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Swarm demand response

Virtual storage by small consumers

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Motivation

- **Electricity systems with large share of intermittent renewables need flexibility**
- May be provided by generation, or storage, or demand response (**DR**)
- DR in the **industrial sector** useful but potential is not unlimited
- Swarm DR (sDR) based on shifting small loads in the **residential sector**,
  - by only a **tiny interval of minutes,**
  - smartly **coordinated**,
  - **delegated** or **automated**

could have significant potential to augment it

What is the potential of sDR on the electricity system level?

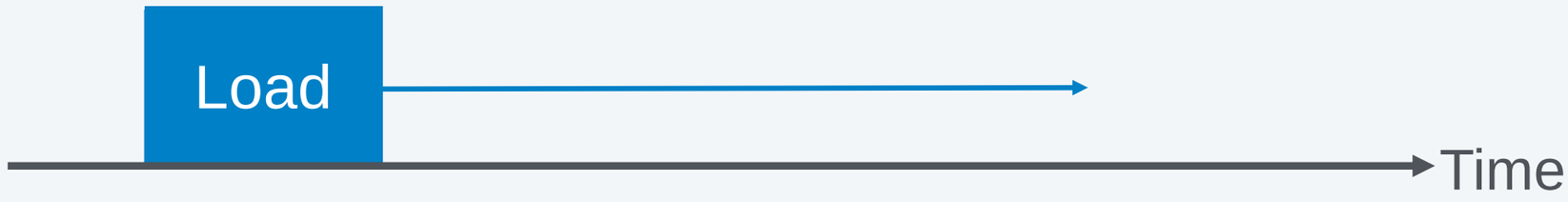
Swarm demand response: virtual storage by small consumers

To answer this question:

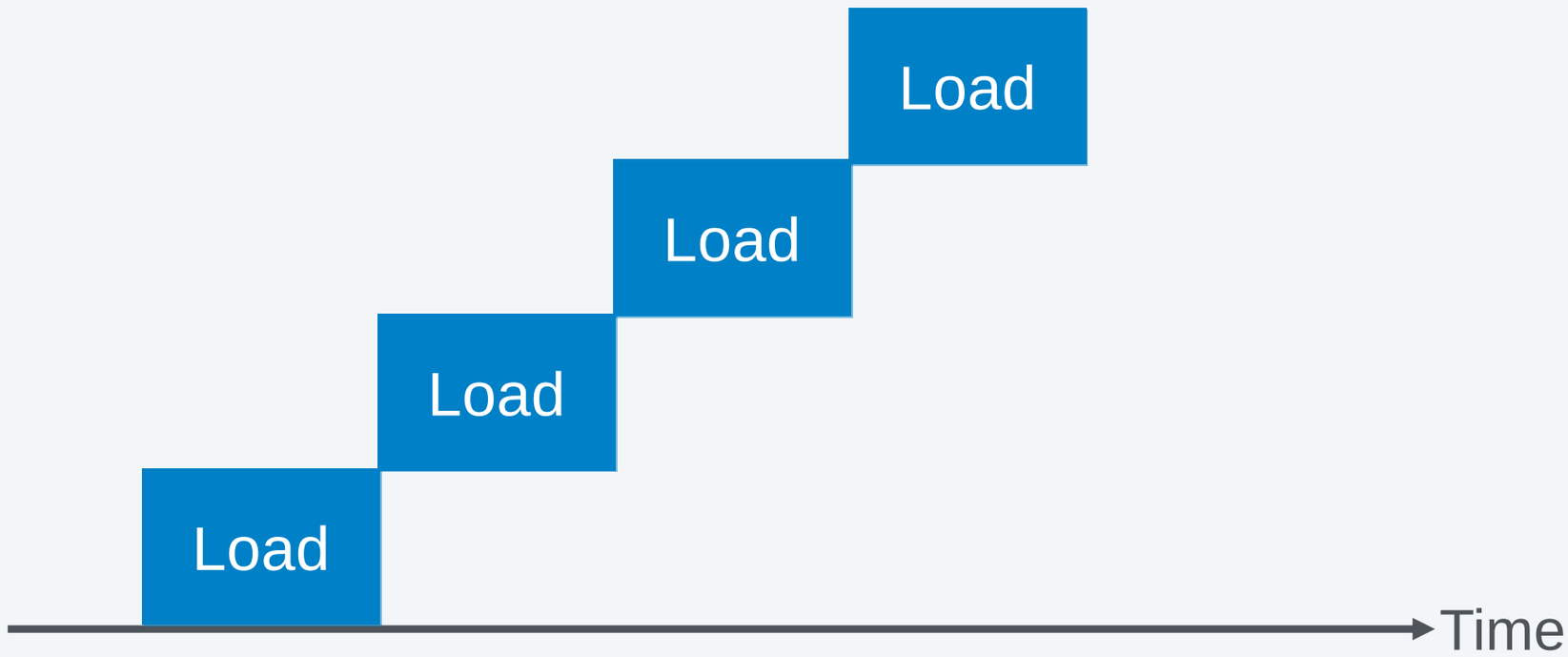
1. **What is sDR? (frequently shifting small loads for short periods in a way that may be costless for the user)**
2. **How much potential is there?**
   a) What loads can be shifted?
   b) How many consumers would participate?
   c) How much conventional storage is this equivalent to?
3. **Conclusion**

1. What is sDR? – load shifting

Traditional DR: Shifting a single load (e.g. industrial process) by several hours



