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Wireline Access Network

DOCSIS 4.0 - A Key Ingredient of the 2030's Broadband Pie

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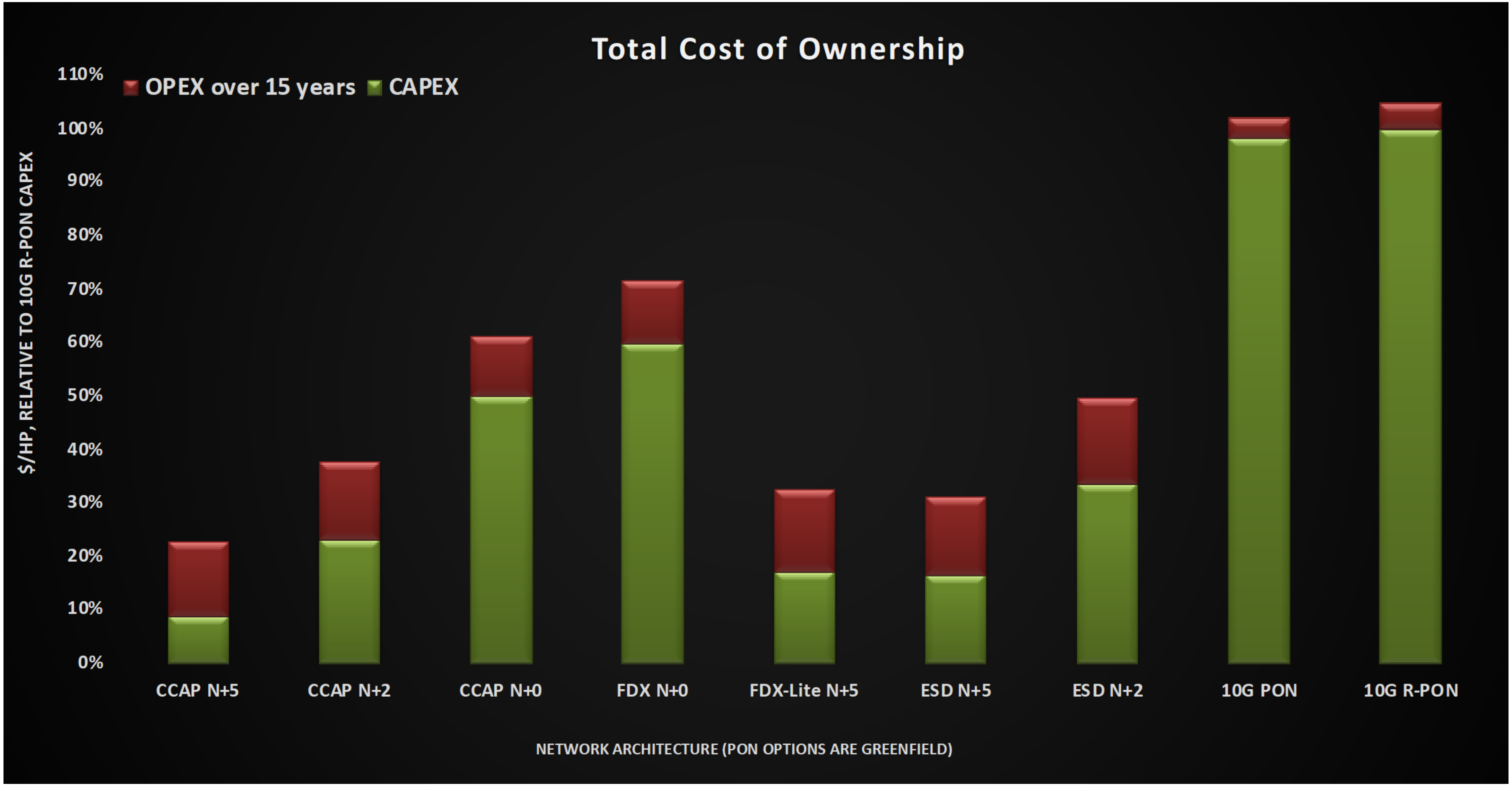
Thanks to My Co-authors:

- James Andis, nbn™ Australia
- Tom Cloonan, CommScope
- John Ulm, CommScope

Begin with the end in mind?



DOCSIS 4.0 - A Key Ingredient of the 2030's Broadband Pie

1. Network Evolution: Drivers and Timing
   a. Traffic Engineering and Quality of Experience
   b. Some Potential Future Service Tier Use Cases

2. Network Evolution: Various Paths Considered
   a. Possible Rollout Scenarios

3. Network Evolution: Total Cost of Ownership Compared
   a. CAPEX and OPEX components of TCO
   b. Sensitivity analysis

4. Will Network Capacity Gains Justify Various Upgrade Costs
   a. Takeaways and Conclusion

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Network Evolution: Drivers and Timing

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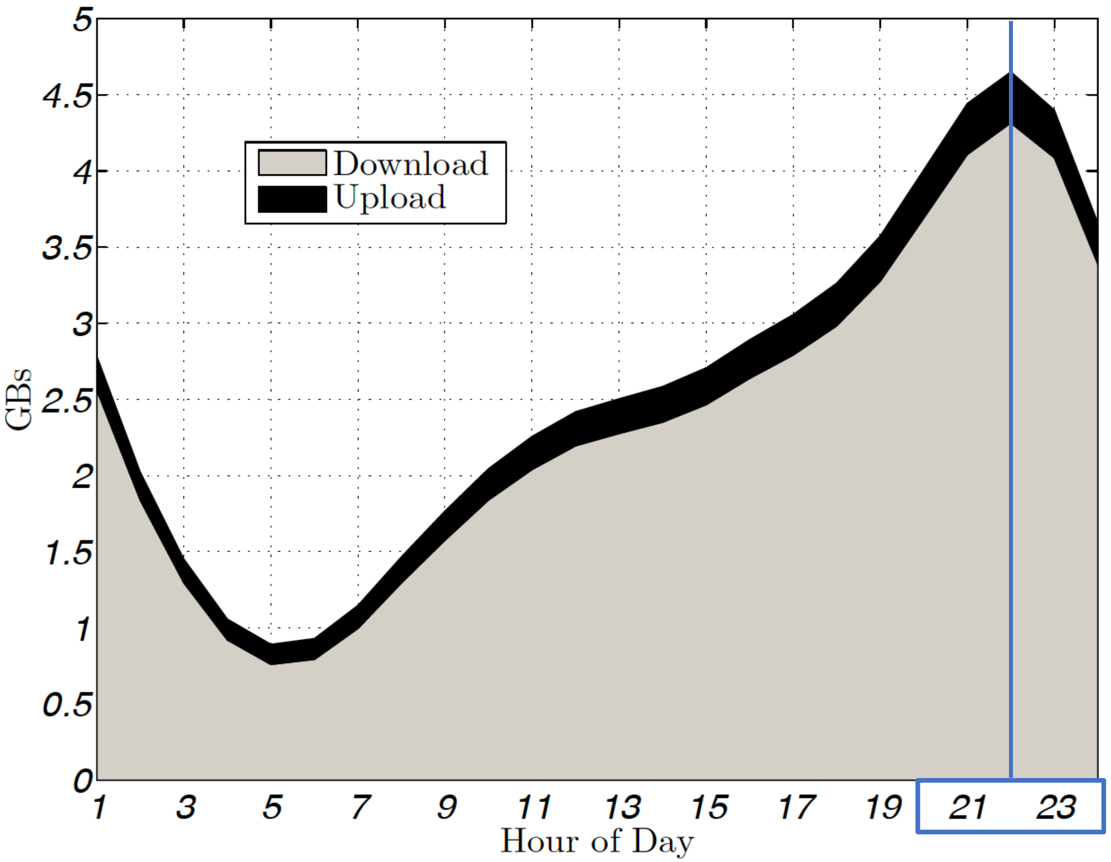
Distribution of Monthly Usage by Hour and Direction

- Total, upstream and downstream, traffic generated by the average user in each hour of the day for one complete billing cycle during May 10th – June 30th, 2012.
- Based on ~55,000 subscribers, from different markets
- Average Bandwidth Demand per Subscriber, at Peak Busy Period, is an important "traffic engineering" parameter



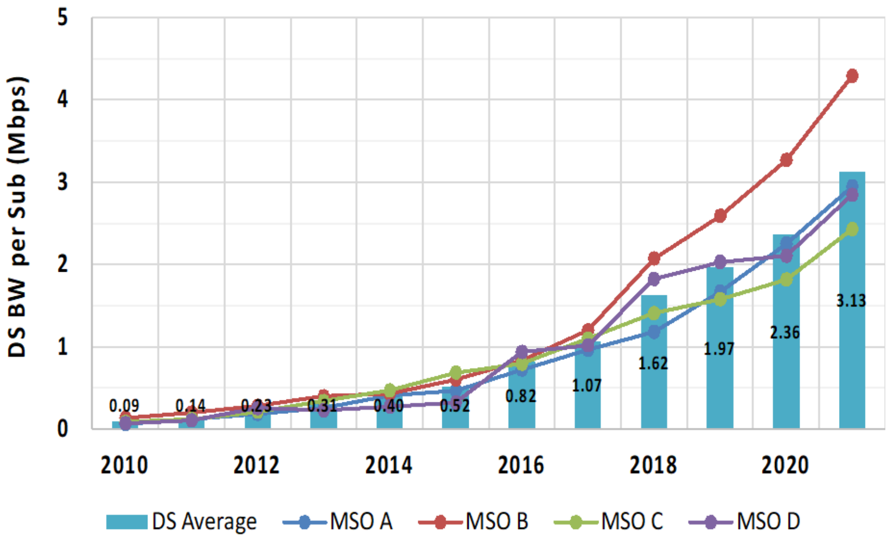
Reference:
"Usage-Based Pricing and Demand for Residential Broadband" Aviv Nevo, Northwestern University and John L. Turner, Jonathan W. Williams of University of Georgia, Sep 2013

Broadband Subscriber Traffic Consumption - Tavg

DOWNSTREAM
Tavg @ Peak Busy Period

DS Avg BW per Subscriber

(2021 Avg = 3.13 MBPS, 3 yr Avg CAGR = 24.5%)

