The IIASA Energy Access Tool (Energy-ENACT)

User Manual

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The online tool is available at:
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About the Global Energy Assessment

The Global Energy Assessment involves specialists from a range of disciplines, industry groups and policy areas in defining a new global energy policy agenda, one that is capable of transforming the way society thinks about, uses and delivers energy and to facilitate equitable and sustainable energy services for all, in particular the two billion people who currently lack access to clean, modern energy.

Coordinated by the International Institute for Applied Systems Analysis (IIASA), the GEA is led by some of the world's leading energy experts, in research, academia, business, industry and policy, representing both the developed and the developing world. GEA is the first ever fully integrated energy assessment analyzing energy challenges, opportunities and strategies for developing industrialized and emerging economies. It is supported by government and non-governmental organizations, the United Nations System and the private sector.

The Assessment is subject to rigorous and independent analysis and review. The final assessment is published by Cambridge University Press and is available online at www.globalenergyassessment.org.

Disclaimer

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1. Introduction

Researchers from the Energy Program at the International Institute for Applied Systems Analysis (IIASA), building on work carried out within the framework of the Global Energy Assessment (GEA), have developed an interactive web-based scenario analysis tool that permits assessment of different policies for achieving universal access to modern energy by 2030. This software, known as the IIASA Energy-ENACT tool, is designed to assist national and regional policy makers and analysts in their strategic policy planning processes. The tool extends work undertaken for the GEA and, as such, is built on an extensive set of energy access scenarios to visualise costs and benefits of specific policy choices and their impacts. This document serves as an introduction to the Energy-ENACT tool and as a brief manual for the typical user.

2. Motivation and Rationale

Multiple social, economic and environmental benefits can potentially result from a transition to cleaner-combusting and more efficient cooking fuels and technologies, and to electricity. There are therefore efforts to accelerate such a transition in many nations and regions. However, progress to date has been rather slow, especially in Sub-Saharan Africa and South Asia (Pachauri, Brew-Hammond et al. 2012). The energy access challenges facing society are as varied as they are great, and in charting a path towards universal access to modern energy carriers and stoves, a number of different factors need to be considered. These include:

- Investments needed to increase access to modern energy
- Affordability of new energy carriers and stoves for heterogeneous consumers
- Health impacts from current solid fuel use
- Greenhouse gas (GHG) emissions at residential and upstream level
- Social and economic benefits from energy access

Improving modern energy access is a major challenge for many countries, especially in developing regions where households have low cash earnings and tight budgets. It is important to understand how different policies impact future residential energy access and demands, and allow policy makers to prioritise multiple objectives. In fact, more often than not, the objectives seem to be competing for scarce funding available. This partly explains the uneven progress with providing access to electricity and modern fuels across different regions and population sub-groups.

The primary aims of the Energy-ENACT tool are to provide policy advice and visualise costs and benefits that each policy or a combination of policies could bring.

By allowing a large number of alternate energy access futures to be compared within a common framework, analysts and decision makers are able to gain a quick understanding of how alternate policies can shape the future of energy access in dramatically different ways, in terms of funding requirements, effectiveness, demand implications, greenhouse gas emissions, air pollution and health impacts.

The Energy-ENACT tool is operationally straightforward, giving users from diverse backgrounds and with varied interests a web-based platform to "play around" with a subset of energy access policies by selecting different choices via a user-friendly interface. This kind of multiple policy approach to energy access policy analysis is important, because the impacts on energy access objectives cannot be easily compared without detailed information on the effects they have on different groups of populations. An important limitation of the tool, however, is that the underlying scenarios and data have a global or regional focus, rather than a national one. In particular, the tool provides an assessment for three key world regions where the lack of access to modern energy is the most acute, i.e. South Asia, Pacific Asia and sub-Saharan Africa.

An elaborated description of the Energy-ENACT tool is found in Section 4 of this document. Before discussing these technicalities, however, a summary of the policies and targets included and the underlying data and scenarios is given.

3. Scenarios and Data Underlying the Tool

A rich ensemble of 60 scenarios underlies the policy tool. These scenarios explore policies and their impacts for achieving universal modern energy access by 2030. For instance, some scenarios include energy access policies such as fuel subsidies for cooking energy but do not consider any rural electrification policies, while other scenarios prioritise credit access and rural electrification only. The scenarios have been developed using the MESSAGE-Access model, a global household energy access model (Pachauri, Van Ruijven et al. In preparation).

The MESSAGE-Access is an extension of a widely used integrated assessment model, MESSAGE (Model for Energy Supply Strategy Alternatives and their General Environmental Impact). MESSAGE is a global systems engineering optimisation model used for medium- to long-term energy system planning, energy policy analysis, and scenario development (Messner and Strubegger 1995; Riahi, Grübler et al. 2007), developed at the International Institute for Applied Systems Analysis (IIASA) for more than two decades.

MESSAGE-Access uses a similar but complementary modelling framework with rich detail on energy access and use in the residential or household sector. It enables accounting for differences in existing energy choices, access and affordability for heterogeneous socio-economic populations and their demand patterns and densities. We use national household survey data from key countries and regions, and national and international energy and economic data to calibrate the models in the base year. We distinguish among rural and urban households belonging to five or more different expenditure groups in each region. For each household group, we disaggregate energy choices and end-use patterns in order to assess the impact of alternative policies for improving access. The model chooses the least total cost energy-equipment combination to satisfy household energy demands for cooking within budget limitations. Figure 1 illustrates energy use by different income groups in different regions for the base year of 2005.

All of the scenarios in the ensemble use the illustrative GEA-Mix pathway of the Global Energy Assessment (2012) as the starting point. Thus, assumptions about the future drivers of global change, namely population and gross domestic product (GDP) at national and regional levels, as well as the future availability of technologies, are the same as in GEA-Mix. The major deviation takes place in the energy use of the residential sector, in which additional fuels and cooking technologies are added. In addition, residential consumers are divided into different income groups, and each group is exposed to different financial constraints. We use the "no new policies" case as our baseline, and then from this baseline other future scenarios for cooking fuels and stoves and for rural electrification are generated. Policies to improve cooking access include those that lower upfront capital costs and recurrent fuel costs.

While the barriers to a transition to modern energy are many, the GEA access scenarios analysis, suggests that two key policy levers, when pursued in tandem, can help increase the adoption of modern cooking fuels and devices among low-income and rural households. These include price support mechanisms such as targeted fuel subsidies for modern fuels and easy access to cheap credit/capital, (such as via microfinance institutes that provide affordable loans at reasonable interest rates) to low-income households for the purchase of stoves. Neither of these measures alone is as effective as when these are pursued together in combination. This is because for low-income households, both the recurrent costs (associated with shifting to using higher-priced more efficient fuels) and the upfront costs associated with switching to the use of new fuels (stove purchases, deposits and connection fees) are a constraint on their wider adoption. Therefore this tool includes various combinations of price support levels with easy microcredit access as the key policy levers that users can choose from to accelerate the household transition to cleaner cooking (Figure 2).