Swarm DR: Shifting a series of small loads by a couple of minutes each



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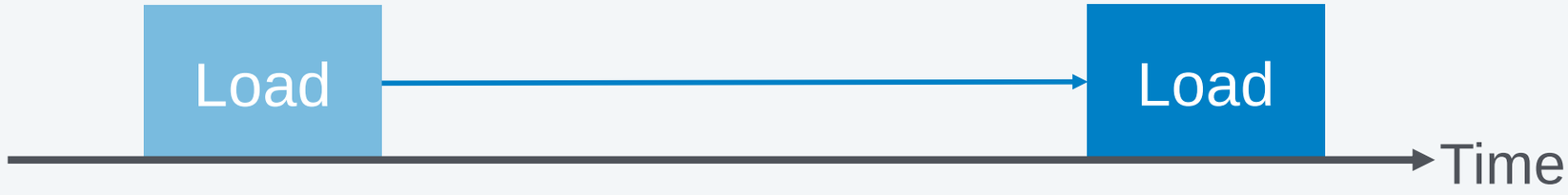

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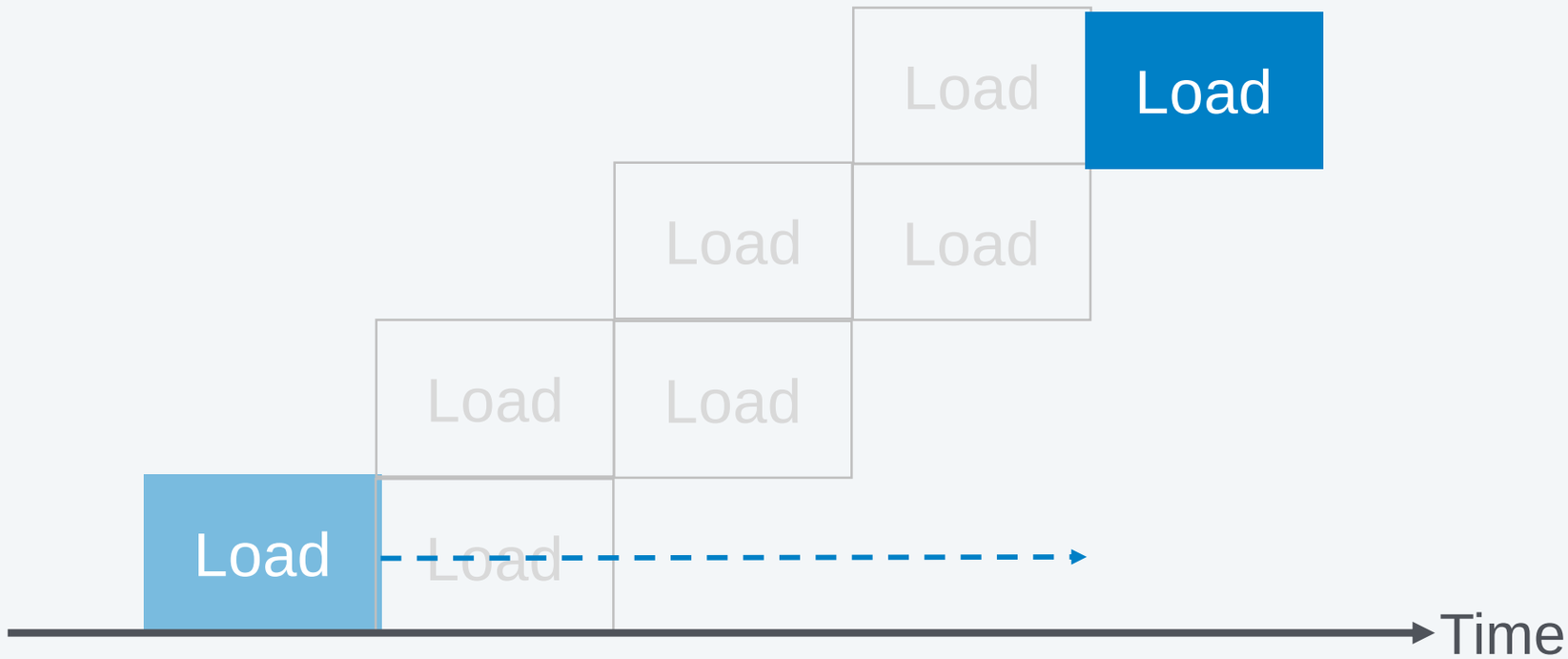
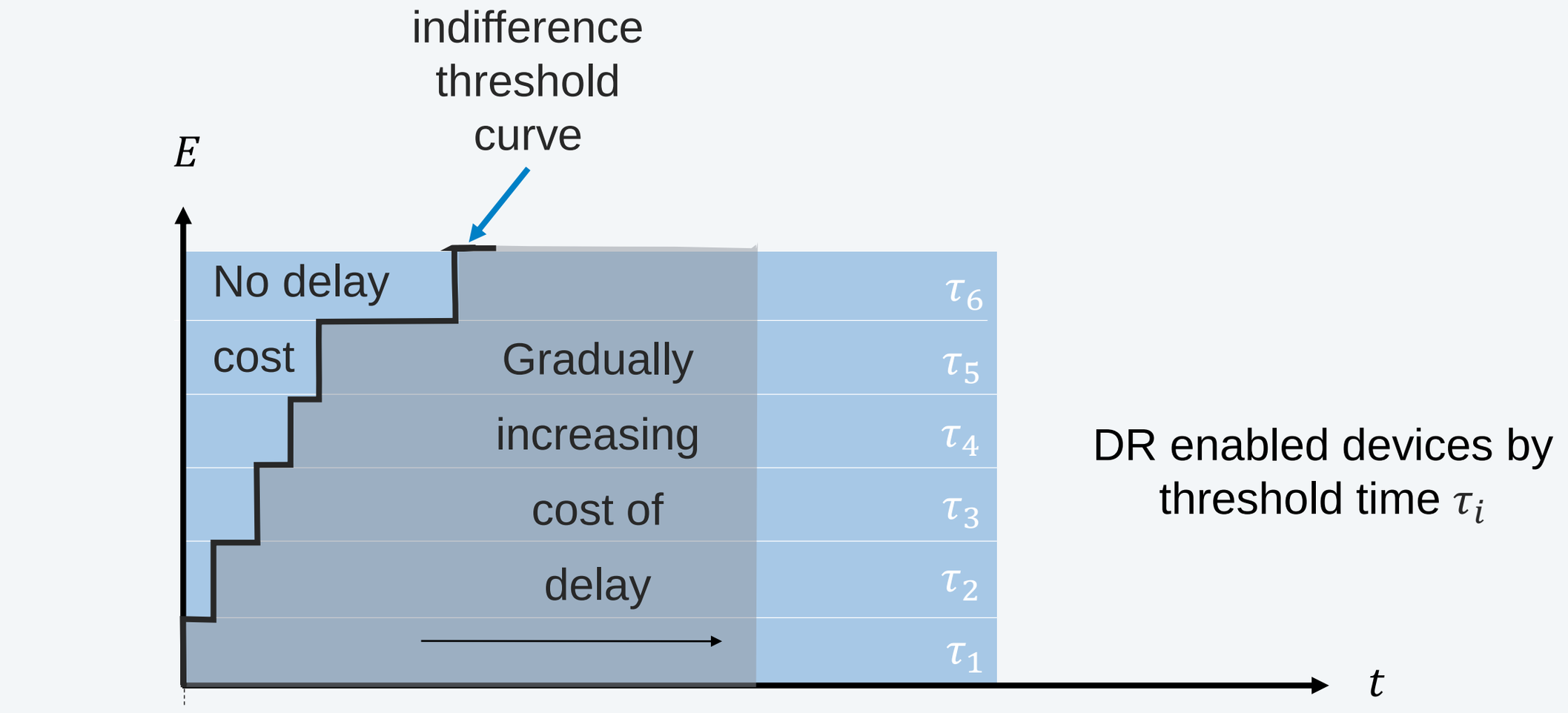


