System of systems approach for exploring energy transition

CESAMES Architecture Days
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Speakers today
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OS-C

WITNESS

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Linux Foundation Open Source for Climate (OS-Climate or OS-C)

Applying the community-based open-source approach that has enabled breakthroughs in Life Sciences & Tech to solve data & analytics challenges required for investment to achieve Paris Climate Accord goals

OPEN SOURCE COMMUNITY

- Governance, licensing, and collaboration structures enabling stakeholders to share cost, intellectual property, and effort.
- Joint projects for new data, modelling, standards, and supporting technology

COMMONS

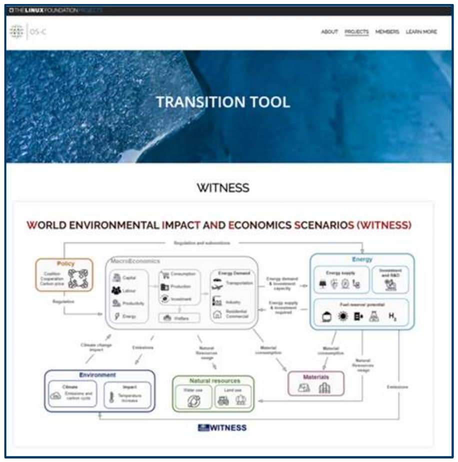
- Curated library of public and private sources, for both transition and physical risk/opportunity
- More accurate corporate historical and forward-looking climate & ESG metrics as a public good

GLOBAL DATA ANALYTIC TOOLS

- Integrate climate-related risk and opportunity into decisions by investors, financial institutions, regulators, etc.
- Top-down and bottom-up modelling
- Scenario analysis tools
- Alignment tools

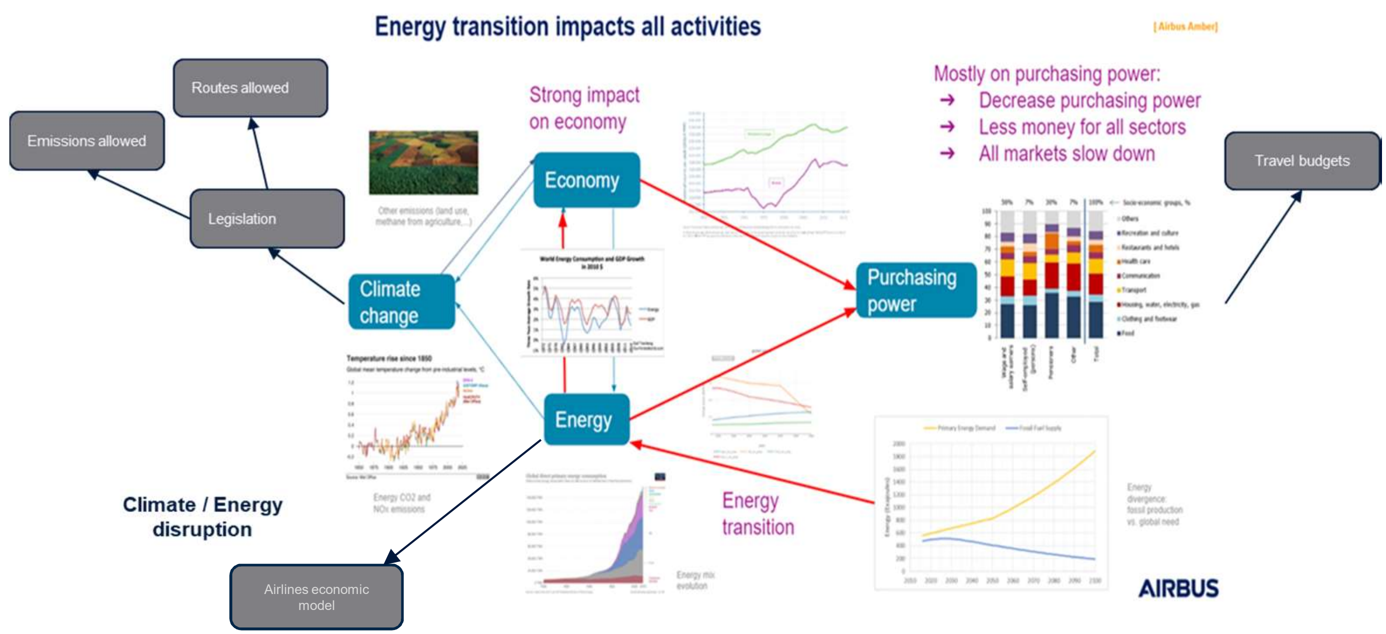
Visit www.os-climate.org for more information

