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With Great Power Comes Great Electricity Bills

Reducing grid dependance of the access network as it evolves toward 10G and beyond

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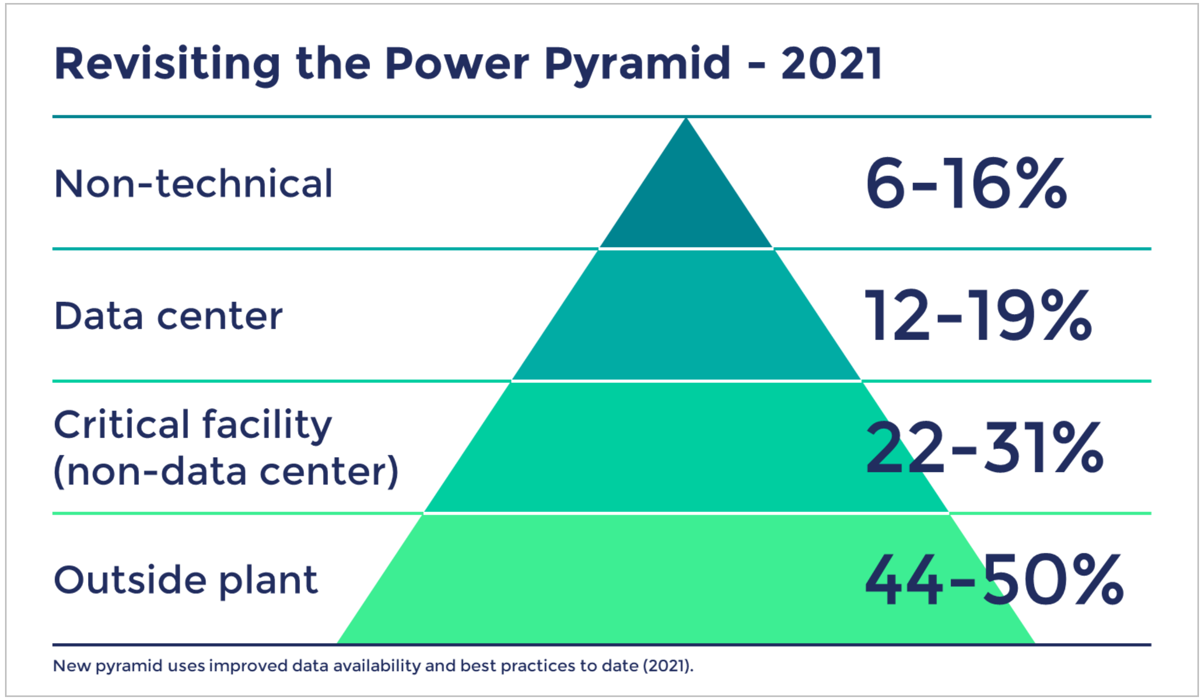
Access Network Impact

