DC Microgrids: Potential and Reality

PhiusCon 2021 | Tarrytown, New York | October 14, 2021

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DC MICROGRIDS: POTENTIAL AND REALITY

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1 What is a Microgrid
- Generate, Distribute and Consume Power Locally
- Nanogrids - The Basic Building Blocks

2 Why build a microgrid?
- Resiliency, Efficiency, EV Integration,
- The big picture

3 Why DC Microgrids are the Future
- Transition to a DC world underway
- Resilience
- Efficiency
- Modular

4 Barriers to entry for DC Microgrids
- Regulatory
- Availability of DC equipment, appliances, standards

5 Examples of what is possible today
- Burnett house
- Fairmount Heights DC Microgrid

6 Q + A

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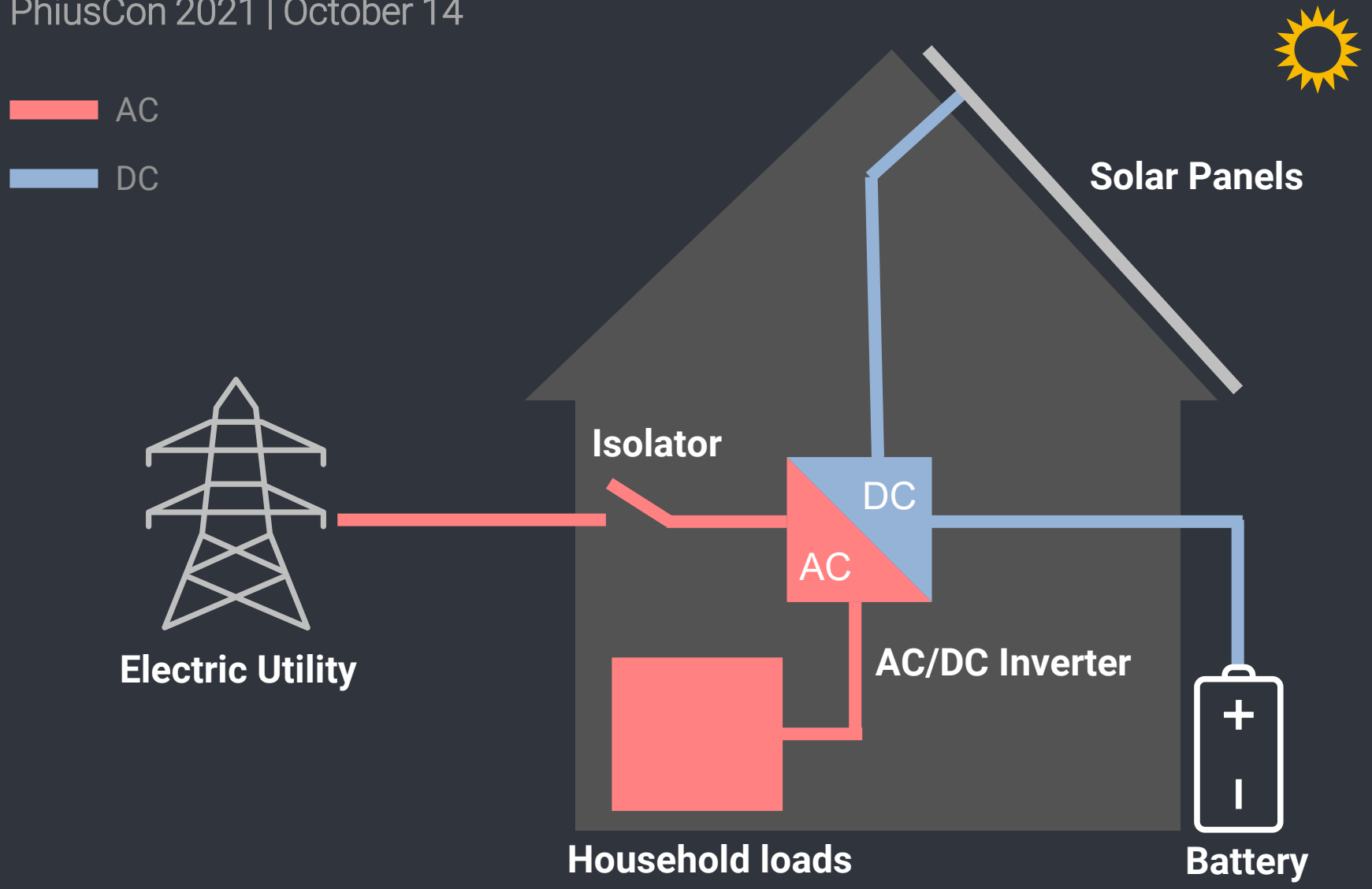

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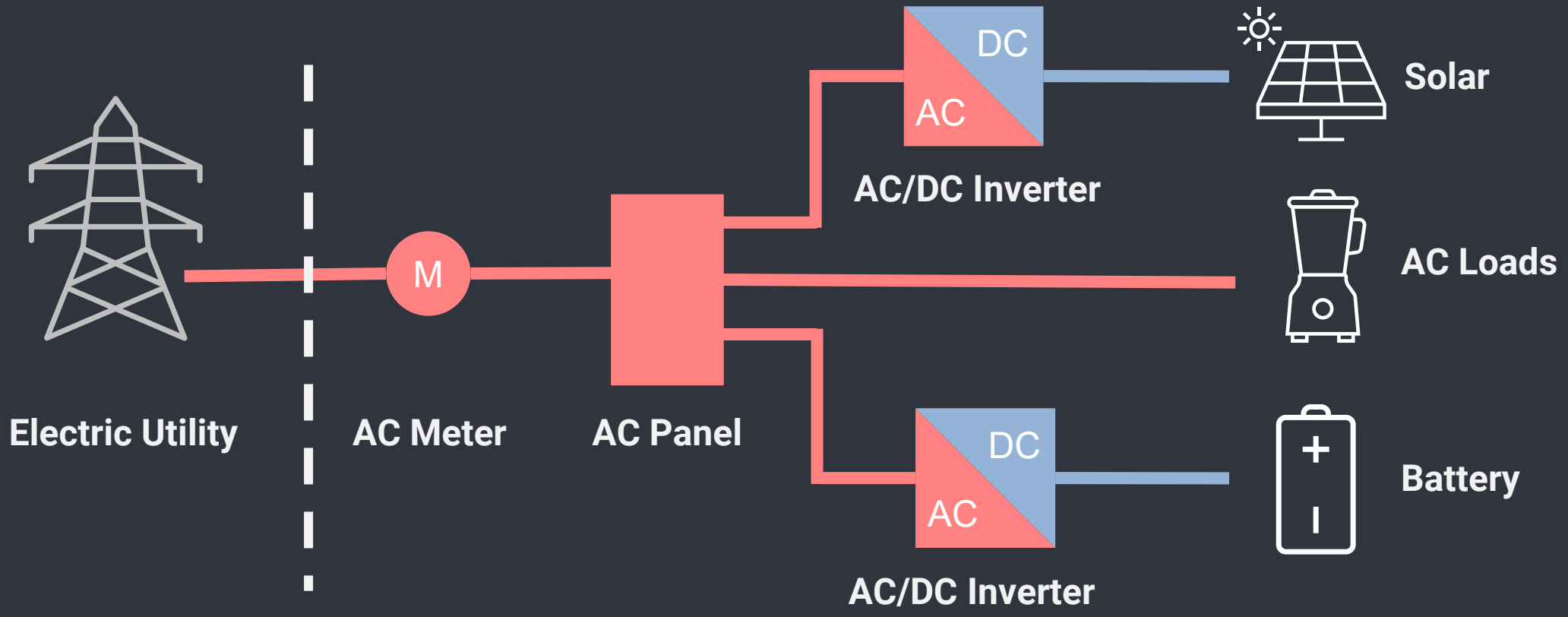

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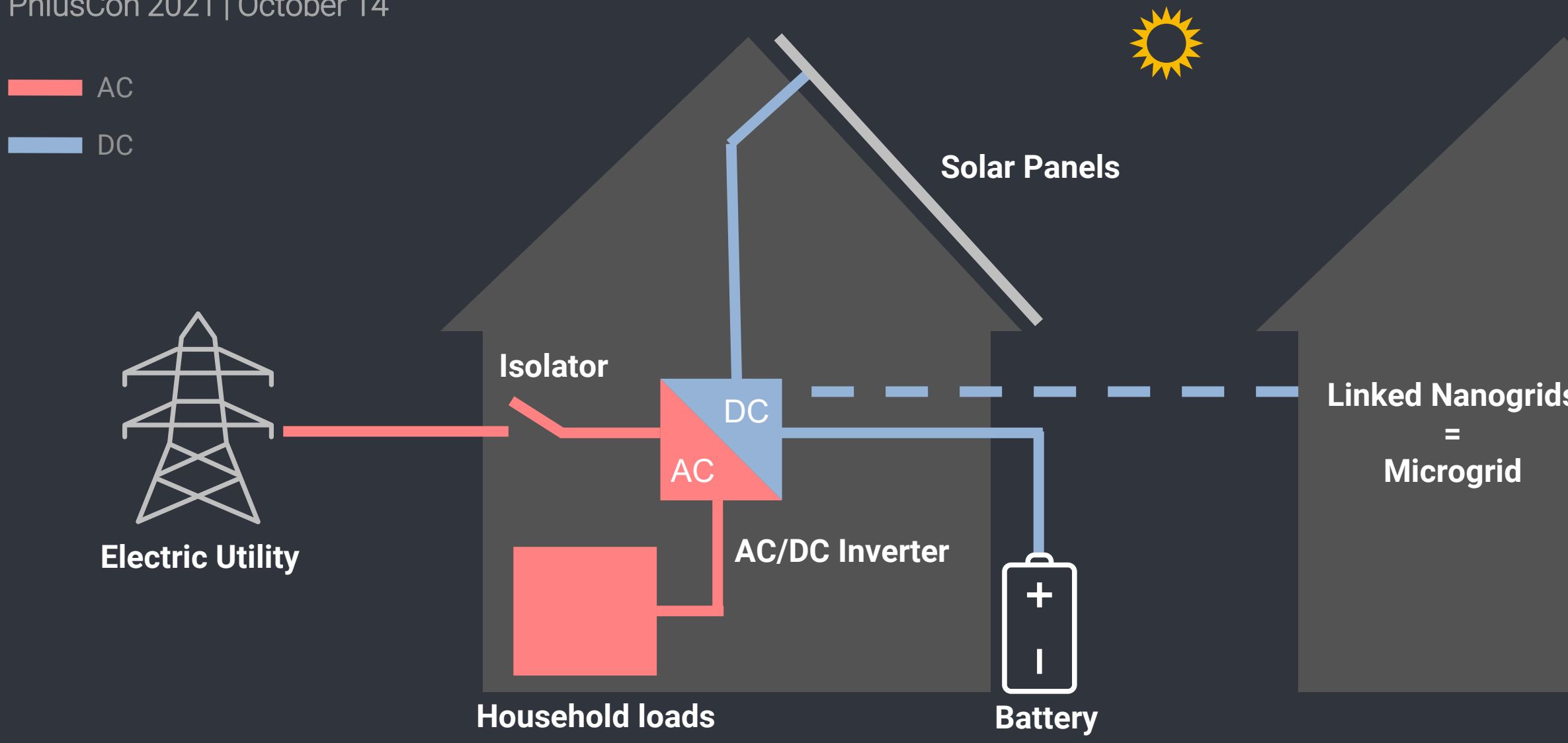

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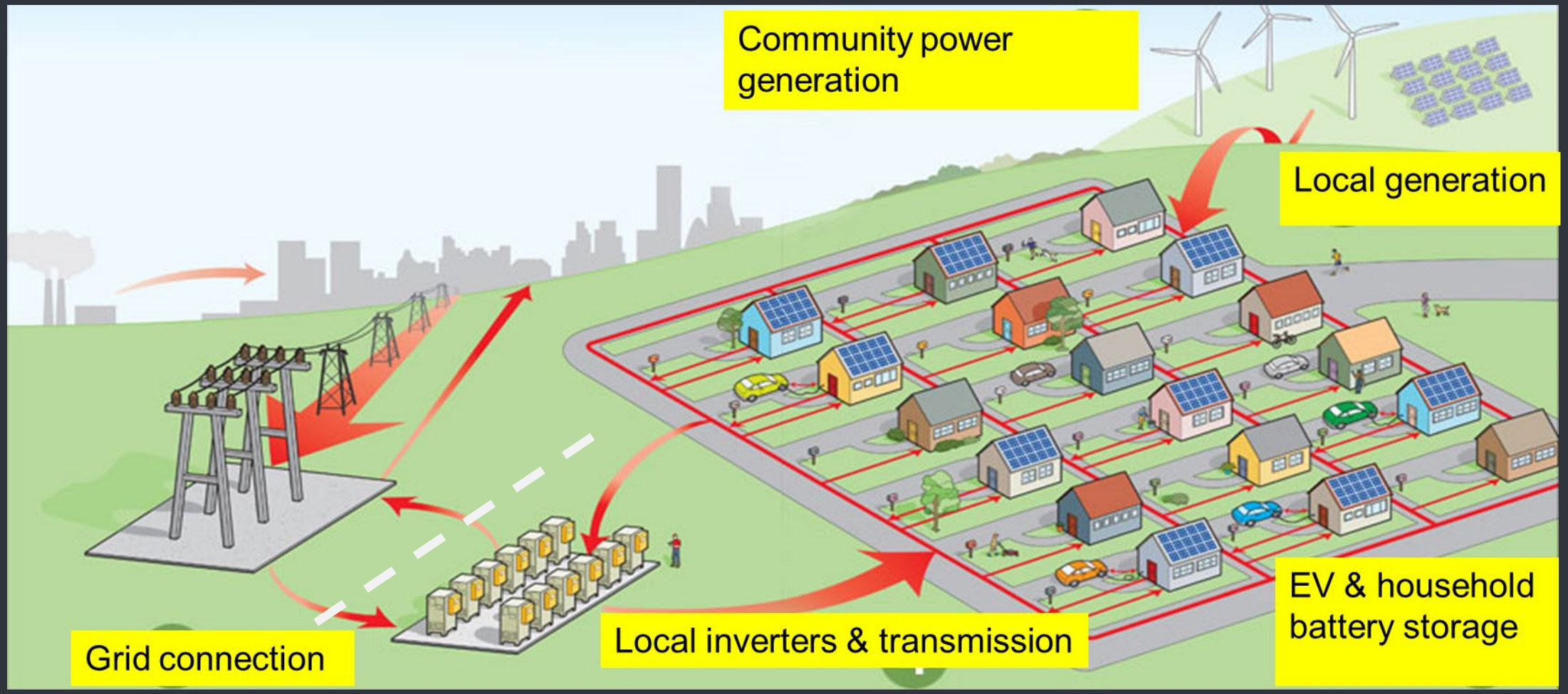

