Balancing Building Performance, Renewables and Load Management

Net Zero Beyond Net Metering

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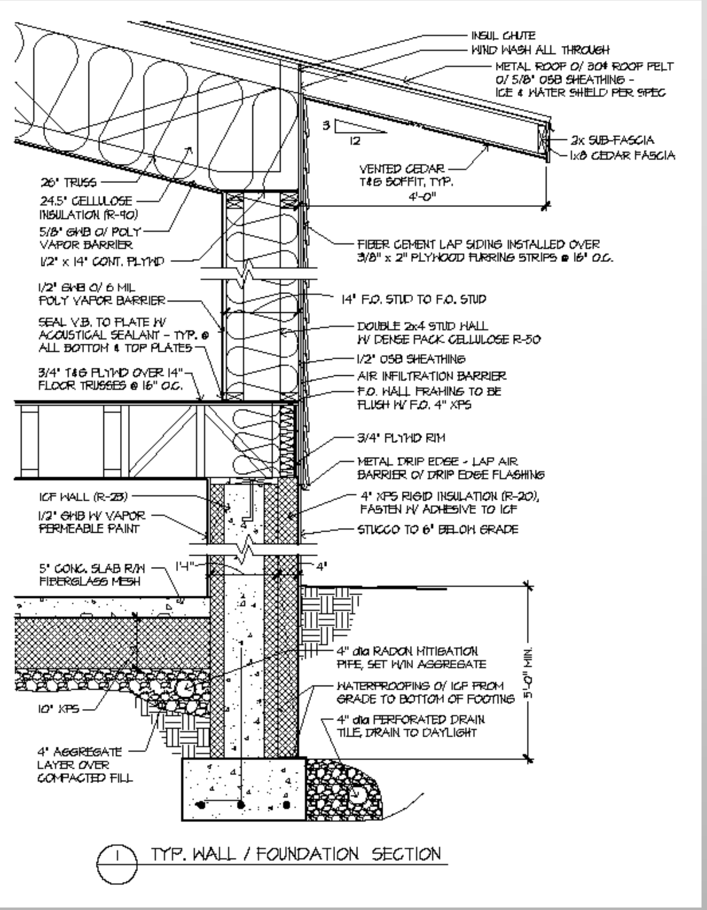
The Balance?



Not Mutually Exclusive!

Future Tense

- Very high performance building shell
- Optimal orientation
- Ultra efficient heating, cooling, appliances and lighting
- Building, and site, designed for PV
- PV sized for annual loads plus…
- Loads managed to optimize PV utilization on-site, while the sun shines.
- Moderate short term battery storage

Well Developed Pieces

- Passive House drives excellence in building performance
- Efficient lighting, appliances and HVAC is readily available
- PV is now affordable – *LET’S TALK ABOUT PV*

PV Growth Trends

- Net Metering laws transformed PV from backwoods to mainstream by allowing very economic long term “storage” without batteries.
- Federal Tax Credit subsidized 30% of the cost.
- State and Utility rebates covered much of the rest.
- These trends multiplied and spread for years.
- The industry grew around subsidies.
- PV expanded and the cost dropped dramatically.

Net Metering Basics

- Varies by State and Utility
- Generally, excess energy exported to the grid credited towards consumption from the grid later.
- Sometimes reconciled monthly at kWh /kWh rate.
- Usually, remaining annual surplus rebated as cash at reduced rate
- Often, different programs for different usage levels
- Always, service, “capacity” or “access” fee monthly
- Rapidly moving target

PV has become dependent on simple reliable storage of excess solar energy on the grid