Key Drivers

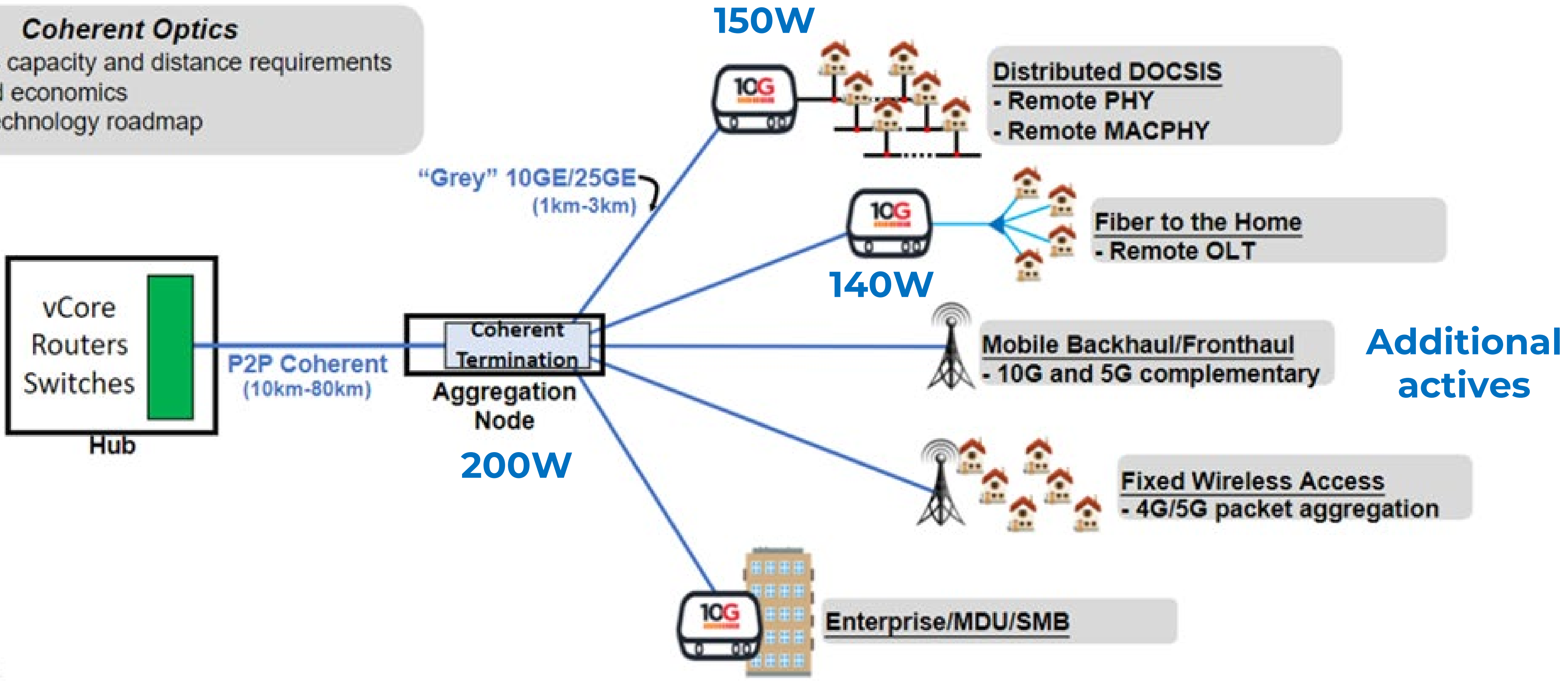
- OSP powering uses more than 5TWh of energy annually in North America
- Progression to 10G and beyond is expected to increase total plant draw
- Operators are pursuing improved sustainability and reduced OpEx
- Outside plant represents the greatest opportunity for energy footprint and cost avoidance



