DC-based Open Energy System:
A Bottom-Up, Distributed Power System for Self-Sustaining Islands

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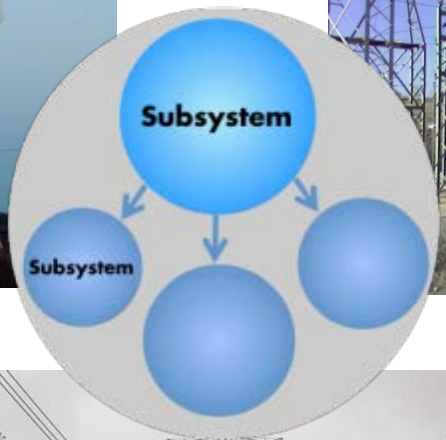
Our Fundamental Thought

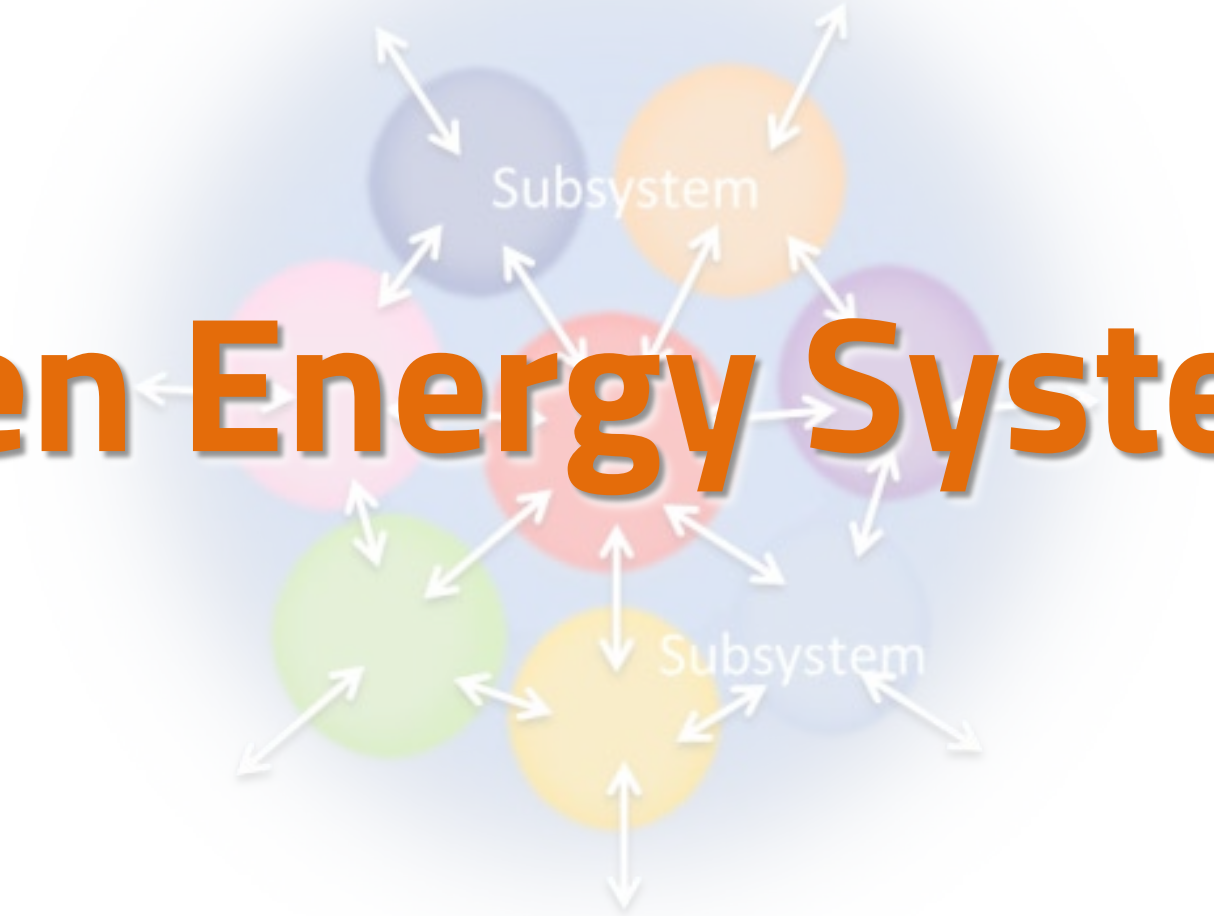
Sustainable	**Do not pass on liability to next generation**
Dependable	**Keep risk manageable**
Affordable	**Accessible to everyone on earth**

Conventional Power Systems

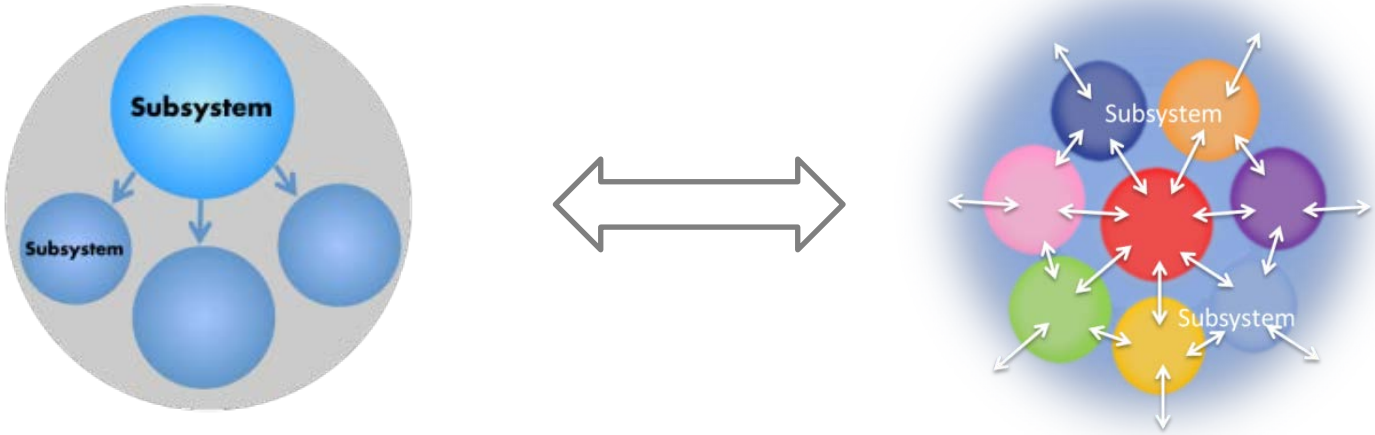


Our Approach

Sustainable	Renewable Energy Sources, which are Distributed, Intermittent, and Unstable, with Batteries
Dependable	Local Consumption of the Locally Produced by Self-Supporting as much, in the form of Bottom-Up, Autonomous, and Interconnected
Affordable	System can start Small yet Expandable in the form of Bottom-Up, Autonomous, and Interconnected



Open Energy Systems



Conventional systems

- *Centralized* energy source
- Transmission for *distant* consumption
- *Top-down* configuration with central control
- Flow based, *synchronous* load/supply balancing
- *Distribution* network

Open Energy Systems

- *Distributed* energy sources
- *Local* consumption of the *locally produced*
- *Bottom-up* and flexible configuration of distributed autonomous systems
- Stock based, *asynchronous* load/supply balancing
- *Exchange* network

How do we achieve OES?