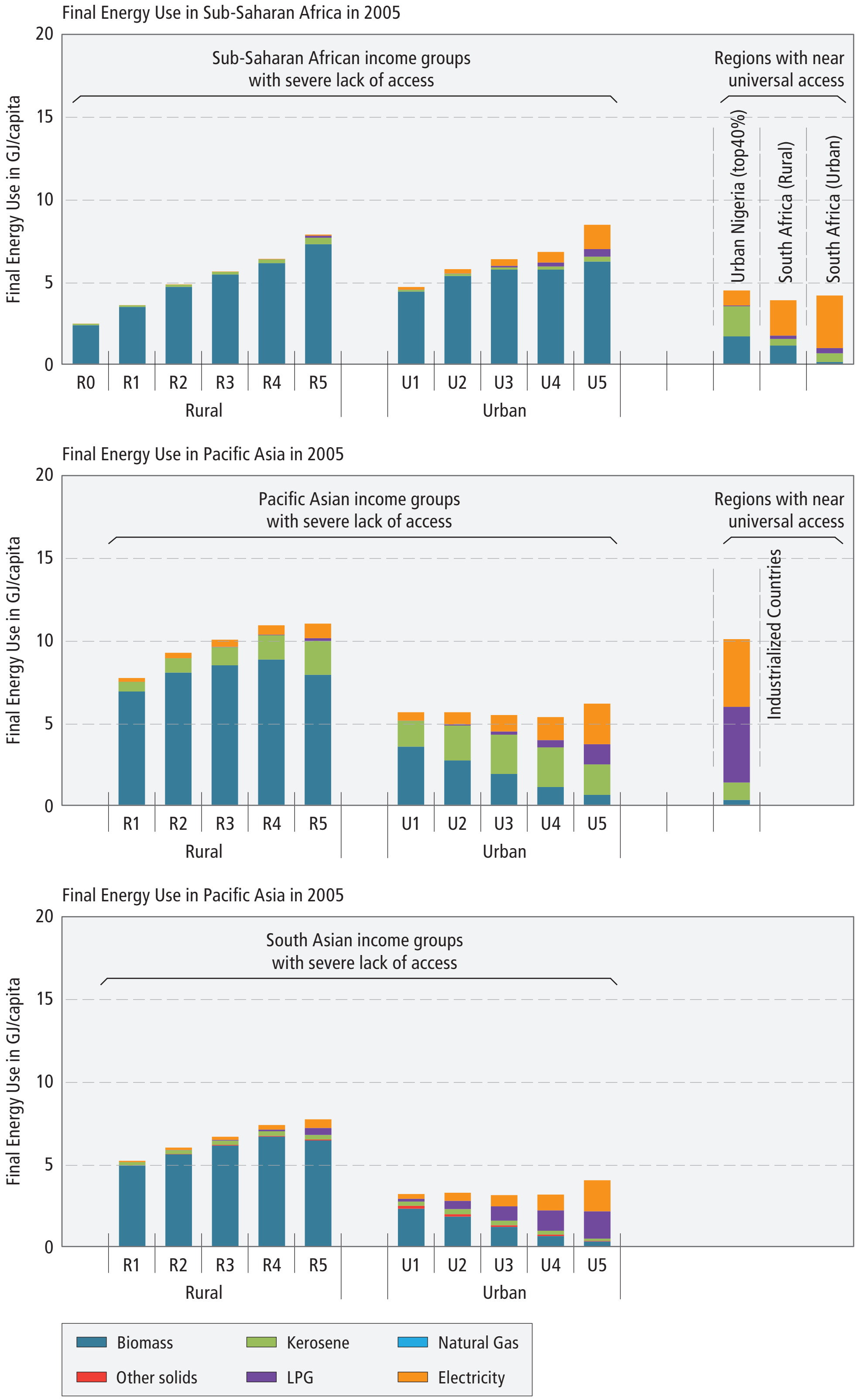


FIGURE 1
Residential final energy use by region and population income groups used to calibrate the MESSAGE-Access model in the base year

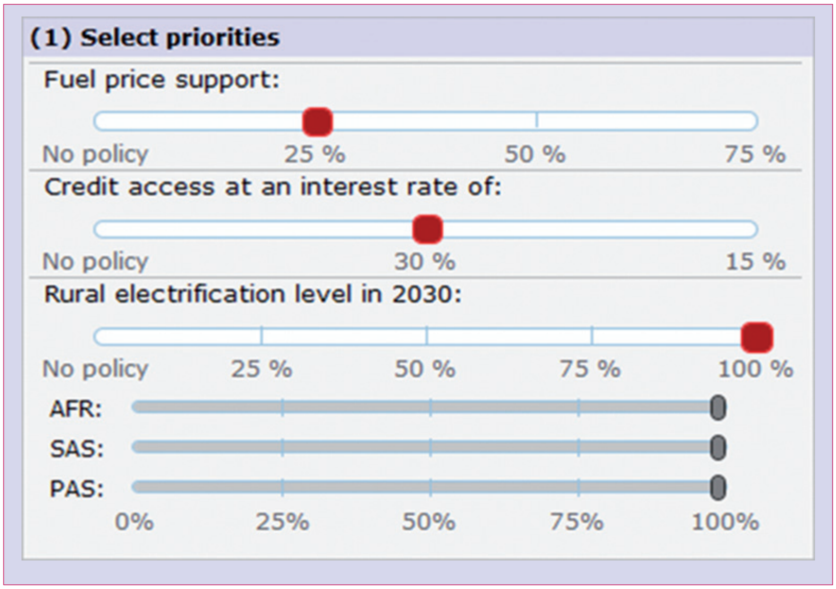


FIGURE 2
Energy-ENACT tool: Interactive slider bars

Policies for providing access to modern cooking fuels and stoves

1. **Fuel price support** Users can choose from four options: No policy, 25%, 50% and 75% support. The percentage represents the extent of price reduction on LPG in each region. Since the market price of LPG is different in each region, the amount of reduction varies among regions. Higher percentage of price support leads to greater access, but is also associated with a higher policy cost.
2. **Microcredit access** Users can choose from three options: No policy, 30% and 15%. The percentage represents the interest rate charged for credit access to consumers. The lower the interest rate charged, the cheaper the cost of the loans for the consumers and the lower the discounted costs of newly purchased cooking stoves, which requires high initial investments.

In the future scenarios regarding electrification, access is driven by the targets set.

