ClimTrans2050

# Energy modeling with a bit more reality

## Functionalities, the interaction of stocks and flows, the choice of technologies

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Are mainstream energy models able to cope with the emerging innovations in our energy systems, e.g. micro grids?

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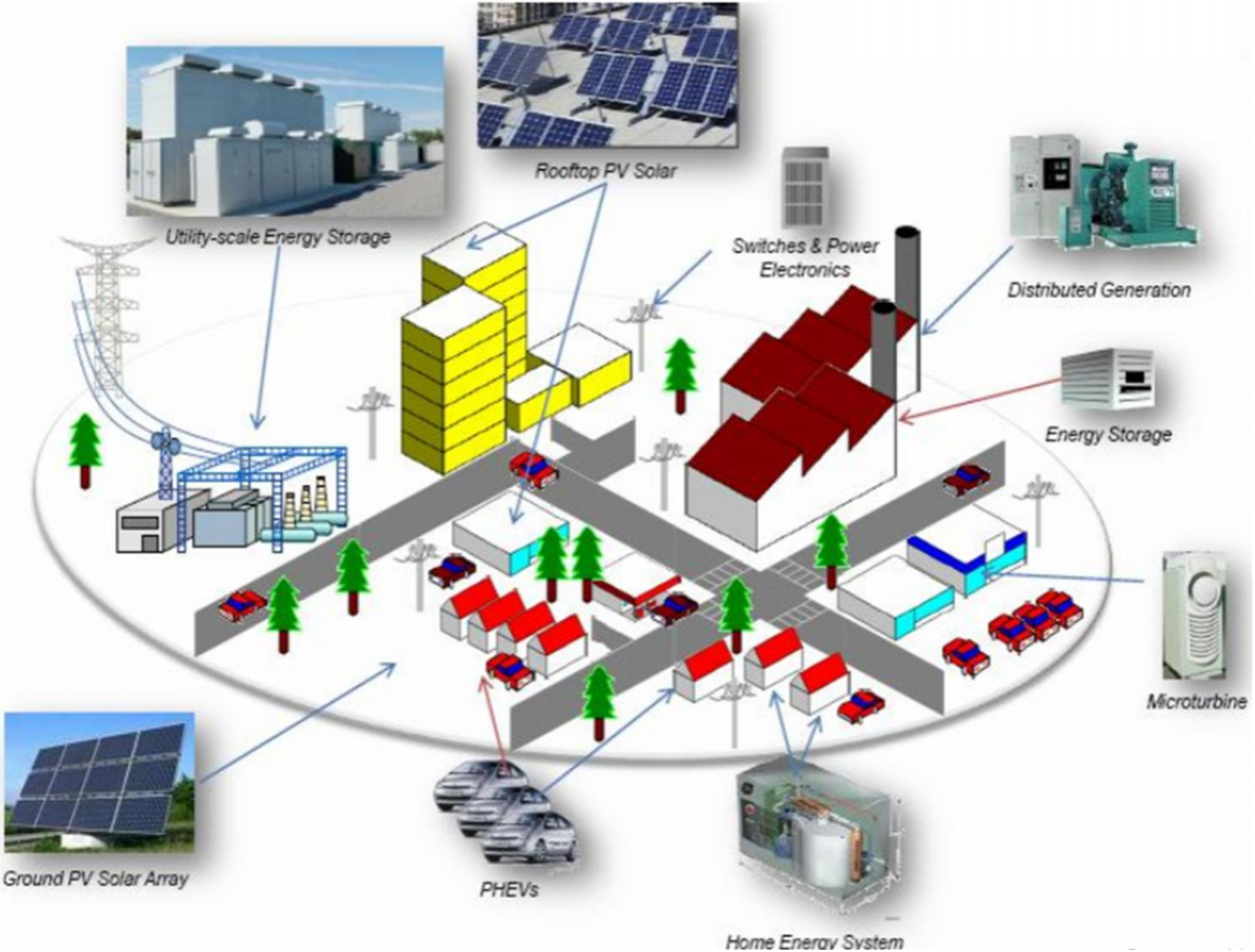
Utility-scale Energy Storage
Rooftop PV Solar
Switches & Power Electronics
Distributed Generation
Energy Storage
Microturbine
Ground PV Solar Array
PHEVs
Home Energy System