OS-Climate Transition tool



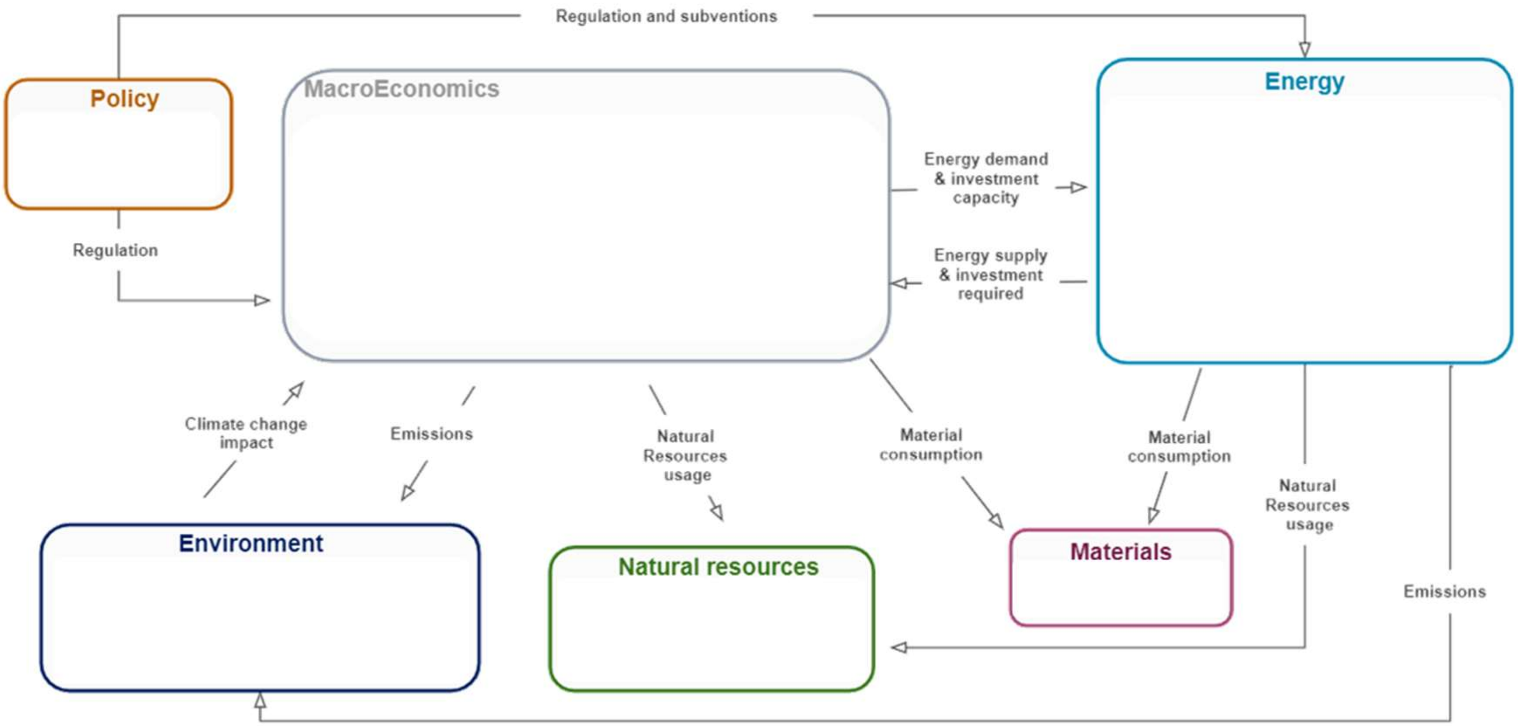
https://os-climate.org/transition-tool/

Policies
Macro-Economy
Energy
Resources
Climate
…/…