3. **Targets for rural electrification** Users can choose from five options: No policy, 25%, 50%, 75% and 100%. The rural electrification target set is a minimum target that is applied uniformly to all regions. The three bars below the main bar (Figure 2) show the electrification rates in 2030 for the selected policy target in each region.

4. Understanding the Tool: Theory and Practice

General description and operation

The IIASA Energy-ENACT tool has been developed at IIASA, building upon work carried out in the Global Energy Assessment. Interested users can find the online tool at the following URL:

www.iiasa.ac.at/web-apps/ene/ENACT

An example screenshot of the tool is shown here in Figure 3.

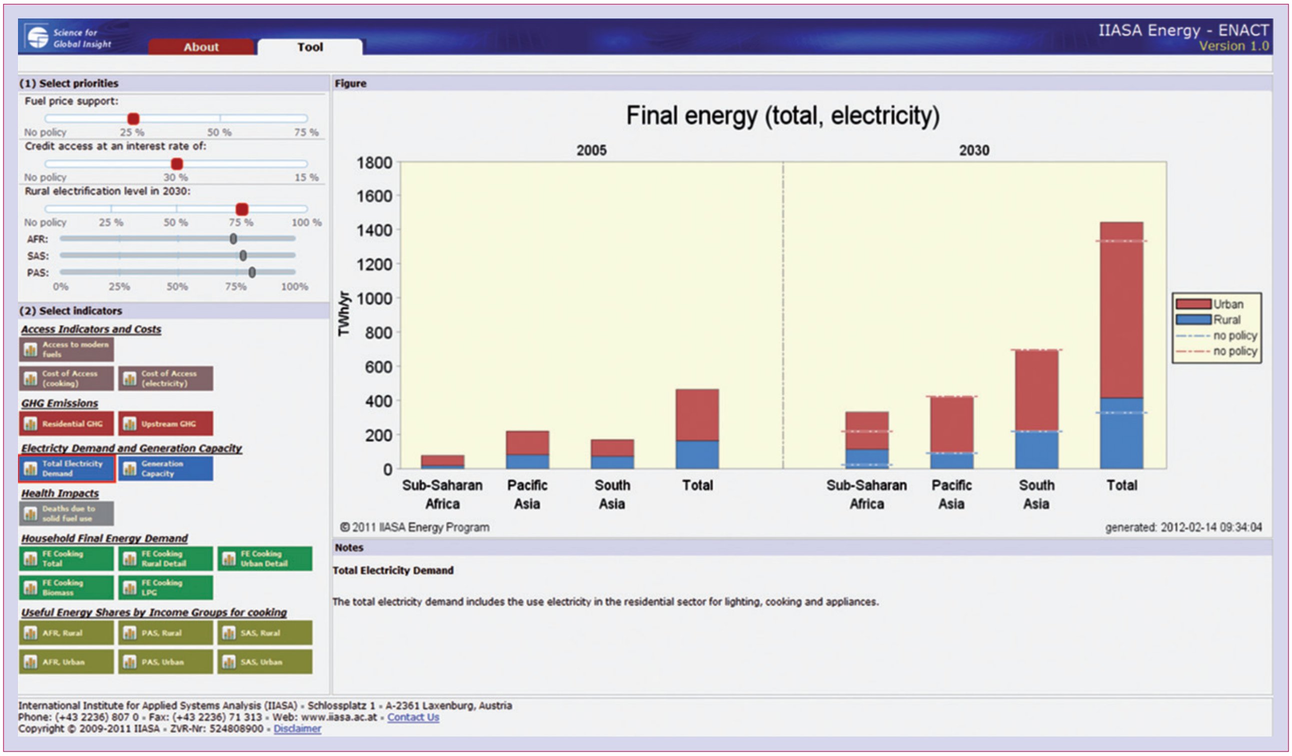


FIGURE 3
Example screenshot of the Energy-ENACT tool

The tool allows users to visualise access policy impacts through a display of costs and benefits using various indicators and lets users analyse and prioritise their objectives. It does this by supporting users in their analysis of a given set of policies, with the level of each policy manually chosen. These alternatives are, within the framework of the tool, individual energy access scenarios. The different scenario pathways represent different future access states in 2030, in which the impact of polices are reflected. The current version of the Energy-ENACT tool shows the following indicators of the impacts that different access policies bring:

- **Access indicators and costs** Number of people with access to modern fuels and the total cost of access policies for cooking and electrification
- **GHG emissions** Residential GHG emissions and upstream GHG emissions from electricity use
- **Electricity demand and generation capacity** Total electricity demand by the residential sector and generation capacity of the regions
- **Health impacts** Deaths due to solid fuel use in the residential sector
- **Household final energy demand** Total final energy demand in detail
- **Useful energy shares by income groups for cooking** Percentage of useful energy supplied by different fuels for each household income group

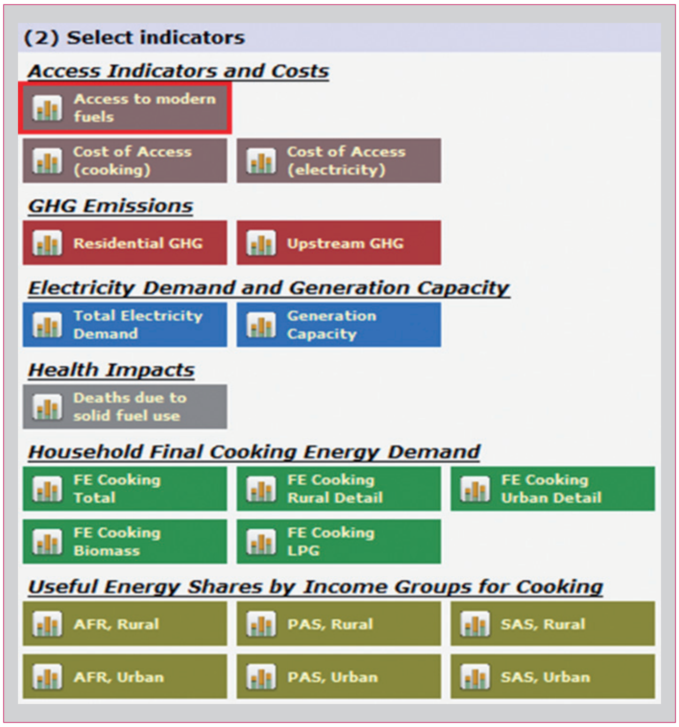
Step-by-step user guide

1. Utilising the interactive slider bars in the upper left portion of the screen (Figure 2), the user can specify his/her preferences for the different policies by choosing a support level for the modern fuel price, credit access and rural electrification target. The rural electrification target set is a minimum target that is applied uniformly to all regions. If the target is below what is projected under the "no additional policy" case, then no electrification policy is implemented for that region.
2. Based on the given three policy specifications, the software provides results of the scenario chosen.
3. The user can then learn more about the impacts of the selected or preferred policies by clicking on the various tabs in the lower left portion of the screen (Figure 4).

