DC-Based Open Energy System

A Sustainable, Dependable, and Affordable Solution for Next-Generation Electrical Power Infrastructures

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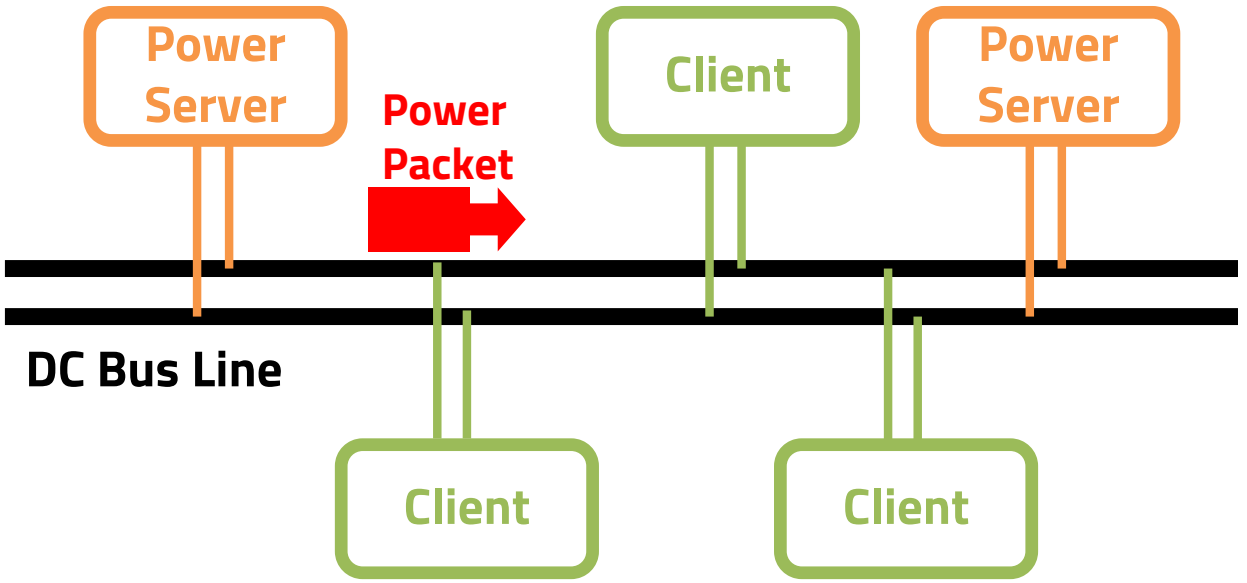
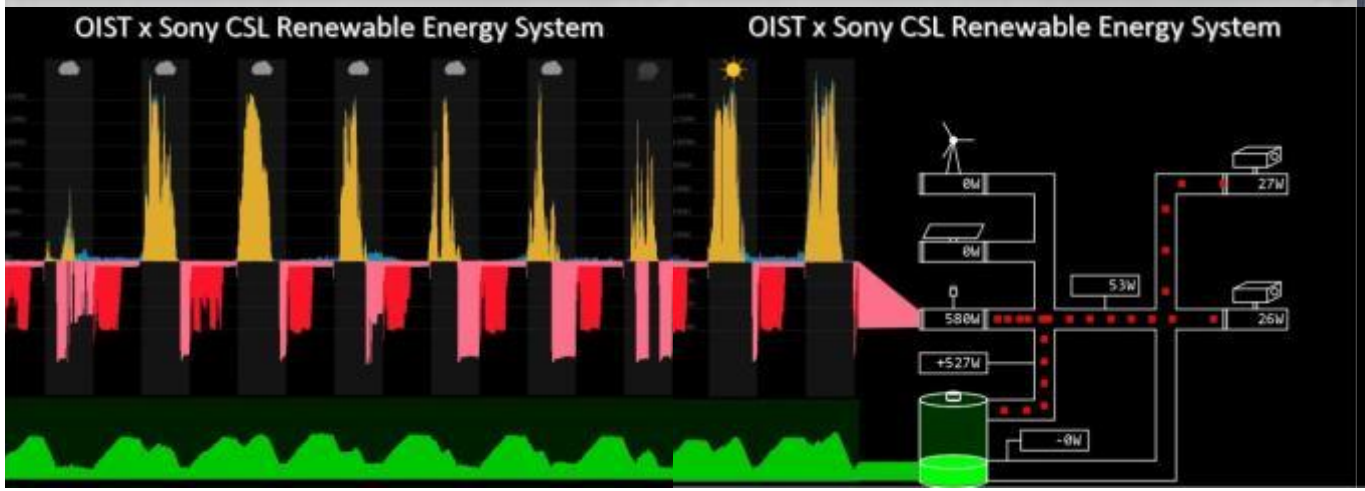


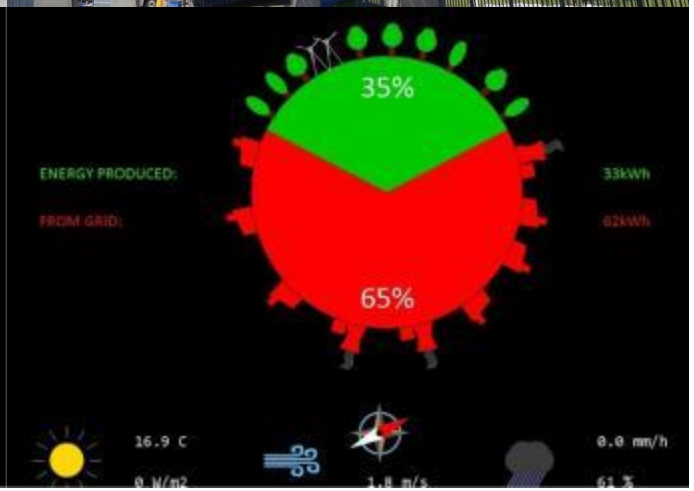
Table-top Experiments, 2005

in Sony CSL

Ghana Expedition, 2010

Supported by JICA





Okinawa, 2012

Sony CSL - OIST Joint project

Bangladesh, 2014

Supported by MOE, Japan

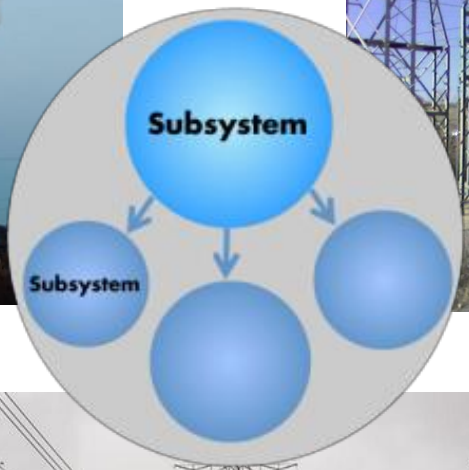
Okinawa, since Dec. 2014

Supported by Okinawa Prefecture Government

Our Fundamental Thought

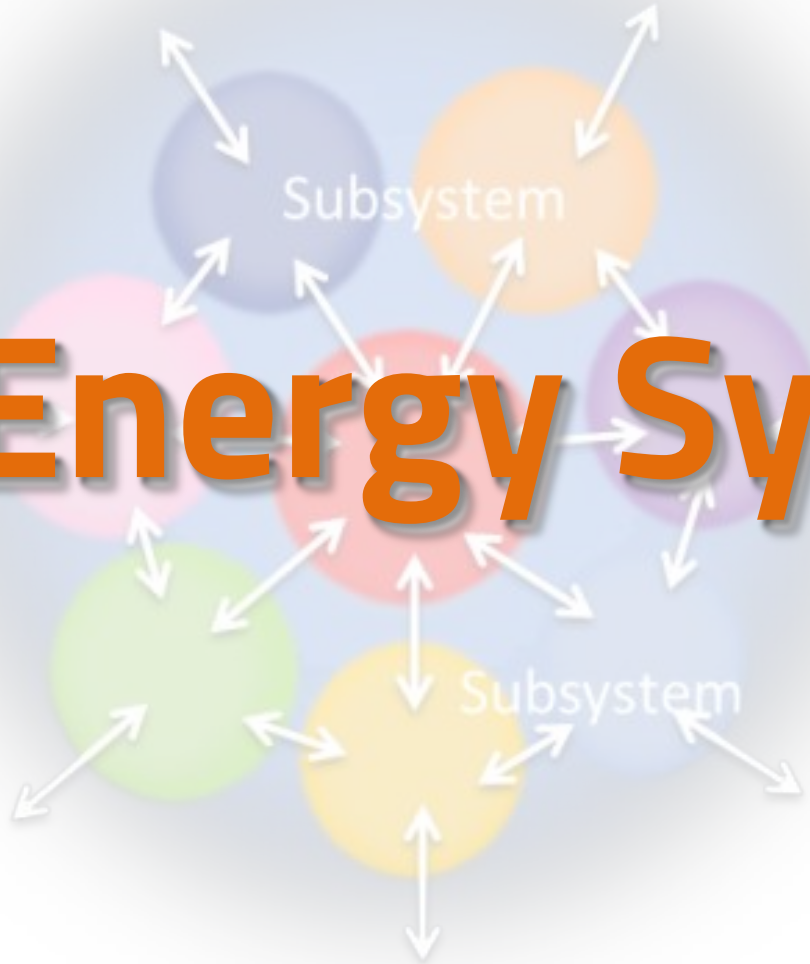
Sustainable	**Do not pass on liability to next generation**
Dependable	**Keep risk manageable**
Affordable	**Accessible to everyone on earth**