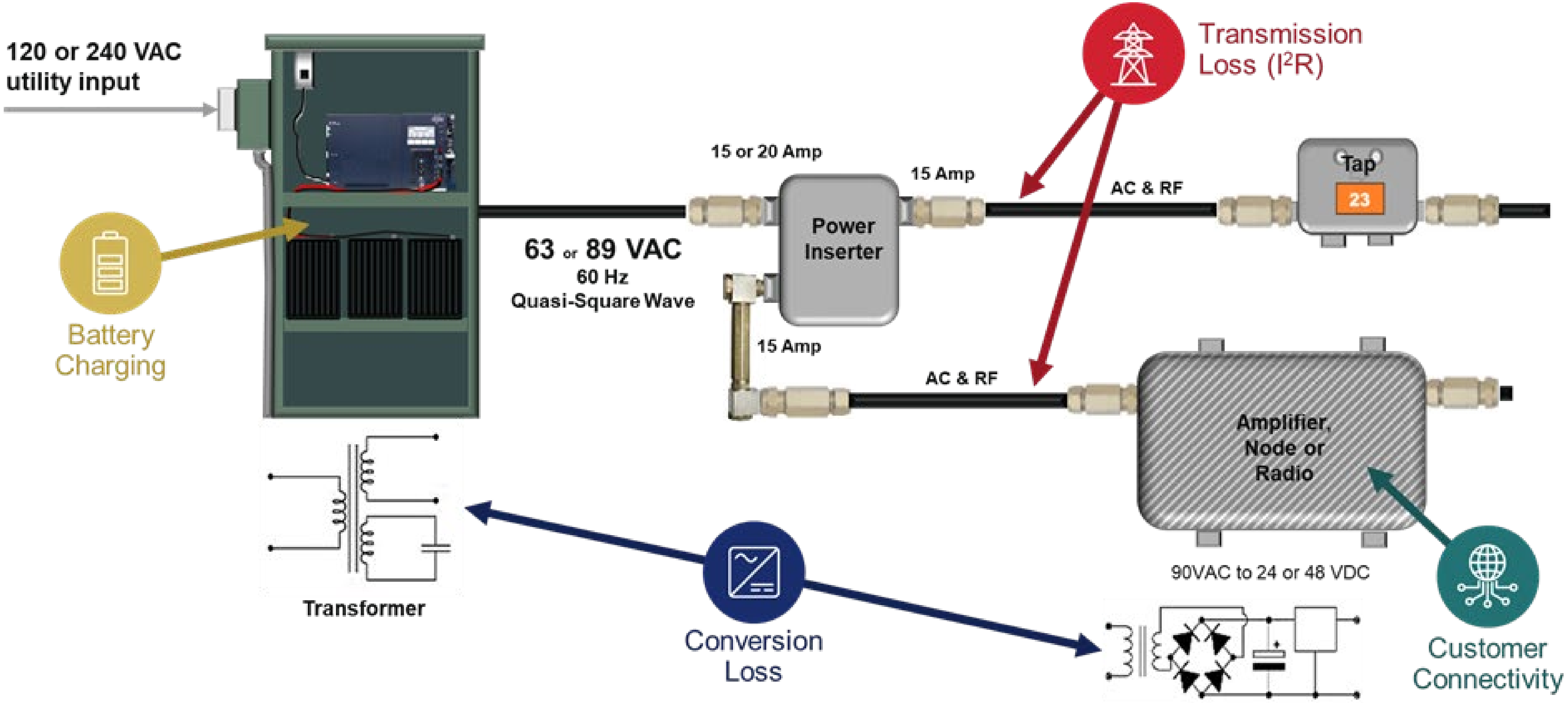
Access Network in the Near Future

Coherent Optics

- Supports capacity and distance requirements
- Improved economics
- Strong technology roadmap



Power Use in the Access Network



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Where does power go in the OSP

Customer Connectivity – Powering equipment necessary to transport data through the network and connect customers to the digital world requires energy

Conversion Loss – Energy lost converting electrical power to a different voltage or from AC to DC and back

Transmission Loss – Power loss inherent from moving power across the network (I2R loss)

Battery charging and management overhead – power used for operation of the network power supplies including the cable modem (transponder) and battery charger

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Where does power go in the OSP

Customer Connectivity – Active power use is an important variable, but for this conversation, they will be treated like a black-box load.