Once a tab is selected, a graphic will load on the right side of the screen (Figure 5). A variety of graphics can be viewed for the selected policy scenario. Below each graphic, the user finds a notes section that provides some additional explanation about the information being presented in the corresponding figure.

After fully exploring the scenario results, the user returns to the first step and can begin to explore a new scenario by moving the interactive slider bars to new positions (Figure 2), thereby comparing different possible combinations of policies.

FIGURE 4
Energy-ENACT tool: Results selection tabs



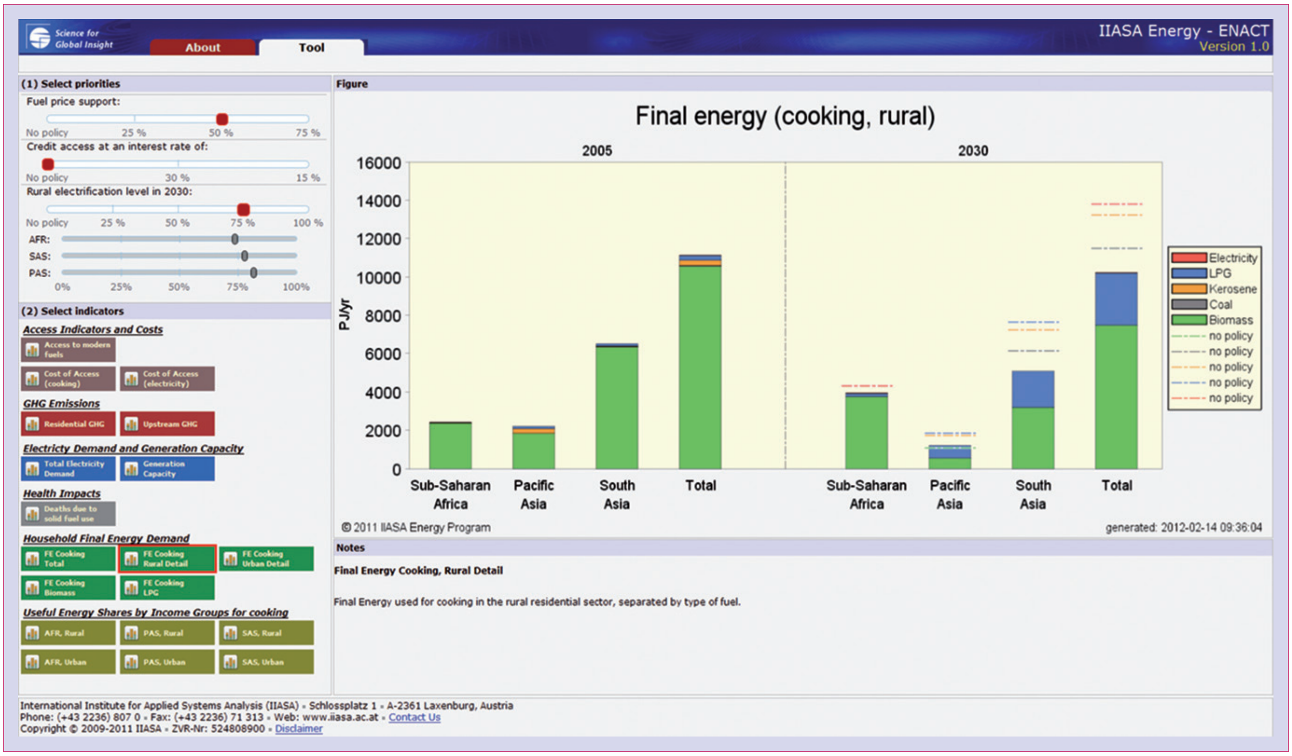


FIGURE 5 Energy-ENACT tool: Results window

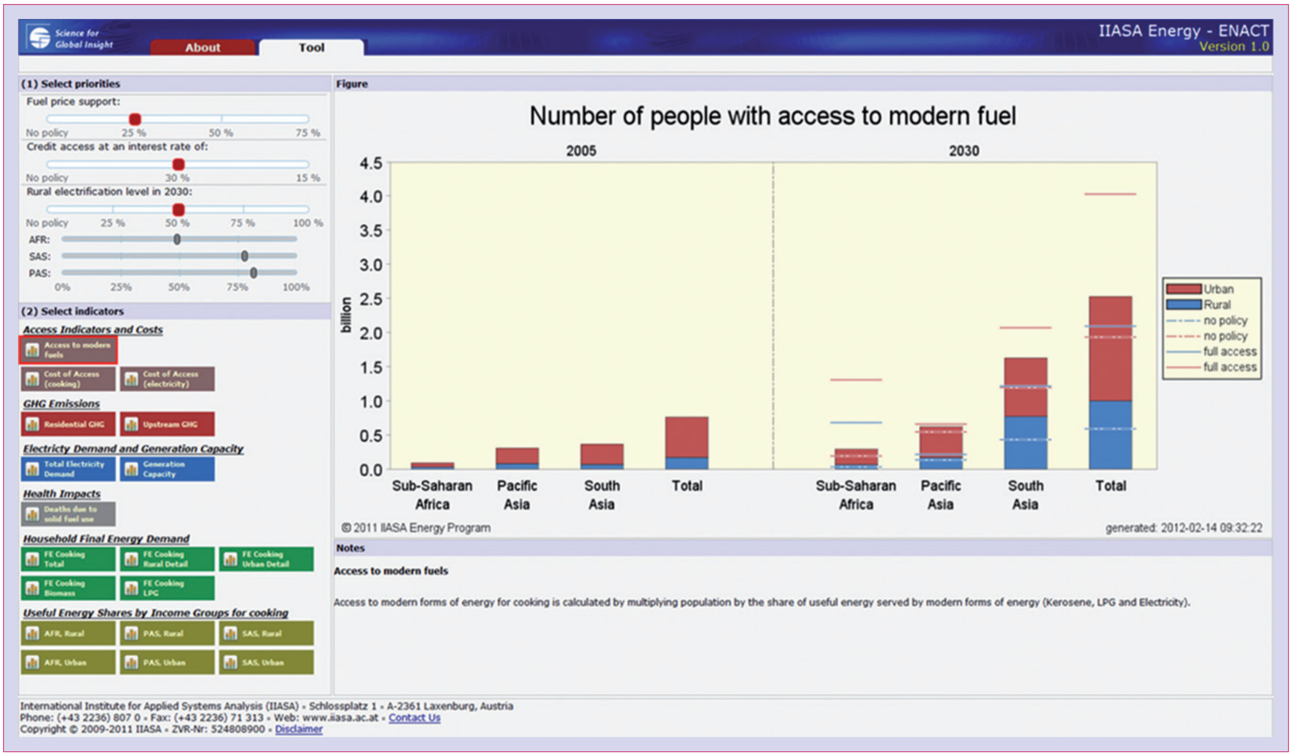


FIGURE 6 Energy-ENACT tool indicator: Number of people with access to modern fuels

Practical example and explanation of indicators

The following provides a practical example of how to use and understand the output of the Energy-ENACT tool. To make comparisons easier, the results from the "no new policies" case are shown throughout with dotted lines. For the indicator "number of people with access to modern fuels" a solid line depicting the full access case is also shown as illustrated in Figure 6.