→ By shifting a series of loads also „long term“ storage possible

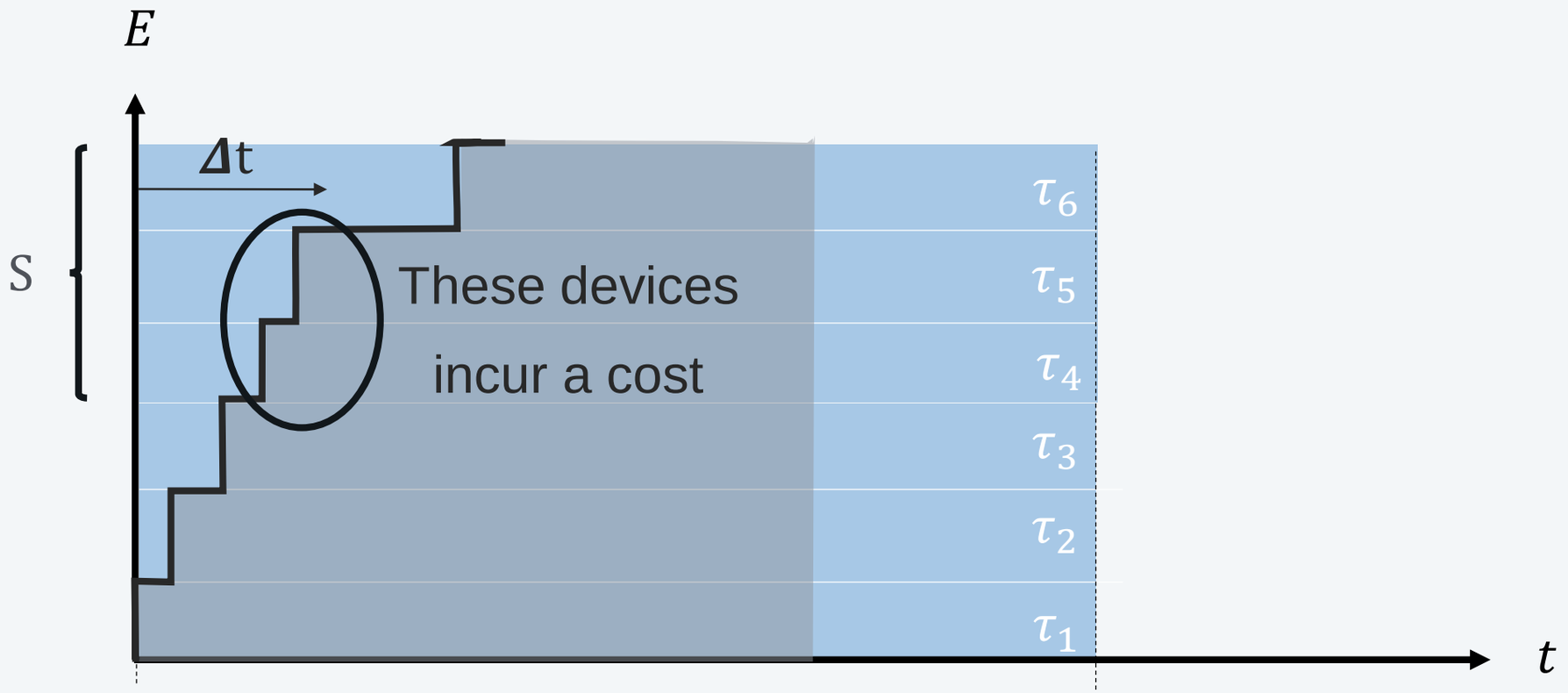
1. What is sDR? – costless load shifting