FORCES DRIVING ADOPTION OF MICROGRIDS

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Grid Fragility

Stressors from age

- 100 years old, uncoordinated ad hoc growth

Stressors from climate

- Increased violent weather events
- Necessity for greater strategic reserves

Vulnerability to attack

- Solar electromagnetic pulses (EMP's)
- Cyberattack
- Terrorist attack

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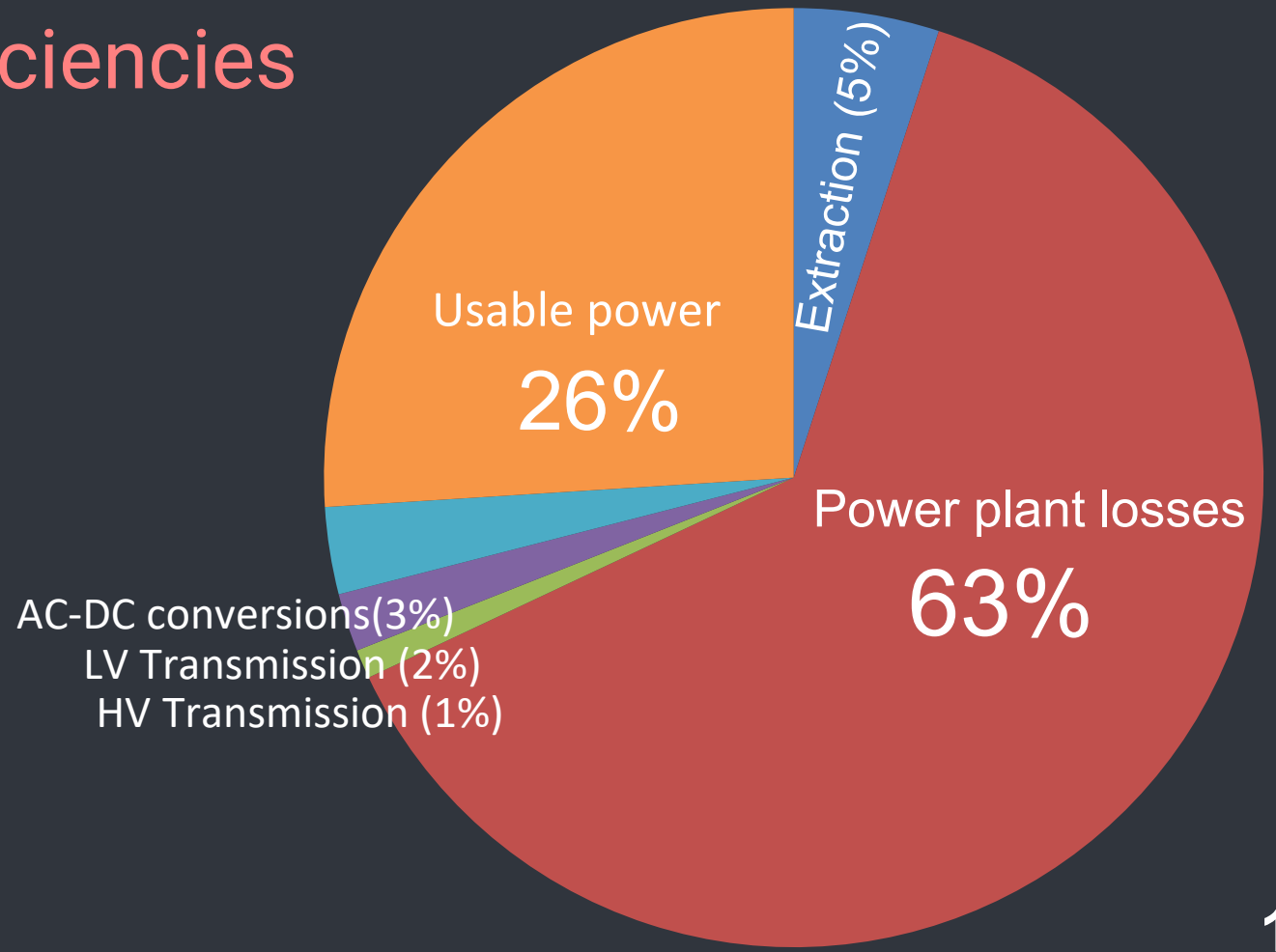
Efficiencies



1999 GRID

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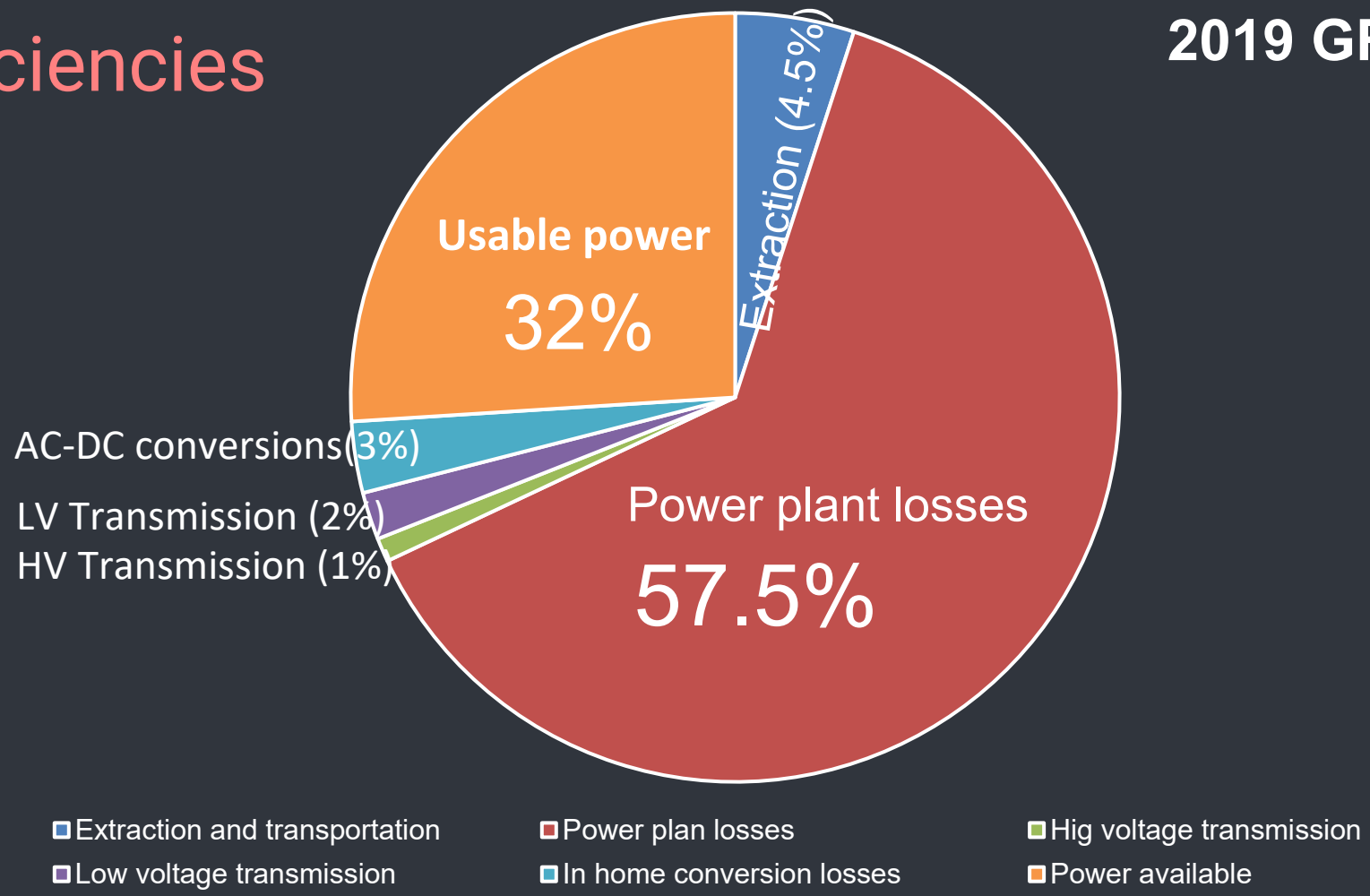
Efficiencies

2019 GRID



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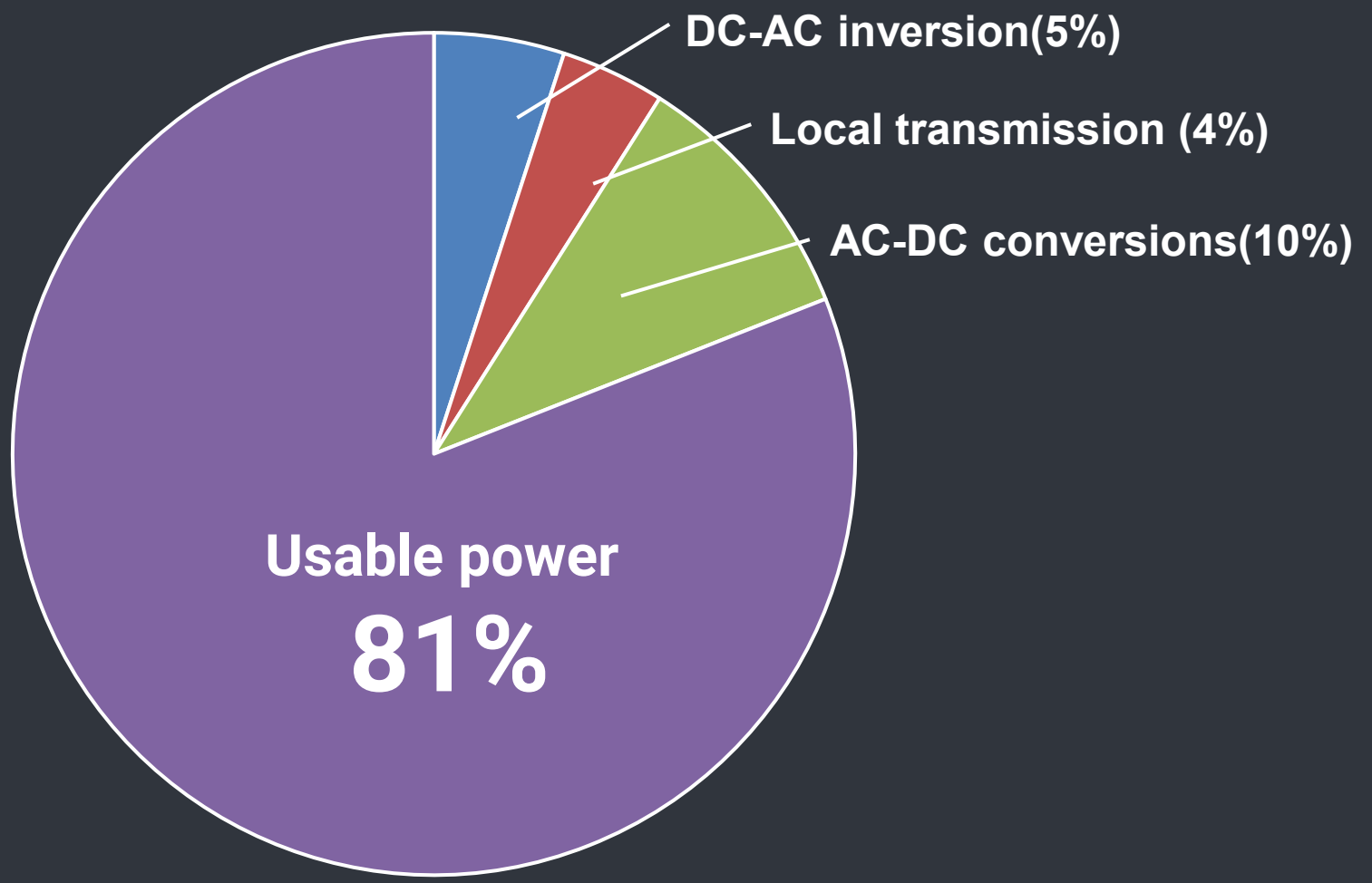
Efficiencies



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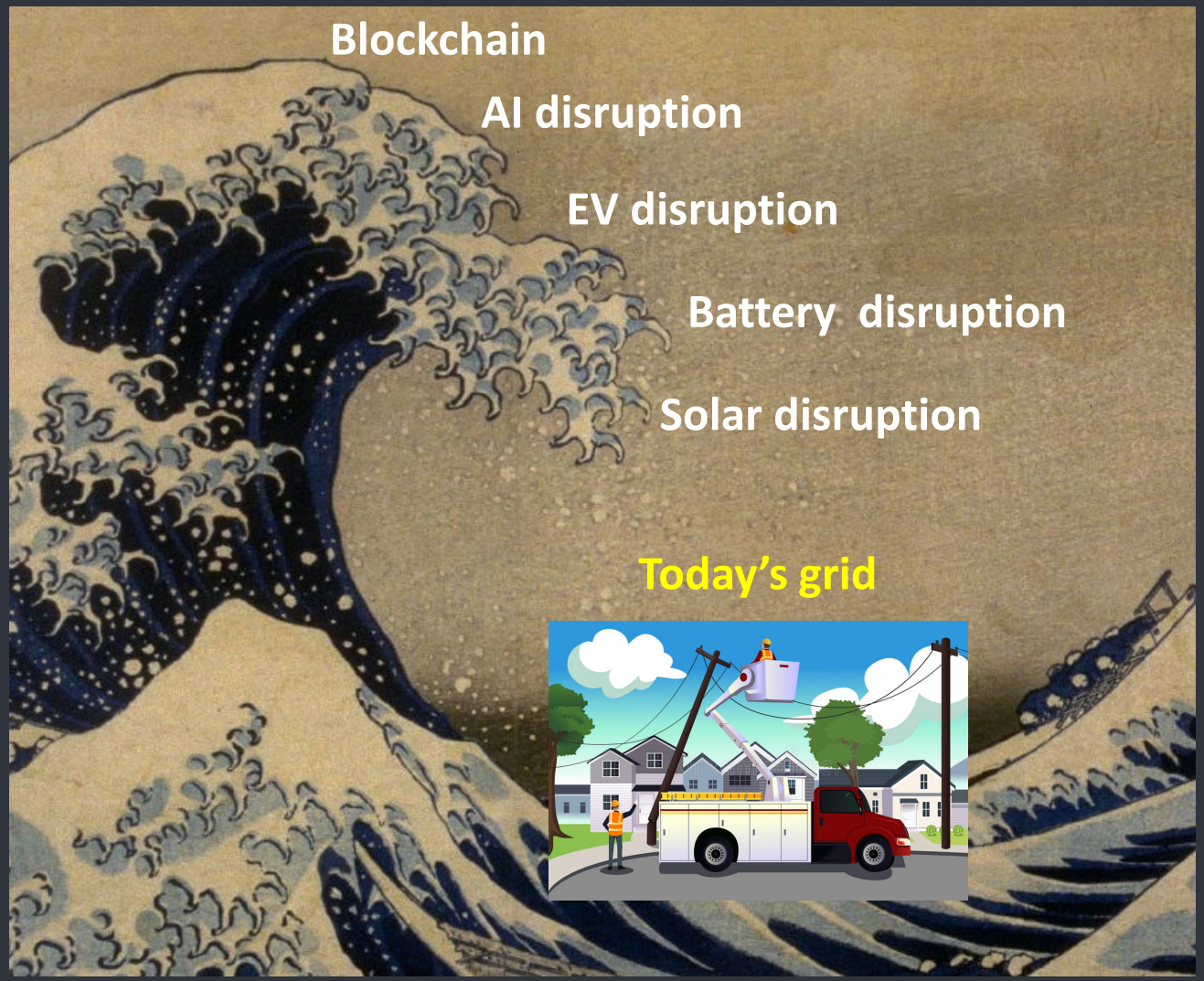
Technology Disruptions