Conventional Power Systems

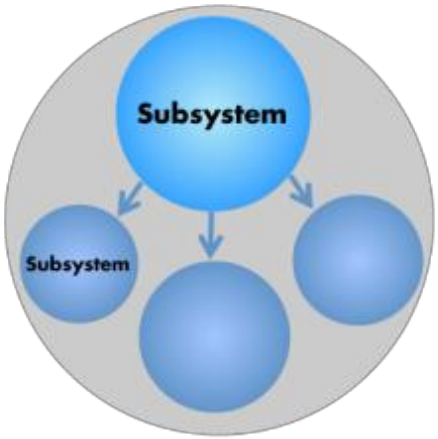


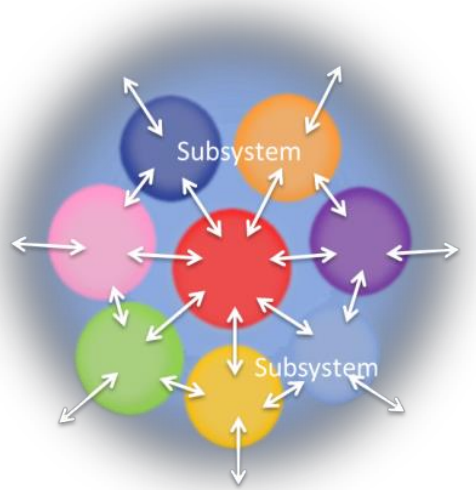
Our Approach

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

SONY Ferro-Phosphoric Acid Li-Ion Batteries

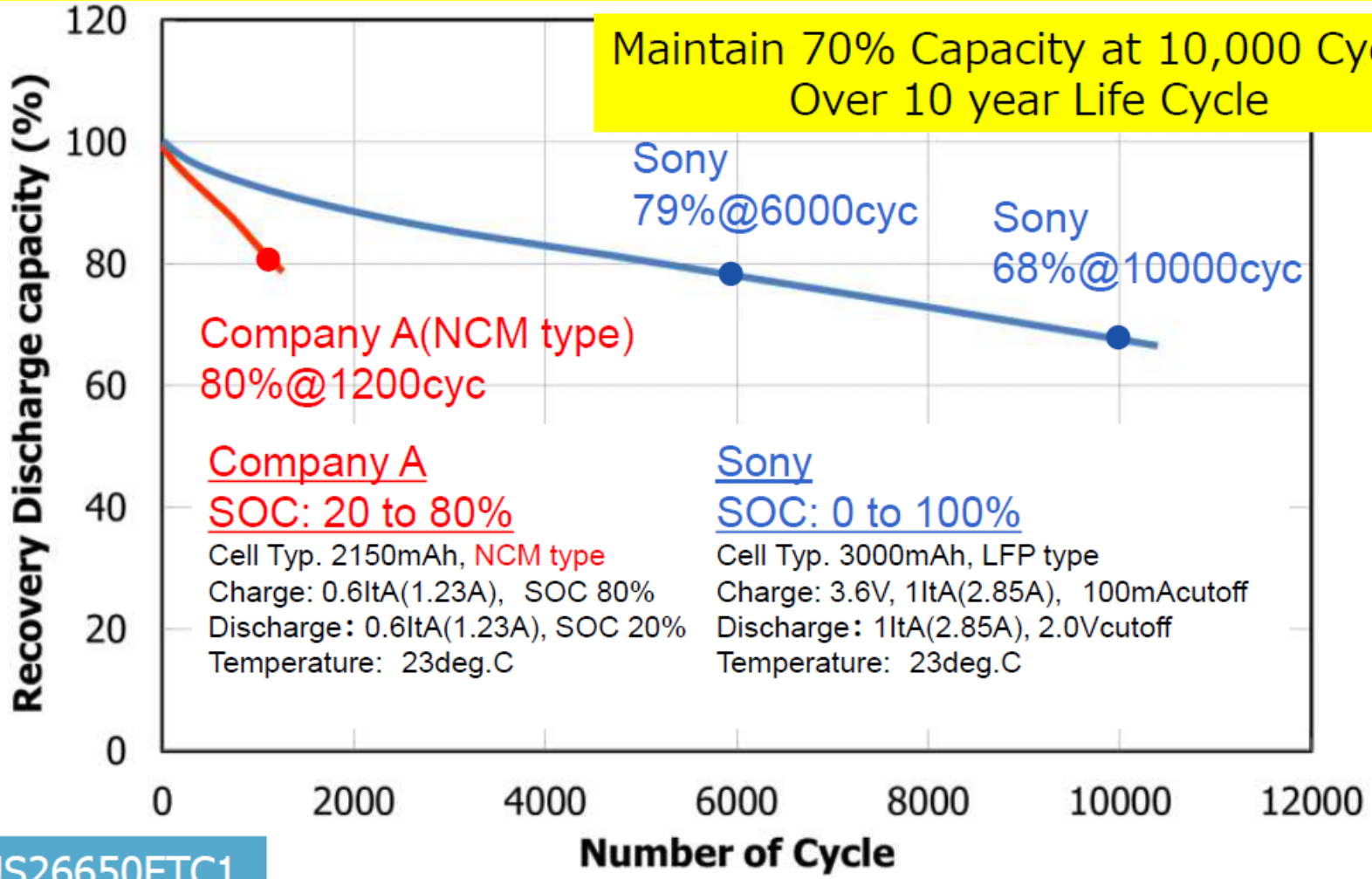
- Full use of capacity
- Long life under tough conditions
- Inherent safety:
  no thermal runaway
- Fast Charging time:
  1 hour for >90% capacity
- Eco-friendly:
  no rare metals

fORTELION

SONY Ferro-Phosphoric Acid Li-Ion Batteries

Cycle Performance

Approx. 5 time as long life as conventional Li-ion



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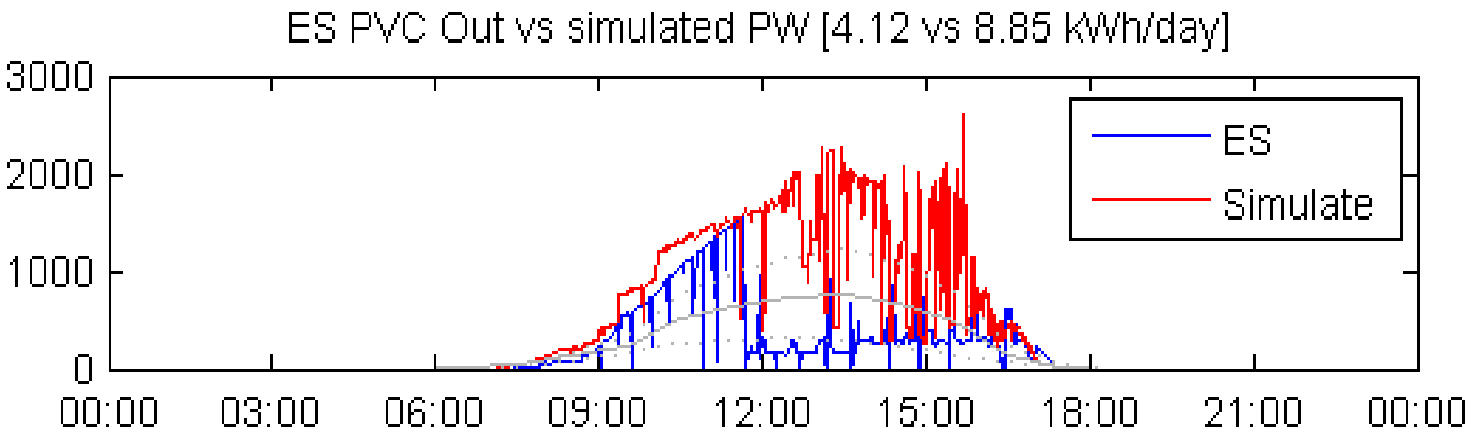
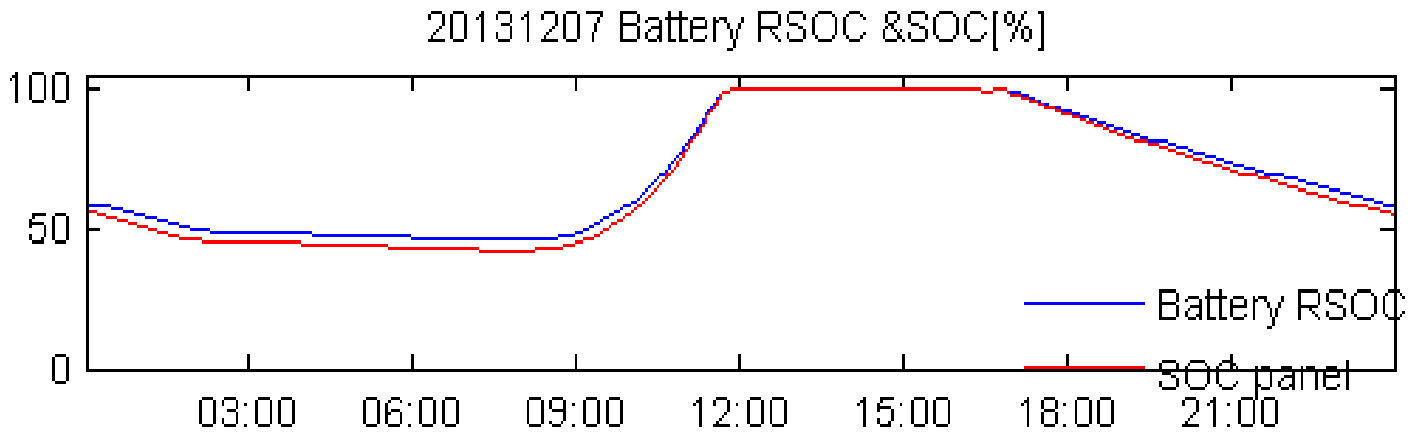
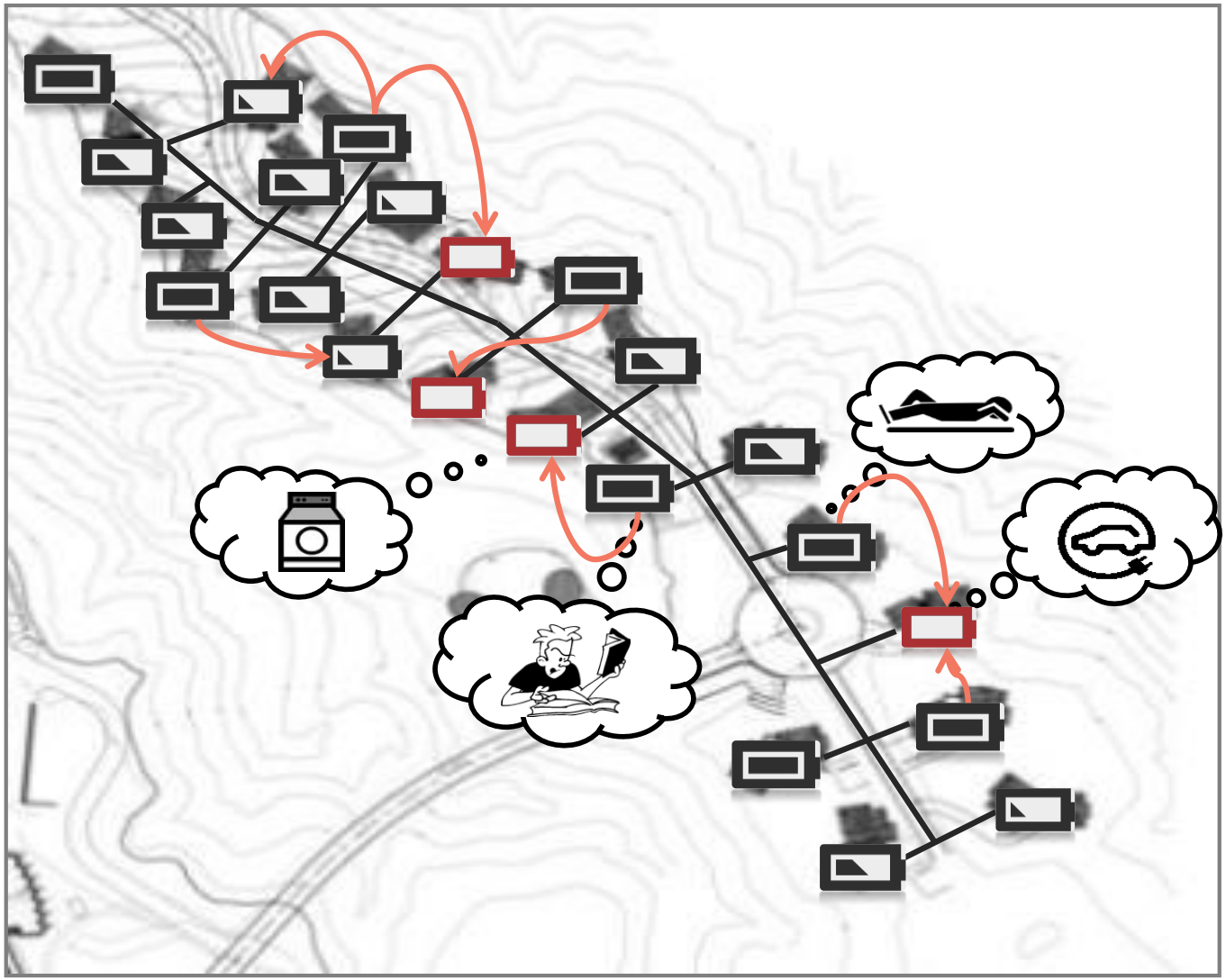
How to balance the PV generation and battery capacity?

