Integrated Implementation of Virtual Power Plants (VPP) & Virtual Power Lines (VPL) Concepts to System Load

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Outline

- Definitions
- Challenges in system expansion
- Daily Load Analysis
- Integrated Concept Application
- Conclusions and Recommendations

Summary

- To reduce CO_2 emissions, there is a need to accelerate transition from fossil fuels to renewable energy generation.
- Considering intermittency of wind and solar resources, a number energy storage technologies are being developed to help increase the penetration of renewables.
- With current developments in Internet of Things (IoT), Blockchain and Artificial Intelligence (AI) technologies and Smart Appliances, power system load can be controlled more efficiently by integrated application of VPP and VPL concepts.

Key References

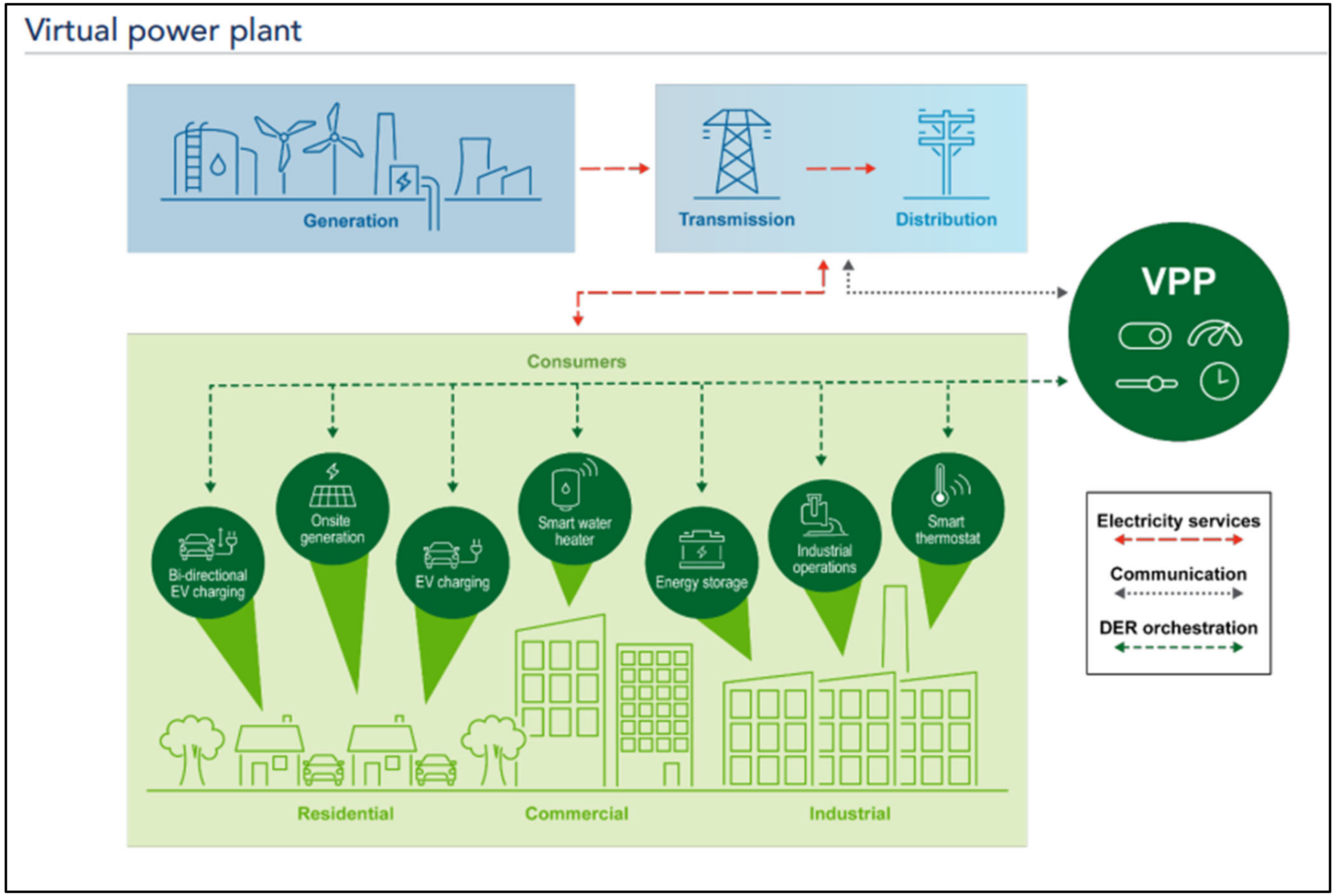
Department of Energy (US DOE)

- Virtual Power Plants (VPP): Pathways to Commercial Liftoff (energy.gov)

International Renewable Energy Agency (IRENA)

- Virtual Power Lines (VPL): Innovation Landscape Brief (irena.org)