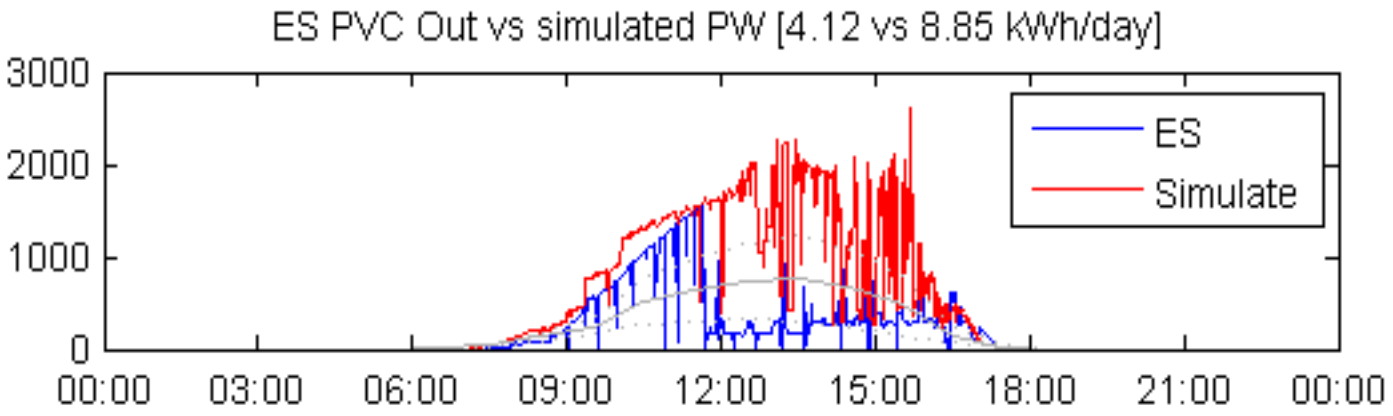
DCOES Technologies

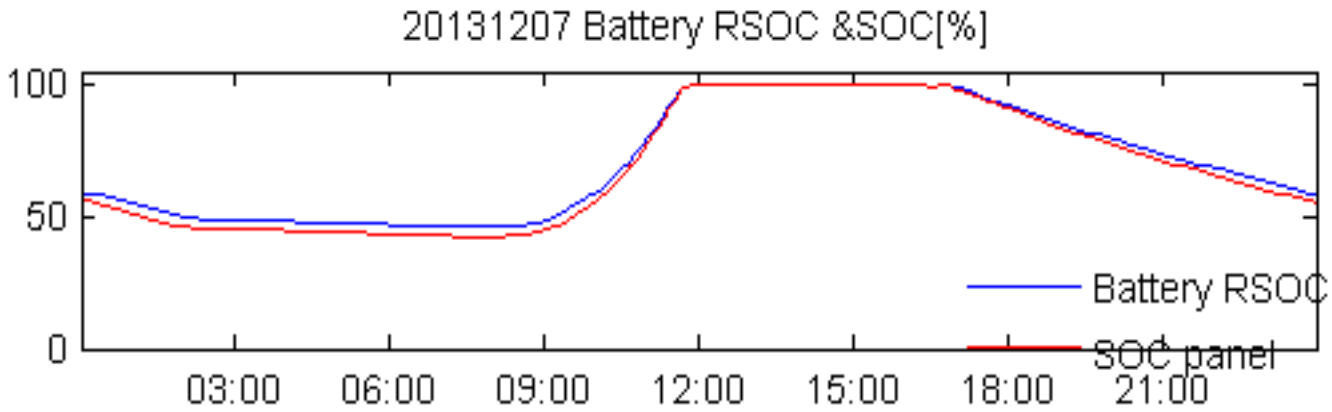
Renewable Energy Sources

Batteries / Energy Storage

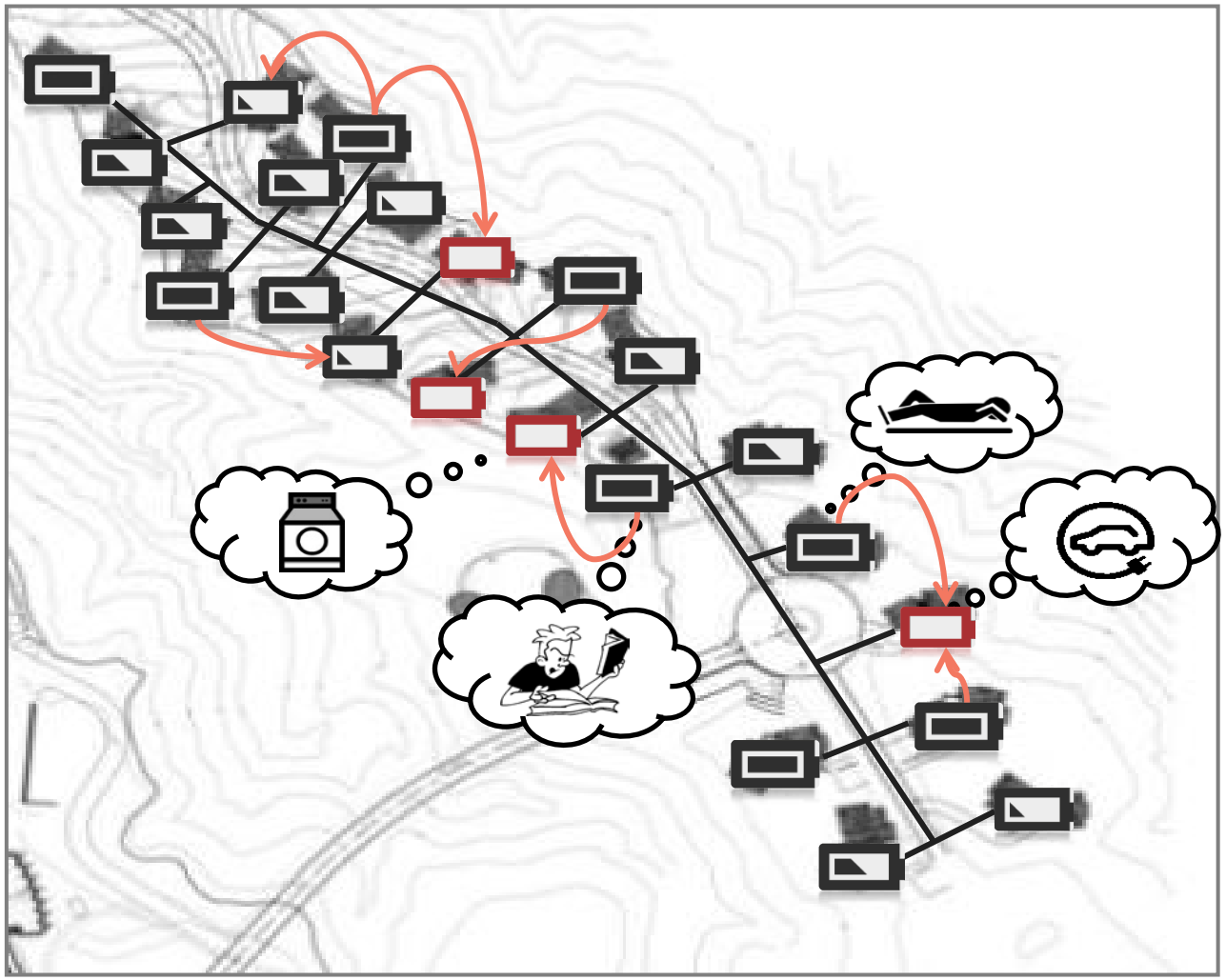
How to balance?

Batteries cannot take whole energy produced by PV





Variety in usage pattern



Energy Exchange Technology

Exchange energy among *batteries*
In the form of ***DC***

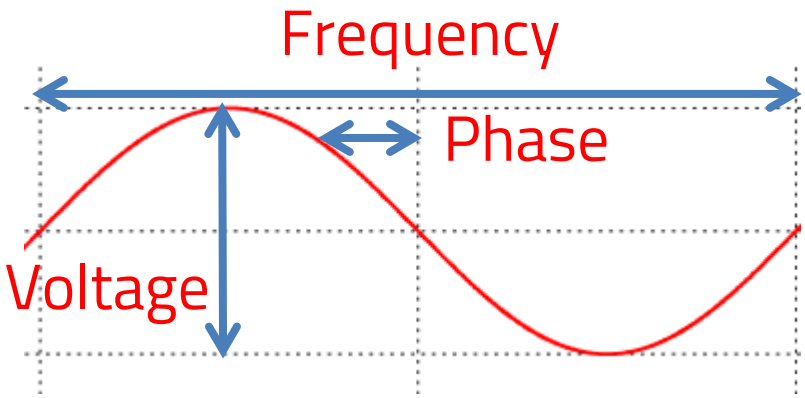
In order to ***maximize*** the use of PV panels and batteries

through complementing ***difference*** in usage patterns

AC

for transformers

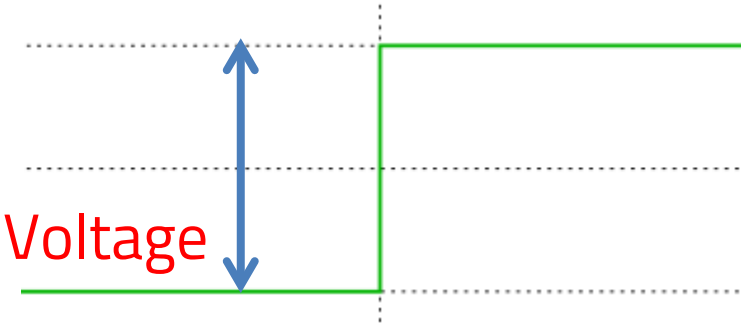
- Reactance loss of power is not negligible
- Interconnection of networks is difficult due to sync.



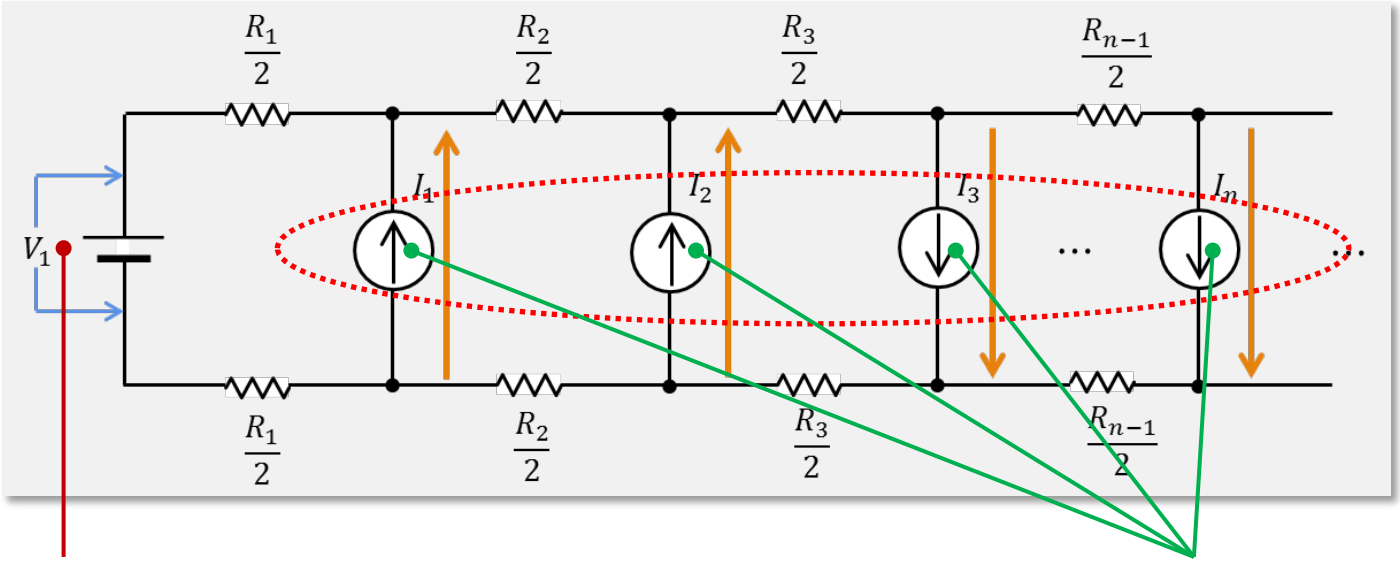
DC

for batteries

- Efficient DC/DC converters are now available
- Interconnection of networks is easy (no sync. is necessary)



