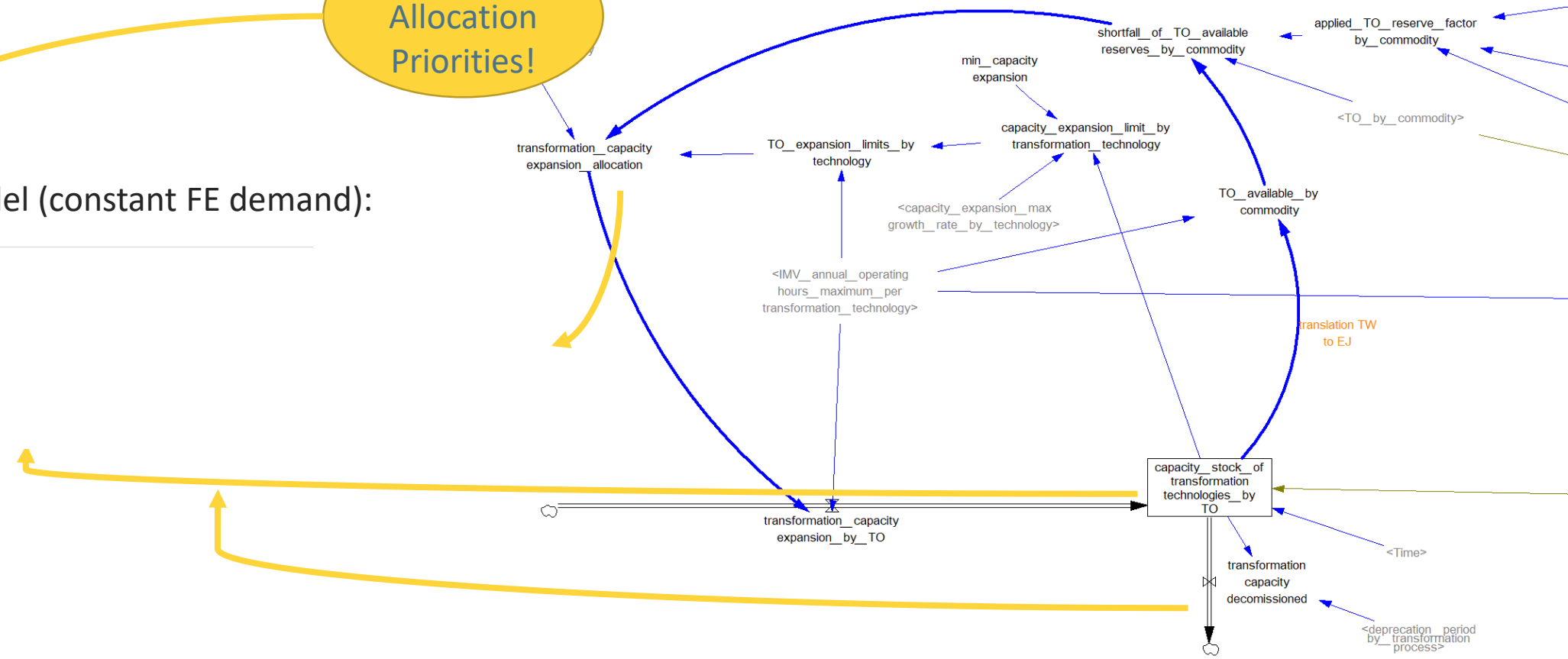


Capacity Expansion Mechanism – working principle

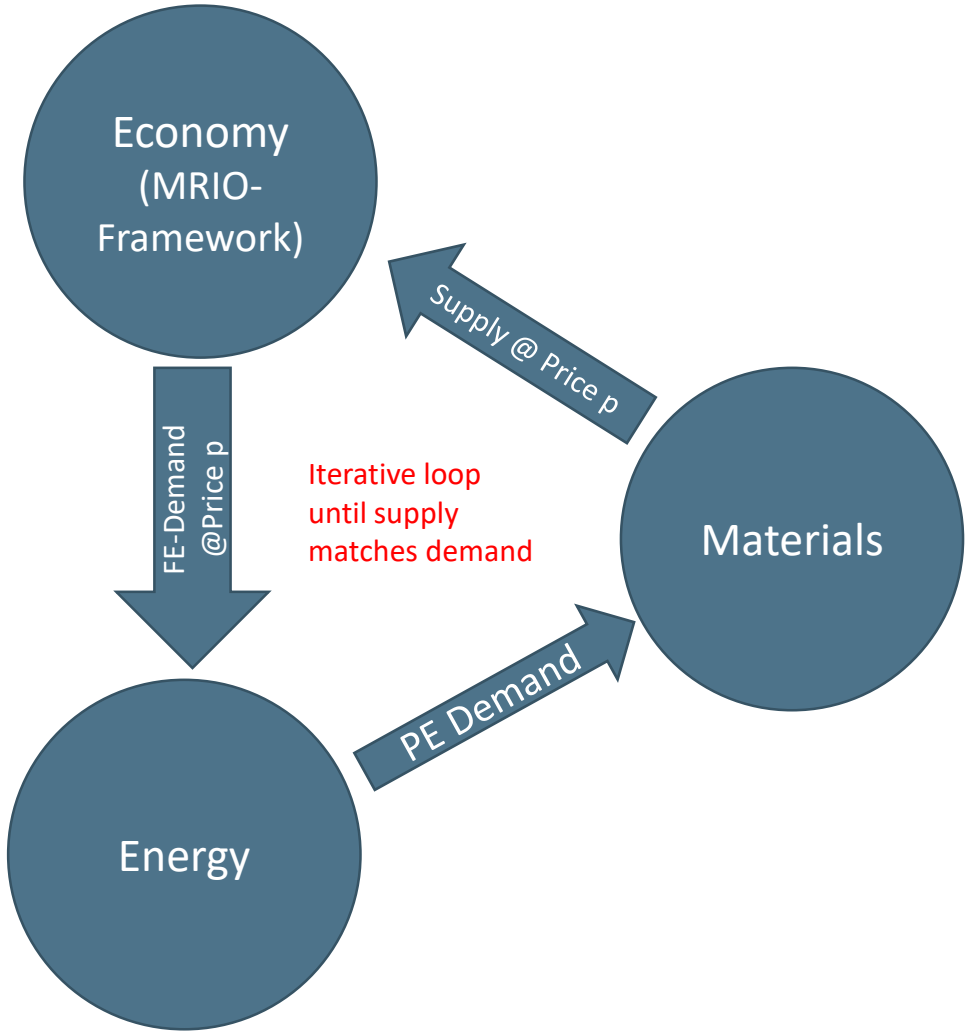
Exogenous Allocation Priorities!

Behaviour of the model (constant FE demand):

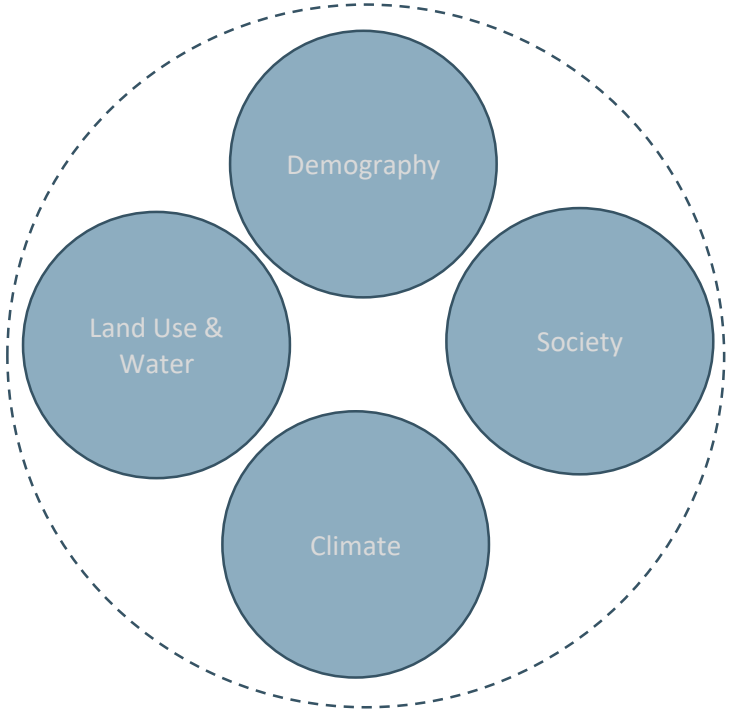
	Priorities
PP Gas Fuels	0.25
PP liquid Fuels	0.10
PP Nuclear	0.10
PP Solar CSP	1.00
PP Solar PV	1.00
PP Solar PV Urban	1.00
PP Wind Offshore	1.00



Spotlight: Energy & Materials Scarcity Feedback



Other Modules (indirectly involved, but not in focus)