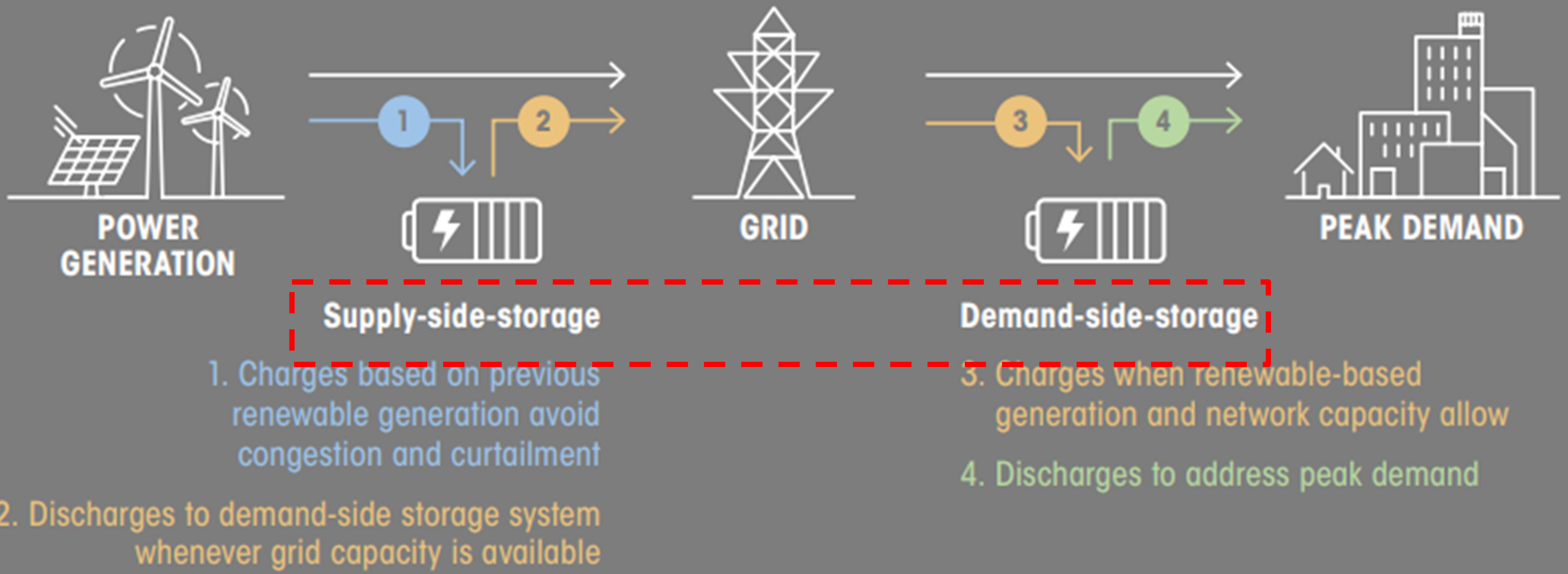
Virtual Power Plants (VPP) (Reference US DOE)



VPPs are aggregations of **distributed energy resources** (DERs) such as rooftop solar with **behind-the-meter** (BTM) **batteries**, electric vehicles (**EVs**) and chargers, electric water heaters, **smart buildings** and their **controls**, and **flexible** commercial and industrial (C&I) **loads** that can **balance electricity demand and supply** and provide utility-scale and utility-grade grid services like a traditional power plant. VPPs enroll DER owners – including residential, commercial, and industrial electricity consumers – in a variety of participation models that offer rewards for contributing to efficient grid operations.

Virtual Power Lines (VPL) (Reference IRENA)

Virtual power lines (VPLs) allow large-scale integration of solar and wind power without grid congestion or redispatch, avoiding any immediate need for large grid infrastructure investments.



Potential Challenges for Renewables Expansion

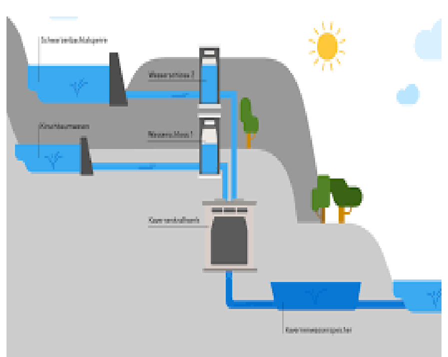
- Renewables is an **Intermittent** power supply
- **Transmission Line** need major upgrade to support renewable integration targets
- Push towards **all electric loads**
- **Upgrade** of power **distribution** system

Potential Challenges – Residential Sector

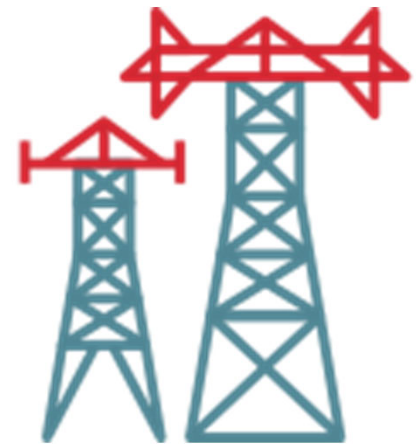
- **All electric loads**
- **Improper sizing** solar and battery system due to lack of load understanding
- High cost for residential solar installation
- High cost of **energy storage** (batteries)
- Solar only available during daytime (**Duck Curve**)

