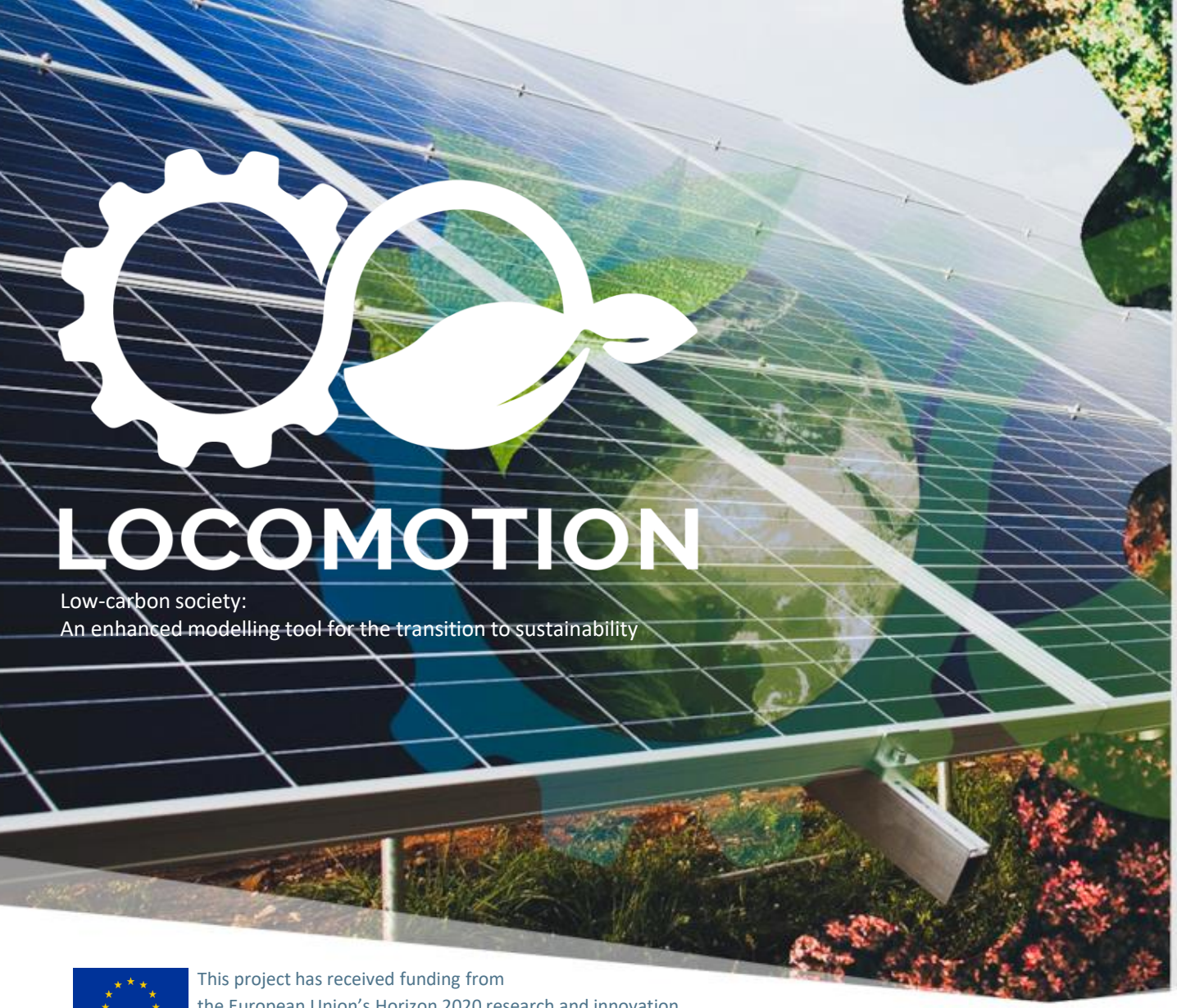

LOCOMOTION

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

Energy Transformation & Intermittency in System Dynamic Models

LOCOMOTION: The power to model sustainable futures in your hands

IEWT, Online, 9.9.2021

Lukas Eggler, Christoph Ploiner, Wolfgang Goritschnig

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

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"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

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- 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 overview

Detail: Energy Transformation chain

Detail: Allocation Functions

Detail: Intermittency

WILIAM

A brief overview

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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 and **financial sub-module** adequately accounting for financial flows of society.
  - **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