Battery charging and management overhead

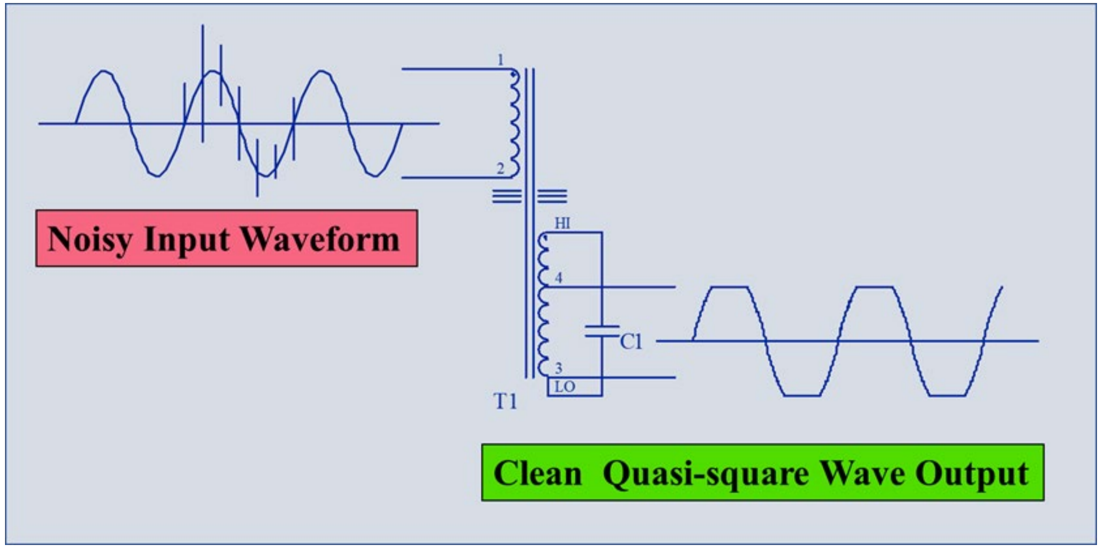
- Status monitoring
  - Currently 5-7W draw with minimal chance of reduction
  - DOCSIS® 3.1 and 4.0 will draw additional power
- Float charging of standby batteries
  - Requires around 4W steadily
  - Newer Advanced AGM batteries need less float charging (75% Rest)
  - Lithium does not require constant float charging

DOCSIS is a registered trademark of Cable Television Laboratories, Inc.

Conversion Loss

Occurs at network power supply and at every active

- Network power supplies are generally Ferroresonant
  - High reliability and resiliency
  - Become less efficient at lower loads
  - Current generation is more efficient
  - Load-Matching benefit
  - Greater efficiency options must be pursued
- Conversion at plant actives
  - Generally more efficient
  - Should be further characterized
  - Rely on plant power supply for fault protection

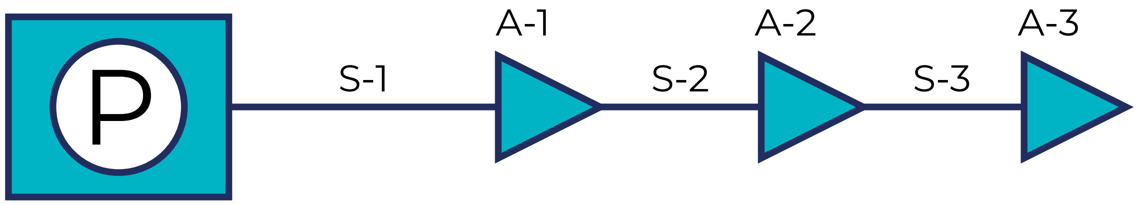


Noise and transient reduction capability of a ferroresonant transformer

Transmission Loss

Occurs from pulling power through coax and passives between active loads

- Derived by Ohm's law - $P_{(loss)} = I^2R$
- Can account for up to 25% of power used in the OSP
- Changes/additions to the plant have an additive effect on loss
  - Complex to model
- Passive resistance needs to be quantified
- Increasing plant voltage reduces loss
  - 60V to 90V
  - NESC allowable limit



Transmission loss =

$$P_{(\text{loss in S-3})} = (P_{(A\text{-}3)}/V_{(A\text{-}3)})^2 \times R_{(S\text{-}3)}$$

$$+$$

$$P_{(\text{loss in S-2})} = ((P_{(A\text{-}3)} + P_{(A\text{-}2)} + P_{(S\text{-}3)}) / V_{(A\text{-}2)})^2 \times R_{(S\text{-}2)}$$

$$+$$

$$P_{(\text{loss in S-1})} = ((P_{(A\text{-}3)} + P_{(A\text{-}2)} + P_{(A\text{-}1)} + P_{(S\text{-}3)} + P_{(S\text{-}2)}) / V_{(A\text{-}1)})^2 \times R_{(S\text{-}1)}$$