Historically – Load Flow

Generation



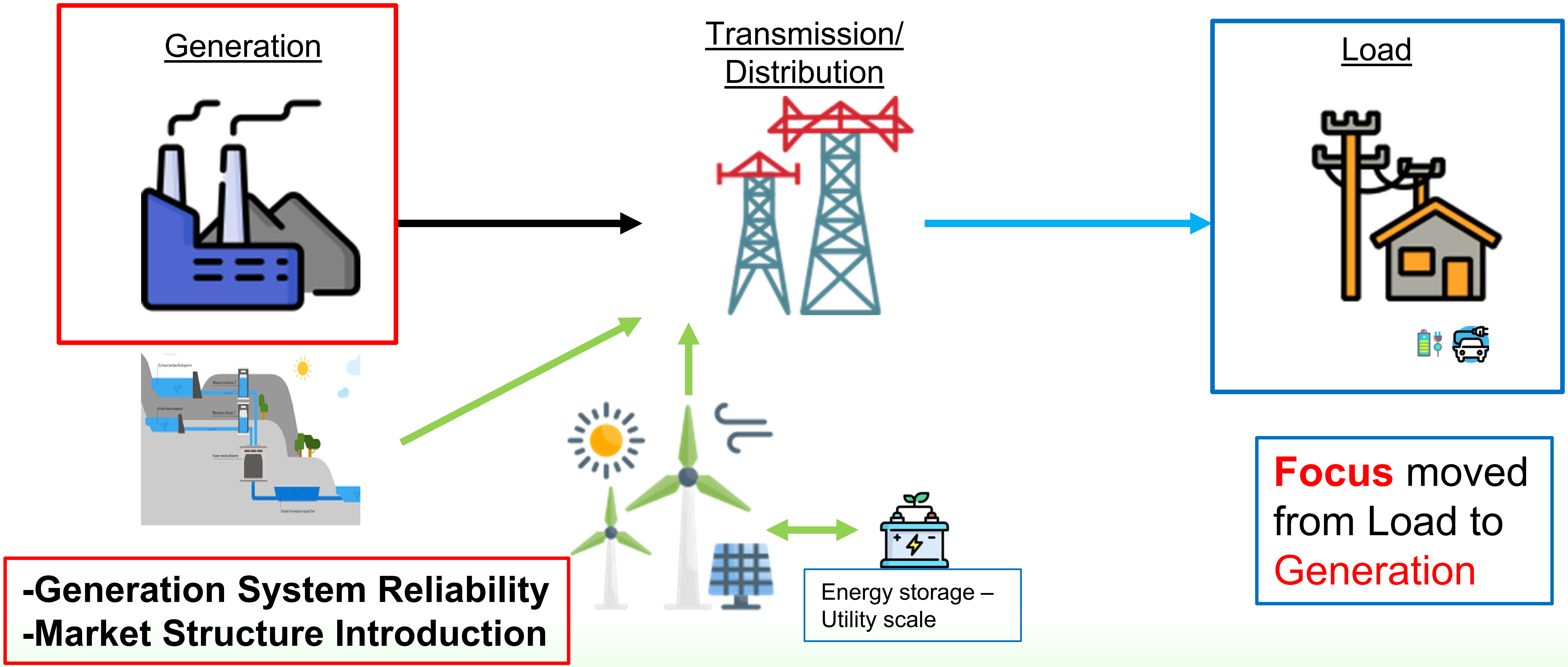
Transmission/
Distribution



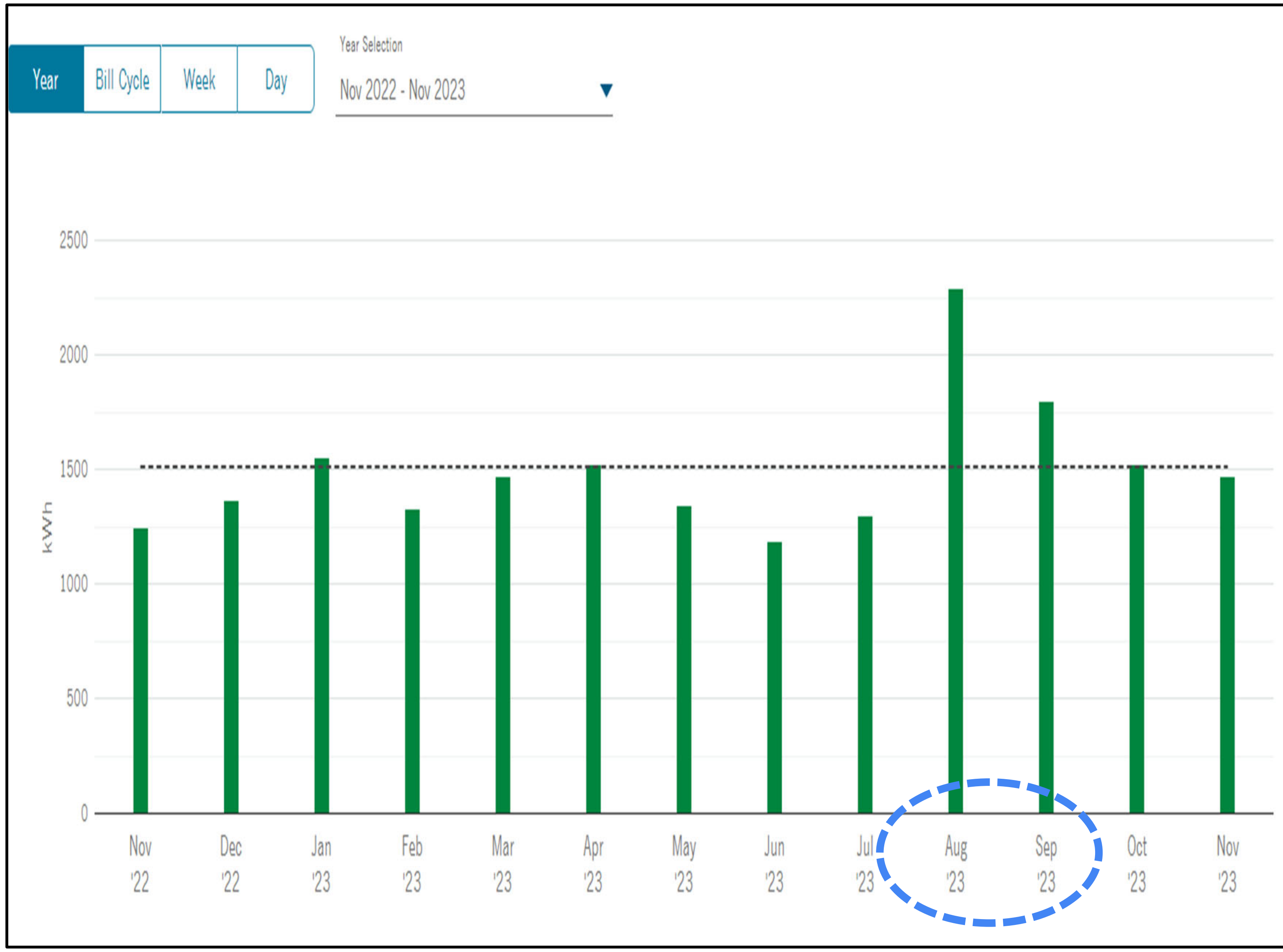
Load

Focus - Load
as it dictates