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Energy Module – design principles

- IEA Energy Balance Consistency
- Adequate representation of technologies that will likely play increasing role in sustainable future scenarios (RES, Storage, CCS, DSM, H2…)
- Energy scarcity linked to Economy Module: Scarcities lead to price increases and subsequent demand reductions through the IO-Framework
- Primary energy fuels = global market => extraction & Prices from materials & mineral module

Energy Module

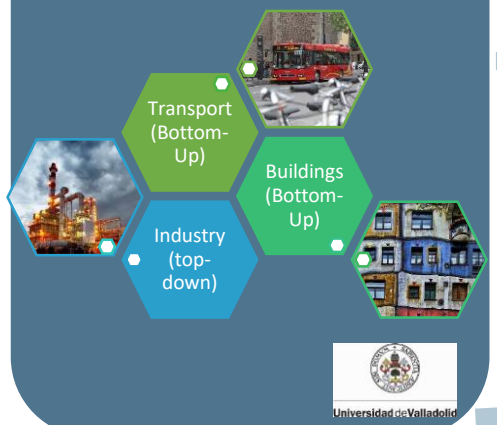
Economic Demand

Fuel & CO2 Prices

Emissions

PE demand

Energy End-Use
„converting USD to kWh“



FE demand

Energy Transformation
„modelling annual energy balances“

- Energy transformation chain
- technology utilization allocation

Available transformation Capacity

Energy Capacity
„accounting for capacity stocks“

- Transformation capacity – Stock- and flow modelling
- Transformation Technology Expansion **allocation**

Material- & Land Use

Investments

Biophysical Limitations

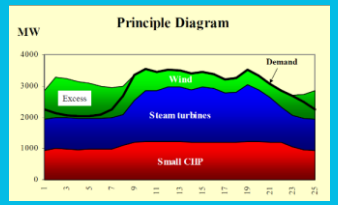
- DSM
- Smart Charging
- V2G
- small heatpumps
- …

- Max. vRES production without curtailment

- vRES production with curtailment
- Storage Losses
- Flexible Production Tech. Utilization

- Transformation Capacity Stock (vRES, flexible generators)