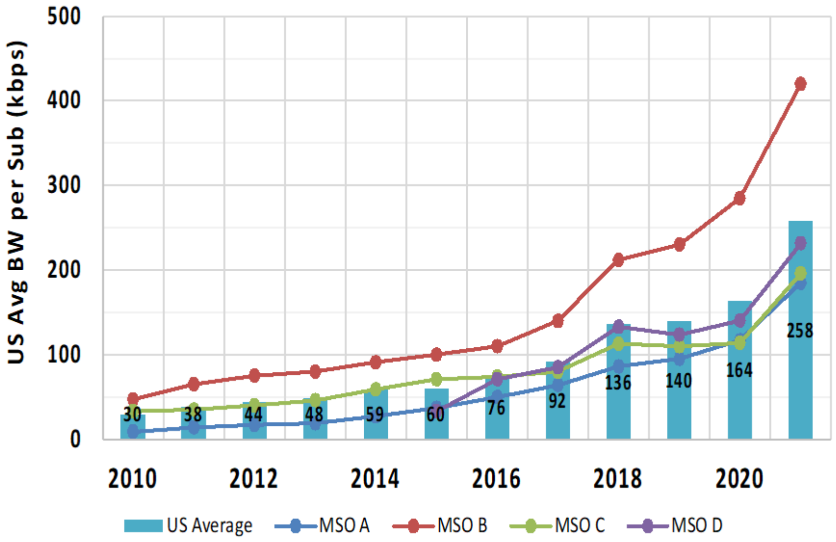


- **DS Tavg grows 32.5% to 3.13 Mbps in 2021**
  - Fastest growing MSO (B) at 4.3 Mbps
- DS Tavg 3-yr CAGR eases to ~25% from ~30%
  - MSOs' 3-yr CAGRs range from ~16% to ~36%

UPSTREAM
Tavg @ Peak Busy Period

US Avg BW per Subscriber

(2021 Avg = 258 kbps, 3 yr Avg CAGR = 23.8%)



- **US Tavg jumps 57% to 258 Kbps in 2021**
  - Large increase over 2020 from COVID-19 BW Surge
  - Fastest growing MSO (B) hits ~420 Kbps,
    - Double the US Tavg of the other 3 MSOs
- US Tavg 3-yr CAGR grows ~24%
  - US 3-yr CAGR now very close to DS 3-yr CAGR

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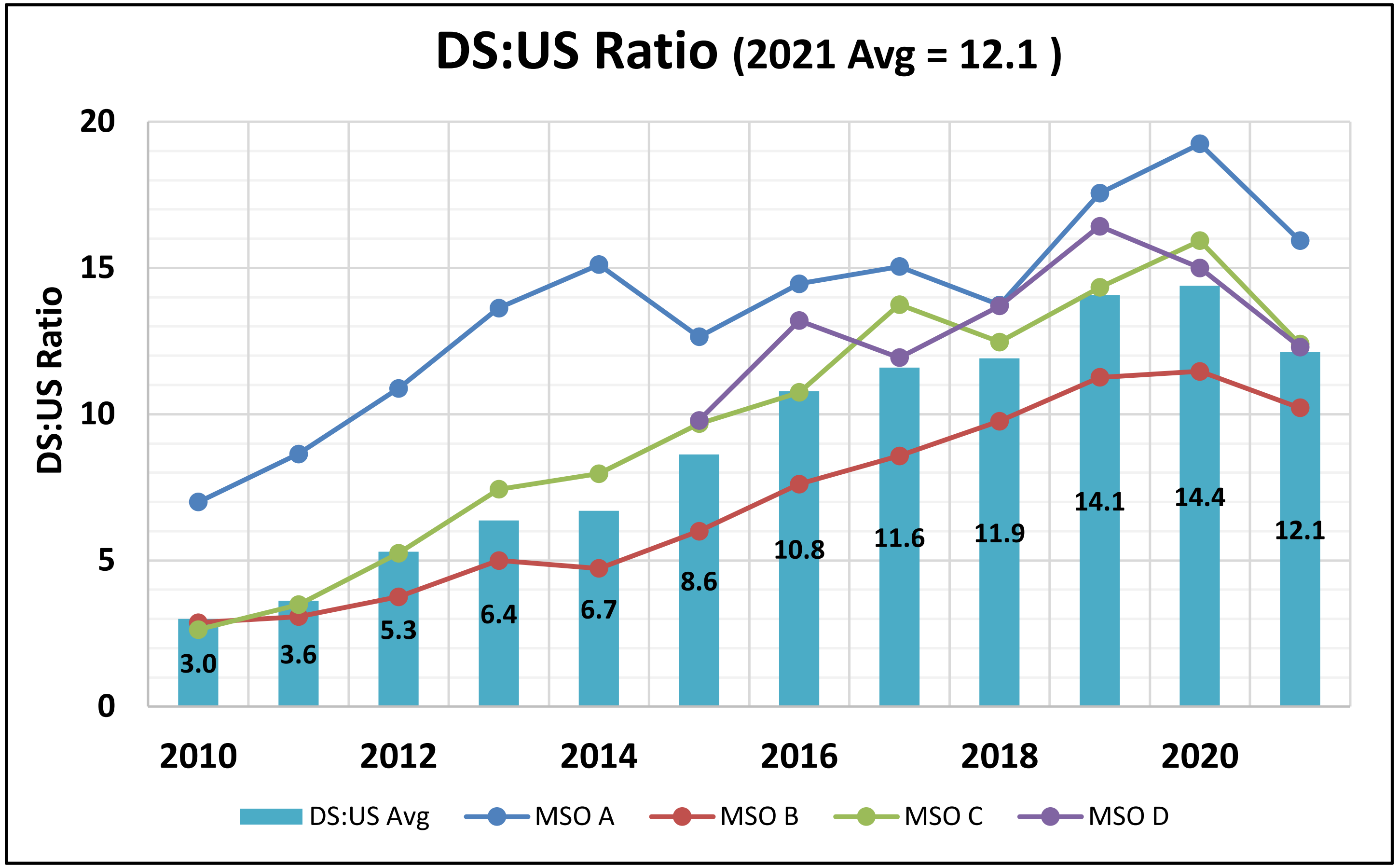
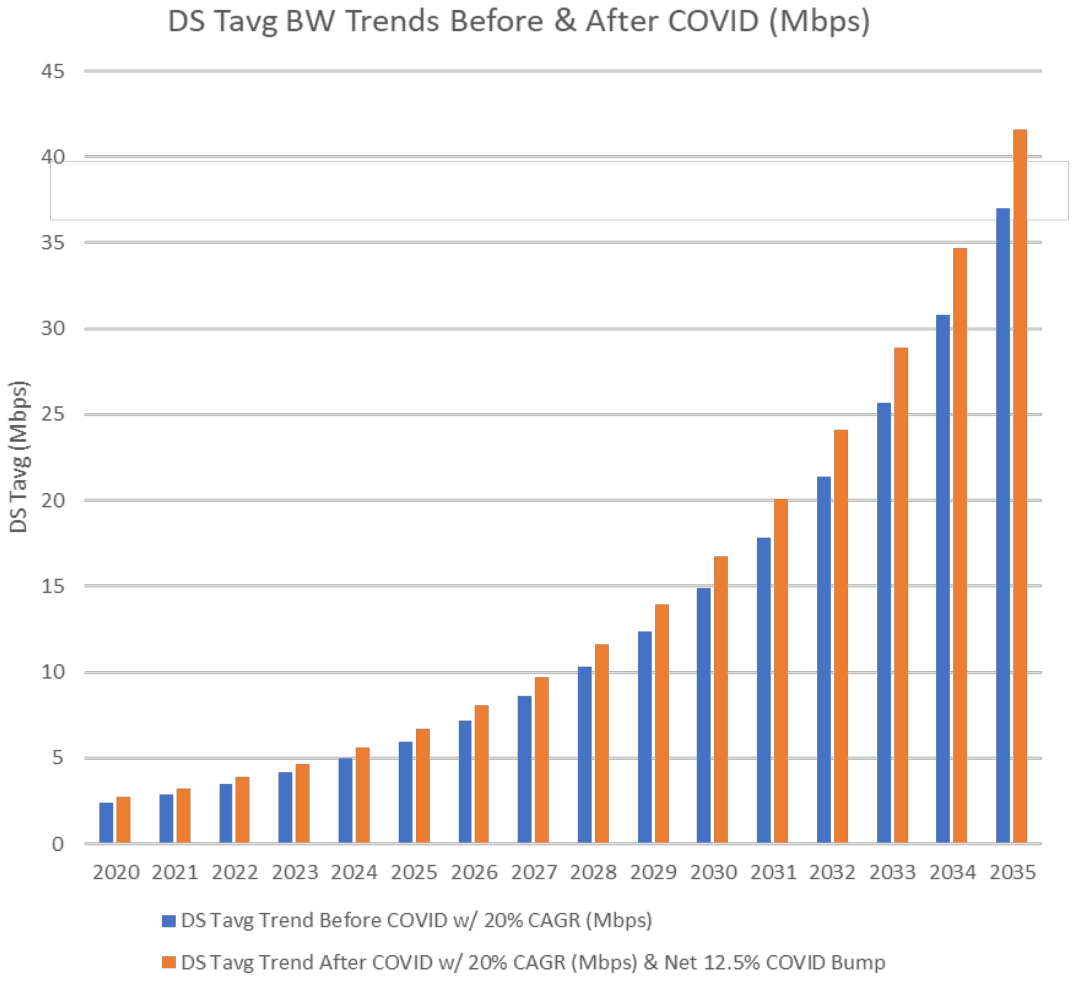
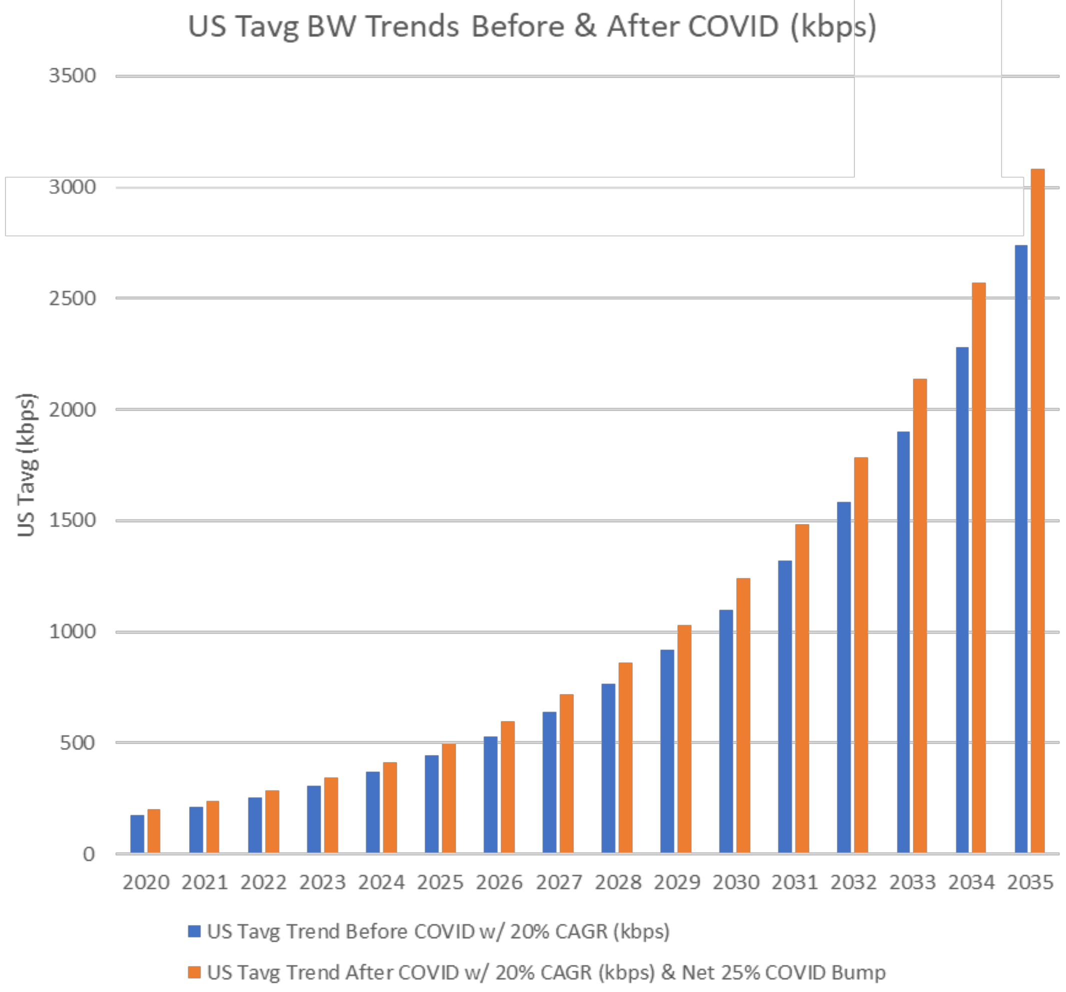
DS:US BW Ratio Halts its climb

