

Demand - IMAGE

Demand is calculated in terms of physical parameters (EJ, tons of grains etc). The demand types represented include energy, agricultural products, and water. Also for timber there is a relatively simple representation. For residential energy use income and urban/rural distribution are taken into account.

Energy demand

Global energy use has increased rapidly since the industrial revolution. For a historical perspective, most increases have occurred in high-income regions but more recently, the largest increase is in emerging economies. With the aspirations for income growth in medium- and low-income countries, energy demand is to be expected to grow in the coming decades, with major implications for sustainability.

In the TIMER energy demand module, final energy demand is simulated as a function of changes in population, economic activity and energy intensity. Five economic sectors are considered: industry; transport; residential; public and private services; and other sectors mainly agriculture. In each sector, final energy use is driven by the demand for energy services, such as motor drive, mass displacement, chemical conversions, lighting, heating and cooling. Energy demand is considered as a function of three groups of parameters and processes:

- activity data, for example on population and income, and more explicit activity indicators, such as steel production;
- long-term trends that determine the intensity of use, for example, economic structural change (SC), autonomous energy efficiency improvement (AEEI) and price-induced energy efficiency improvement (PIEEI);
- price-based fuel substitution (the choice of energy carrier on the basis of its relative costs).

These factors are implemented in different ways in the various sectors. In some sectors, a detailed end-use service-oriented modelling approach is used while in other sectors, the description is more generic and aggregate. The detailed energy end use models are described in the [energy section](#). Energy prices link the demand module with other parts of the energy model, as they respond dynamically to changes in demand, supply and conversion.

The energy demand module has aggregated formulations for some sectors and more detailed formulations for other sectors. In the description that follows, the generic model is presented which is used for the service sector, part of the industry sector (light) and in the category other sectors. Next, the more technology detailed sectors of residential energy use, heavy industry and transport are discussed in relation to the elements of the generic model. In the generic module, demand for final energy is calculated for each region (R), sector (S) and energy form (F, heat or electricity) according to:

$$FE_{R,S,F} = \frac{POP_R * (ACT_{R,S} / POP_R) * SC_{R,S,F} * AEEI_{R,S,F} * PIEEI_{R,S,F}}{\sum_F \eta_{R,S,F} * MS_{R,S,F}}$$

in which FE represents final energy, POP represents population, ACT/POP the sectoral activity per capita, SC a factor capturing intra-sectoral structural change, AEEI the autonomous energy efficiency improvement and PIEEI the price-induced energy efficiency improvement. In the denominator, η is the end-use efficiency of energy carriers used, for example in boilers and stoves, and MS represents the share of each energy carrier. Population and economic activity levels are exogenous inputs into the module.

Demand Agricultural products

In the IMAGE framework, future development of the agricultural economy can be calculated using the agro-economic model MAGNET (formerly LEITAP; [Woltjer et al. \(2011\)](#); [Woltjer et al. \(2014\)](#)). MAGNET is a computable general equilibrium (CGE) model that is connected via a soft link to the core model of IMAGE. Demographic changes and rising incomes are the primary driving factors of the MAGNET model, and lead to increasing and changing demand for all commodities including agricultural commodities. In response to changing demand, agricultural production is increasing, and the model also takes into account changing prices of production factors, resource availability and technological progress. In MAGNET, agricultural production supplies domestic markets, and other countries and regions are supplied via international trade, depending on historical trade balances, competitiveness (relative price developments), transport costs and trade policies. MAGNET uses information from IMAGE on land availability and suitability, and on changes in crop yields due to climate change and agricultural expansion on inhomogeneous land areas. The results from MAGNET on production and endogenous yield (management factor) are used in IMAGE to calculate spatially explicit land-use change, and the environmental impacts on carbon, nutrient and water cycles, biodiversity, and climate.

In IMAGE, demand for forest products can be derived from several sources, the most simplest being via a relationship with GDP or preferably, from specific forest demand models, such as EFI-GTM ([Kallio et al., 2004](#)). In the future, competition between forestry and other land uses can be included using the forestry module in MAGNET. Other land-use changes, such as infrastructure expansion, which do not require interregional links, are described in the land-use allocation model.

A brief overview is presented here, for more information see the [IMAGE 3.0 web page](#).