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

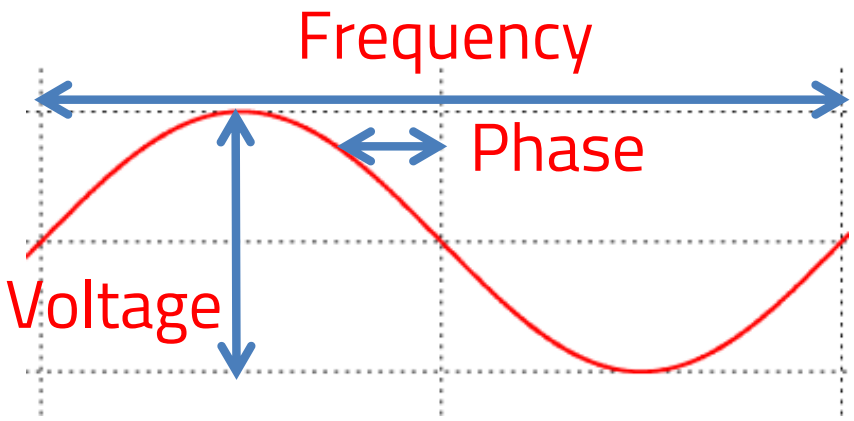
AC

for transformers

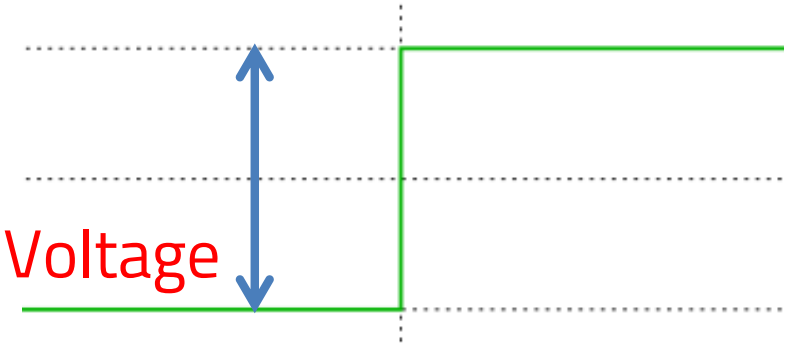
DC

for batteries

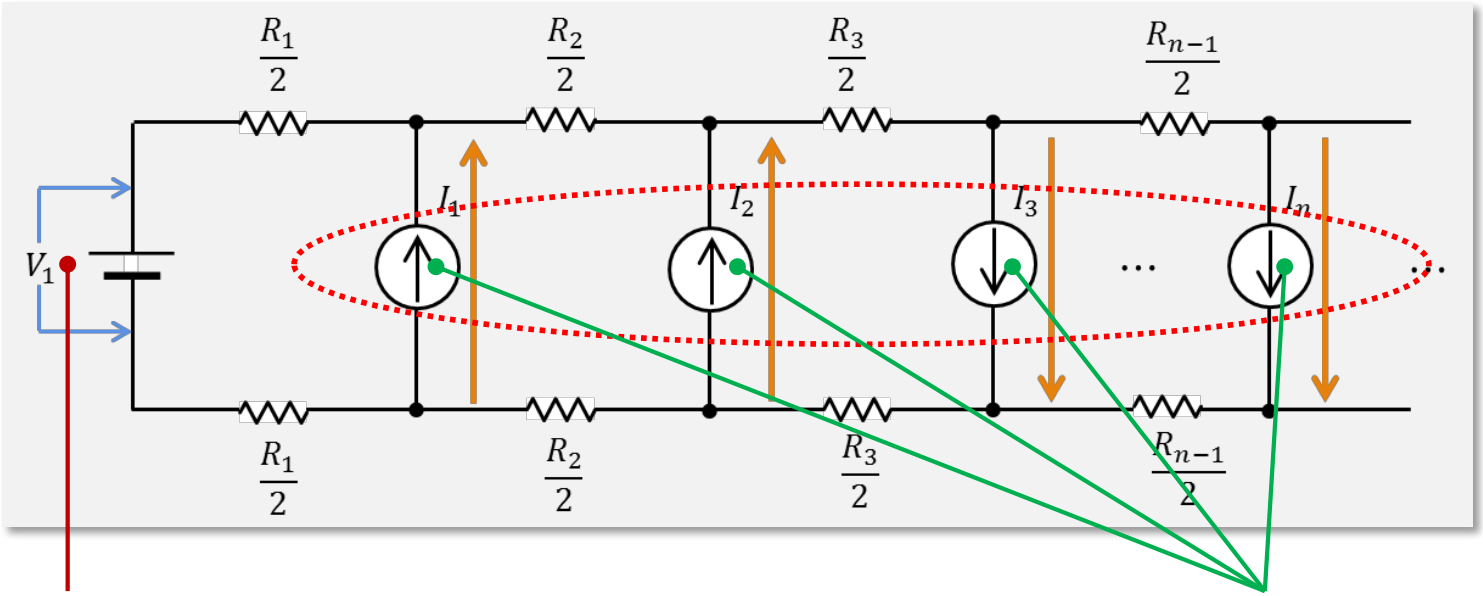
- Reactance loss of power is not negligible
- Interconnection of networks is difficult due to sync.



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



Base Theory

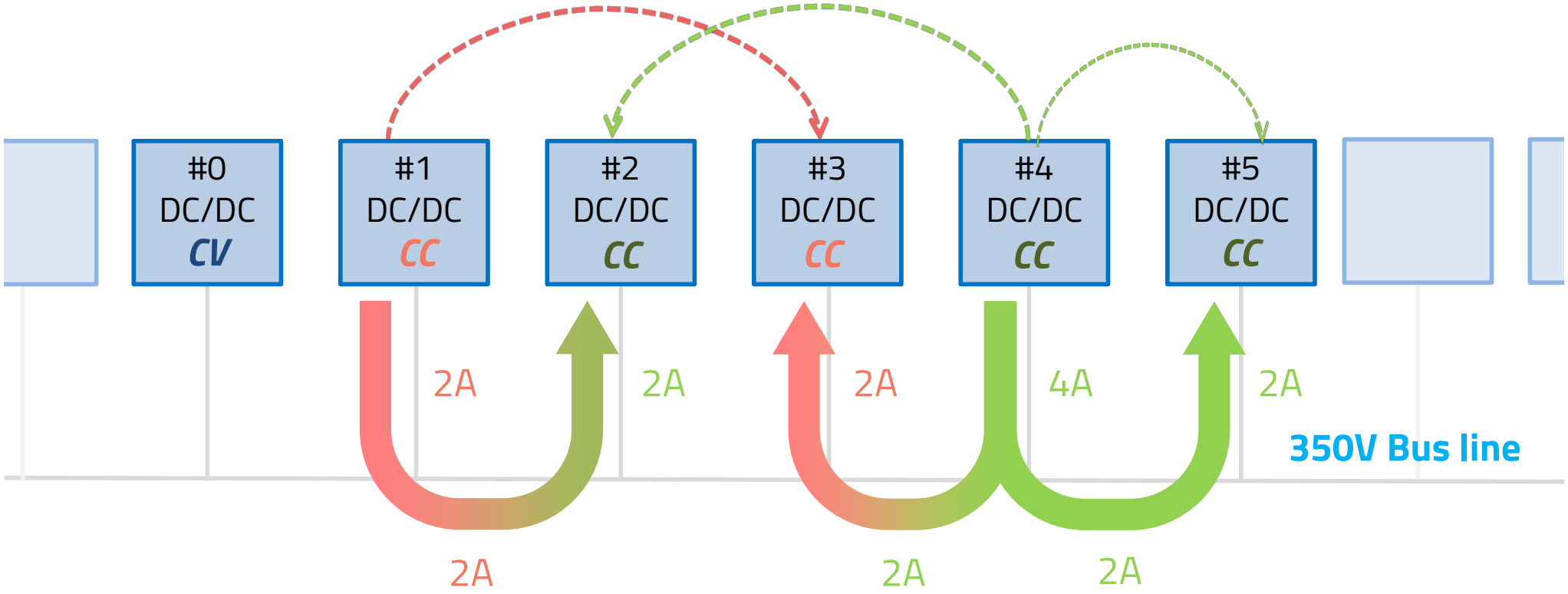


Constant Voltage Source keeps the grid voltage at 350V

Constant Current Sources set desired current

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

m-to-n Energy Exchange



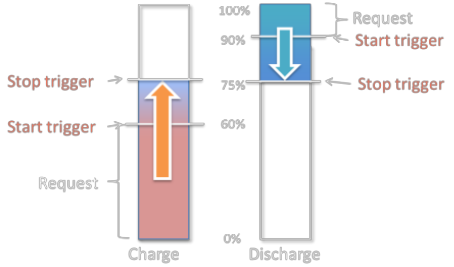
Set the Grid to 350V by CV mode (#0)
Deal 1: Send energy from #1 -> #3
Deal 2: Send energy from #4 -> #2, #5

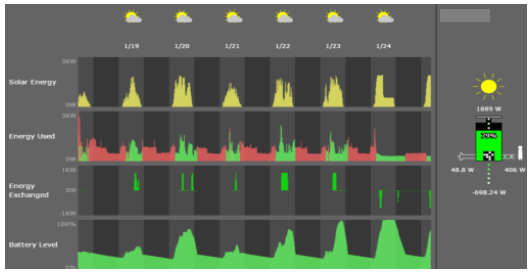
DC/DC converter can have 3 modes:

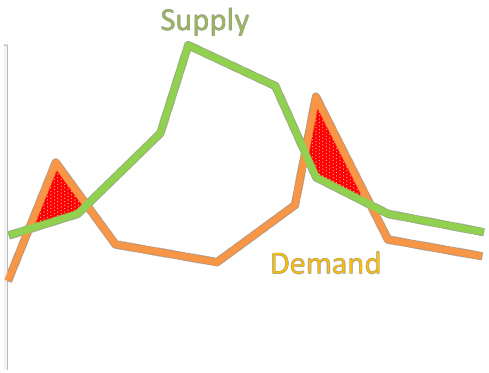
- Waiting (stop)
- Constant Voltage mode (CV)
- Constant Current mode (CC)

Energy Exchange Policies

- Baseline policy
  - Capacity available for giving/receiving
  - Request for consumption
- Advanced policies
  - Prediction based on past usage pattern
  - Weather forecast for generation and consumption
  - Dynamic pricing reflecting demand and supply