power to flow

Present – Load Flow to Power Flow



Understanding Load – Energy Consumption



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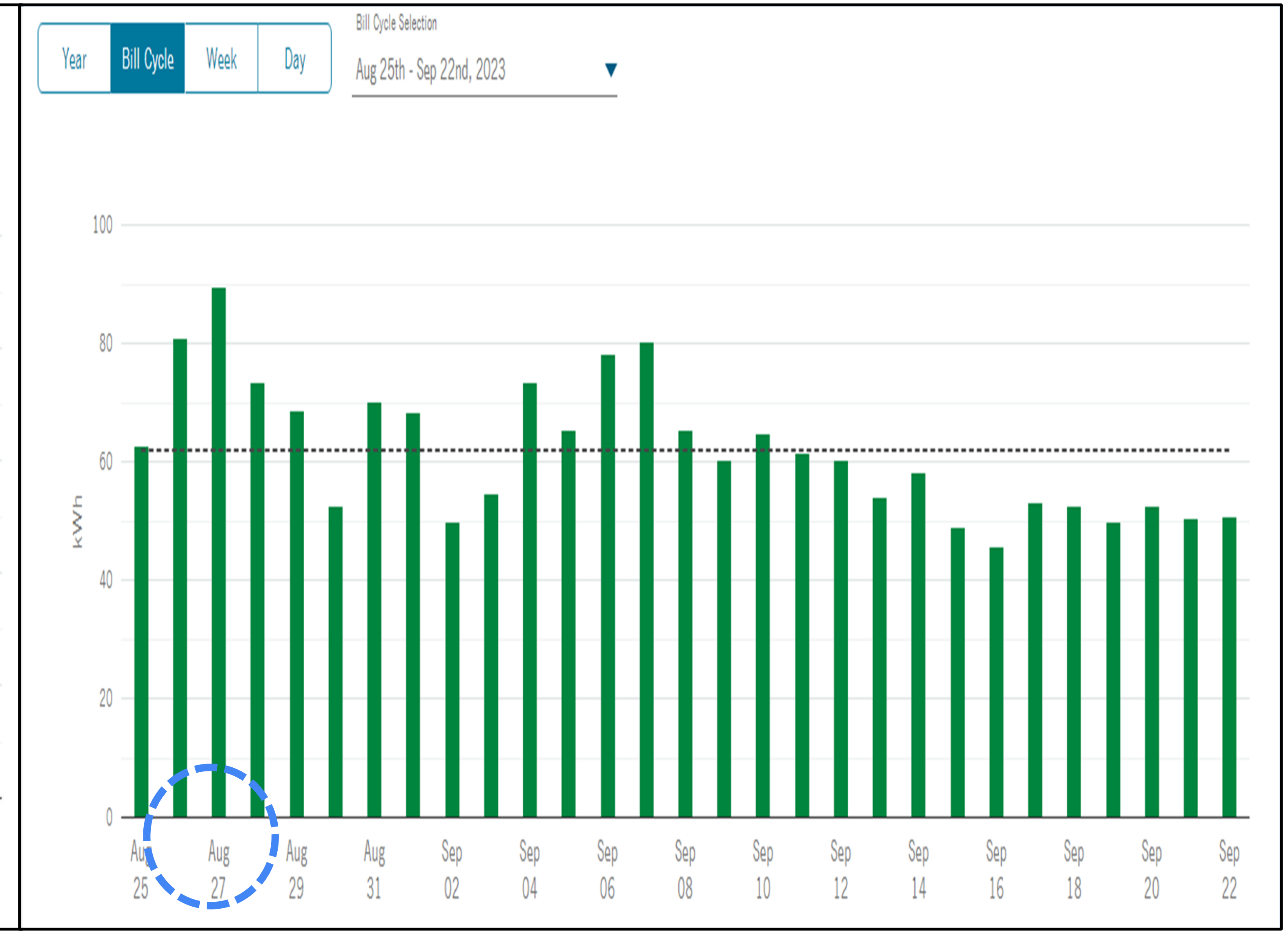