Intermittency and Storage



„impact of intermittent power sources on annual energy balances“

sdewes

Policy Assumptions

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

Transformation Sub-Module

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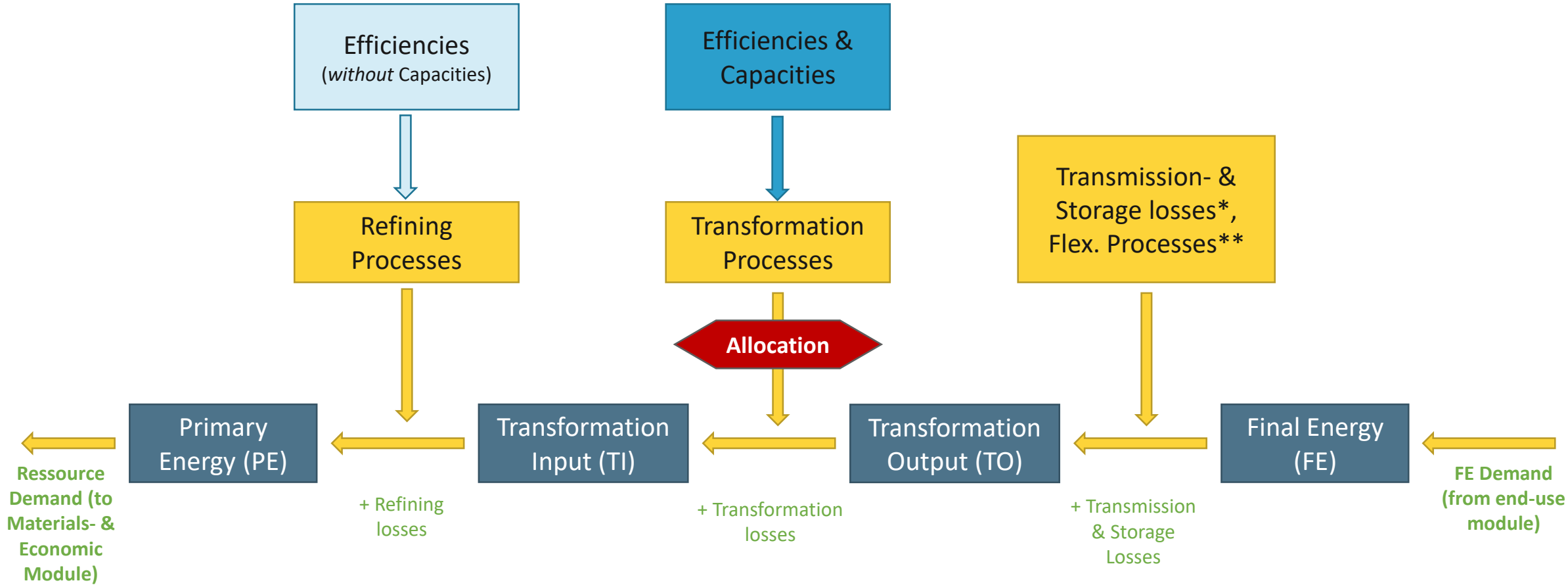
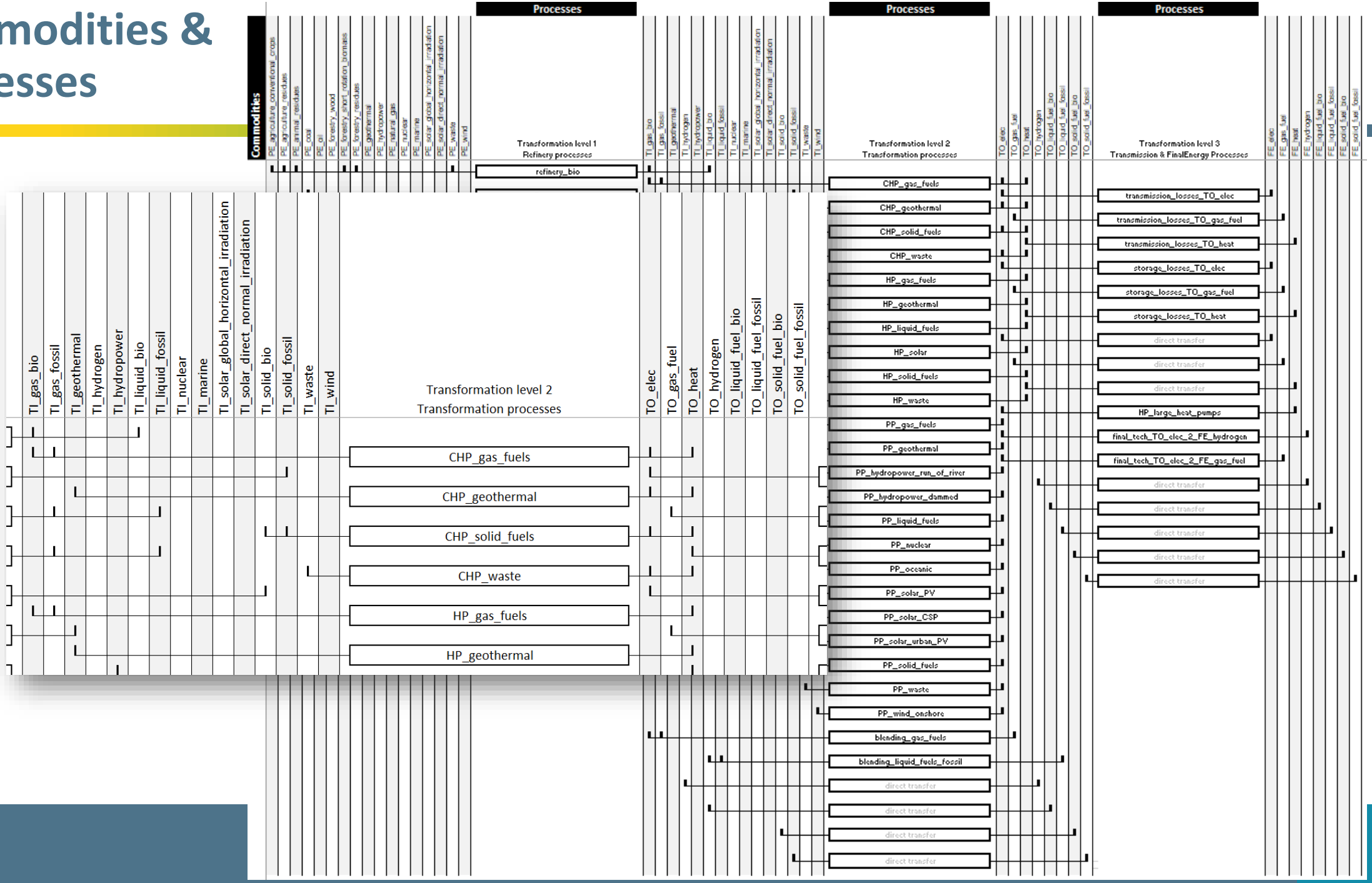
WILIAMs Energy Transformation Chain