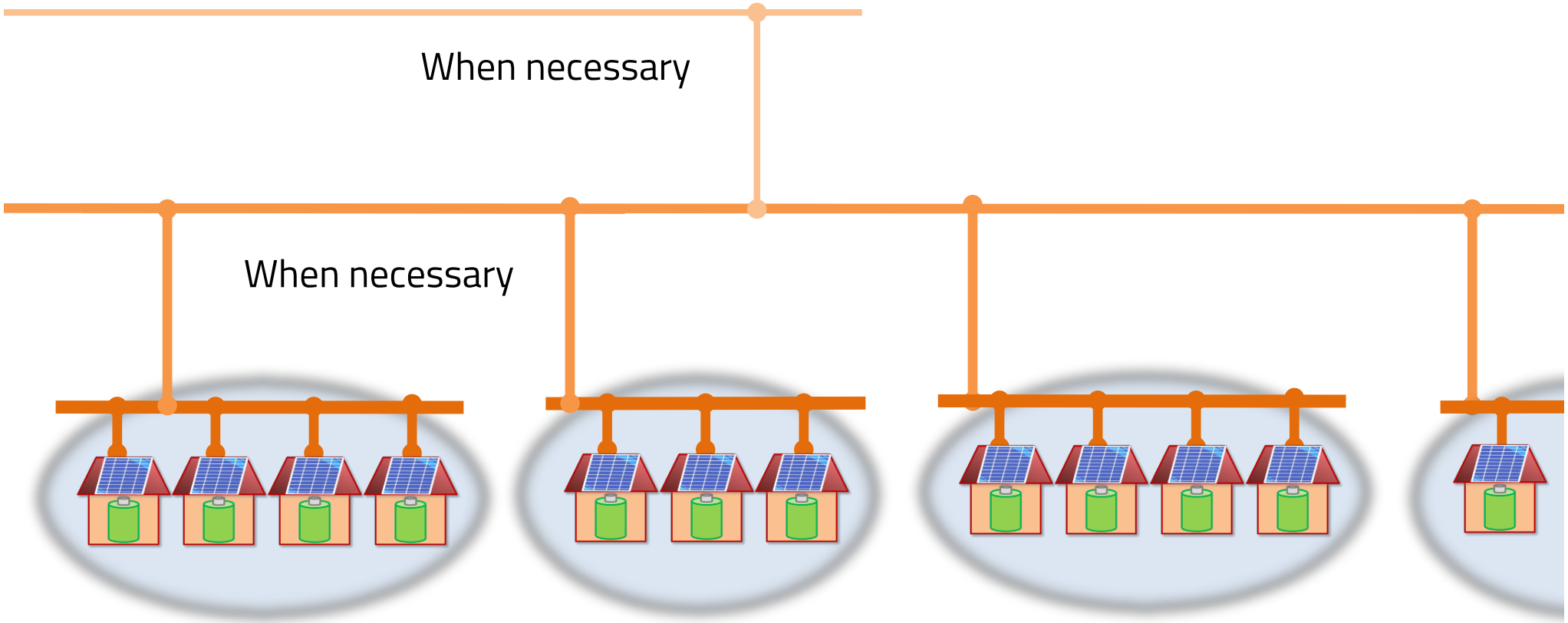




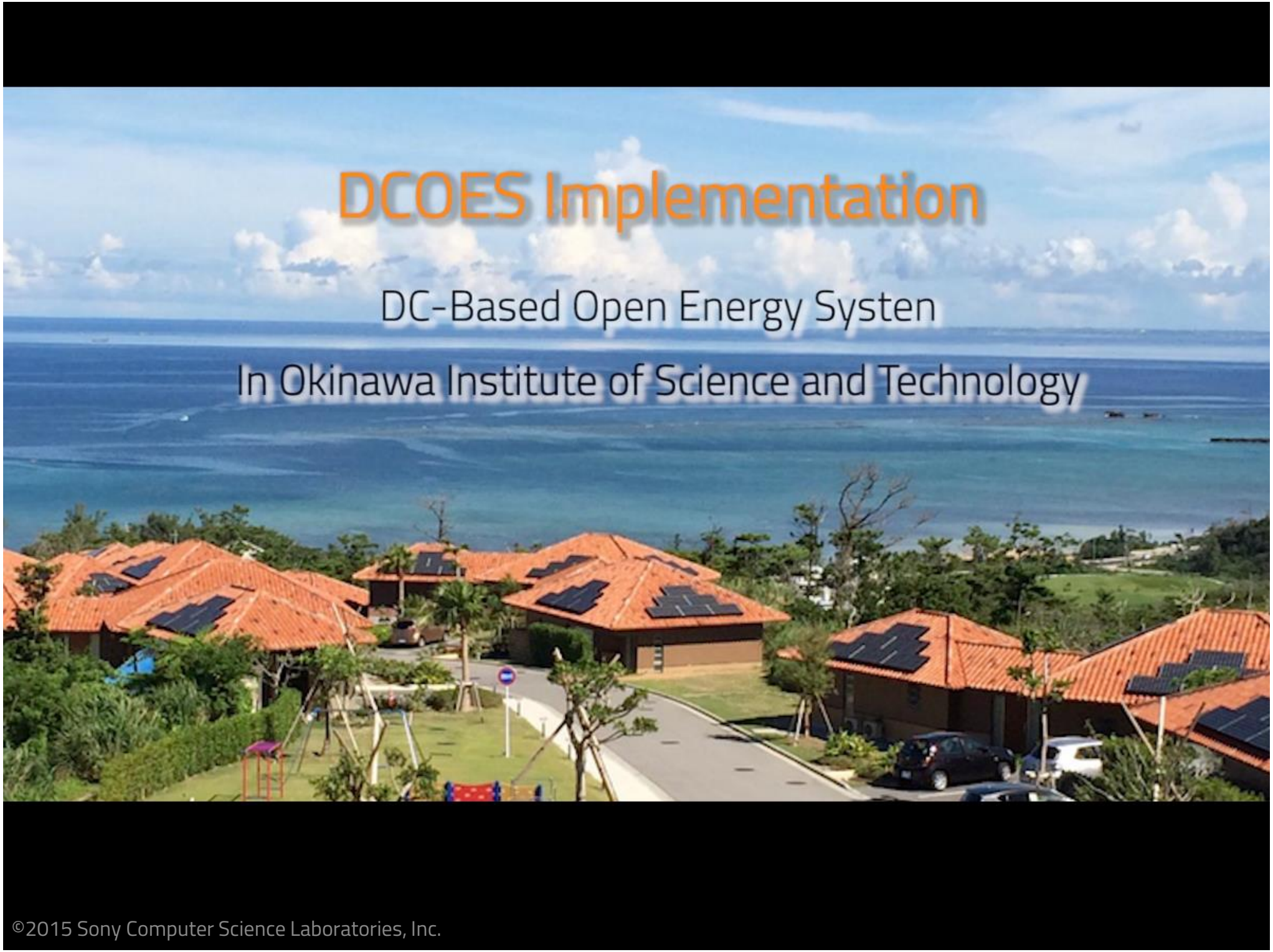


Power Exchange Network

Scalable Architecture

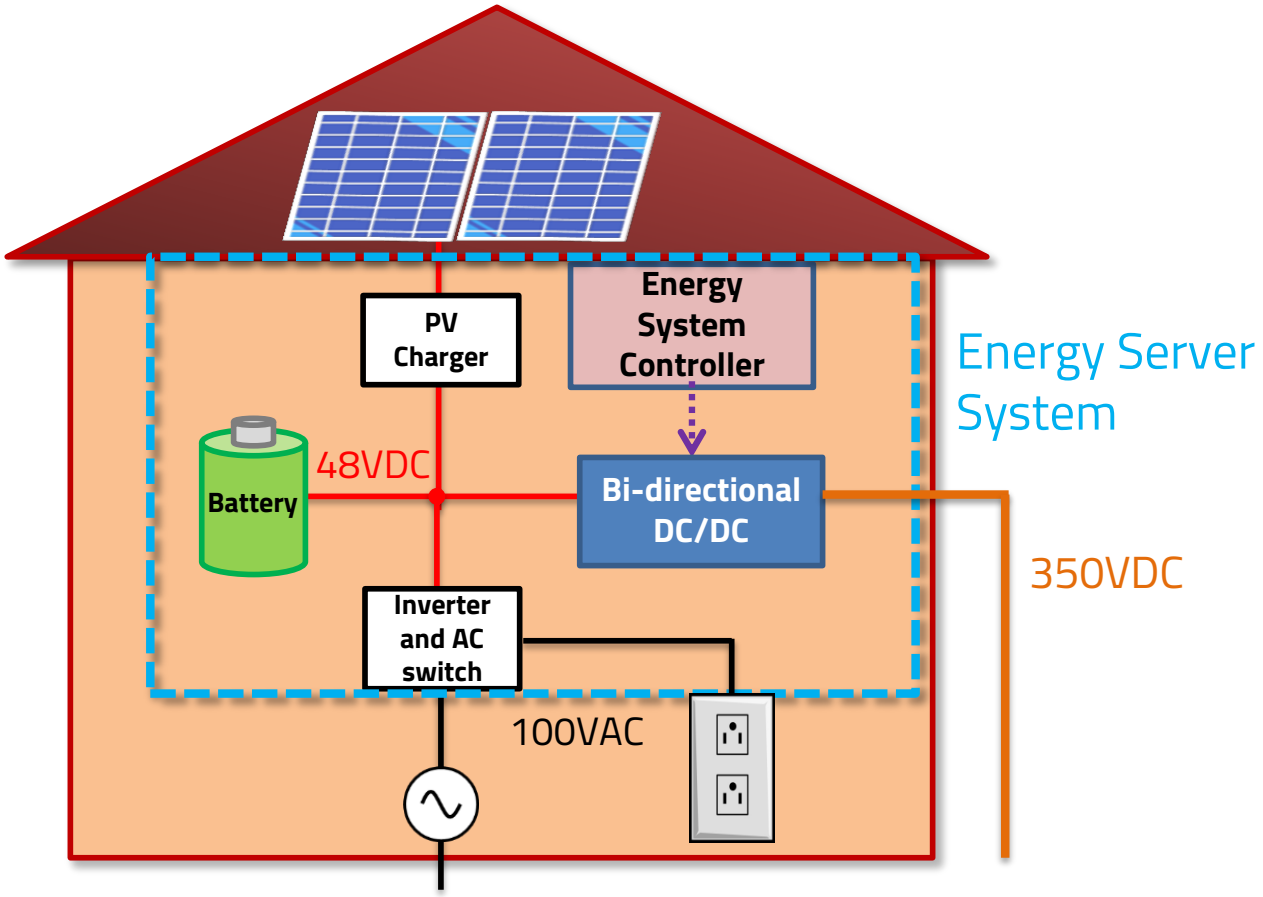


Most exchanges happen at the lowest level!

