Hybrid AC/DC House for Future Net Zero Energy Home

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CAL POLY

Outline

- Future Sustainable Net Zero Energy Homes
- Problems with AC
- Needs to Complement with DC
- Proposed Solution: Hybrid AC/DC House
- Challenges & Opportunities
- Summary

Future Sustainable Net Zero Energy Homes

- NZEH as the Future Homes
  - ***AC Grid-tied*** energy efficient homes that produce as much renewable energy as they consume over the course of a year, resulting in a net zero energy bill, and a carbon-free home
  - combines advanced design and superior building systems
  - mostly rely on ***DC operated*** solar panels as the energy source and optional energy storage
  - will incorporate sensors, intelligent devices, ICT technologies to enable automation and remote control or home appliances as well as management or coordination of energy source(s), energy storage, and loads

- The use of existing AC residential electrical system will make it *more challenging* to achieve the NZEH ➔ Needs for DC electrical system

Problems with AC

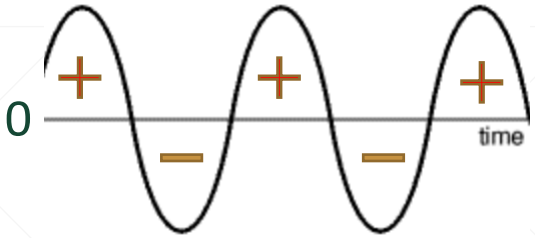
Power conversion loss from the mismatching signals ➔ more energy consumption ➔ makes it harder to achieve NZEH

AC Wall Outlet

AC to DC Converter

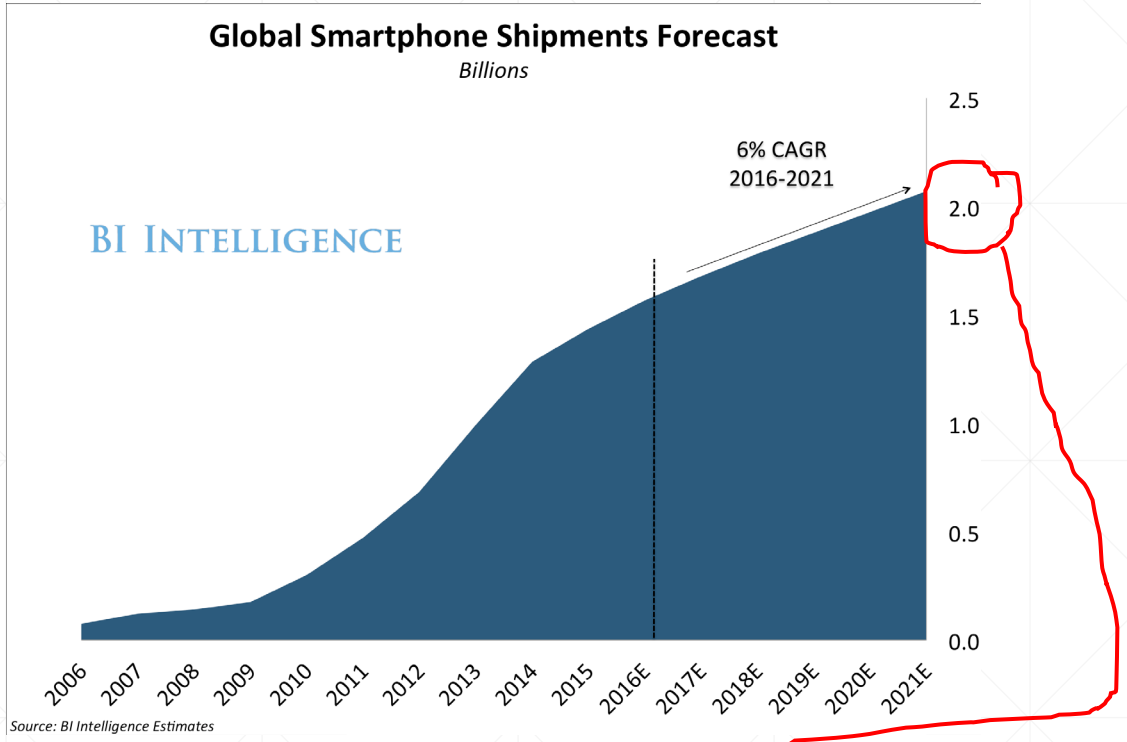
DC Load

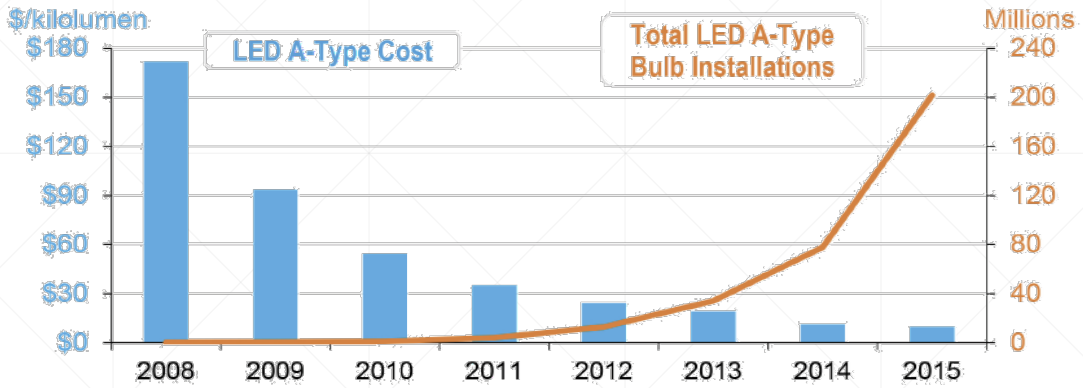
17 to 35% Loss



Needs to Complement with DC

Increasing number and uses of residential DC loads





Source: Energy Source at Haas

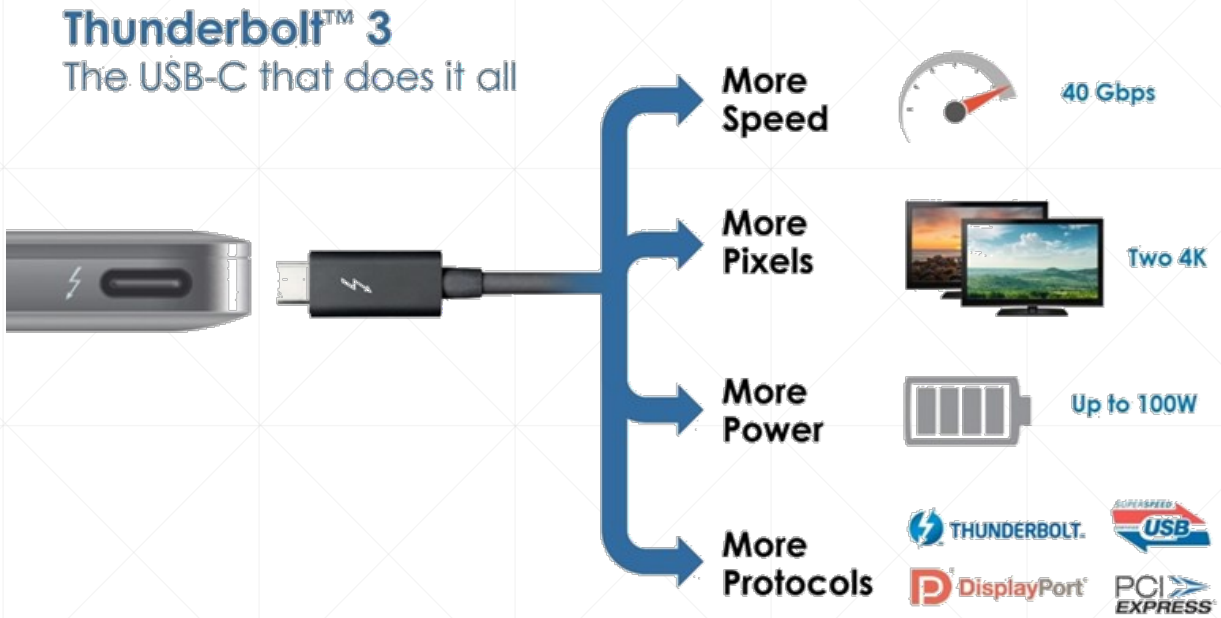
- Smart homes (smart lighting, locks, blinds, thermostat, etc.) and CCTV require DC

5V x 1A x 1 hr x 2 Billions = 10,000,000,000 Wh = 10 GWh!

Needs to Complement with DC

Advances in technologies facilitating increased proliferation of residential DC loads

- Example is **USB-C**
- Earlier provision of ***Up to 100 W ➔ Now Upgraded to 240 W***

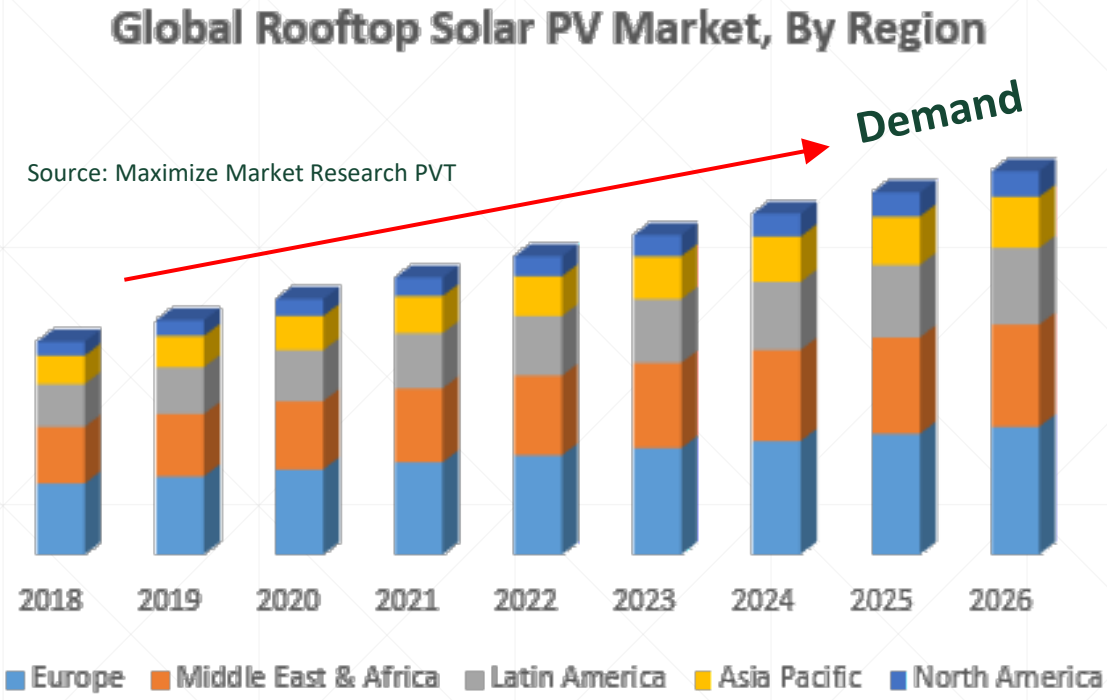


Ability to power bigger devices can be powered through USB

Needs to Complement with DC

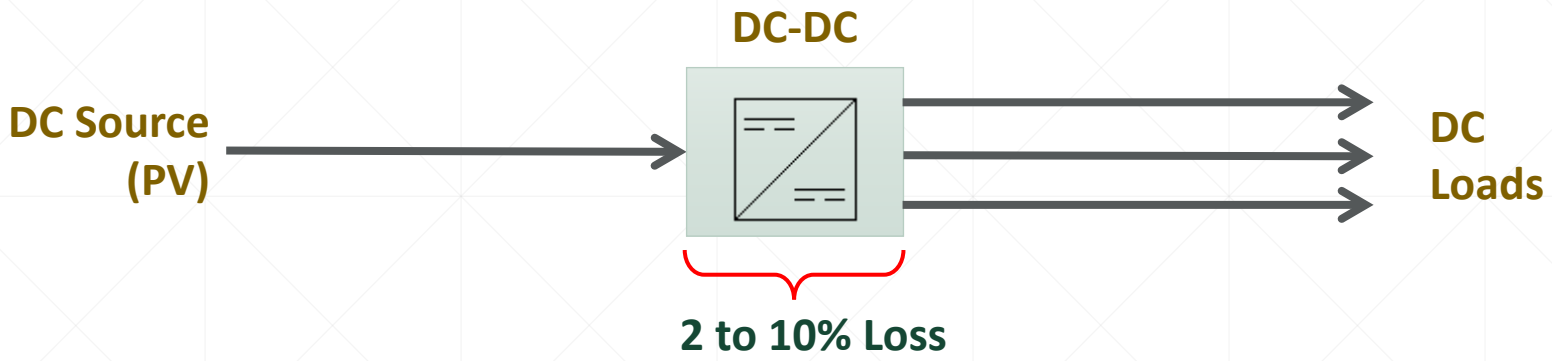
Increasing Use of Renewables, especially Rooftop Solar Panels

- More prevalent residential rooftop PVs
- DC power source right at your fingertips!