- Today, MSOs DS:US Avg BW Ratios in 10:1 to 16:1 range
- Big US growth in ‘21 reduces DS:US BW ratio from ~14:1 back down to ~12:1
- Is the DS:US Ratio leveling off???
  - Implication is that US growth will match DS growth going forward!!
  - Not clear yet how much of 2020 COVID BW changes will stick longer term



Future Downstream and Upstream Average Bandwidth Usage Predictions





One Popular Tmax Bandwidth Growth Prediction for the 2020 Decade

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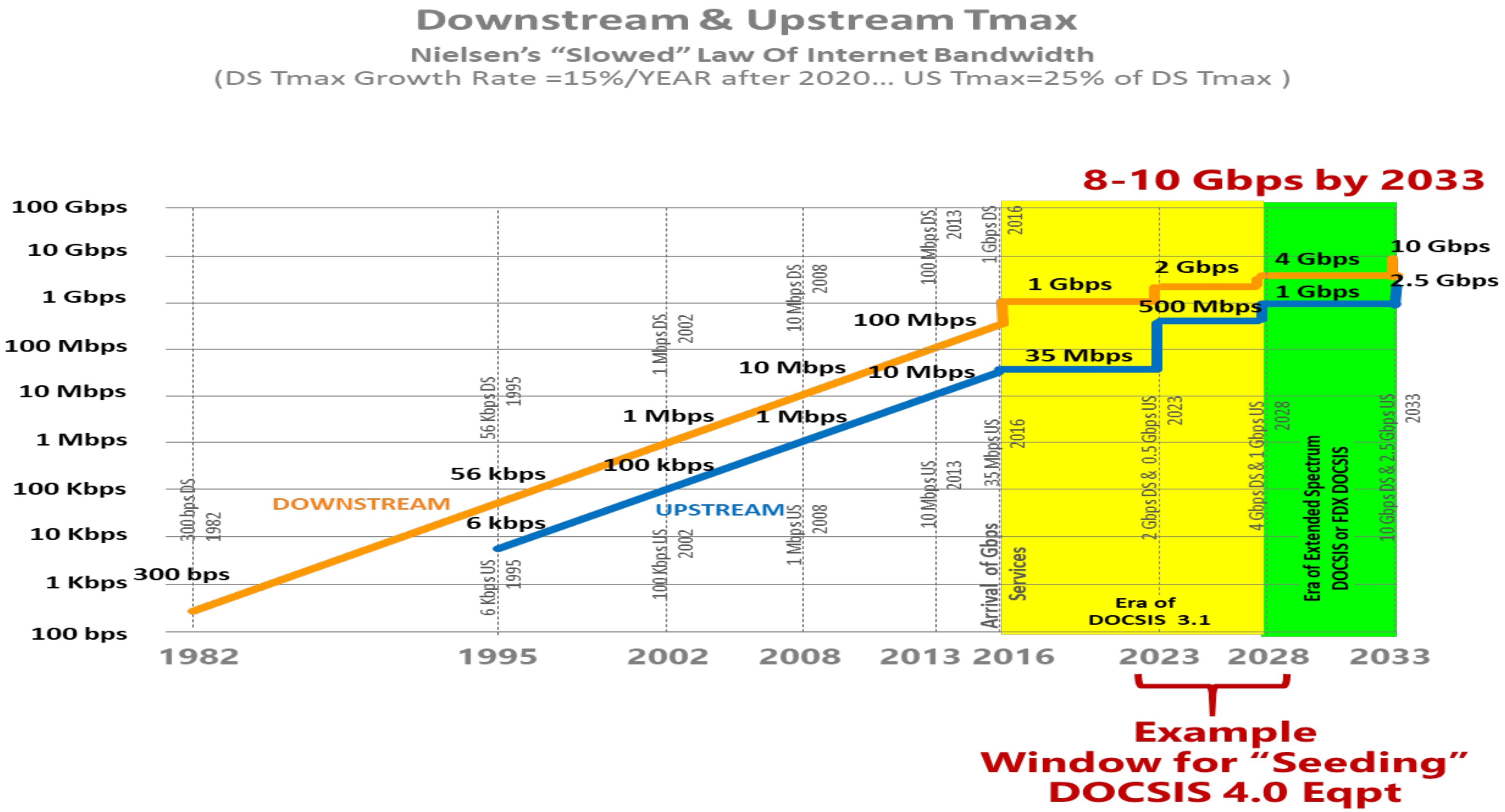
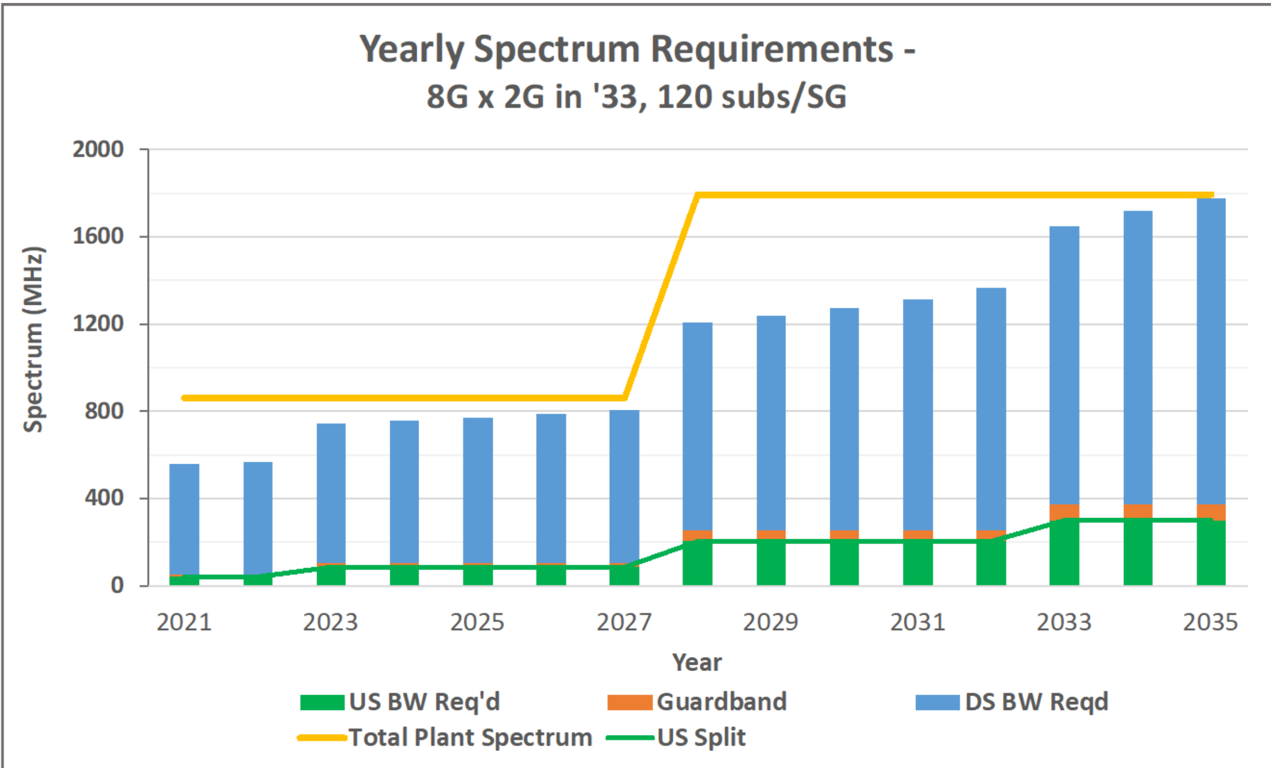
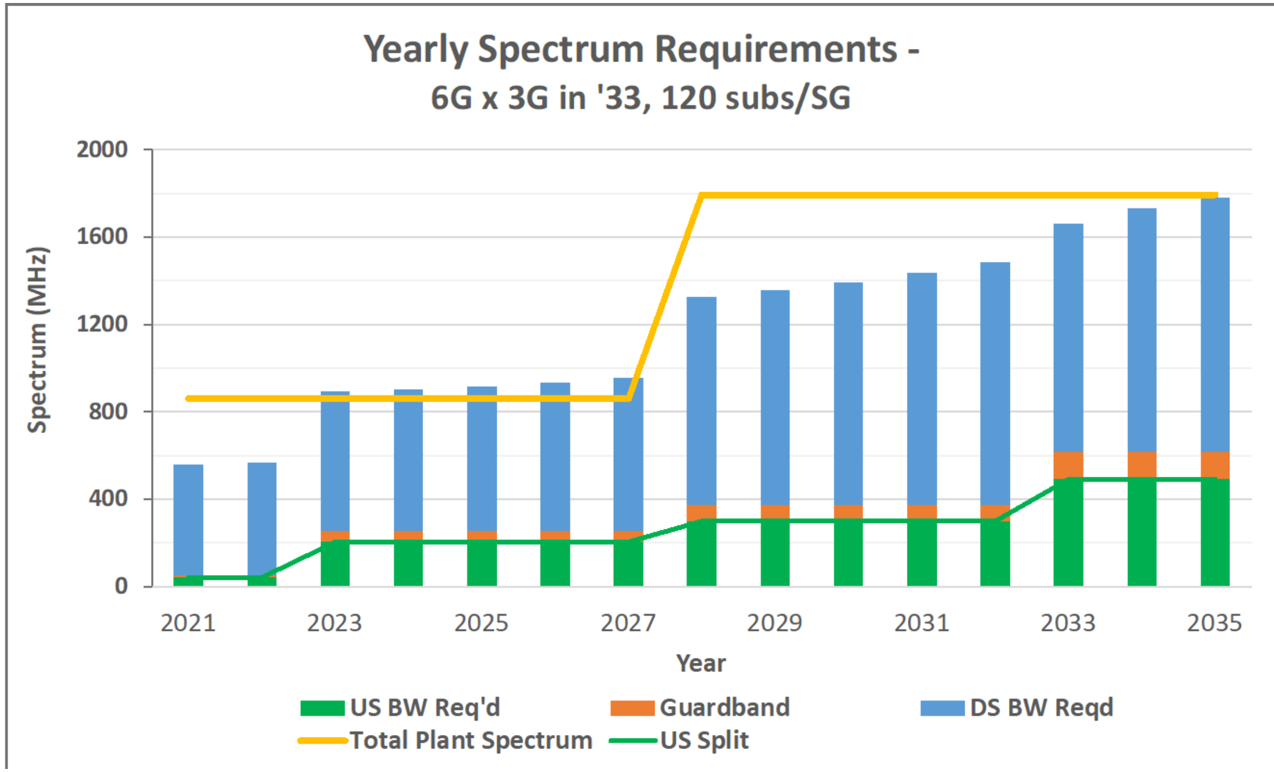