- devices with shifting indifference (threshold) time
- Cost = inconvenience

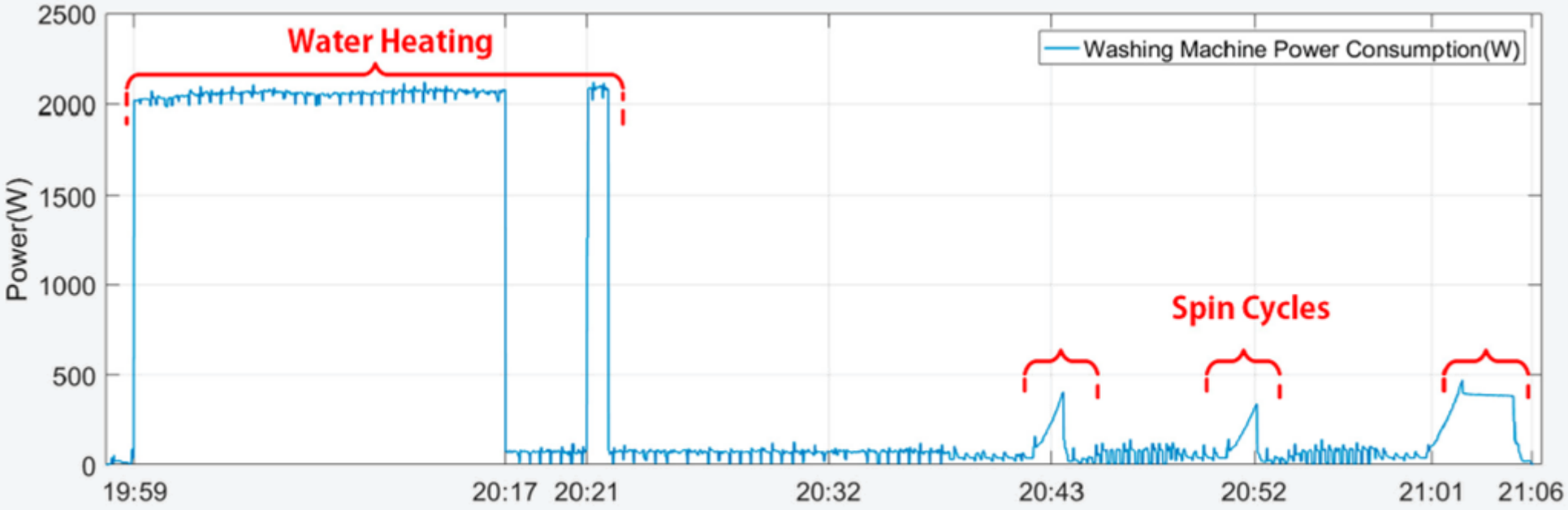


1. What is sDR? – costless load shifting

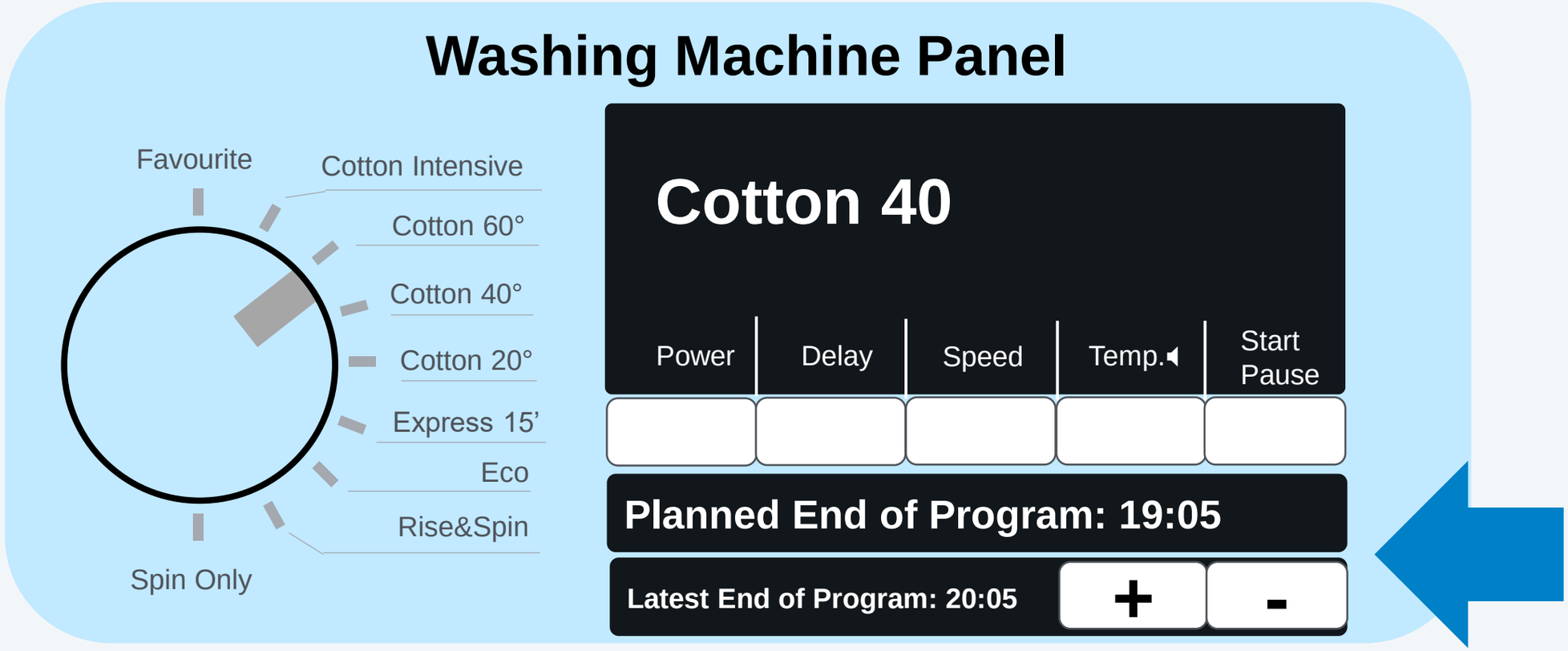
- shifting devices 4, 5 and 6 by Δt
- device 6 does not incur a cost
- We are only interested in **costlessly shiftable devices**