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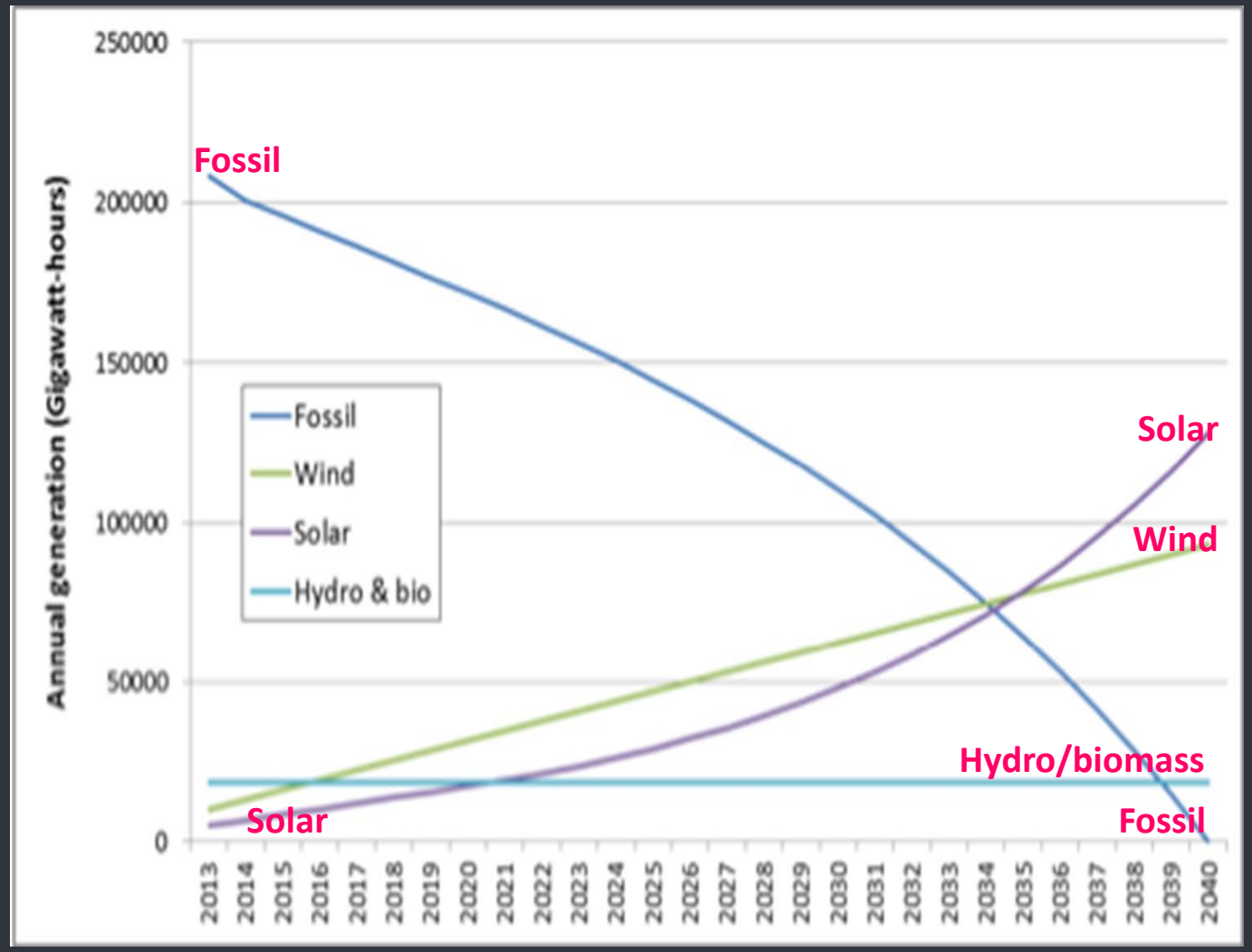

Solar Growth

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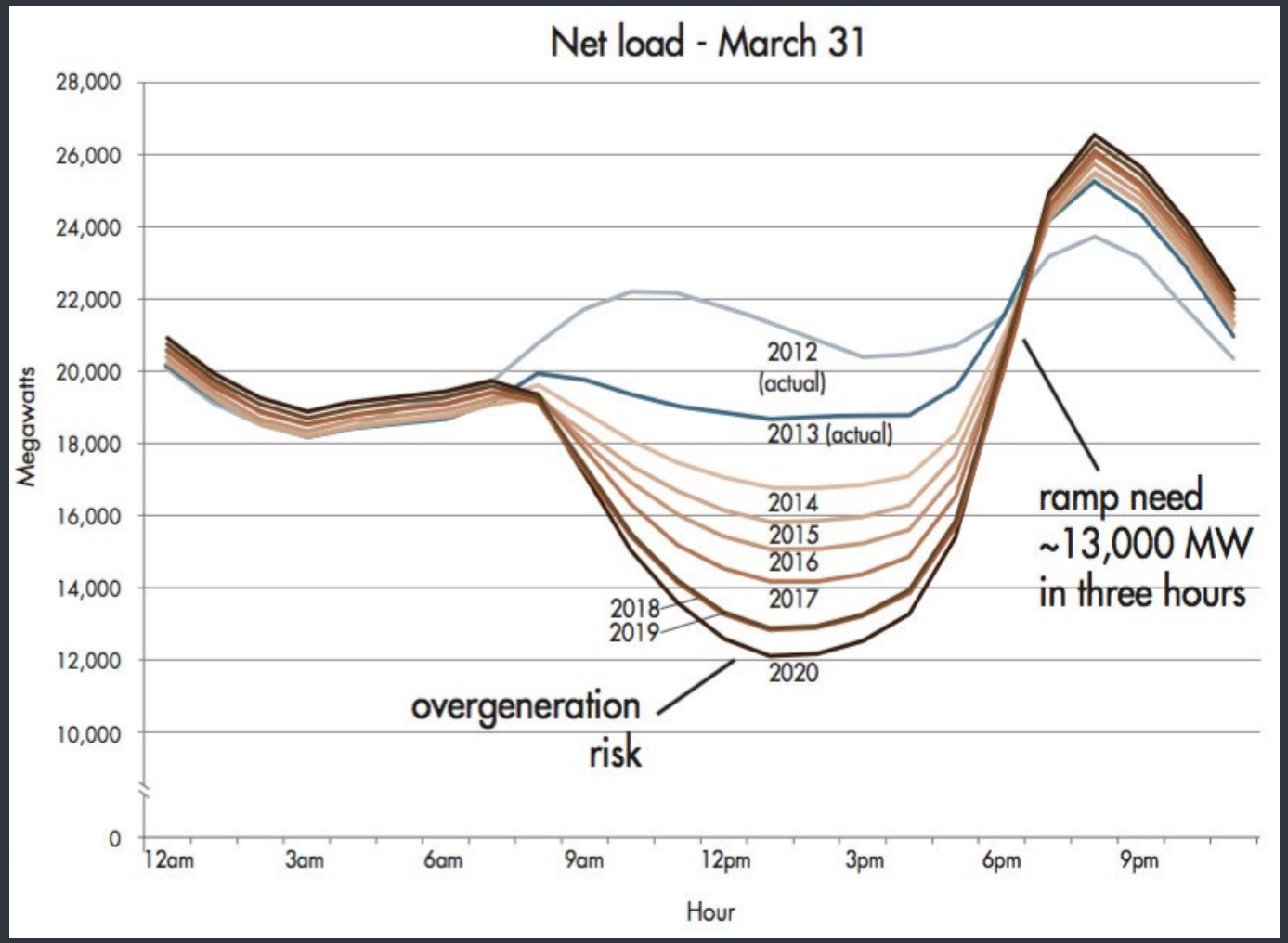
Technology Disruptions

Solar Intermittency



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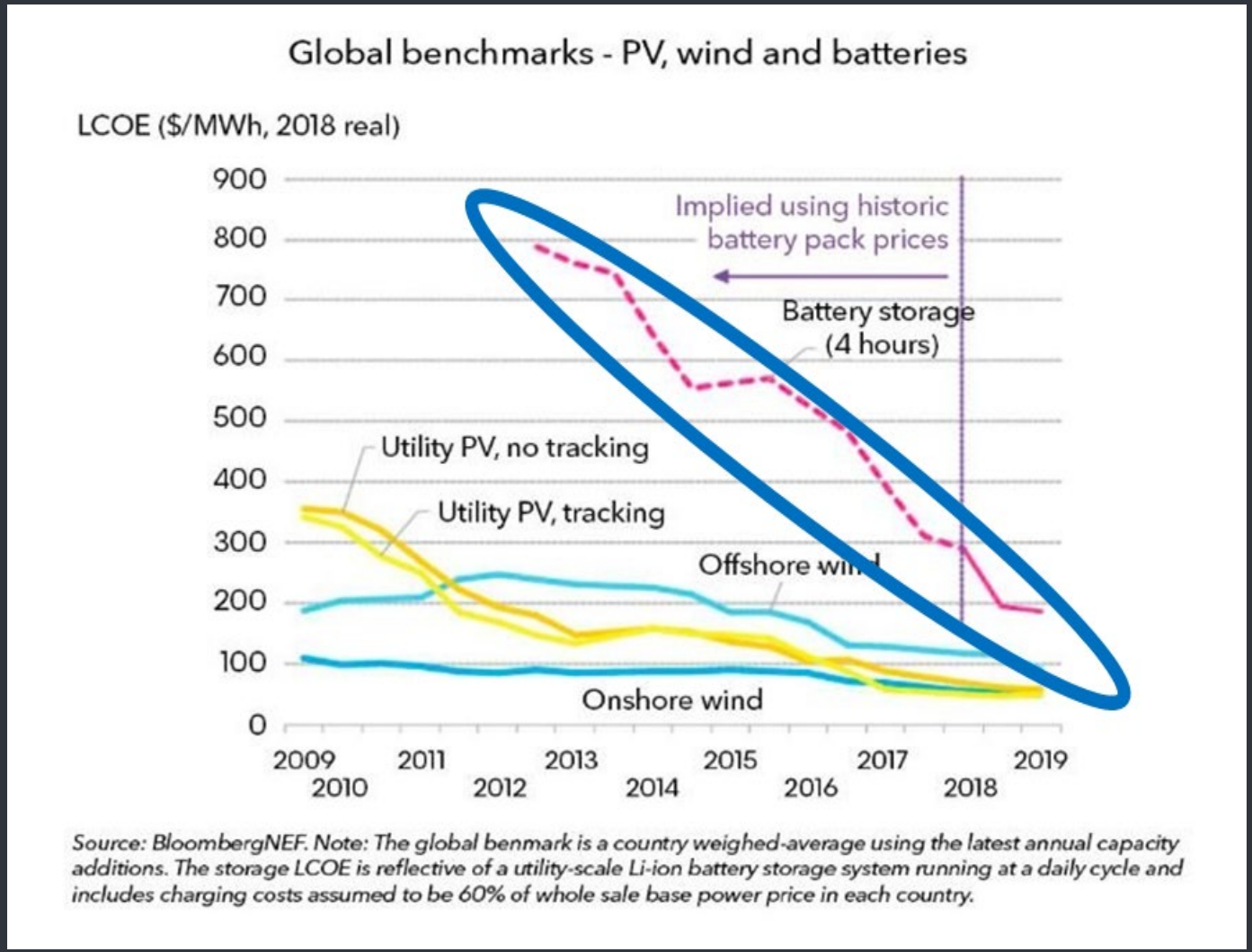
Technology Disruptions

Battery Cost



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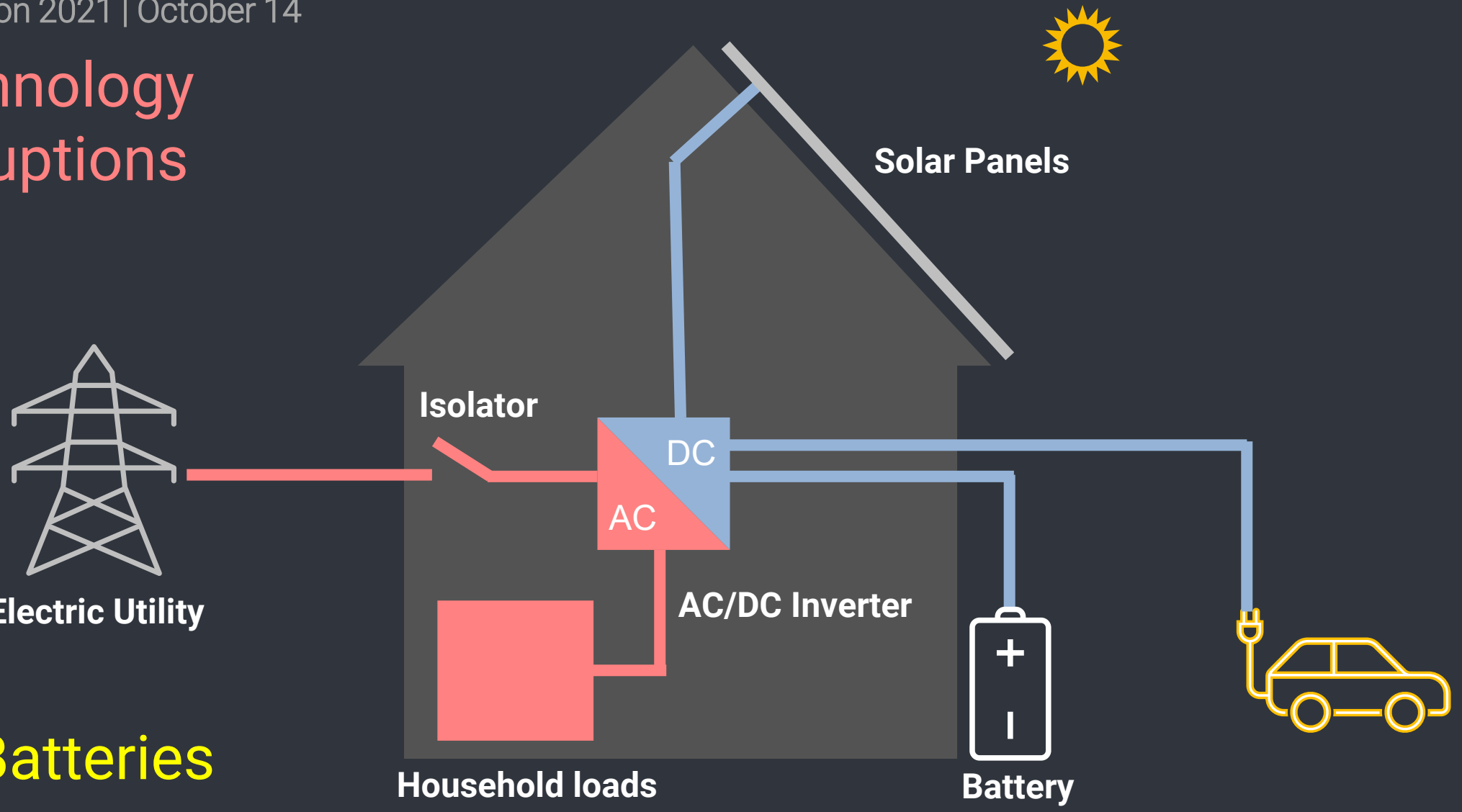
Technology Disruptions



EV Batteries

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Technology Disruptions

- **Peer to peer energy trading**
- **Buildings become virtual power plants**
- **Homeowners become prosumers of energy**

> ***"Around 2030, because of the convergent disruptions acting upon the energy grid, locally produced and stored power will be cheaper than the cost of transporation alone of any other form of energy. Game over."***
>
> ***Tony Seba, Stanford University***