4:1 vs. 2:1 DS:US Tmax Scenarios for 120 subs/SG

2G x 500M, 4G x 1G, 8G x 2G Progression

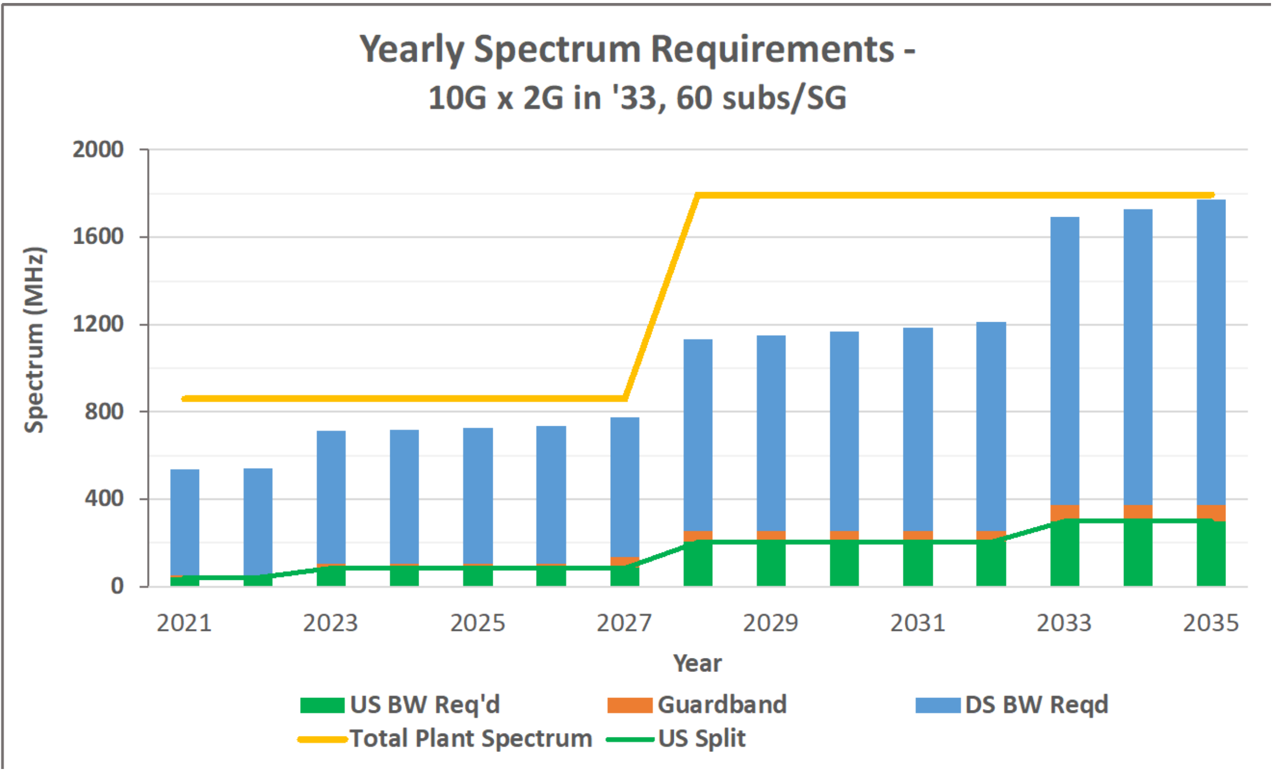


2G x 1G, 4G x 2G, 6G x 3G Progression

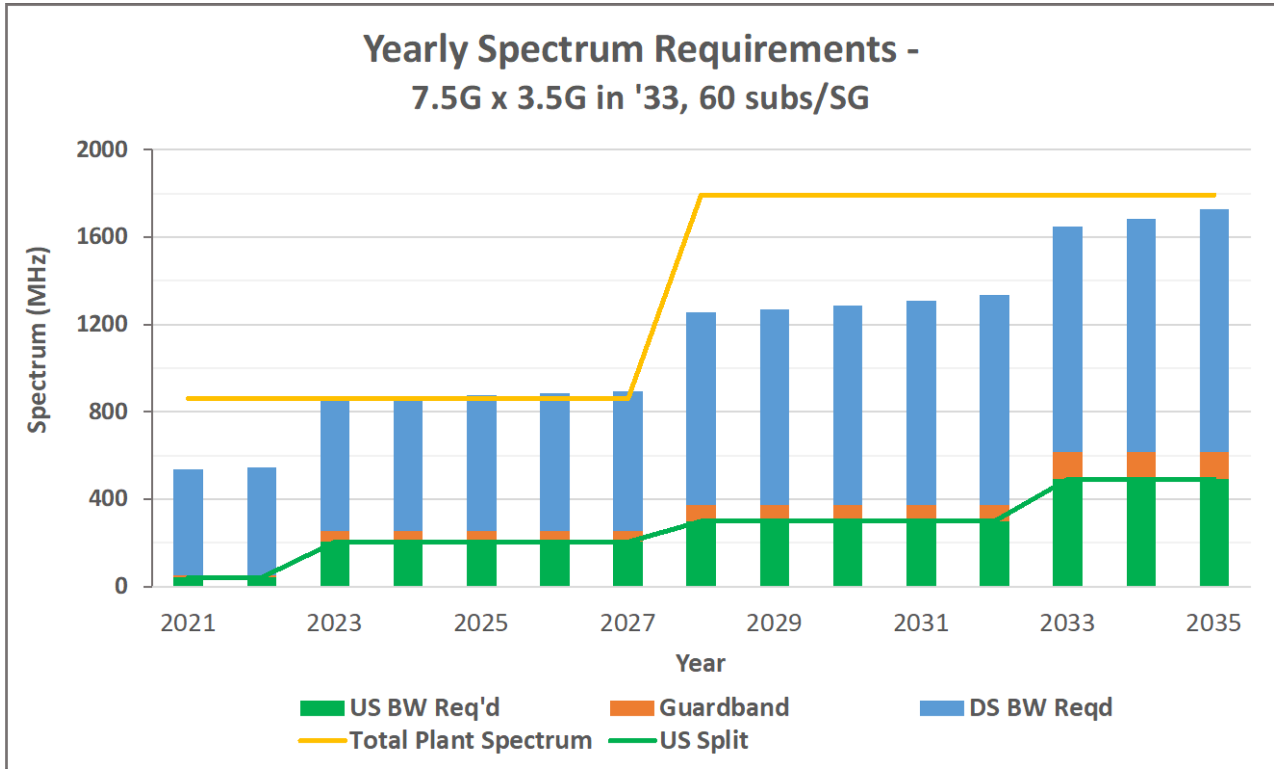


4:1 vs. 2:1 DS:US Tmax Scenarios for 60 subs/SG

2G x 500M, 4G x 1G, 10G x 2G Progression



2G x 1G, 4G x 2G, 7.5G x 3.5G Progression



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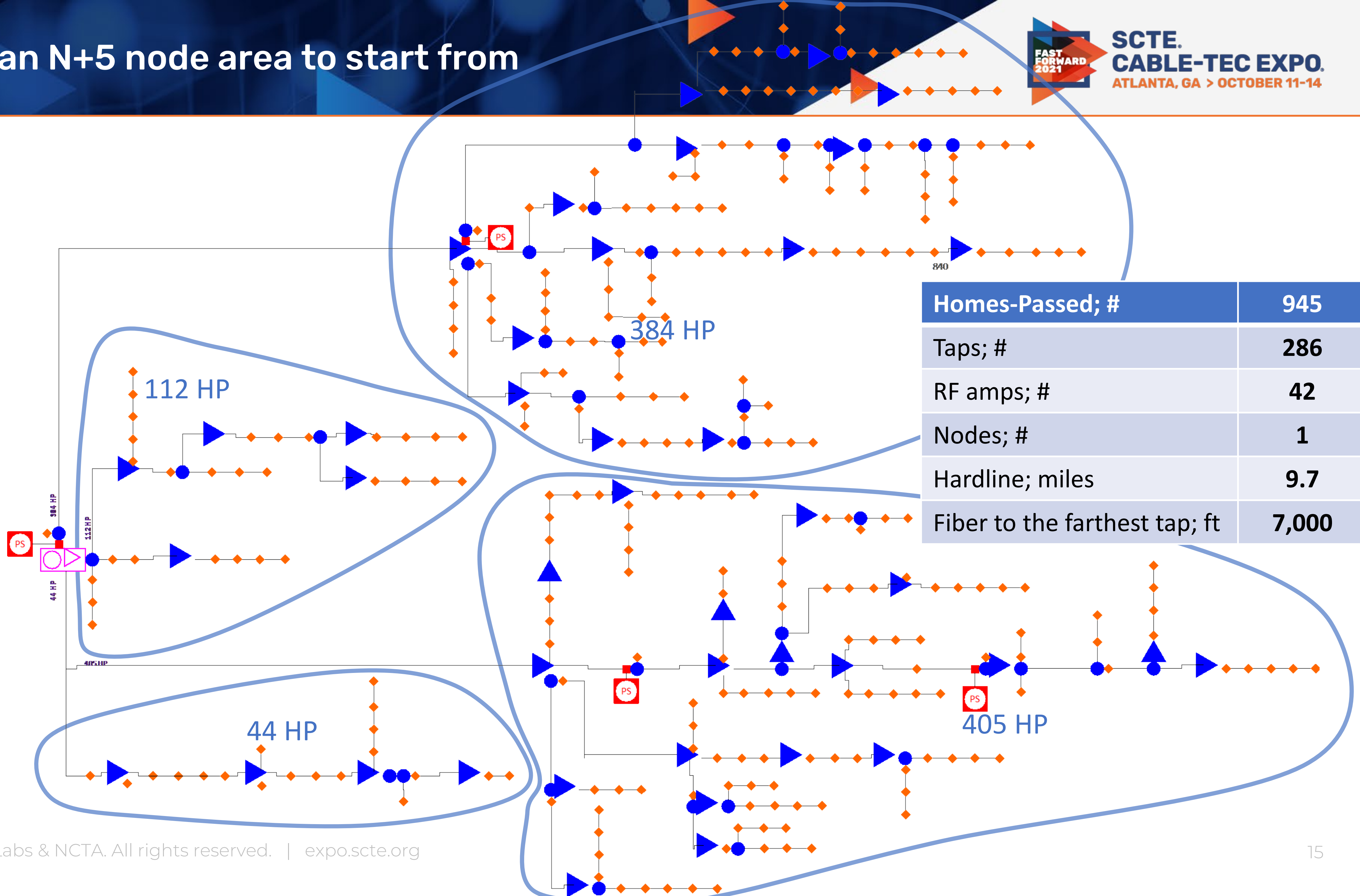