Base Theory

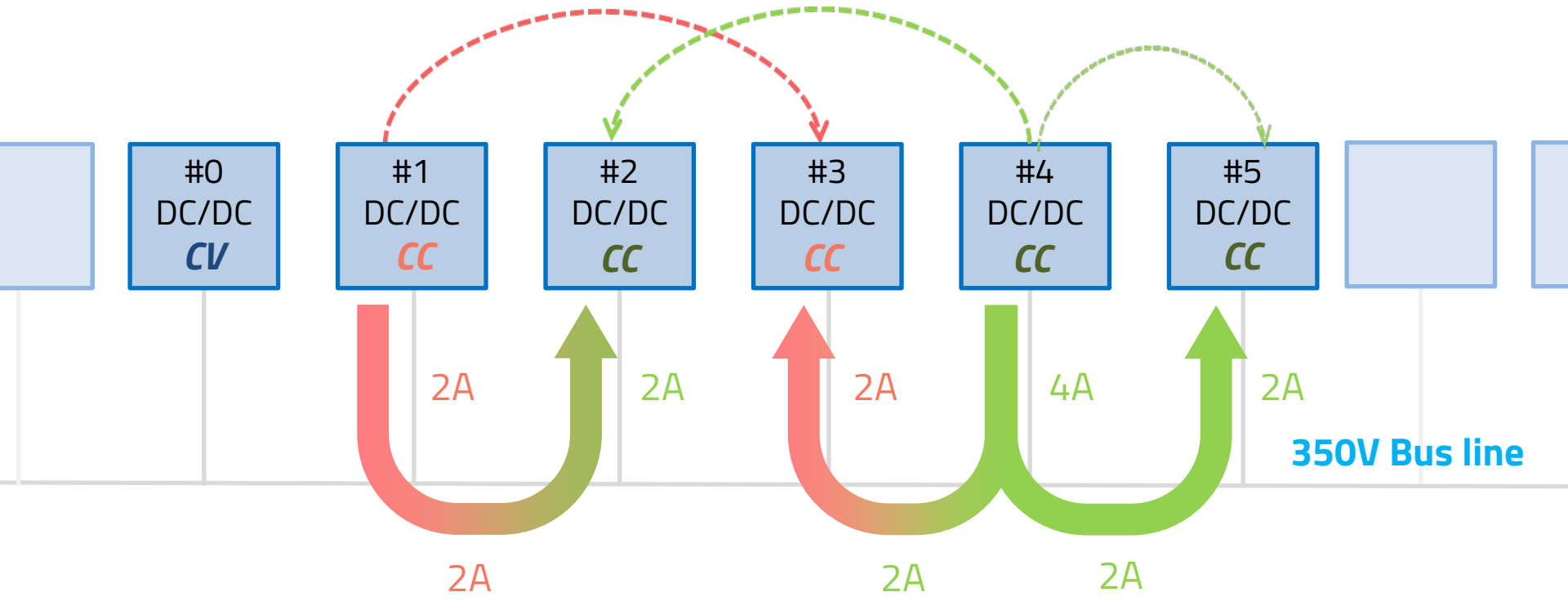


Constant Voltage Source keeps the grid voltage at 350V

Constant Current Sources set desired current

One Voltage Source and n Current Sources with *Durable* and *Flexible* Distributed Control

m-to-n Energy Exchange



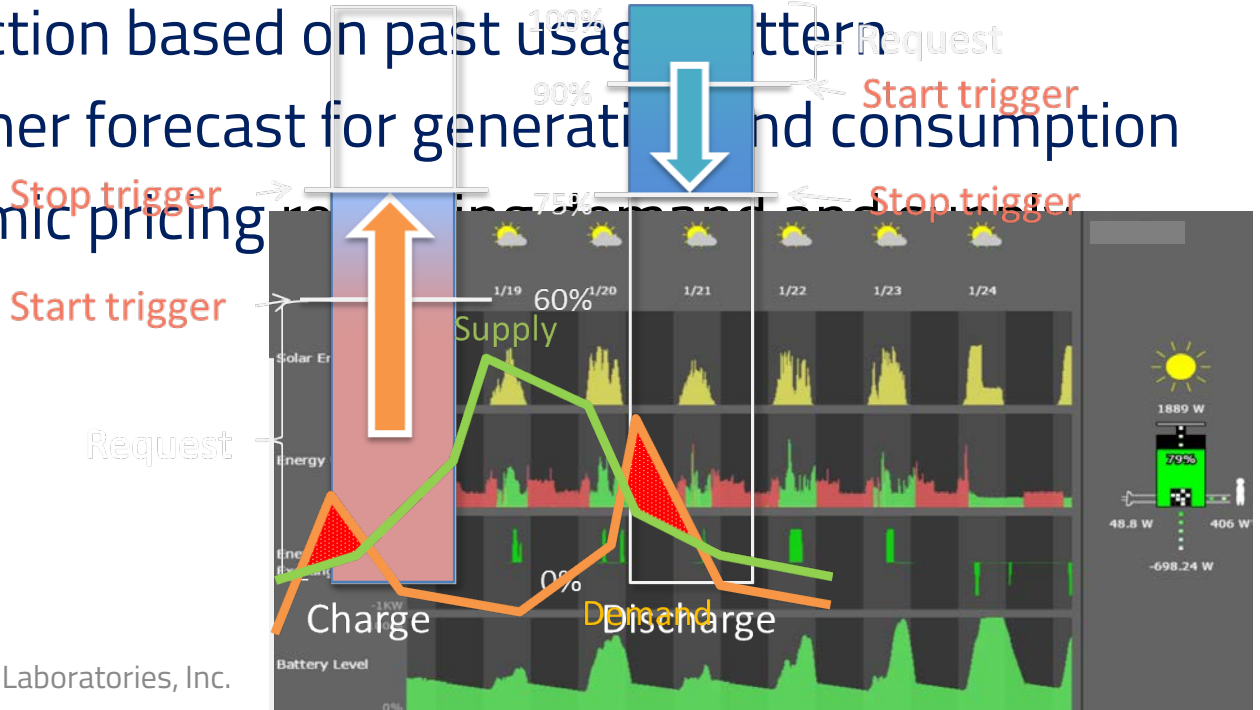
Set the Grid to 350V by CV mode (#0)
Deal 1: Send energy from #1 -> #3
Deal 2: Send energy from #4 -> #2, #5

DC/DC converter can have 3 modes:

- Waiting (stop)
- Constant Voltage mode (CV)
- Constant Current mode (CC)

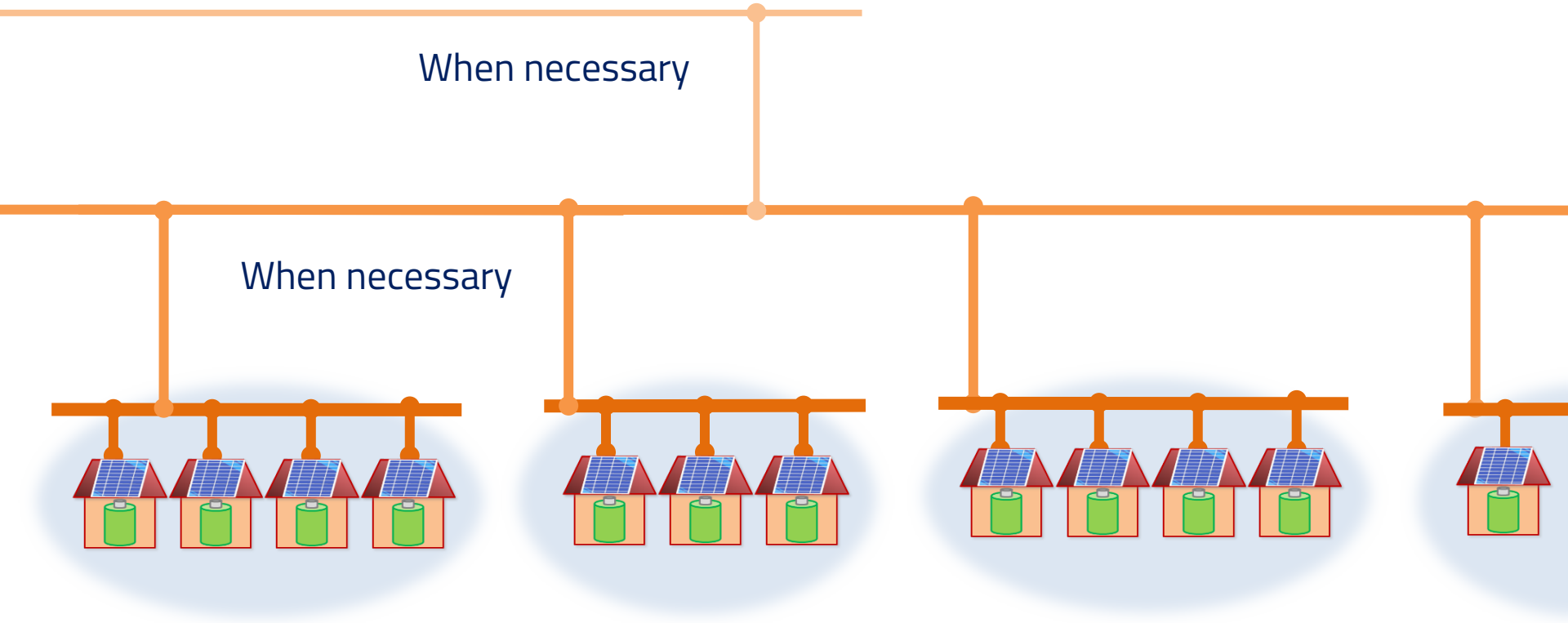
Energy Exchange Policies

- Baseline policy
  - Capacity available for giving/receiving
  - Request for consumption
- Advanced policies
  - Prediction based on past usag[illegible]ttern
  - Weather forecast for generati[illegible]nd consumption
  - Dynamic pricing [illegible]