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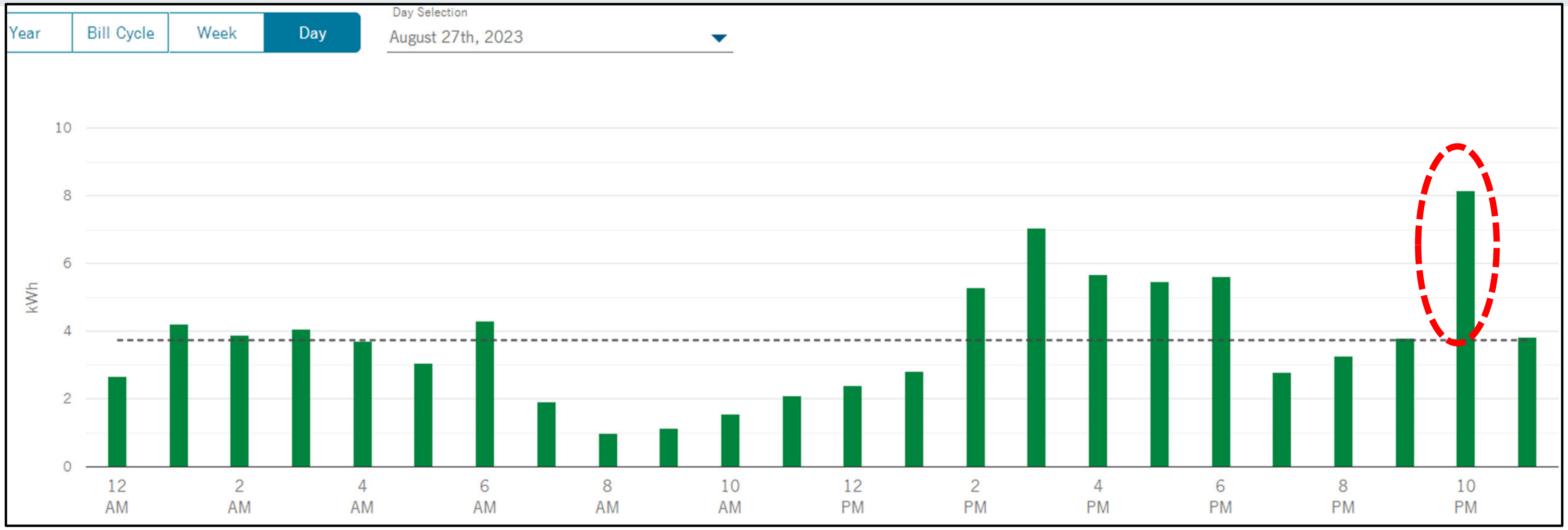
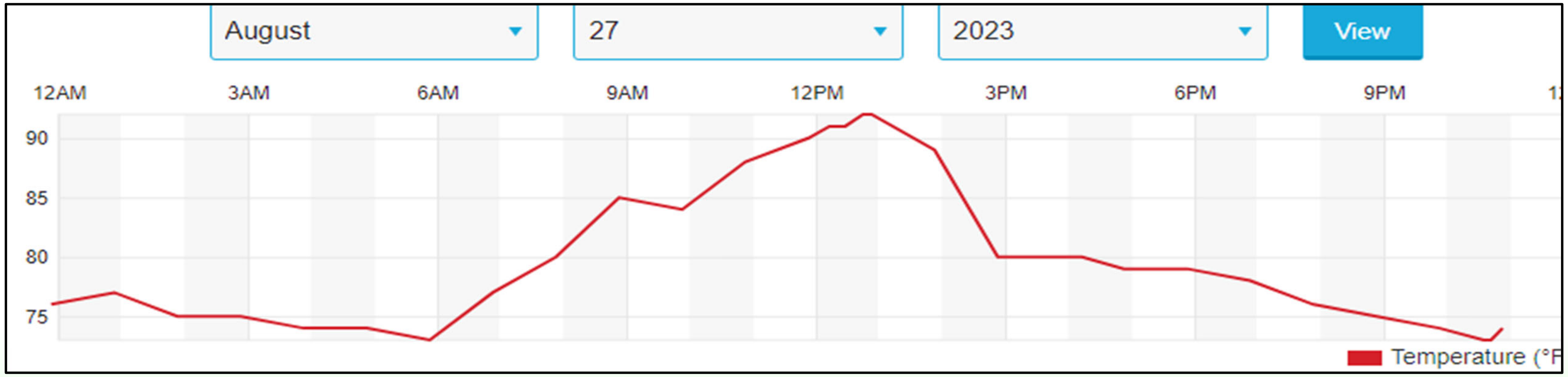
Understanding Load – Energy Consumption