# Why micro grids are emerging

- **The flagship example of the UC San Diego**
  - High-efficiency co- and poly-generation, heat-pumps
  - PV and thermal solar, heat and electricity storage
  - Integrated demand-side management
- **Two types of energy efficiency**
  - Mass efficiency
  - Exergy efficiency
- **Other qualities**
  - Resilience and reliability
  - Renewables fit into decentralized structures
- **From economies of scale to economies of scope**

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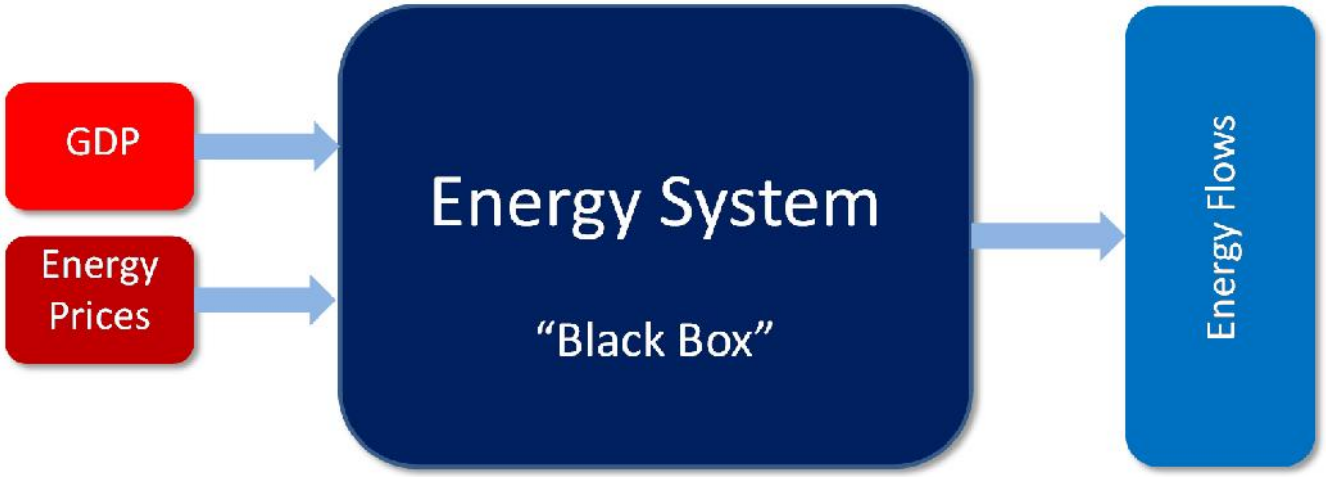
# The conventional "black box" modeling approach to energy systems




- **The energy system is described by a transfer functions between energy flows and presumed causalities**

# Why the conventional "black box" approach is insufficient

- **Poor representation of structures and technologies**
- **The role of (capital) stocks is hardly visible**
- **Other drivers besides prices and economic activity are neglected**
- **Not sufficiently capable for analyzing long-run transitions**