Power Exchange Network

Scalable Architecture

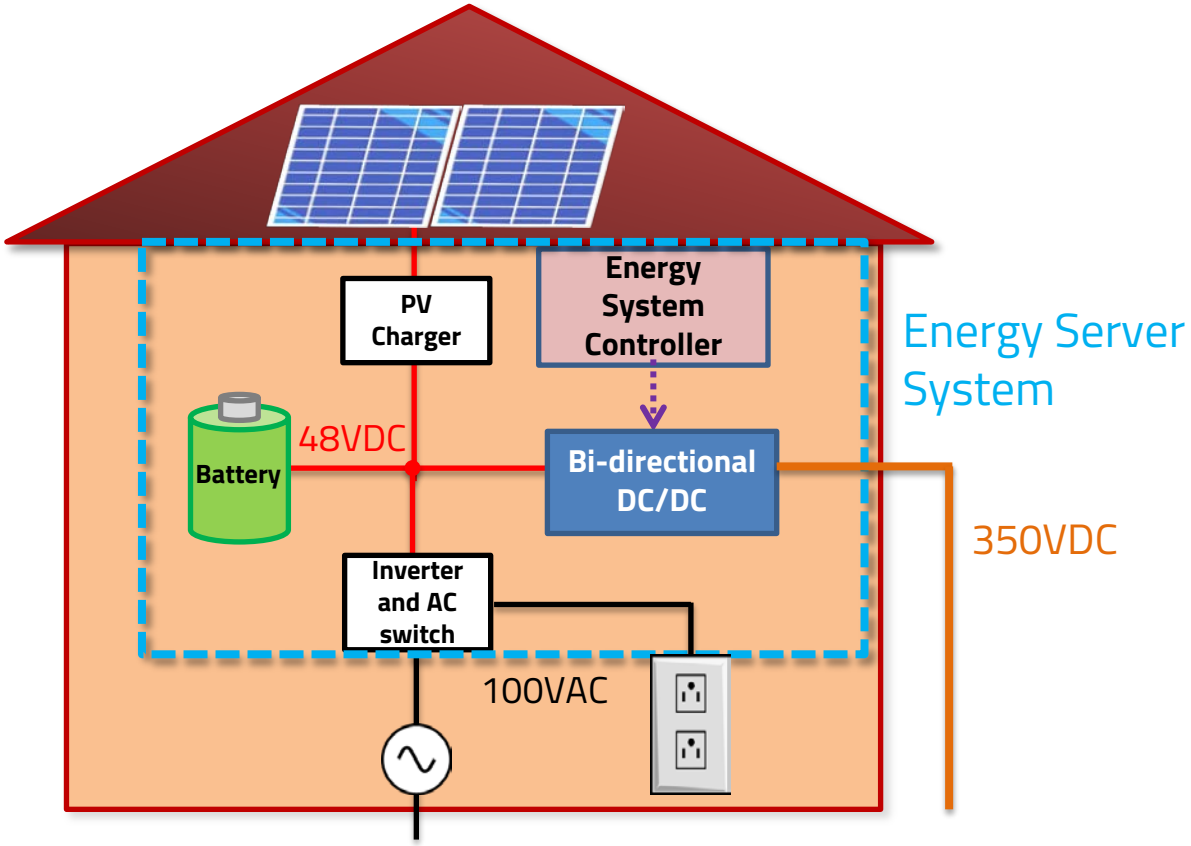


Most exchanges happen at the lowest level!

Video 1

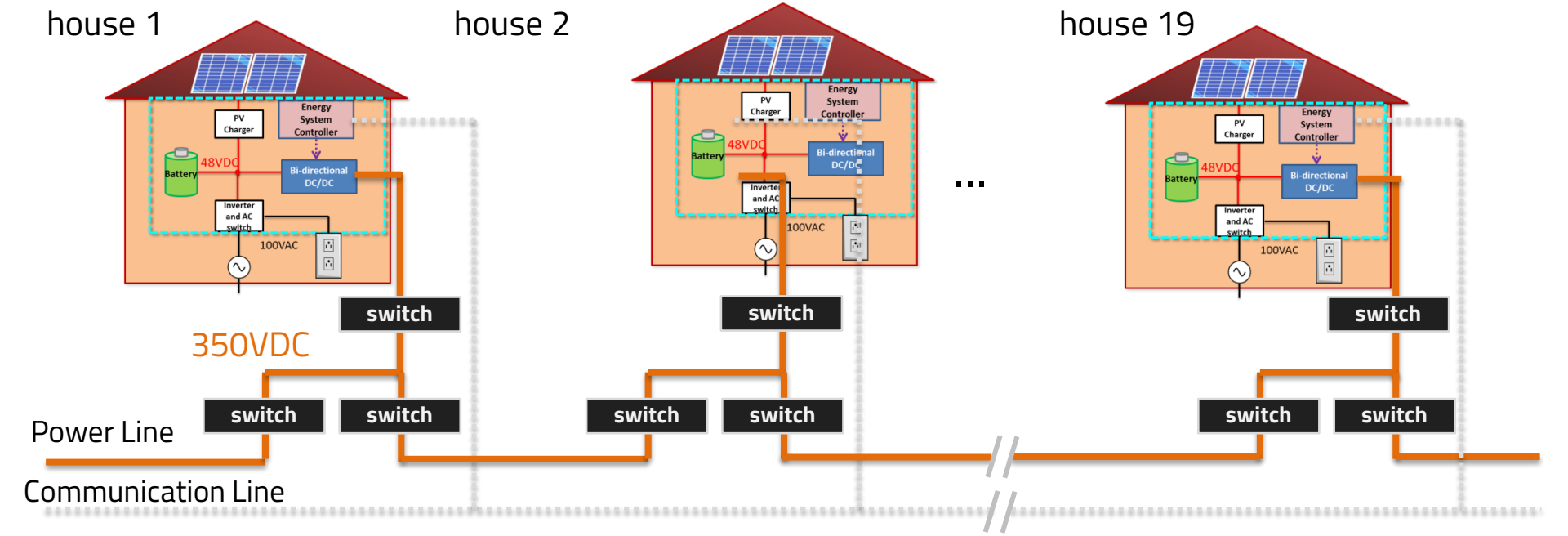
DCOES@OIST20 System Structure (1)

- Configuration of each house



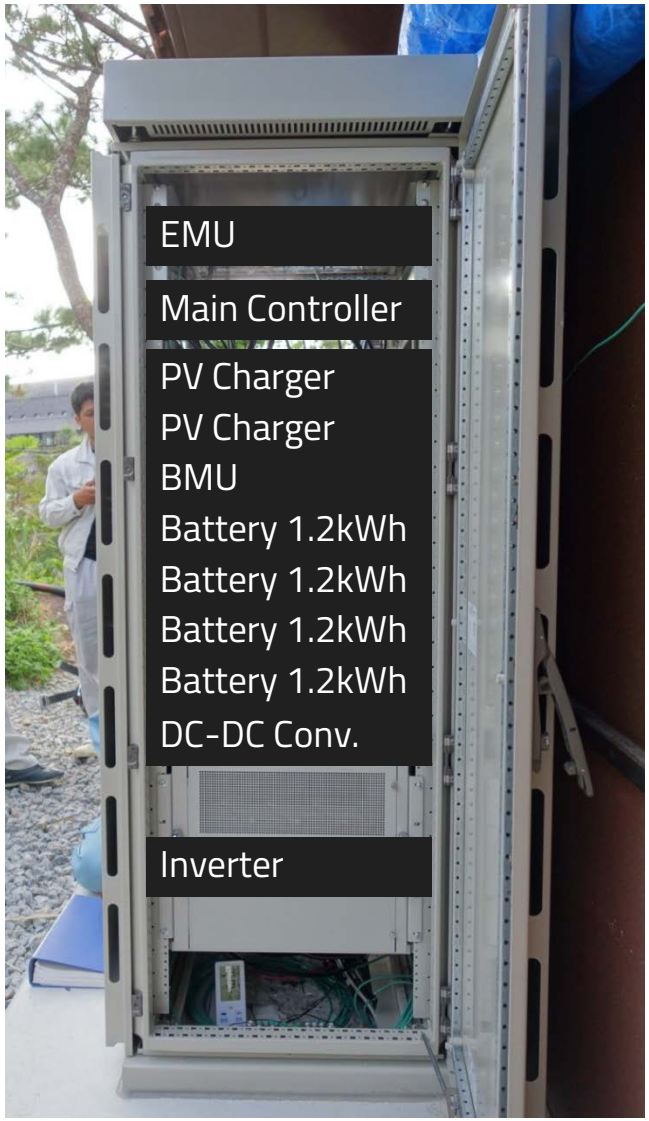
DCOES@OIST20 System Structure (2)