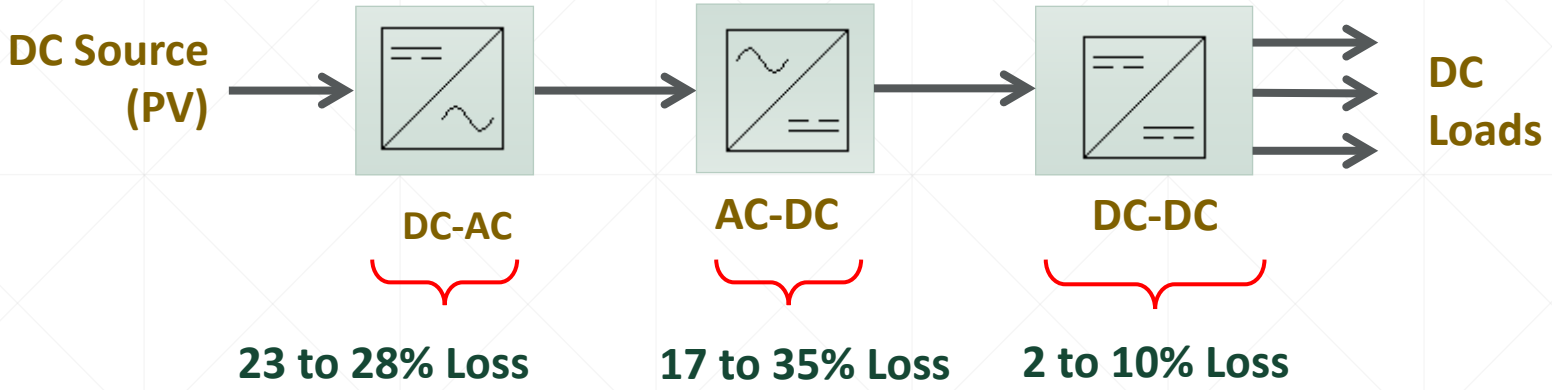


Needs to Complement with DC

Improving Electrical System's Performance and Efficiency



is definitely more efficient than

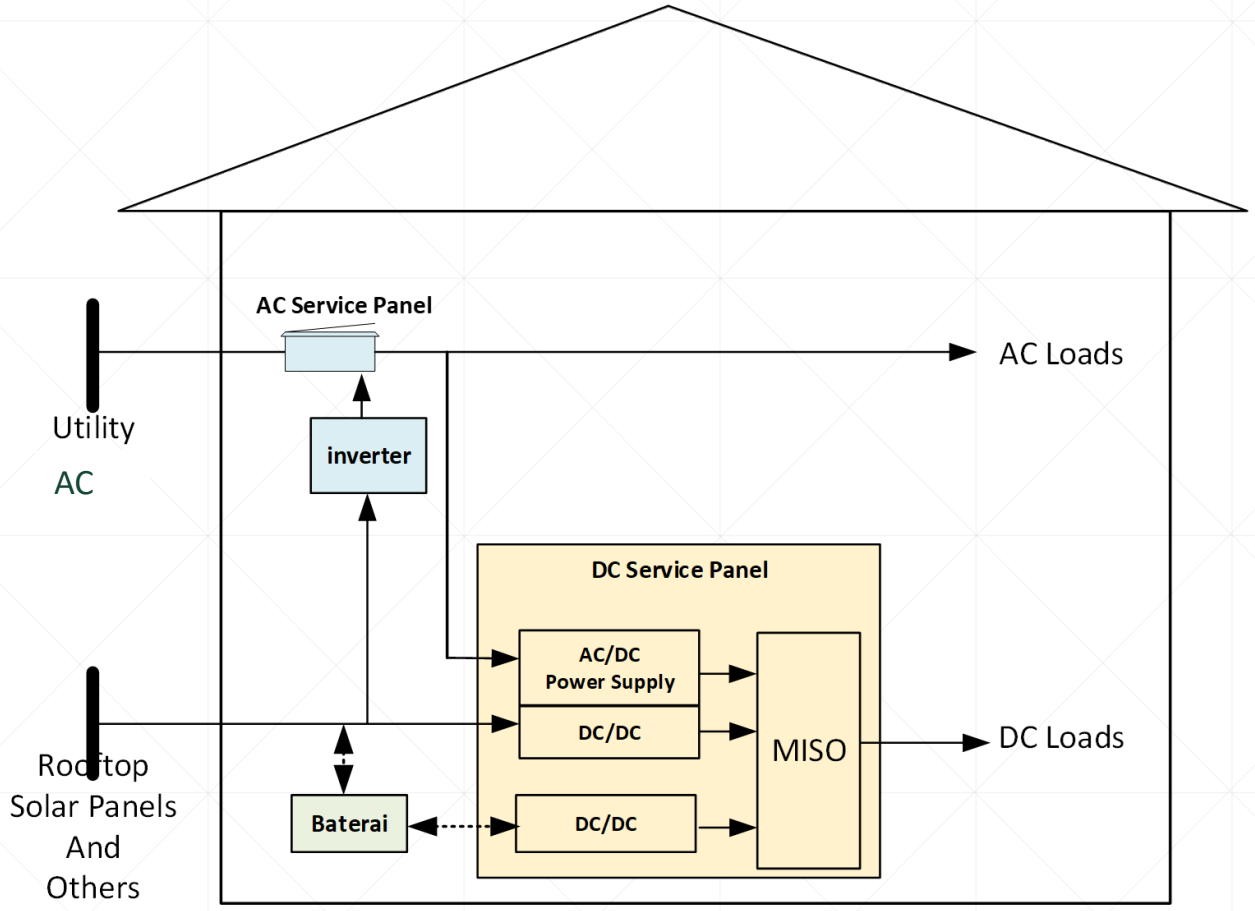


Needs to Complement with DC

Enhanced reliability via additional residential scale DC based energy storage

Proposed Solution: AC/DC Hybrid House

- Hybrid AC/DC House
  - Operates on crisscrossing AC and DC electrical systems
  - Dedicated AC line for AC loads
  - Dedicated DC line for DC loads
  - Ability to support either load type when their corresponding source is down
  - Battery is optional but will improve system reliability and performance
  - DC line may utilize the DC House Technology
  - Additional sources may be connected to the house



Hybrid AC/DC Demo House at Cal Poly

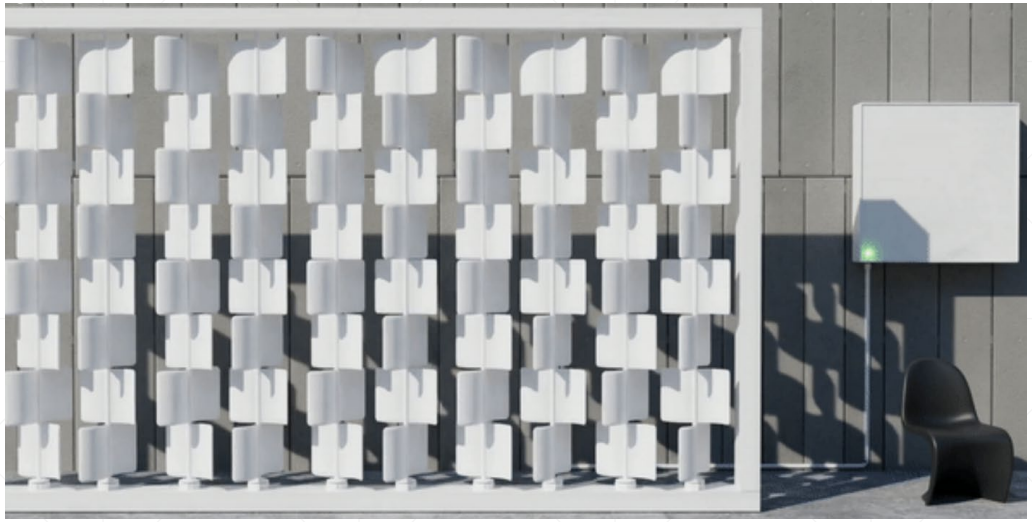
Challenges on the Hybrid AC/DC House

- **CHALLENGES** present **OPPORTUNITIES** for new technological developments bringing in **INNOVATIONS**
  - Limited DC sources and Maximizing the use of Renewable Energy Source
    - Even more important in areas where AC grid is not reliable
  - Making other renewable energy sources adoptable
  - DC bus and loads are not standardized, unlike AC
  - DC is more difficult to protect from faults
  - Strict regulations due to ability to back feed power
  - A unifying energy management system (EMS) has NOT yet been developed

Challenges: Adoptability

NIMBY: Not In My Back Yard!

vs.

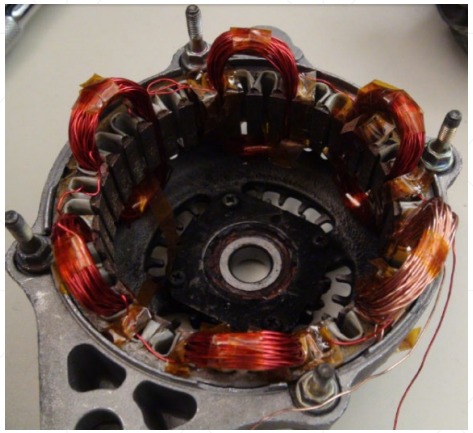


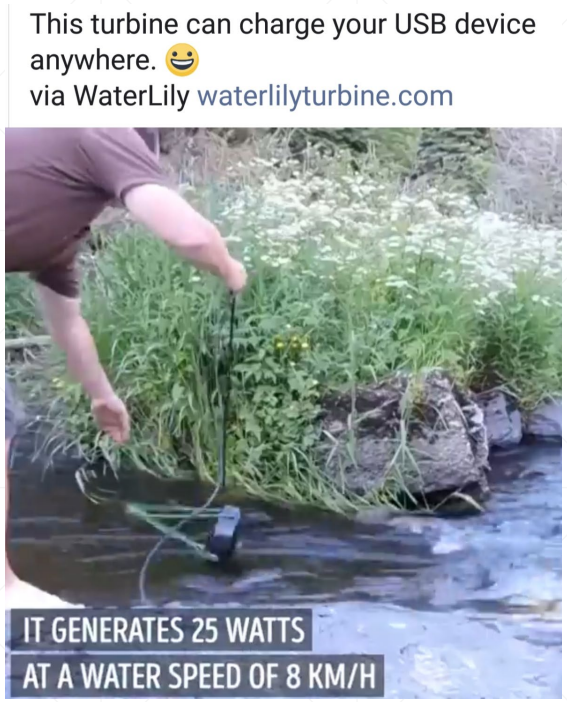
Wind power wall

Status: Generation Technologies

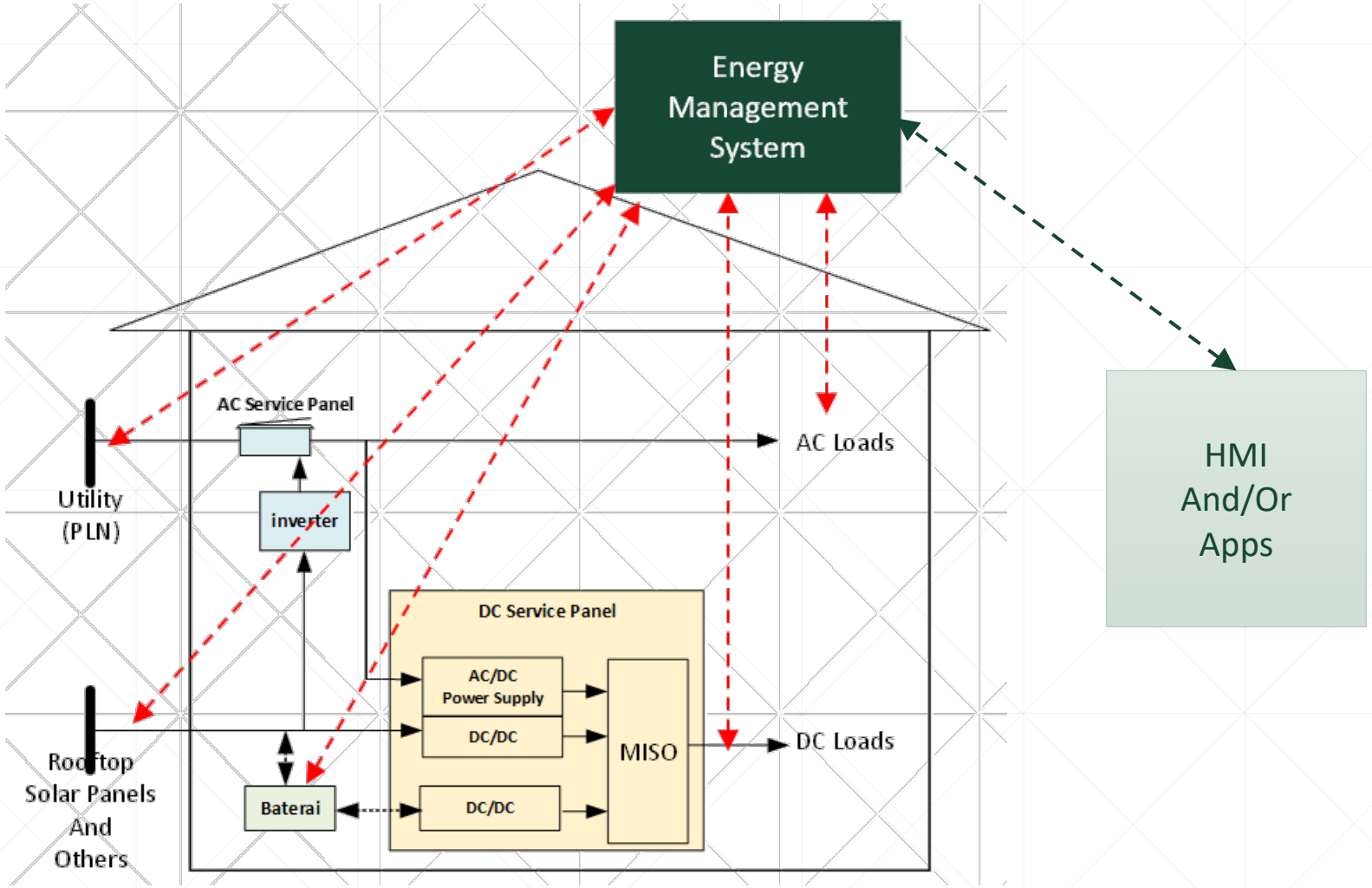
Electric Power Generators

- Portable hydro & wind power generators
- Re-winding used car alternators
- Play-park and exercising machine power generators