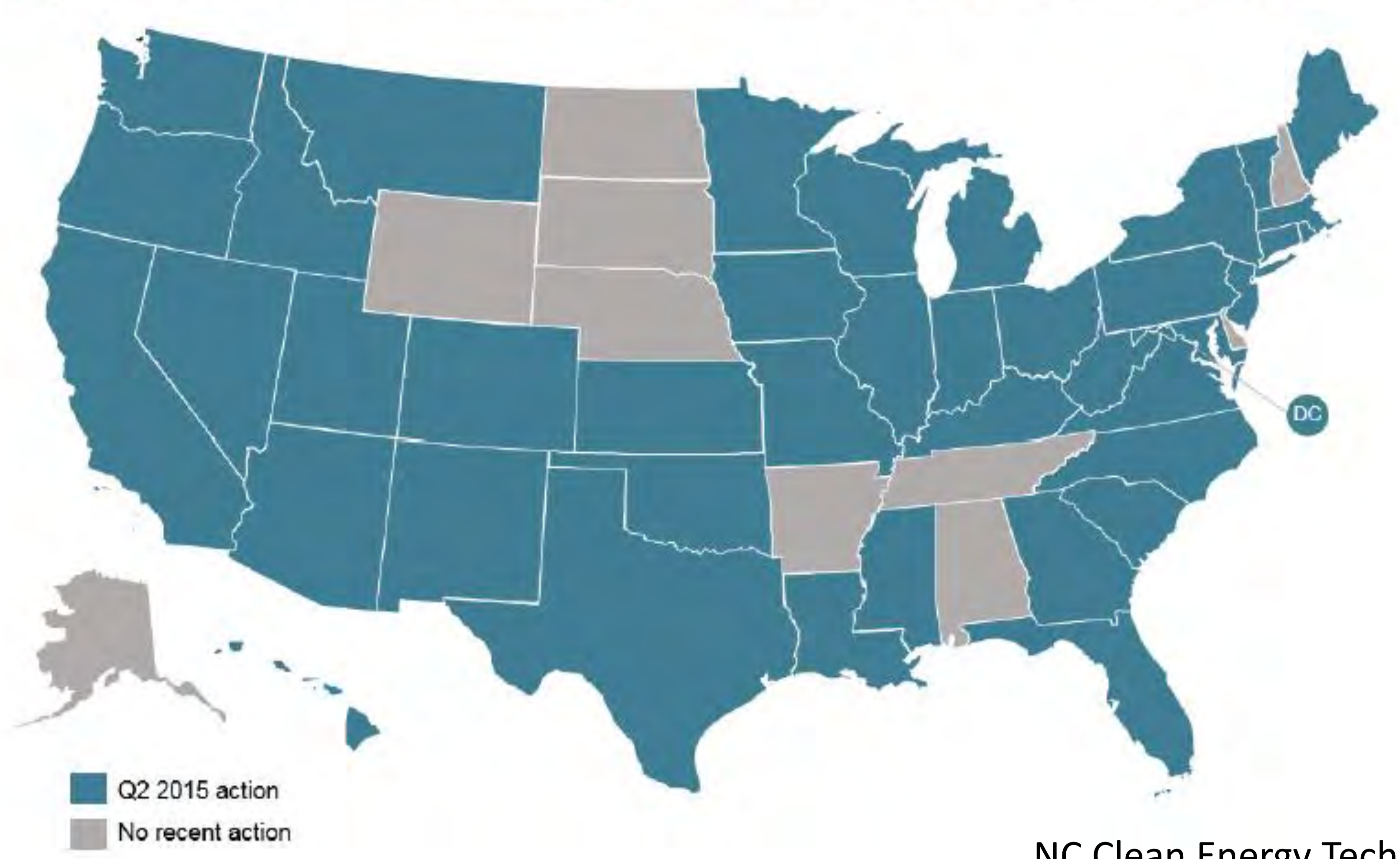
- Offsetting other grid usage by exporting surplus solar energy – good.
- It has been economically feasible because of generous rates.
- We now often burn fossil fuels for thermal loads while sending PV energy to the grid.
- In some areas PV saturation is happening – limits to additional development are being proposed

Reversing Trends

- Federal Tax Credit rolls back after 2016
- Many State rebates have expired
- Net Metering programs are being challenged across the US by Utilities and “Consumer Groups”
- “Access” or “Capacity” charges are being imposed
  - Often $3-4 / kW / month (Some flat rate of $50 / month)

Change is Taking Place Now

Figure 1. Recent Action on Net Metering, Rate Design, and Solar Ownership Policies



NC Clean Energy Technology Center

In the near future, to make solar pay, we will need to keep more of the harvested energy on site

- Use as much of it as possible while the sun is shining – scheduling
- Store some in thermal media - hot or cold
- Store some for night time electric loads in moderate battery bank
- Develop / refine long term storage methods

PHIUS+ 2015 Standards Now Credit PV

- Currently using an estimated amount.
  - Based on portion determined to be consumed concurrent with production.
  - Currently defined such that for typical residential project, most of the output of a 2 kW PV system would count.
  - For “Source Net Zero Energy” calculations remaining production credited at a Site / Source ration of 3.16

Net Zero Defined (Wikipedia)

- A **zero-energy building**, also known as a **zero net energy** (ZNE) building, **net-zero energy building** (NZEB), or **net zero building**, is a building with zero net energy consumption, meaning the total amount of energy used by the building is roughly equal to the amount of renewable energy created on the site **on an annual basis**.

- This is good, really really good.

- How can it be better?

Source-Site Ratios of Various Fuels (EPA 2013)

*(Electrical values vary regionally, and over time, as the generation fuel mix shifts)

Energy Type	U.S. Ratio *	Canadian Ratio
Electricity (Grid Purchase)*	3.16 *	2.05
Electricity (on-Site Solar or Wind Installation)	1	1
Natural Gas	1.05	1.02
Fuel Oil (1,2,4,5,6,Diesel, Kerosene)	1.01	1.01
Propane & Liquid Propane	1.01	1.03
Steam	1.2	1.2
Hot Water	1.2	1.2
Chilled Water	1	0.71
Wood	1	1
Coal/Coke	1	1
Other	1	1

Net Zero in Challenging Climates

(Far Northern MN - 4,000 ft2 example)

- PHIUS+2015 Heating Allowance = 9.1 kbtu/ft2/yr
  - (92% increase over previous standard of 4.75)

- 9000 x 4000=36,000 btu (**10,550 kwh) (site)** (4,000 ft2 house example)

- 10,550 / 1,200 = **8.8 kW PV to meet allowed annual heating load.**

Net Zero in Challenging Climates (cont.)

(Far Northern MN – 4,000 ft2 Example)

- Old Primary Energy Standard
  - 38 kbtu = 11kWh / ft2/yr X 4,000 = 44,000 kWh
  - 44,000 / 1,200 = **36.66 kW PV** (ignoring **Site /Source** factor)

- PHIUS+2015 Source Energy Standard
  - 6200 X 4 = 24,800 kWh / year
  - 24,800 / 1,200 = **21 kW PV** (ignoring **Site / Source** factor)

