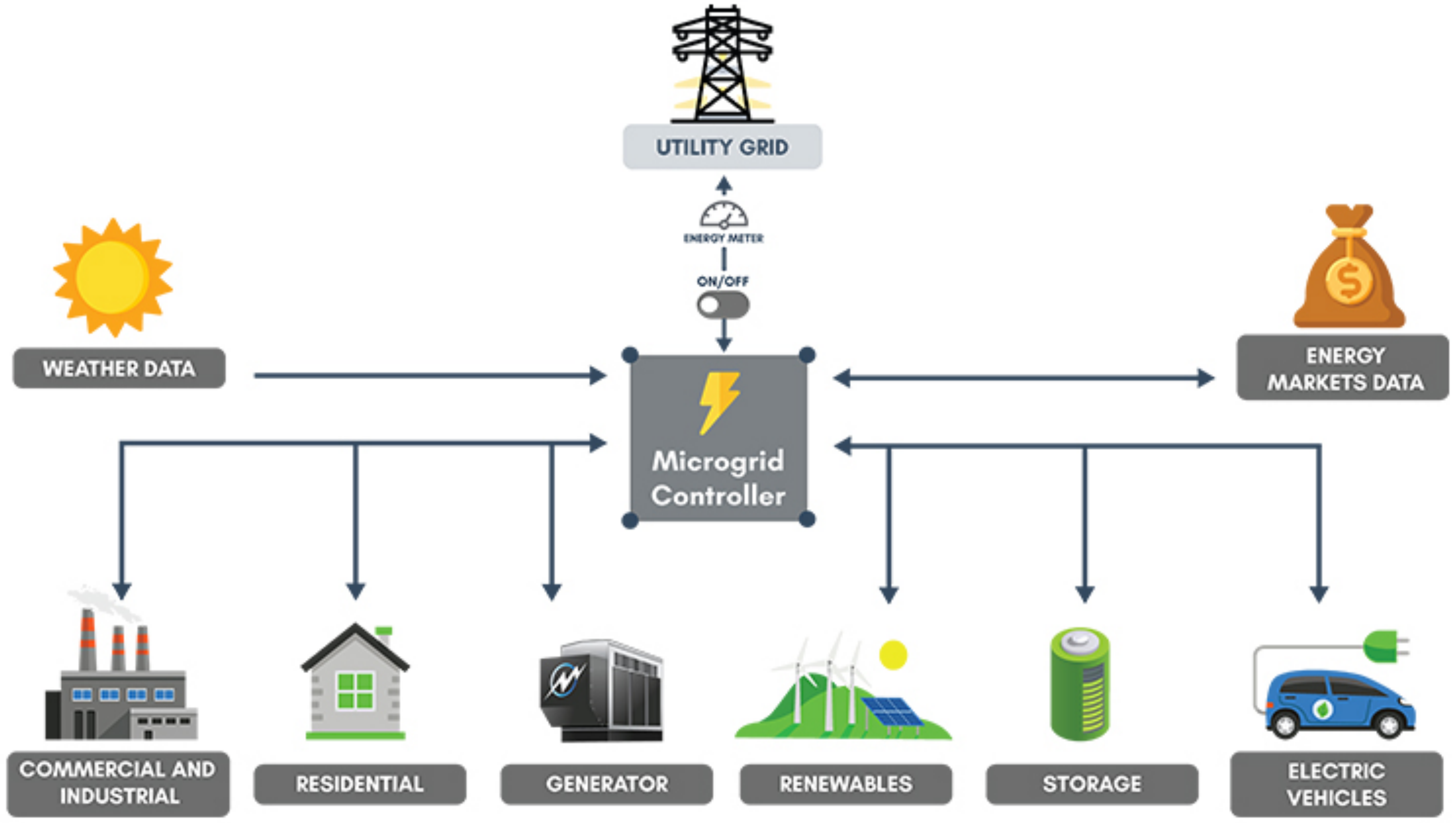
BriX

Energy as a Service

Energy Management System

Challenge: Problem

- Raise of new green technologies (PV panels, wind turbines, electrical batteries)
- New ways of consuming energy
- **Smart Microgrid**
- Managed by *Energy Management System* (EMS)



Challenge: Description

- Proposed by the Centre for Research and Technology Hellas (CERTH)
- Goal: develop a system capable of optimising the operation of the building as a micro-grid
- Expected outcomes:
    - 20% RES optimisation
    - 20% storage optimisation
    - 20% energy savings

Technical Scope: Data

- CERTH Energy: Energy information related to building energy consumption, generation and storage
  - Data issue:
    - Few data scores
- Phoops G-Smart: 10 years of photovoltaic measurements (energy production, load curves, power exported to the grid, solar radiation and weather conditions)

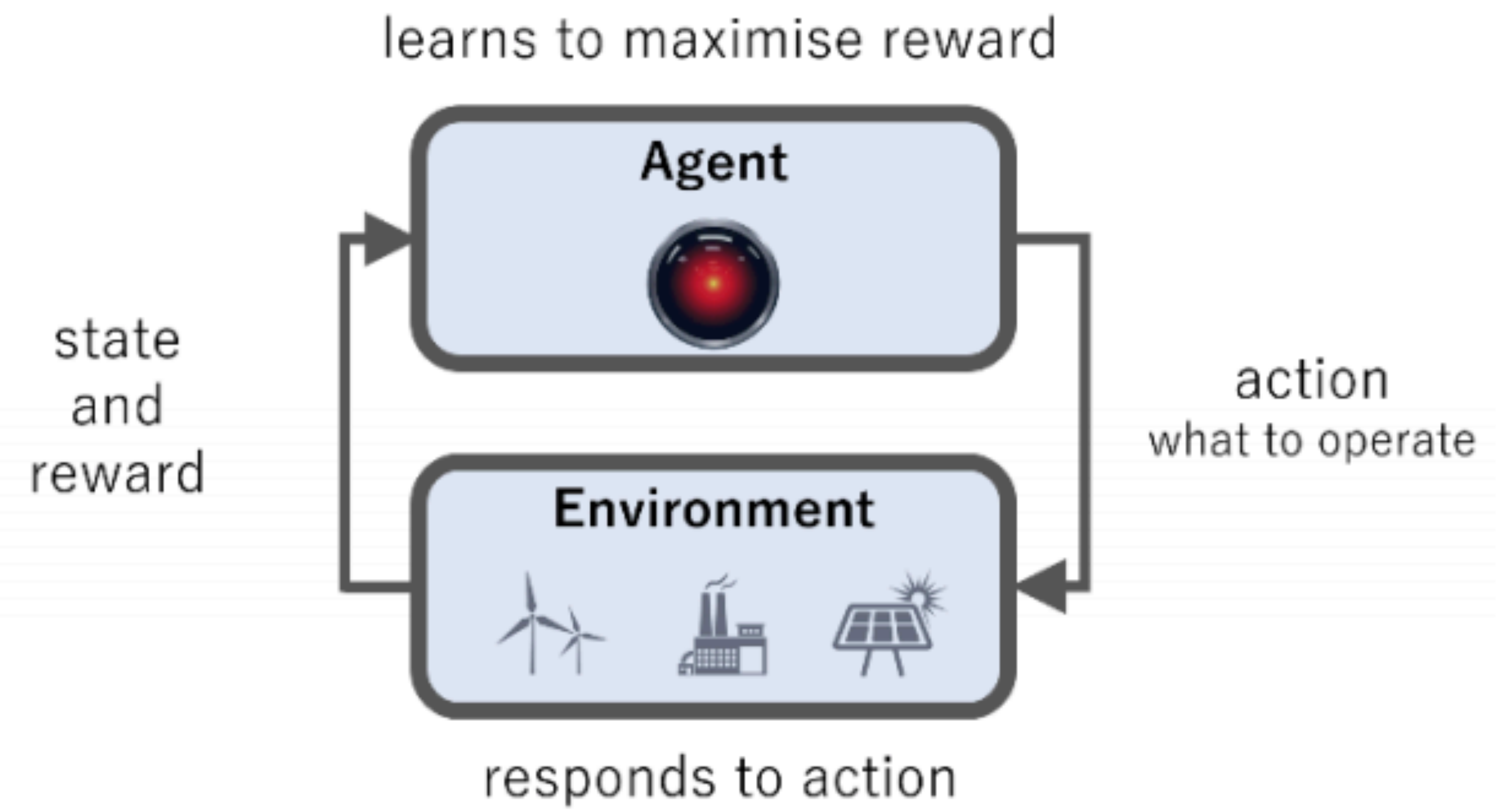
Technical Scope: Solution

Reinforcement Learning (RL):