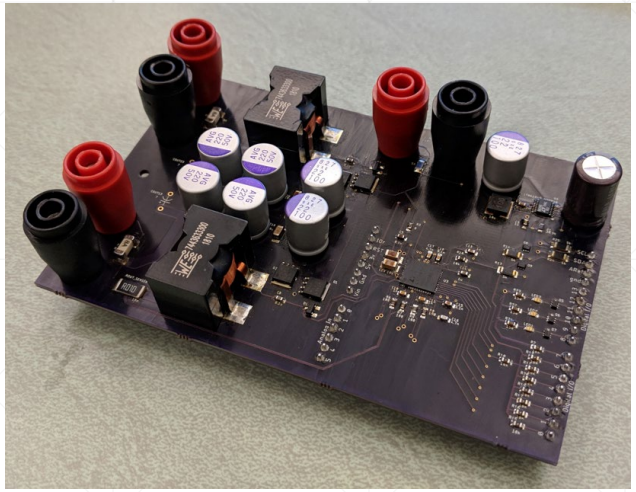


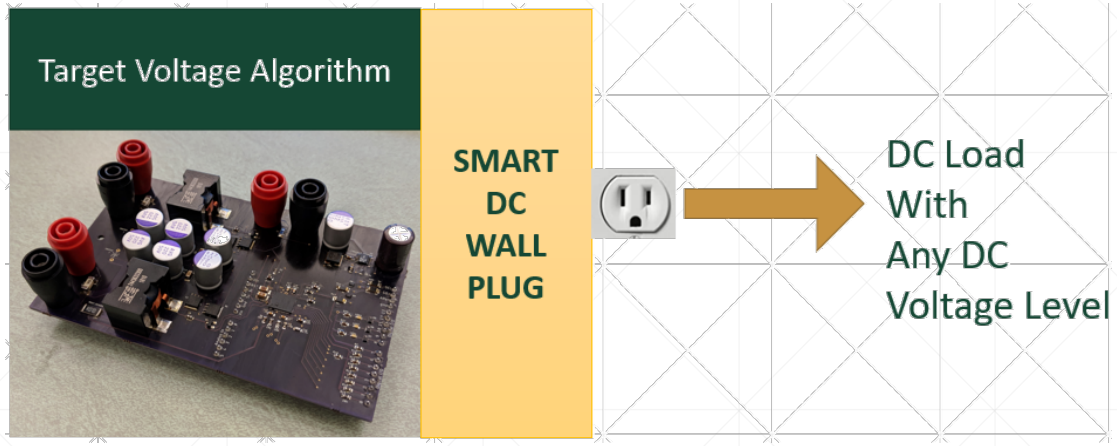
Challenges: A Unifying Self Automated EMS



Challenges: Unstandardized DC

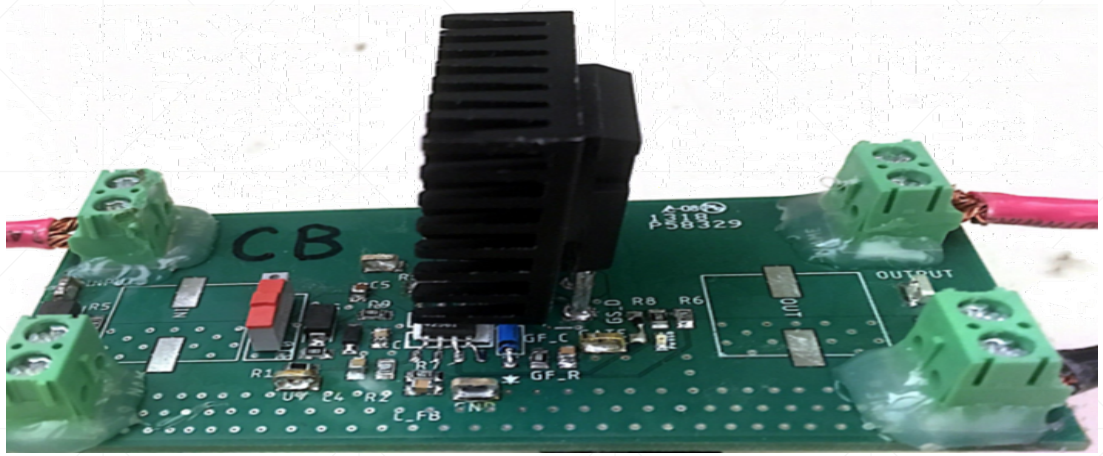
- Smart Wall Plug allowing any load with various DC operating voltage
- USB-C PD Compatible Plug





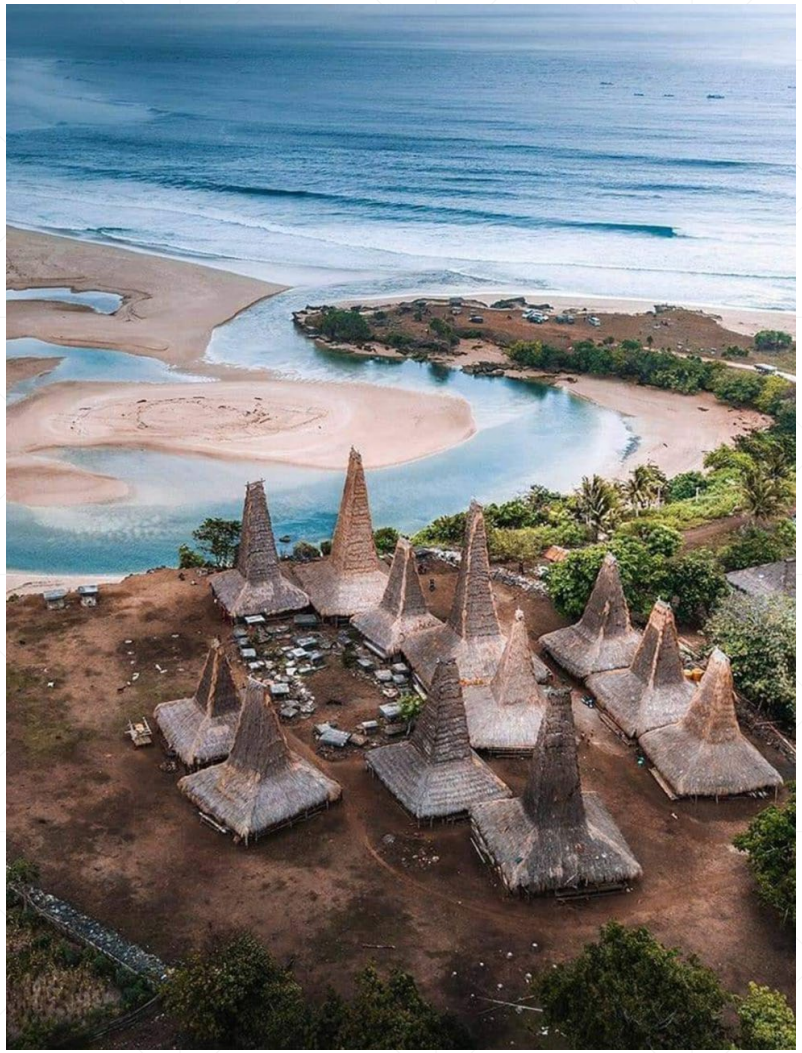
Challenges: Protecting DC

- DC is harder to protect since DC current is always high (no zero crossing)
- DC Circuit breaker must be able to clear fault fast at high current
  - Solid state DC breaker



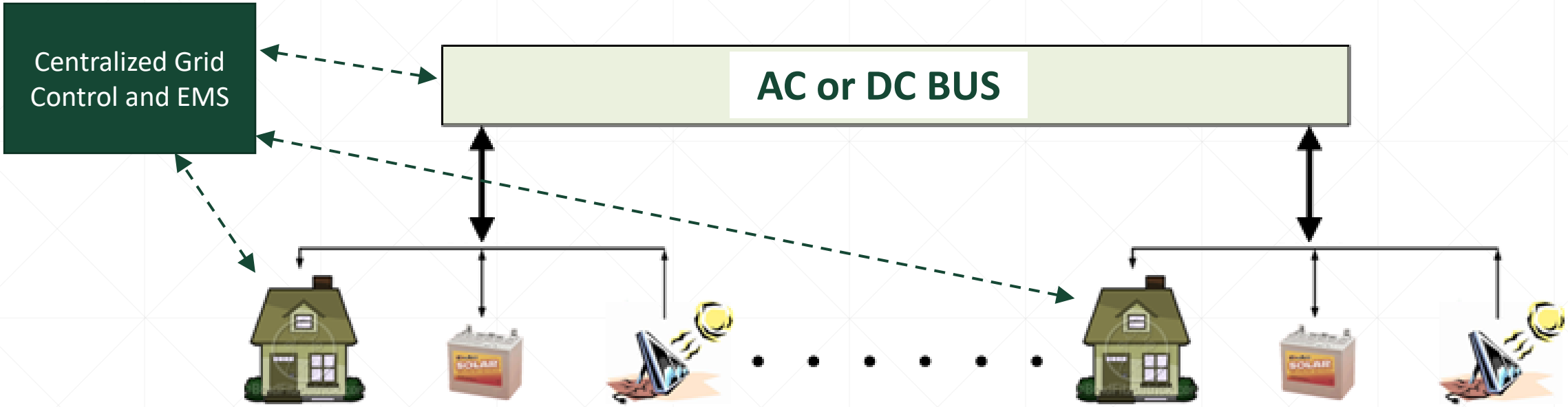
Opportunities for Improving Rural Electrification

- Villages with Clustered Houses



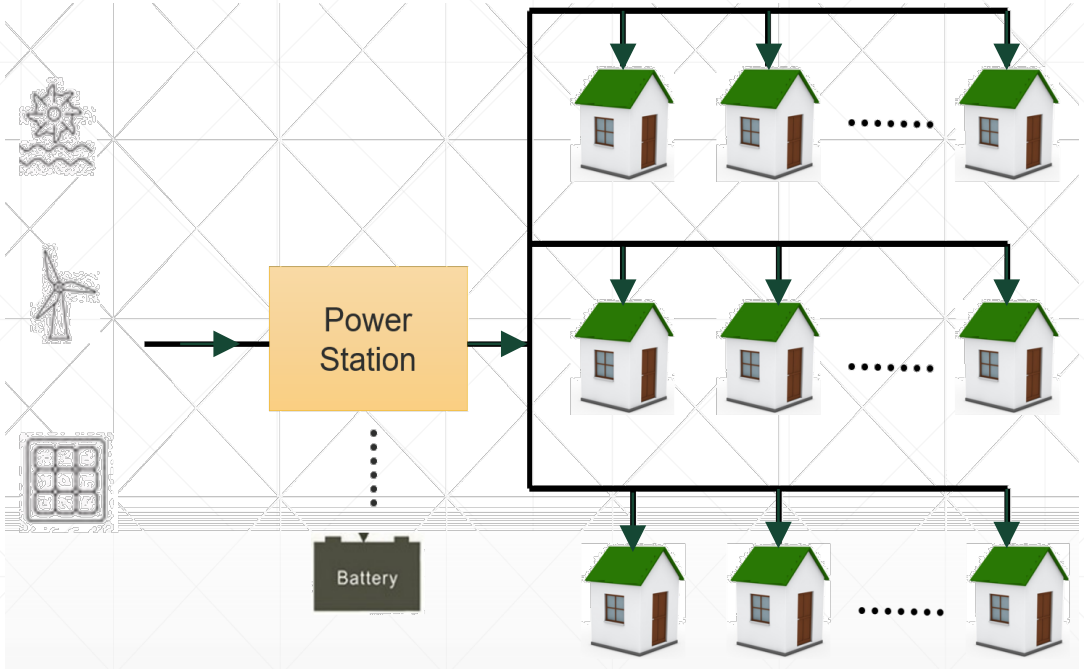
Opportunities for Improving Rural Electrification

- Allows exchange of power in a small cluster of Hybrid AC/DC houses
  - Allows improved reliability due to redundancy
  - Suitable for villages consisting of more concentrated population (island, cluster of remote villages)



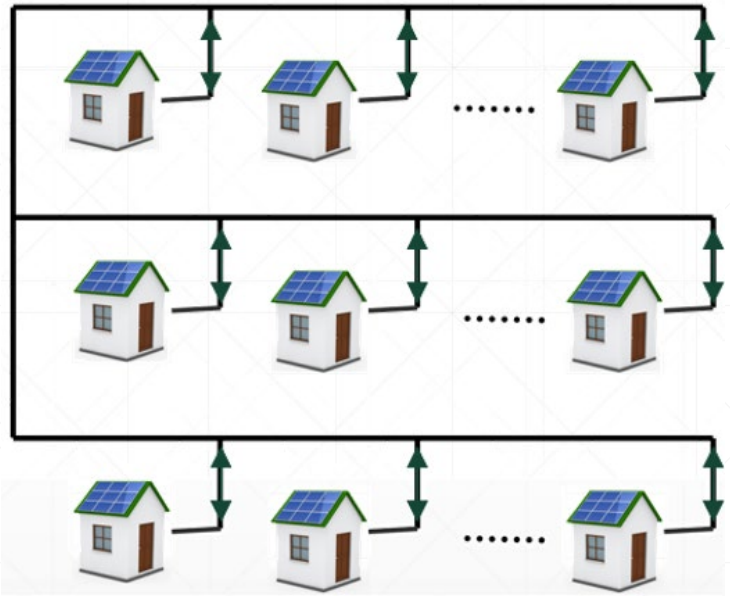
Opportunities for Improving Rural Electrification