Access indicators and costs

The first indicator tab shows the number of people with access to modern fuels for cooking and additional costs of implementing the user-defined policies chosen compared to the "no new policies" case. The number of people with access to modern fuels is determined by the share of useful energy that is supplied by modern fuels for cooking. How the useful energy is estimated is discussed further later in this section under the section on "Useful energy shares by income groups for cooking".

For cumulative cost needed for selected policies, results appear as in Figure 7. The costs are the total cumulative cost over 20 years (2010–2030) in 2005 US$ and they are broken down further into three components:

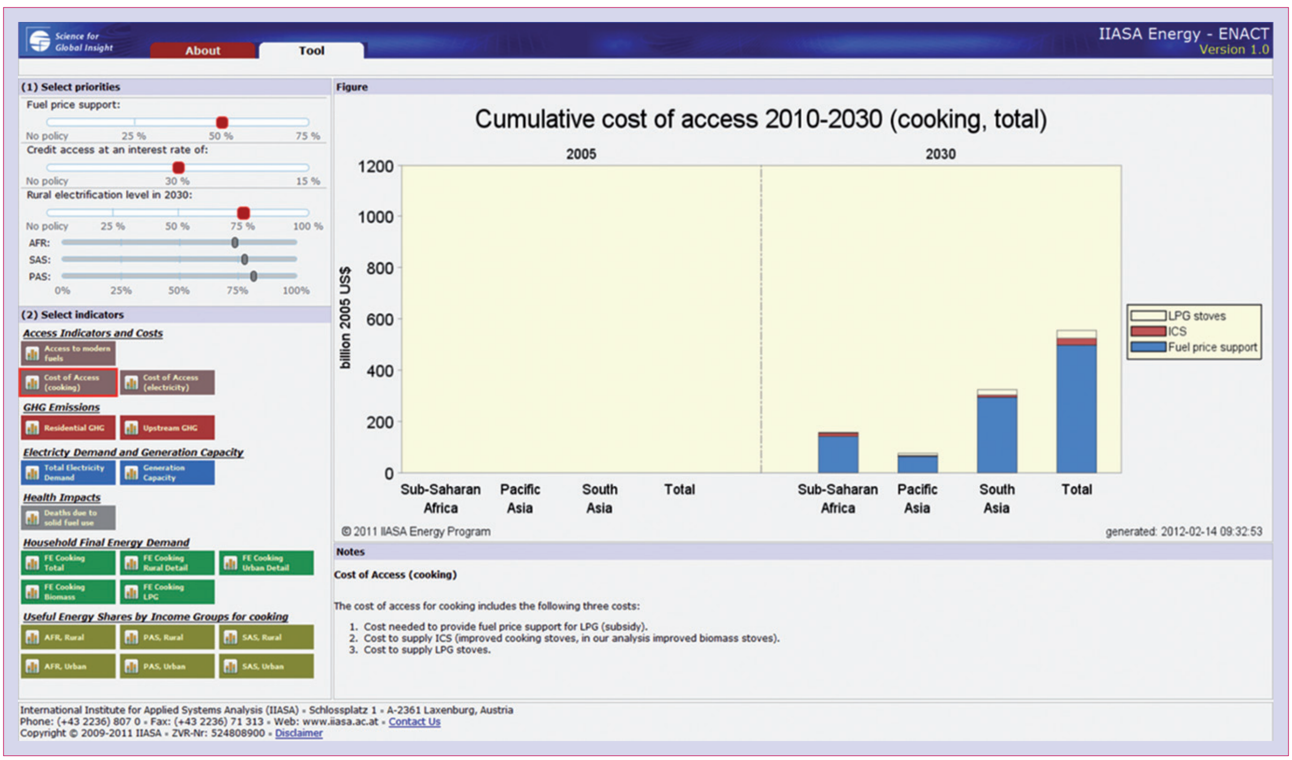


FIGURE 7 Energy-ENACT tool indicator: Cumulative investments for cooking access 2010–2030

