

# The Energy Market

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## 1. Goal

The goal of this programming project is to design and implement a multi-process and multi-thread simulation in Python. This document defines the functionalities that it has to implement at a minimum. Some questions are deliberately left open for you to propose your own solution. Any extensions and developments will act in your favor in the evaluation. Be rigorous and creative!

## 2. Presentation

### 2.1. Minimum specifications

The program simulates an energy market where energy-producing and consuming homes, weather conditions and random events contribute to the evolution of energy price over time. Homes may choose to give away their surplus of energy to other homes that are in shortage, or may sell it to the market thus contributing to the diminution of energy price. Homes in need of energy will have to buy it from the market if others would not give away any. Naturally, energy prices climb when the average consumption exceeds that of production. Random events, such as the enactment of a law, diplomatic tension etc. can impact energy prices. Temperature changes also impact energy consumption, hence its price.

### 2.2. A minimal design

The simulation involves 4 types of processes.

- **home**: represents an energy-producing and consuming home, with initial production and consumption rates and energy trade policy which is one of three possibilities 1. always give away, 2. always sell on the market, and 3. sell on the market if no takers.
- **market**: represents the market with current energy price which evolves according to transactions with homes (selling and buying), weather conditions and random events. The market process is multi-threaded and carries out transactions with home processes in separate threads. Furthermore it limits the number of simultaneous transactions that can take place with homes.
- **weather**: simulates weather parameters impacting energy consumption, such as temperature and its variation over time.
- **external**: simulates random events of predefined types that can impact the energy price.

**Inter-process communication:** Processes in the simulation communicate in the following way: home processes communicate among themselves using a message queue and with the market process via sockets. The weather process updates a shared memory with weather condition parameters. The external process, a child of market process, signals random events to the latter which takes the corresponding action impacting energy price. home and market processes update their displays permitting the operator of the simulation to track the progress.

**Energy price:** The energy price can be calculated according to the following linear model:

$$P_t = \gamma P_{t-1} + \sum_i \alpha_i f_{i,t} + \sum_j \beta_j u_{j,t}$$

$P_t$	is the energy price at instant $t$	€/kWh
$P_{t-1}$	is the energy price at instant $t-1$	€/kWh
$\gamma$	is a long-term attenuation coefficient	unitless
$f_{i,t}$	is the contribution of the $i^{th}$ internal factor at instant $t$ , such as the current temperature, amount of energy sold or bought on the market etc.	depends on $f_{i,t}$
$\alpha_i$	is a modulating coefficient for factor $f_{i,t}$	€/kWh
$u_{j,t}$	is the contribution of the $j^{th}$ external factor at instant $t$ , such diplomatic tension, social unrest, fuel shortage etc. To simplify, we consider that $u_{j,t} \in \{0,1\}$ indicating the absence/presence of a given external circumstance	unitless
$\beta_j$	is a modulating coefficient for factor $u_{j,t}$	€/kWh

Here's a numerical example. For  $\gamma=0.99$ ,  $P_{t-1}=0.145$  €/kWh,  $\alpha_0=0.001$ ,  $f_{0,t}=1/5$  °the inverse of current temperature,  $\beta_0=0.01$ ,  $u_{0,t}=1$  indicating a presence of fuel shortage, the price of energy at instant  $t$  is  $P_t=0.15375$  €/kWh.

In your design, you are required to define at least 1 internal and 1 external factors.

### 3. Solution

#### 3.1. Design

Start with a diagram to visualize the interactions between processes/threads. State machine diagrams can be helpful during this stage. The following points need to be addressed and justified:

- relationships between processes (parent-child or unrelated)
- message queues used in communication and messages exchanged between processes along with their types, content and order of exchange
- sockets used in communication between processes along with exchanged messages, their content and order of exchange
- data structures stored in shared memory and how they are accessed
- synchronization primitives to protect access to shared resources or to count resources
- signals exchanged between processes and their types
- tubes involved in pairwise process communication, if any, and their types

Write down a Python-like pseudo-code of main algorithms for each process.

#### 3.2. Implementation plan

Plan your implementation and test steps. We strongly encourage you to first implement and test every process/thread separately on hard-coded data in the beginning. Then you can implement and test each pair of communicating processes/threads, again on hard-coded data in the beginning, if necessary. Only after implementing and testing each inter-process communication you can put all processes together and test the simulation. Think about how to automate the startup and the proper shutdown of the simulation, freeing all resources. Identify possible failure scenarios and think about recovery or termination strategies.

#### 4. Deadlines and deliverables

16/1/2023	project proposal is published on Moodle
1/2/2023	15-minute demonstration per project with the teacher in charge of your group
3/2/2023 - midnight	submission of project code and report archive on Moodle, refer to organization slides for the content of the report