Existing (Present) Centralized System
For Rural Electrification

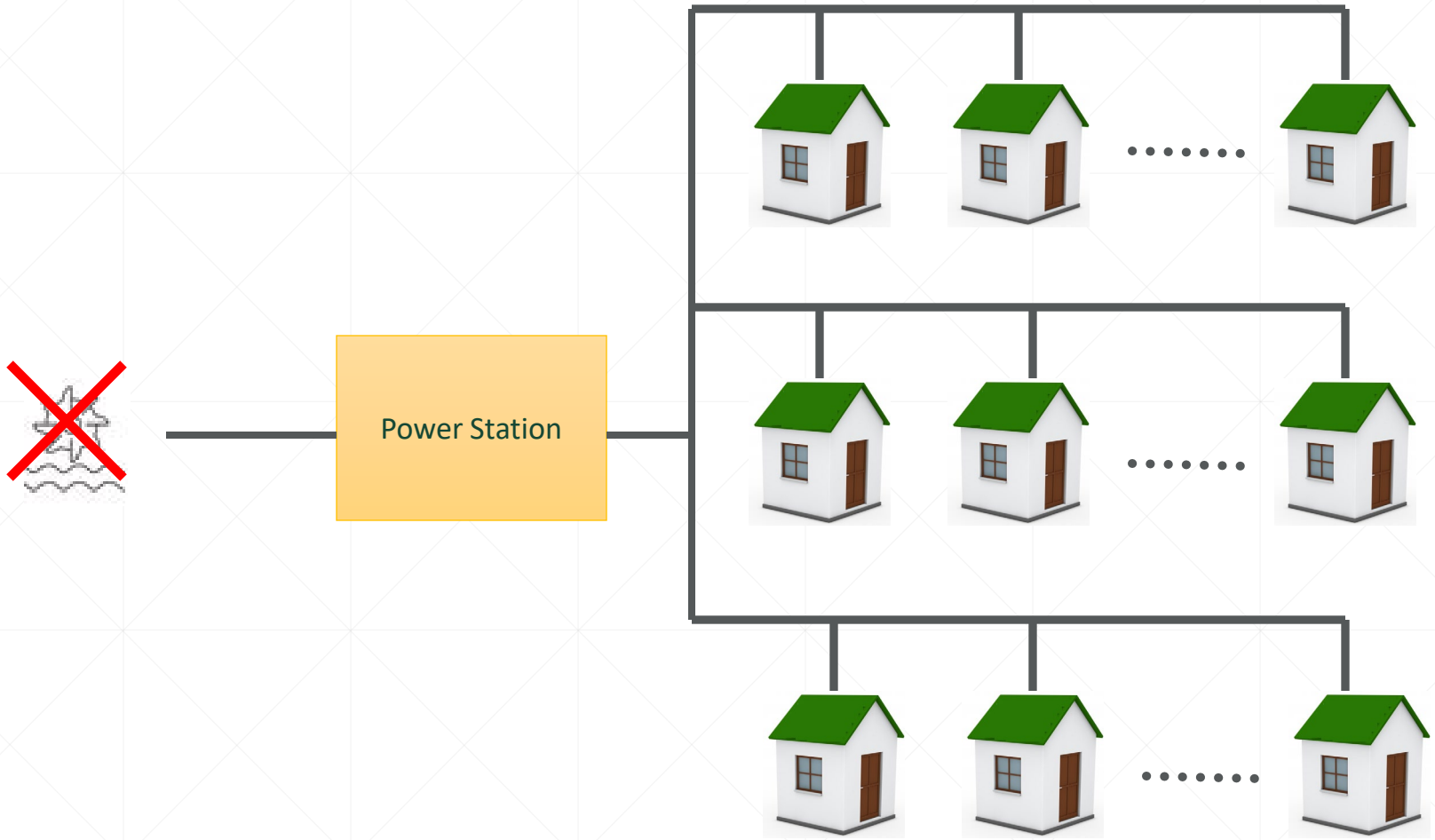


vs.

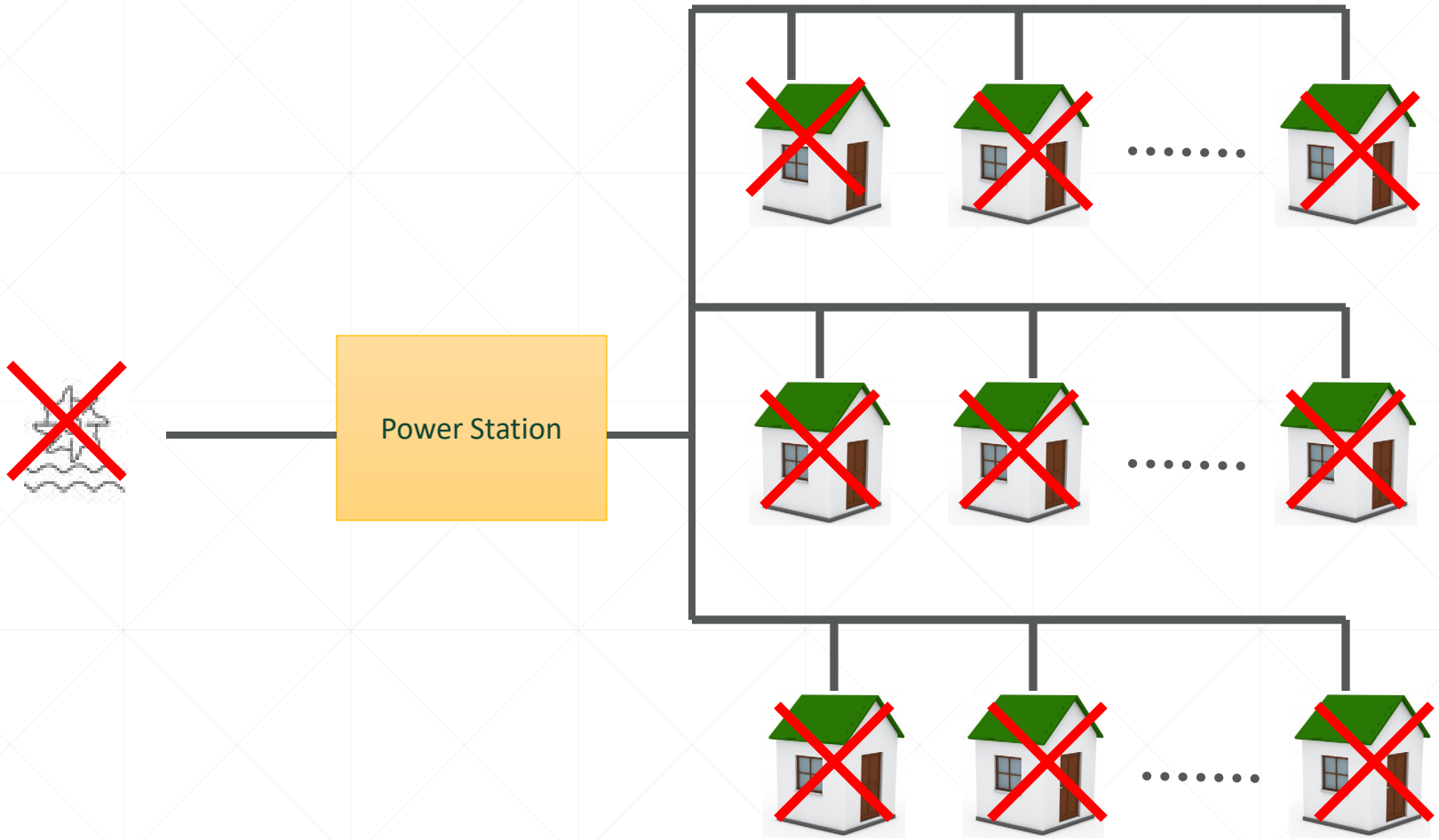
Improved Hybrid AC/DC House
System For Rural Electrification



Improved Reliability, Resiliency, Scalability



Example of Existing System



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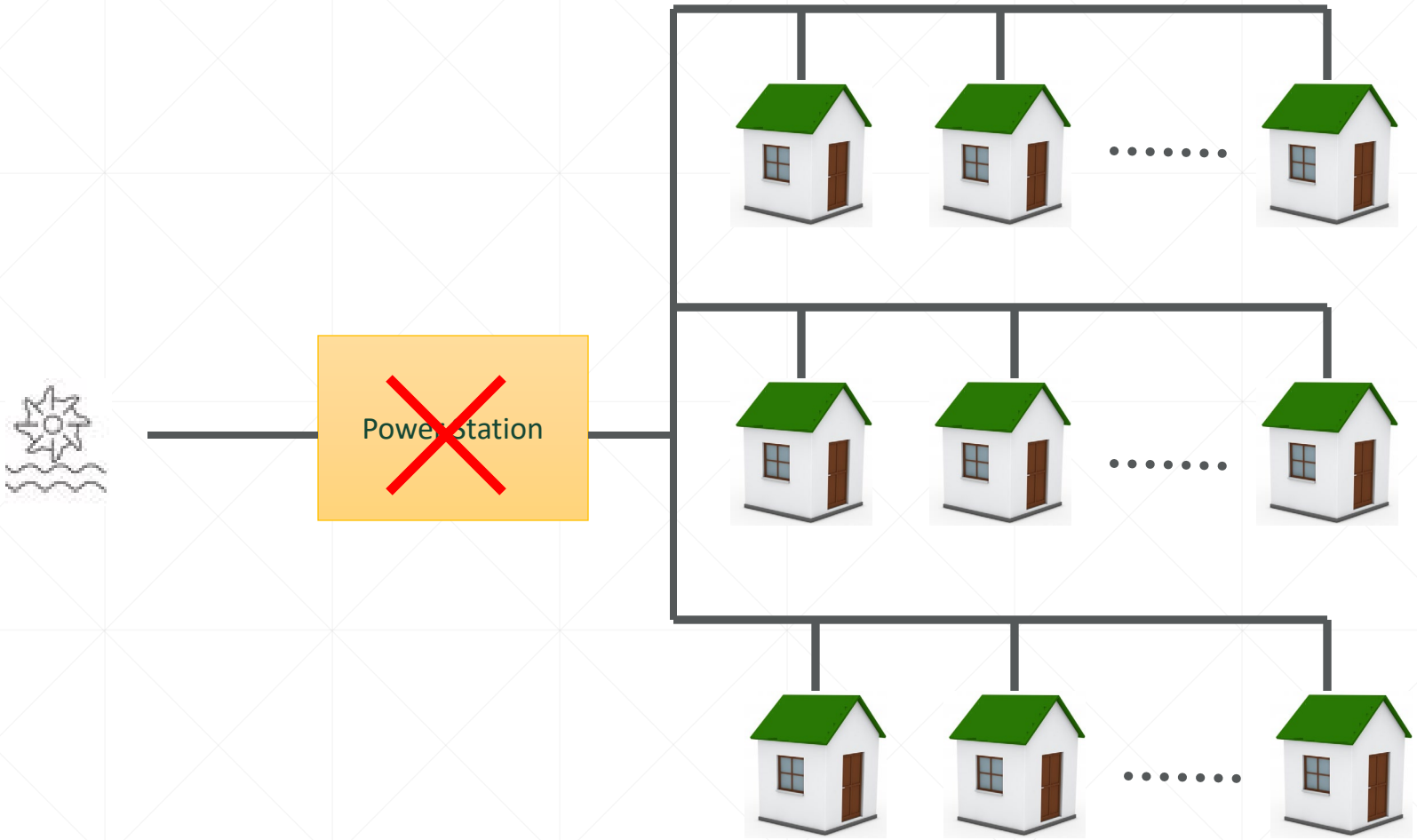