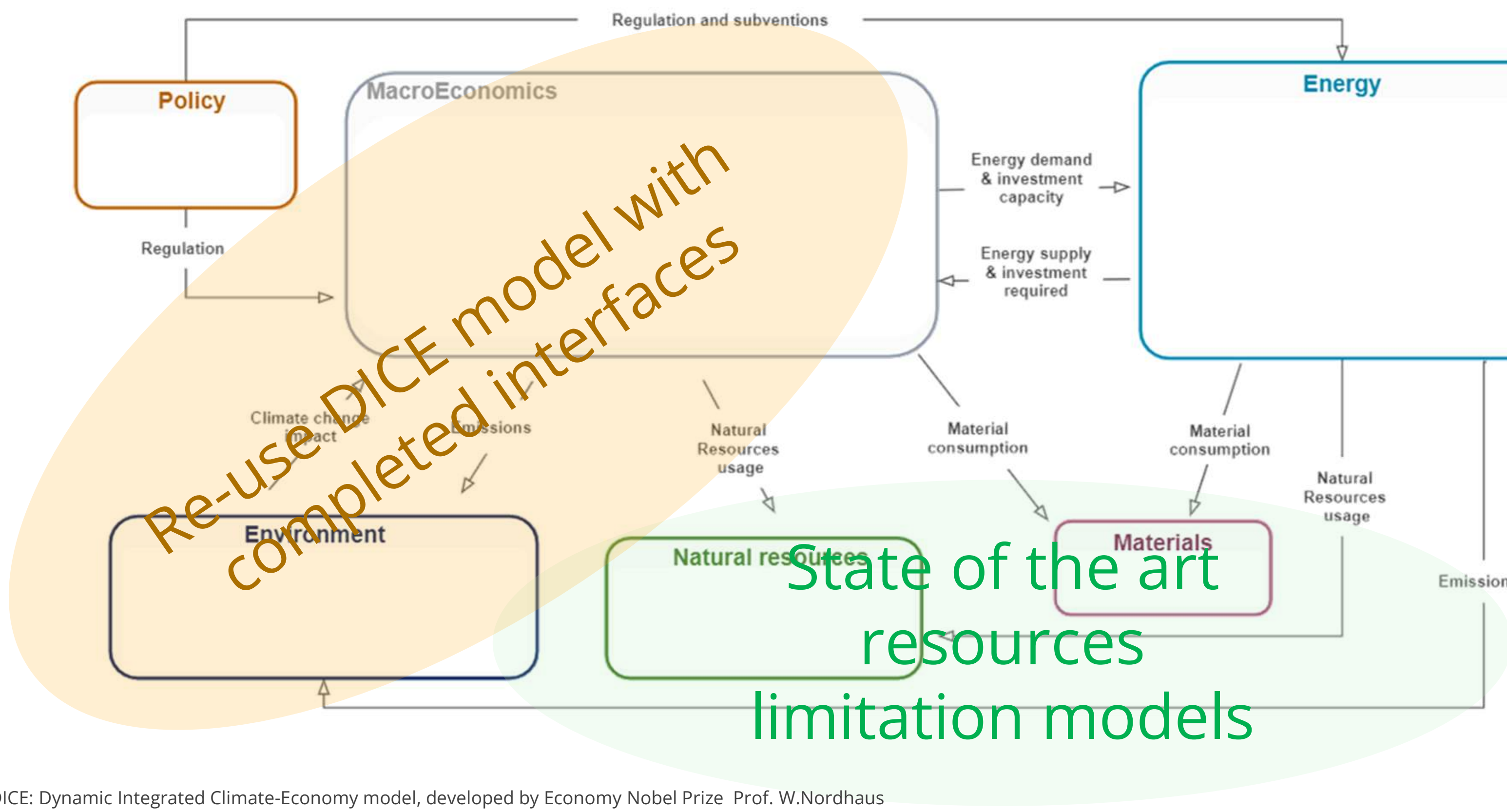


How to define robust development or investment targets through such manyfold futures ?
How to evaluate the transition risk ?