Load



Temperature



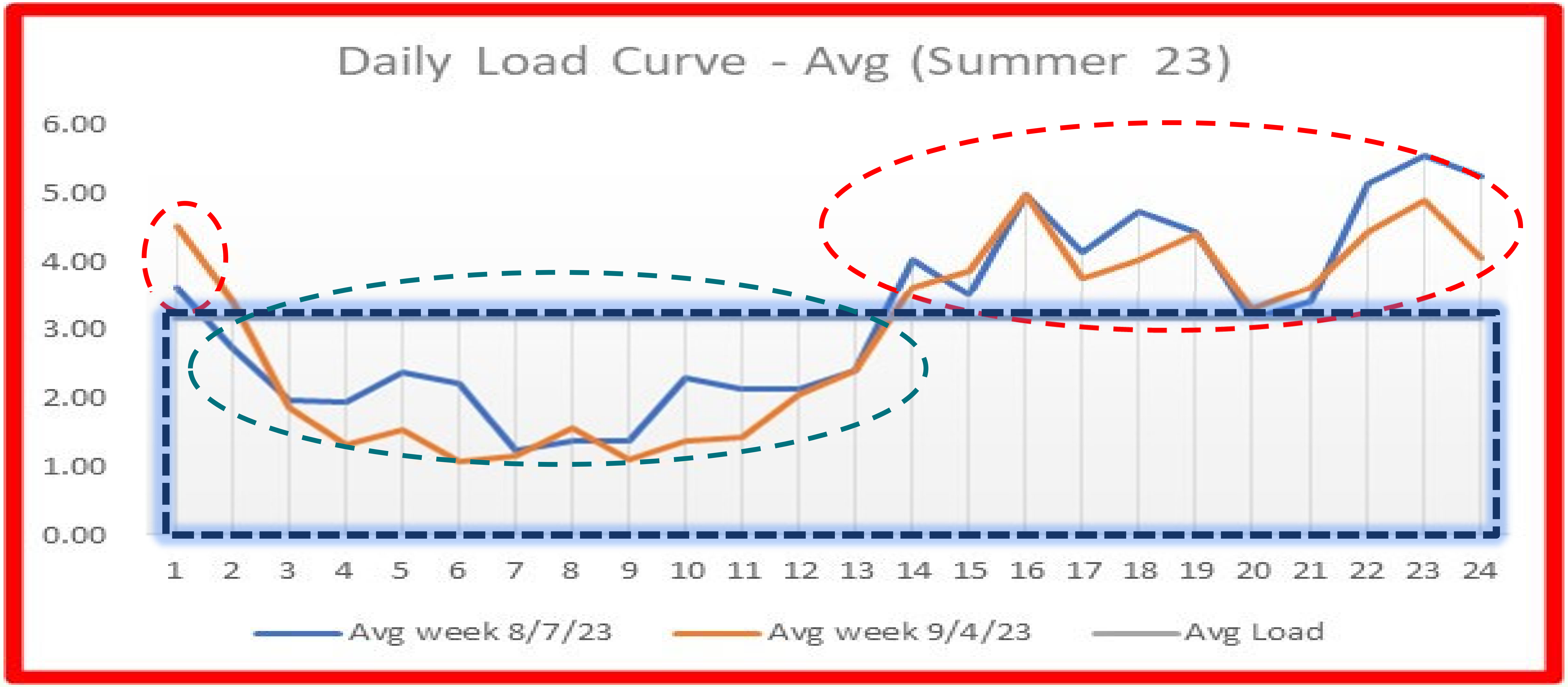
-Well insulated house

-Major Electrical Appliances/Loads

Air Conditioning

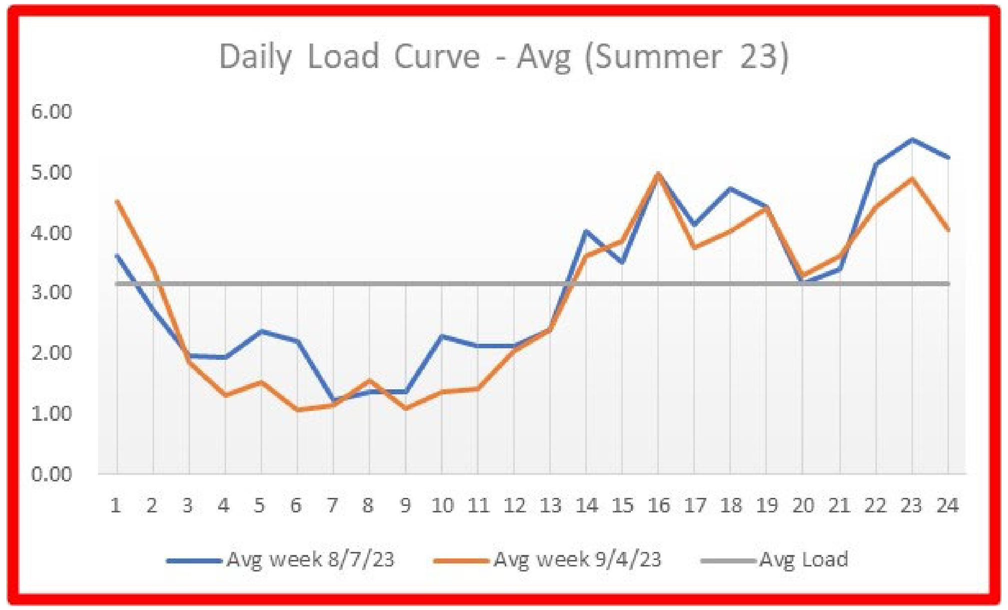
Water Boiler

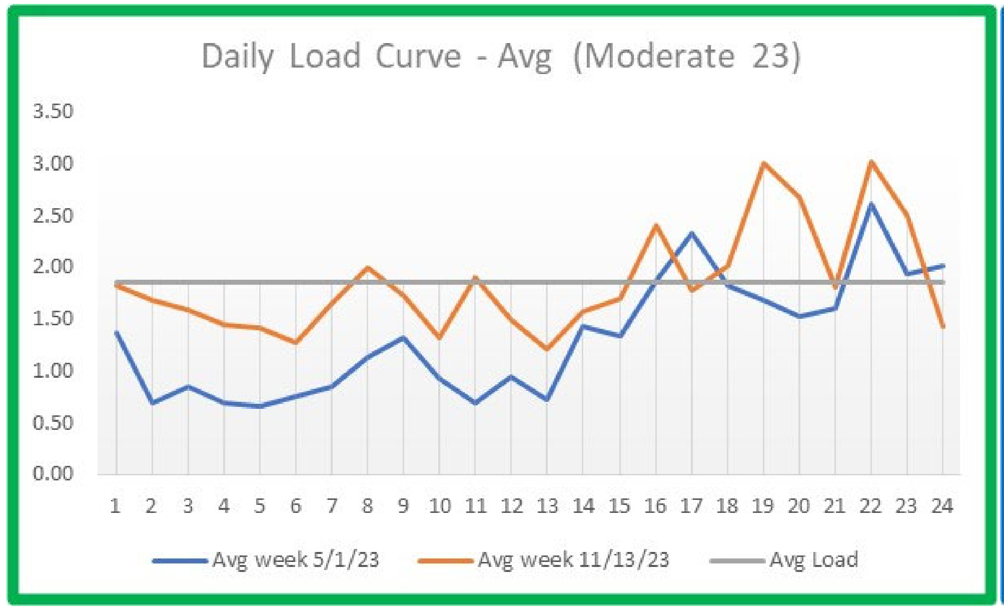
Daily Load Curve (Residential Load Sample)

