This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691287

EU Framework Program for Research and Innovation actions (H2020 LCE-21-2015)

Project Nr: 691287

Guiding European Policy toward a low-carbon economy. Modelling sustainable Energy system Development under Environmental And Socioeconomic constraints

D4.1(D13) Annexes 2 to 4: Exogenous Energy Intensity Targets and Fuel Replacement conditions, and other minor corrections in the MEDEAS Global (World) model

Version 3.0.0

Due date of deliverable: Actual submission date: 30/05/2019

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Document info sheet

Lead Beneficiary: University of Valladolid

WP: 4, Model building and models implementation

Task: 4.1, MEDEAS Model and IOA implementation at global geographical level

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Dissemination level : Public

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Annex 2: Exogenous energy intensity targets

In previous versions of MEDEAS, the evolution of energy intensities was estimated dynamically based on historical trends and the changes that can be produced on them due to the market conditions of the final energy types or due to the energy policies.

In medeas_w 1.3 version, a modification has been introduced and the energy intensity targets in a given year can be defined exogenously, so that the model evolves towards them. Thus, for the energy intensities (sectoral and household), three options can be selected in the model:

1) The energy intensities remain constant with the value of the last historical year.
2) Dynamic evolution of energy intensities (option selected by default).
3) Introduction of energy intensity targets for a specific year, so that the model evolves towards it.

At the same time, two options for the energy intensity target can be selected:

1) The energy intensity target is directly chosen by the user according to particular targets.
2) The energy target is defined by the variation of the energy intensity over the value of a specific year.

In the case that specific energy intensity targets are defined for a certain year, the scarcity perception and fuel replacement activation can produce a different result not arriving to the objective or arriving previously.

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Annex 3: Modelling of fuel replacement

How to measure the scarcity or abundancy of natural resources has been a controversial issue in economics for a long time (Neumayer, 2000). Ecological Economics criticizes the mainstream approach considering prices as a reliable indicator of scarcity of natural resources, given its theoretical and empirical weaknesses. Energy and mineral prices are subject to multiple influences (institutional framework, oligopolistic market structure, etc.), which prevent perfect competition to happen neither in the short nor long-term (Norgaard, 1990; Reynolds, 1999). Moreover, given the inertia and rigidities in the productive processes highly dependent on natural resources, important adjustments in the economic system are produced with *quantity* changes (instead of prices), as post-Keynesian approaches have highlighted (Lavoie, 2014). For both reasons, MEDEAS applies an alternative "biophysical" perspective to model fuel replacement which takes into account the evolution of the extraction of natural resources and their physical availability/scarcity (Campbell and Laherrère, 1998; Valero et al., 2014).

There is a first allocation mechanism in MEDEAS models at primary energy level for the generation of electricity, assuming that, given infrastructure available, different fuels can contribute to the electricity mix. Given that priority is given by default to renewable energy sources and nuclear, the remaining supply is allocated between oil, natural gas and coal. The adjustment for heat is modelled directly at final energy level given that the large majority of heat is not traded and is thus subject to the infrastructure at final user level.

There is a second allocation mechanism in MEDEAS models at final energy level, by replacing those fuels, which are scarcer, by fuels that are not/less scarce. This is performed through the variation of the final energy intensities. This variation is modelled on top of the exogenous trends for its future variation set by the user through the inputs.xlsx (see MEDEAS deliverables D4.1 (Capellán-Pérez et al., 2017), D4.2 (de Blas Sanz et al., 2018) and D4.3 (Álvarez Antelo et al., 2018)). Additionally, fuel scarcity also has the effect of accelerating efficiency use for this fuel. These fuel replacements and efficiency improvements are limited, in the standard version of the model, by the historical maximum from WIOD time-series (Genty et al., 2012; Timmer et al., 2012)).

Fuel scarcity for fuel i (primary and final) is defined as follows:

$$scarcity_i(t) = 1 - abundance_i(t)$$

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$$abundance_i(t) = 1 - \frac{demand_i(t) - supply_i(t))}{demand_i(t)}$$

The perception of inter-fuel energy scarcities are modelled through the balance of the effect of the sensitivity to scarcity and the forgetting factor (see Figure 1 for the loop diagram of the modelling for final energy scarcities).

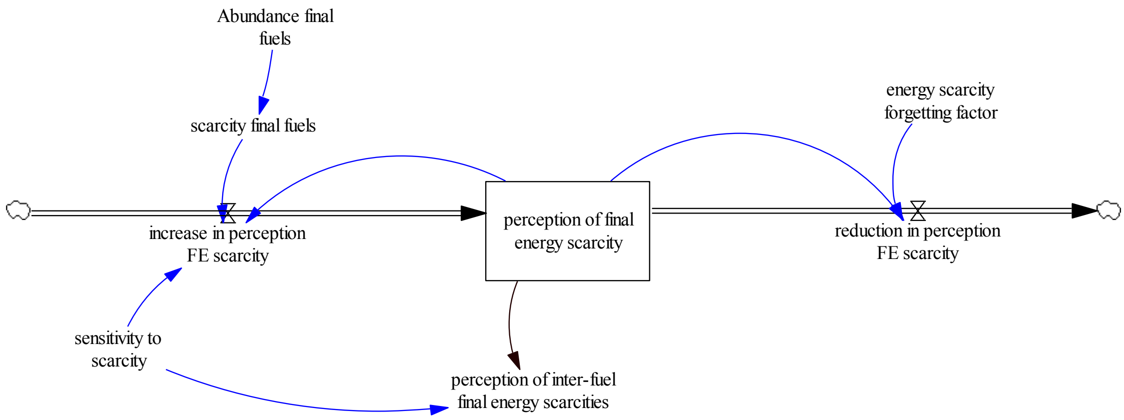

Figure 1: Loop diagram of the modelling of the perception of inter-fuel final energy scarcities in MEDEAS. Own elaboration.

Both parameters can be edited by the user through the inputs file excel sheet:

- **Sensitivity to scarcity**: this parameter reflects that economic agents and households may have different perceptions of scarcity and accordingly react differently (i.e., at a different speed) in a situation of fuel scarcity. 3 levels are pre-defined for the user: low, middle and high.

- **Forgetting factor**: this parameter reflects that the perception of scarcity of the economic agents is also influenced by the persistence in the memory of past events of fuel scarcity. A by default value of 5 years is assumed.

Annex 4: Other minor corrections

Minor corrections have been introduced in the medeas_w v1.3 model with relation to the materials submodule (material intensity (kg/new MW) of glass for the construction phase of solar PV and the energy consumption per unit of material consumption of Ga and Te), and with relation to the calculation of the EROI of the system.

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