System Engineering approach to break down complexity

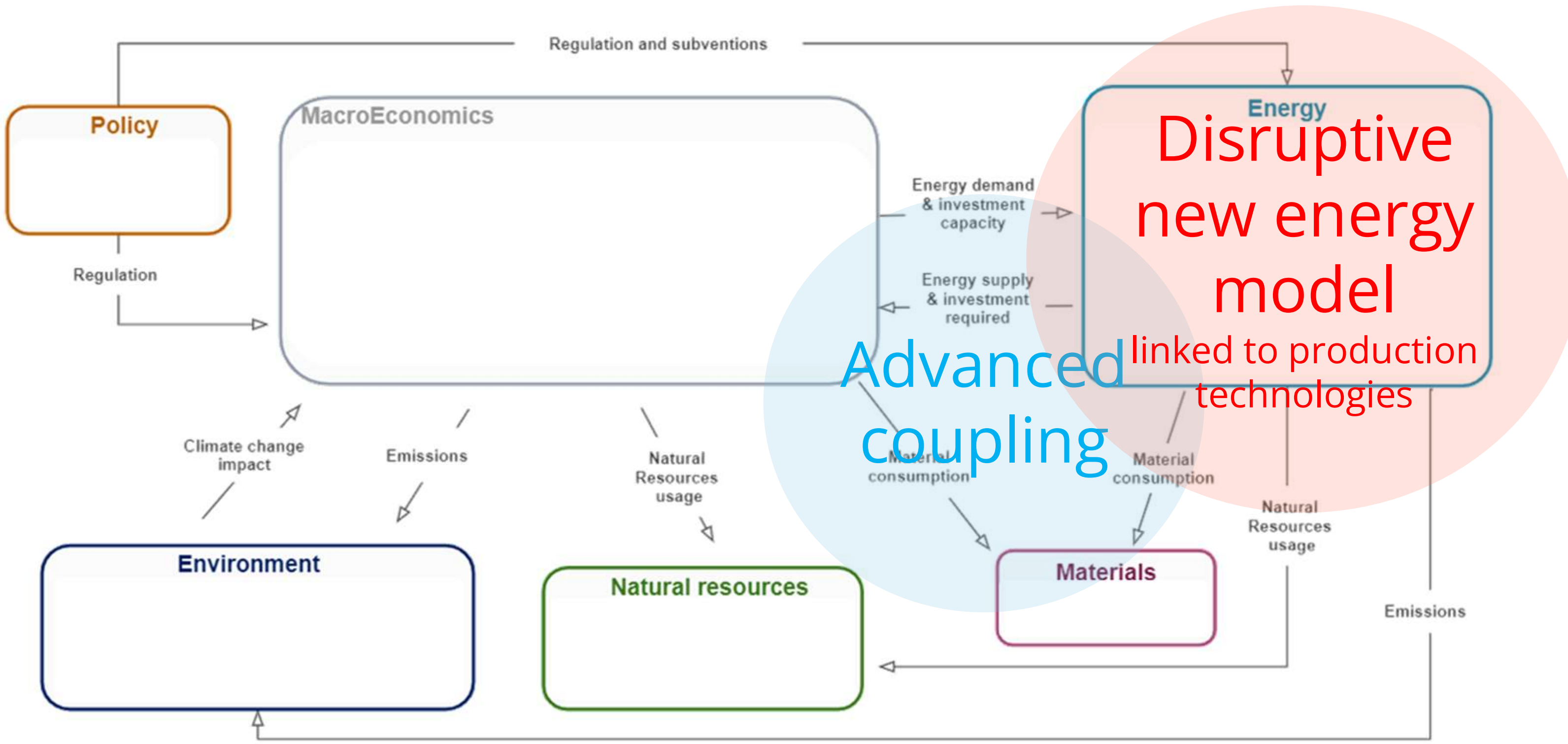


Components re-use with updated interfaces for coupling



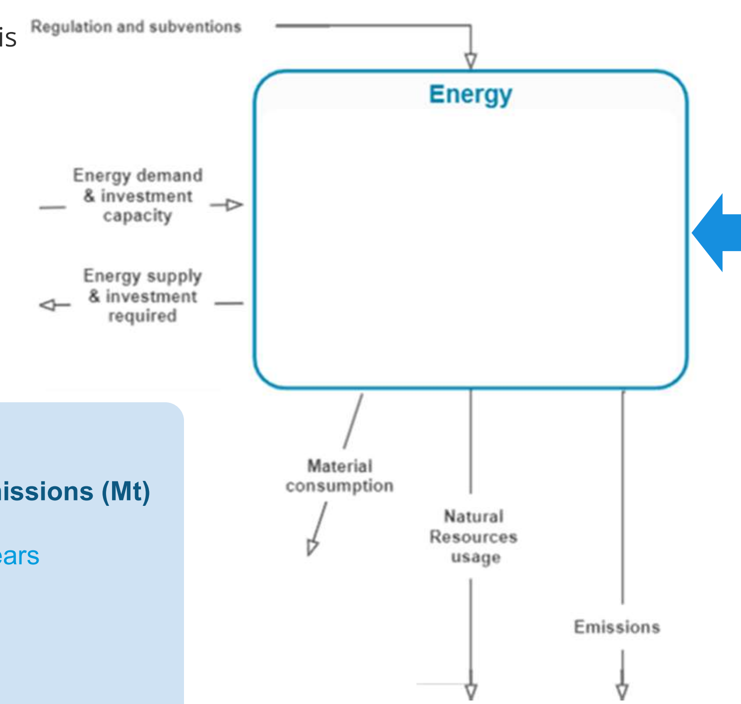
DICE: Dynamic Integrated Climate-Economy model, developed by Economy Nobel Prize Prof. W.Nordhaus

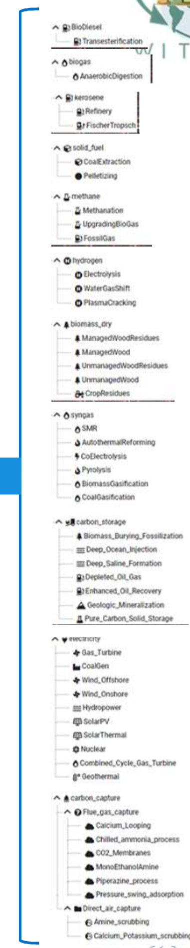
New energy framework needed
to satisfy the materials & resources interactions envisaged