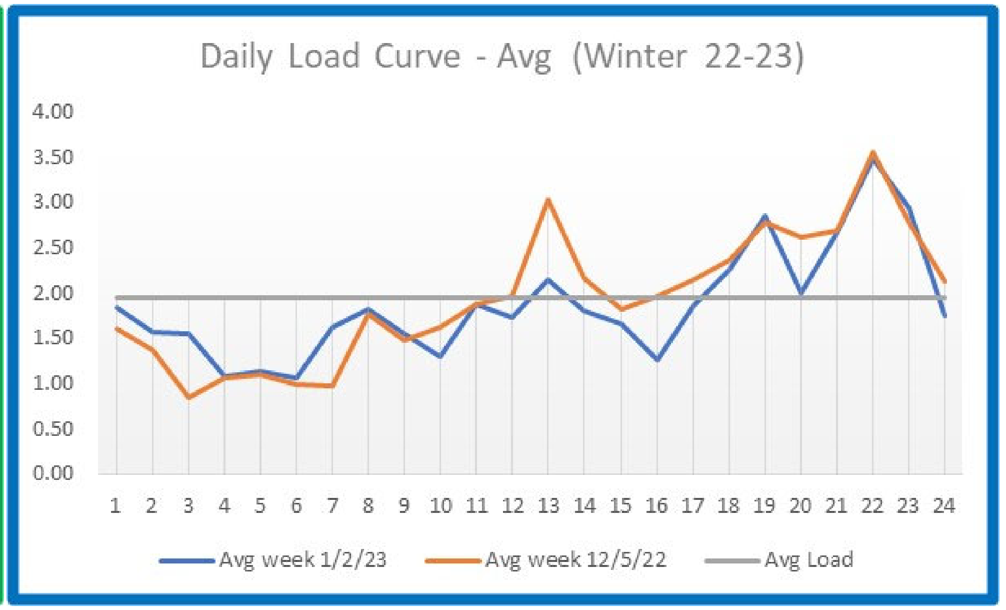


Daily Load Curve (Sample Residential Load) - continued

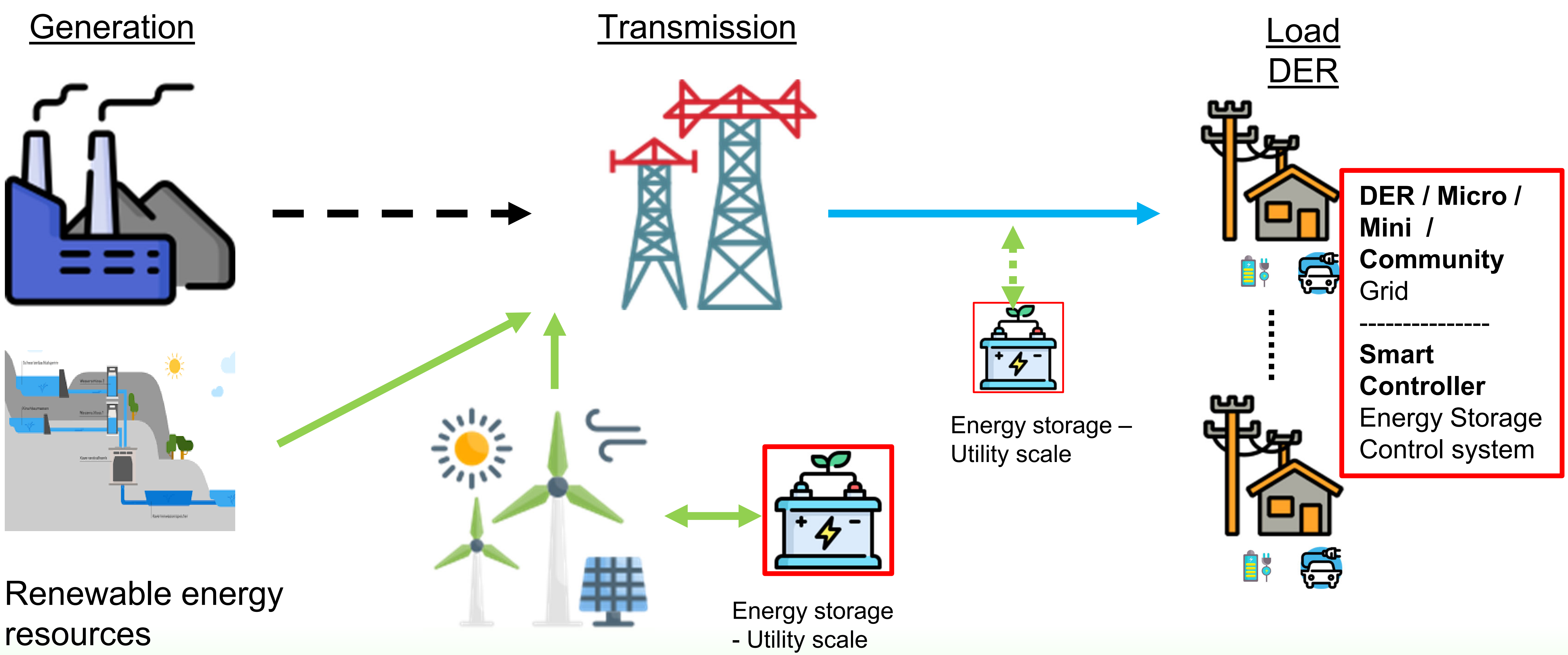
- Analyzing Summer, Winter and Moderate weather loads
- Peak load = 5.5 kW
- Average Load = 3 kW (Summer)
- Average Load = 2 kW others
- Minimum Load = 0.66 kW (Moderate)
- Goal to reduce peak to average Load (3 kW)
- Major loads are air-conditioning and water heater
- Shift load from peak to fill valleys