Example calculation of transmission loss

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Modelling Impact Scenarios

Understanding the impact of all loss scenarios

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Building a model

To understand the impact of these factors:

- A computer model was built
  - Uses iterative calculations to determine transmission loss
  - Allows for variables to be adjusted and utility power draw analyzed
  - Goal was to use an average section of plant (700W output) for scenarios
- Local section of plant was mapped using assumed active draws
  - Calculated output was 724W

Pictures of the model plant and my assistants

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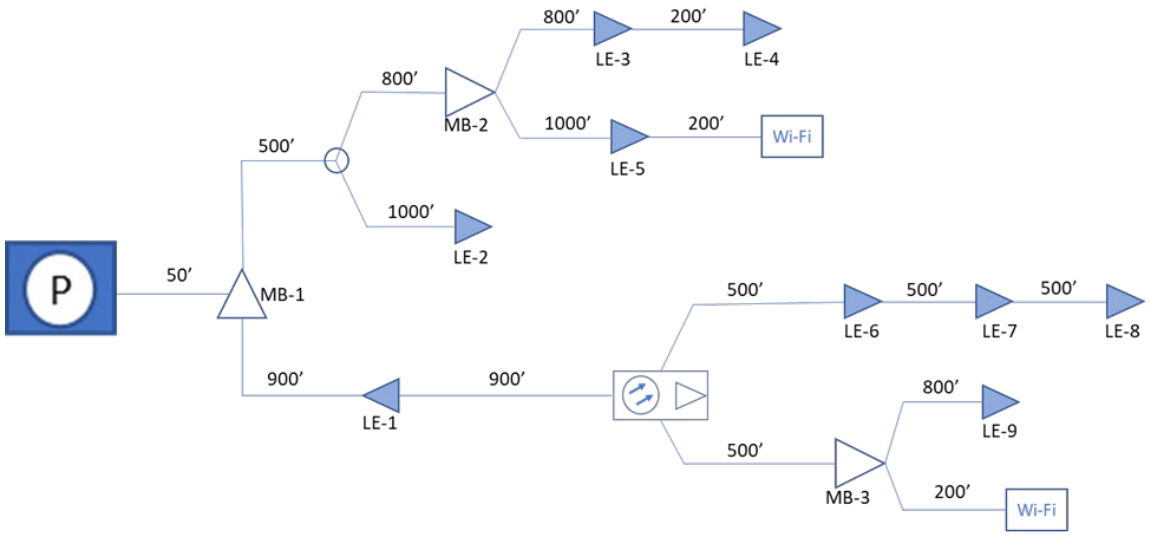
Map of plant for modeling



Active type	Power Consumed (W)	Quantity	Total Draw (W)
Legacy Node	90	1	90
WiFi Access	55	2	110
Amplifier (LE)	35	9	315
Mini bridger	50	3	150
Total Customer Connectivity Load			665

Basic assumptions:

- Loading of actives per adjacent table
- Active conversion efficiency is 95%
- Power supply efficiency is 86%
- Plant passive add 10% to total resistance
- Coax is 75/25 mix of .75 and .625 P3 cable
- Battery management overhead is 10W fixed

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Baseline for scenarios

- Required load for plant function is 632W
  - This is the theoretical minimum for targeted reductions
- Maximum reductions possible is 222W
  - Some loss will always be present, but this shows us non plant-critical load target
- Total annualized:
  - Usage = 7,481 KWh
  - Cost at US average utility = $892

	Original Baseline
Required Power for Connectivity	631.75W
Conversion Loss (Actives)	33.25W
Transmission Loss	59.48W
Battery Management Overhead	10W
Conversion Loss (Power Supply)	119.57W
Total Utility Power Draw	**854.05W**

Conversion loss impact scenario (power supply)