Isabella Experiment Station

eGauge

View | LAN Access | Tools | Settings | Help

8/8/2015 11:54pm – 8/15/2015 11:54pm

Summary for time-period shown in graph

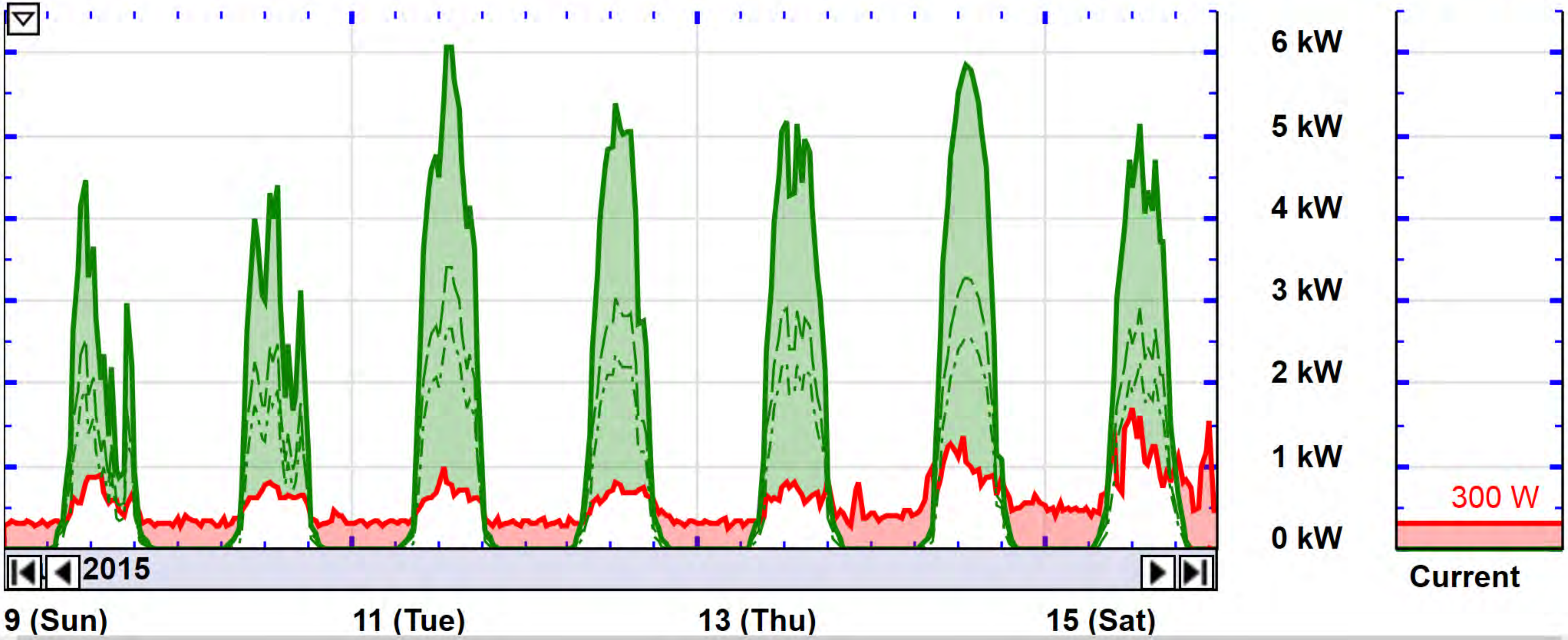
Energy Used	92.5 kWh	(approx. $12.02 used)
Energy Generated	236 kWh	(approx. $30.72 saved)
Net	144 kWh sold	(approx. $18.70 earned)

Summary over last 30 days

Energy Used	480 kWh	(approx. $62.45 used)
Energy Generated	812 kWh	(approx. $105.60 saved)
Net	332 kWh sold	(approx. $43.15 earned)

All | 1y | 6M | 3M | 1M | 3w | 1w | 3d | 1d | 12h | 6h | 3h | 1h | 10m

Auto | 500kW | 100kW | 50kW | 10kW | 5kW | 1kW | 500W | 100W | 50W



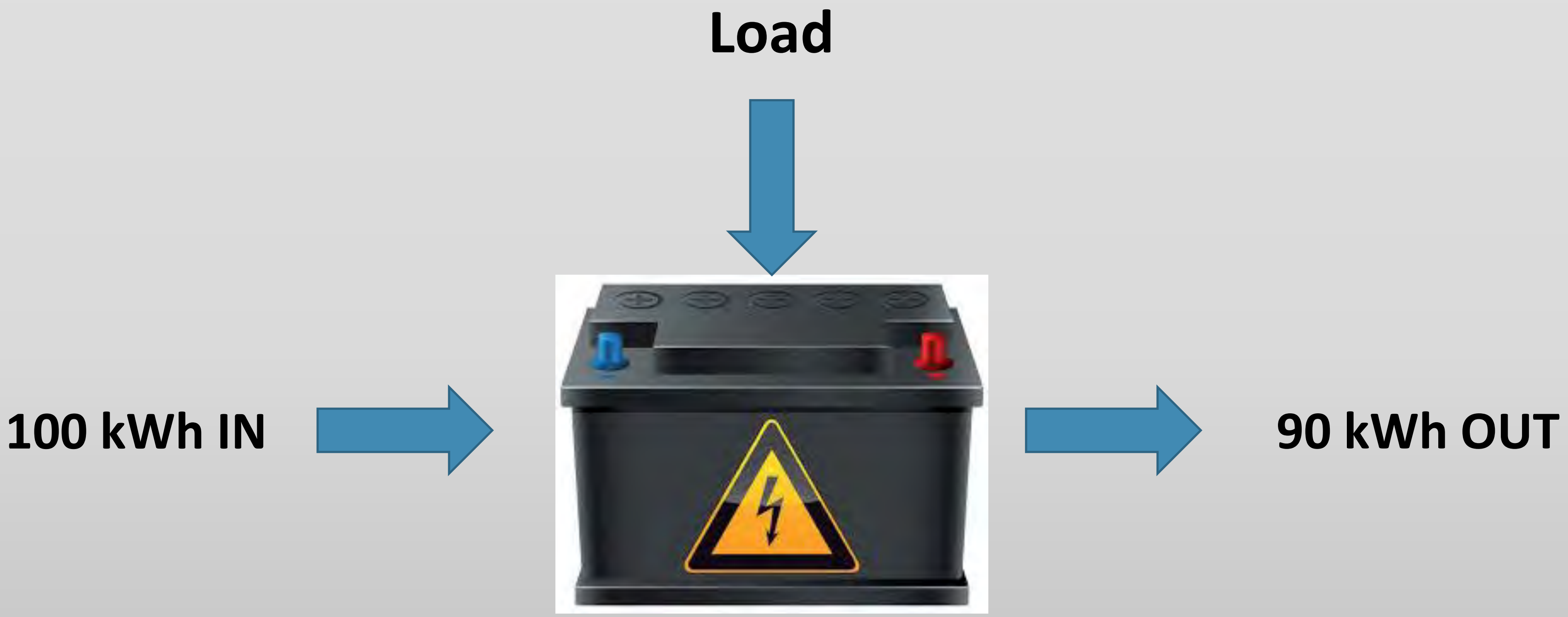
Fuel Switching for Better PV Utilization