- **Most of the well-known models, as PRIMES, POLES, are conventional**

# Building blocks for a deepened modeling approach to energy systems

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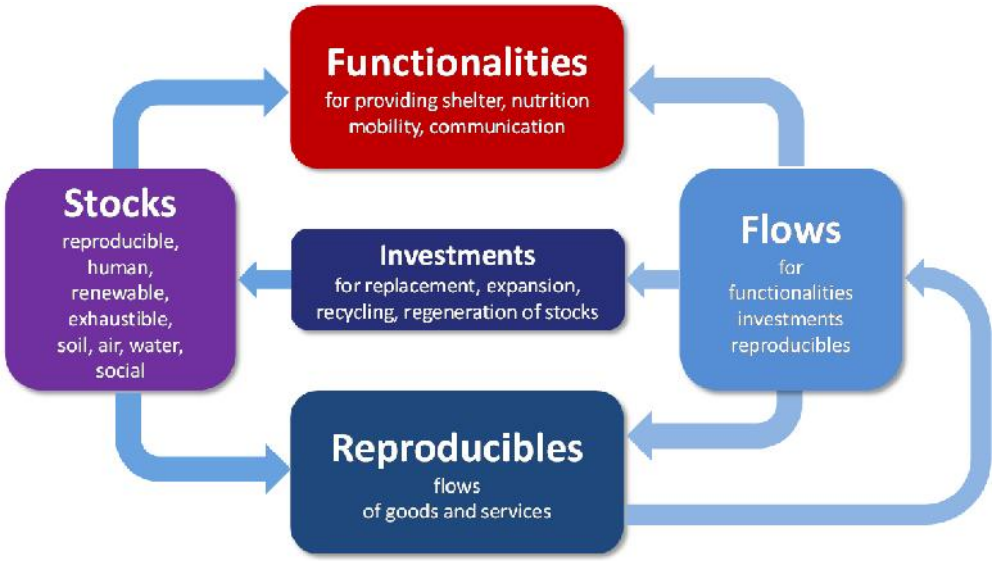
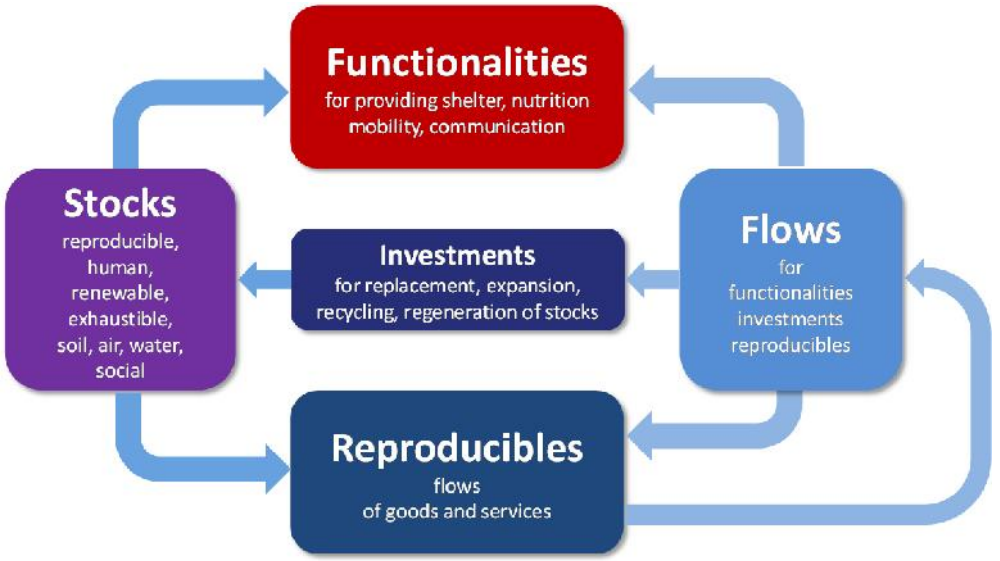
# Tier One: The physical dimension
# From functionalities to energy flows

- **Functionality:**
  **The thermal services of a building**
- **Useful / final energy:**
  **Determined by application technology**
- **Primary energy:**
  **Determined by transformation technology and energy mix**



# Tier Two: The economic dimension
# From functionalities to energy flows

- **Investment: Creating/maintaining/ Improving/expanding the stoci of buildings**
- **Operating: Flows of energy and other resources**

