System of systems approach for exploring energy transition

CESAMES Architecture Days
Dec 16th 2021

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Speakers today
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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/

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

State of the art resources limitation models

Re-use DICE model with completed interfaces

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

Disruptive new energy model linked to production technologies

Advanced coupling
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...

\[
\text{with given investment plan ($/y)}
\]

**Objective**: maximize Net production (TWh) and minimize CO2 emissions (Mt)

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

**Constraints**: with constraints on energy production
\[
\text{TWh}_i_{-}\text{produced} - \text{TWh}_i_{-}\text{usedforenergyprod} > \text{TWh}_i_{-}\text{for_economy}
\]
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
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 CO2 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,...)

**Key Numbers**

**MDO**
- 65 disciplines
- 4240 design variables
- 265383 variables
- 1200 constraints

**MDA**
- 63 disciplines
- 25064 coupling variables
- 262715 variables

**Optimization Solver**
- L-BFGS-B

**B-splines**
- 8 poles per variable vector
- 80 components per variable vector

**MDA Analysis**
- Newton-Raphson solver
- ~30 iterations
- ~8 minutes

**Lagrangian Objective Formulation**
- 1 scalar objective instead of 1200 constraints and 160 objectives

**Adjoint Based Gradient Computation**
- 1 function evaluation
- 1 adjoint system
- instead of 241 function evaluations per iteration

**Solved in ~10 hours**
WITNESS Demo

10+ Energies and 60+ technologies

Wellfare vs T° rise pareto
Contribute to OS-Climate initiative
Join us soon!

First release end’21
Community opening planned end of Q1’22
Thank You!

Interested in Learning More:
https://os-climate.org/transition-tool/
https://os-climate.org/contact-us/