AI & Blockchain

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WHY **DC** MICROGRIDS

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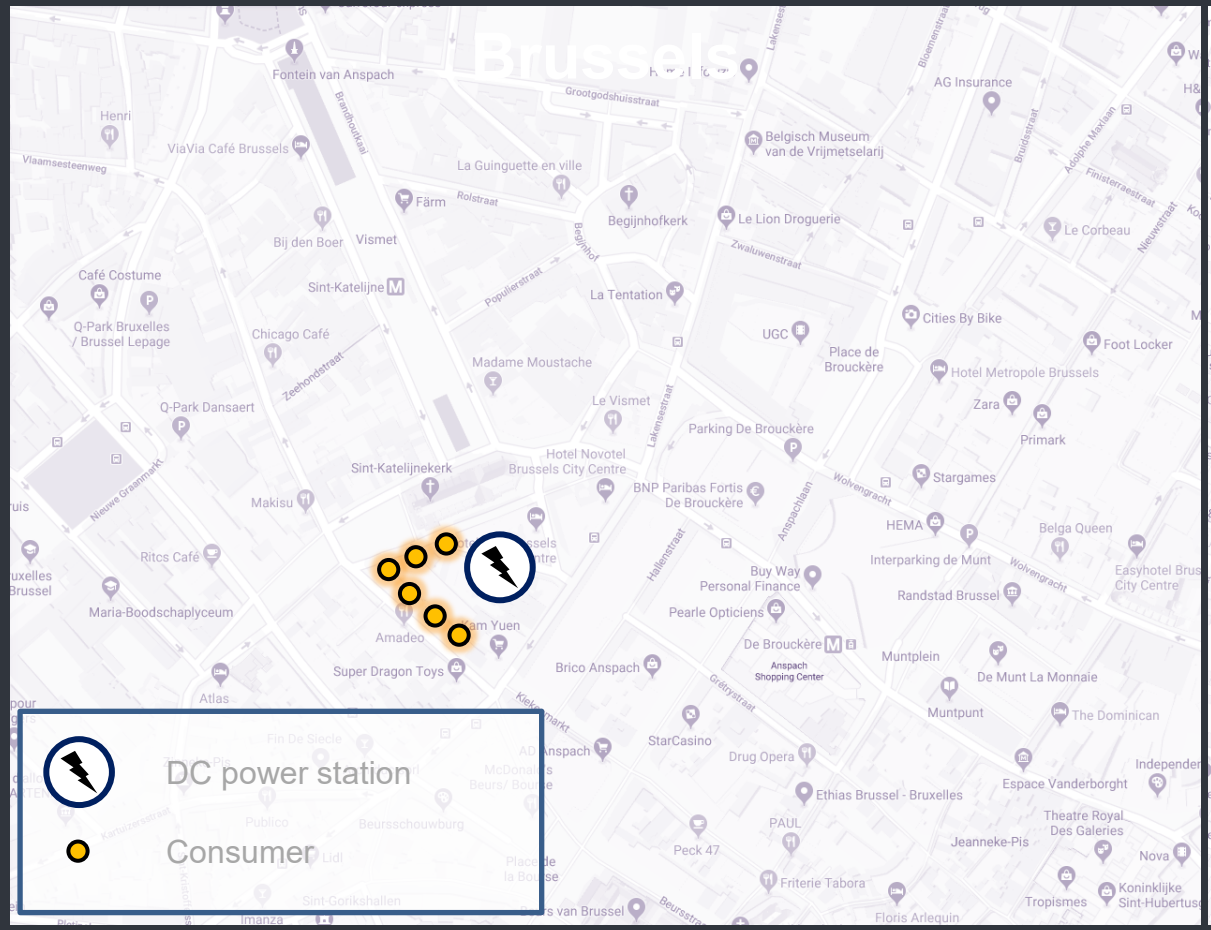

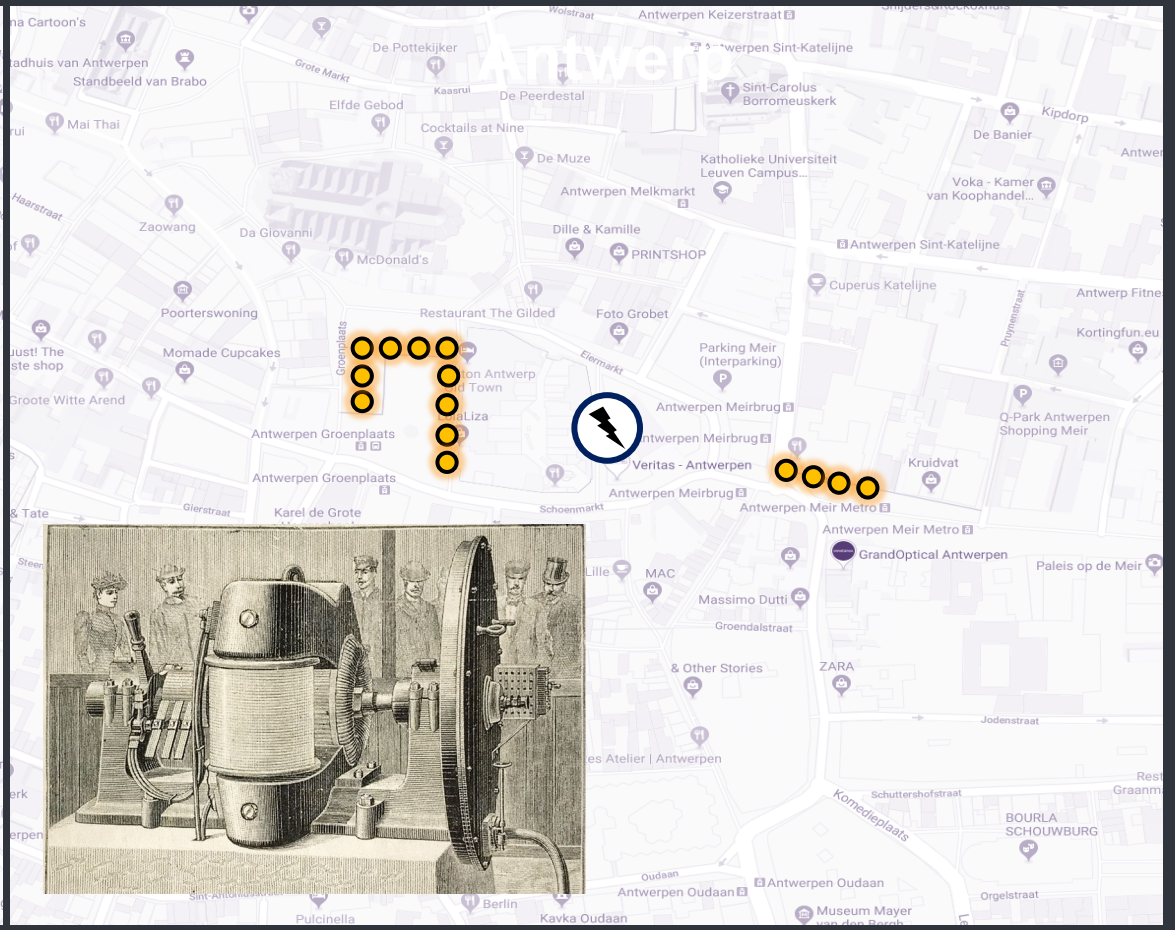

BACK TO THE FUTURE

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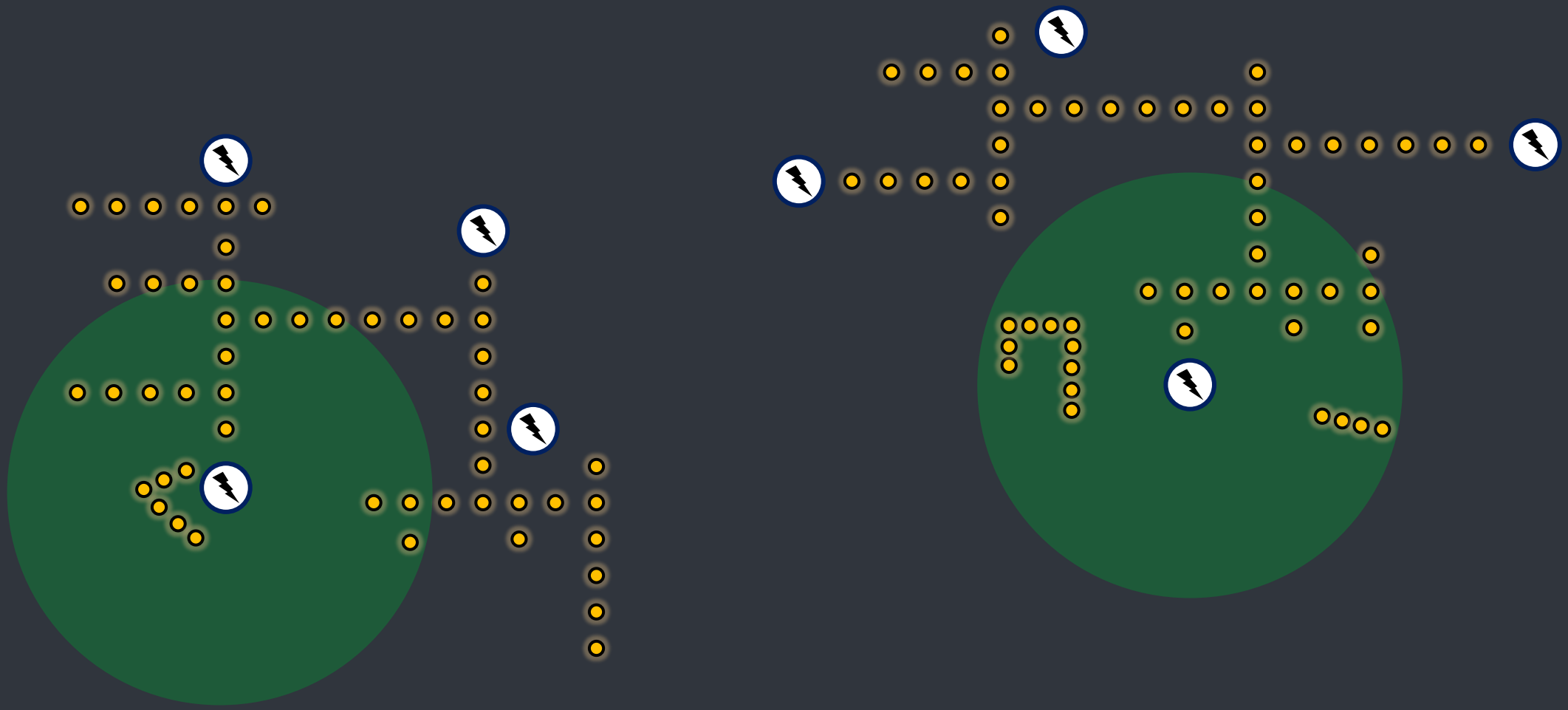

ECONOMICAL RANGE OF DC SYSTEMS WAS LIMITED TO 500M

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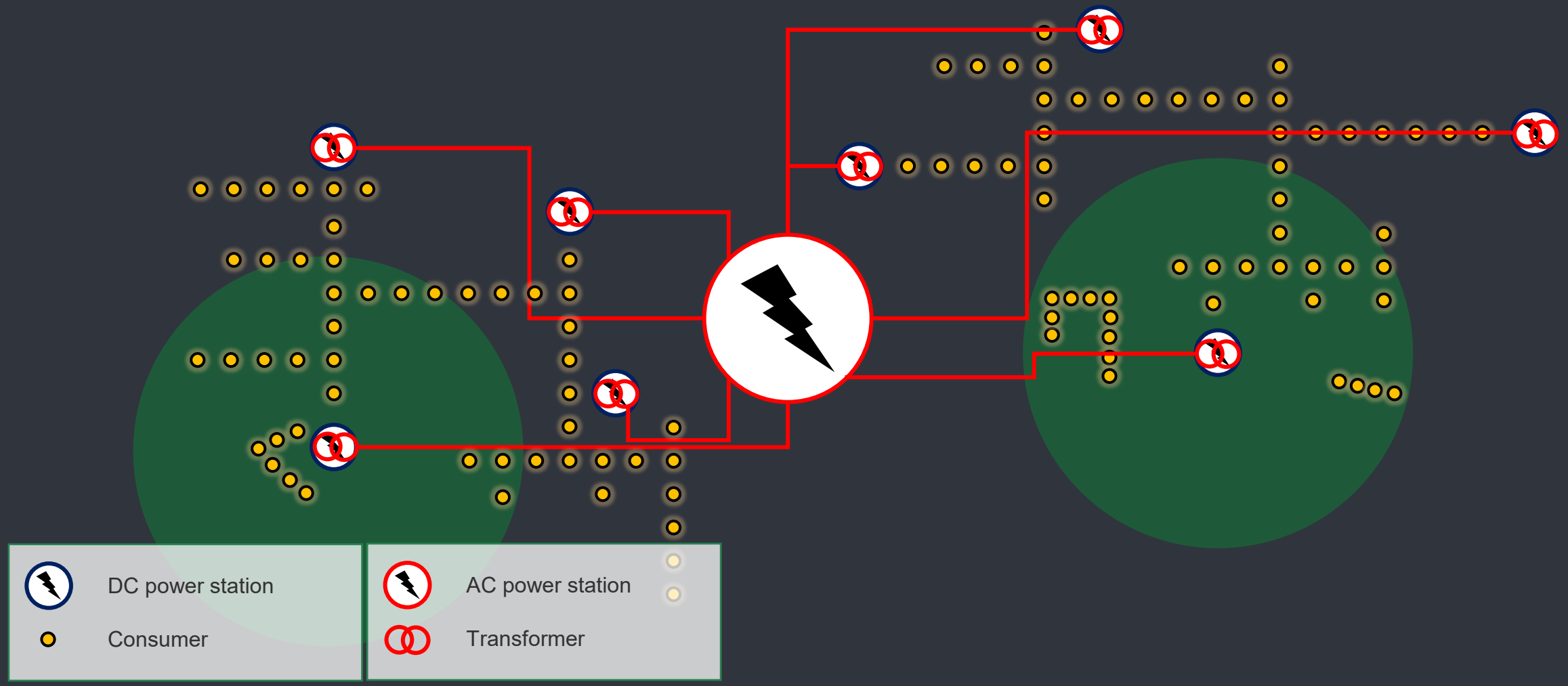

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BUT TIMES HAVE CHANGED …

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- Decentralized load and generation assets are co-located
- Why?
  - Big = beautiful no longer holds in case of solar photovoltaics and battery systems
  - Modularity is the keyword
- But…
  - It presents us with a challenging power management problem
  - It presents us with an infrastructure paradigm shift with bidirectional power flows
- Microgrids: a “Divide and conquer” approach

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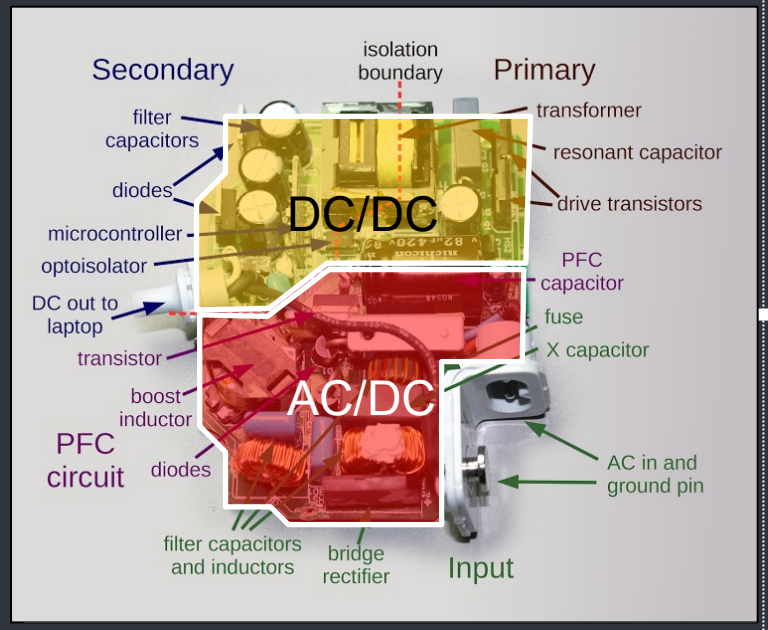

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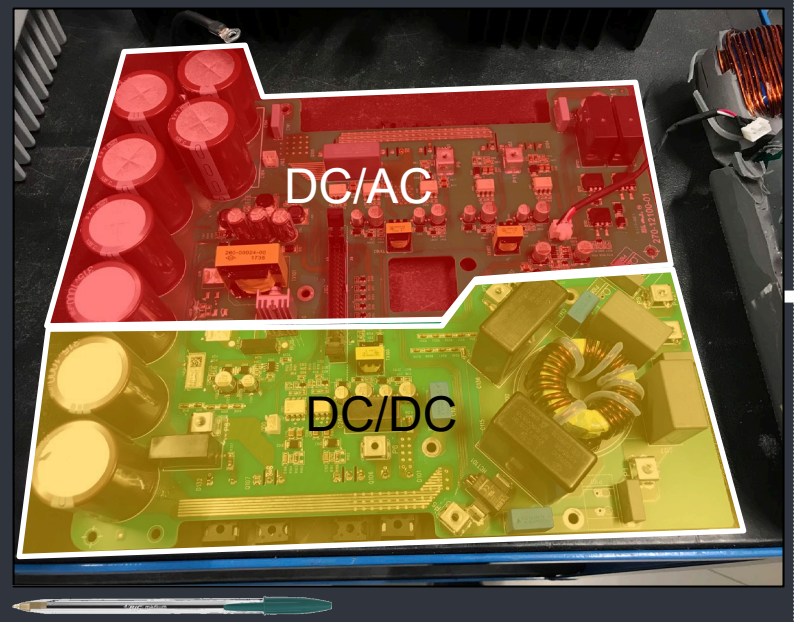