But coupling approach for energy production is tricky…

- 40+ energy production technologies & more by the day
  need to be able to add easily new energy production technologies
- Interactions between energy production technologies
  e.g. produced electricity used to produce hydrogen by electrolysis
- Dynamic investment capacity depending on Economy
  itself impacted by damages induced by emissions…
  … and cost/availability of produced energy
- Resources and materials limitations / constraints
  some limitations potentially limiting several technologies
- Various modeling & coupling strategies needed
  e.g. analytic & stochastic, continuous & discrete…





with given investment plan ($/y)

Objective: **maximize Net production (TWh)** and **minimize CO_2 emissions (Mt)**

Design variables : *Investment distribution over technologies* for all years
(techno invest mixes)

Constraints : with **constraints on energy production**
TWh_i_produced - TWh_i_usedforenergyprod > TWh_for_economy

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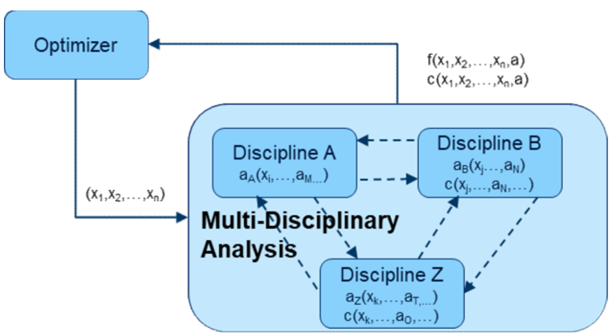
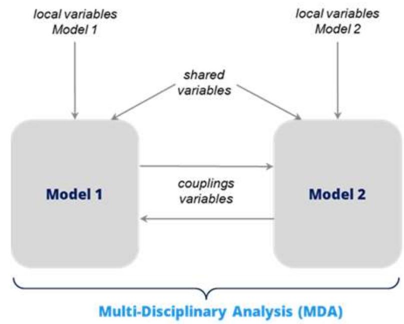
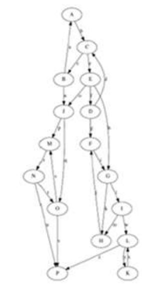
Advanced simulation architecture match the need however

- 40+ energy production technologies & more by the day
  => capability to “dump” new energy production techno in framework
- Interactions between energy production technologies
  => loop in framework with Multi-Disciplinary Feasible strategy
- Investment capacity varying depending on Economy
  => investment capacity is an input of the model
- Resources and materials limitations / constraints
  => resource & materials modules introduced to represent limitations
- Various modeling & coupling strategies needed
  => python models, library of coupling plug-ins





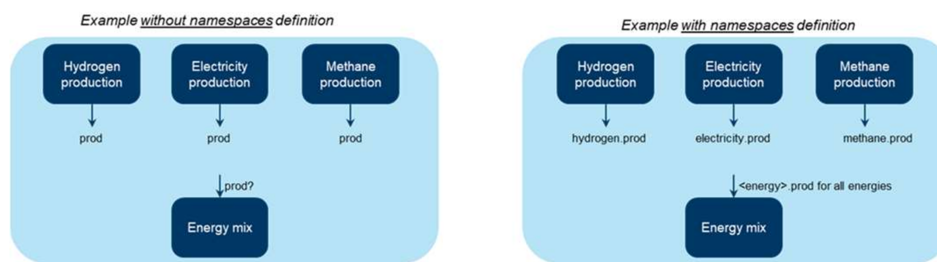
*According to the discipline I/O names, **couplings variables are automatically identified** and **multi-disciplinary analyses automatically built**.*



GEMSEO
A Generic Engine for Multidisciplinary Scenarios, Exploration and Optimization

Pluggable coupling or formulation templates

*In order to be able to **distinguish different i/o with the same names** and **avoid undesired couplings**, the **namespace definition** has been introduced*