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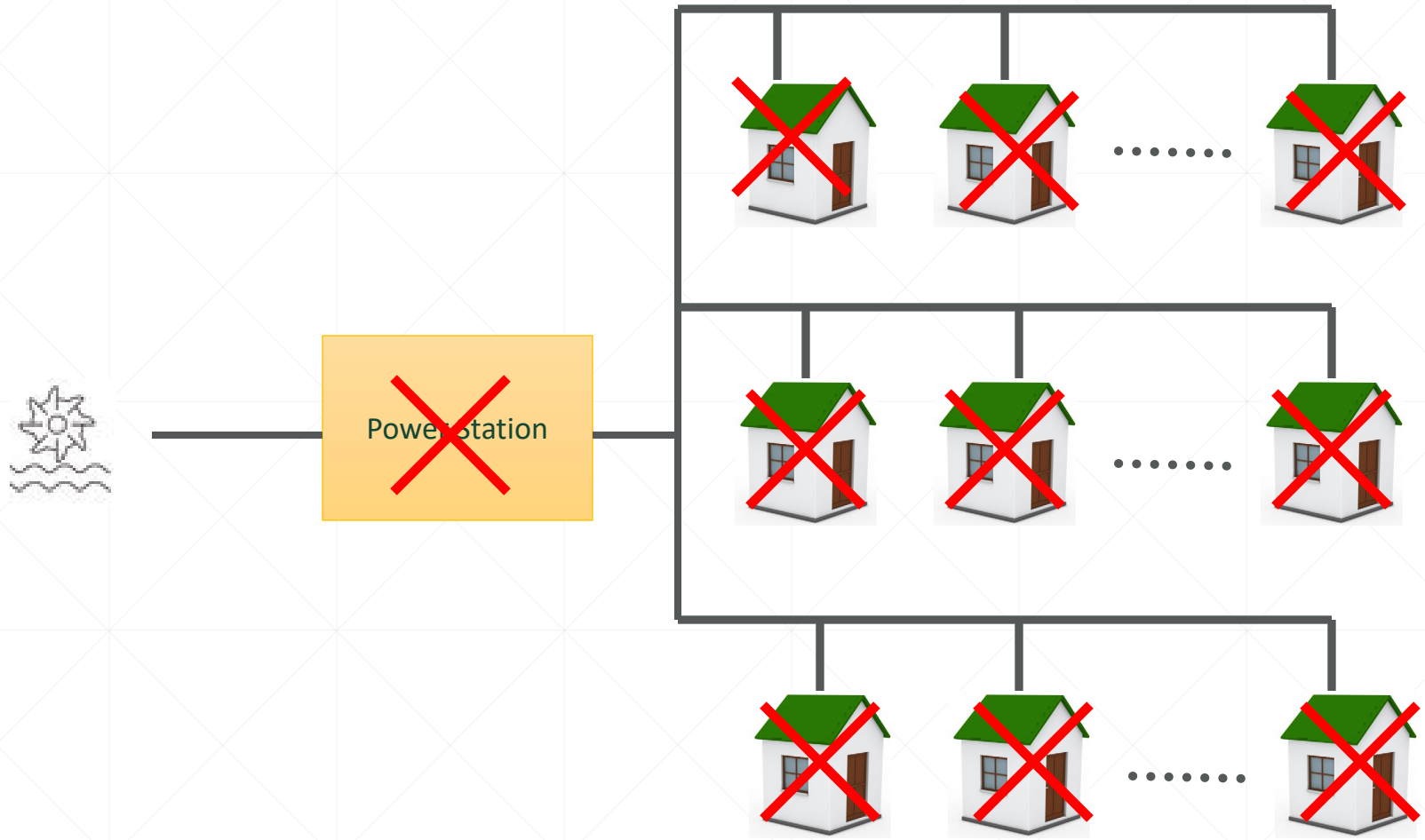

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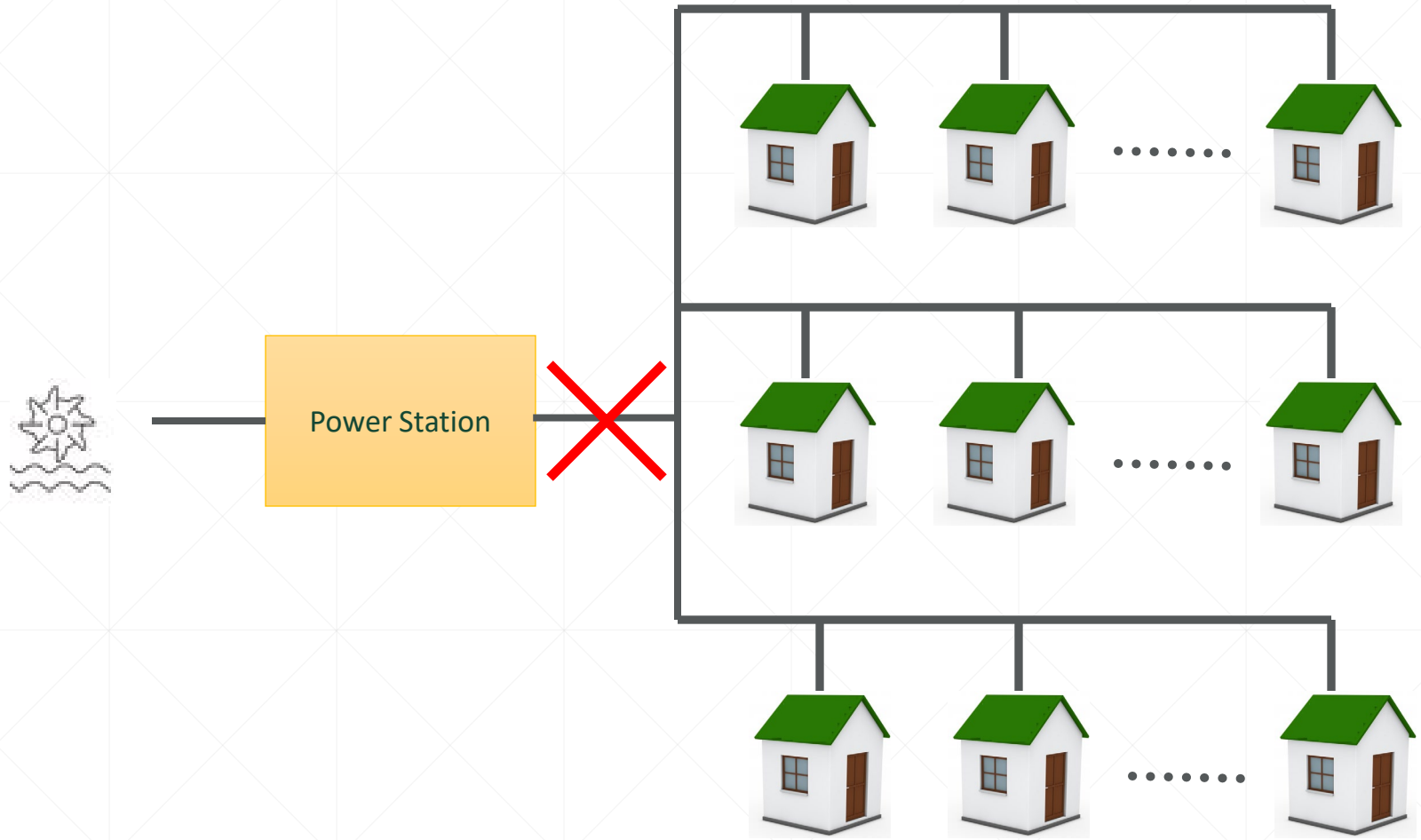

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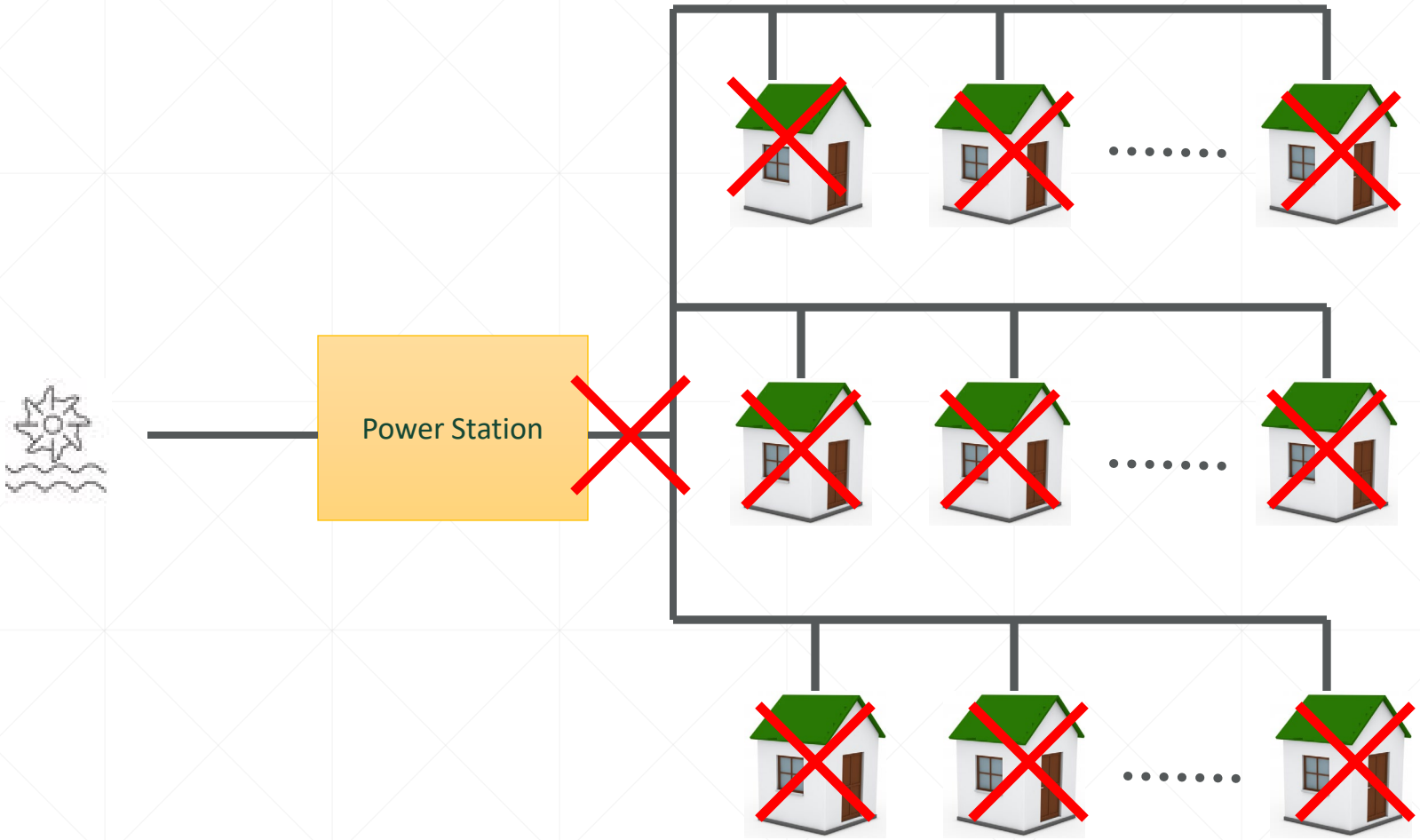

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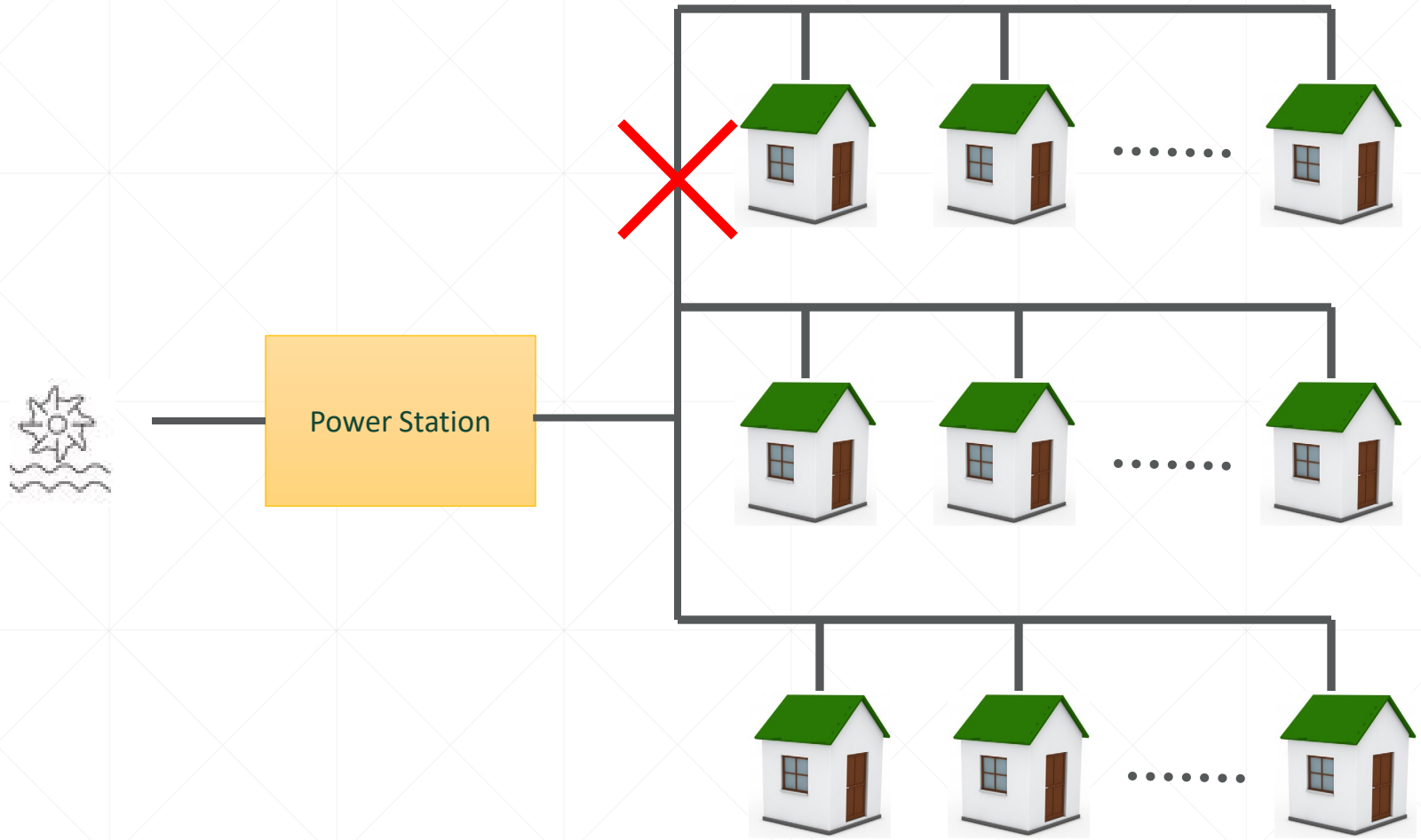