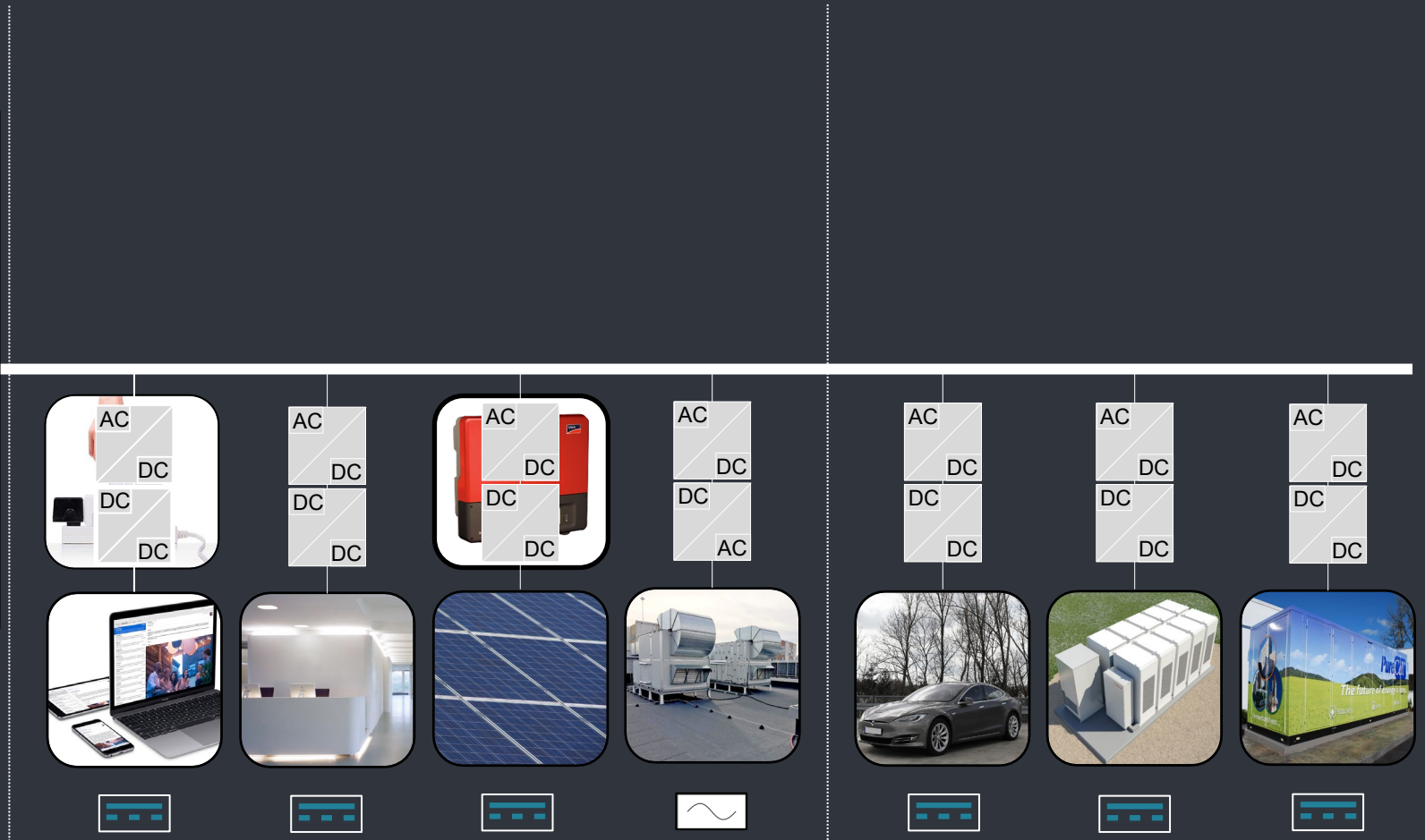

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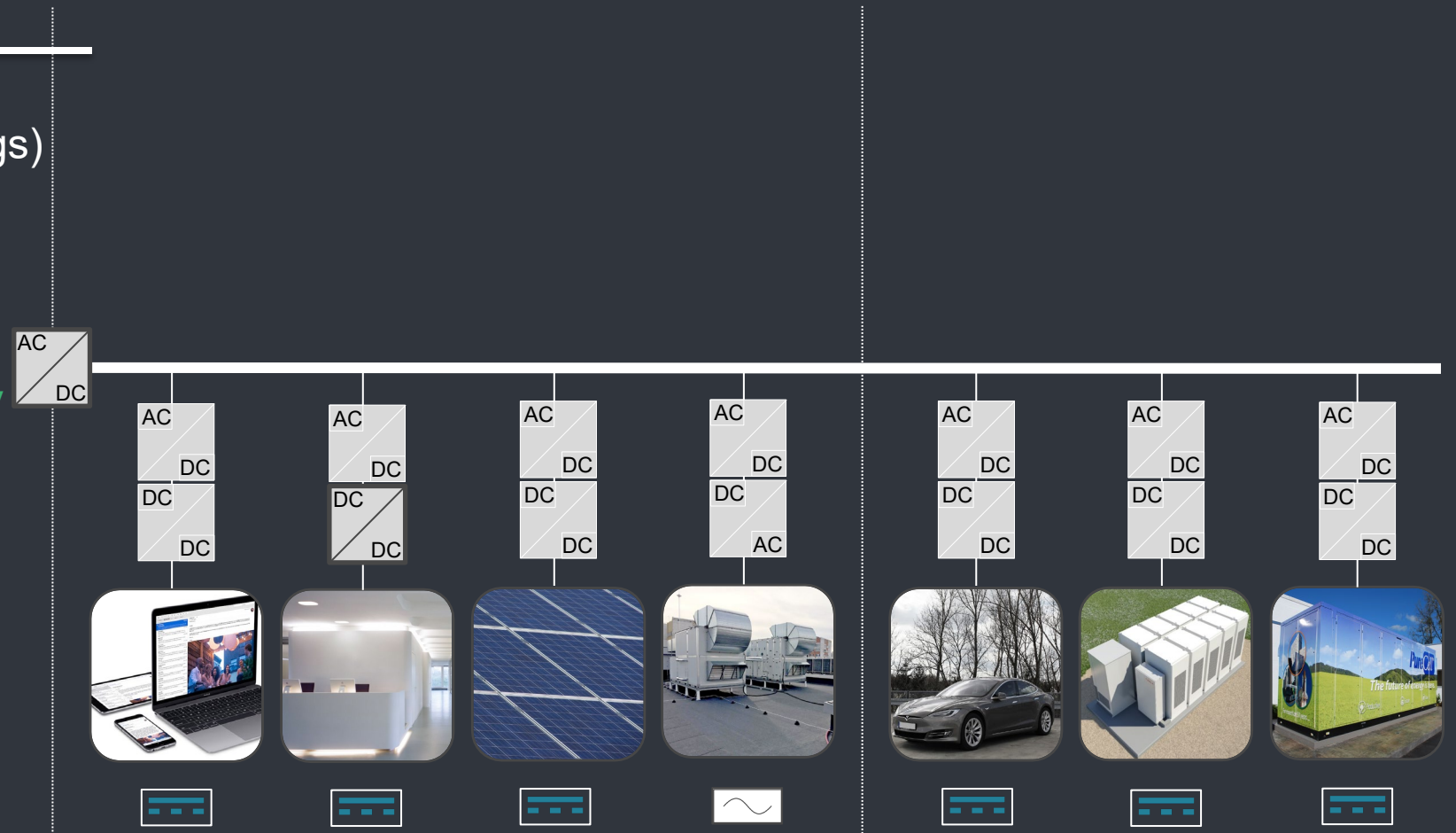
Why DC distribution systems?

- Increased compatibility
  - Efficiency gains (5-15% savings)
  - Reliability improvement (less components)
  - Upfront cost savings (-30%)
  - Material resource savings
- Increased power transfer capability
  - Upfront cost savings
  - Material resource savings



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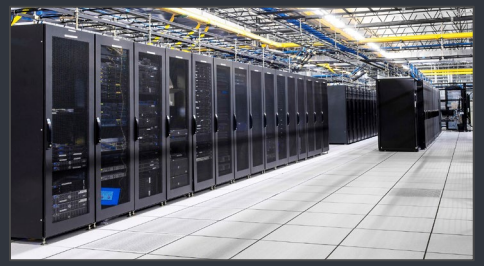

Source: https://www.quadranet.com

DATA CENTERS (380VDC)

- 10% efficiency gains (ABB, Green.ch datacenter, 1 MW)
- 15% less upfront capital cost
- 33% less floor space occupied
- Increased availability

Source: Direct Current BV

STREET LIGHTING (+/- 350VDC)

- Copper conductor savings
- Feeder length up to 4 km reduces the number of AC connection points
- LED driver becomes more reliable

Source: Arda Power

COMMERCIAL BUILDINGS AND DISTRICTS (+/- 380VDC)

- Reduce the number of converters
- Less conversion losses
- Able to operate in islanding mode
- Able to provide ancillary services to the AC grid

Source: A. Jhunjhunwala

RURAL ELECTRIFICATION (48VDC)

- 4000 households in India
- 125W solar panel, lead-acid battery and a controller
- LED lighting, DC ceiling fan and smartphone charger

Source: DC Industrie

INDUSTRY (600VDC)

Running on $600V_{DC}$

- DC improves immunity and grid stability
- 40% less copper consumption
- Able to operate in islanding mode

Source: Airbus

ALL ELECTRIC AIRCRAFT (370VDC)

Running on $270V_{DC}$

- Hydraulic actuators are going electric (Boeing 787 - Airbus A380)
  - Weight reduction
- DC systems reduce the number of components
  - Weight and reliability improvement

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BARRIERS TO ADOPTION OF DC MICROGRIDS

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- National Electrical Code – Legacy AC specific language
- Standards and testing
- Economies of Scale
- Market Readiness
- Product availability
- Customer/ Builder Adoption or Resistance
- Business Models

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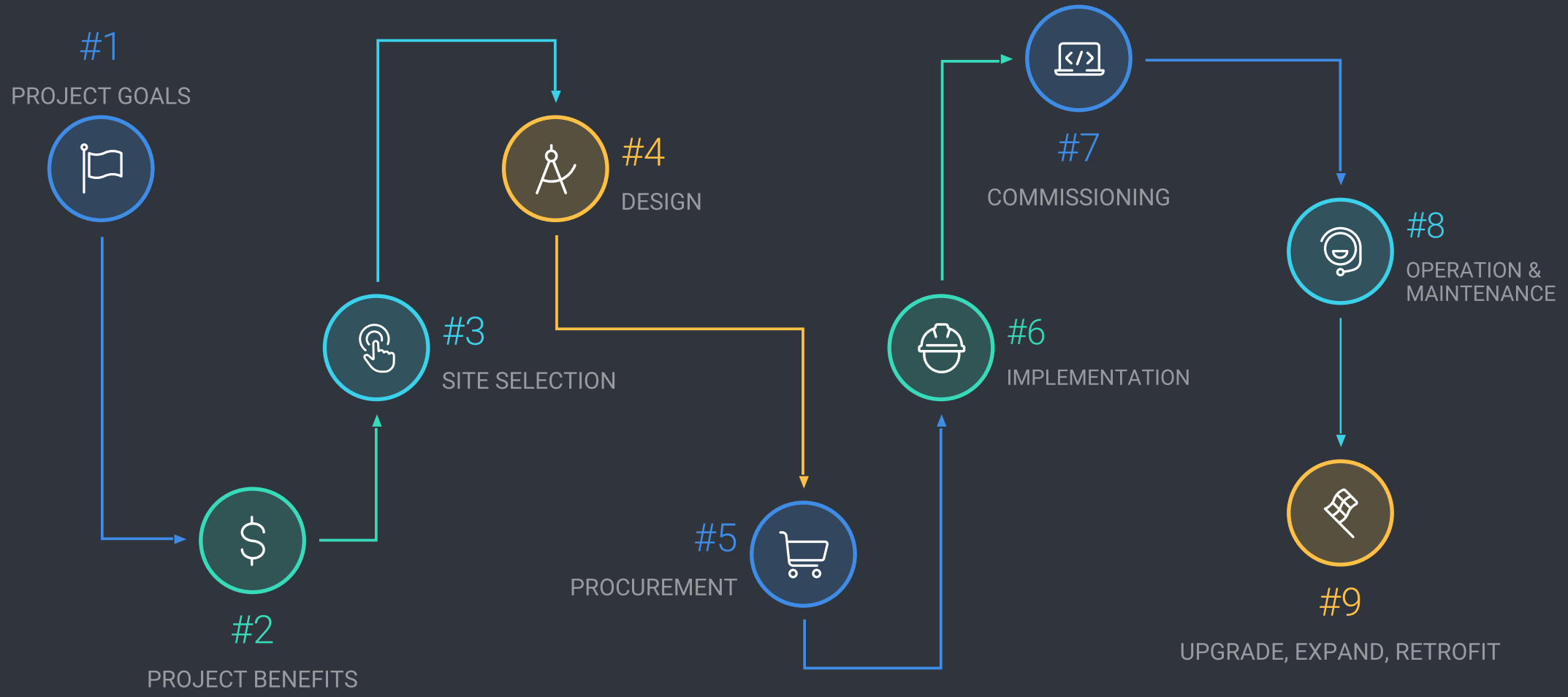

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EXAMPLES OF WHAT IS POSSIBLE TODAY

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DC SOLAR

DC STORAGE

DC WIND

DC FUEL CELL (HYDROGEN)

DC POWER DISTRIBUTION

DC APPLIANCES

DC LIGHTING

DC HVAC … ETC.