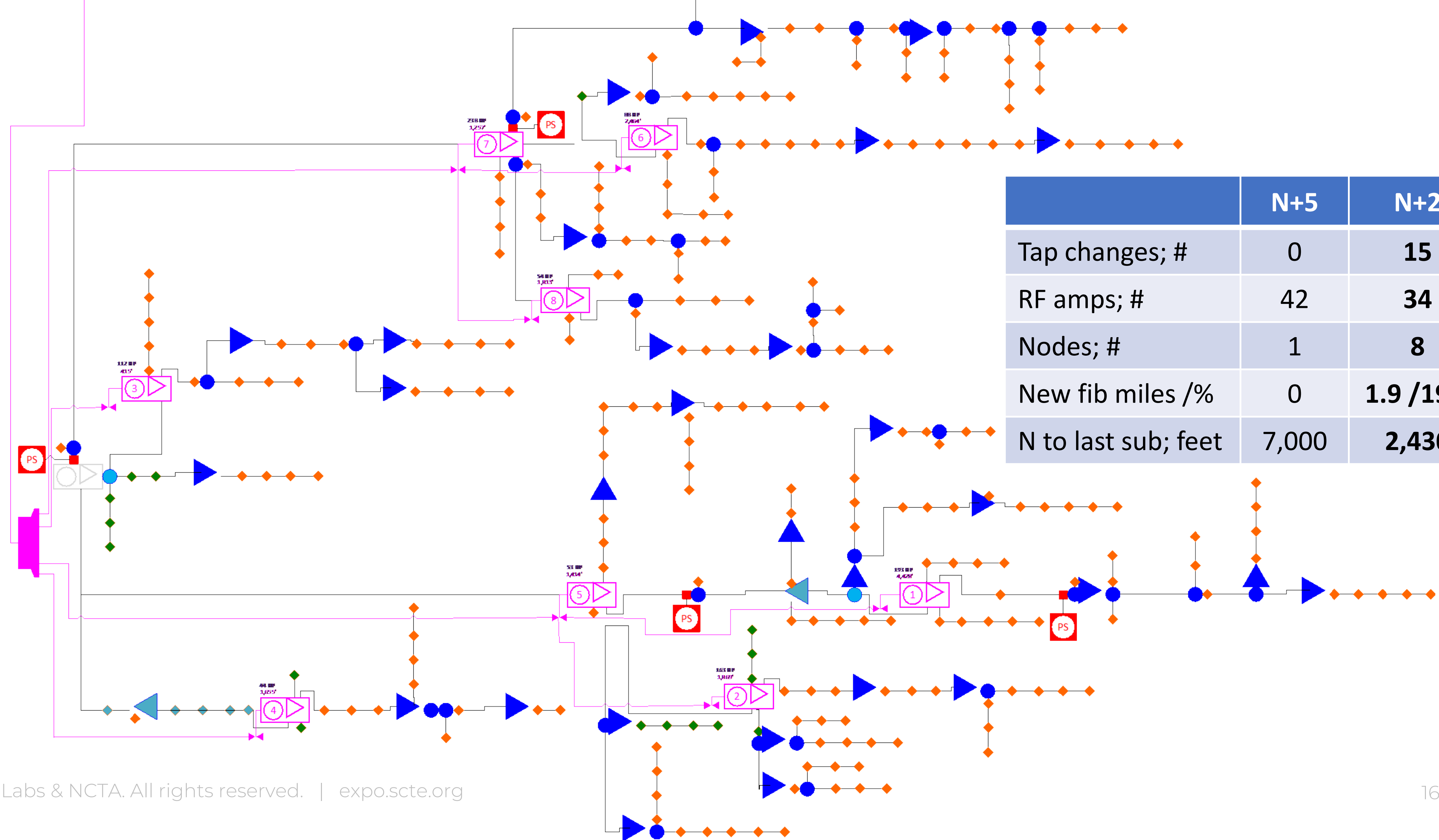
Network Evolution: Various Paths Considered

Baseline – an N+5 node area to start from



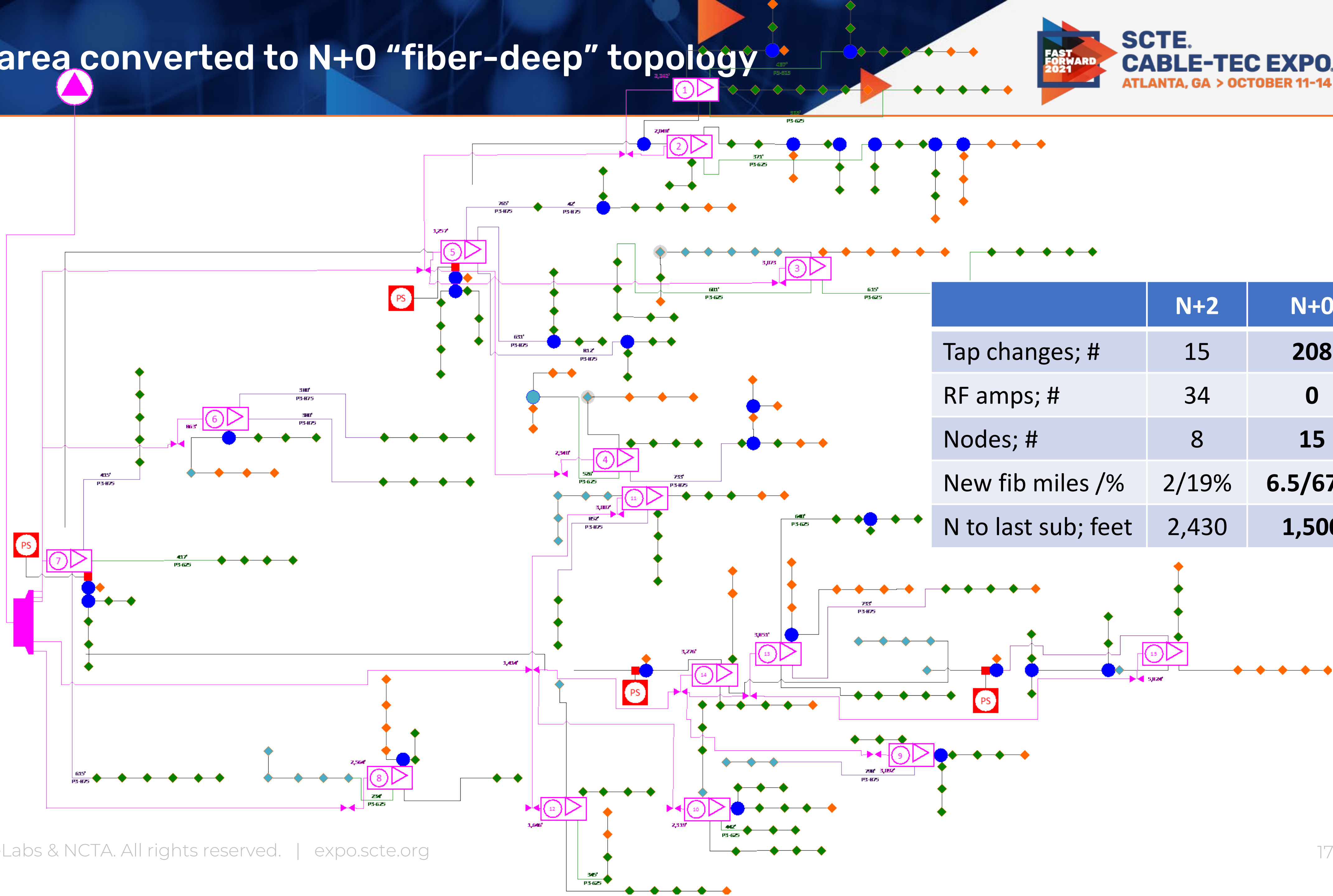
Homes-Passed; #	945
Taps; #	286
RF amps; #	42
Nodes; #	1
Hardline; miles	9.7
Fiber to the farthest tap; ft	7,000

N+5 node area converted to N+2 topology



	N+5	N+2
Tap changes; #	0	**15**
RF amps; #	42	**34**
Nodes; #	1	**8**
New fib miles /%	0	**1.9 /19%**
N to last sub; feet	7,000	**2,430**