SoS TRADES

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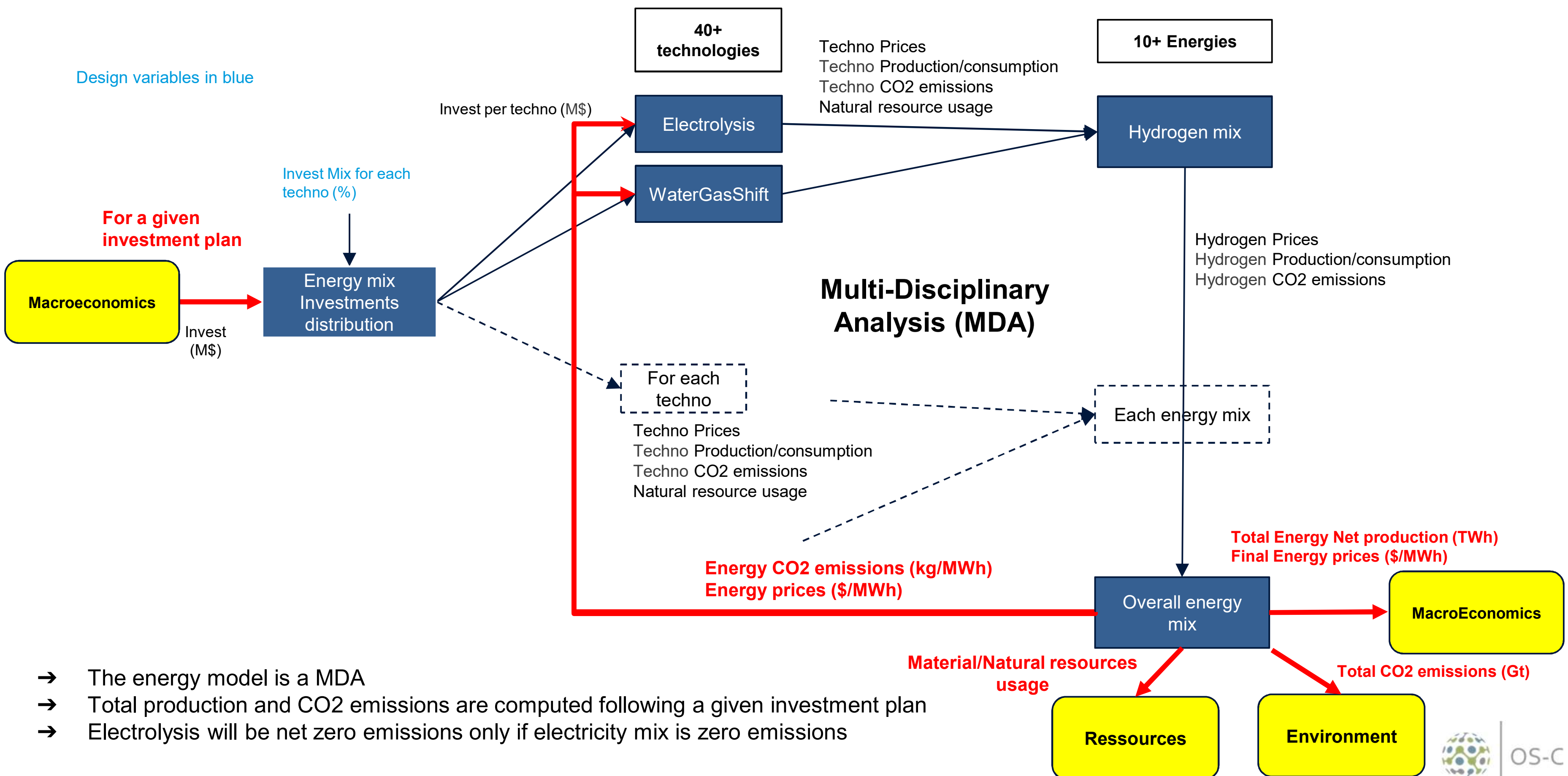
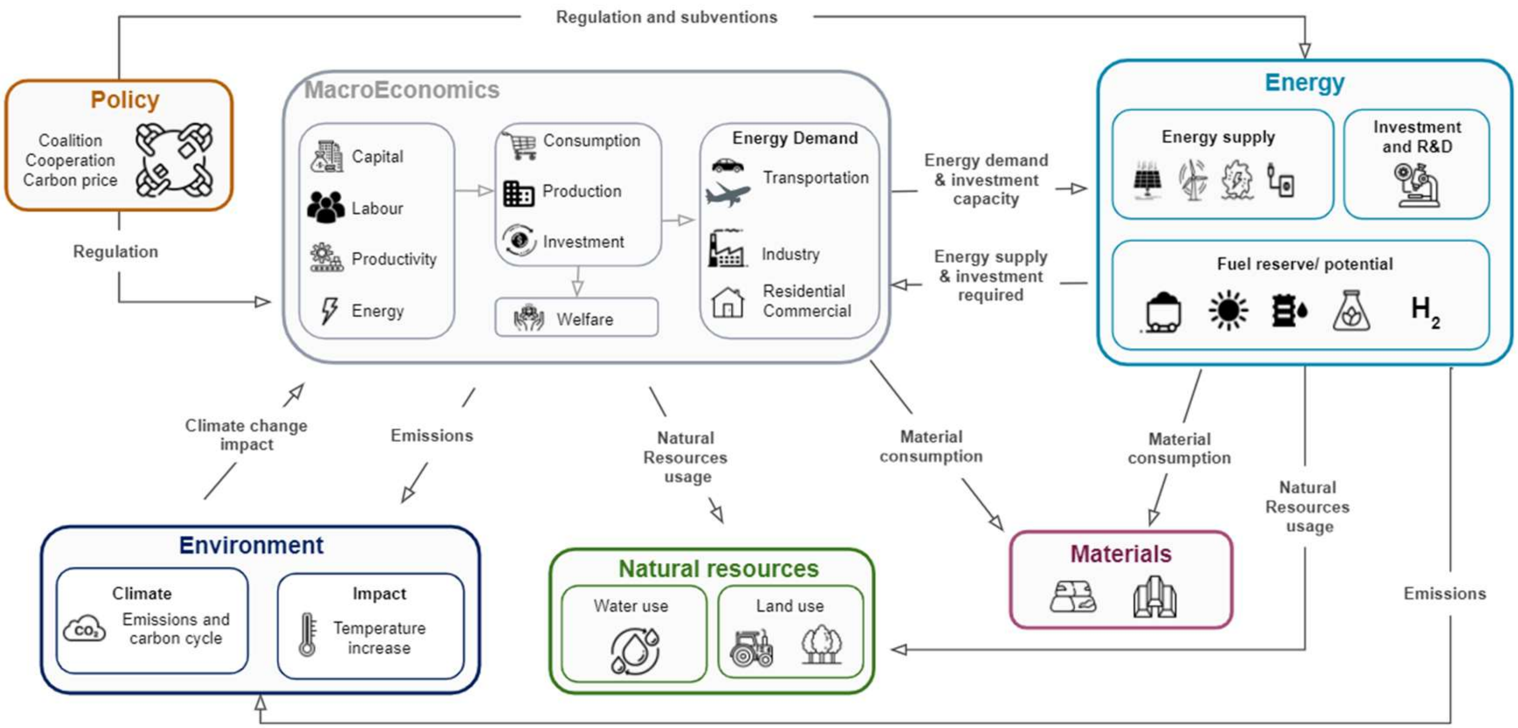
Zooming on energy integration framework