1. What is sDR? - Example: washing machine

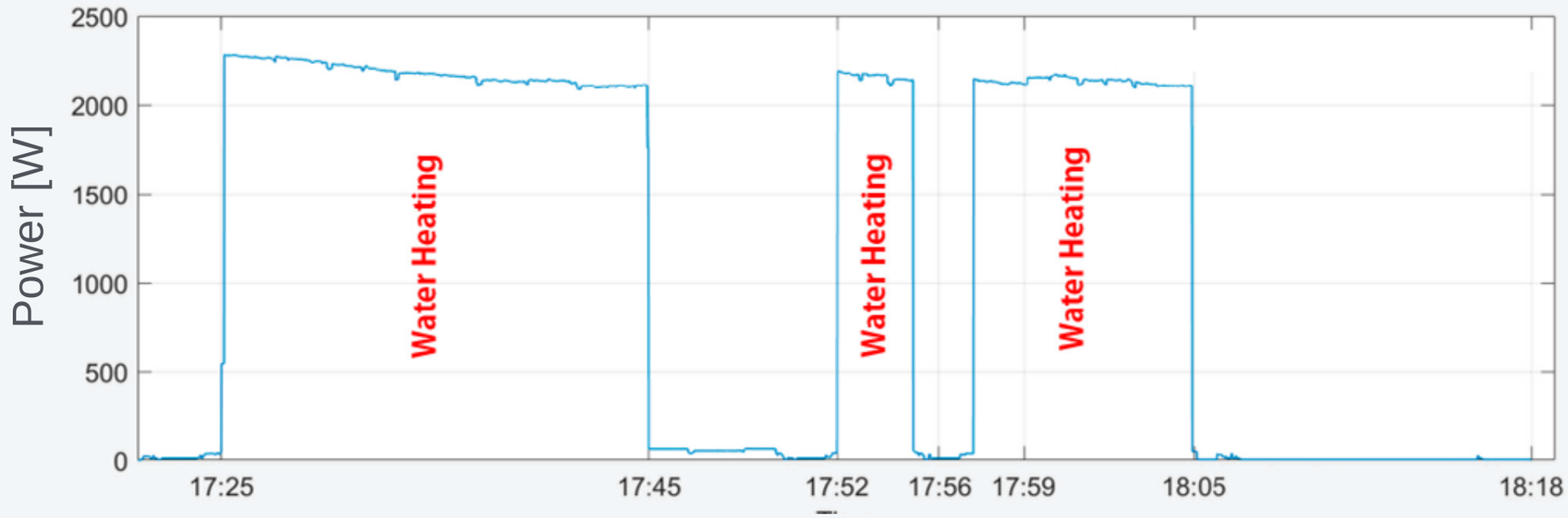


Source: F. Issi and O. Kaplan, 2018:"The Determination of Load Profiles and Power Consumptions of Home Appliances", Energies 2018, 11, 607.



1. What is sDR? - Examples

Dishwasher



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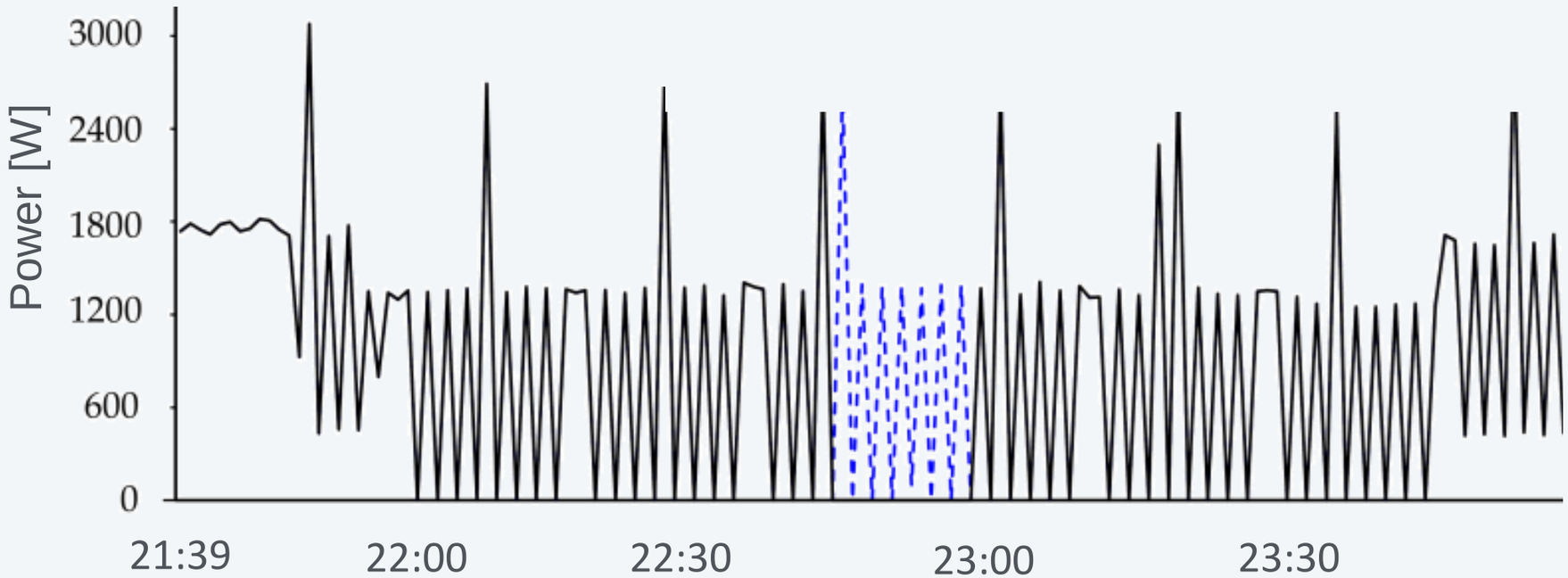
Electrical heater