- Sizing PV for most or all on-site energy loads.
- Heat Pump Water Heaters can replace gas units.
- Heat pumps for space conditioning as replacement for gas plants.

Battery Storage Can Be Part of Leveling Out Short Term Mismatch, - But…

- Investment in batteries diverted from efficiency or more production
- Short lived if used regularly
- Questionable embodied energy balance
- Energy consumer
- Heavy, bulky

Batteries Consume 8-10% of the Energy Stored…



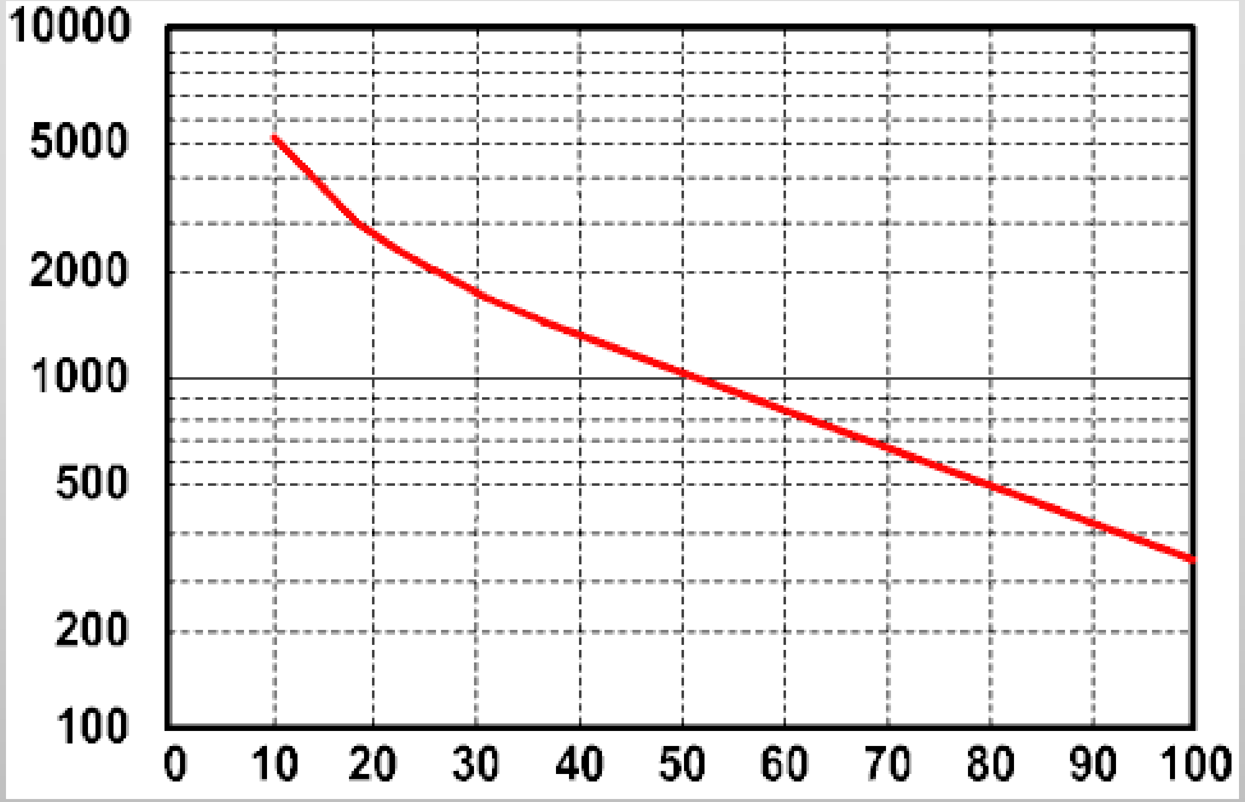
Not Long Term Storage - Battery Monthly Self Discharge Rate