N+5 node area converted to N+0 “fiber-deep” topology



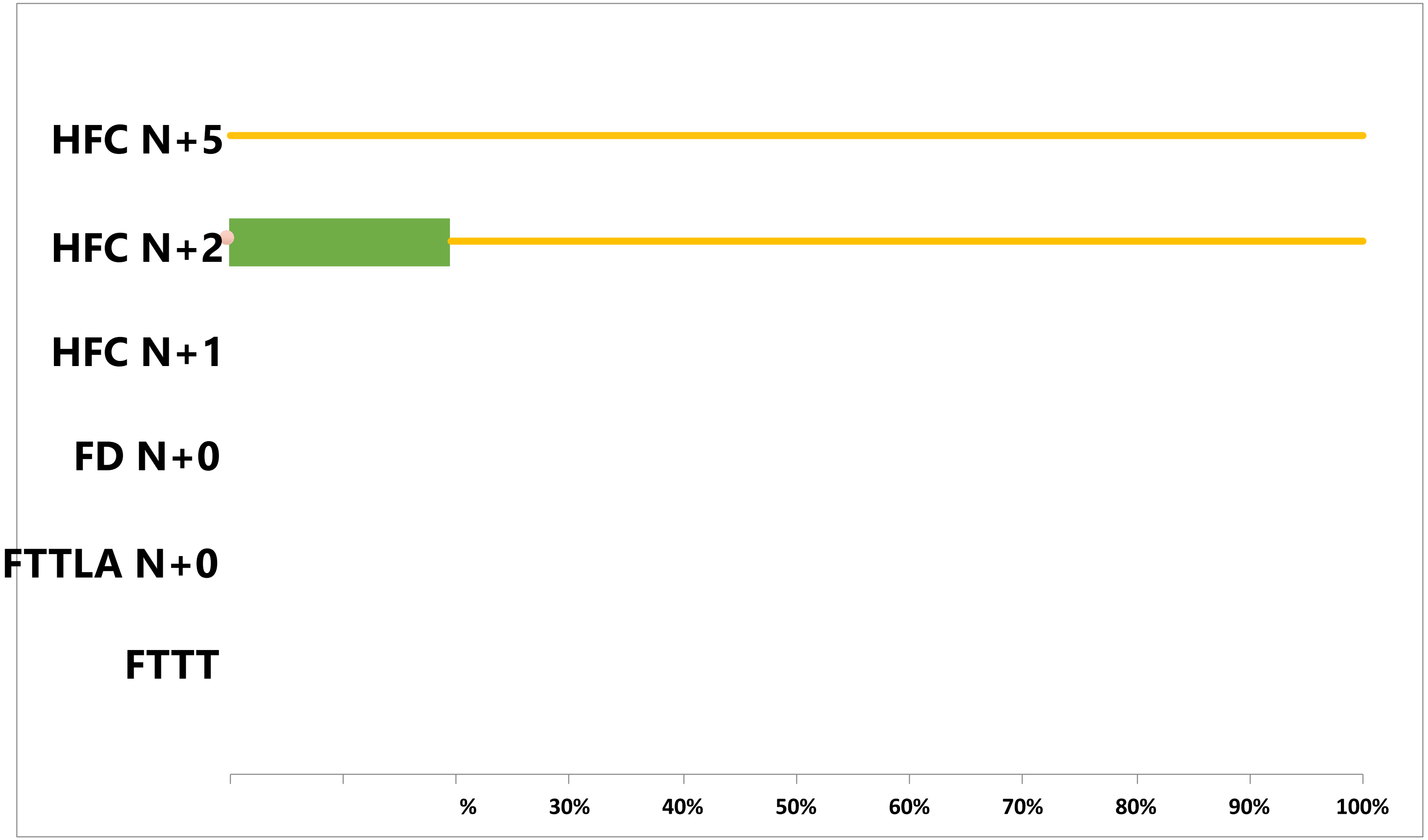
	N+2	N+0
Tap changes; #	15	**208**
RF amps; #	34	**0**
Nodes; #	8	**15**
New fib miles /%	2/19%	**6.5/67%**
N to last sub; feet	2,430	**1,500**

Network Evolution: Various Paths Considered

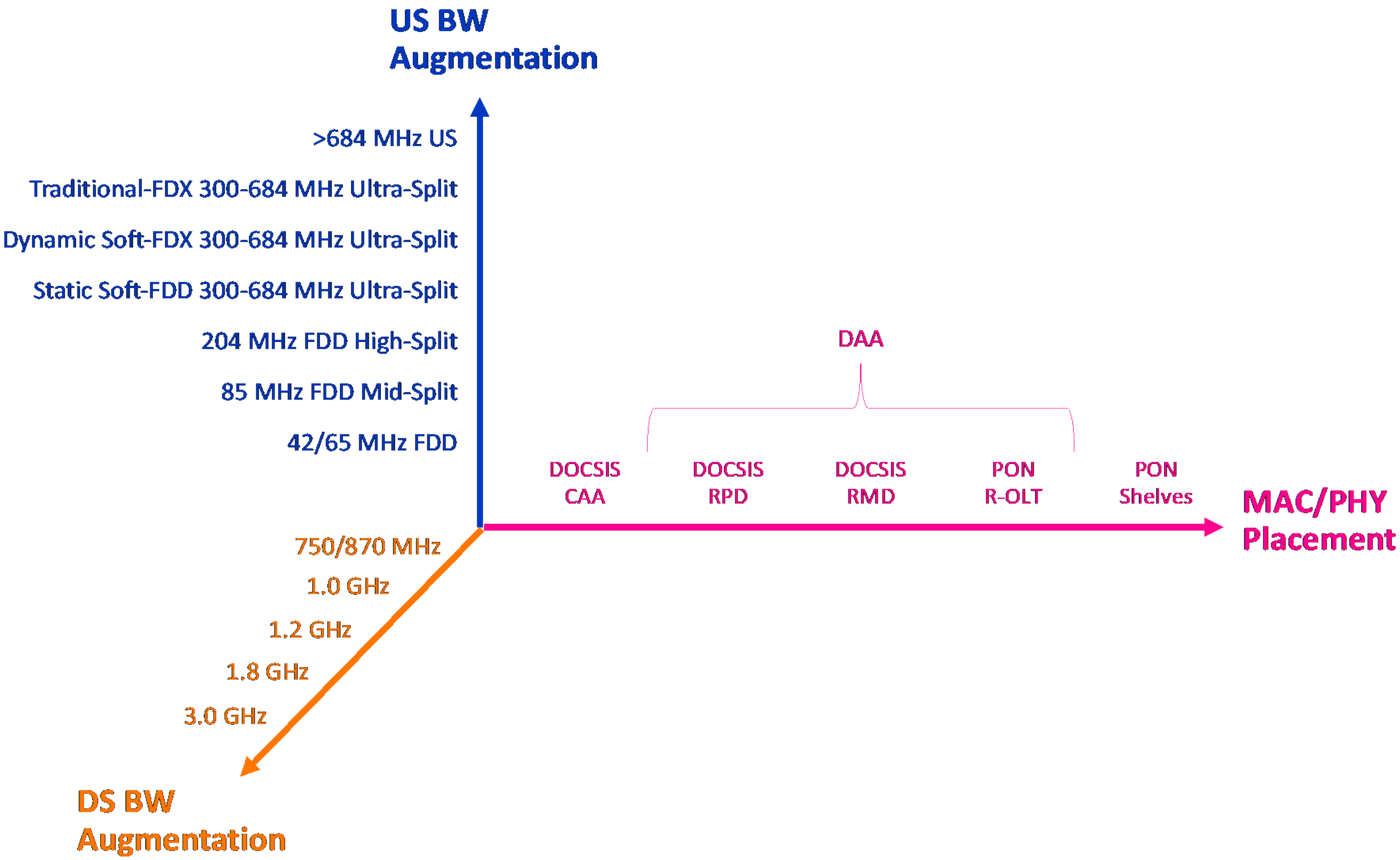
Network attribute changes with upgrading N+5 area to N+2 and N+0

Topology:	N + 5	N + 2	N + 0
Number of Standard **Nodes**	**1**	**8**	**15**
Number of RF Amps	42	34	0
Number of tap faceplate changes	0 / 286	15 / 286	208 / 286
New plant; miles	0 miles	1.9 miles	6.5 miles
New plant; %	0%	19%	67%
Fiber to the farthest sub	<7,000 ft	<2,500 ft	<1,600 ft

Legend: Hardline coax | New Fiber | New Coax



Other Possible Future Evolution Path Directions



Network Upgrade Scenarios Considered

Name	Architecture	# of SG	HP/SG	# of nodes	RF split	DS BW
CCAP N+5	I-CCAP	2	~480	2	Mid or high	1,218 MHz
CCAP N+2	I-CCAP	4	~240	8	Mid or high	1,218 MHz
CCAP N+0	I-CCAP	4	~240	15	Mid or high	1,218 MHz
FDX N+0	DAA	4	~240	15	108-684	1,218 MHz
FDX-Lite N+5	DAA	2	~480	2	108-396	1,218 MHz
ESD N+5	DAA	2	~480	2	396/492 UHS	1,794 MHz
ESD N+2	DAA	4	~240	8	396/492 UHS	1,794 MHz
10G PON	OLT in hub	15	64	N.A.	N.A.	N.A.
10G R-PON	OLT in node	8	128	N.A.	N.A.	N.A.

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Network Evolution: Total Cost of Ownership Compared

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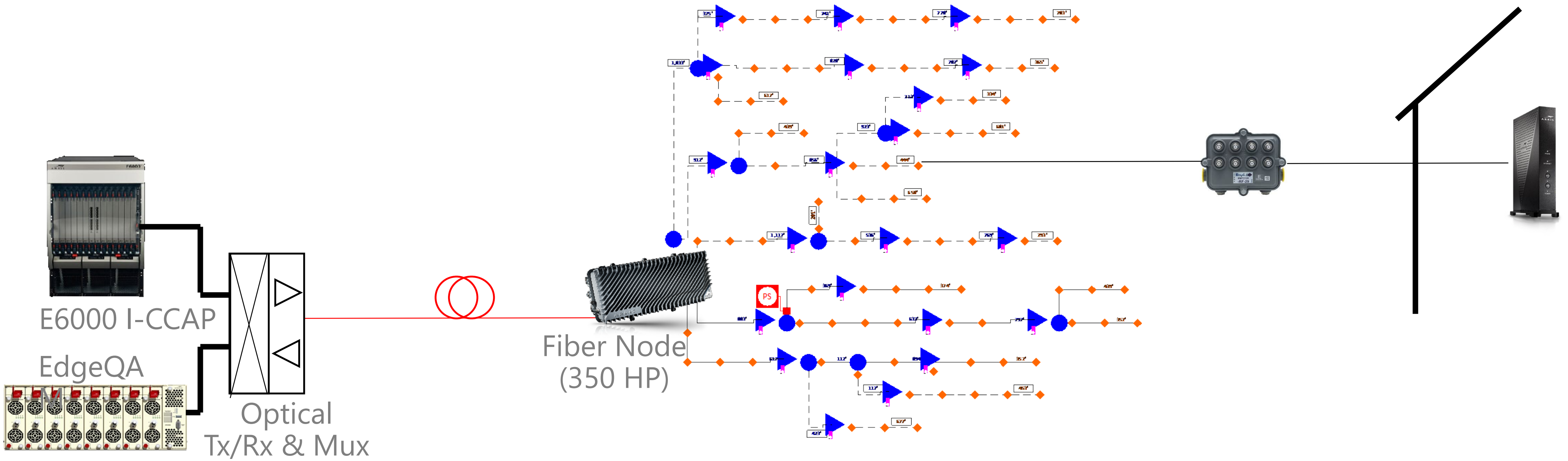
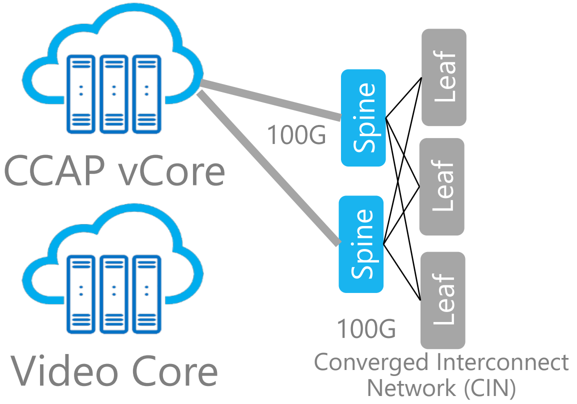
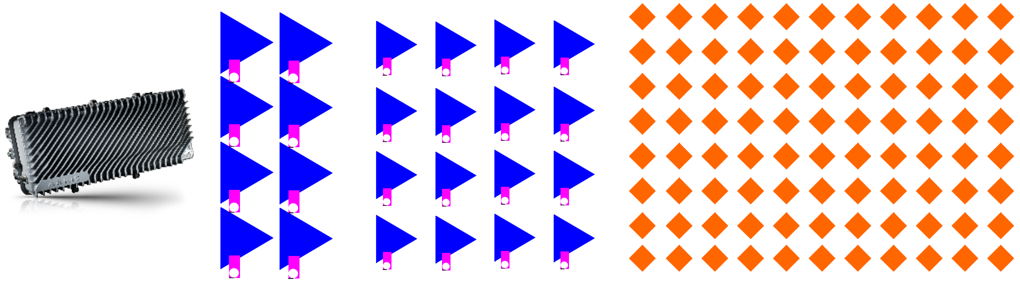
CAPEX Components