- 19 houses connected

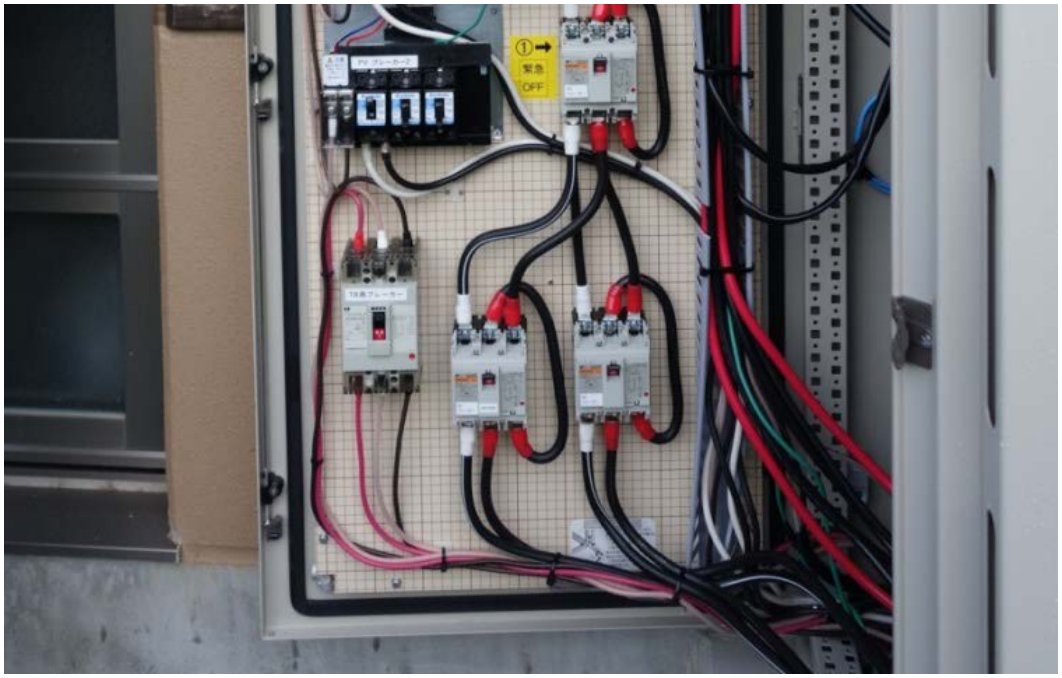


Energy Server System

- SONY 48V Li-Ion battery modules
- 350V Grid
- Energy exchange module, DCDC
- DC to AC inverter for appliances
- AC backup by utility company



350V DC Power Lines (Privately Owned)



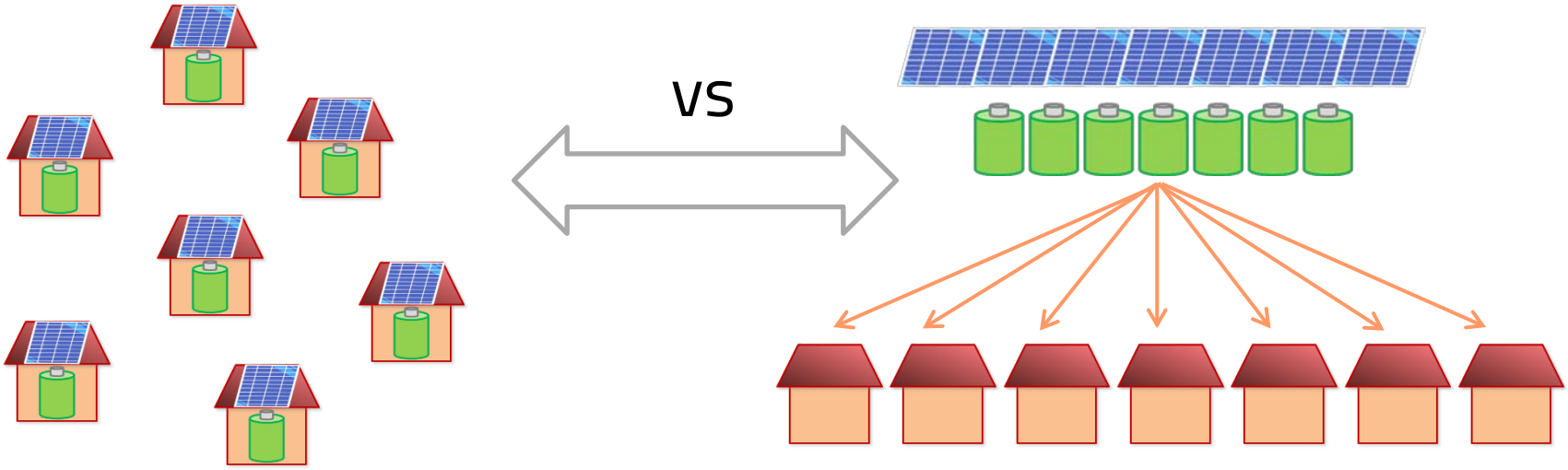
Video 2

Performance Evaluation

Performance Evaluation

Distributed stand-alone

Centralized



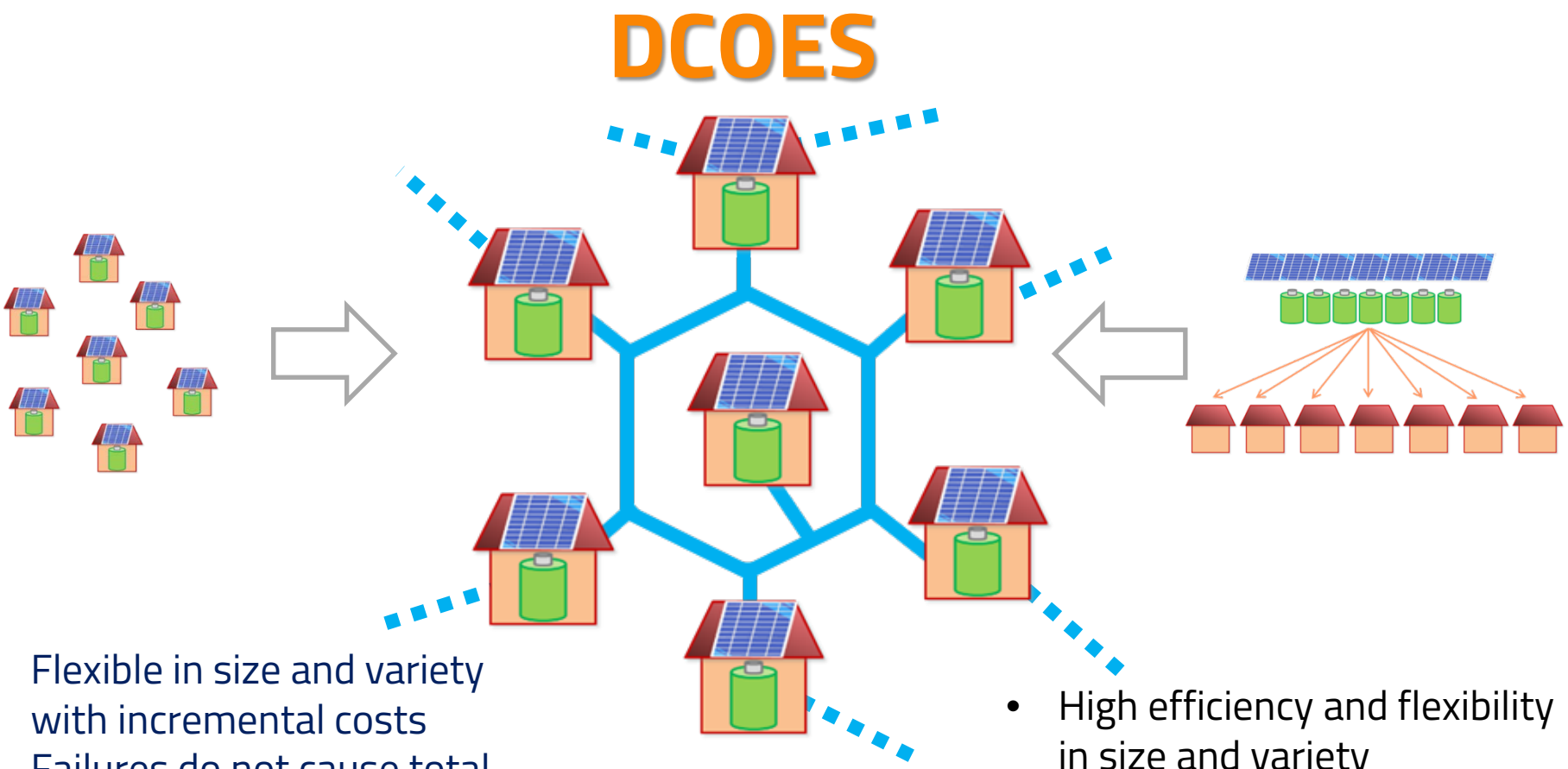
Bottom-up by individuals

- Flexible in size and variety with incremental costs
- Failures do not cause total system outage
- May not be efficient overall

Top-down by a single entity

- Fixed in size with high initial costs
- Single failure may cause total system outage
- Efficient for a predefined users and usage patterns

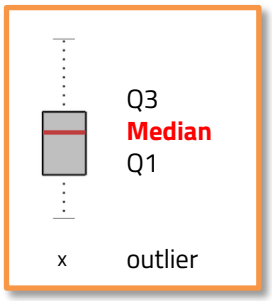
DCOES: Distributed System with Energy Exchange

