**MUSE-SGI Non-Technical Overview**

**Industry Sector Module**

# Context

Projected growing demands for goods and stricter calls for GHG emissions cuts are challenging the development of industries worldwide. The industrial sector energy demand is expected to increase up to 31.3-31.4 % of the total final consumption by 2040 on a global scale. This upwards trend will be more relevant in the developing countries, particularly those characterised by rapid economic growth like China [1].

Historically, the industrial sector has shown progress in the energy efficiency and waste reduction in order to produce goods at a cheaper cost. In this context, electrification and increased efficiency have proven to be suitable options to reduce energy and environmental impacts [2]. However, stringent regulations on carbon will urge this sector to promote technological change at an unprecedented rate compared to the past, prioritising key targets for investments in RD&D that will go beyond the sole cost reduction.

# Problem Statement

Within the MUSE modelling environment, the industry sector module, ISM, models the production of material commodities (i.e. industrial goods). It includes non-metallic minerals, non-ferrous metals, iron and steel, pulp and paper and chemical and petrochemical products.

The purpose of the ISM is to project future demand for material commodities on a global scale, disaggregated into regions and temporally resolved into timeslices, using historical trends dependent on a time series of macroeconomic drivers. In addition, the ISM uses an agent based modelling approach to simulate realistic decision-making in the operation of assets as well as investment in capacity addition to meet the commodity demand, considering the decommissioning profile of the existing stock. The ISM applies a bottom-up approach to technology modelling in order to capture effects of changes in technology performance and regulation.

# Module Approach

The ISM is based on a two-step simulation approach to model investment decisions and operating strategies representing real investors' behaviour in the market. In a first instance, the ISM uses historical trends and macroeconomic driver timeseries to project future demand for industrial goods on a global scale with a regional disaggregation.

The ISM applies a merit-order approach based on net present value (NPV) to simulate the production of material commodities. As such, the demand for material commodities is first covered by the processes with the highest profit and then by the less profitable ones until demand is fulfilled. Based on the mix of technologies used, the required amount of fuels is determined. The market strike price of the produced commodities is determined at the balance point between demand and supply and reflect the production costs, which ultimately depend on technology mix and fuel portfolio.

The decision on investment in new assets to meet future demand takes into account the decommissioning profile of the existing stock and reflects changes in policies and technological innovation.

# Relationship with MUSE Modules

The ISM module dynamically exchanges a set of variables with the Market Clearing Algorithm (MCA) in MUSE to determine the price in every modelled region per time period and timeslice.

A snapshot of the data workflow for a generic iteration in a generic time period, timeslice and region is shown in Figure 1. The module uploads exogenous parameters for the techno-economic and environmental characterisation of each process type per region in the base year as well as projected improvements in the next simulation periods.

The data exchange protocol between the ISM and the next modules in MUSE is in Table 1.

forward demand for fuels,

forward emissions

ISM

MCA

**Exogenous Inputs:**

macroeconomic drivers,

assumptions on policies,

cost by asset type,

efficiencies by asset type,

emissions by asset type,

operational constraints by asset type,

existing stock by asset type and retirement profile

**Specific Outputs:**

aggregate CAPEX,

aggregate OPEX,

production by technology, emissions by technology,

capacity by technology

forward supply cost of fuels,

forward carbon price

Figure 1: Major interactions between ISM and the rest of MUSE

Table 1: Description of the data exchange protocol for the ISM.

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| --- | --- |
| ISM Key Inputs | ISM Key Outputs |
| MUSE core dynamic variables* Forward fuel price for each time period with timeslice disaggregation (MUSD2010/PJ)
* Forward carbon price (MUSD2010/GtCO2)

ISM-specific input parameters* Techno-economic characterisation (conversion efficiency, unit investment and operating costs) of each industrial process by asset type in each time period and region
* Environmental characterisation (GHG emissions, F-gases) of each industrial process by asset type in each time period and region
* Existing industrial facilities for the model base year by asset type, including their retirement profile
* Policy framework and fiscal regimes
 | **MUSE core dynamic variables*** Forward supply curve for all material commodities for each time period, region and timeslice (MUSD2010/PJ)
* Forward emissions for each time period, region and timeslice (GtCO2/year)
* Forward fuel demand for each time period, region and timeslice (PJ/year)

**ISM-specific outputs*** Investment and retirement in capacity terms by time period, asset type and region
* Aggregate CAPEX and OPEX by time period, timeslice and region
* Industrial technologies operation details (e.g. activity, energy consumption and emissions) by time slice, asset type and region
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# References

1. Key world energy statistics 2016. International Energy Agency, 2016.
2. World Energy Outlook 2016. International Energy Agency, 2016.