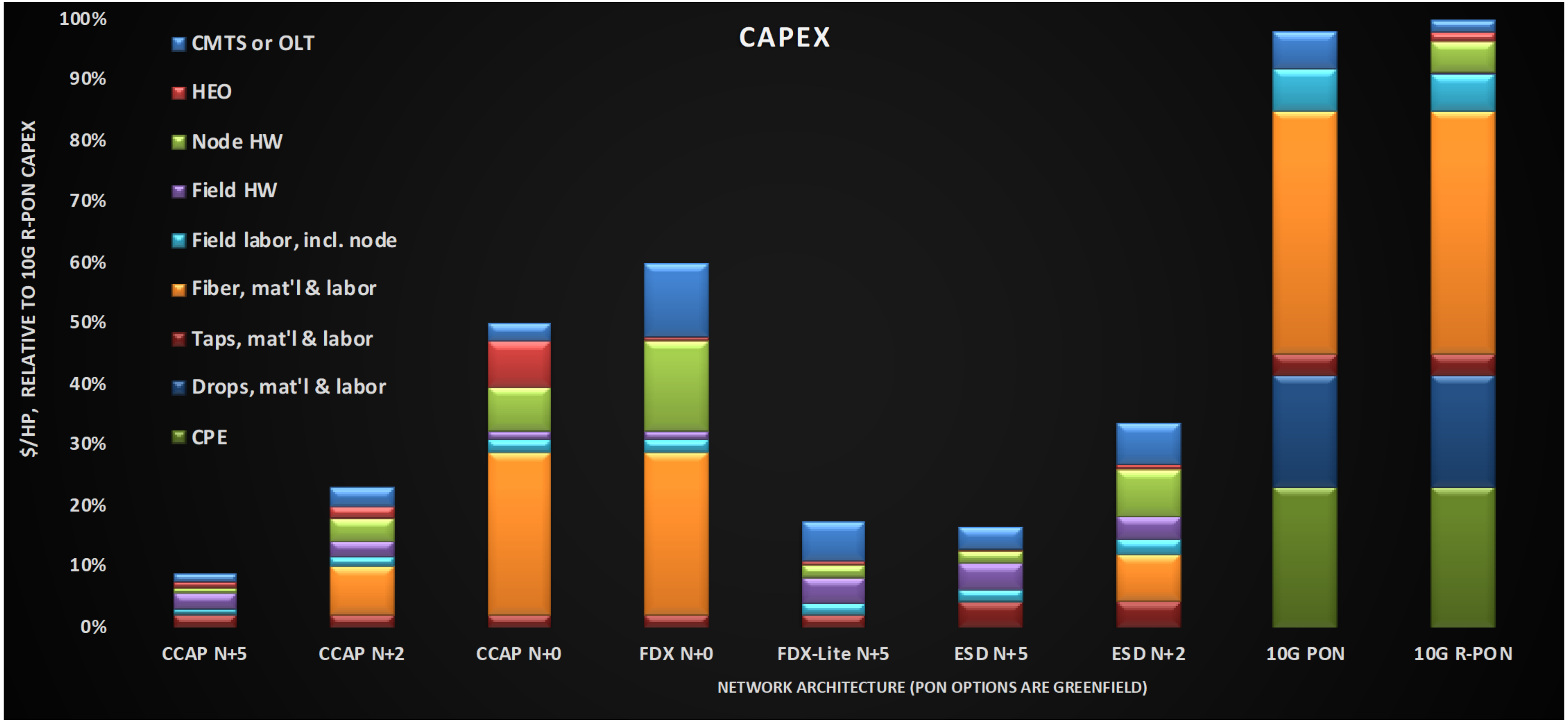




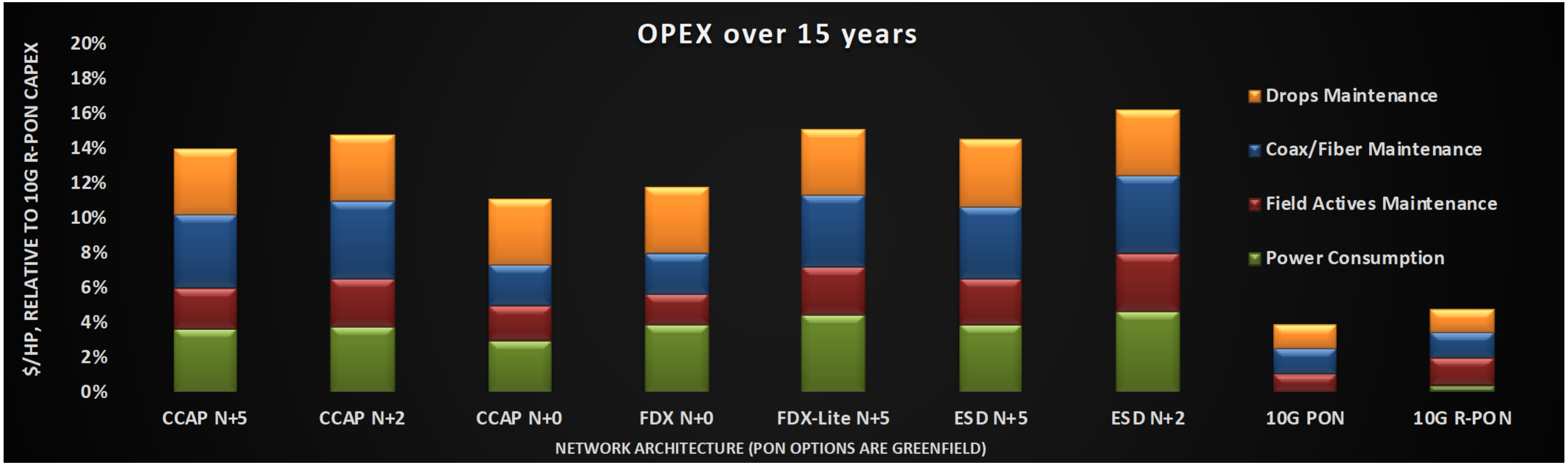
1 HEO Port
1 Fiber Node
8 Bridger Amps
16 Line Extenders
88 Taps
350 Homes Passed

CAPEX = (1/HP) x ∑(material & labor)

