# *DESIGNING AN INTER-SECTORAL ENERGY STORAGE SYSTEM*

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## Overview

Interest in self-sustaining energy systems is precipitously gaining attention. With the increasing deployment of these energy systems, a clear need arises to include more flexibility options. One of the most promising flexibility options to realise this is through energy storage systems.

Energy storage devices increase flexibility of an energy system by decreasing imbalances in electrical supply and demand. There is a large range of energy storage technologies, each having their own characteristics. These characteristics make them helpful to provide flexibility in different time scales. While some fast reacting energy storage devices, such as flywheels, are considered to have a large power efficiency, others, such as pumped hydro storage devices, have a large energy efficiency. Since each energy application demands a certain level of energy and power efficiency, combining technologies typically outperforms any stand-alone technology and hence is preferable.

While typical hybrid storage systems exploit the diversity of storage technologies in energy and power efficiency, sector coupling uses the differences of energy profiles across multiple energy sectors. In this study, we explore inter-sectoral storage devices, which combine the role of energy storage and inter-sectoral impacts (here, heat and electricity). Surplus energy in one sector can serve as energy demand in another. For example, electricity demand is typically low at night while hot water demand in the same time interval can increase by appliances such as dishwashers.

Inter-sectoral energy storage systems use both of the above flexibilities and have been shown to provide highly interesting potential (e.g. Beck et al., 2017). Although some recent studies have been exploring the design and operation of hybrid electrical storage devices (e.g., Ghiassi-Farrokhfal et al., 2016), there is still paucity of research in designing inter-sectoral storage devices. This paper attempts to find the optimal operating strategy and configuration for inter-sectoral storage devices.

## Methods

A simulation scenario is used based on real-world data from Pecan Street Inc. Dataport1 to analyse this question. Pecan Sreet Inc. is the largest research database in the world of customer water and disaggregated electricity insights. The data used for this study comprises the electrical power consumption (in kW), electrical power generation (in kW), and hot water consumption (in gallons) of one particular single-family residential dwelling between 1 January 2017 00:00:00h and 31 December 2017 18:00:00h located in Austin, Texas and is collected on a fifteen-minute basis. The household generated 39,725 kWh and consumed 18,744 kWh, was modelled to have 28 kW of installed solar PV panels and the heat storage and battery are both modelled to have a capacity of 200 kWh. Weather data from the same source is used as a proxy for cold water temperature to determine hot water electricity requirements, which was the heat source considered. The desired hot water temperature was set to 40°C.

We consider two scenarios in the configuration. In Scenario I (Figure 1a) the heat-pump is the primary storage and the battery serves as the backup storage and in Scenario II (Figure 1b) the reverse is true. To be more precise, the energy follow in these two scenarios is as follows; in both scenarios, heat demand (*Dh,t*) and electricity demand (*De,t*) attimeslot*t*arefirstmetdirectlybythesolarPVpanelgenerationwithoutput*Se,t* (1).InScenarioI(Figure1a),losses or surpluses resulting from this initial step are tried to be resolved first by heat storage with a state of charge at timeslot *t* *Bh,t* (2) and then by a battery with a state of charge *Be,t* at timeslot *t* (3). In Scenario II (Figure 1b), losses or surpluses resulting from the initial step are tried to be solved first by a battery (*Be,t*, (2)) and then by heat storage (*Bh,t*, (3)).

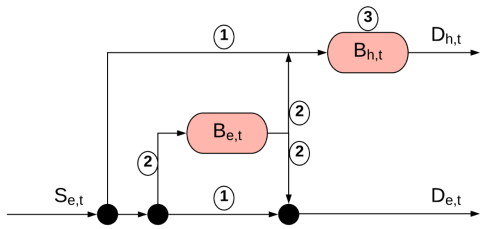


*Figure 1a Schematic overview of Scenario I.*

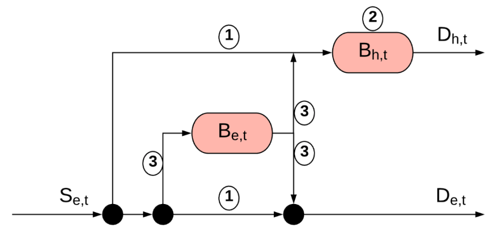


*Figure 1b Schematic overview Scenario of II.*

Storage devices' inefficiencies and technical parameters can be found in Table 1 (Beck et al., 2017; Ghiassi-Farrokhfal et al., 2015). In both scenarios, the capacity and type of the storage devices is fixed. Two reliability metrics are considered in this study. The ratio of times demand (either electrical or thermal) could not be satisfied is defined as the loss of load probability (LOLP). Furthermore, the amount of load that cannot be met as fraction of the total demand, defined as unmet load, is also considered.

*Table 1 Inefficiency values for storage devices.*

| **Storage device** | **Capacity *B* (kWh)** | **Charging efficiency $\eta_c$** | **Discharging efficiency $\eta_d$** | **24h self-discharge $\gamma$** | **Min. state of charge $SOC_{min}$** | **Max. state of charge $SOC_{max}$** | **Charging rate limit $\alpha_c$ (kWh)** | **Discharging rate limit $\alpha_d$ (kWh)** |
|---|---|---|---|---|---|---|---|---|
| Li-ion battery | 200 | .95 | .95 | 1.0 | 0 | .80 | B/180 | $5\bullet\alpha_c$ |
| Hot water storage | 200 | 1.0 | 1.0 | .85 | .20 | 1.0 | »1 | »1 |

## Results

The results can be found in Table 2. Analysis of LOLP and unmet load shows that that both LOLP and unmet load in the Scenario II are lower than in Scenario I. This observation shows that the choice of configuration substantially affects the performance of the inter-sectoral energy system. Moreover, the best configuration of such an inter-sectoral energy storage is highly dependent on the object metric.

*Table 2 LOLP and unmet load for the different scenarios.*

| | **LOLP** | **Unmet load** |
|---|---|---|
| **Scenario I** | 0.073 | 0.040 |
| **Scenario II** | 0.013 | 0.004 |

## Conclusions

In conclusion, we took a first step towards determining an optimal operating strategy and configuration of inter-sectoral energy systems. We demonstrated that the operating strategy and configuration have large impact on the reliability of these systems. This materialised in the preference of hierarchically placing electrical storage higher than thermal storage. We further observed that optimal configuration and operation of inter-sectoral energy systems might vary based on the measurement metric. This provides valuable insights for designing inter-sectoral energy systems.

An important future research direction regards the inclusion of economic parameters to estimate the impact of costs on the optimal system. Besides, flexibility increases with the inclusion of multiple hence, a second important future research direction regards the expansion of the results for a micro-grid or an energy co-operative.

## References


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