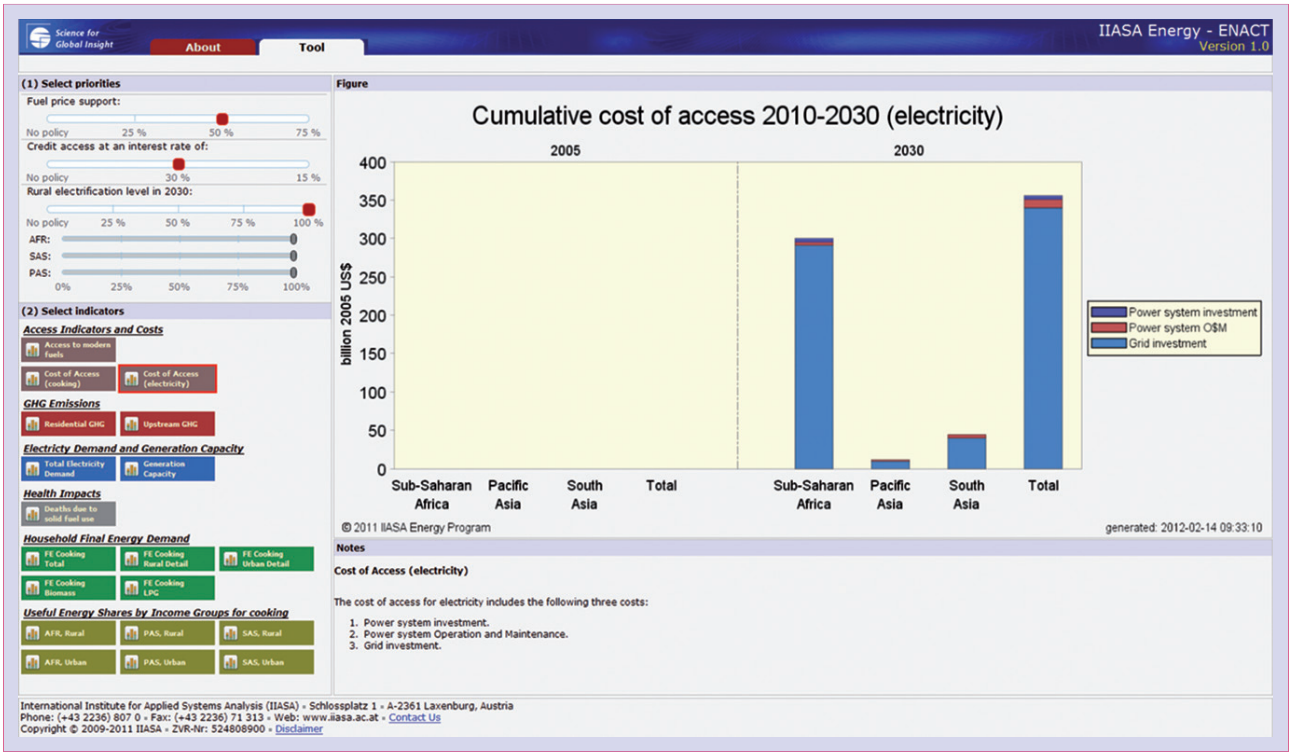


FIGURE 8 Energy-ENACT tool indicator: Cumulative investments for electrification 2010–2030

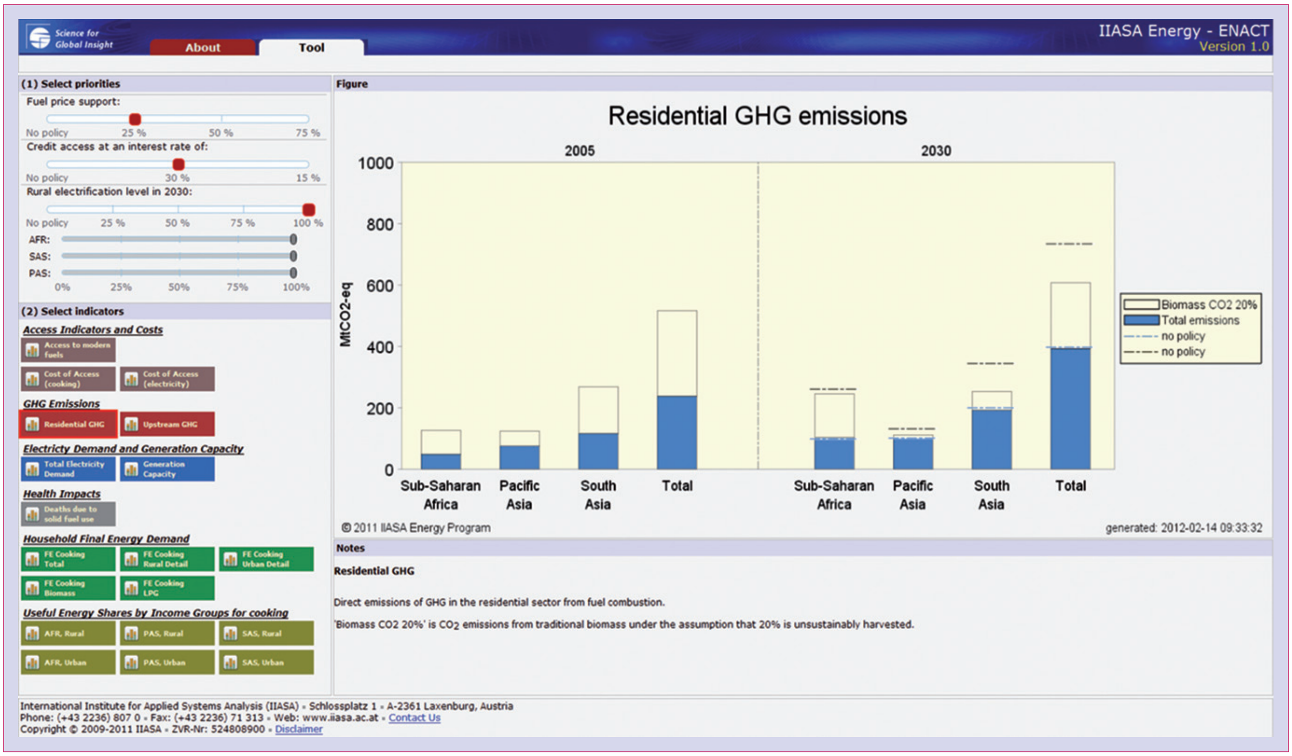


FIGURE 9 Energy-ENACT tool indicator: Residential GHG emissions

- **LPG stoves** Cost to supply LPG stoves.
- **ICS** Cost to supply ICS (improved cooking stoves; in our analysis, improved biomass stoves).
- **Fuel price support** The cost of fuel price support for LPG (subsidy costs).

The cost of electrification (Figure 8) is displayed in a similar manner with total cumulative costs over 20 years (2010–2030). The costs are broken down differently into:

- **Power system investment** The costs of additional electricity generation.
- **Power system O&M** The costs for operation and maintenance of the power system.
- **Grid investment** The costs for expanding the transmission and distribution grid.

Greenhouse gas (GHG) emissions

GHG emissions related to household energy use are separated into two categories, Residential and Upstream. Residential GHG emissions include direct emissions from fuel combustion for cooking. The use of traditional biomass might include some amount that is unsustainably harvested. Therefore, additional CO_2 emissions under an assumption that 20% of biomass use comes from unsustainable sources is shown as "Biomass CO_2 20%" (Figure 9). Upstream GHG emissions result from upstream combustion for electricity supply to the residential sector. The additional electricity use in each region resulting from the chosen electrification targets or policies is multiplied by the carbon intensity of electricity generation in each region to estimate these upstream GHG emissions.

Electricity demand and generation capacity

Total electricity demand (including demand for cooking, lighting, and appliances) and the electric generation capacity of each region are presented in this tab. The total electricity demand is shown separately for rural and urban households. The generation capacity is broken down into different fuel sources including renewable energy (Figure 10).

Health impacts

The estimated number of premature deaths in 2030 due to the use of solid fuels for cooking is displayed in this indicator (Figure 11). We estimate the health benefits of using cleaner combusting cooking fuels and devices following the standard World Health Organization (WHO) methodology (Desai, Mehta et al. 2004; also described in Rao, Chirkov et al. 2011).