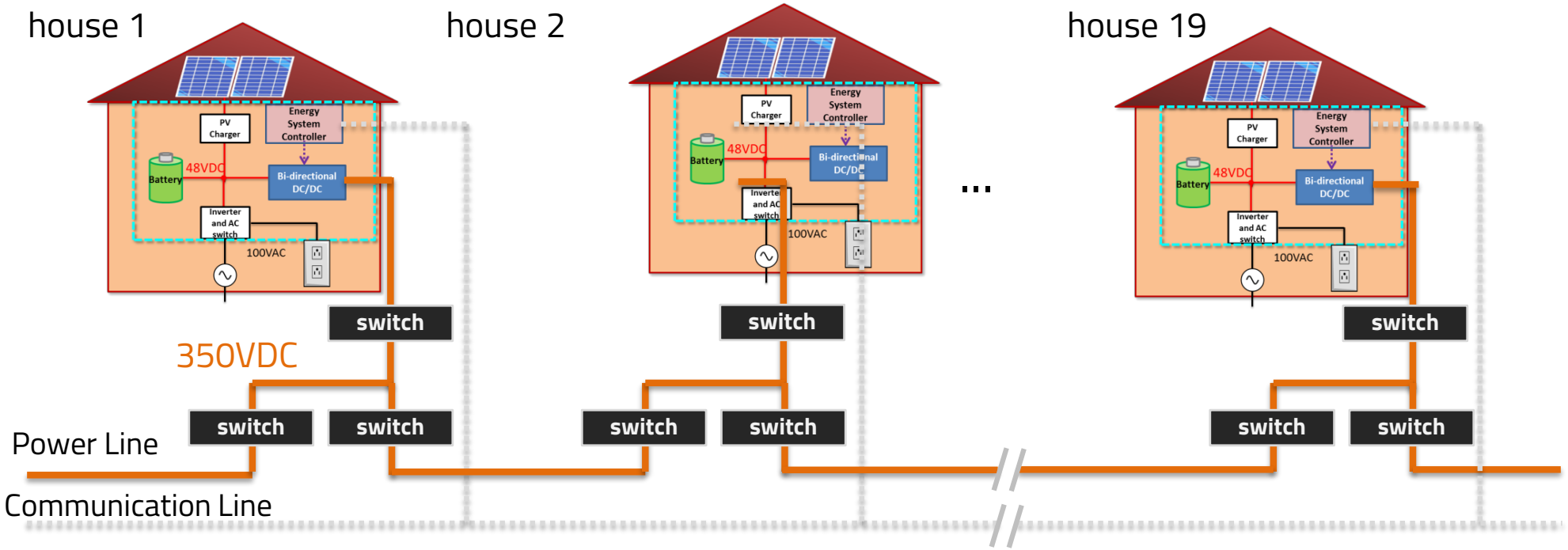


DCOES@OIST20 System Structure (1)

- Configuration of each house

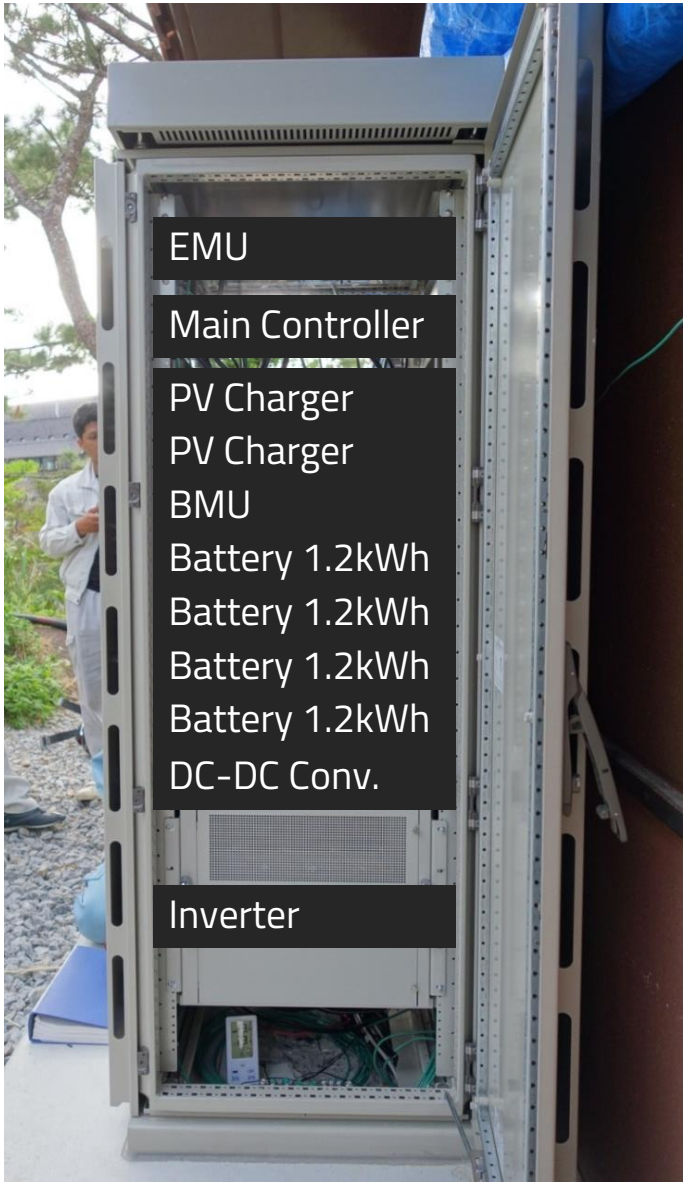


DCOES@OIST20 System Structure (2)

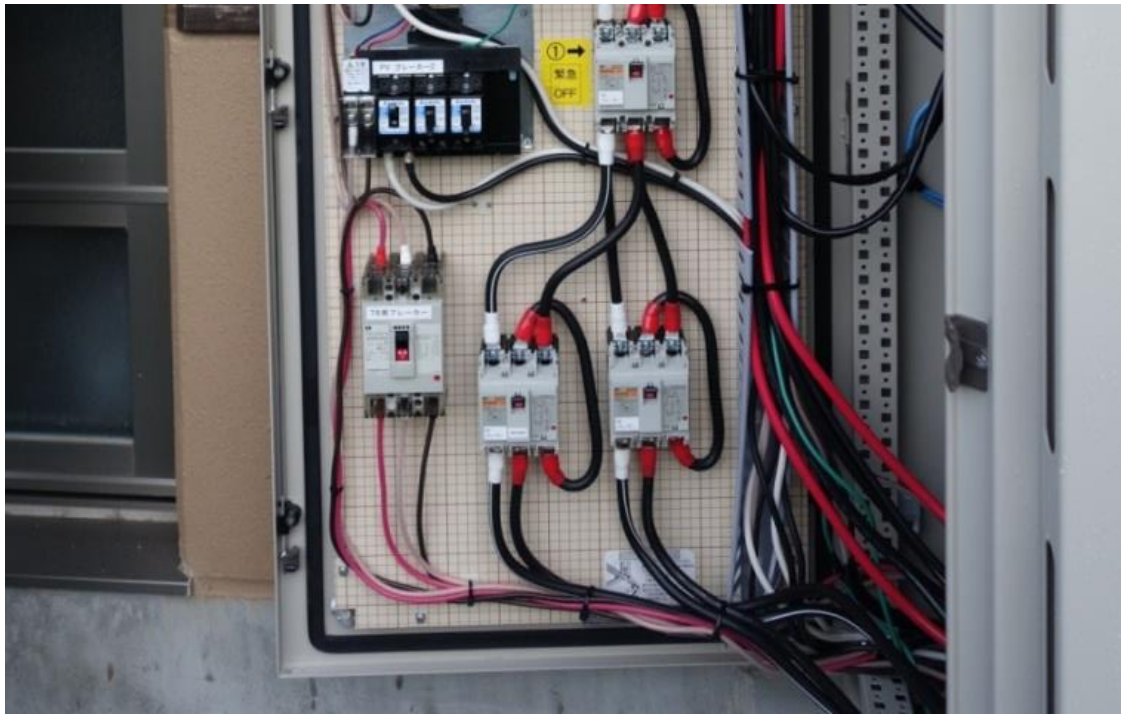


Energy Server System

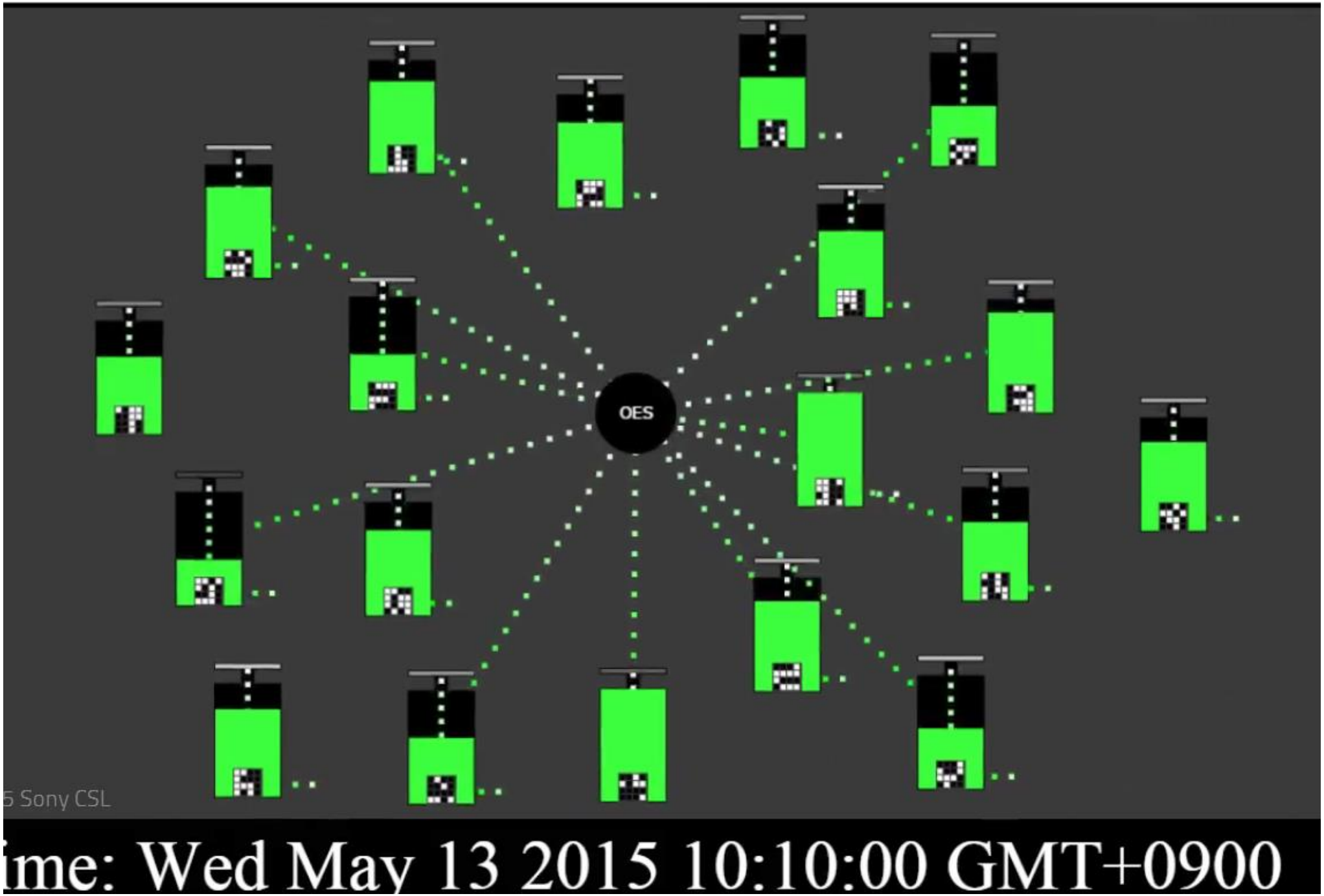
- SONY 48V Li-Ion battery modules
- 350V Grid
- Energy exchange module, DCDC
- DC to AC inverter for appliances
- AC backup by utility company