- Gives a machine the ability to learn to take actions
- Machine try to optimize a reward signal

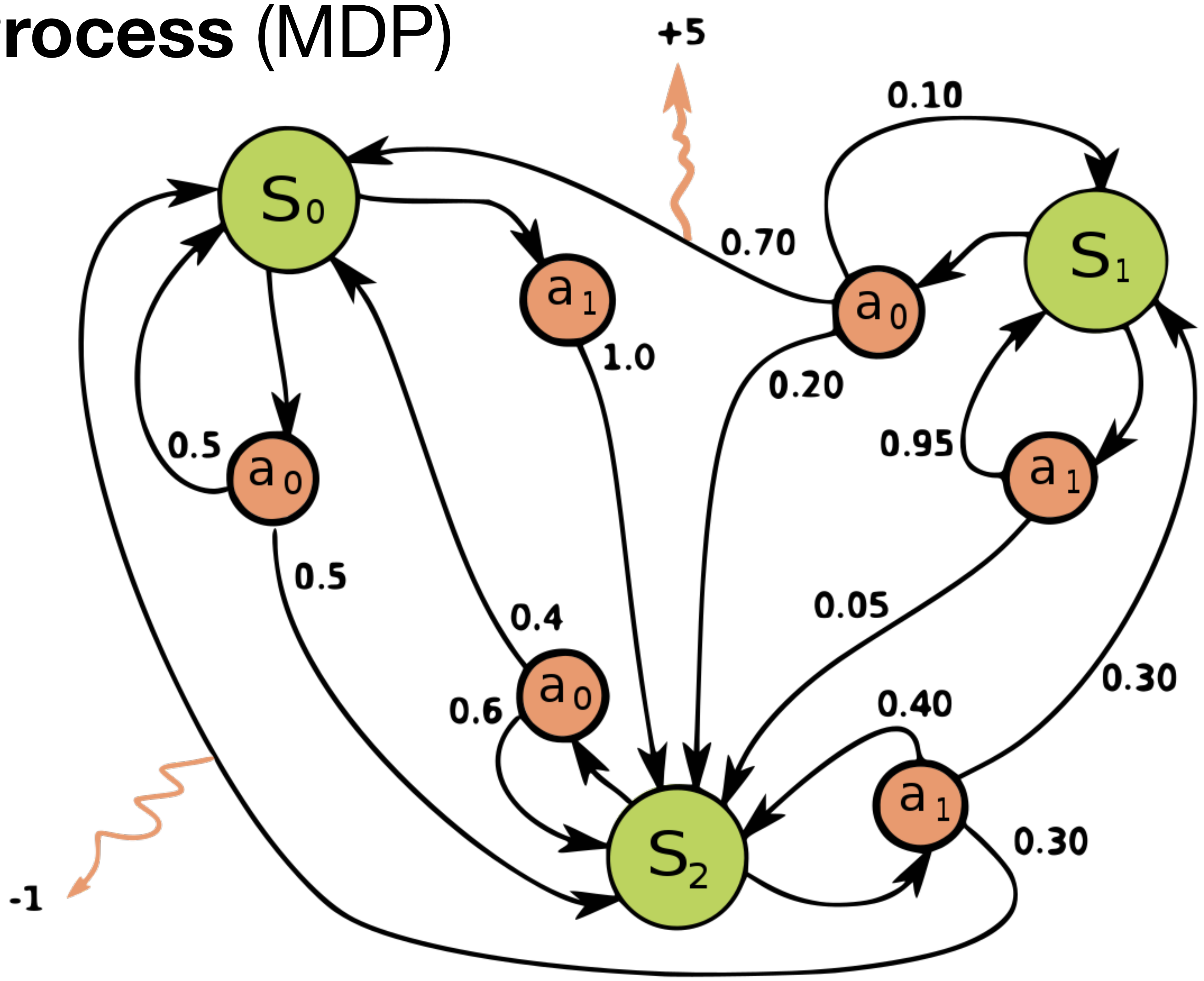
Microgrid context:

- Reward signal could be energy cost, peak of load, safety



Technical Scope: Solution

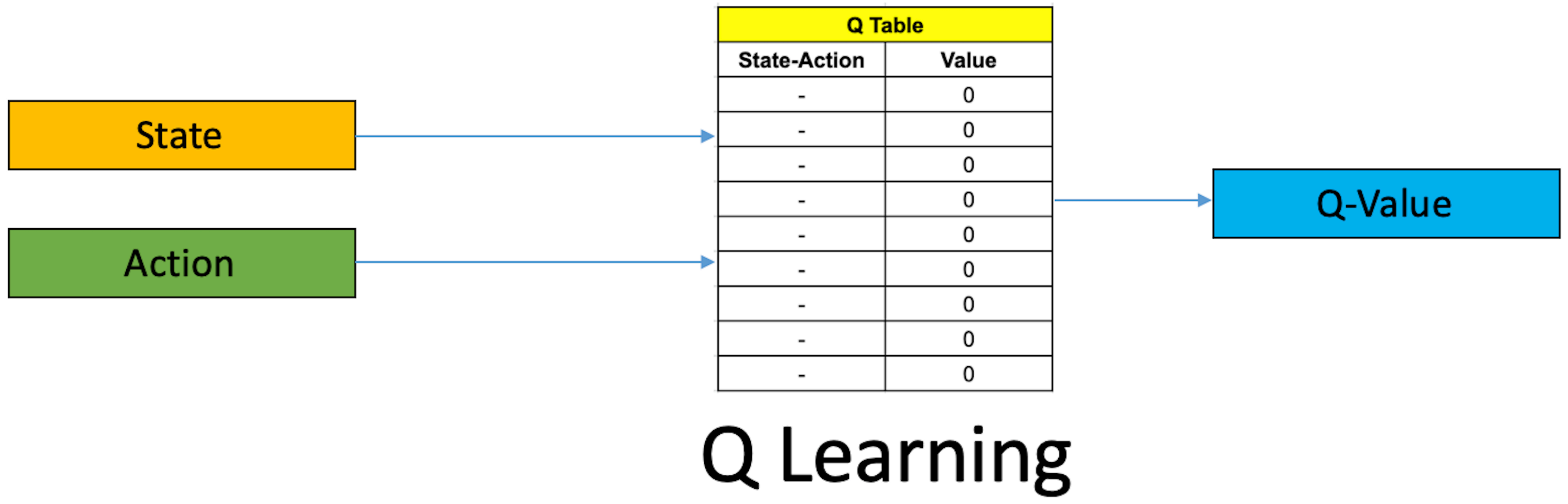
- Microgrid formulated as **Markov Decision Process** (MDP)
  - Defined by a 4-tuple: (S, A, P, R)
    - **S**: finite set of states
    - **A**: finite set of actions
    - **P**: transition function
    - **R**: reward function