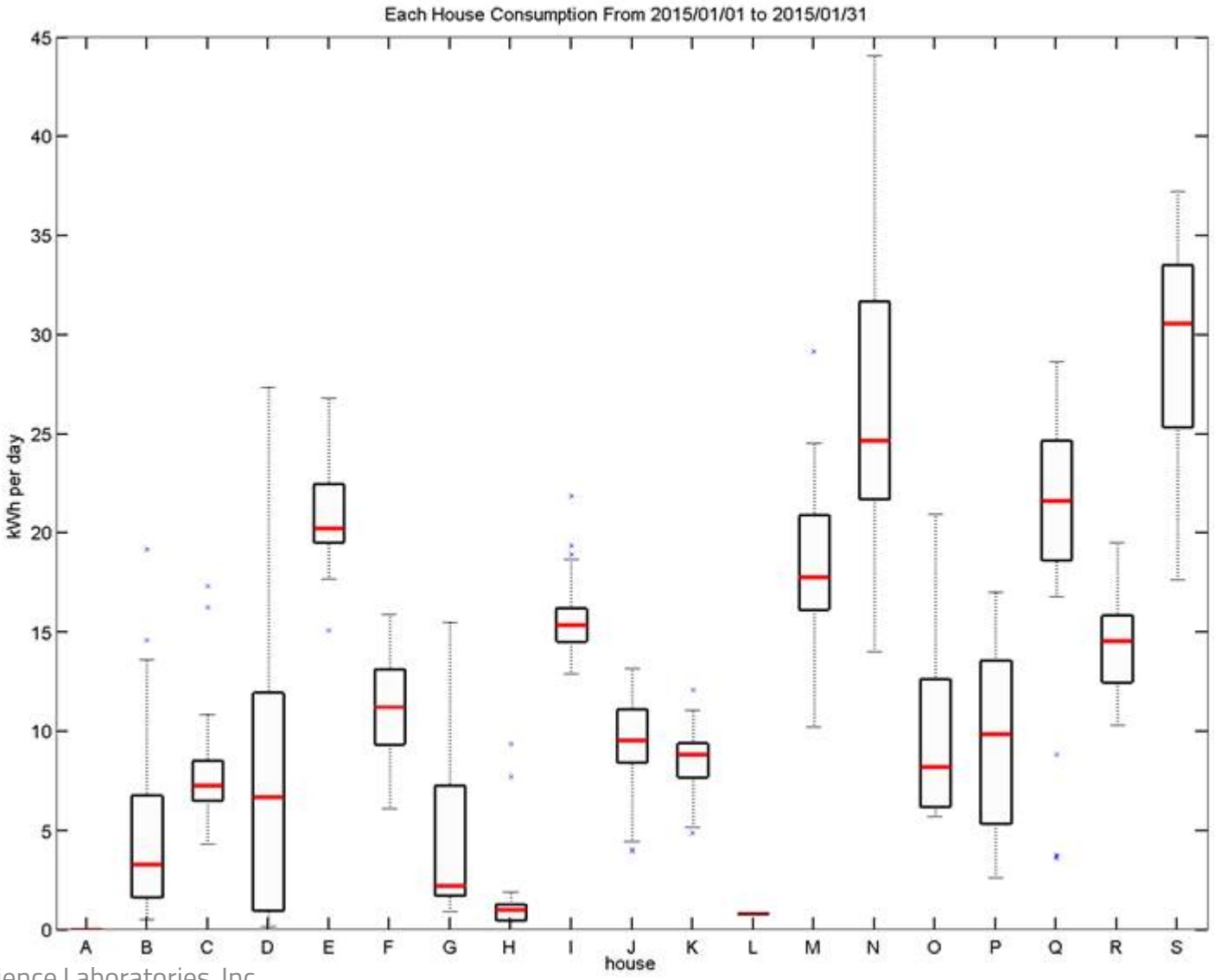


- Flexible in size and variety with incremental costs
- Failures do not cause total system outages

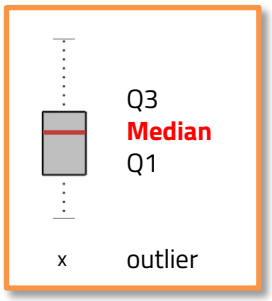
- High efficiency and flexibility in size and variety

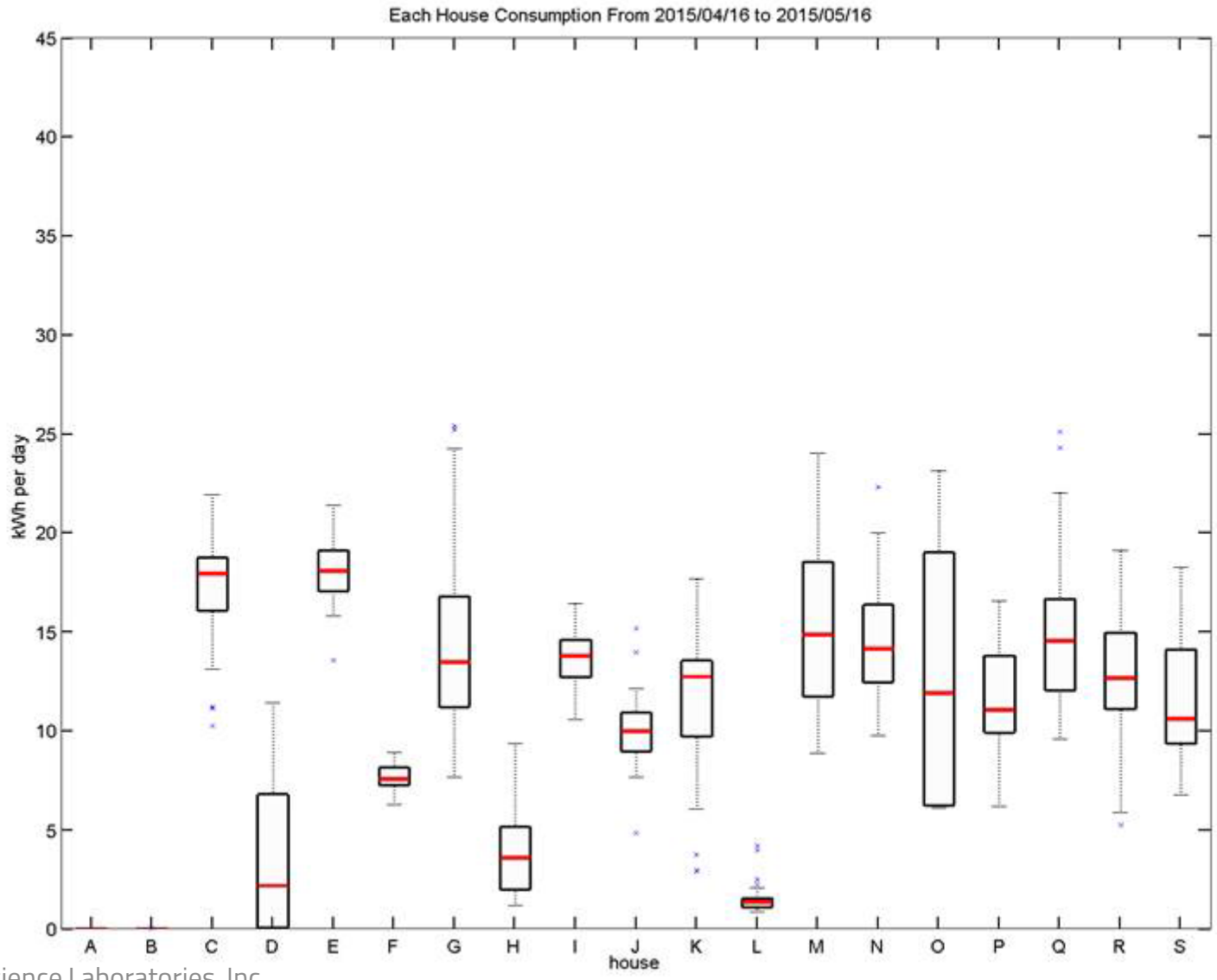
Variety in usage pattern (Winter)





Variety in usage pattern (Spring)