350V DC Power Lines (Privately Owned)



Example Daily Operation

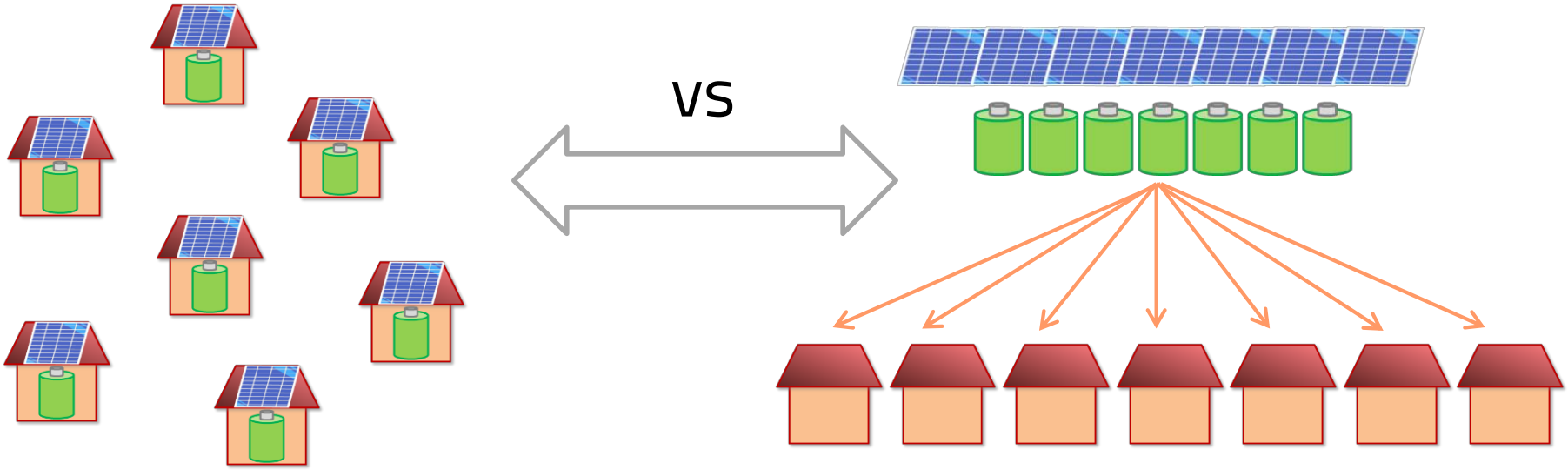


Performance Evaluation

Performance Evaluation

Distributed stand-alone

Centralized



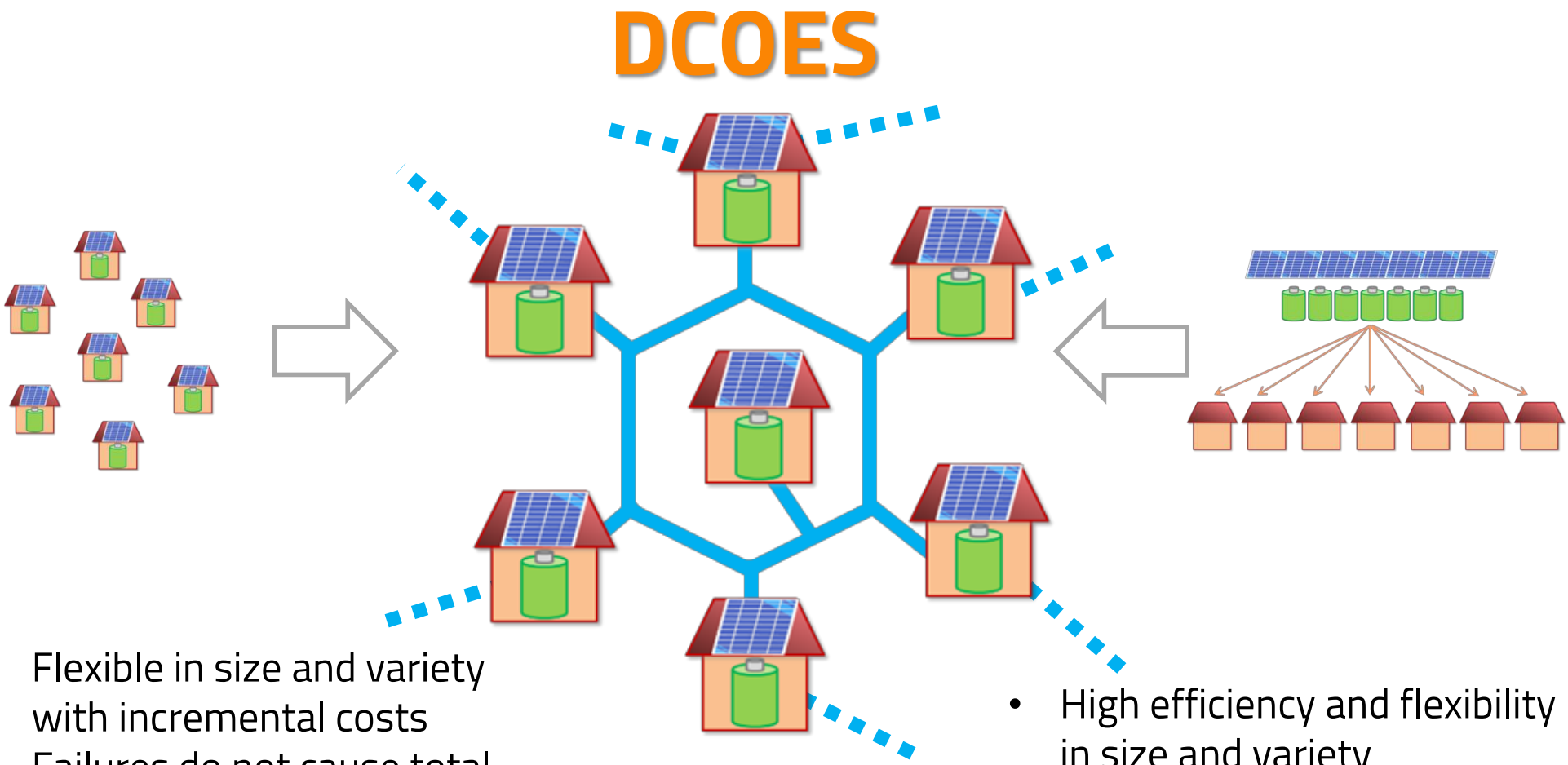
Bottom-up by individuals

- 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

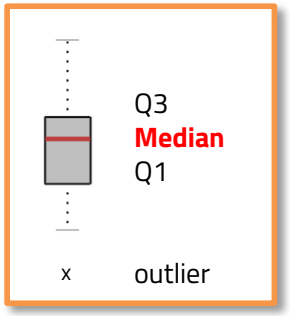
DCOES: Distributed System with Energy Exchange

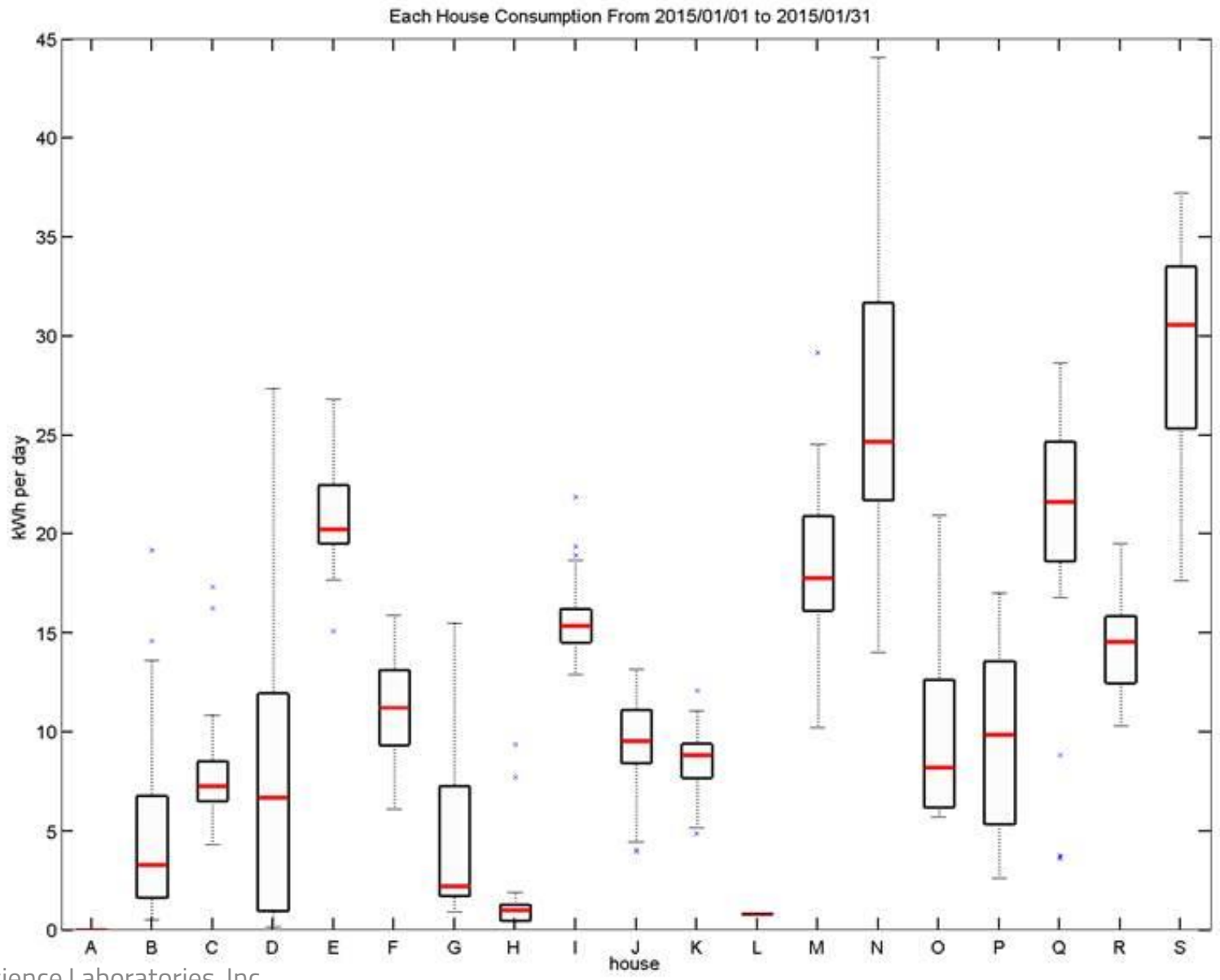


- Flexible in size and variety with incremental costs
- Failures do not cause total system outages

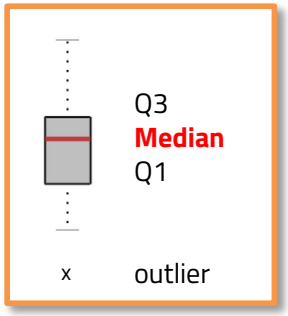
- High efficiency and flexibility in size and variety