Source: S. Bissey, S. Jacques, and J.-C. Le Bunetel, 2017: "The Fuzzy Logic Method to Efficiently Optimize Electricity Consumption in Individual Housing", Energies, 10, 1701

2. How much potential is there? What loads can be shifted?

Participation rate: Appliances, example household

Device	Duration	Usage Density	Monthly Cons. [Wh]
Refrigerator	24 h	All time	23.5
Washing machine	4x1 h	1 per week	8.0
Dishwasher	3 h	8 per month	7.4
Oven	50 min	4 per week	16.4
Iron	38 min	1 per week	1.9
Hair dryer	43 min	1 per week	5.0
Kettle	1 min 53 sec	9 per week	6.8
Range hood	34 min	8 per week	1.1
Toast	13 min	14 per month	2.9
Printer	7 min 53 sec	16 per month	2.9
TV	4 h 17 min	22 per month	8.4
PC	2 h 14 min	everyday	14.9
Total			99.4

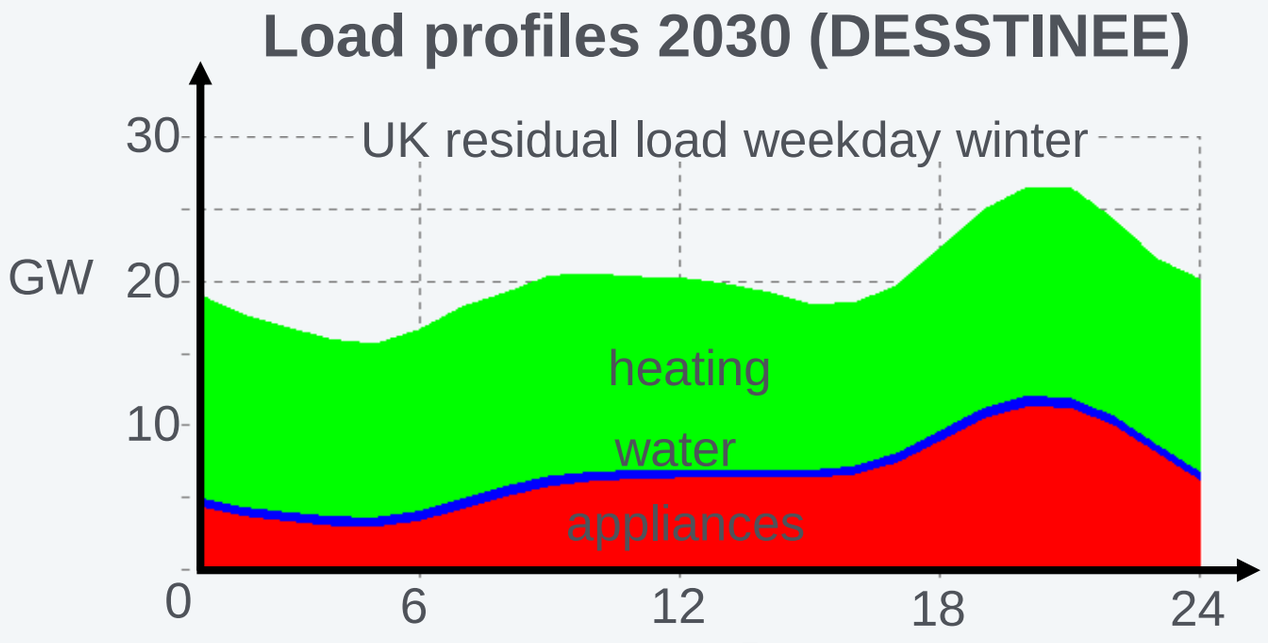
40%

Profiles and Power Consumptions of Home Appliances", Energies 2018, 11, 607.