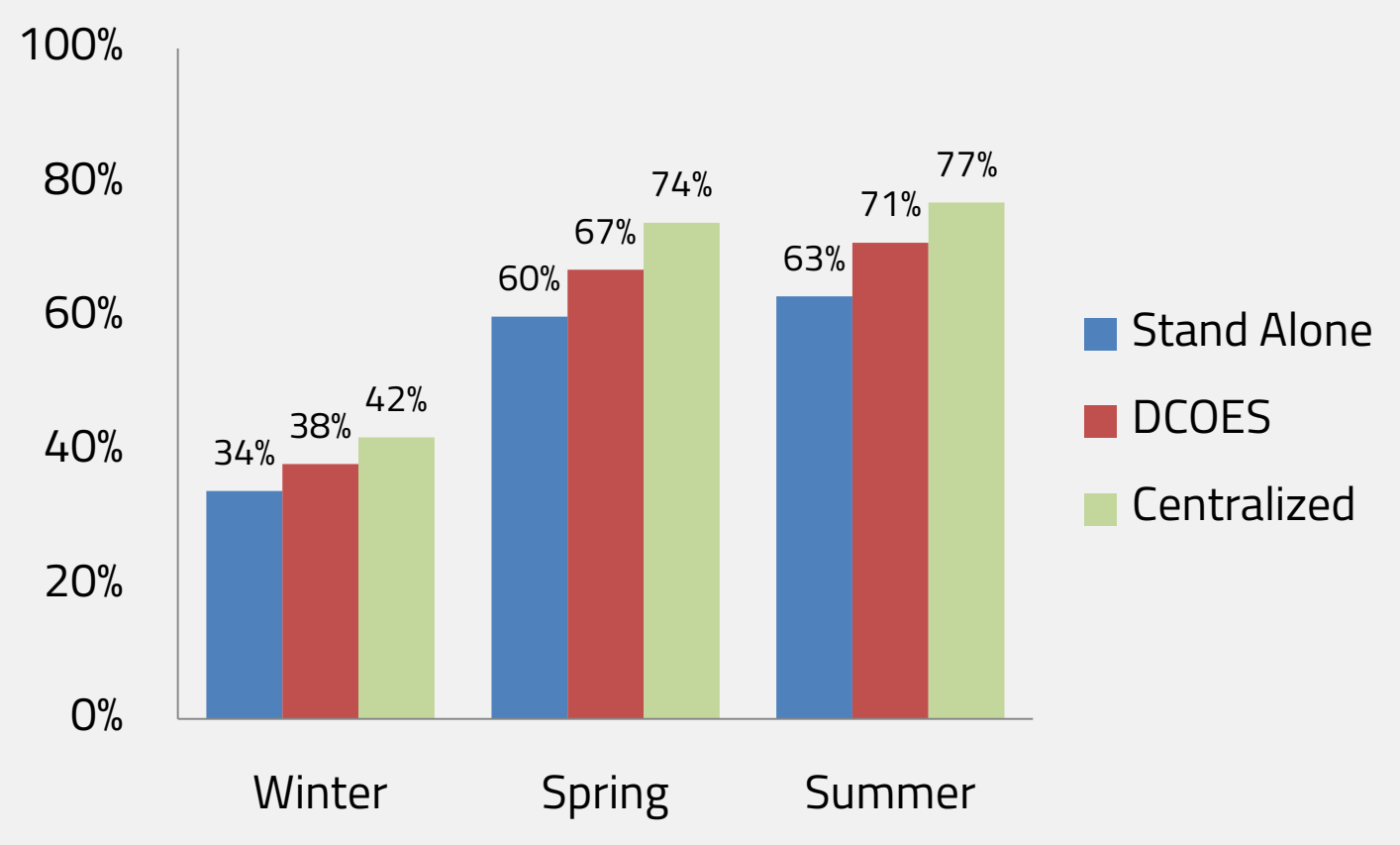


Performance Result and Estimation
(Current OIST configuration with baseline policy)

Winter: Real OIST Data (19 houses)
2015/1/1- 1/31

Spring: Real OIST Data (19 houses)
2015/4/16- 5/16

Summer: Simulation (19 houses)
2015/7/16- 8/15



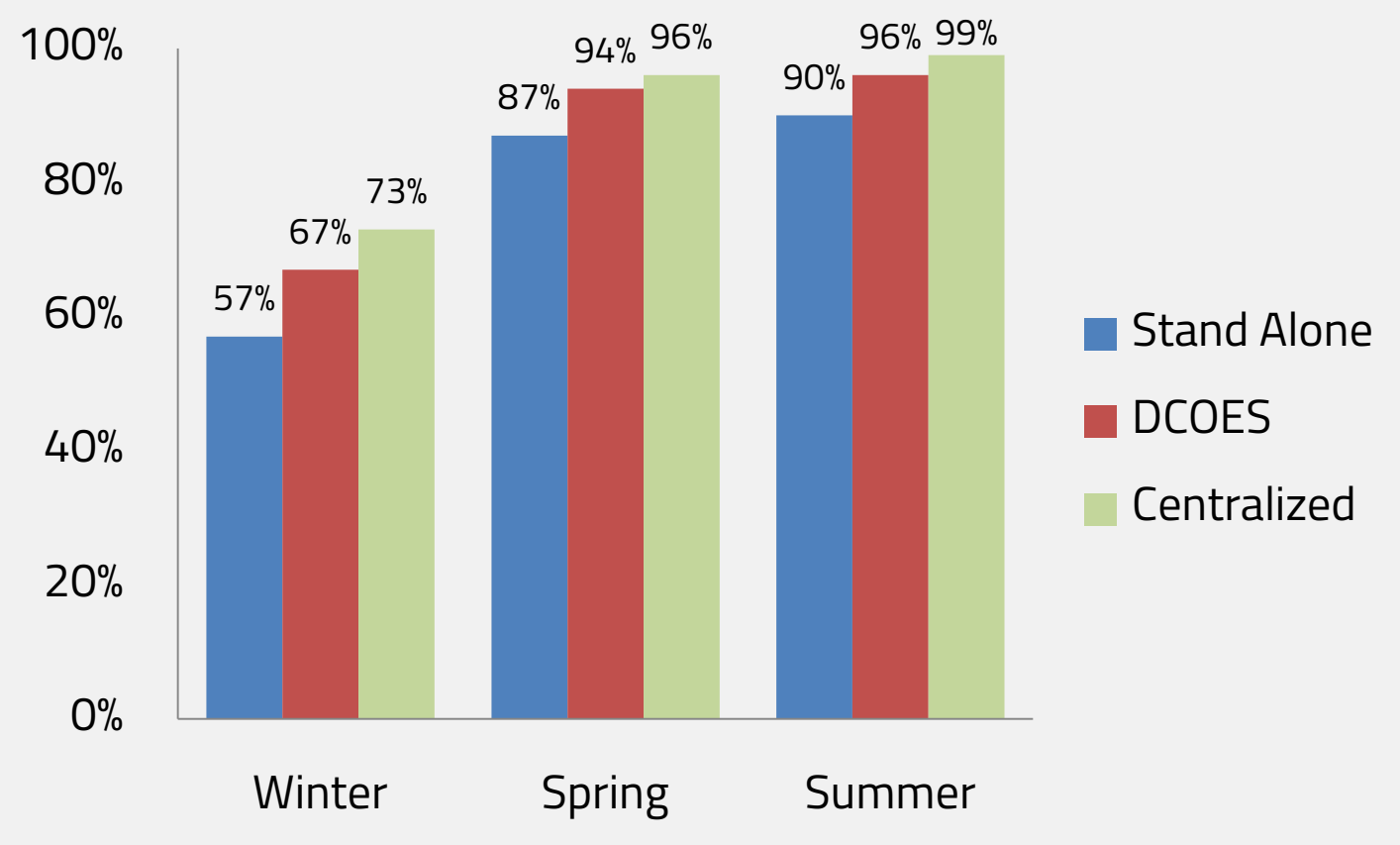
Self-sufficiency ratio = (Energy used - Energy bought)/ Energy used

Performance Result and Estimation
(Solar x2, Battery x2 with baseline policy)

Winter: Real OIST Data (19 houses)
2015/1/1- 1/31

Spring: Real OIST Data (19 houses)
2015/4/16- 5/16

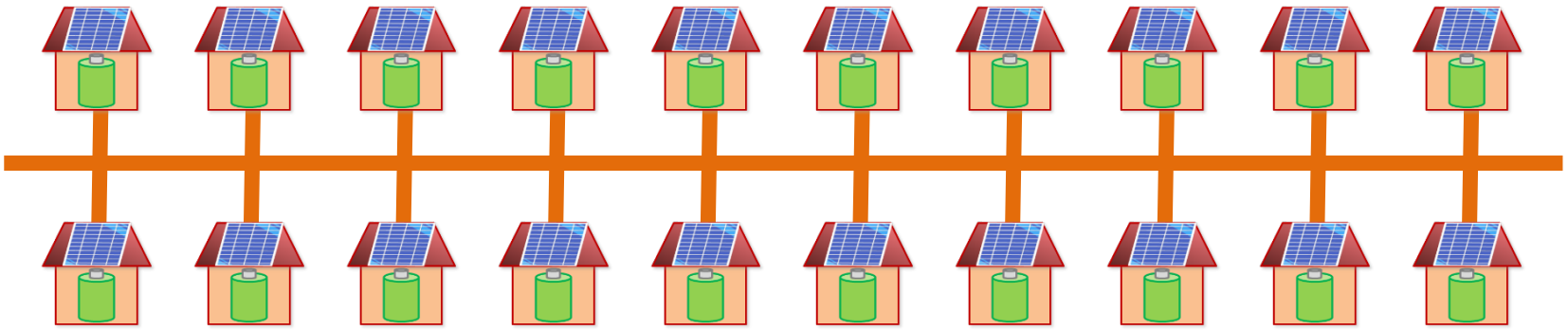
Summer: Simulation (19 houses)
2015/7/16- 8/15