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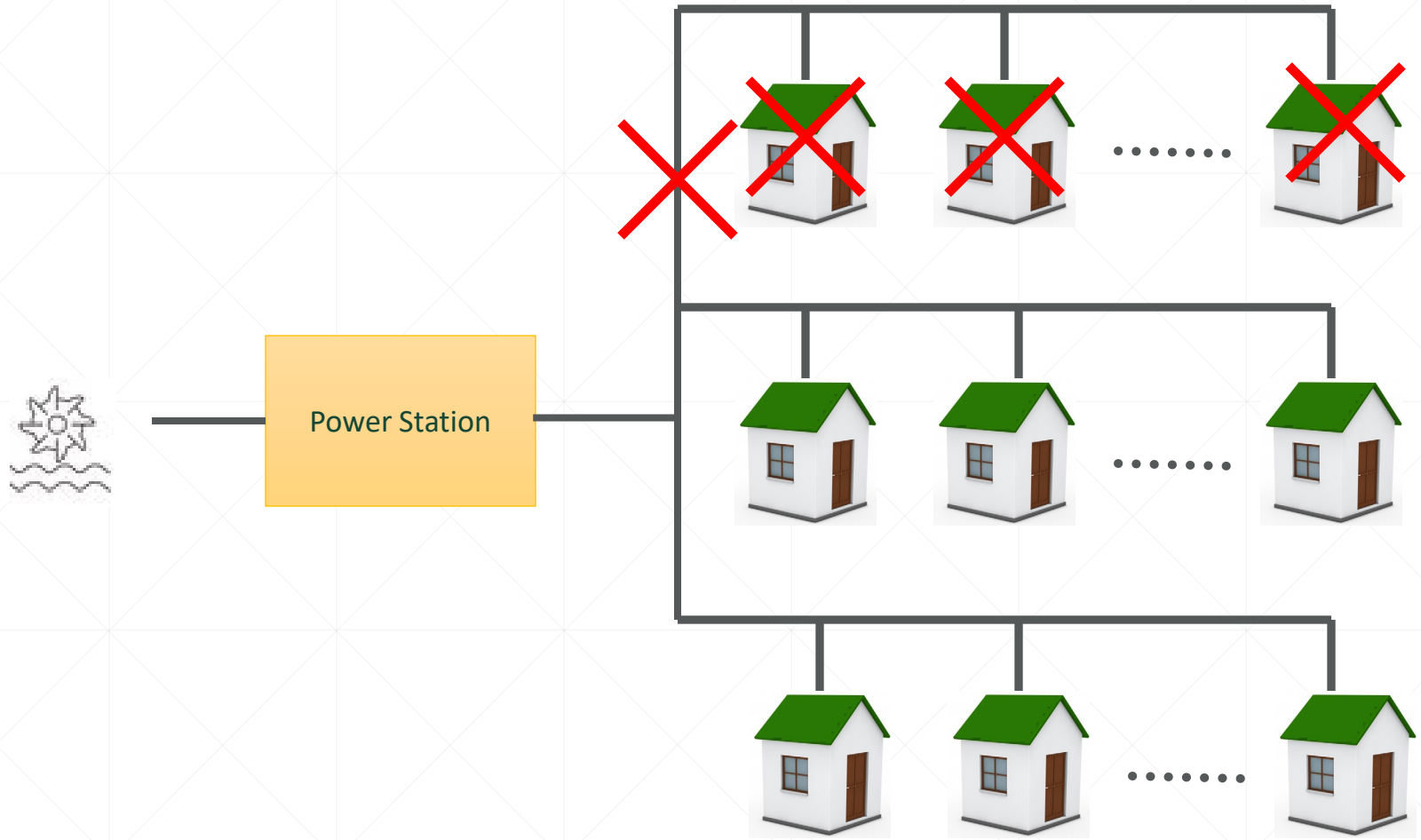

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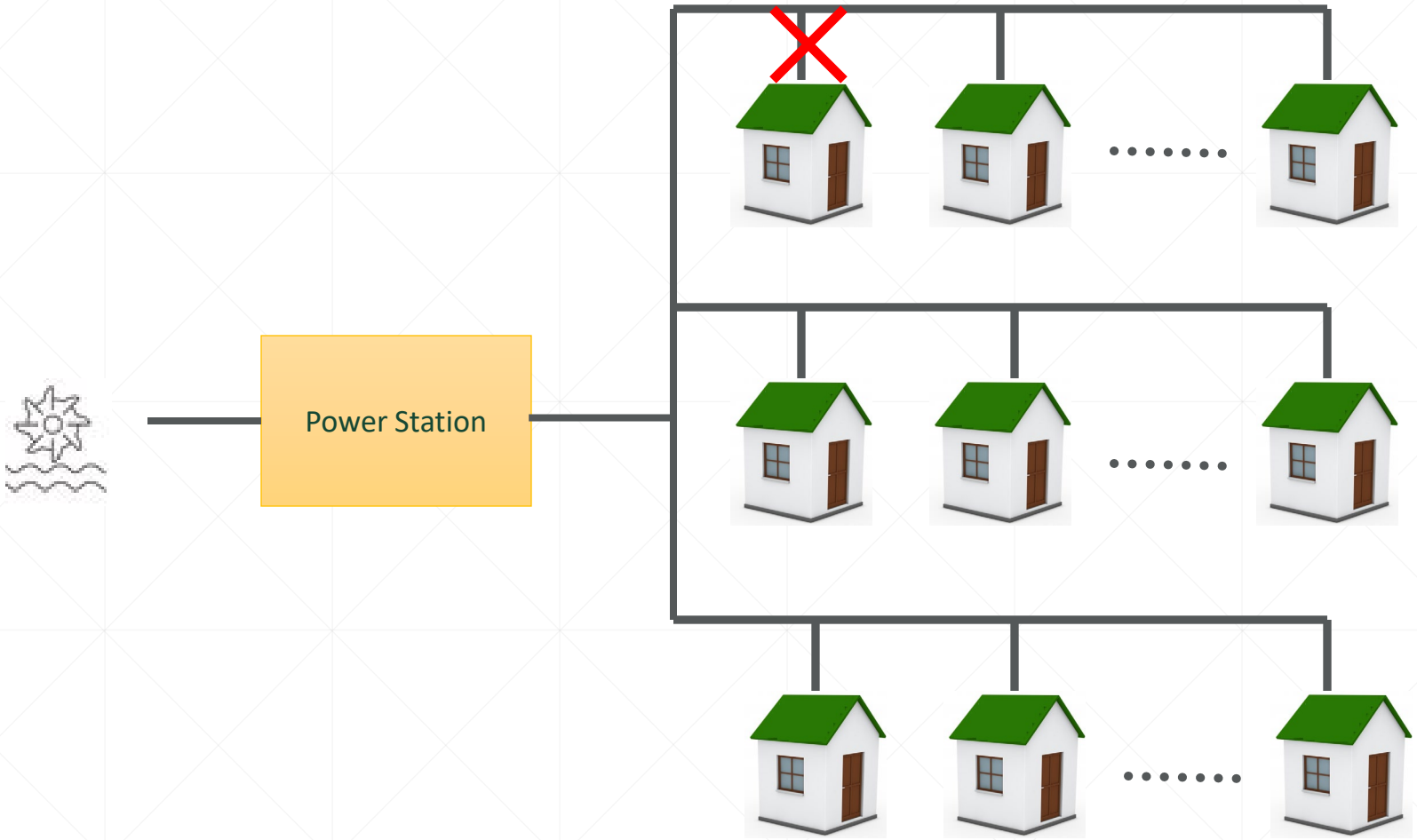

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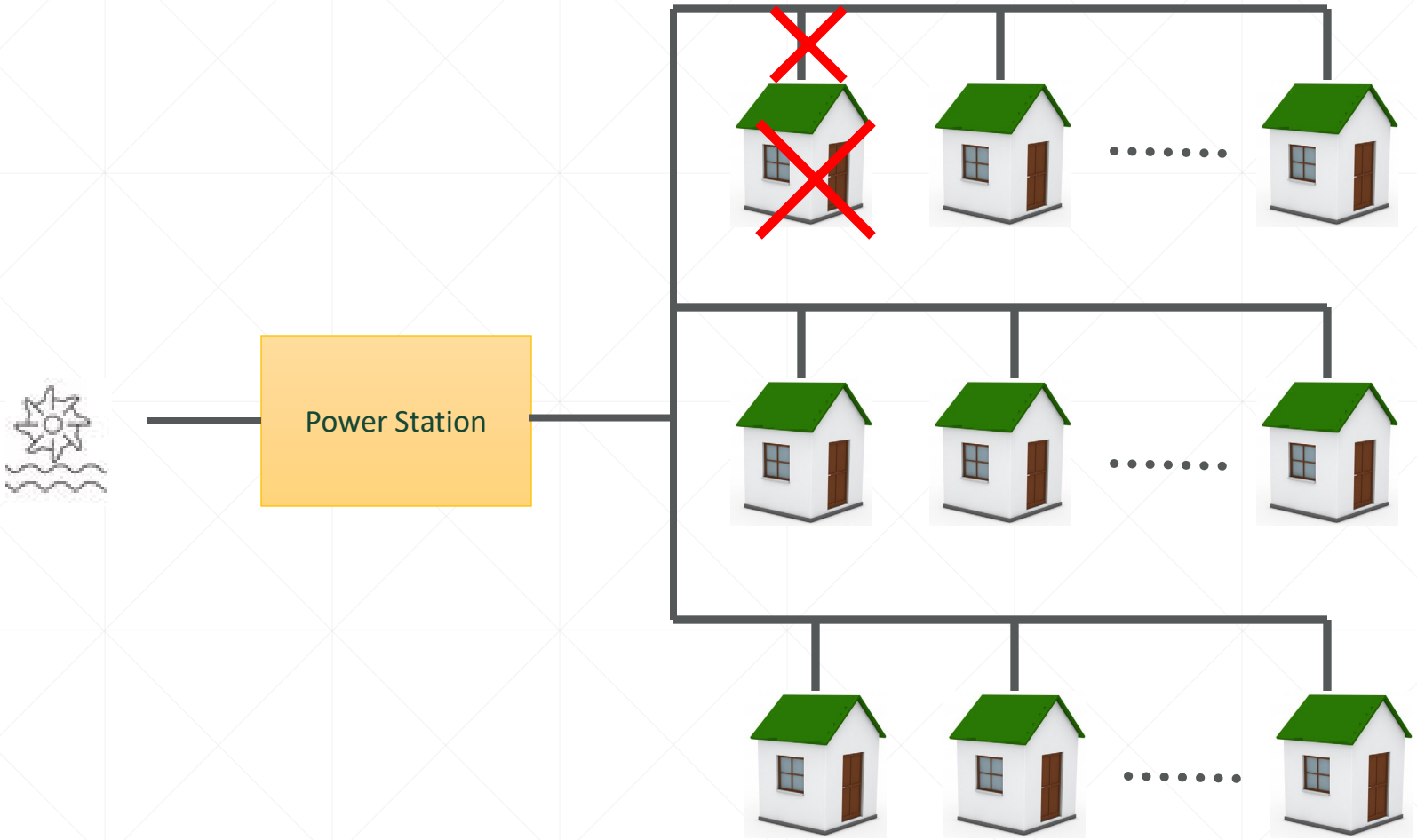