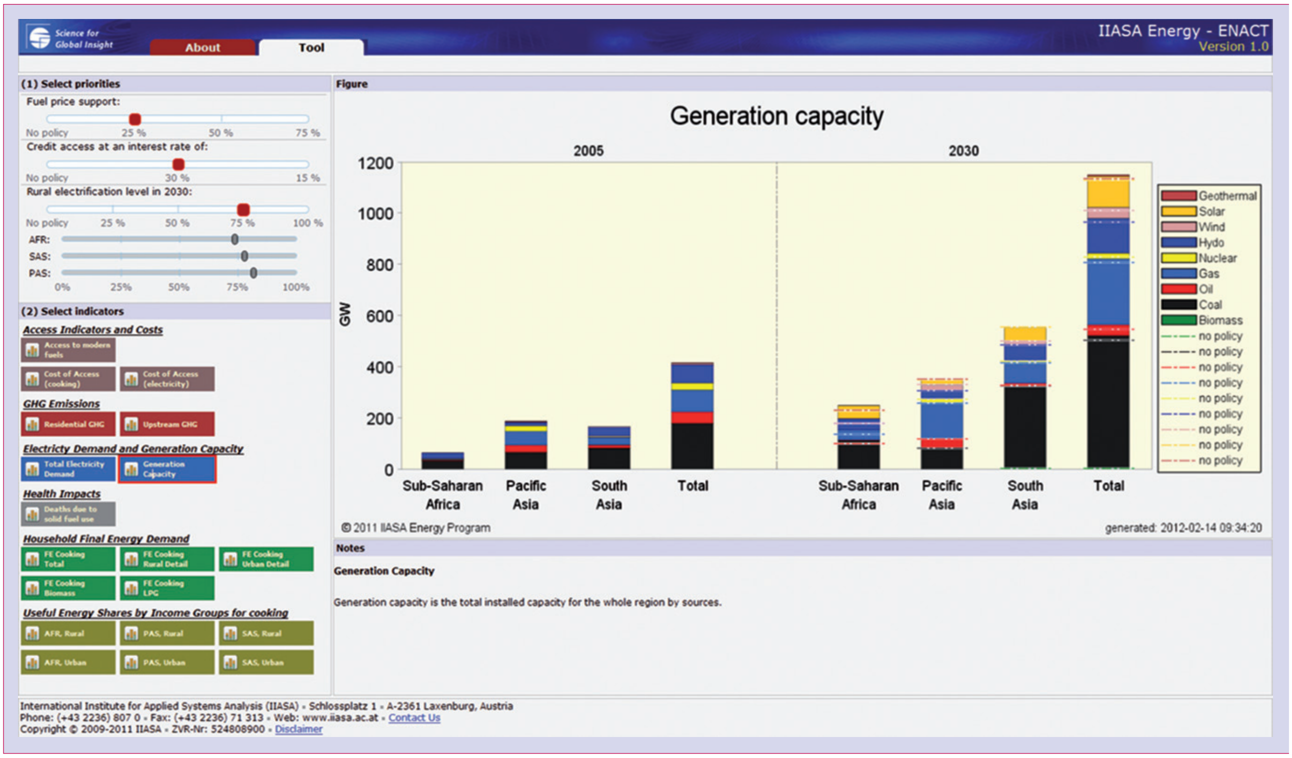


FIGURE 10 Energy-ENACT tool indicator: Generation capacity

FIGURE 11 Energy-ENACT tool indicator: Health impacts due to solid fuel use

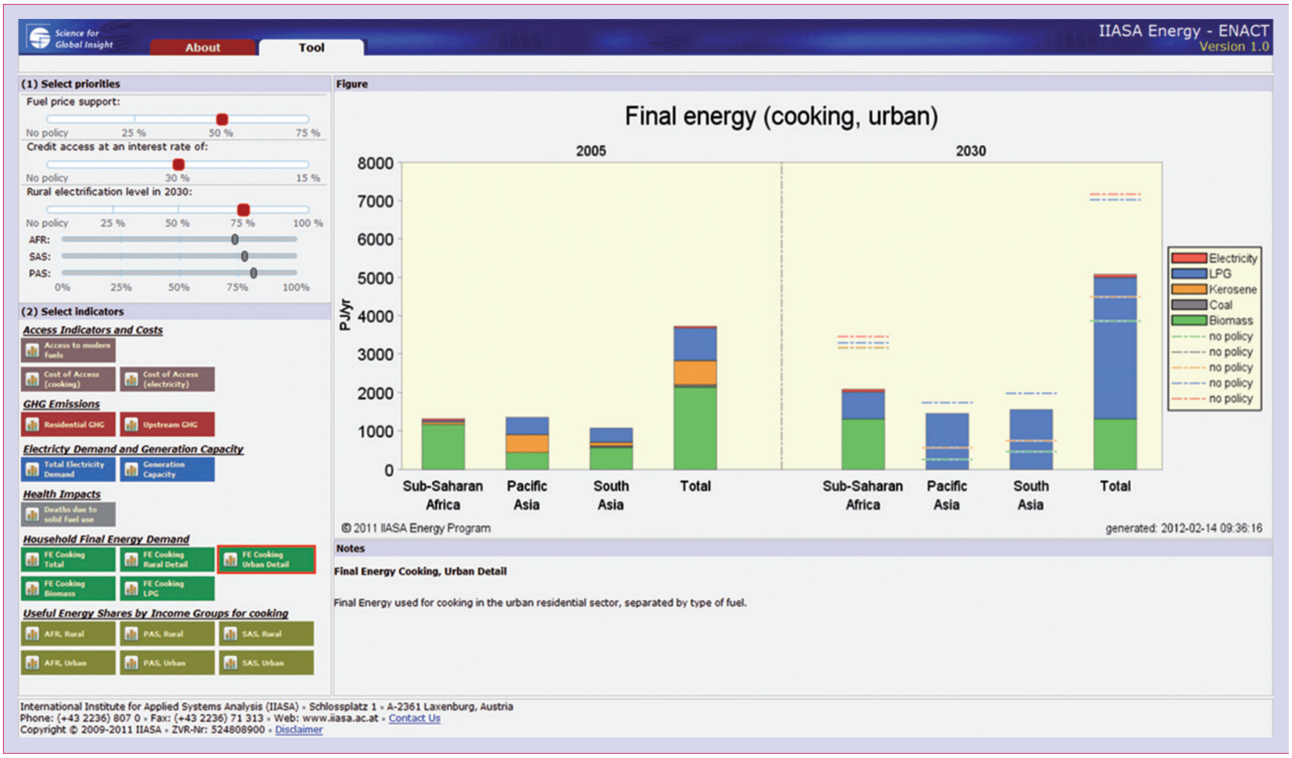


FIGURE 12 Energy-ENACT tool indicator: Final energy for cooking in urban regions

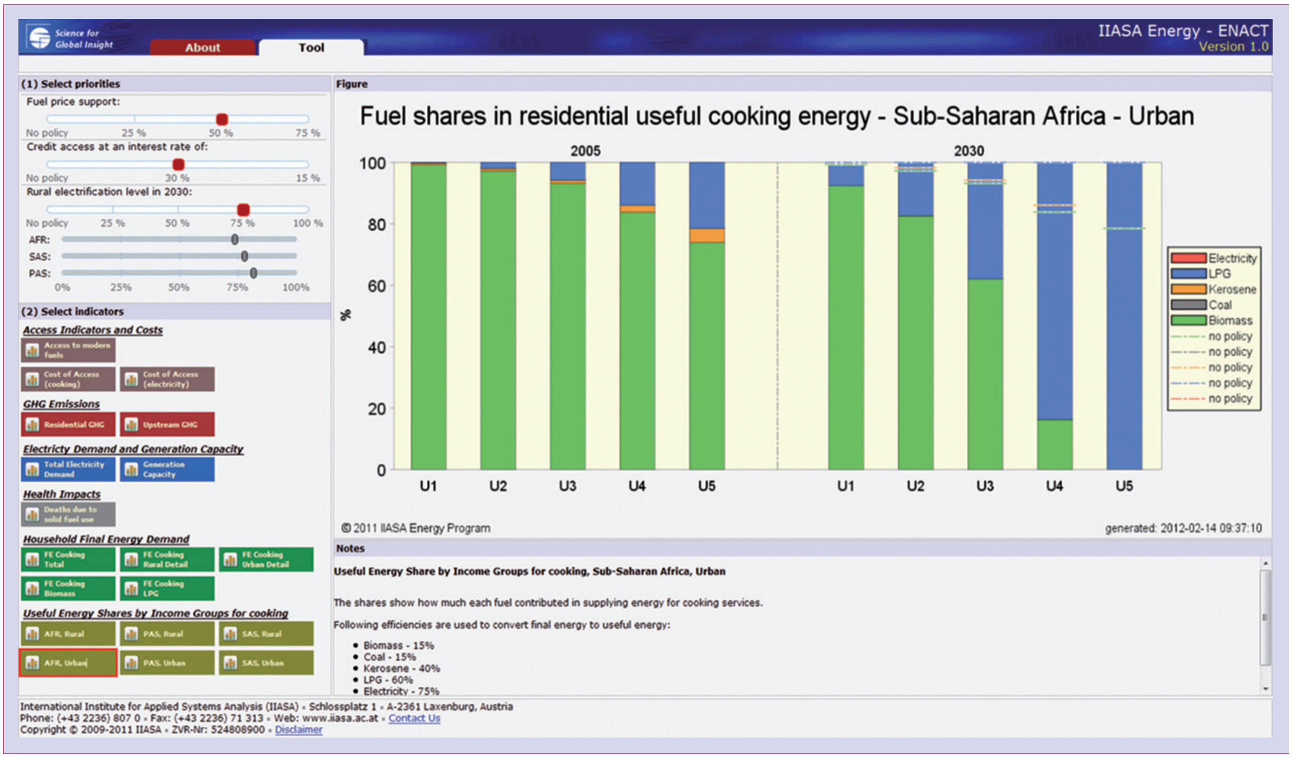


FIGURE 13 Energy-ENACT tool indicator: Fuel shares in residential useful cooking energy

Household final energy demand

Details of final energy demand (FE) for cooking are shown in this tab. FE total, FE biomass, and FE LPG are broken down for rural and urban households. The data on final energy are presented for rural and urban households by type of cooking fuel (Figure 12).

Useful energy shares by income groups for cooking

The different fuel mix for cooking in households is presented as useful energy shares as shown in Figure 13. The results are presented for different income groups and are shown separately for rural and urban households. The share of modern fuels normally rises with growing income. To convert final energy to useful energy, the following efficiencies are used for each cooking technolology:

- Biomass – 15%
- Coal – 15%
- Kerosene – 40%
- LPG – 60%
- Electricity – 75%

5. Additional Information

Model regions

As mentioned earlier, the tool presents information at a regional level and is focused on three world regions where the lack of access to modern energy is the most acute. The composition of these regions is presented in Table 1 below.

TABLE 1 Regional Composition

Region	Nations included
Sub-Saharan Africa	Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo (Rep), Congo (Dem. Rep.), Côte d'Ivoire, Djibouti, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Réunion, Senegal, Sierra Leone, Somalia, South Africa, Swaziland, Tanzania, Togo, Uganda, Zambia, Zimbabwe
Pacific Asia	Brunei Darussalam, East Timor, Fiji, French Polynesia, Indonesia, Malaysia, Myanmar, New Caledonia, Papua, New Guinea, Philippines, Republic of Korea, Samoa, Singapore, Solomon Islands, Taiwan (China), Thailand, Vanuatu
South Asia	Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, Sri Lanka

Fuel choice

A detailed description of the methodology and variables included in the assessment of fuel and equipment choices to meet household cooking energy needs can be found in Ekholm et al. (2010) and Pachauri et al. (in preparation). Here we provide a brief overview for convenience and to provide some background. A clear distinction is made in the model between households living in rural areas or urban centres, as the energy access situation varies considerably between the two. In addition to energy prices and household income determining the specific fuel and end-use technology or stove combination that meets cooking energy needs, we include two additional parameters that determine choices in the model. The first we refer to as ***inconvenience costs***. This variable is introduced to capture some of the non-monetary aspects of preferences for households in developing countries. The second parameter that also determines cooking energy choices for households is ***income dependent implicit discount rates***. These rates are used to calculate annualised capital costs of stoves used to meet cooking energy needs.