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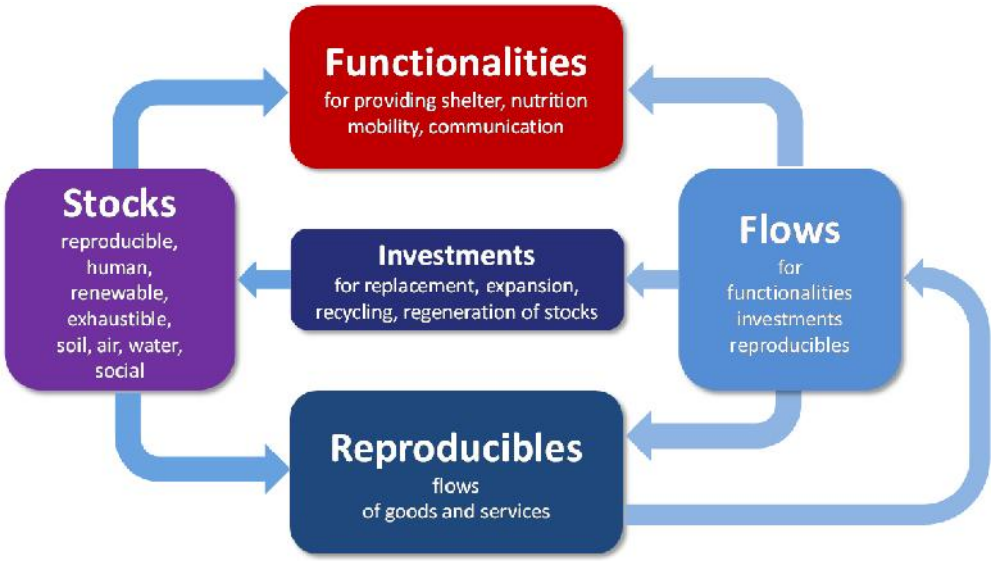
# Tier Three: The institutional dimension
# Mechanisms for incentives and coordination

- **Markets: Relevance for investment and operating decisions**
- **Non-markets: Regulations and institutions**



# Making this deepened modeling approach operational

sGAIN modeling family
sustainable General Analysis of Innovative Notions

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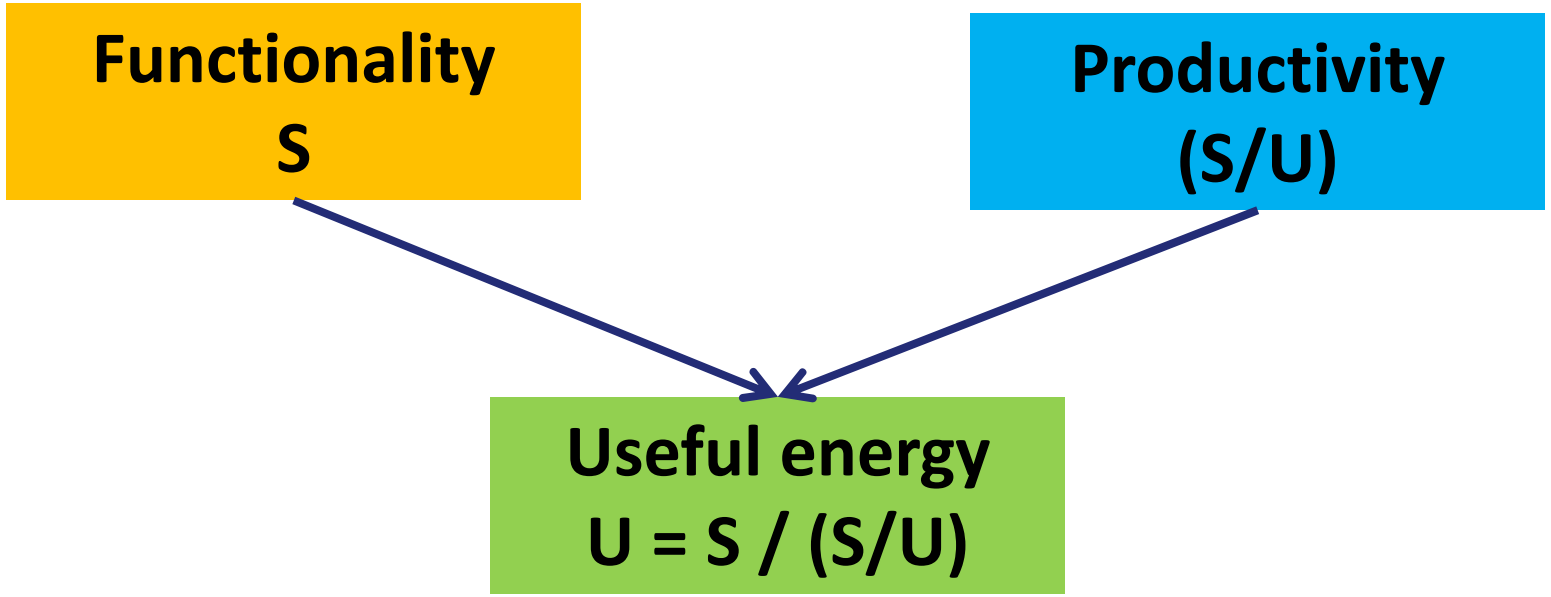
# The key role of functionalities