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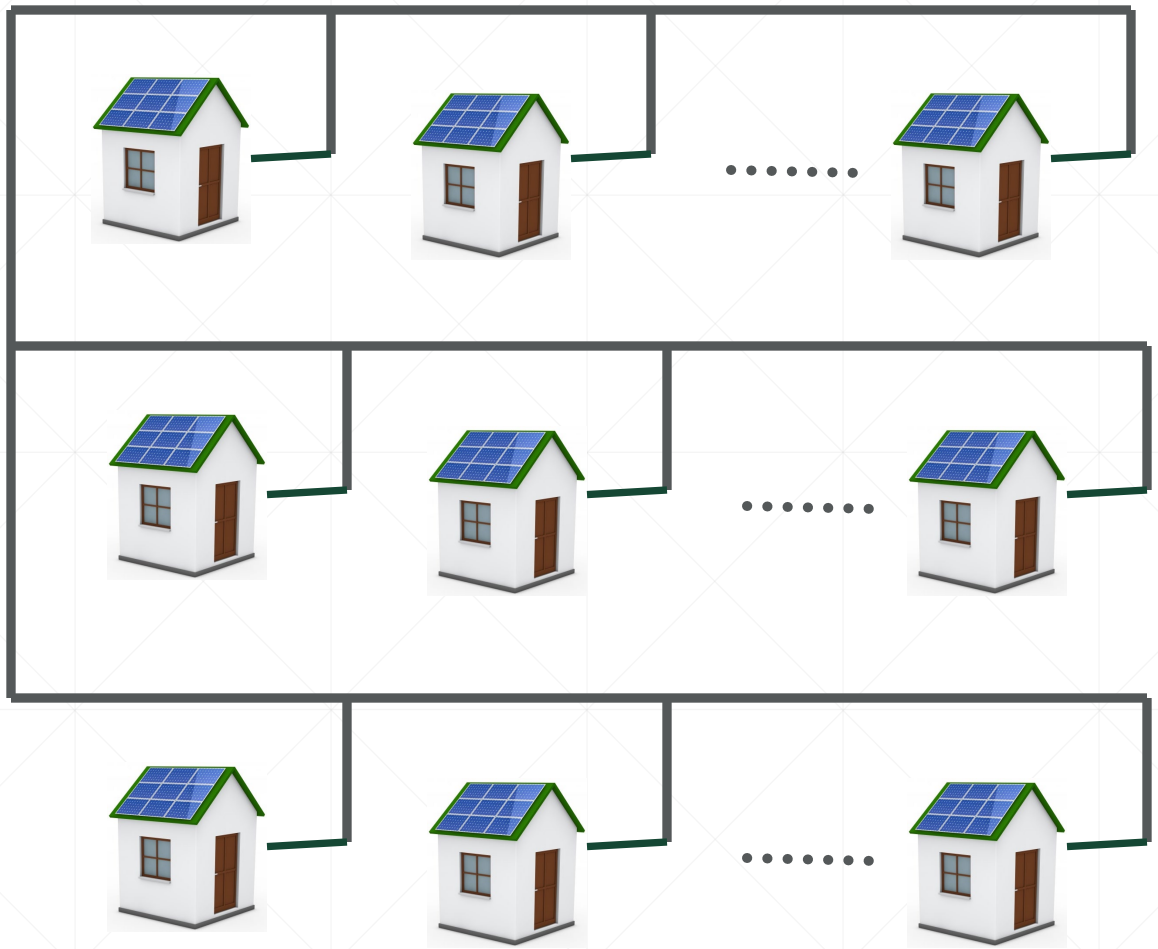
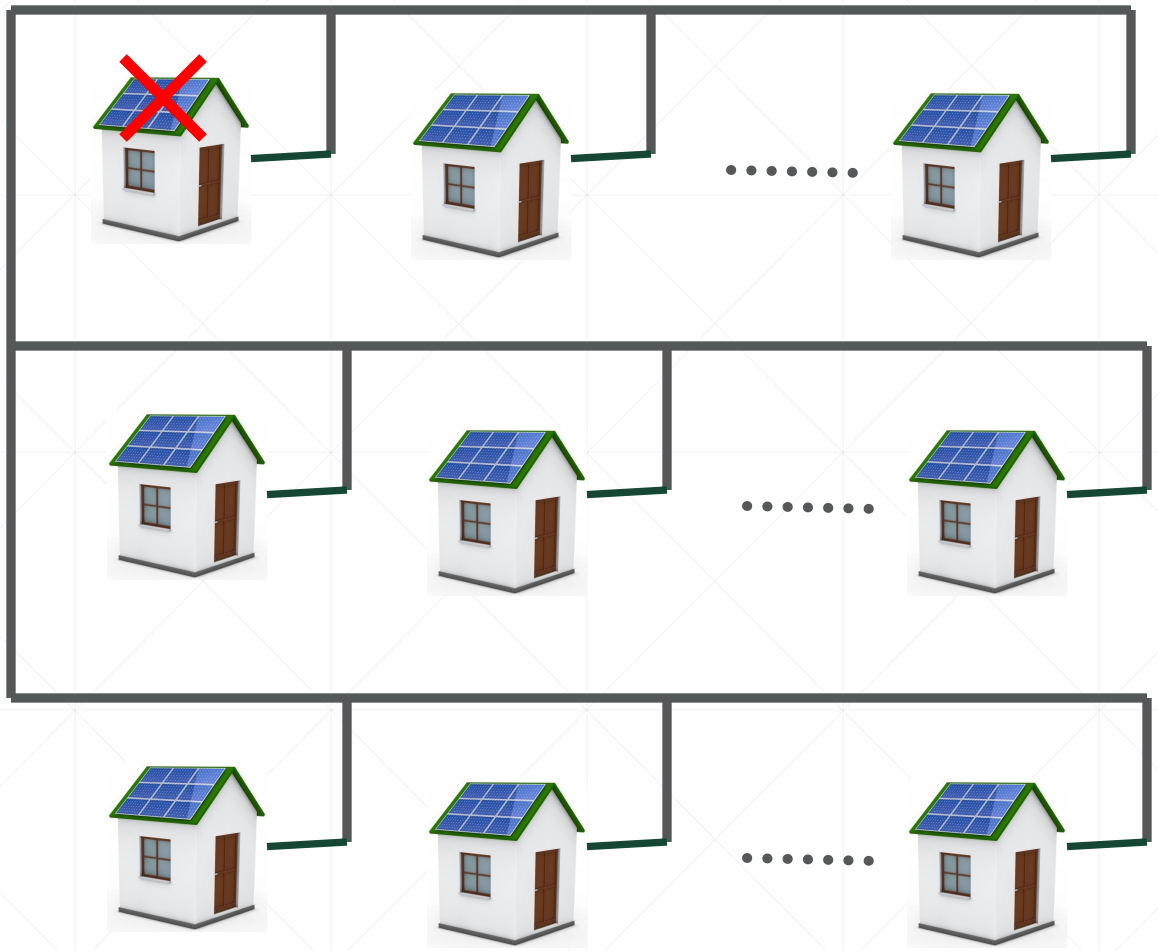


Example of Proposed System



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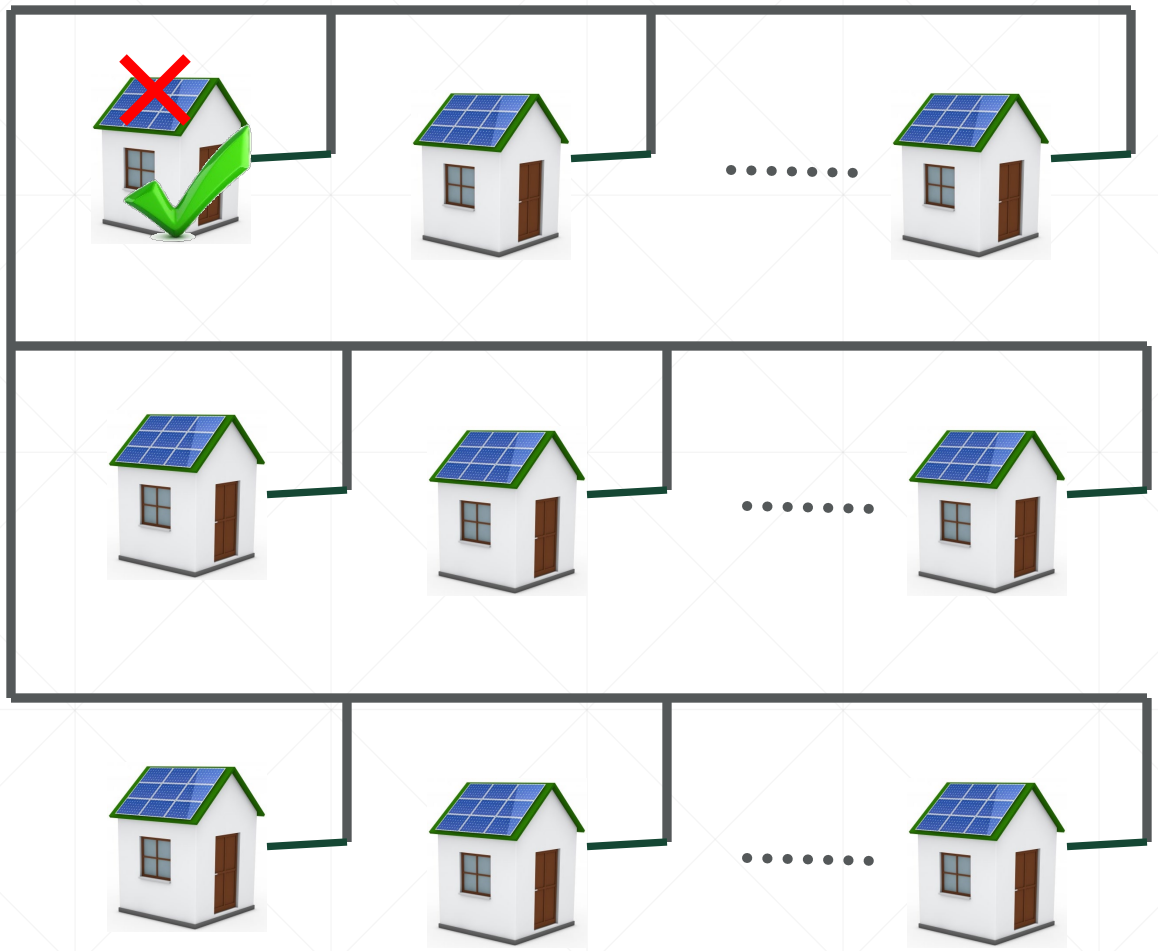

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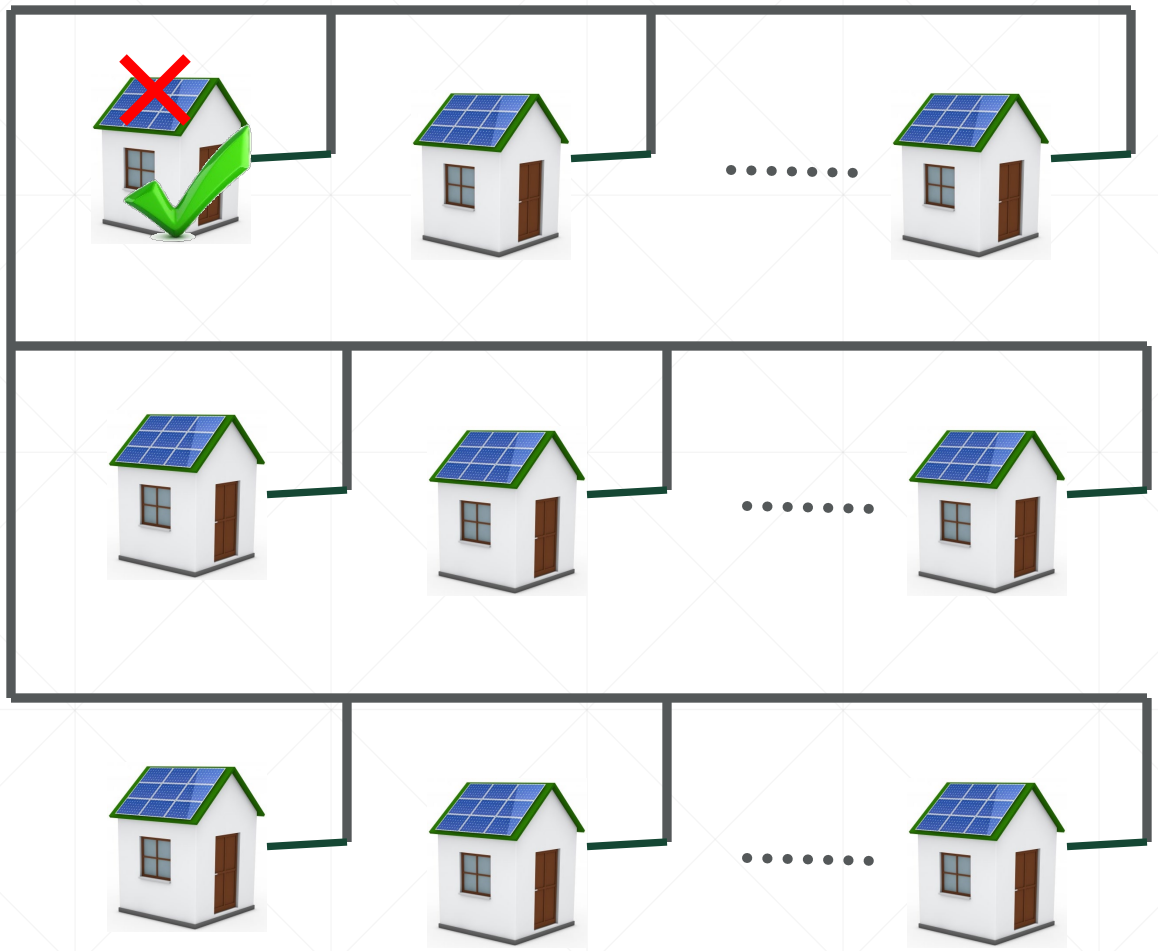