	Original Baseline	Newer 15A Power Supply	Load-Matched 10A PS	Theoretical High-Efficiency PS
Required Power for Connectivity	631.75W	631.75W	631.75W	631.75W
Conversion Loss (Actives)	33.25W	33.25W	33.25W	33.25W
Transmission Loss	59.48W	59.48W	59.48W	59.48W
Battery Management Overhead	10W	10W	10W	10W
Conversion Loss (Power Supply)	119.57W	100.16W	80.7W	46.88W
Total Utility Power Draw	**854.05W**	**834.64W**	**815.18W**	**781.36W**

Result:

- Conversion efficiency of network power supplies can be impacted by 4-5% with a load-matching strategy
- Maximizing network power supply efficiency will show significant power savings

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Conversion loss impact scenario (Actives)

	Original Baseline	Plant actives at 98% efficiency
Required Power for Connectivity	631.75W	631.75W
Conversion Loss (Actives)	33.25W	12.89W
Transmission Loss	59.48W	55.52W
Battery Management Overhead	10W	10W
Conversion Loss (Power Supply)	119.57W	115.61W
Total Utility Power Draw	**854.05W**	**825.77W**

Result:

- Conversion efficiency of actives should be maximized, however theoretical gains shown in this scenario are difficult to quantify without published efficiencies available
- This scenario demonstrates the cascading effect of load changes in the plant

Transmission loss impact scenario (Actives)

	Plant Modeled at 60V	Original Baseline (90V)	Theoretical 150VDC
Required Power for Connectivity	631.75W	631.75W	631.75W
Conversion Loss (Actives)	33.25W	33.25W	33.25W
Transmission Loss	154.67W	59.48W	18.46W
Battery Management Overhead	10W	10W	10W
Conversion Loss (Power Supply)	135.06W	119.57W	112.89W
Total Utility Power Draw	**964.73W**	**854.05W**	**806.35W**
Voltage at Last Active	**47.2V**	**79.8V**	**145.3V**

Result:

- Converting plant from 60V to 90V can yield large power savings and is generally part of the upgrade path for Near-Future architectures
- Increasing voltage beyond 90V will create major savings in Near-Future architectures with higher draw actives as well as adding additional reach

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Theoretical best-case reduction

	Original Baseline	Theoretical Best Case
Required Power for Connectivity	631.75W	631.75W
Conversion Loss (Actives)	33.25W	12.89W
Transmission Loss	59.48W	16.48W
Battery Management Overhead	10W	6W
Conversion Loss (Power Supply)	119.57W	42.84W
Total Utility Power Draw	**854.05W**	**709.96W**

Result:

- Maximizing the effectiveness of all scenarios yields a 17% reduction in draw
  - Applying the results at NA scale would save $110M and 1TWh annually
- While this scenario is hypothetical, it is within the realm of possibility

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More power reduction opportunities

While eliminating wasted energy should be pursued aggressively, it can only gain back what is wasted. These opportunities could show gains that are not limited to site used or wasted power.

Solar Augmentation

Takes advantage of existing footprint with added benefit of shading cabinets

- Installed cost of solar has gone down by as much as 70% since 2010
  - Approximately $2.50 per watt
  - 2 common panels could generate 3.2 KWh of energy daily
  - Could reduce energy consumption by 20% in addition to other savings discussed
- Could also be installed with intelligence to maximize savings and leverage solar for extended runtime during long outages

Example of a solar augmented cable power supply

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Time-of-use mitigation

Takes advantage of utility rates designed to reduce peak demand

- System would run on batteries during high-rate period and recharge during low-rates
  - Based on known rate-structures, strategy could save $1/day in summer months
  - No net reduction of energy, but reduction of carbon footprint (cleaner non-peak)
- Combined with intelligent solar augmentation would maximize energy and OpEx savings.