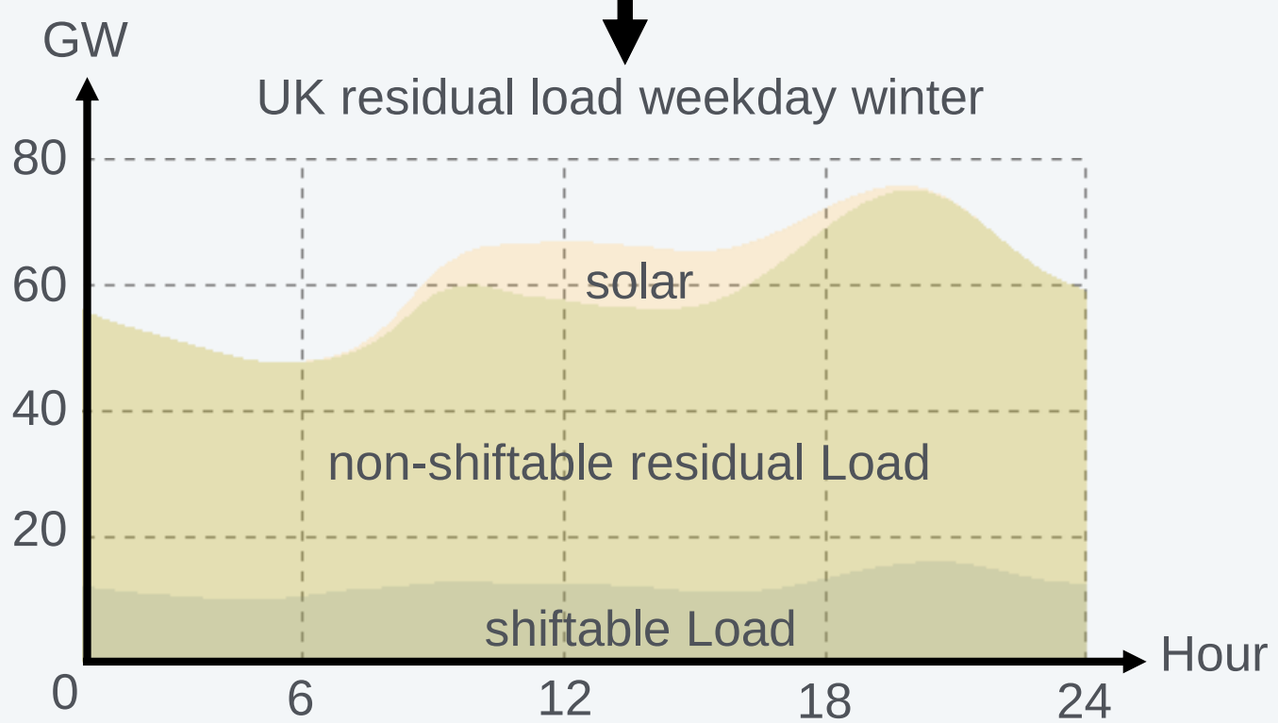
2. How much potential is there?

How many consumers would participate?

Shiftable load component	Participation rate
Appliance	40%
Water	0%
Heating	70%
Cooling	70%



Weighted sum → shiftable load



2. How much potential is there?

How much conventional storage is this equivalent to?

Shiftable load

↓

Optimization of DR Model

↓

Generation Profile

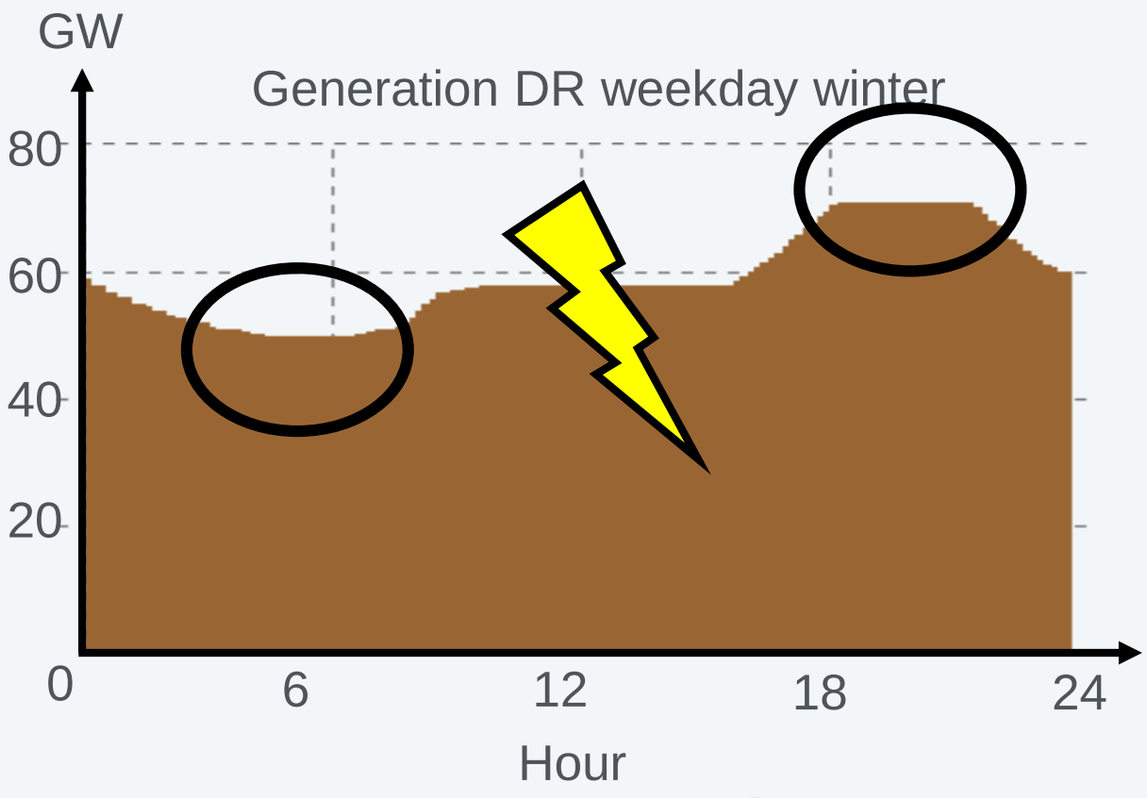
Storage Capacity = 12GWh

↓

Optimization of a storage Model

↓

Generation Profile



Storage Capacity > sDR potential → lower storage capacity

2. How much potential is there?

How much conventional storage is this equivalent to?