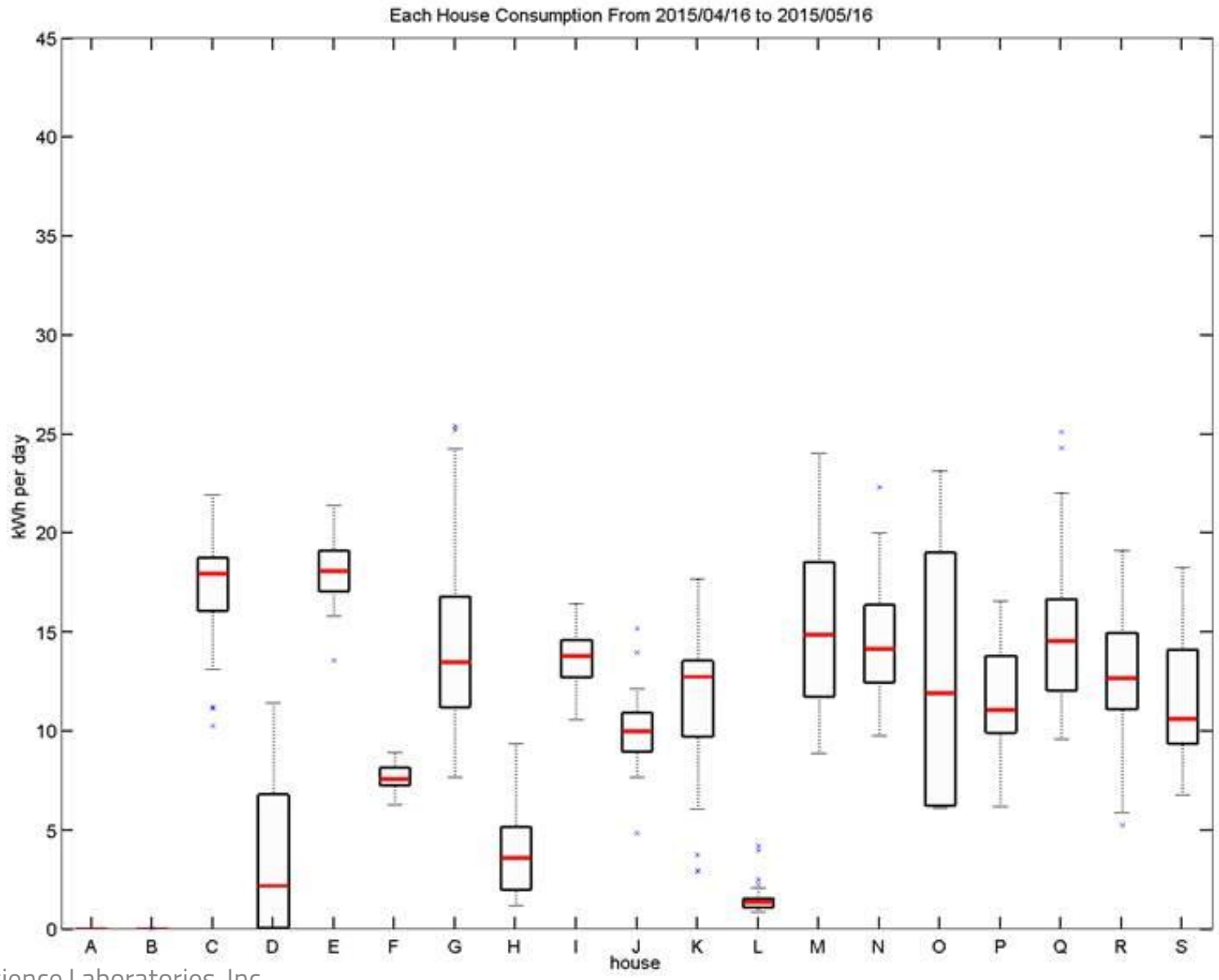
Variety in usage pattern (Winter)





Variety in usage pattern (Spring)



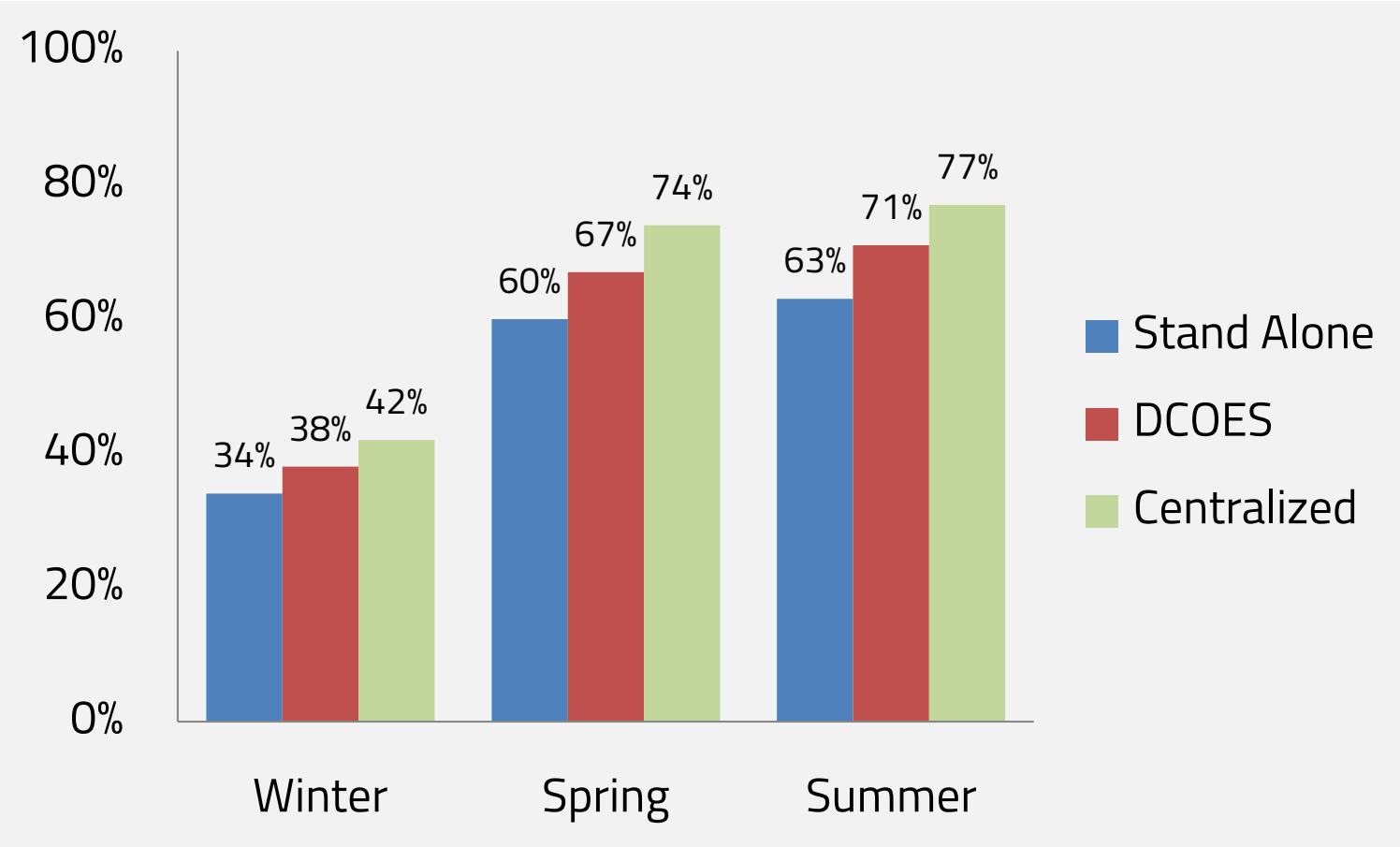


Performance Result and Estimation
(Current OIST configuration with baseline policy)

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



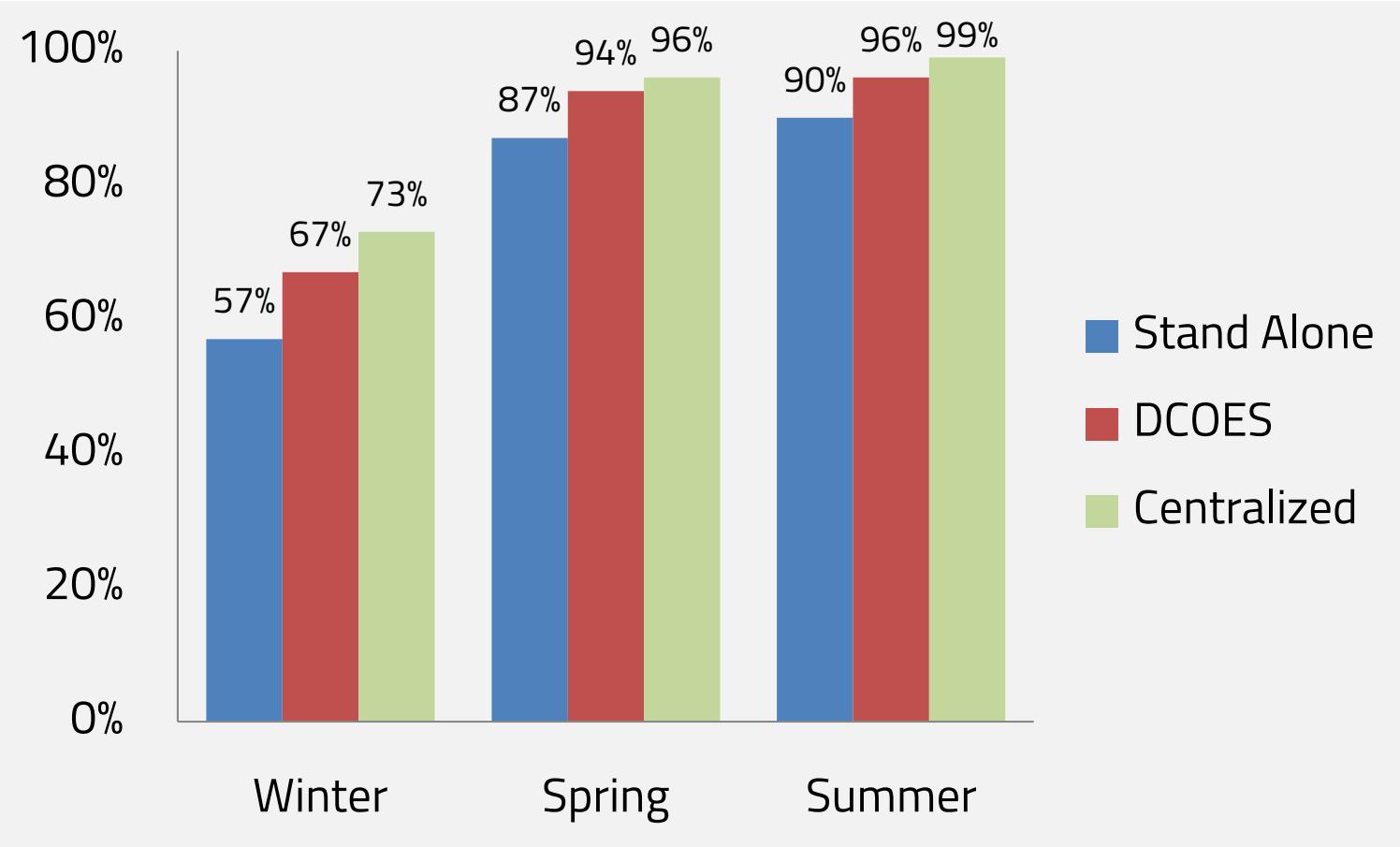
Self-sufficiency ratio = (Energy used - Energy bought)/ Energy used