WILIAM

Outlook

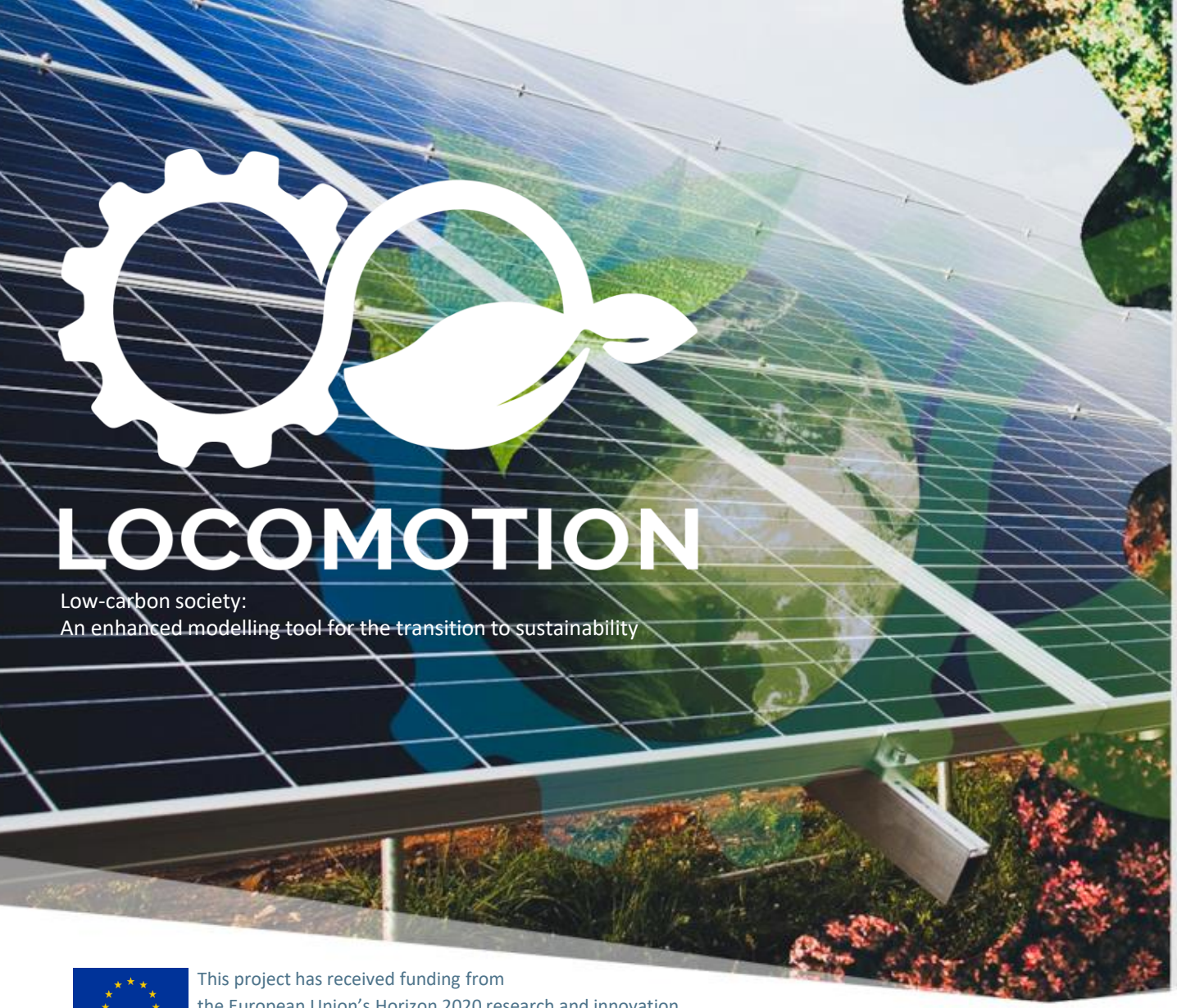
Outlook & Learnings

Outlook:

- Model **Implementation** is **ongoing**
- Next critical Step: **Linking Modules**
- Parallel: **Scenario** building
- Parallel: **Scenario Explorer** for Visualization of Results
- **First Scenario Results**: Summer ’22
- Parallel: Translation of Model to **Python**

Learnings:

- Creating an IAM (scientific) **software development**…
- …and requires the **Methods** of software developers.
- **Face-to-Face workshops** difficult to substitute



LOCOMOTION

Low-carbon society:
An enhanced modelling tool for the transition to sustainability

lukas.eggler@energyagency.at

info@locomotion-h2020.eu

www.locomotion-h2020.eu

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 821105.

Follow us

Follow LOCOMOTION

Bookmark our website, follow us on social media and subscribe to our newsletter.

- **Website:** https://www.locomotion-h2020.eu/
- **Newsletter:** https://www.locomotion-h2020.eu/news-events/newsletters/
- **Twitter:** @LocomotionH2020
- **Facebook:** @locomotion.h2020
- **LinkedIn:** https://www.linkedin.com/company/locomotion-h2020/