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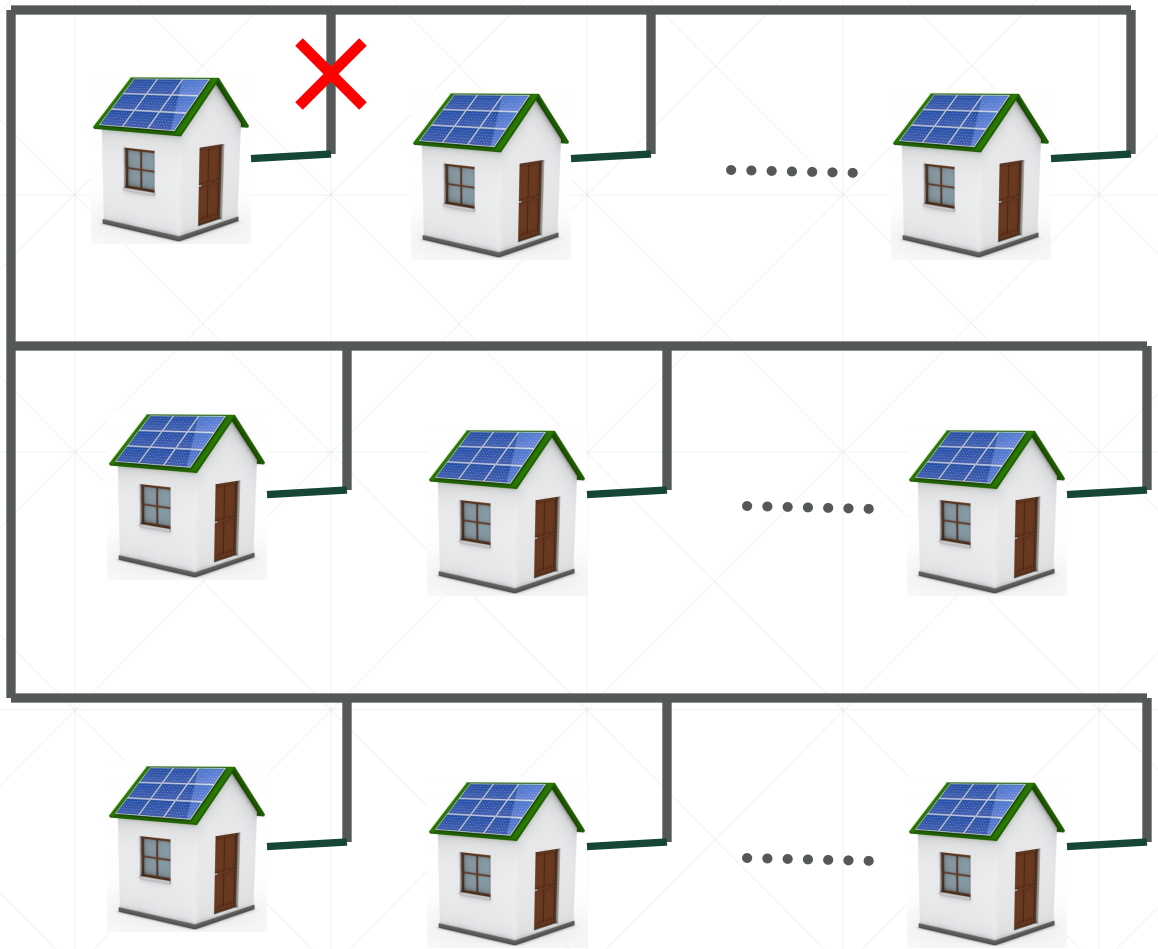

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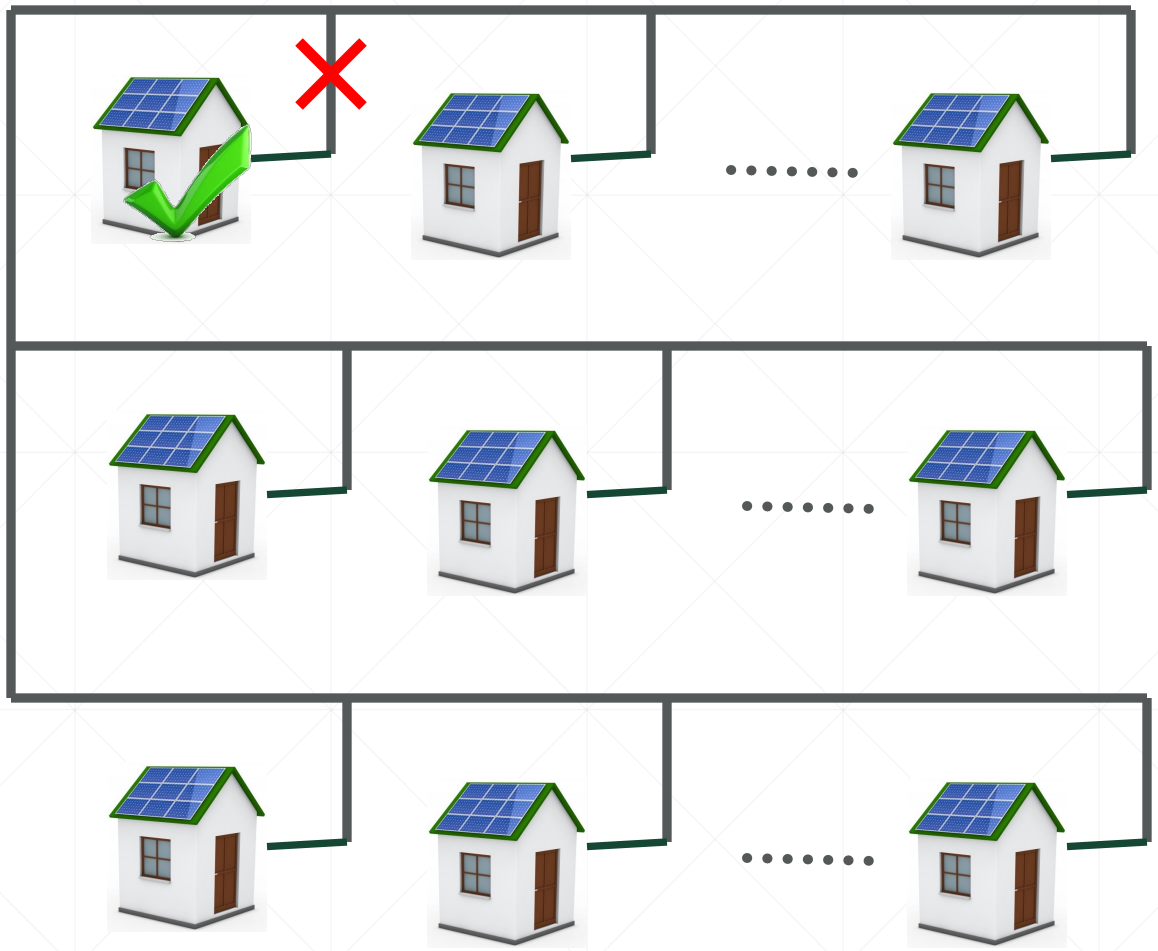

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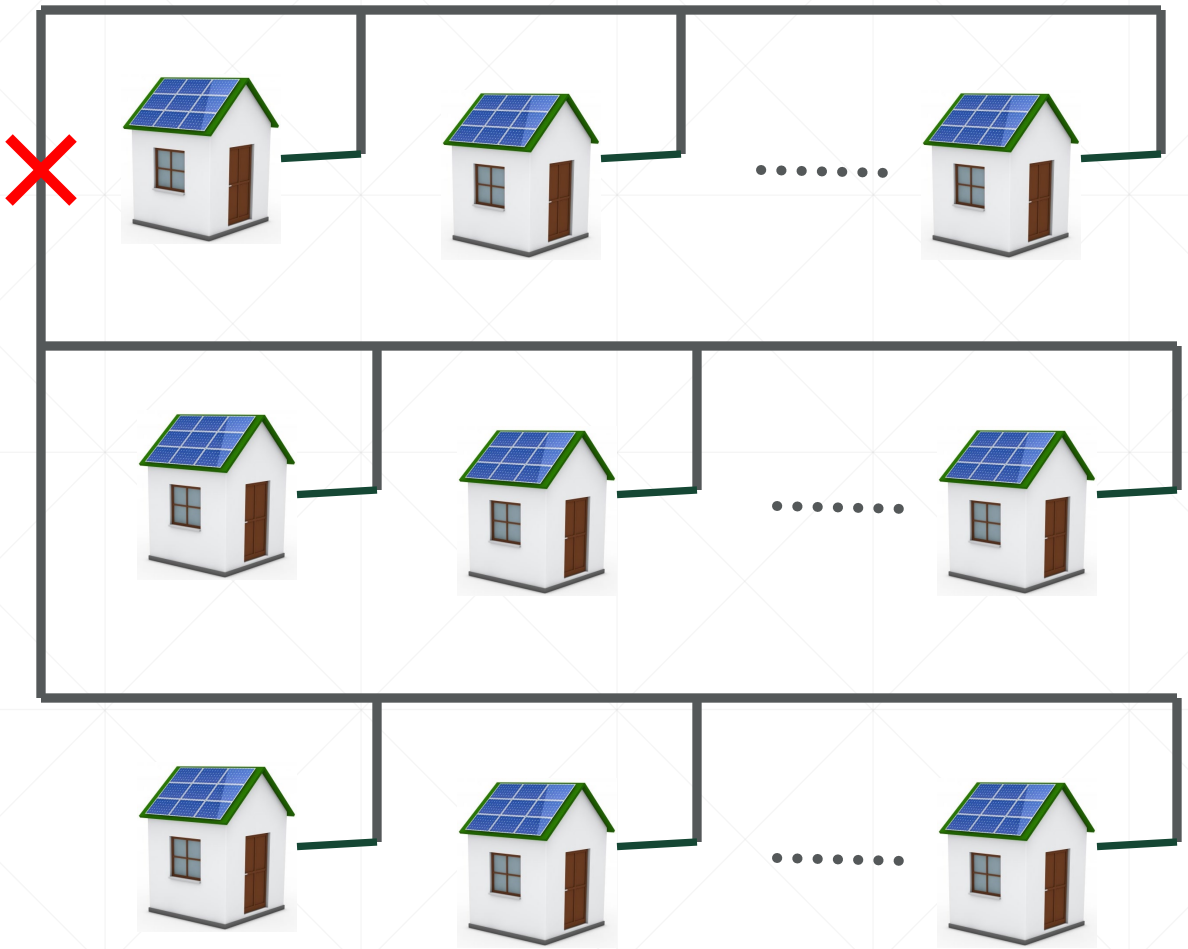

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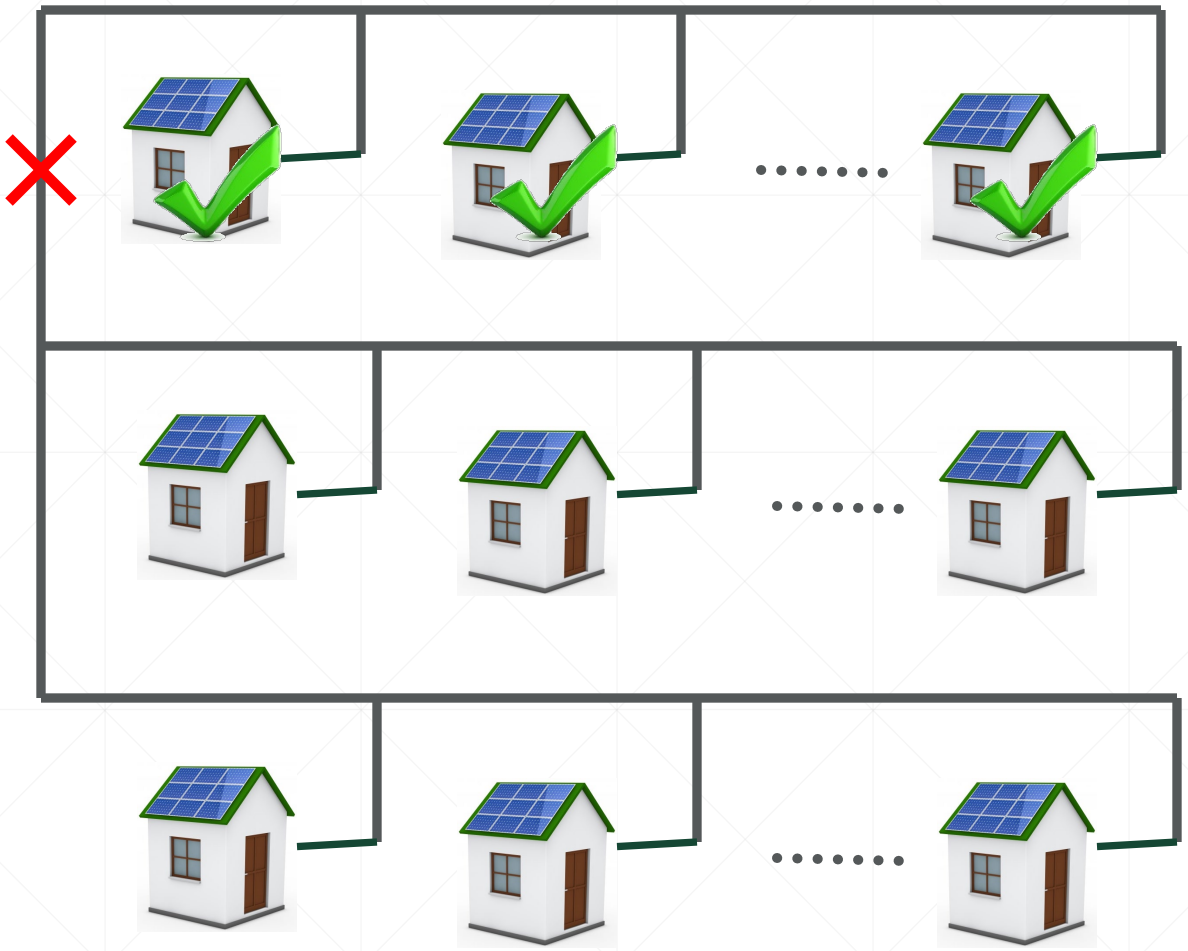

Example of Proposed System

Opportunities: “Everything is DC” Appliances

- DC Water Pump
- DC Water Filtration System
- DC air conditioner
- DC freezer
- DC kitchen appliances (stove, microwave, oven)
- USB-C powered appliances
  - DC refrigerator
  - DC TV
  - DC chargers for phones, laptops, others.
- Etc. …

Summary

Let's Collaborate on Hybridizing Electrical Systems!

- The need to complement the conventional AC residential electrical system with DC
  - AC is not going away, so the best is to complement with DC
  - Promote the use of renewable energy
  - Maximize system efficiency when DC loads are continuously growing
  - Help achieve Net Zero Energy Houses
- DC has technical **challenges** ➔ present **opportunities** for new solutions & **innovations** & business opportunities
- Hybrid AC/DC House improves reliability of residential electrical system in grid-tied and off-grid homes
- Hybrid AC/DC House is the FUTURE HOUSE!
  - We need to move fast to be the leader in this "new" field
  - A lot to explore (technological, economic, environmental, social, etc.)

Questions?

DC HOUSE WEBSITE  https://dchouse.calpoly.edu/

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