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

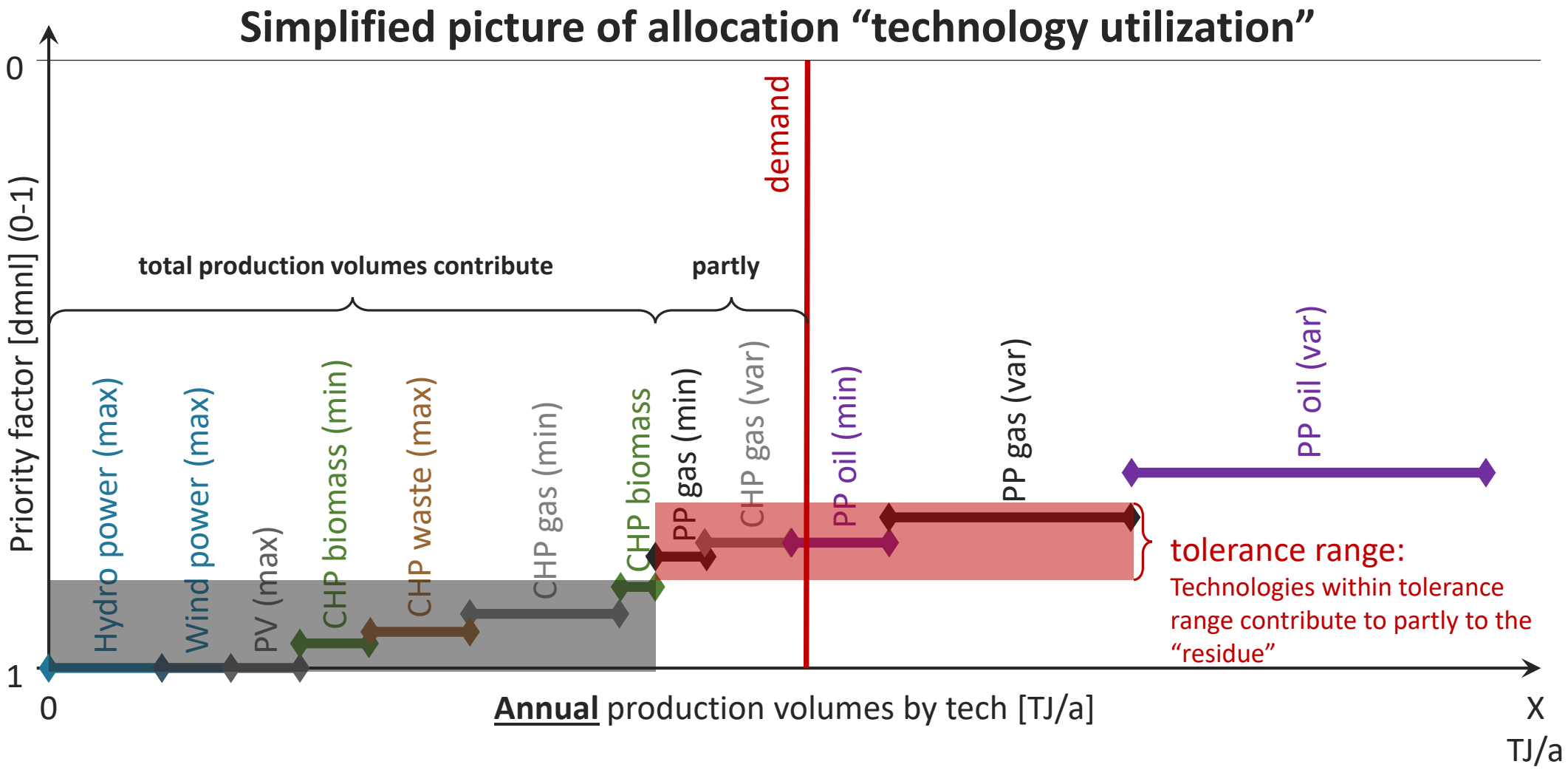
Commodities & Processes



Allocation functions

- Allocation problems
  - Common problem in System Dynamics Models
  - Always needed when there is a (potential) mismatch of a quantity available, and a quantity demanded
- Differentiation between “One-to-Many” and “Many-to-Many” allocation problems
- In the energy Module, two “One-to-Many” allocation functions are needed:
  - Utilization of existing transformation capacity Stock
    - **(one) Energy demand needs to be allocated to (many) powerplant types**
    - decision which installed capacities should be used to produce the needed amount of electricity and district heat.