Shiftable load

↓

Optimization of DR Model

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Generation Profile

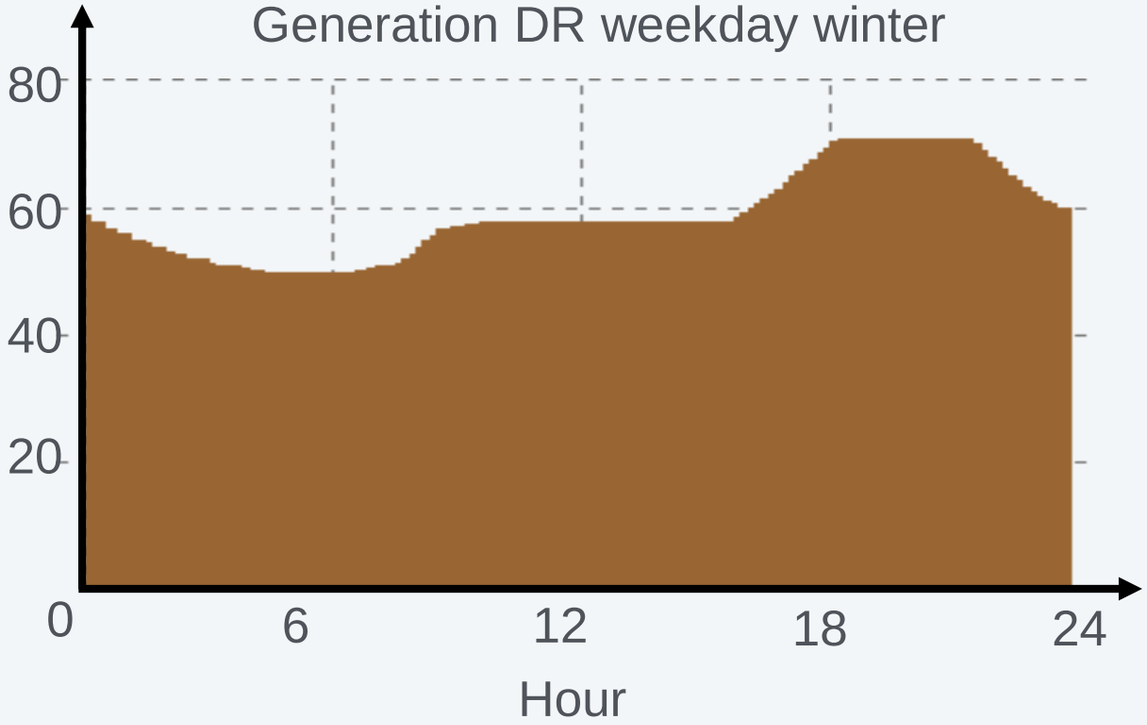
Storage Capacity = 9GWh

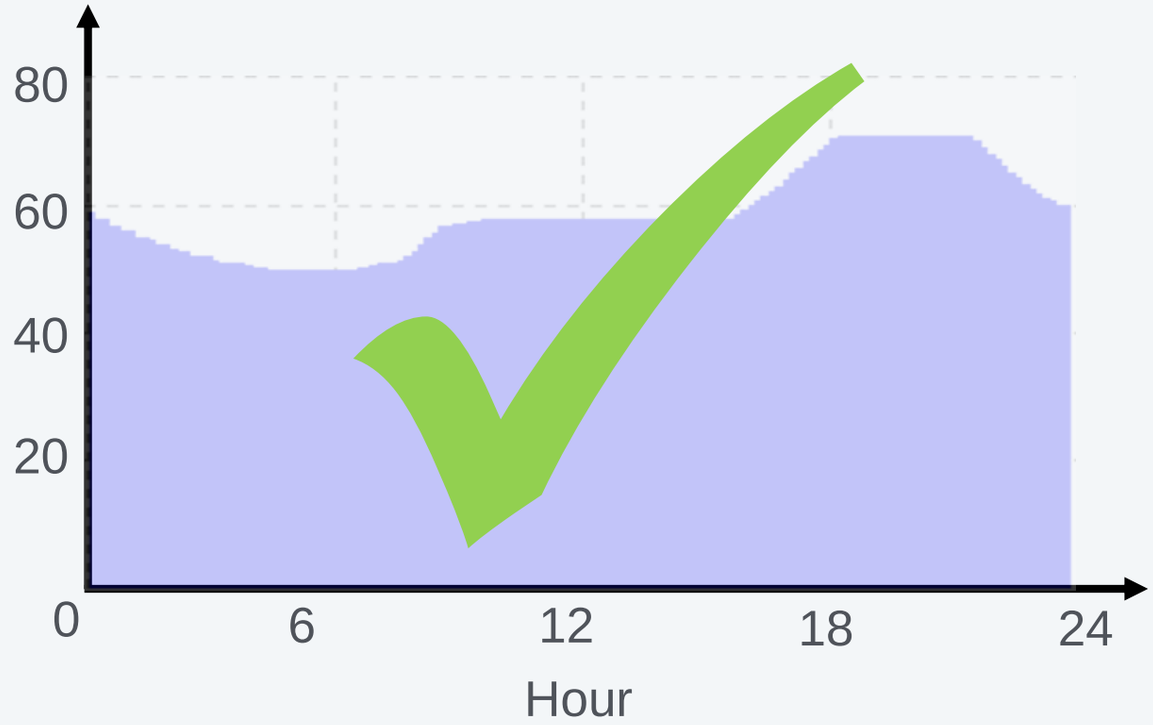
↓

Optimization of a storage Model

↓

Generation Profile





sDR equivalent to a conventional storage of 9 GWh during a winter day

3. Conclusion

1. Interpretation of DR in the residential sector (quantified model)
2. sDR ≈ conventional storage with variable capacity between 2 and 9 GWh.
3. sDR might replace expensive conventional storage or enable countries without a natural storage potential.
4. sDR enabled by communication technology could provide flexibility for the power system with high shares of renewables, but its reliability will need to be seen to be proved.
5. Prices ‘find’ successive shifters to smooth load shifting in a welfare enhancing way. No evidence of spikes!

→ **A swarm of imperceptible demand shifts directed by market signals behaves like a gigantic storage unit, unknown to participants.**


ANY
QUESTIONS
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