- MDP goal: compute optimal *policy* π^* *that maximizes the expected sum of rewards*

Technical Scope: Solution

- Transition function (P) requires well knowledge of the system states which are composed
- **Q-Learning**: model-free reinforcement learning algorithm to learn the value of an action in a particular state
- New state at time-slot t (triplet): $S(t) = (D(t), SE(t), P_u(t))$
  - $D(t) = L(t) - G(t)$ net demand
    - $L(t)$ demand load at time t
    - $G(t)$ produced energy at time t
  - $SE(t)$ stored energy in the battery at time t
  - $P_u(t)$ price of the utility energy at time t



Technical Scope: Solution

- **Actions:**
  - $D(t) \leq 0$
    - a_0 **:** use generated energy to fulfil the load and to charge the battery
  - $S(t) = \{D(t) > 0, SE(t), P_u(t)\}$
    - a_1 : feed the net demand D with only the utility energy
    - a_2 : use the battery to feed the net demand with utility energy if necessary
- **Reward:** instantaneous operational revenues r_t at time t. Three quantities:
  - Electricity generated locally by the PV panels
  - Net demand (difference between consumption and production)
  - Power balance within the microgrid

Technical Scope: Solution

- Core of the Q-Learning algorithm: **Q-value** function (quality of each action)

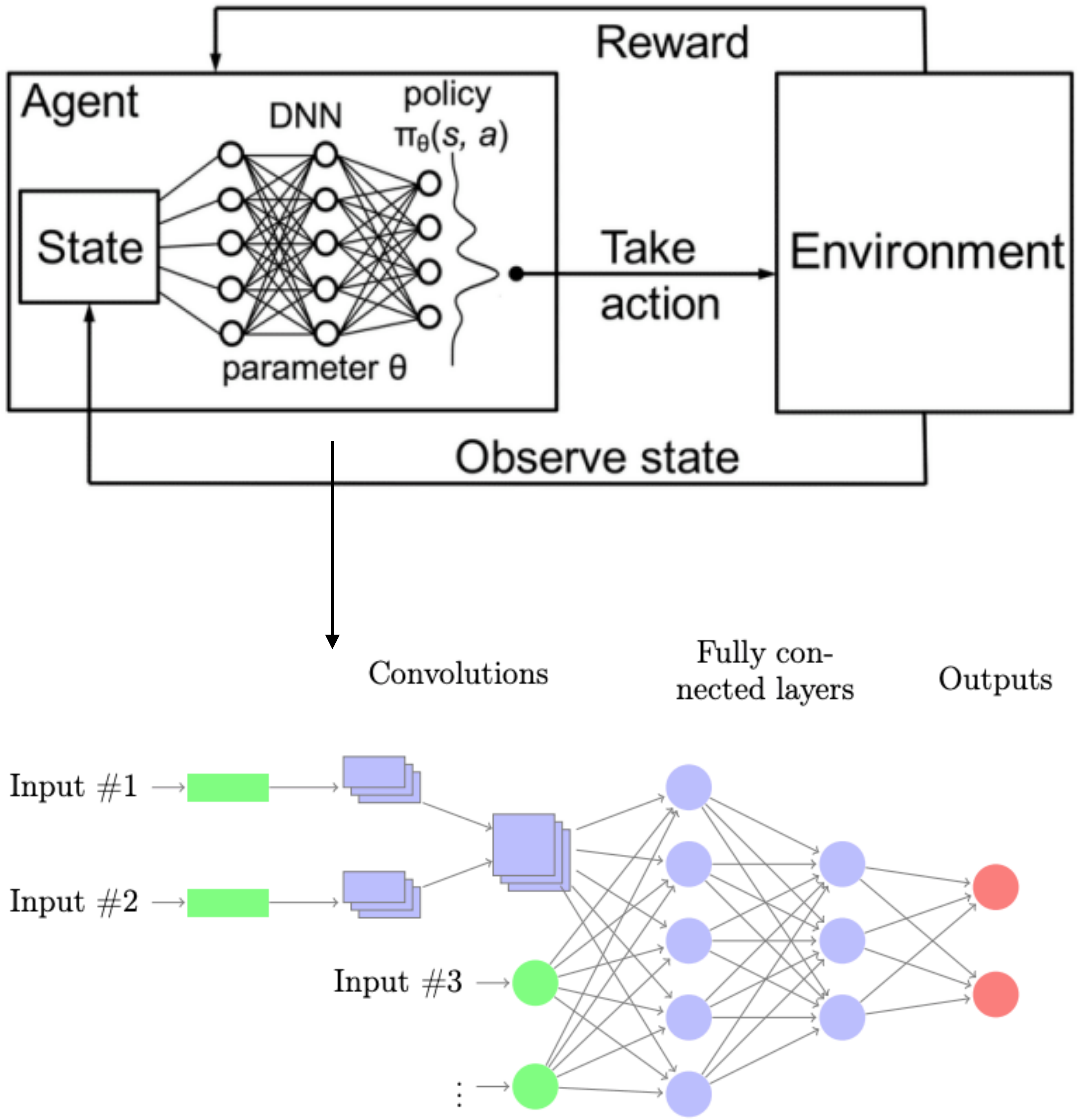
$$Q^{new}(s,a) \leftarrow (1-\alpha)Q(s,a) + \alpha[r + \gamma \max_{a'} Q(s',a')]$$

(Bellman equation)

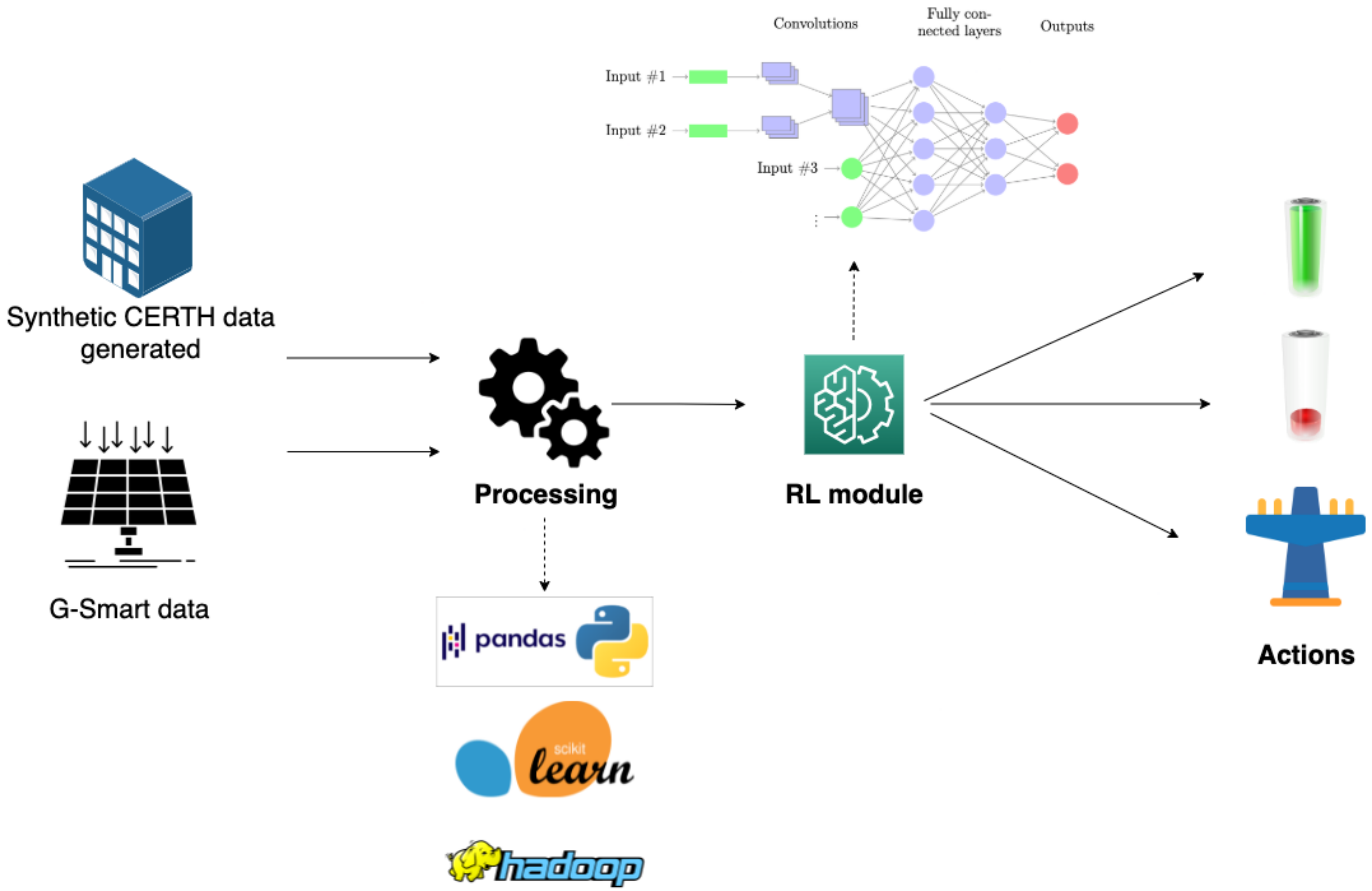
- $Q(s,a)$ sum of three factors:
  - $(1-\alpha)Q(s,a)$: current value weighted by the learning rate (α)
  - αr_t: the reward to obtain if action a is taken when in state s
  - $\alpha\gamma \max_{a'} Q(s',a')$: the maximum reward that can be obtained from state s' (weighted by discount factor $[0,1]$)