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LUXURY HOMES POWERED BY DC MICROGRID

GENERATE

DISTRIBUTE

CONSUME

& SHARE

POWER

AS

DC

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CENTRALLY GENERATE & DISTRIBUTE POWER AS DC

CENTRAL DC POWER DISTRIBUTION

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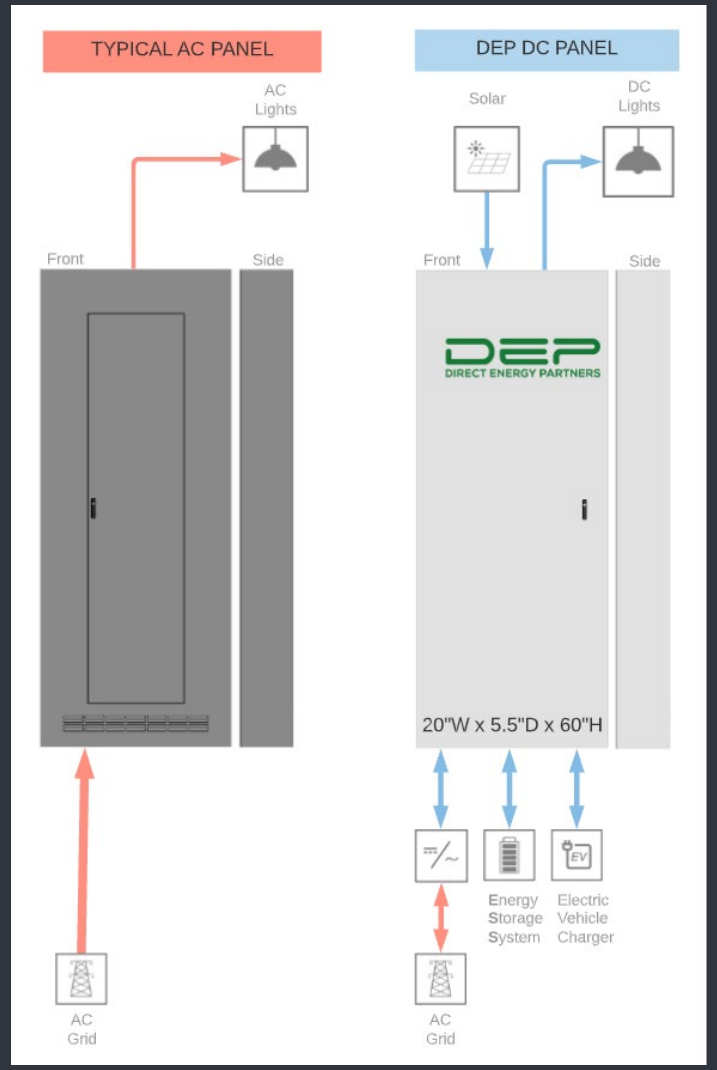
DC POWER DISTRIBUTION PANEL



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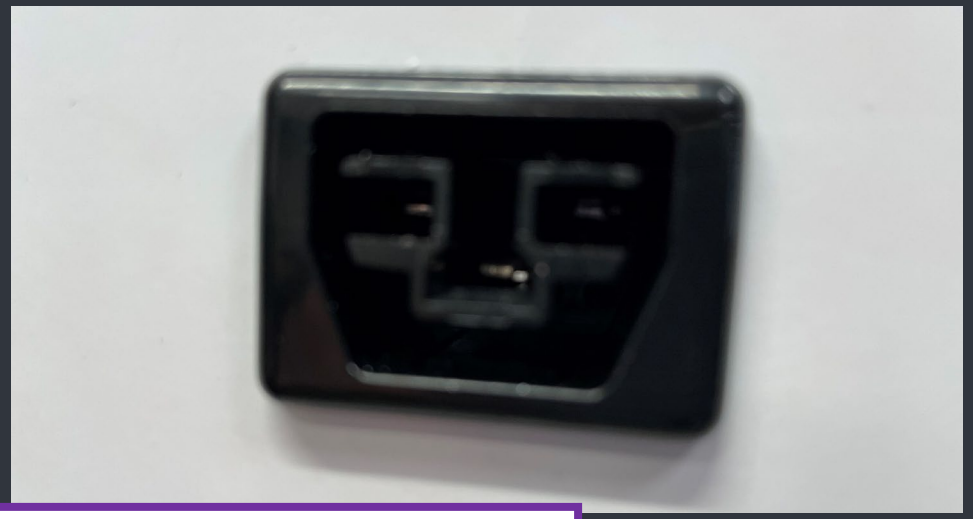

Anderson 380VDC Connector

Nextek DCO USB-A, USB-C

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Goals

- PHIUS+2018
- “DC- Ready” : Build in adaptability to next-generation appliances and equipment.

Challenges

- Single family home
- Owner not interested in living in “an experiment”
- High end finishes, appliances and lighting
- Supply chain of DC equipment not mature for residential market

Zero-energy nanogrid, Arlington, VA

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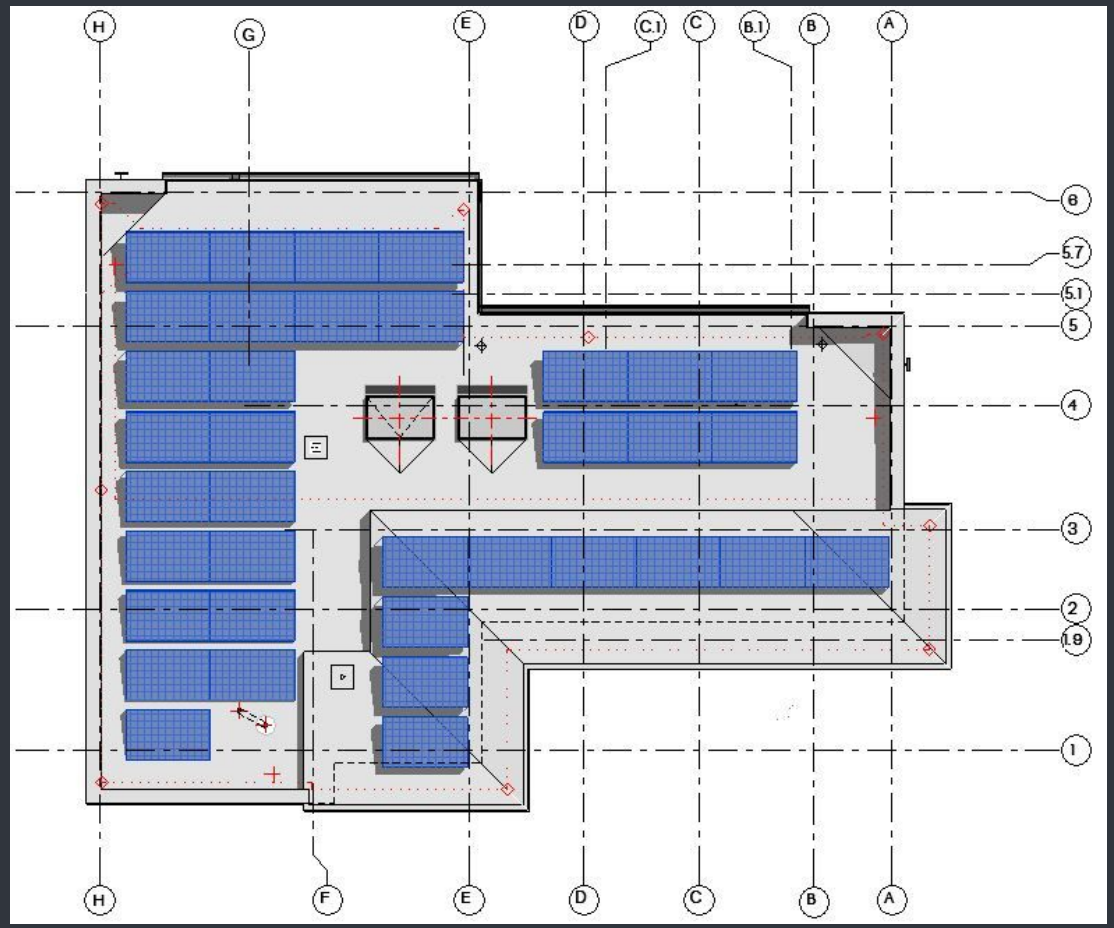
BASIC DATA

SIZE:	3,900 SF ~ 3 Bedrooms; 3-½ Baths	
FOOTINGS:	4” high density EPS below;	R(20)
	4” EPS at sides	R(20)
SLAB:	4” concrete with 4” EPS below	R(20)
FOUNDATION:	10” concrete with 4” EPS outside,	
	2” EPS+ 3-1/2” batts inside	(R44)
WALLS:	Double studs with 9-1/4” densepack	
	fiberglass + 4” EIFS outboard	(R48)
ROOF:	14” sloped wood trusses with dense-	
	pack fiberglass and 2” polyiso	(R69)
WINDOWS:	Zola triple glazed	(R6)
AIRTIGHT LAYER:	Outside face of sheathing	
MECHANCAL:	Central high static VRF system	
	Zehnder Comfo-350 ERV	
HOT WATER:	Heat pump hot water heater	
SOLAR:	15.2 kW of REC 450-72 Series panels	
	SolarEdge Energy Hub inverter	
BATTERIES	2- LG Chem RESU 16H (32 kWh)	
AIRTIGHTNESS:	1.3ACH@50pa	

Zero-energy nanogrid, Arlington, VA



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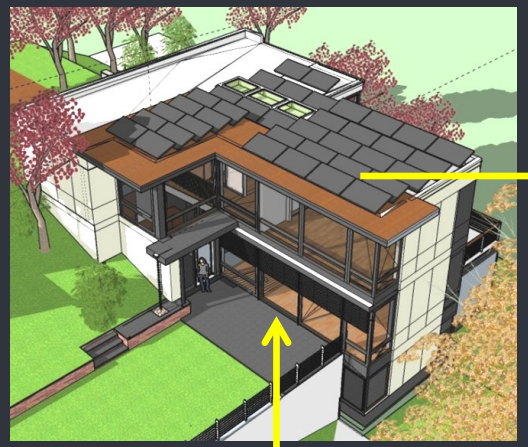

generation

ENERGY DEMAND **14,200 KWH/YR**

SOLAR ARRAY: **15.2KW**

ENERGY PRODUCTION 19.500 KWH/YR

ENERGY STORAGE **32KWH**

storage

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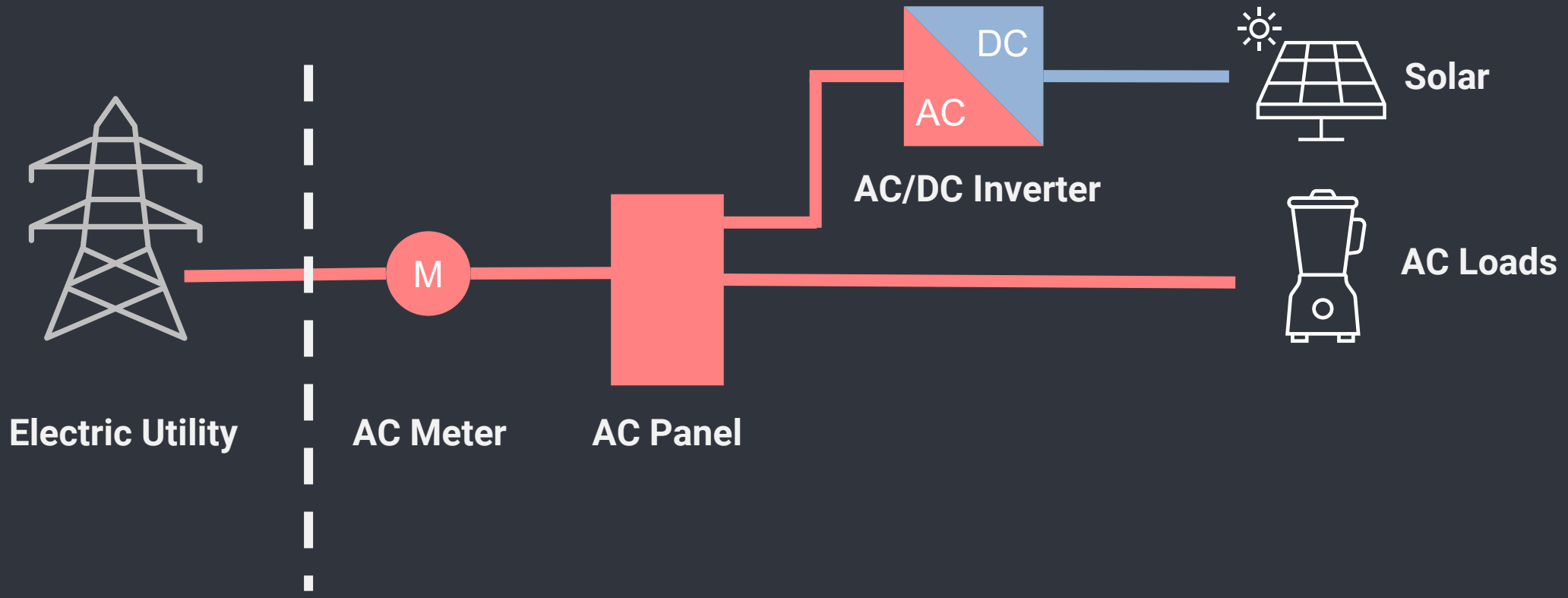

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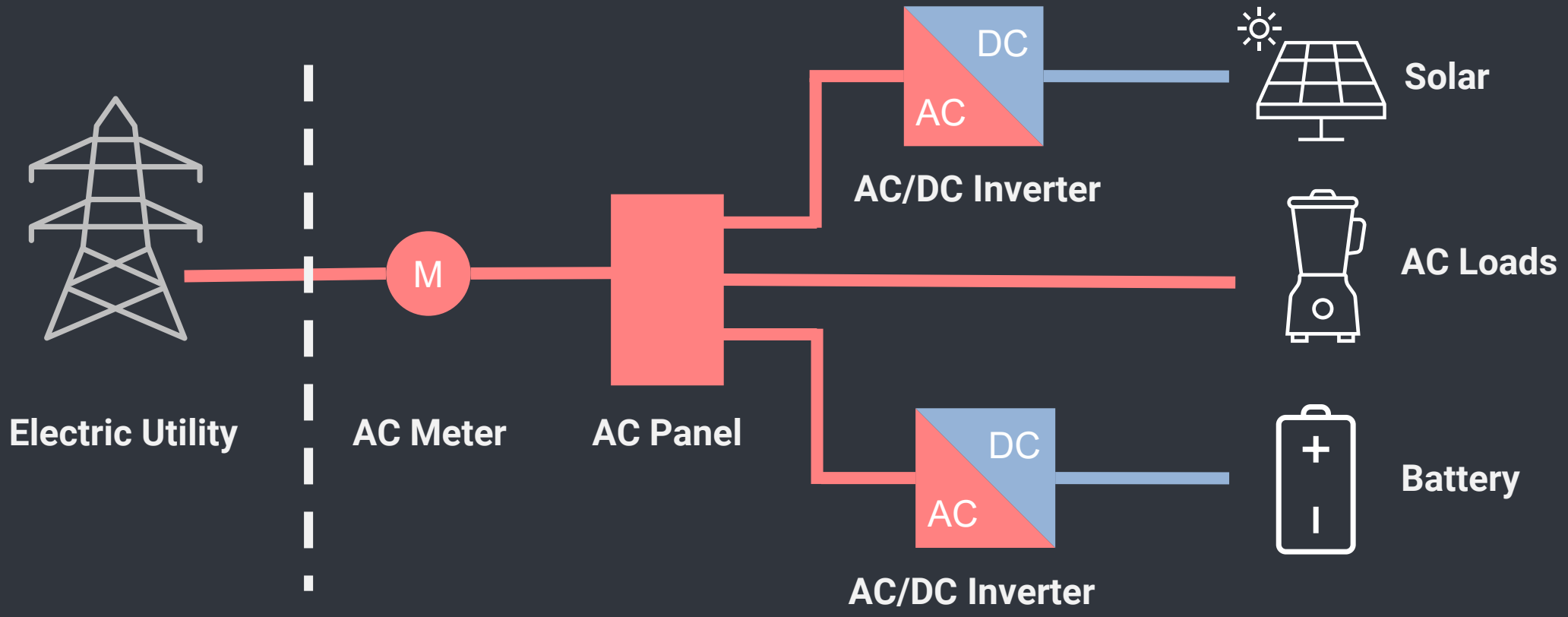