  - Capacity expansion of new transformation technologies
    - **Allocate needed new transformation capacity (one) to different available technologies (many)**
- **DEMAND and PRIORITIES** (by technology) are needed (e.g. Price signals, policy priorities, …)
- The outcome of such functions will not lead to cost-optimal energy production (Simulation vs. Optimization models)

Exemplary: Technology Utilization



Intermittency

Accounting for sub-annual effects in an annual model

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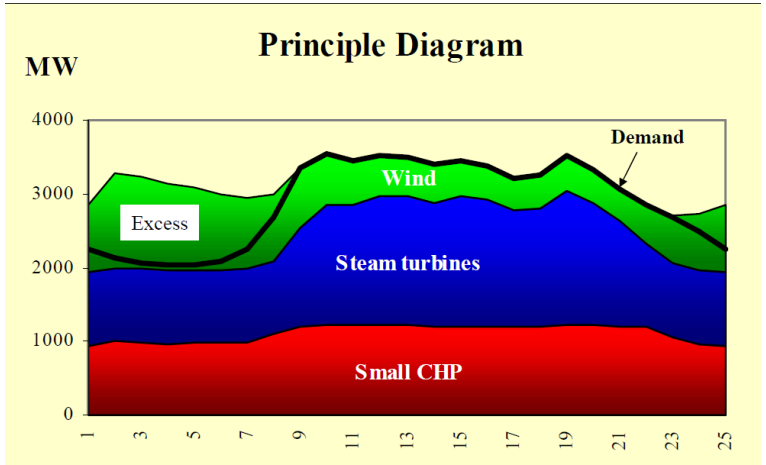
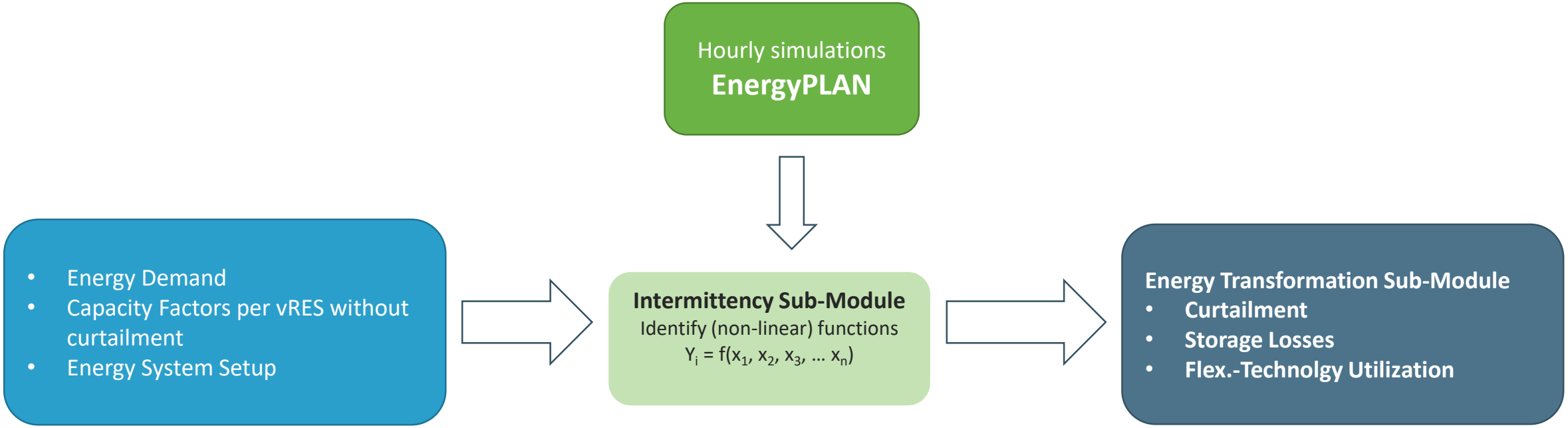
Intermittency