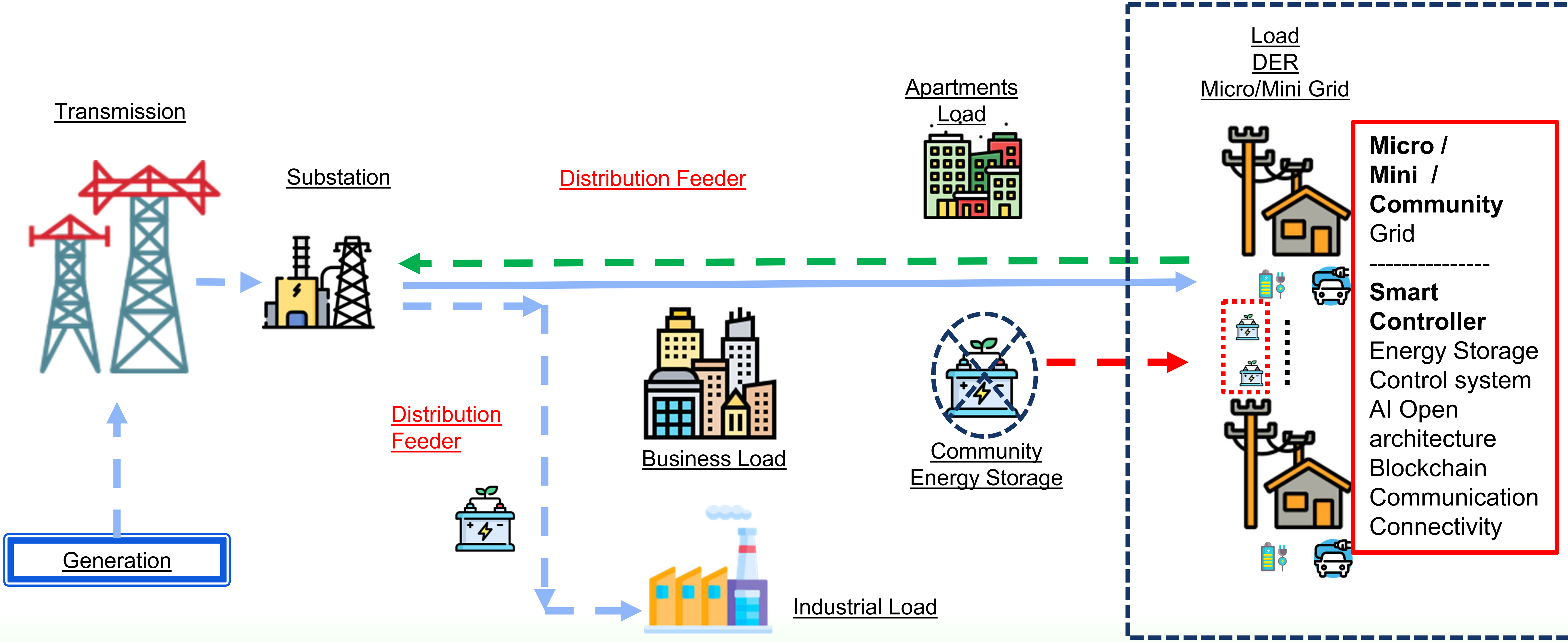




Future - Power Flow



Vision – VPP+VPL Application - DER



Proposed Strategy - Residential Load

- **Goal**: **Constant and Stable and predicatable Load**
- **Charge batteries** during day using renewables. **Use batteries** during peak conditions. **Charge batteries** partially at night using utility power
- **Target** area for piloting - start with goal of **30% reduction** in distribution feeder load
- Utility supported detailed load analysis as they have the data
- Utility funded/subsidized **Generation Kits** for residential customers
- **Smart Control** system – Support VPP
- **Sell power** back to **Utility** or **Blockchain** application

Benefits of VPP + VPL Implementation to Load

- Optimized size for battery and solar/renewable generation
- Increased renewable installations – increased renewables penetration
- Reduction in carbon footprint
- Increased transmission capacity to add more renewables generation
- Improved **distribution system stability**
- **Capital cost reduction** to maintain distribution system stability
- **O&M cost reduction**
- Increased EV penetration

Conclusion - Recommendations

1. **Integrated Implementation** of VPP+VPL system.
2. Define **System Design Criteria**
3. **Pilot Projects** - lessons learned
4. **Best Practices** supported by local utilities
5. Time of day tariffs
6. **Utility cost sharing** criteria to encourage Behind the Meter Renewables
7. Apply to Commercial and Industrial loads as next phases (II and III).

Thank You

*Credit: Free AI generated visuals – Slides go

Pilot Projects

VPP

- **Texas:** **Tesla** Electric Virtual Power Plant Beta with ERCOT
- **VPP4ALL - Electric Power Research Institute** (EPRI)

VPL

- **Vermont:** **Tesla's** Virtual Power Plant (Green Mountain Power)
- **Florida** FPL | Energy My Way | Battery Storage

Reference News

*Tons of clean energy stuck waiting in line (cnbc.com)
*Queued Up… But in Need of Transmission | DOE
*California rooftop solar installations drop 80% following Net Energy Metering (NEM 3.0) – (PV-magazine) – Dec 01, 2023

*Confronting the Duck Curve: How to Address Over-Generation of Solar Energy | Department of Energy

Back to the Basics

To meet the goal of all electric load we need to:

- **Integrate residential** energy systems in system planning
- Understand **LOAD, as it dictates flow of power**
- Delta between **Peak** and **Minimum** load, as it affects system reliability and stability
- **Peak Shaving**. It involves shifting energy consumption from peak to off-peak hours
- **Load Shedding** involves temporarily reducing non-essential loads during periods of high demand scenarios