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

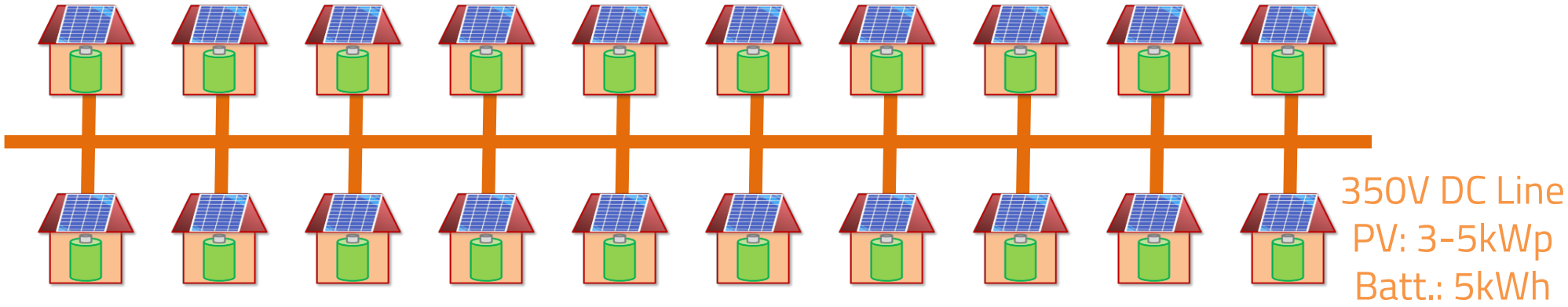
Summer: Simulation (19 houses)
2015/7/16- 8/15



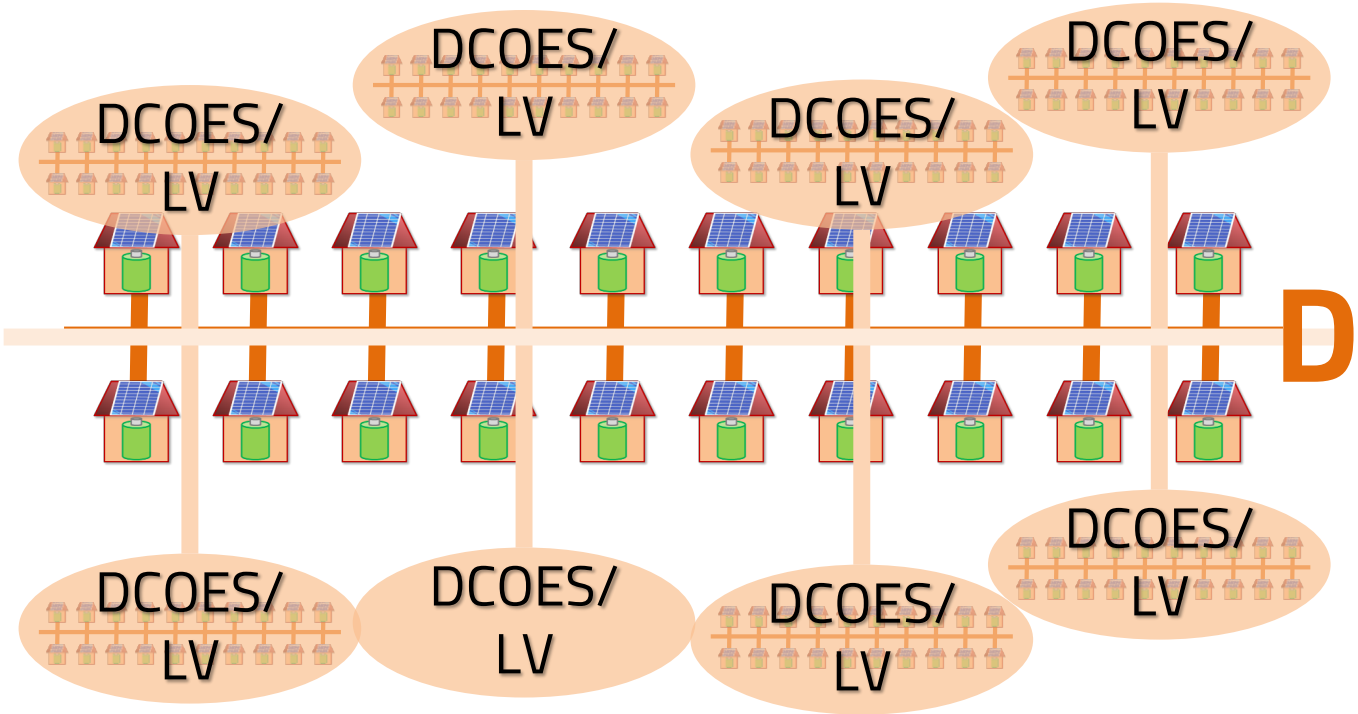
Self-sufficiency ratio = (Energy used - Energy bought)/ Energy used

Next Plans

DCOES/LV for Houses in a Community



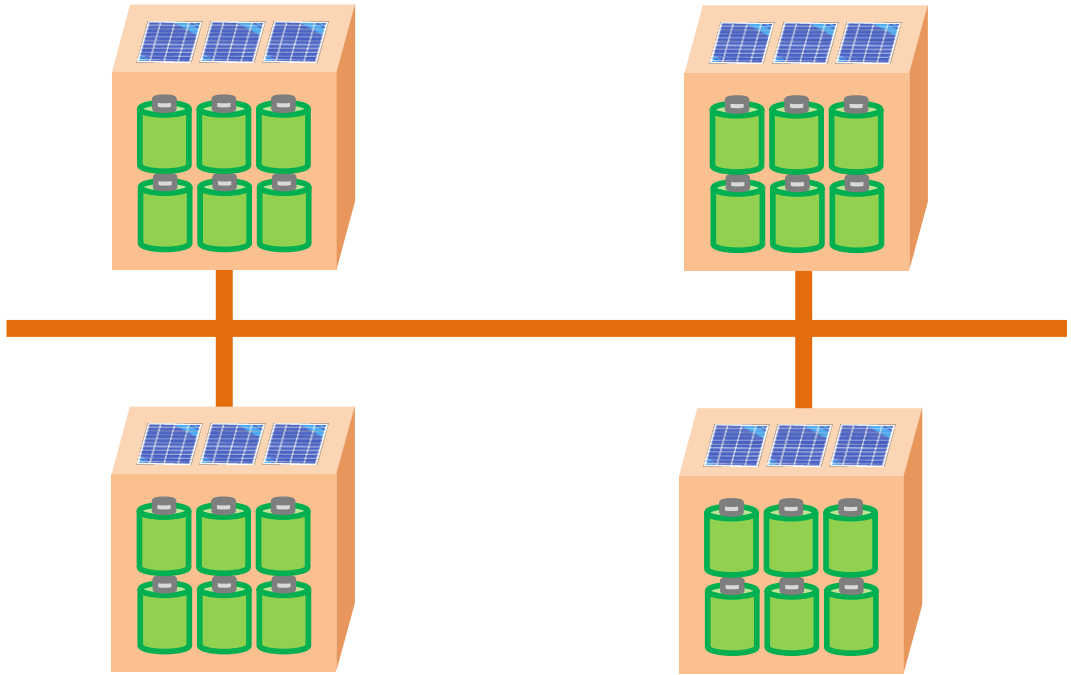
DCOES/MV for Larger Communities



DCOES/MV

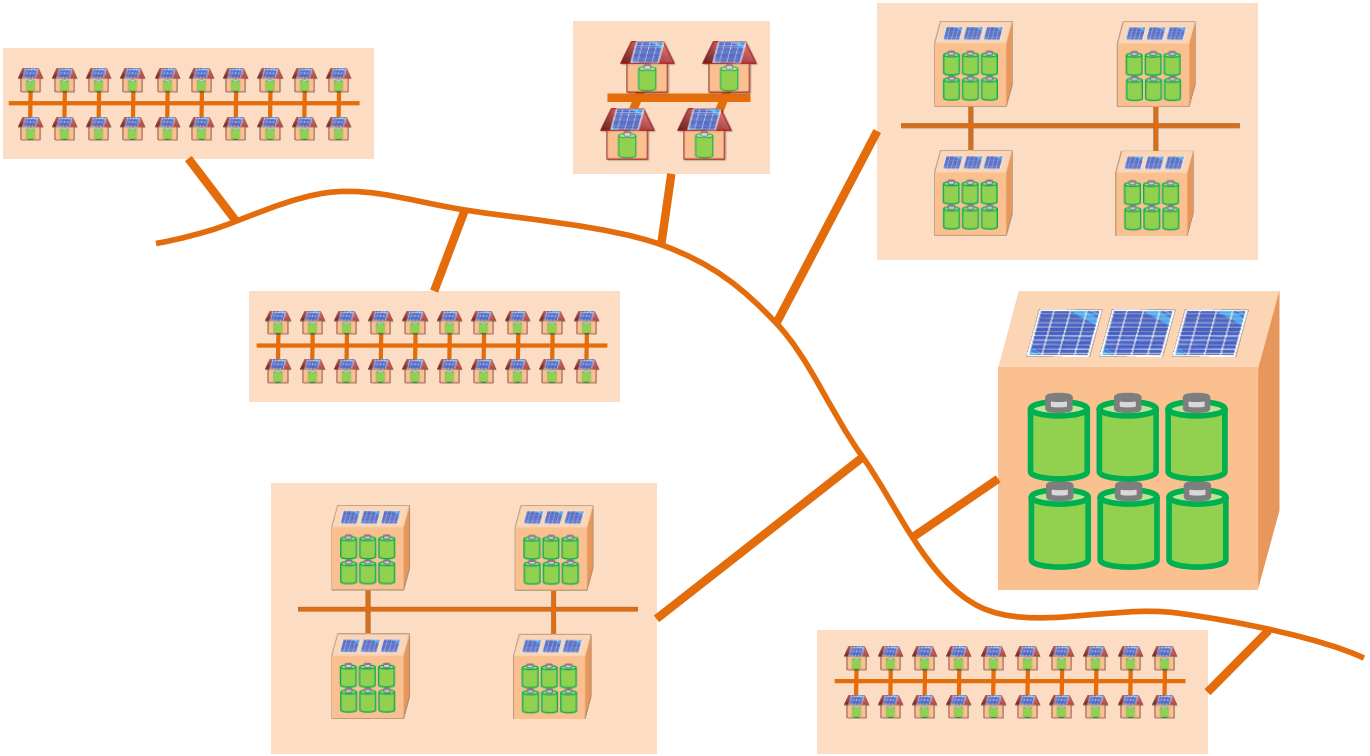
350V DC Line
PV: 3-5kWp
Batt.: 5kWh **+ 1KV Line**

DCOES/MV for Eco Campuses



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

DCOES/HV for Cities



Acknowledgements

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