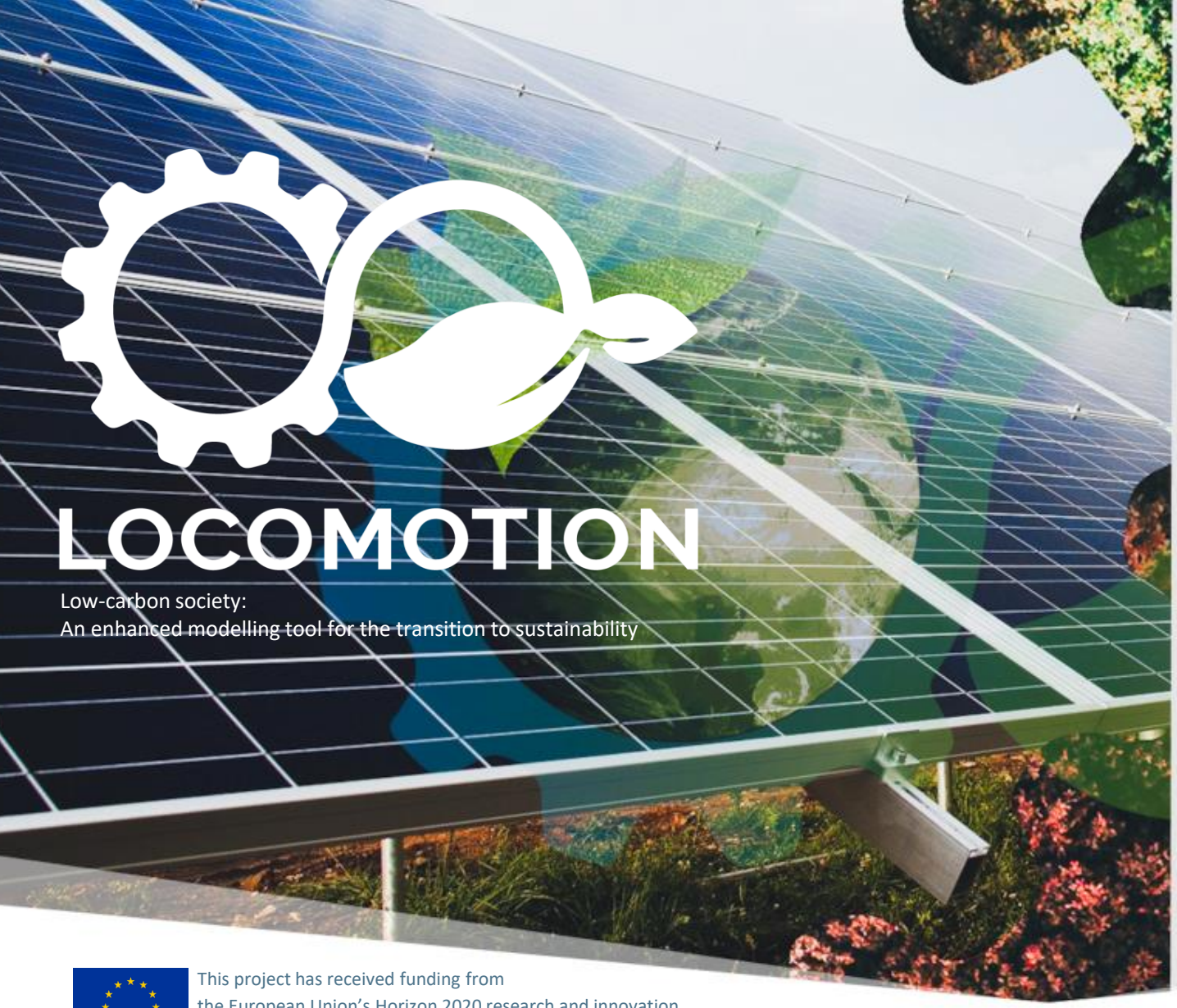
- Typical Problem:



- Challenge: time steps cant be reduced to hourly level because of computational performance and data
- Problem: Accounting for sub-annual effects in annual model
- Methodological Approach: Emulating hourly effects based on a large number of dispatch-model runs with different system setups

Conceptual Approach of Intermittency Sub-Module





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