- ➔ The energy model is a MDA
- ➔ Total production and CO2 emissions are computed following a given investment plan
- ➔ Electrolysis will be net zero emissions only if electricity mix is zero emissions

Overall system of systems framework for transition models integration



WITNESS : World environmental ImpacT aNd Economics ScenarioS

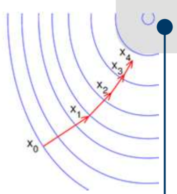
WITNESS : paving the way for optimization of energy transition path

Objective	*maximize* **welfare** and *minimize* **CO_2 emissions**
Design Variables	**technology investment mixes** *(from 2020 to 2100)*
Constraints	*(from 2020 to 2100)*: total energy production > energy lower bound net energies production > energies demand liquid fuel + H2 prod + H2 liquid production > % total production solid fuel + electricity + biomass production > % total production hydropower production < hydropower production in 2020 H2 liquid production > %H2 total production available land > land demand (for forest, agriculture,...)

Adjoint based gradient computation

1 function evaluation
1 adjoint system
instead of
241 functions evaluations per iteration

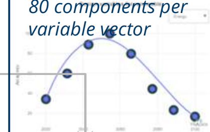
Optimization solver



L-BFGS-B

B-splines

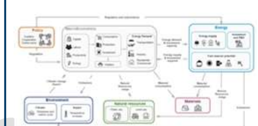
8 poles per variable vector
instead of
80 components per variable vector