- **Thermal**
  - **Low and high temperatures**
- **Mechanical**
  - **Stationary and mobile engines**
- **Specific electric**
  - **Lighting, electronics**

# Functionalities and energy productivity determine the demand for useful energy



# Low temperature heat

| Functionalities and Useful Energy | | | | Total | Coal, Waste | Oil | Gas | Renewables | Electricity | Heat |
|---|---|---|---|---|---|---|---|---|---|---|
| **Low temperature heat** | | | *TJ* | **117.122** | 897 | 12.293 | 15.998 | 57.838 | 17.879 | 12.218 |
| End Period | Functionality | Productivity | | | End Period Energy Mix | | | | | |
| *2050* | *130* | *350* | *Index* | *37* | *1%* | *10%* | *14%* | *49%* | *15%* | *10%* |
| | | | | | Change of Energy Mix | | | | | |
| *Change* | *30* | *250* | *Index* | *-63* | *0%* | *-5%* | *-10%* | *18%* | *7%* | *-10%* |
| Start Period | | | | | Start Period Energy Mix | | | | | |
| *2014* | *100* | *100* | *Index* | *100* | *1%* | *15%* | *24%* | *31%* | *8%* | *20%* |
| | | | *TJ* | **315.329** | 2.416 | 48.862 | 74.605 | 98.958 | 26.062 | 64.427 |

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# High temperature heat

| Functionalities and Useful Energy | | | | Total | Coal, Waste | Oil | Gas | Renewables | Electricity | Heat |
|---|---|---|---|---|---|---|---|---|---|---|
| **High temperature heat** | | | *TJ* | **188.001** | 13.375 | 3.838 | 53.773 | 57.118 | 44.417 | 15.479 |
| End Period | Functionality | Productivity | | | End Period Energy Mix | | | | | |
| *2050* | *120* | *150* | *Index* | *80* | *7%* | *2%* | *29%* | *30%* | *24%* | *8%* |
| | | | | | Change of Energy Mix | | | | | |
| *Change* | *20* | *50* | *Index* | *-20* | *-3%* | *-2%* | *-10%* | *8%* | *3%* | *4%* |
| Start Period | | | | | Start Period Energy Mix | | | | | |
| *2014* | *100* | *100* | *Index* | *100* | *10%* | *4%* | *39%* | *22%* | *21%* | *4%* |
| | | | *TJ* | **235.001** | 23.769 | 9.498 | 90.717 | 52.597 | 48.471 | 9.948 |