Lead Acid	4-6%
Lithium Ion	2-3%
NiMH	2-3%
NiCad	15-20%

Life Expectancy Drops With Deep Use

Battery Expected Life (# cycles) vs. Depth of Discharge

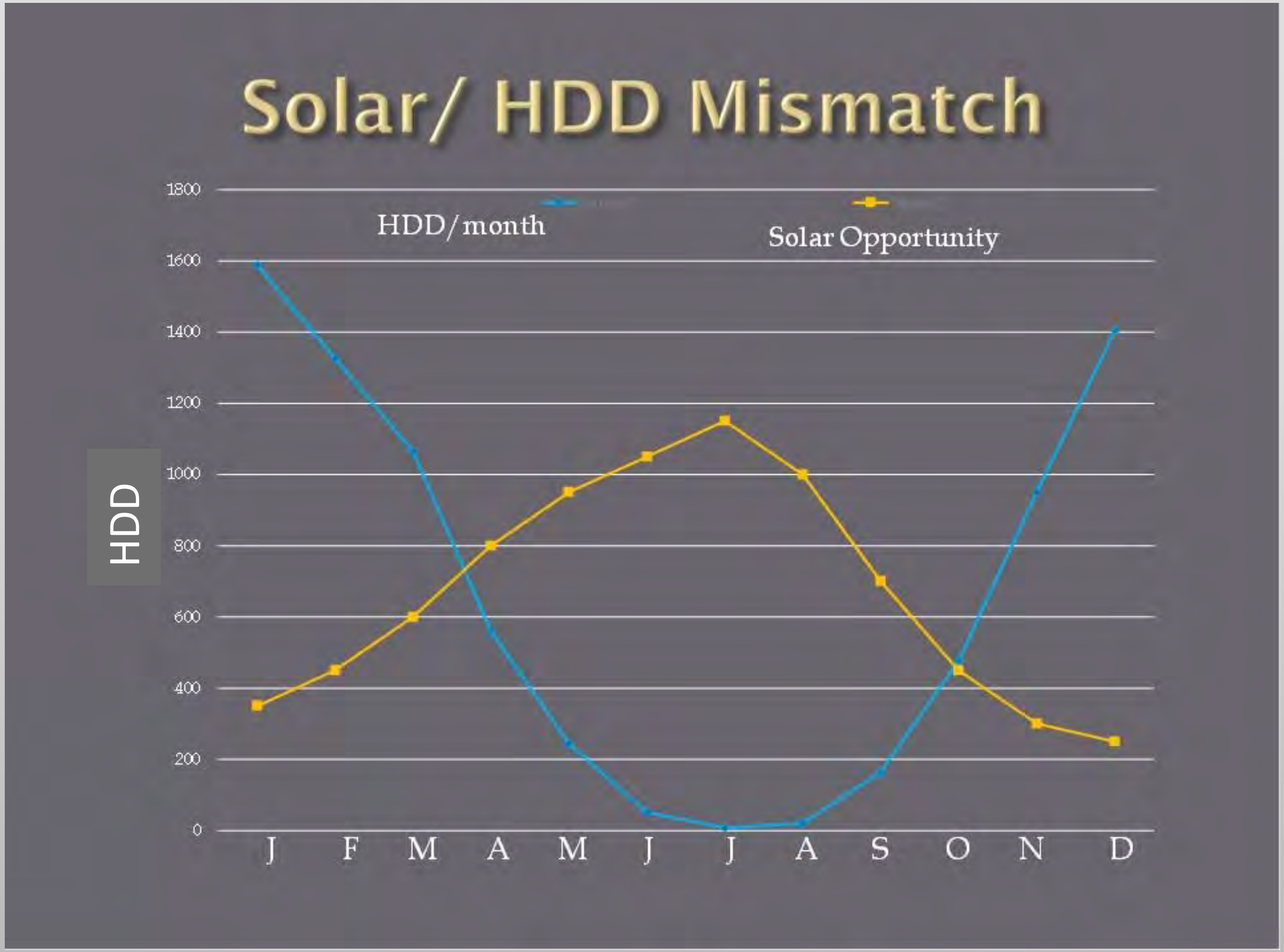
# of Cycles in Life of Battery



Depth of discharge %

Our Solar Resource is Predictably Seasonal

Solar Opportunity vs. HDD – North Central US



Storage Beyond Batteries

- Thermal storage
  - Hot water for domestic service or space heating
  - Chilled fluids, or ice, for cooling and refrigeration

- Pumping water
  - Irrigation
  - Livestock watering
  - Municipal water towers or perched reservoirs

Longer Term Storage Options?

- Micro Compressed Air shows promise but not ready yet
- Pumped hydro well known on utility level
- Hydrogen fuel cell cycle would be nice

Load Management to Better Coincide With PV Production

- Turning on “Dispatchable” Loads when solar is available
  - Electric water heaters (resistance or heat pump)
  - Electric boilers (heating storage tanks or maybe radiant slabs)
  - Chillers (cooling tanks or massive storage)
  - Dropping temperature of frozen food below setpoints
  - Water pumping for Irrigation or livestock watering
  - “Smart” Outlets with alerts to let us know there is surplus available to use
  - Refilling batteries or longer term storage methods