Technical Scope: Solution

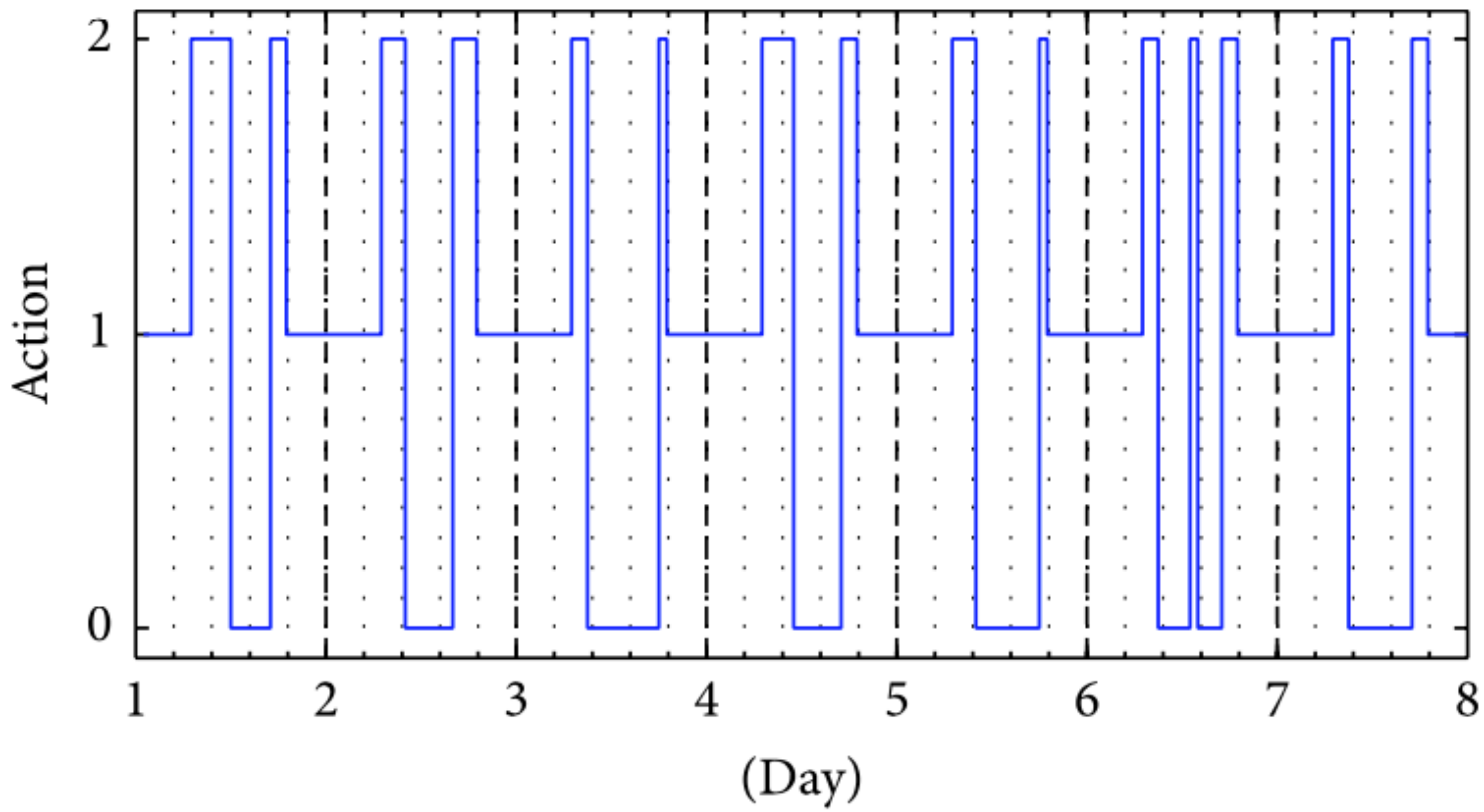
- To approximate Q^{new} we propose using a **Neural Network** (NN) (Francois-Lavet et al., 2016)
  - *Inputs*: state vector
  - *Output*: Q-values for each discretised action:
    1. Charge the battery
    2. Keep it idle
    3. Discharge the battery