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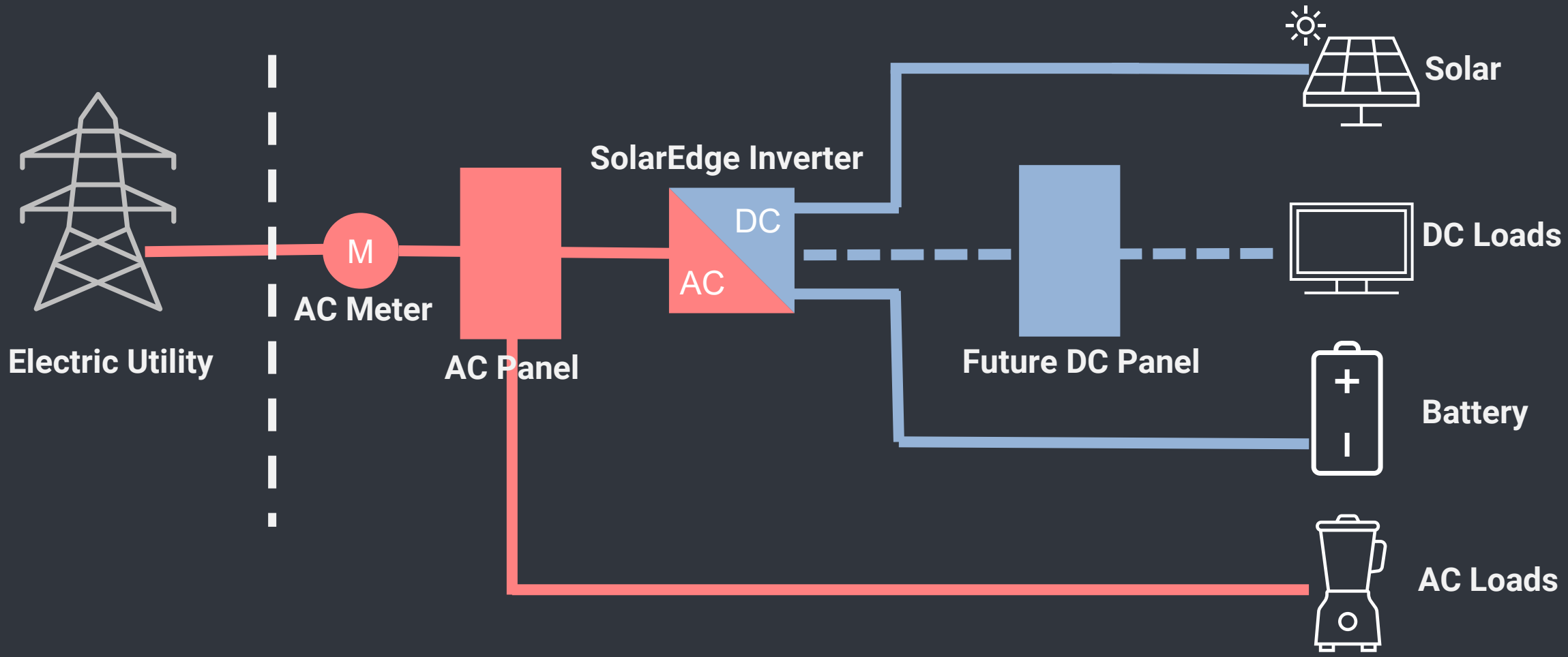

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DC - READY

- 15.2 kW on main roof with room for additional 5kW on garage roof
- SolarEdge Energy Hub inverter takes DC from roof to battery without inverting to DC
- CAT7 cable runs to all lighting fixtures for power and control of future DC fixtures
- Electrical system can adapt to a future dc power management system with a DC bus
- Conduit runs to garage for future high voltage charging of EV's and for tying EV battery into household battery system
- Conduit runs to each neighboring property line for peer to peer connection in future neighborhood microgrid
- DC convenience outlets (USB ports) are installed throughout the house.

Zero-energy nanogrid, Arlington, VA

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Fairmount Heights AC-DC hybrid community microgrid

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SIZE:	1600 SF ~ 3 Bedrooms; 2 ½ Baths
FOOTINGS:	Standard non-insulated
CRAWL SPACE:	Un-insulated, closed
WALLS:	9-1/4" double stud with densepack fiberglass . ZipWall sheathing 1" open faced polyiso outboard (R40)
ROOF:	2x8 over vented attic
2nd FL. CEILING:	Loose fill cellulose over open-faced 1.5" SIP panels (R100)
1st FL. ASSEMBLY:	2x12's with densepacked fiberglass insulation + 1.5" polyiso below R51)
WINDOWS:	Zola triple glazed (R6)
AIRTIGHT LAYER:	Outside face of sheathing
MECHANCAL:	LG Residential 38K btu (3 ton) system Air handlers: 1 ducted, 1 cassette Zehnder ERV with Comfotube ducting
AIRTIGHTNESS:	0.42 ACH @ 50 Pascals

Fairmount Heights AC-DC hybrid community microgrid

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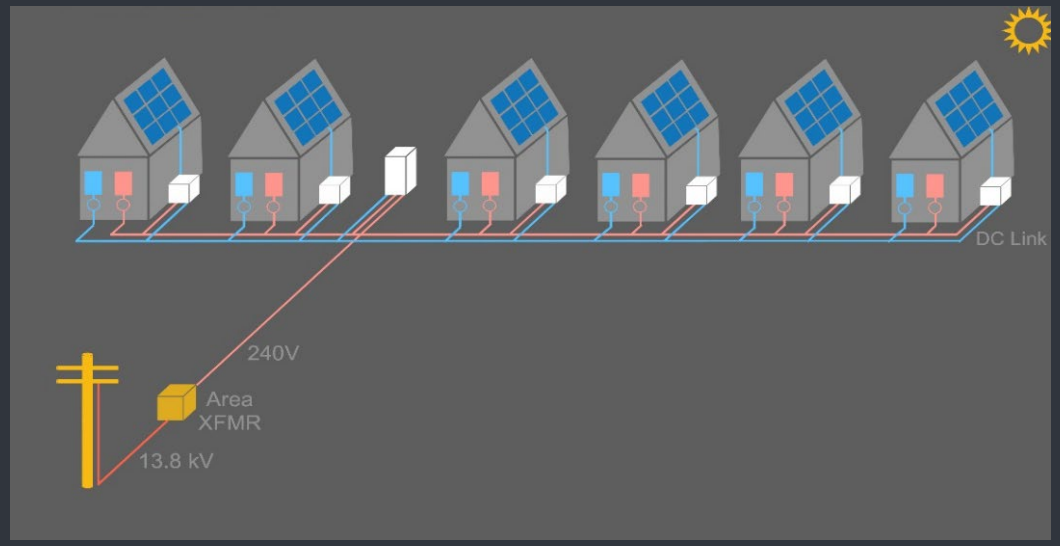

GOALS OF THE PROJECT

DC Rooftop Solar

DC Energy Storage

DC Load Panel for High Efficiency DC Loads

AC Load Panel for Legacy AC Loads

EACH HOME WILL SHARE

Locally generated and stored solar energy with each other via a Direct Current (DC) Link

ISLANDABLE * AFFORDABLE * RENEWABLE

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Front of the Meter

Typically utility scale generation / energy storage

Transmission and Distribution Lines

Utility Meter

Behind the Meter
On-Site Generation

Solar Panels, Gas Powered Generators, Small Wind Turbines, Energy Storage

Power can be used on-site

Power generated does not pass through the utility meter

Excess energy generated can be sent back to the utility

Home

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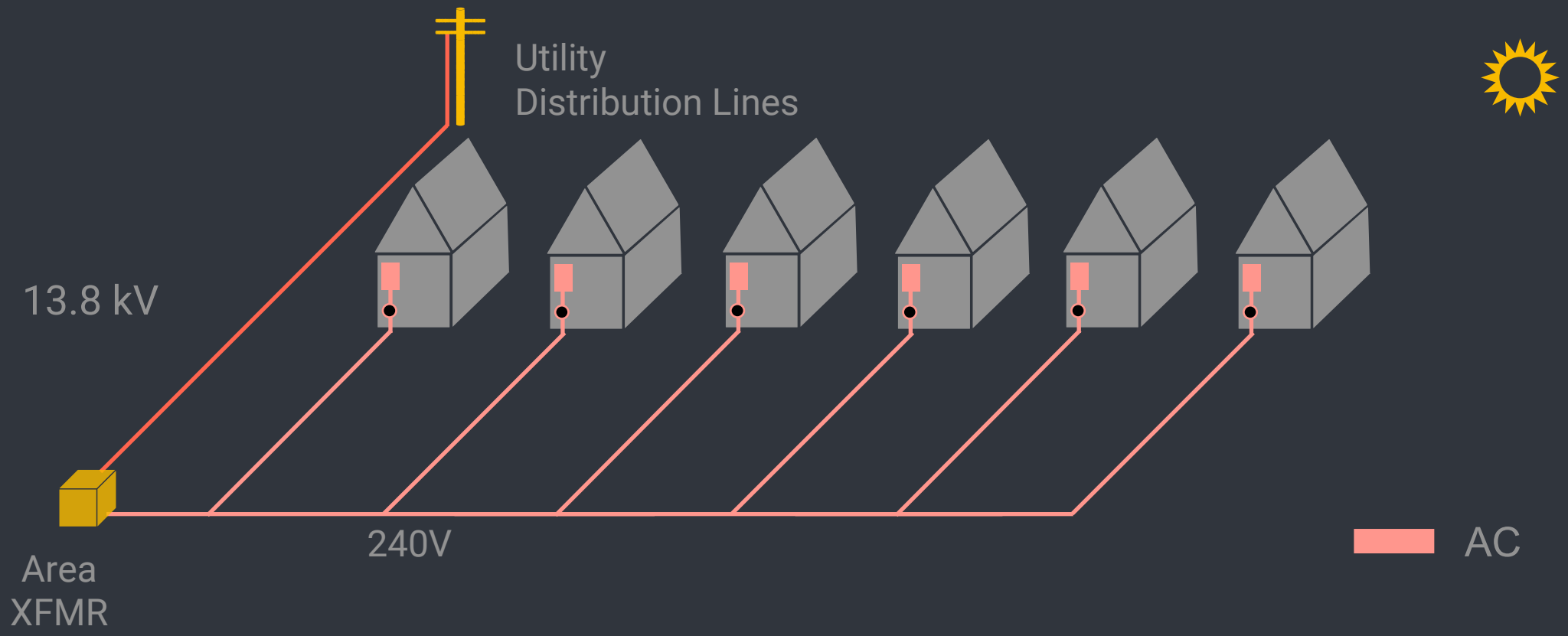
Typical Neighborhood



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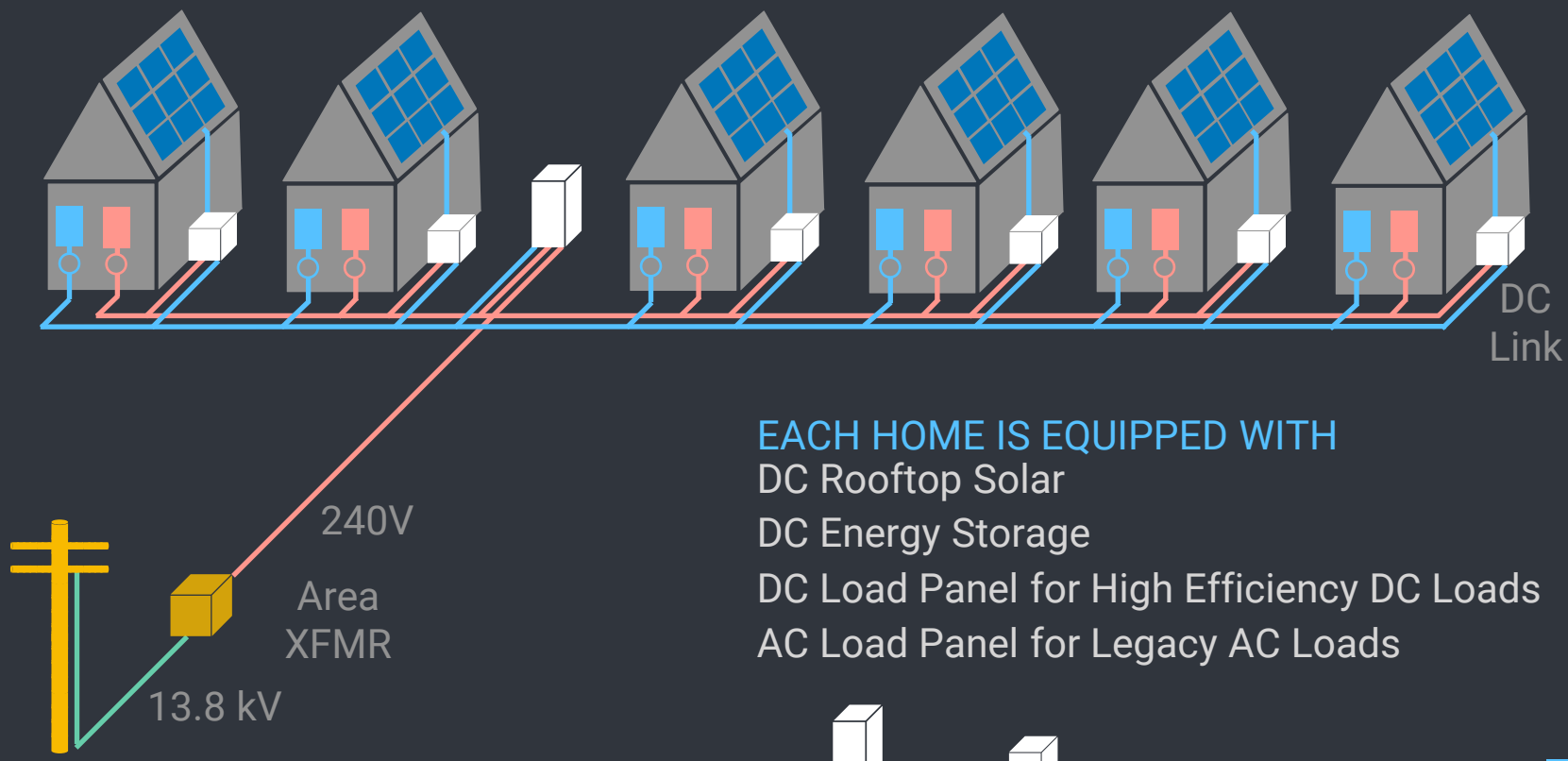
The 60th PLACE COMMUNITY MICROGRID

In front of the meter



EACH HOME IS EQUIPPED WITH

DC Rooftop Solar

DC Energy Storage

DC Load Panel for High Efficiency DC Loads

AC Load Panel for Legacy AC Loads

Central Energy Power Box

Local Energy Power Box

AC Meter

DC Meter

AC

DC

DC Panel

AC Panel

Home + Solar + Energy Storage + DC Link + DC Loads + Utility Backup

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DC MICROGRIDS: POTENTIAL AND REALITY

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The Microgrid

The community microgrid will combine these six isolated DOE Zero Energy Ready homes into a single zero energy microgrid that offers resilience to both the homeowners and the utility. In broad terms the microgrid will include the following:

- 8 kW solar array on each roof to produce approximately 11,282 kWh per year, equaling the projected annual energy demand of each home.
- Onsite battery storage of a minimum 17 kWh, available to be shared between the homes.
- Power management hardware and software, owned and managed by Pepco or an energy-as-service provider working with Pepco.
- Capacity to provide both an AC and DC service connection to the individual homes.
- Capacity to incorporate battery storage of future electric vehicles in the microgrid.

Benefits

Anticipated benefits include:

- Improved asset utilization through shared resources (solar and storage)
- Improved power resilience through optimized and coordinated control of microgrid assets.
- Enhanced demand response and load shape
- Lower ratepayer costs
- Reduced energy consumption of homes by adding high efficiency DC lighting and appliances.