Managing Loads by Curtailment

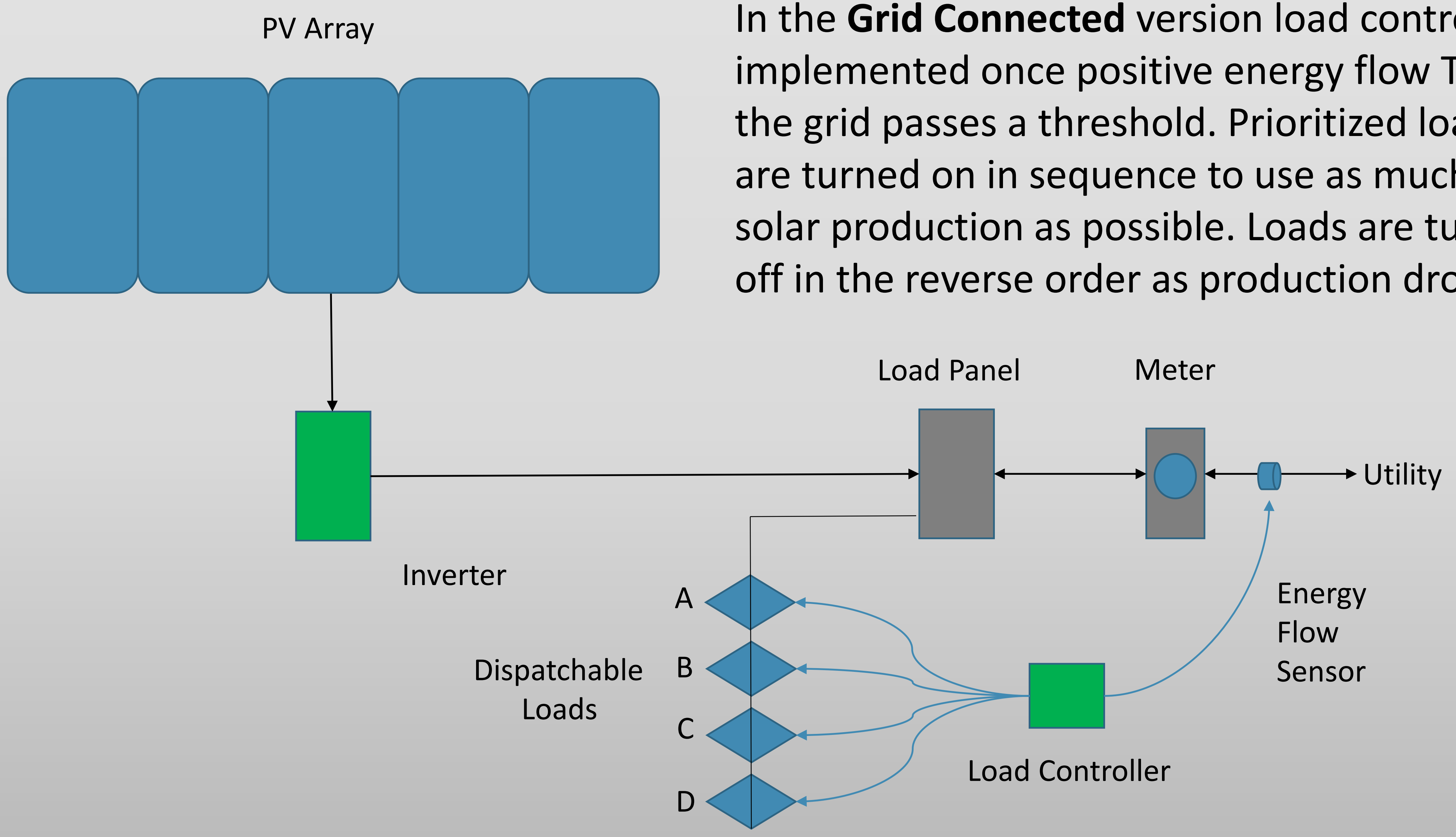
- Turning off running loads that can wait to minimize grid consumption
- If a load starts when solar production is expected – have it wait awhile
- Must be managed to still meet occupants needs
- Programmed thresholds to make sure no cold showers!