Electrification

Data on electricity access in the base year of 2005 are sourced from household survey data from key countries in each region and are scaled to each region based on rural and urban electrification estimates from UNDP and WHO (2009) and IEA (2010). We assume that in the future, electrification is driven by income growth and distribution. To determine the trend in electrification in the absence of new policies or targets, we use the group specific electrification rates and weight these by the population estimates for each income group in each time period to determine the region specific rural and urban electrification levels in each time period.

Income distribution

Heterogeneity of demand and socio-economic characteristics are accounted for in the model by including multiple household groups defined by income levels across urban and rural regions. In cases where some countries in a region have distinctly different energy use patterns, they are treated separately and allocated to special groups.

In future time periods, income growth and distribution are estimated as follows. The growth in total GDP and the split of GDP between urban and rural areas relies on projections from the *Global Energy Assessment* (Riahi et al. 2012). As income grows over time, population share shifts from lower income groups to higher income groups. The GDP per capita of only the highest income groups is assumed to change to reflect the overall economic growth patterns of the respective regions.

The methodology for estimating the population shifts from the lower groups to the next higher income group in each time period is as follows. Since economic growth is faster than population growth in all of our regions, the percentage of population in the highest group continues to grow. To determine how many people in each group move to the next income group in each time period, we use the difference between the economic growth rate and population growth rate. The potentially shifting population is estimated as the difference in population size between that which would be implied by natural growth and that if the share of income for each group had stayed the same. This potentially shifting population is then weighted by the income share of the respective income group. This process is repeated for each group and for all time periods. There are alternate methods for determining how the income distribution may change over time. We select this method as it results in reasonable changes in Gini coefficients over time.

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