DesignVar

MDA Analysis

NewtonRaphson solver
~30 iterations
~8 minutes



WITNESS model

Lagrangian objective formulation

1 scalar objective
instead of
1200 constraints and 160 objectives

FuncManager

key numbers

MDO
65 disciplines
4240 design variables
265383 variables
1200 constraints

MDA
63 disciplines
25064 coupling variables
262715 variables

MDO
65 disciplines
424 design variables
265383 variables
0 constraint

MDA
63 disciplines
25064 coupling variables
262715 variables

solved in ~10 hours

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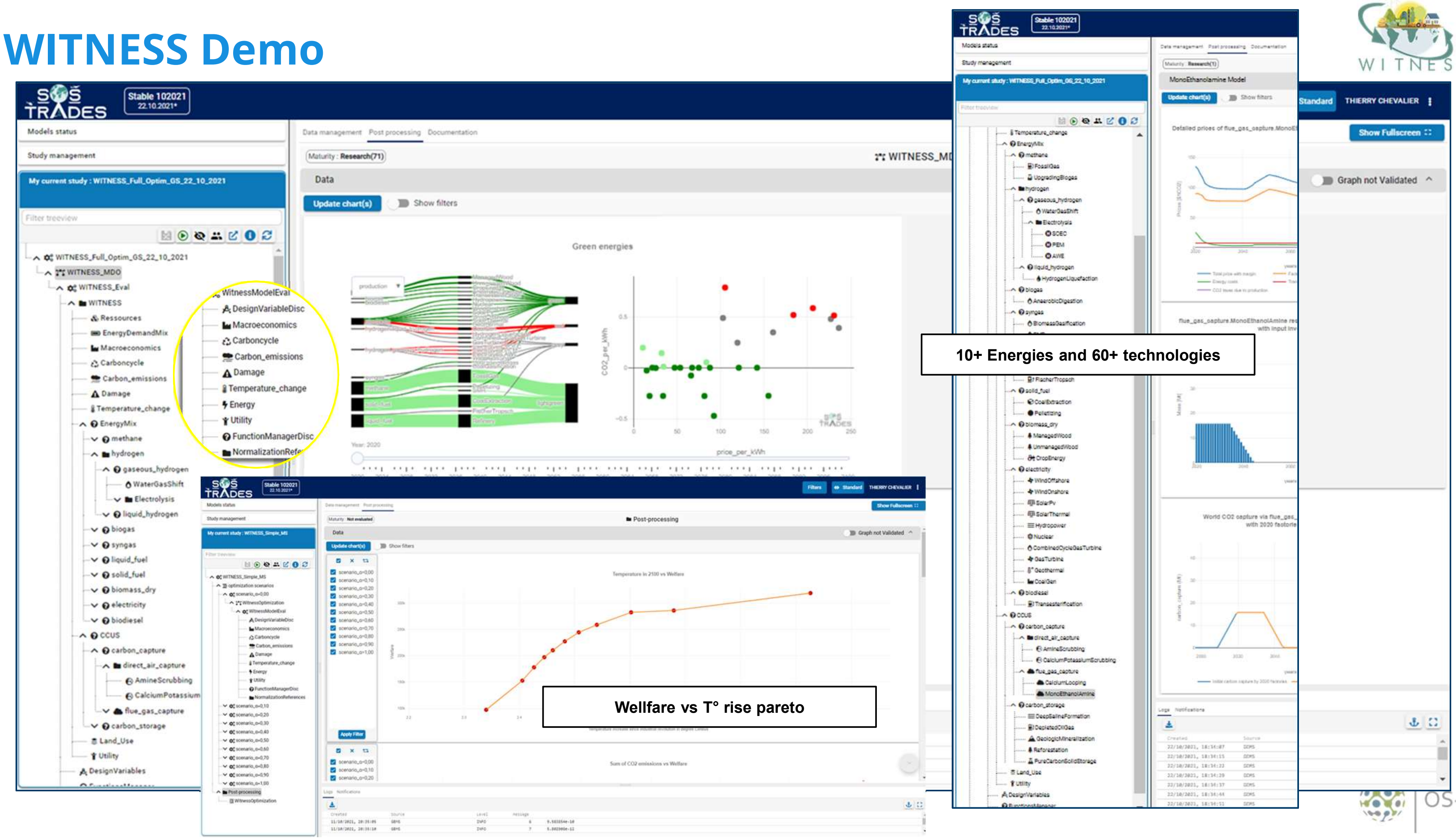
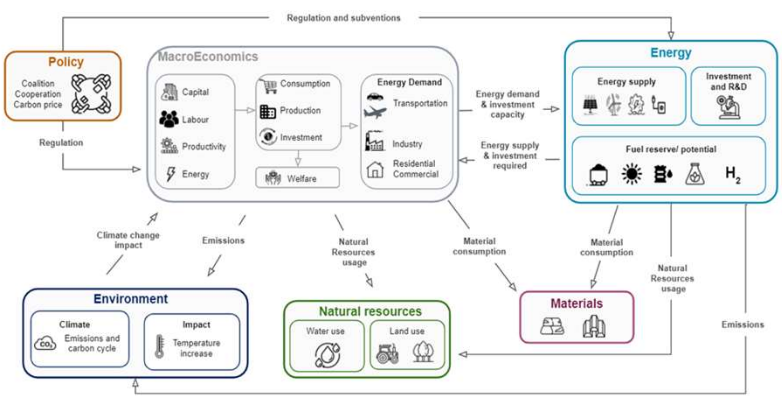
WITNESS Demo



Contribute to OS-Climate initiative
Join us soon !

First release end'21
Community opening planned end of Q1'22



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Thank You!

Interested in Learning More:

https://os-climate.org/transition-tool/
https://os-climate.org/contact-us/

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