Example of Residential Demand Controller for Load Curtailment

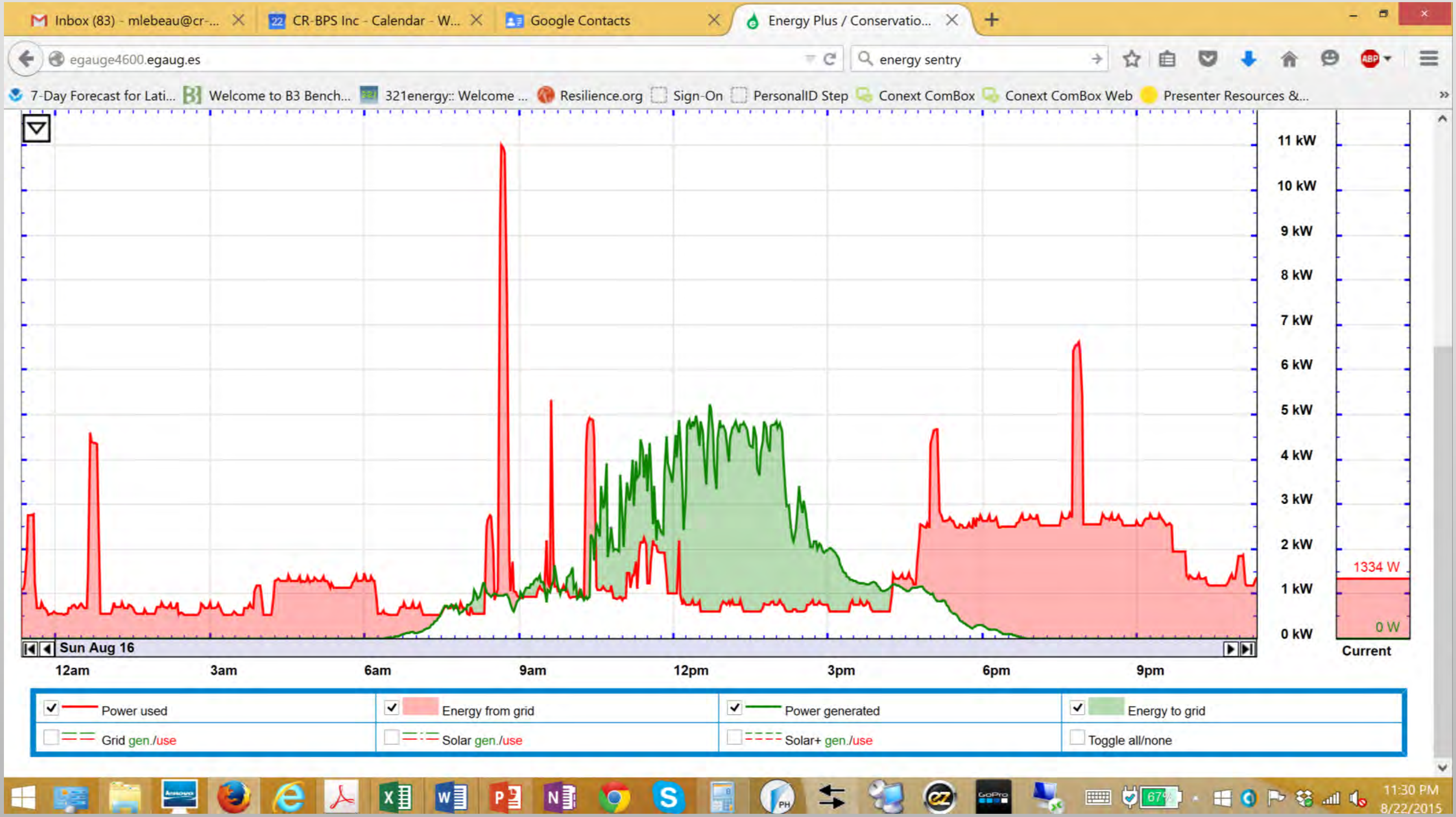
Courtesy of Energy Sentry

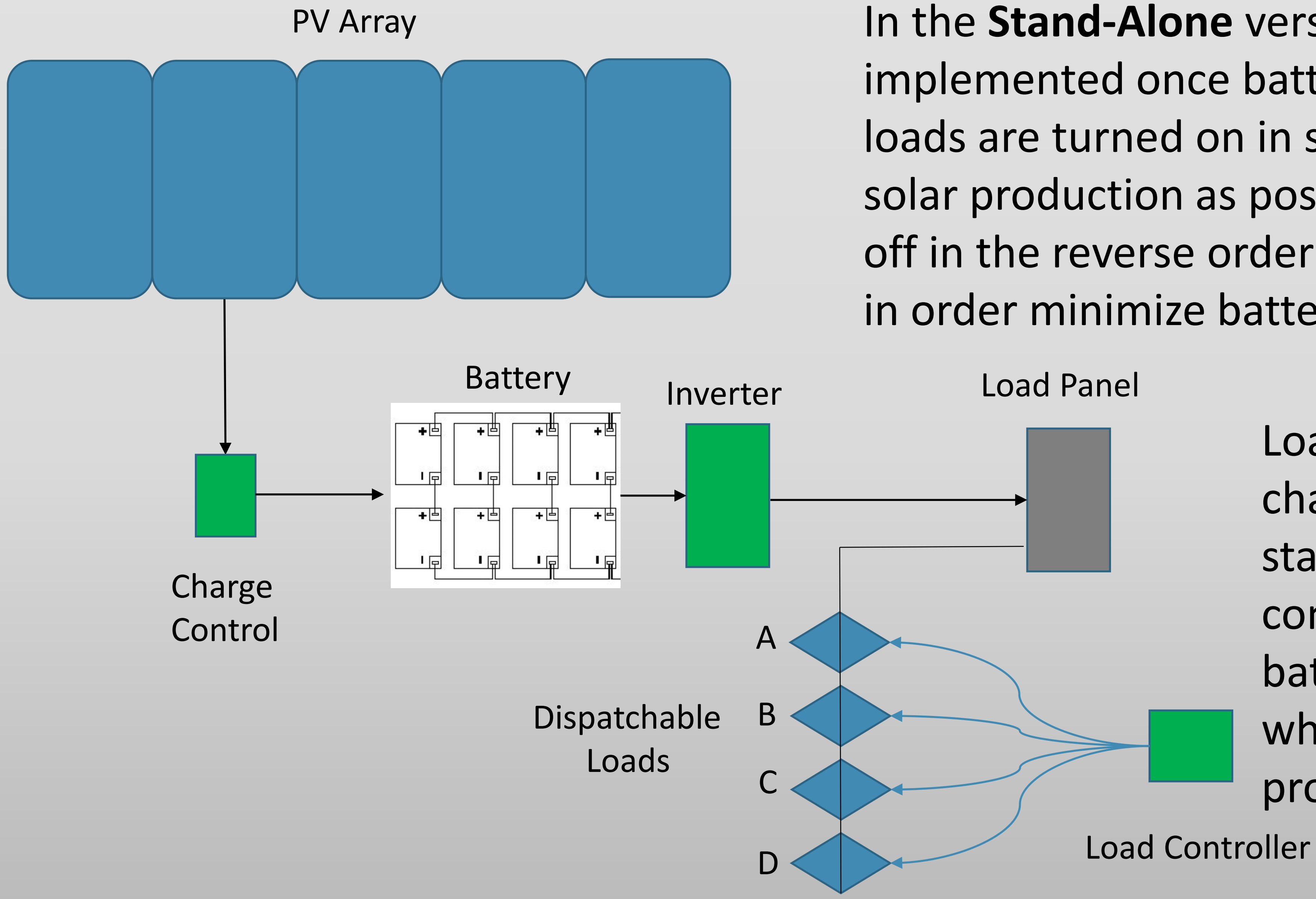
Using similar equipment to divert solar energy to dispatchable loads instead of selling it at a loss

In the **Grid Connected** version load control is implemented once positive energy flow TO the grid passes a threshold. Prioritized loads are turned on in sequence to use as much solar production as possible. Loads are turned off in the reverse order as production drops.