DC MICROGRIDS: POTENTIAL AND REALITY

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POWER CONVERSION CAPACITY [kW]																	
SCENARIO ID	DESCRIPTION	LED (per house)		HVAC (per house)	EV (per house)		SOLAR (per house)		BATTERY (per house)		AC/DC (per house)	DC/DC (per house)	CENTRAL (community)	TOTAL (per house)			REL. ([3]) [%]
		AC/DC	DC/DC	AC/DC	AC/DC	DC/DC	AC/DC	DC/DC	AC/DC	DC/DC	AC/DC	DC/DC	AC/DC	AC/DC	DC/DC	AC/DC +DC/DC	AC/DC +DC/DC
1	AC DISTRIBUTION ONLY NO SOLAR NO BATTERY	1	1	12	10	10	0	0	0	0	0	0	0	23	11	34	-45%
2	AC DISTRIBUTION ONLY SOLAR NO BATTERY	1	1	12	10	10	8	8	0	0	0	0	0	31	19	50	-19%
3	AC DISTRIBUTION ONLY SOLAR BATTERY	1	1	12	10	10	8	8	6	6	0	0	0	37	25	62	0%
6	AC DISTRIBUTION & IN-HOME DC SOLAR BATTERY	0	1	6	0	10	0	8	0	5	7	0	0	13	24	37	-40%
4	AC & DC DISTRIBUTION SOLAR BATTERY	0	1	6	0	10	0	8	0	6	4	7 ([2]) 0	0	10	32 25	42 35	-32% - 44%
5 ([1])	DC DISTRIBUTION ONLY SOLAR BATTERY	1	1	6	0	10	0	8	0	6	0	0	22	11	25	36	-42%

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DC MICROGRIDS: POTENTIAL AND REALITY

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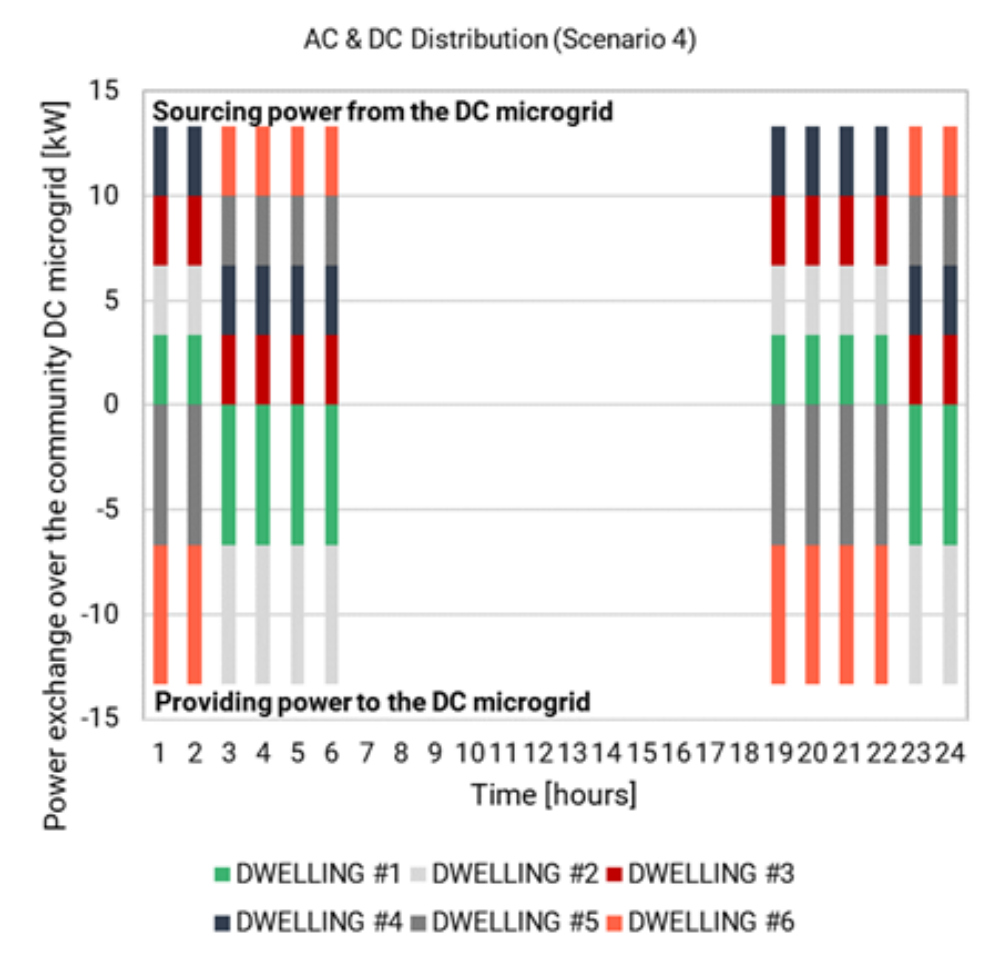

No Energy Exchange Between Dwellings During Day

DC MICROGRIDS: POTENTIAL AND REALITY

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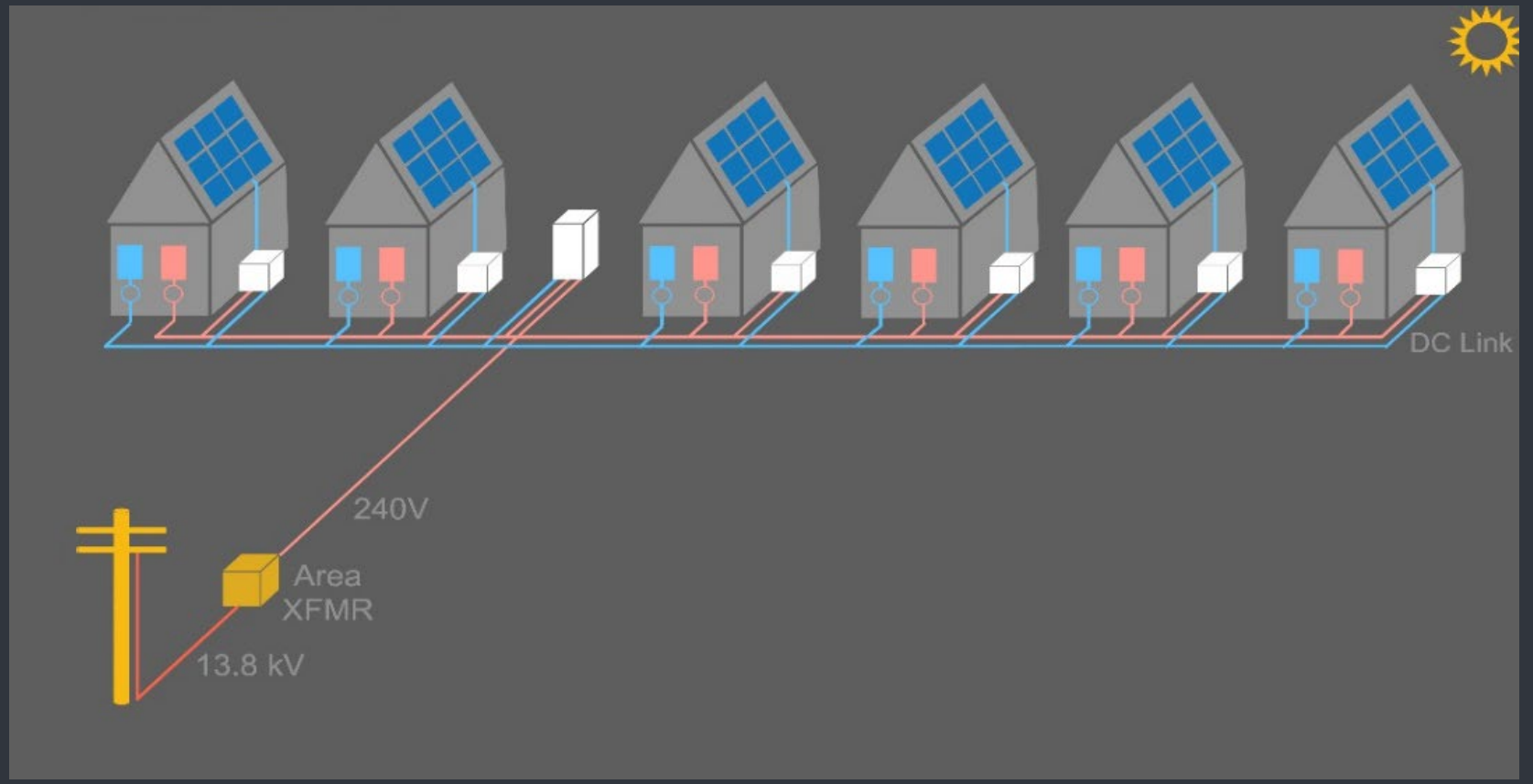

Tariffs

- Utility does not have microgrid tariffs
- Difficult to build new tariffs

Business Model

- New business models needed
- Pilot programs are possible

Q&A

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MICROGRIDS

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Generation	Storage	Distribution	Consumption
Solar	Battery	Local Distribution	Loads

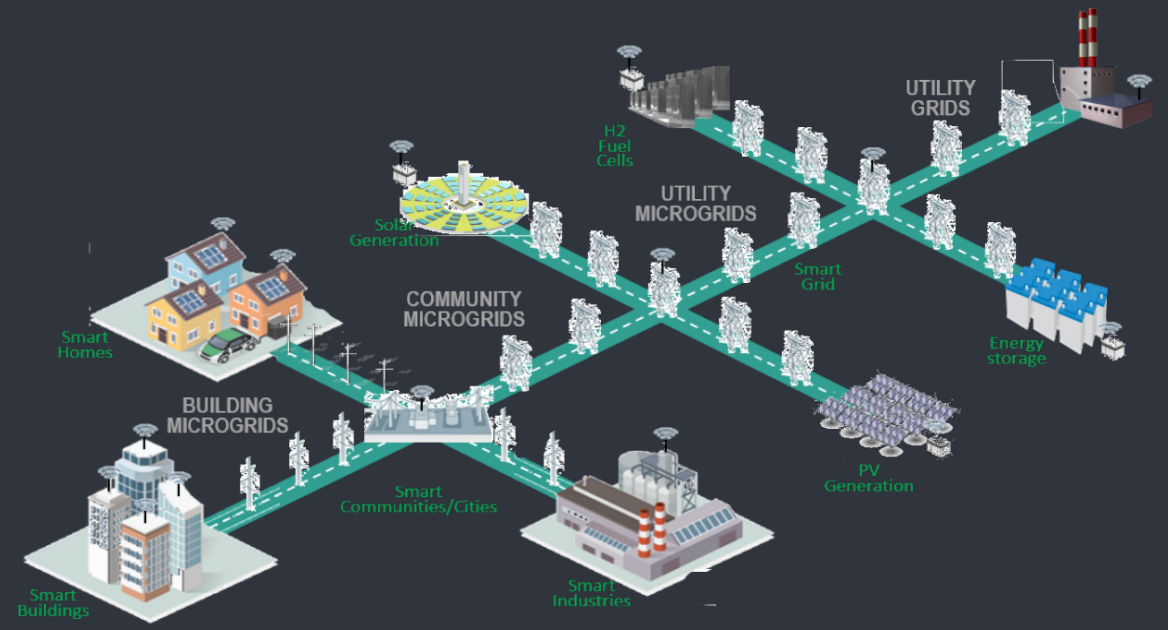

Image source: emergealliance.org

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TYPICAL NEIGHBORHOOD

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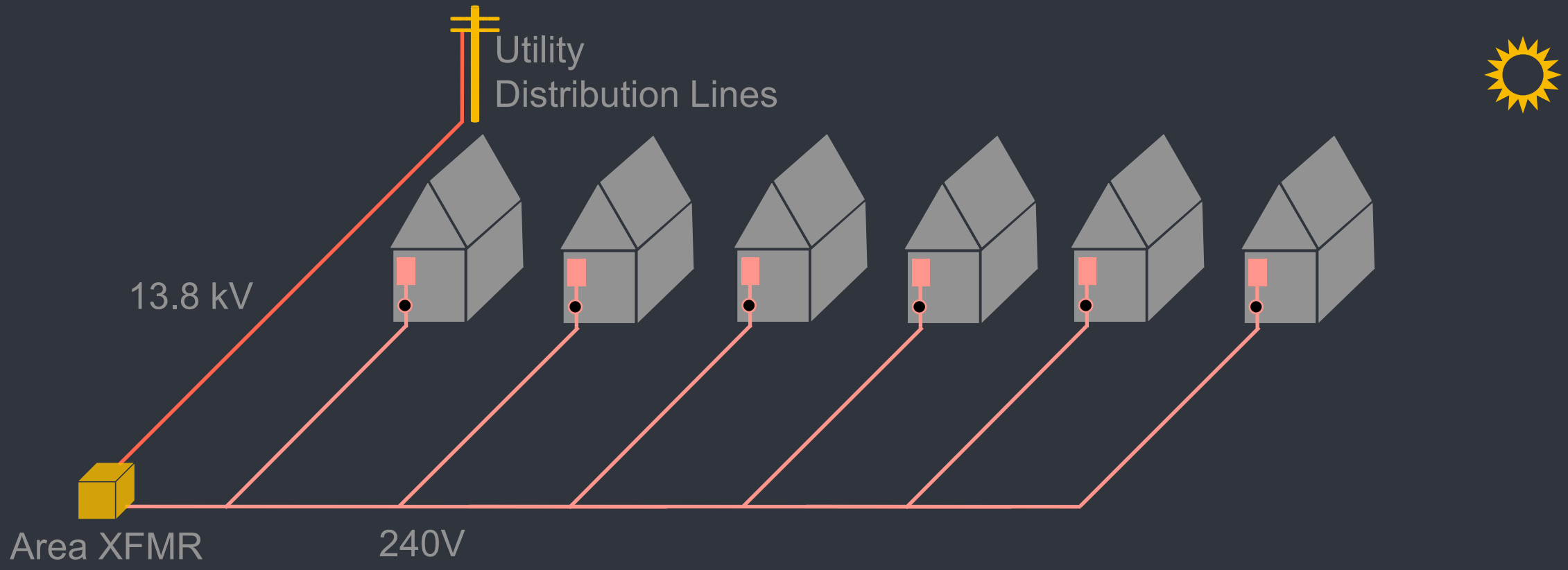

TYPICAL NEIGHBORHOOD

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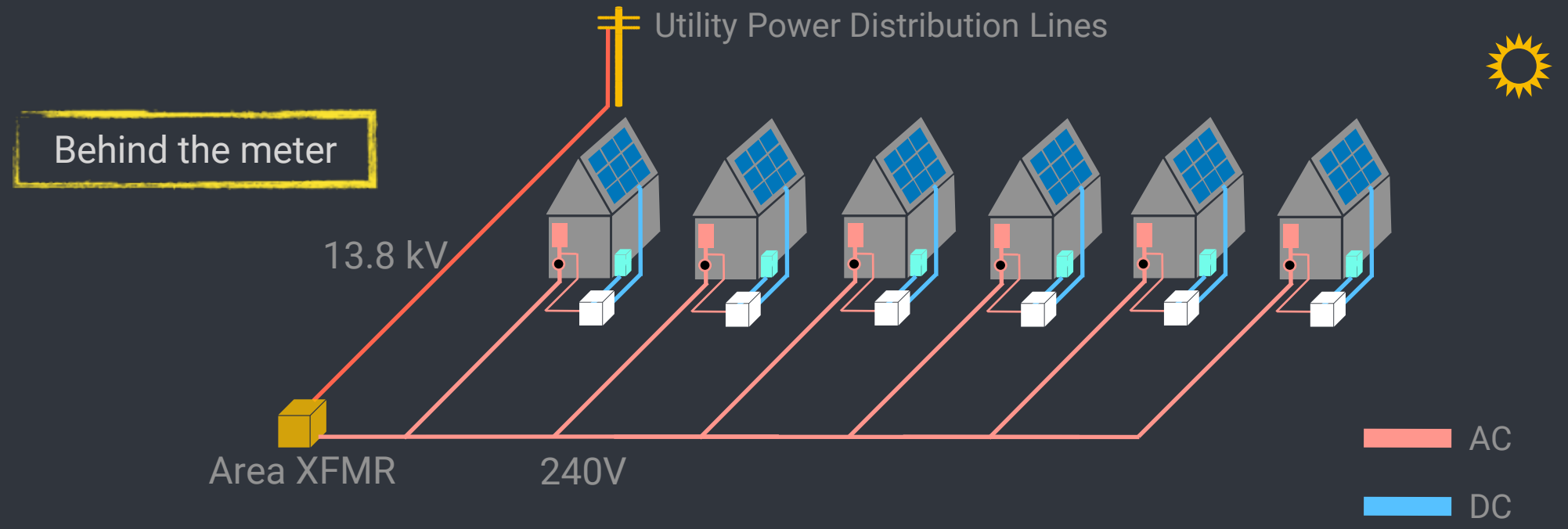

Benefits

Islanding - isolate from utility, operate without utility

Smooth electricity prices through arbitrage

No noise or air pollution

Use energy storage during high utility peak hours

Cons

Not allowed to transfer power across property lines in **regulated** utilities.