Self-sufficiency ratio = (Energy used - Energy bought)/ Energy used

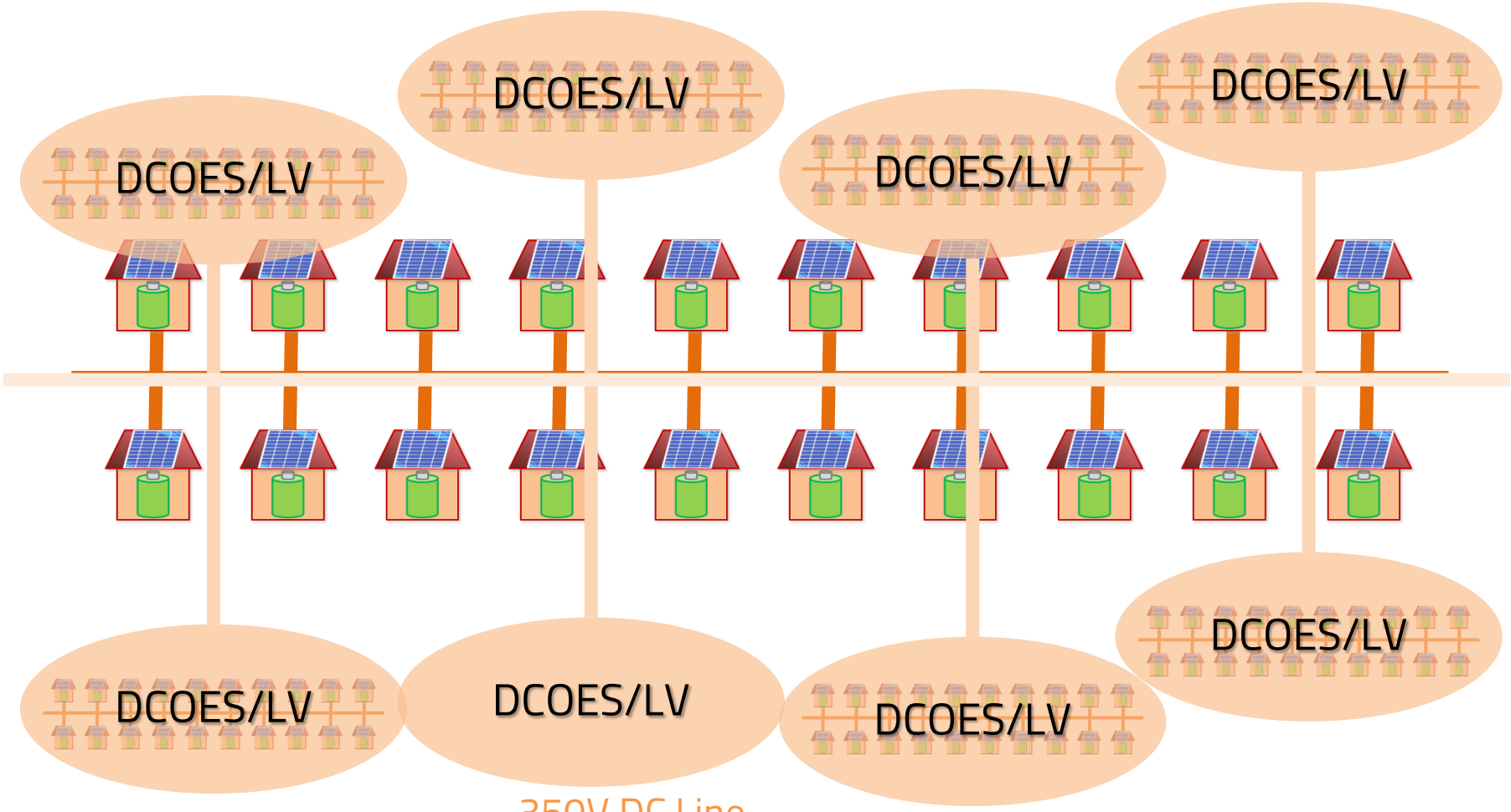
Next Plans

DCOES/LV for Houses in a Community



350V DC Line
PV: 3-5kWp
Batt.: 5kWh

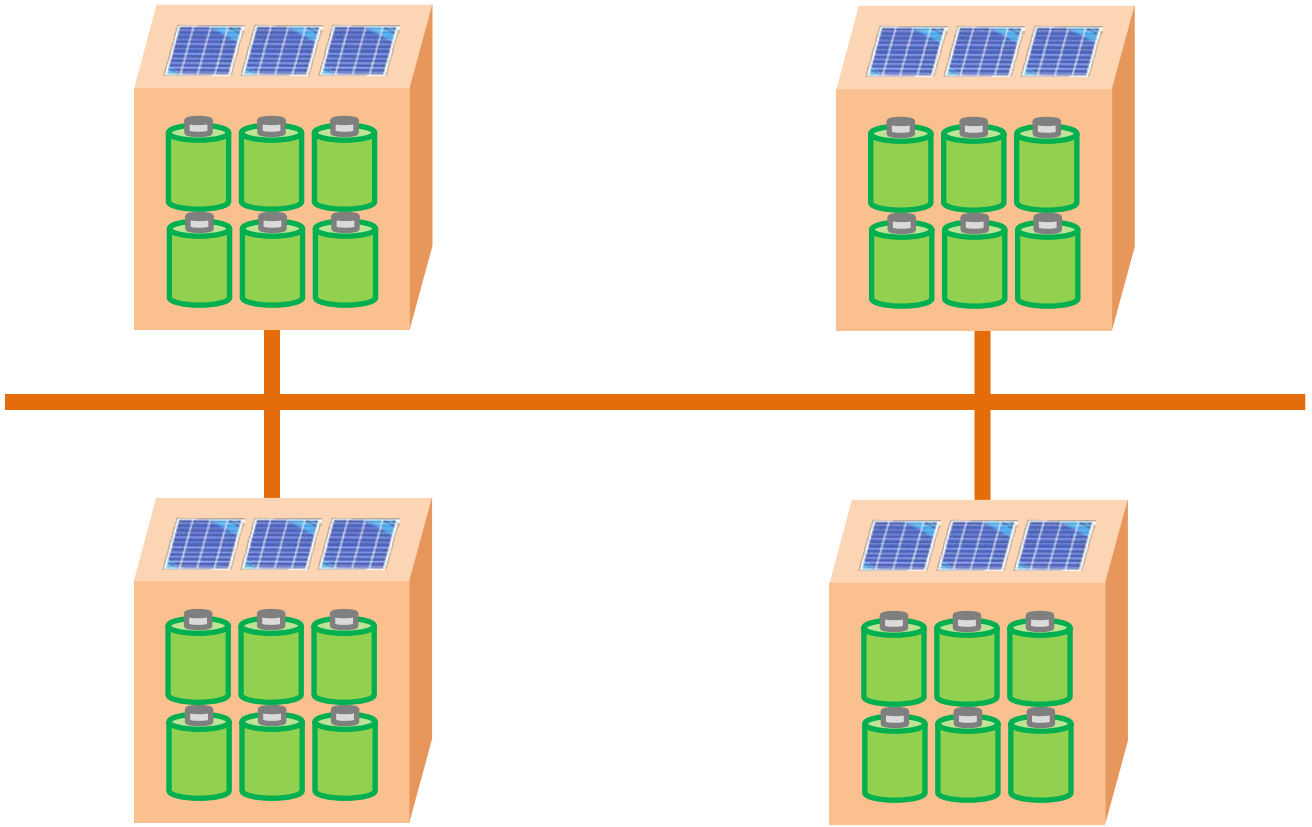
DCOES/MV for Larger Communities



350V DC Line
PV: 3-5kWp
Batt.: 5kWh

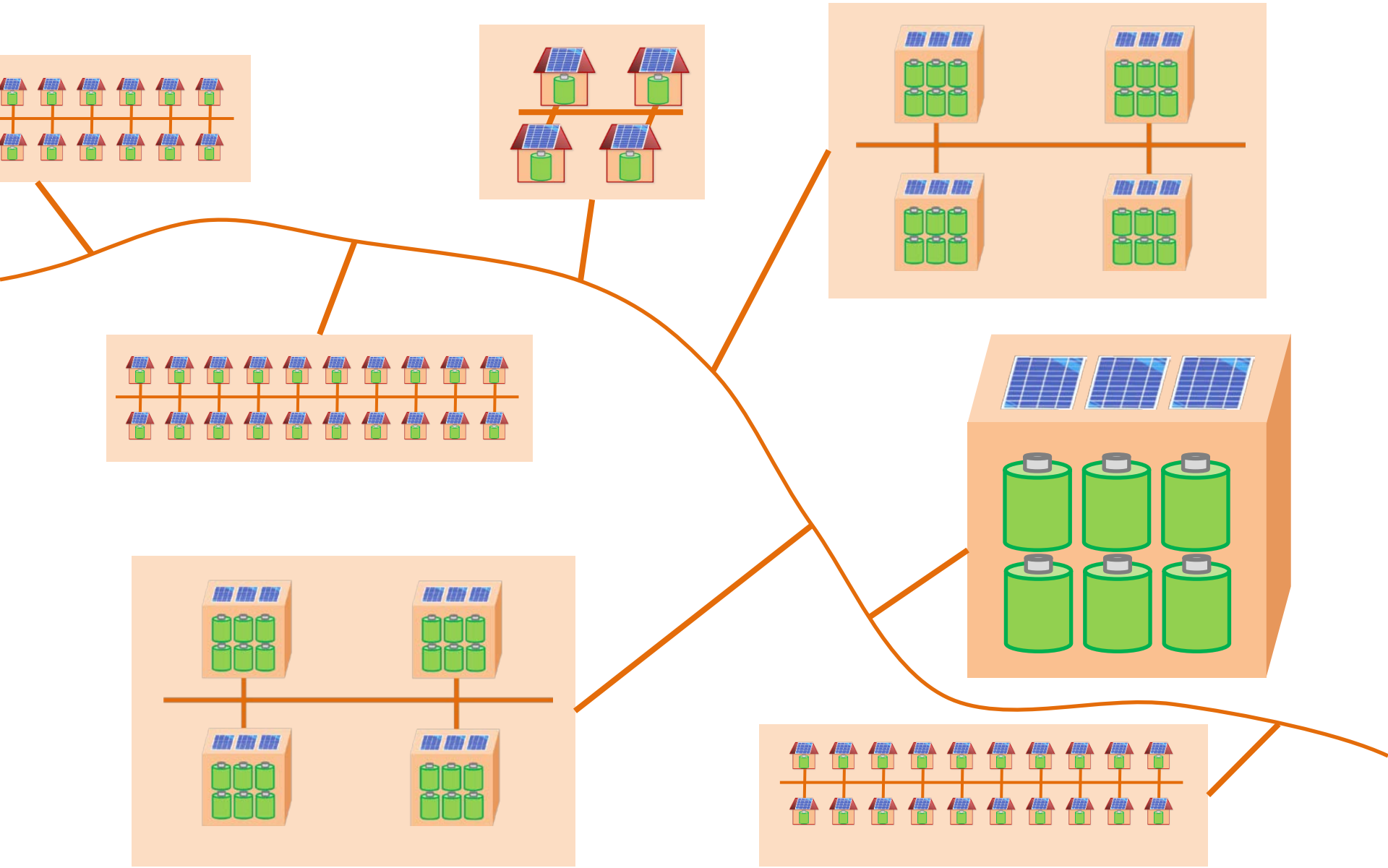
+ 1KV Line

DCOES/MV for Buildings



1KV DC Line
PV: 100kWp
Batt.: 500kWh

DCOES/HV for Self-Sustaining Island



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Acknowledgements

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