Monitoring demand and production to help users track energy balance and control loads





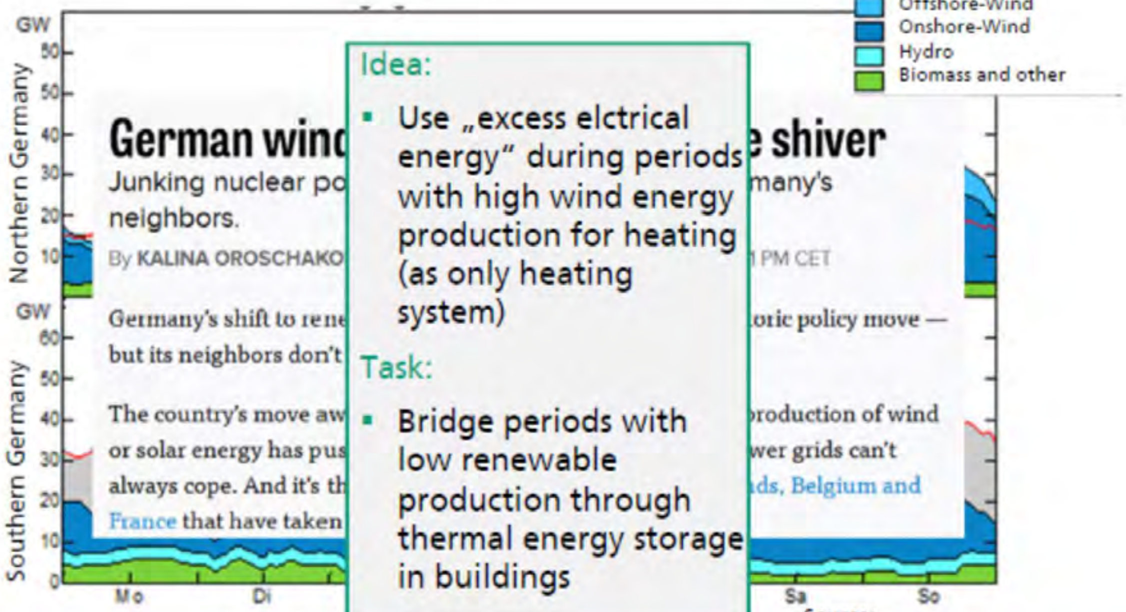
In the **Stand-Alone** version load control is implemented once batteries are full. Prioritized loads are turned on in sequence to use as much solar production as possible. Loads are turned off in the reverse order as production decreases in order minimize battery cycling.

Load controller monitors charge control for battery state of charge. Loads are controlled to balance battery state of charge while using as much solar production as possible.

Other Efforts – Storing Excess Wind Energy in Buildings

(Kunzel/Antretter Fraunhofer IBP)

Project: Wind Heating 2.0



Idea:

- Use „excess elctrical energy" during periods with high wind energy production for heating (as only heating system)

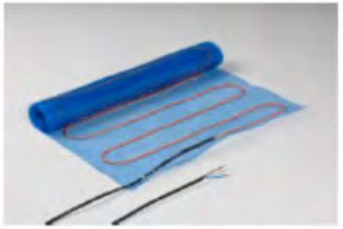
Task:

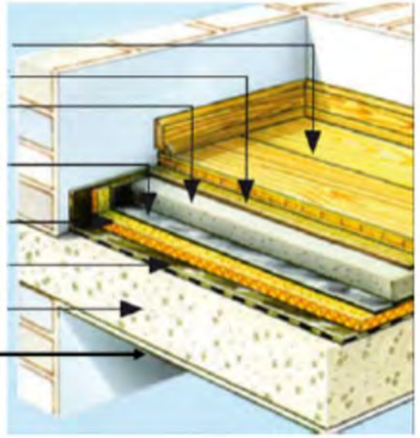
- Bridge periods with low renewable production through thermal energy storage in buildings

Source:
Fraunhofer IWES im Auftrag von Agora Energiewende

Fraunhofer IBP

Modeling of Loaded Component





Homogenous layers
Thermalresistance: 3,332 m²K/W
Heat transfer coefficient (U-value): 0,28 W/m²K
Thickness: 0,4 m

Nr.	Material/Layer (from outside to inside)	ρ [kg/m³]	c [J/kgK]	λ [W/mK]	Thickness [m]	Color
1	EPS (heat cond.: 0.04 W/mK - density: 15 kg/m³)	15	1500	0,04	0,08	
2	Concrete, C 12/15	2200	850	1,6	0,02	
3	Concrete, C 12/15	2200	850	1,6	0,2	
4	Mineral Insulation Board	115	850	0,043	0,05	
5	Concrete Screed, mid layer	1970	850	1,6	0,05	

Panel Heating as Source in Component

Additional Insulation below

Fraunhofer IBP

Thank you

Questions?

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"Don't let the mediocre be the enemy of what close examination shows needs to be done"