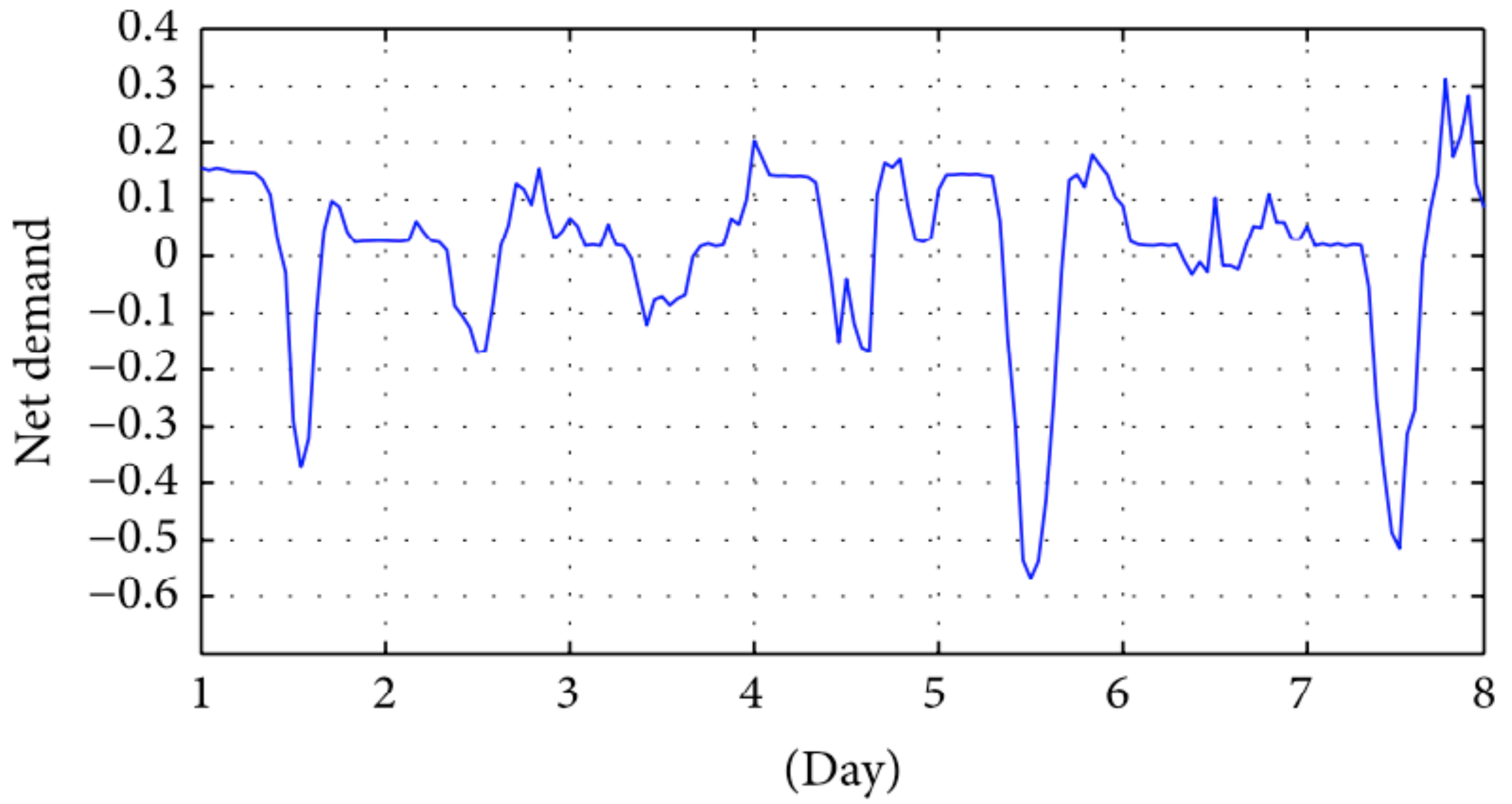


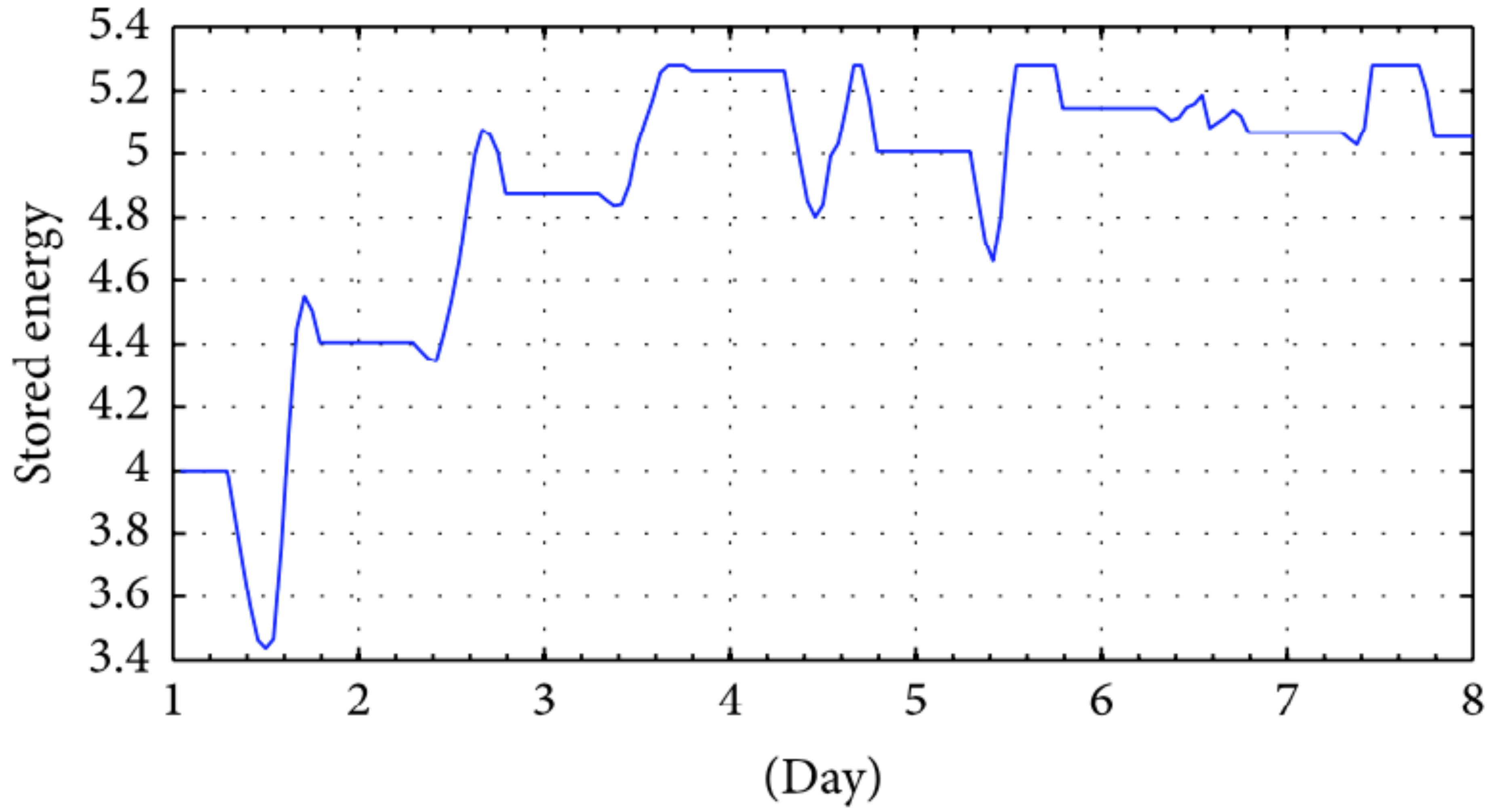
Technical Scope: Solution



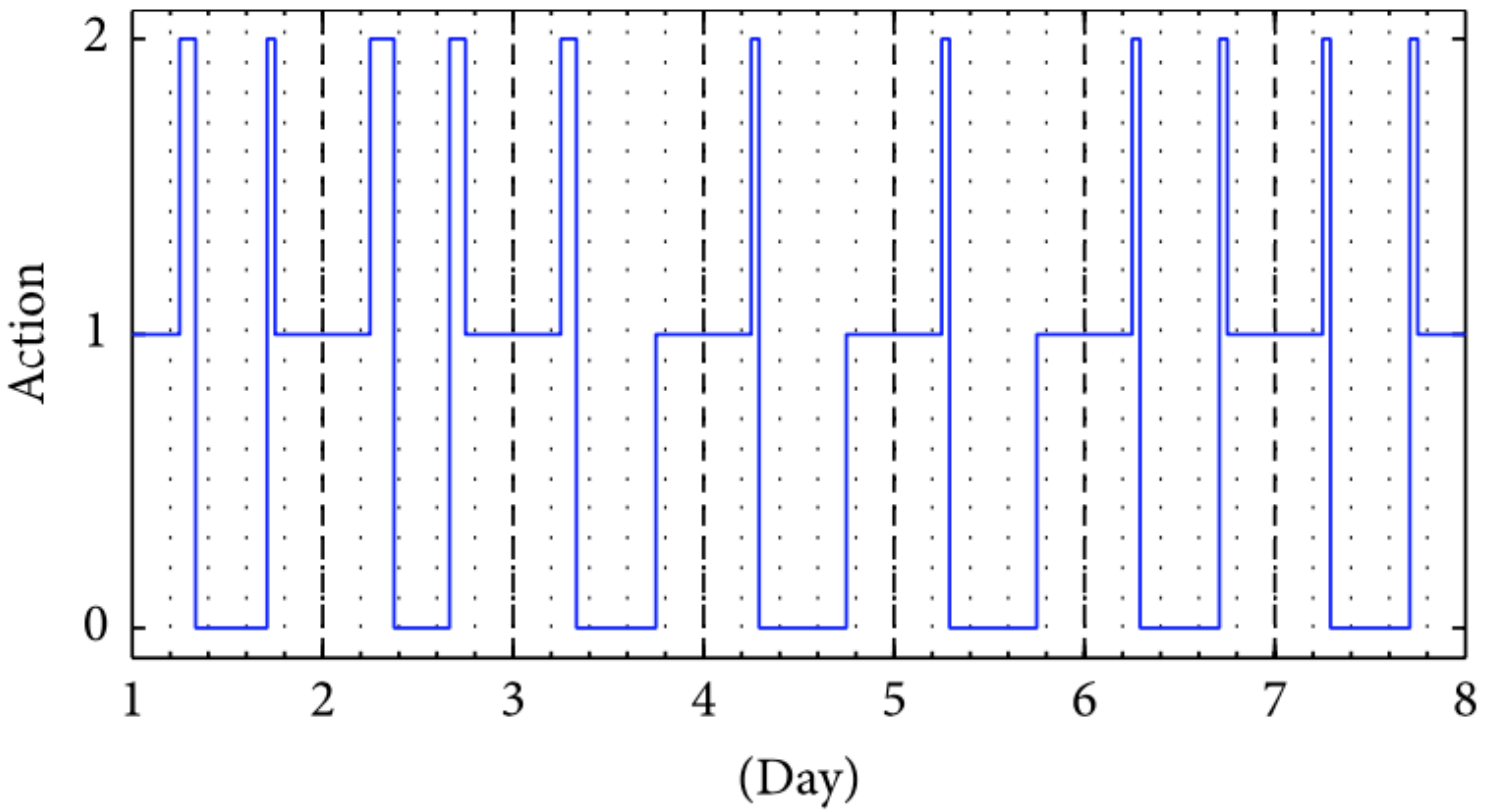
Results: winter week

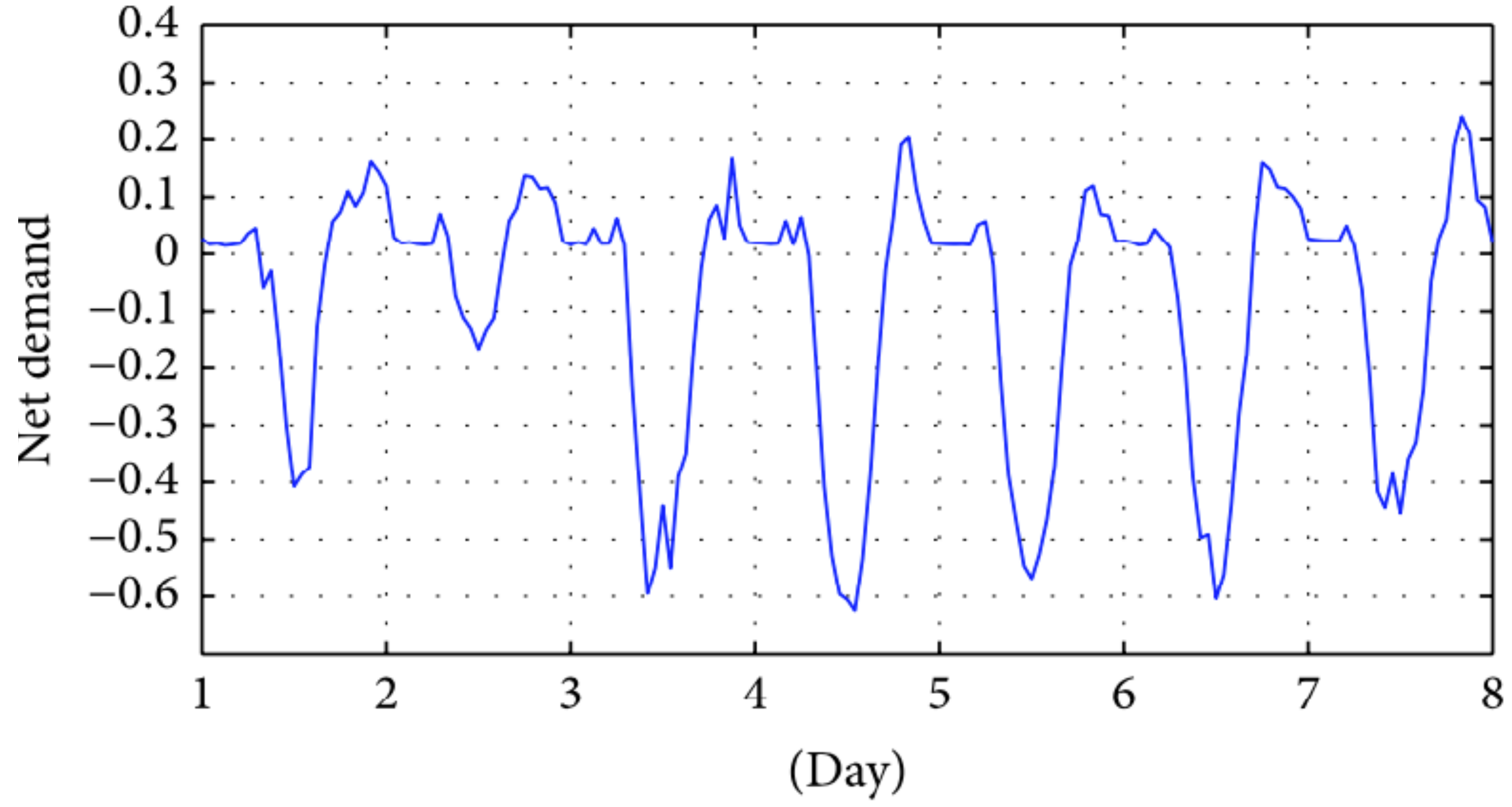


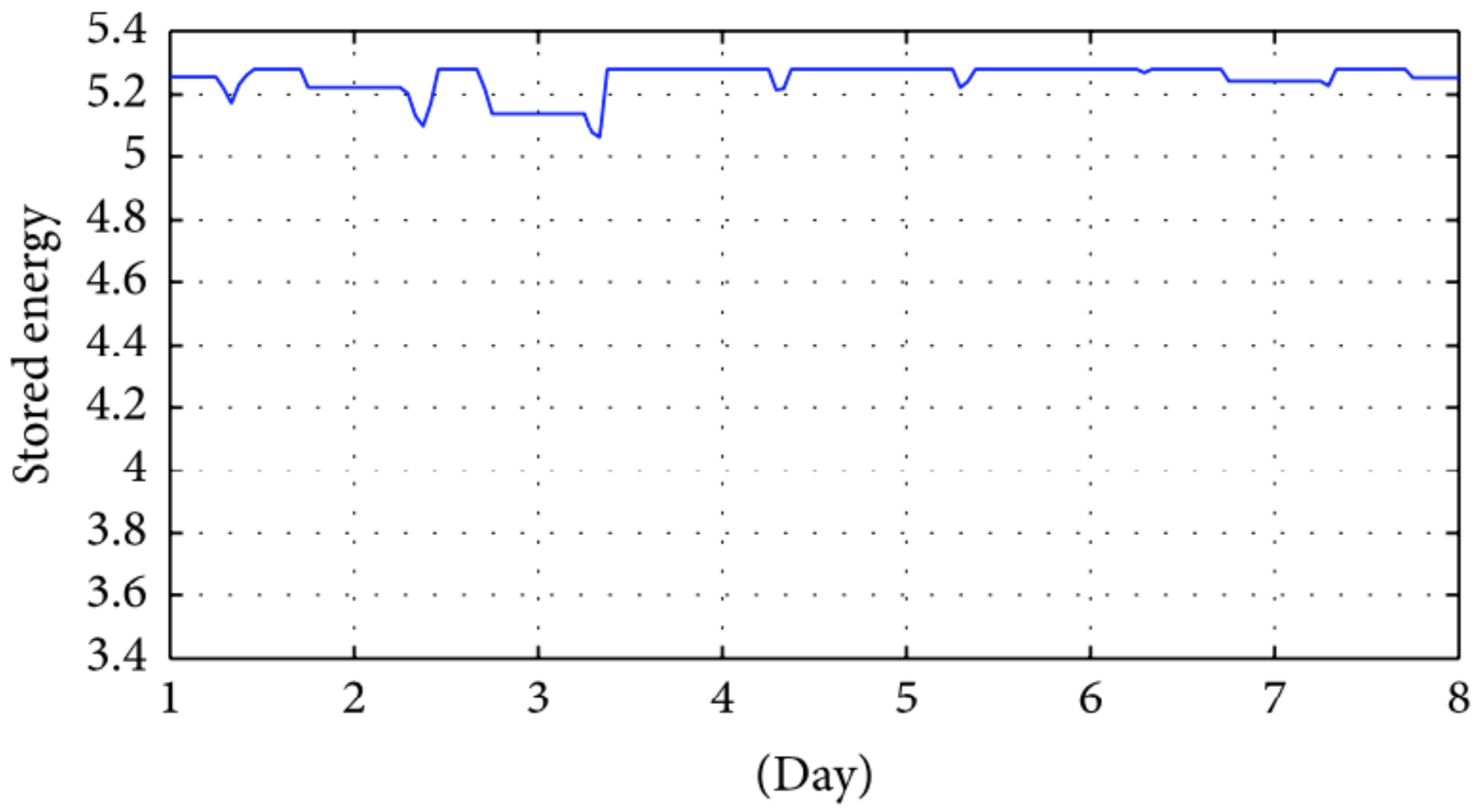




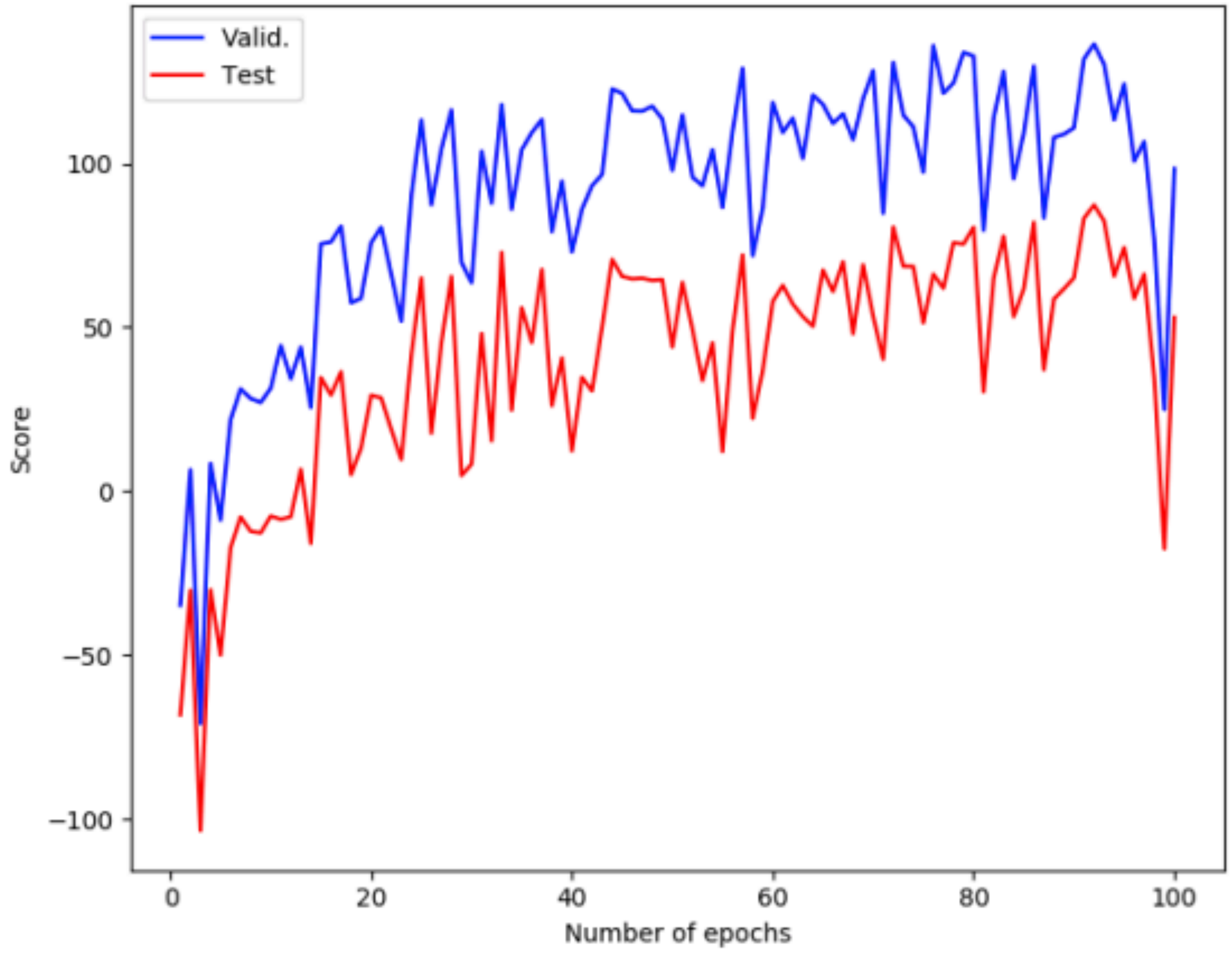
Results: summer week





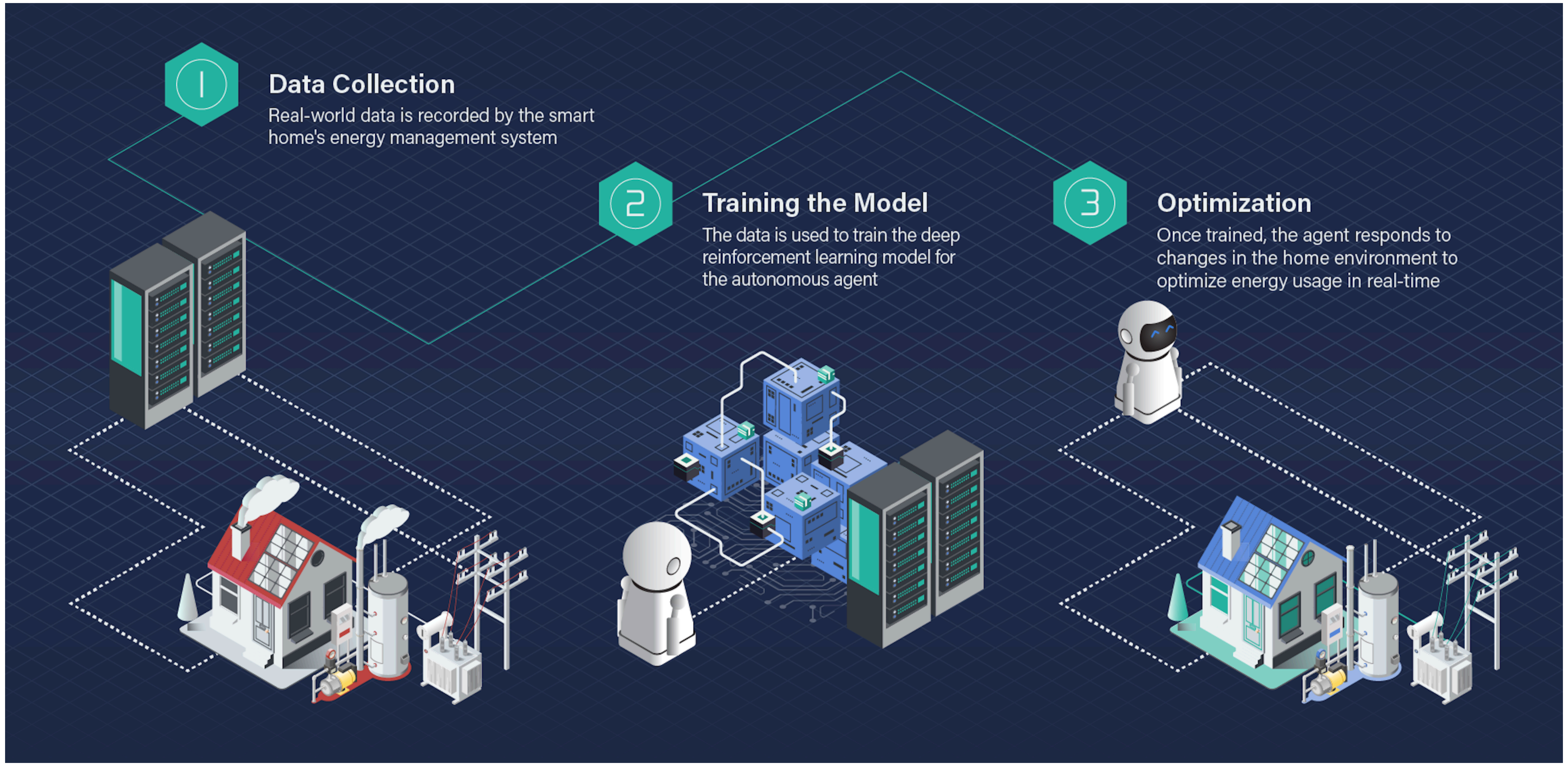


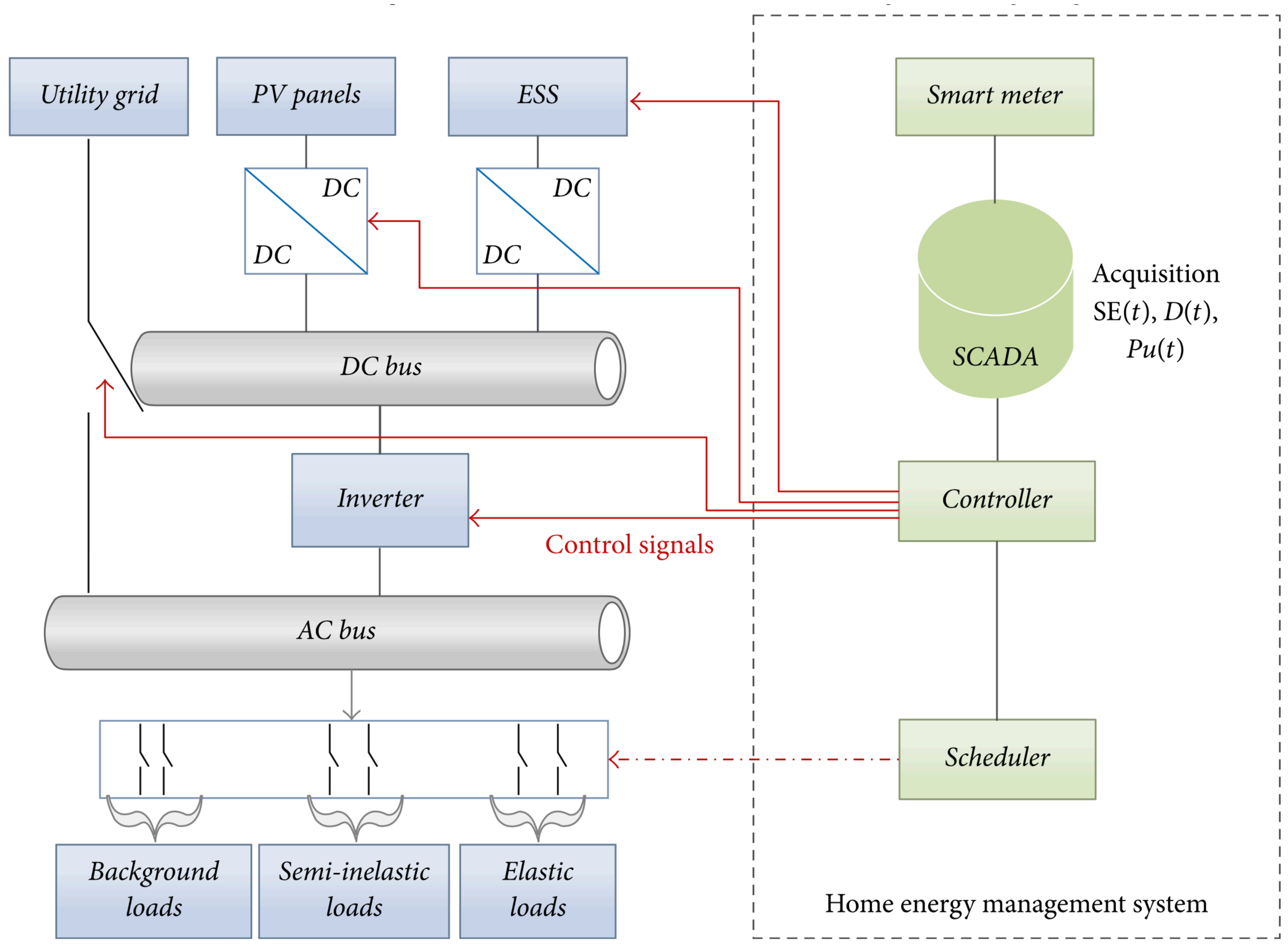
Results: Operational Revenue



Operational Revenue on the test and validation data. Beste results obtained after 92 epochs, with validation score 136.46€/year. Test score is 87.34€/year

Example: Home Energy Agent





Scalability & Flexibility

Scalability:

- Horizontal Scalability (Kubernetes)
- Distributed Processing (Hadoop/Spark)

Flexibility

- Several outcomes
- Multiple environment (house, building, city)
  - BriX As a Service

Data Security and Legal Compliance

- Certified Identity Management solution (Keycloak)
- Public key validation on API gateway (Kong)
- Token-based security operation
- Transport Layer Security (TLS)
- Firewall
- Private Network
- GDPR compliance: personal data separation and encrypted storage

Quality assurance and Risk management

- Lack of data in microgrid context
  - Mitigation: real-world data (G-Smart)
- Microgrid relies on a complex stochastic structure
  - Risk: model is unknown
  - Mitigation: model-free (deep) Reinforcement Learning algorithm

- Best coding practices
  - State of the art software components, libraries, languages and testing techniques
  - Continuous automated delivery pipelines
  - Real-time monitoring system (Prometheus and Grafana)
  - Pull request approach with code reviews for the source code development

Future Developments

- Possibility to sell excess of energy
- Add seasonal infos
- Add predictions of future production

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