Business

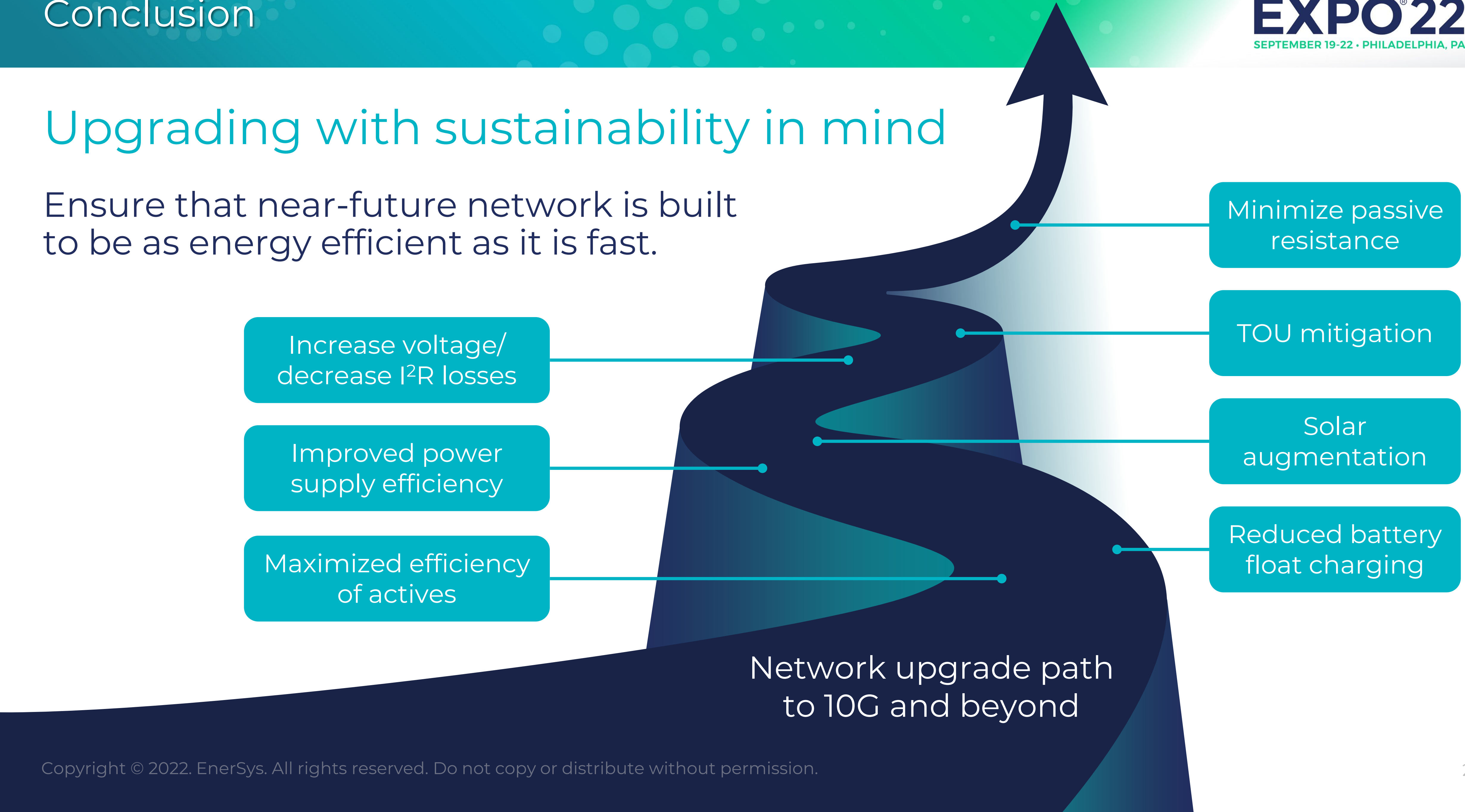
Business Time Periods and Delivery Rates

	Peak	Off-Peak
Hours	8 a.m. to 10 p.m.	10 p.m. to 8 a.m. and all day on weekends
TIME-OF-USE DELIVERY RATES		
June 1 to Sept 30	29.38 cents/kWh	1.08 cents/kWh
All other months	14.47 cents/kWh	1.08 cents/kWh

Example utility time-of-use rate structure

Upgrading with sustainability in mind

Ensure that near-future network is built to be as energy efficient as it is fast.



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Thank You!

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