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

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Abstract

WILIAM (Within Limit Integrated Assessment Model) is a global Integrated Assessment Model (IAM) developed within the H2020 project LOCOMOTION [1] that combines economic, social, demographic, environmental and energy related aspects into one system dynamics model. Because energy production is one of the most important sources for GHG, the adequate representation of the energy sector is key to assess future sustainable pathways.

The main function of the developed energy module is to calculate the primary energy requirements for satisfying the economic demand. The energy module is split into four major sub-modules:

(1) End-use: translates the economic demand into final energy demand through a hybrid approach combining bottom-up approaches with energy intensities for different sectors.
(2) Energy transformation: maps the entire energy conversion chain from final- to primary energy, including intermediary energy commodities and an allocation function for power plant utilization
(3) Energy capacity: keeps track of the current power plant capacity stock, decommissioning of expired capacities as well as the build-up of new capacities. An allocation function for choosing the suitable technology types for new capacities stands at the core of this sub-module.
(4) Variability and storage: keeps track of sub-annual time scale effects on annual energy balances
(5) Consideration of techno-sustainable potentials of RES considering geographical, resource and EROI constraints.

First results show that the chosen structure is capable of adequately reproducing all major energy commodity flows assuming a fixed, exogenous final energy demand (EU27 in year 2015) as input.

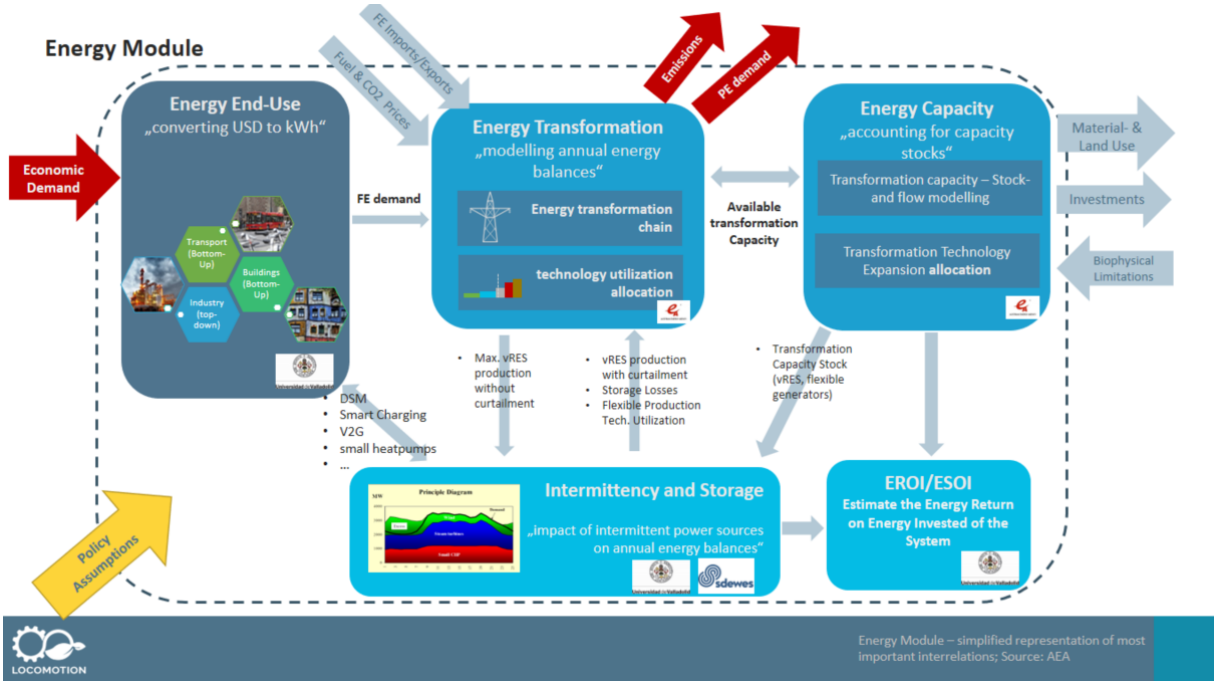

Figure 1: WILIAM energy module: Major Interrelations

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Methods

WILIAM shares the general methodological approach and characteristics with its predecessor model MEDEAS:

- System dynamics simulation
- Input-Output modelling (in the economic module)
- Time horizon 2050 with annual resolution
- Multiregional approach (MEDEAS: Nested approach with three levels “World”, “EU”, “Country”; WILIAM: 8 regions + EU countries in parallel)
- Implemented in VENSIM and translated to Python
- Open source philosophy

However, WILIAM aims to improve MEDEAS by adding new modules (e.g. Demography) and increasing *accuracy* and *consistency* in all existing modules. In the energy module the main improvements compared to MEDEAS include (1) a more detailed representation of the power sector (covering the whole transformation process from primary- to final energy, including intermediate energy commodities and 39 different transformation technologies in the electricity and heat sector), (2) a more detailed representation of the energy transformation capacities (unlike MEDEAS, also fossil generation technology capacities are modelled explicitly) and (3) an improved representation of variability effects on annual energy balances depending on the current power system setup (share of intermittent power sources, storages, demand side management, hydrogen production etc.).One of the main design principles was to remain energy balance consistent and identifying a suitable technological disaggregation to depict the most relevant energy conversion chains for future carbon neutral scenarios while reducing complexity to a manageable level. An allocation function for power plant utilization (simplified representation of the merit order principle) stands at the core of the sub-module.

Expected Results

The results show a significant improvement of the conceptual design of the energy module compared to the predecessor model:

- Modelling fossil *and* renewable transformation capacities allows a complete representation of the whole energy system and ensures consistent balancing of energy flows at any step of the transformation chain.
- Careful linkages to the economic module ensures that monetary and physical flows of the energy related sectors are consistent
- The new allocation algorithm significantly improves the model, increasing accuracy while providing high flexibility with regard to the method for technology prioritization.
- The improved representation of sub-annual intermittency effects on the annual energy balances improves the reliability of the results. It will enable high vRES integration in the energy system while balancing curtailment with the available flexibility technology setups (DSM, Storage, sector coupling).

References

[1] https://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