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# Stationary engines

| Functionalities and Useful Energy | | | | Total | Coal, Waste | Oil | Gas | Renewables | Electricity | Heat |
|---|---|---|---|---|---|---|---|---|---|---|
| **Stationary Engines** | | | *TJ* | **134.231** | 0 | 11.145 | 3.534 | 2.946 | 116.606 | 0 |
| End Period | Functionality | Productivity | | | | | End Period Energy Mix | | | |
| *2050* | *130* | *120* | *Index* | *108* | *0%* | *8%* | *3%* | *2%* | *87%* | *0%* |
| | | | | | | | Change of Energy Mix | | | |
| *Change* | *30* | *20* | *Index* | *8* | *0%* | *-3%* | *-2%* | *1%* | *4%* | *0%* |
| Start Period | | | | | | | Start Period Energy Mix | | | |
| *2014* | *100* | *100* | *Index* | *100* | *0%* | *11%* | *5%* | *1%* | *83%* | *0%* |
| | | | *TJ* | **123.906** | 0 | 14.005 | 5.741 | 1.480 | 102.680 | 0 |

# Mobile engines

| Functionalities and Useful Energy | | | | Total | Coal, Waste | Oil | Gas | Renewables | Electricity | Heat |
|---|---|---|---|---|---|---|---|---|---|---|
| **Mobile Engines** | | | *TJ* | **176.018** | 3 | 106.152 | 10.638 | 9.943 | 49.282 | 0 |
| End Period | Functionality | Productivity | | | | | End Period Energy Mix | | | |
| *2050* | *120* | *250* | *Index* | *48* | *0%* | *60%* | *6%* | *6%* | *28%* | *0%* |
| | | | | | | | Change of Energy Mix | | | |
| *Change* | *20* | *150* | *Index* | *-52* | *0%* | *-28%* | *3%* | *0%* | *25%* | *0%* |
| Start Period | | | | | | | Start Period Energy Mix | | | |
| *2014* | *100* | *100* | *Index* | *100* | *0%* | *88%* | *3%* | *6%* | *3%* | *0%* |
| | | | *TJ* | **366.704** | 5 | 323.827 | 11.161 | 20.714 | 10.996 | 0 |

# Lighting and electronics

| Functionalities and Useful Energy | | | | Total | Coal, Waste | Oil | Gas | Renewables | Electricity | Heat |
|---|---|---|---|---|---|---|---|---|---|---|
| **Lighting and Electronics** | | | *TJ* | **23.734** | 0 | 0 | 0 | 0 | 23.734 | 0 |
| End Period | Functionality | Productivity | | | | | | End Period Energy Mix | | |
| *2050* | *220* | *300* | *Index* | *73* | *0%* | *0%* | *0%* | *0%* | *100%* | *0%* |
| | | | | | | | | Change of Energy Mix | | |
| *Change* | *120* | *200* | *Index* | *-27* | *0%* | *0%* | *0%* | *0%* | *0%* | *0%* |
| Start Period | | | | | | | | Start Period Energy Mix | | |
| *2014* | *100* | *100* | *Index* | *100* | *0%* | *0%* | *0%* | *0%* | *100%* | *0%* |
| | | | *TJ* | **32.364** | 0 | 0 | 0 | 0 | 32.364 | 0 |

# Non-energetic energy use

| Functionalities and Useful Energy | | | | Total | Coal, Waste | Oil | Gas | Renewables | Electricity | Heat |
|---|---|---|---|---|---|---|---|---|---|---|
| **Non-energetic energy consumption** | | | *TJ* | **140.076** | 36.227 | 83.068 | 20.781 | 0 | 0 | 0 |
| End Period *2050* | Functionality *120* | Productivity *110* | *Index* | *109* | *End Period Energy Mix* *26%* | *59%* | *15%* | *0%* | *0%* | *0%* |
| *Change* | *20* | *10* | *Index* | *9* | *Change of Energy Mix* *0%* | *0%* | *0%* | *0%* | *0%* | *0%* |
| Start Period *2014* | *100* | *100* | *Index* | *100* | *Start Period Energy Mix* *26%* | *59%* | *15%* | *0%* | *0%* | *0%* |
| | | | *TJ* | **128.403** | 33.208 | 76.146 | 19.049 | 0 | 0 | 0 |