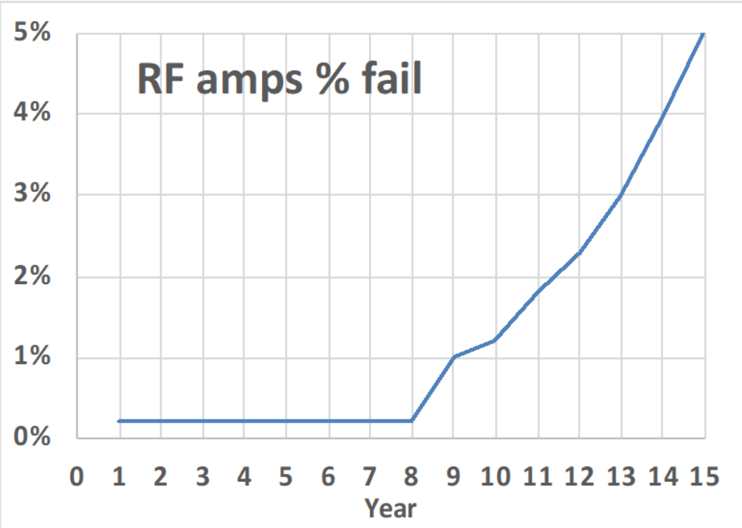
CAPEX for the nine upgrade paths



OPEX for the nine upgrade paths

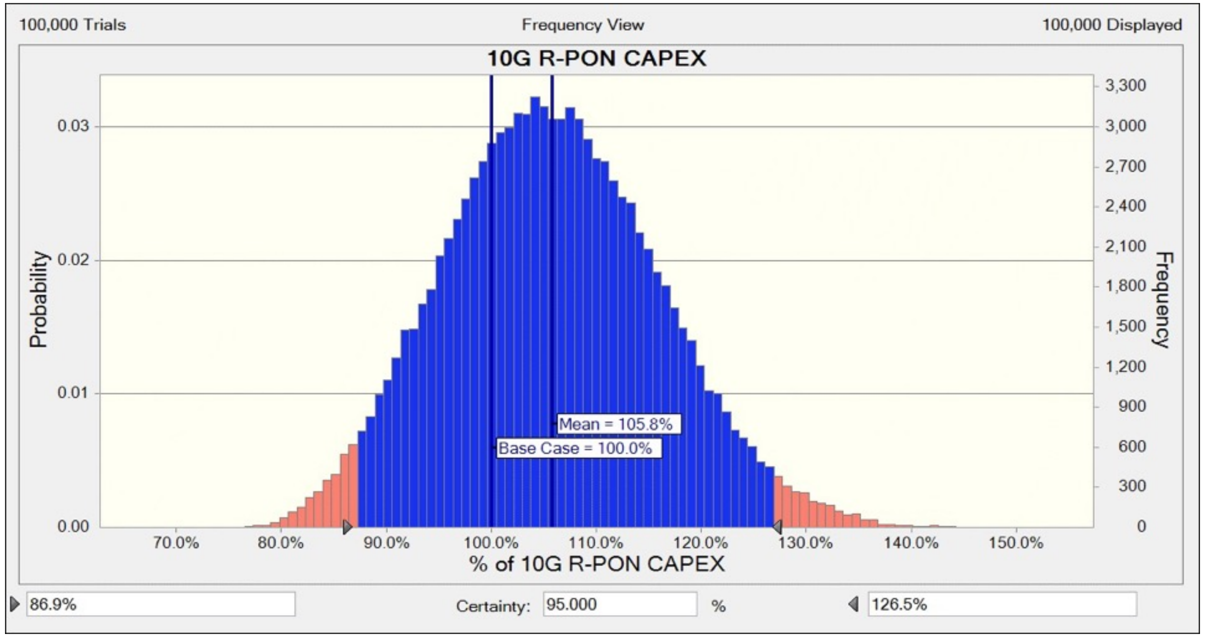


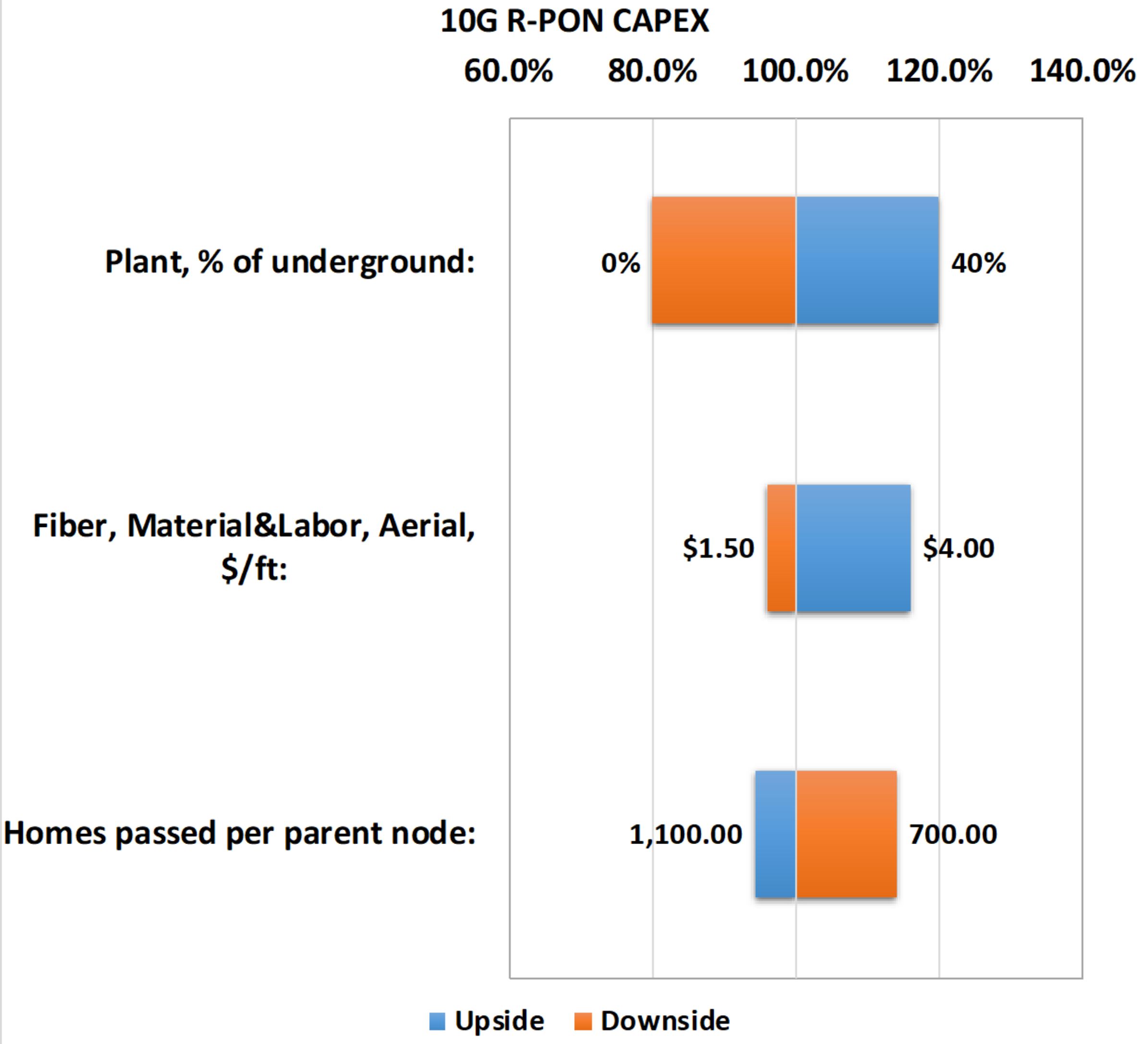
- $0.12/kWh
- 0.2% - 5% HW/year
- ~1% coax/year
- ~1% drops/year



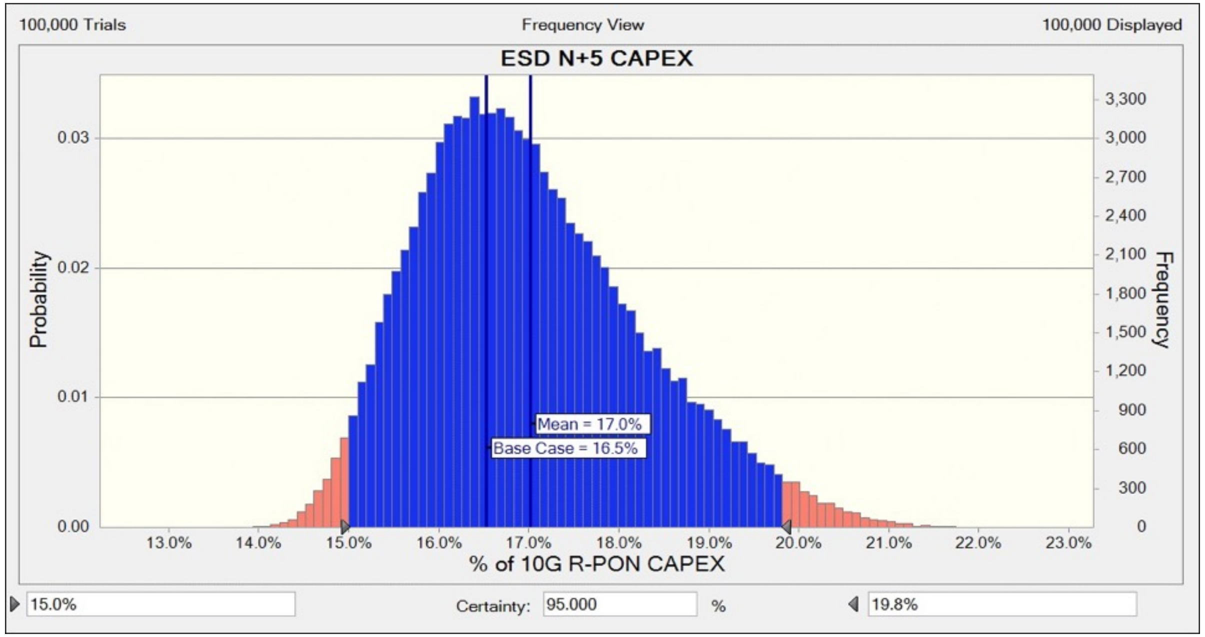
Monte-Carlo variability and sensitivity analysis

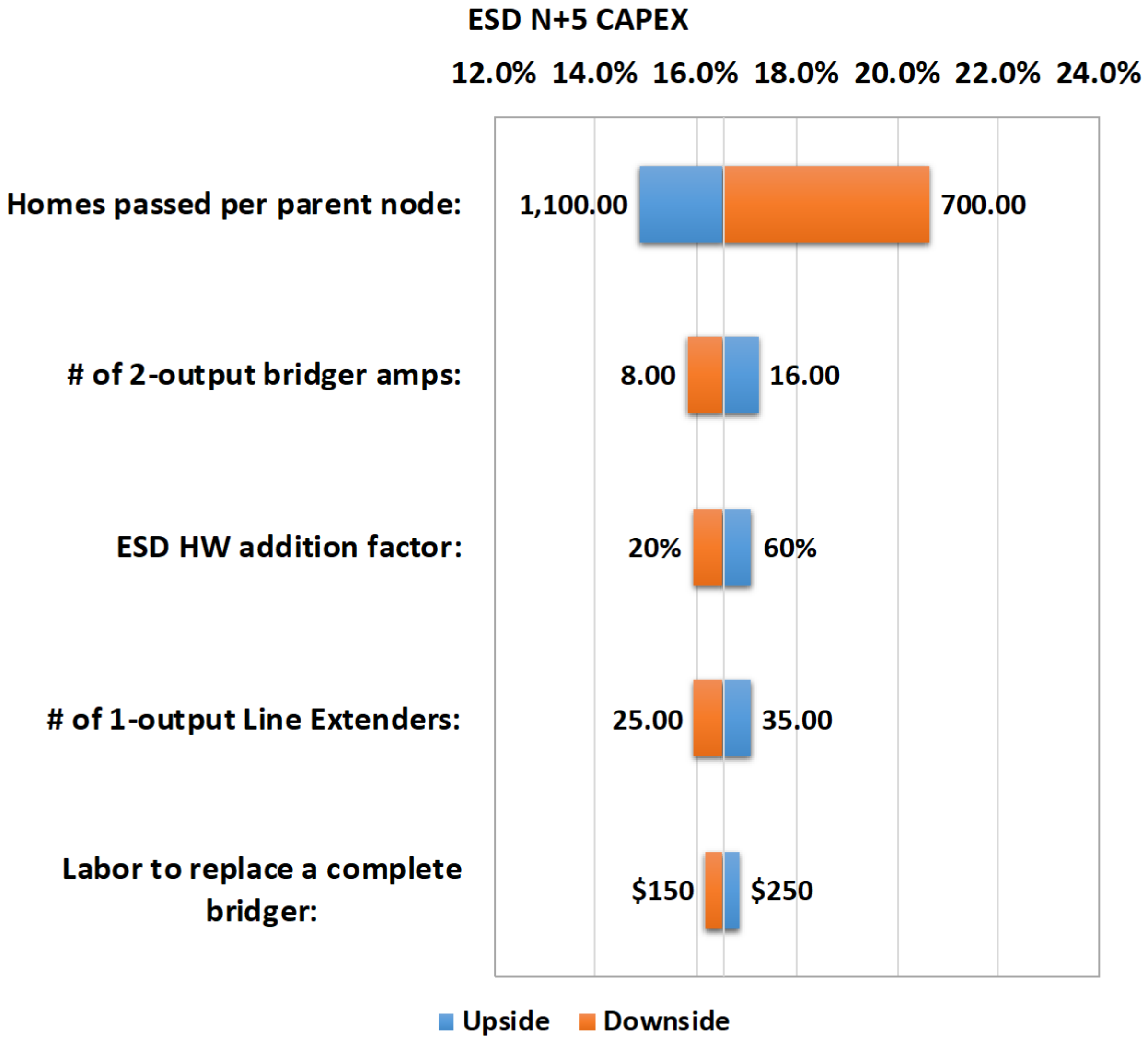
CAPEX; 10G R-PON





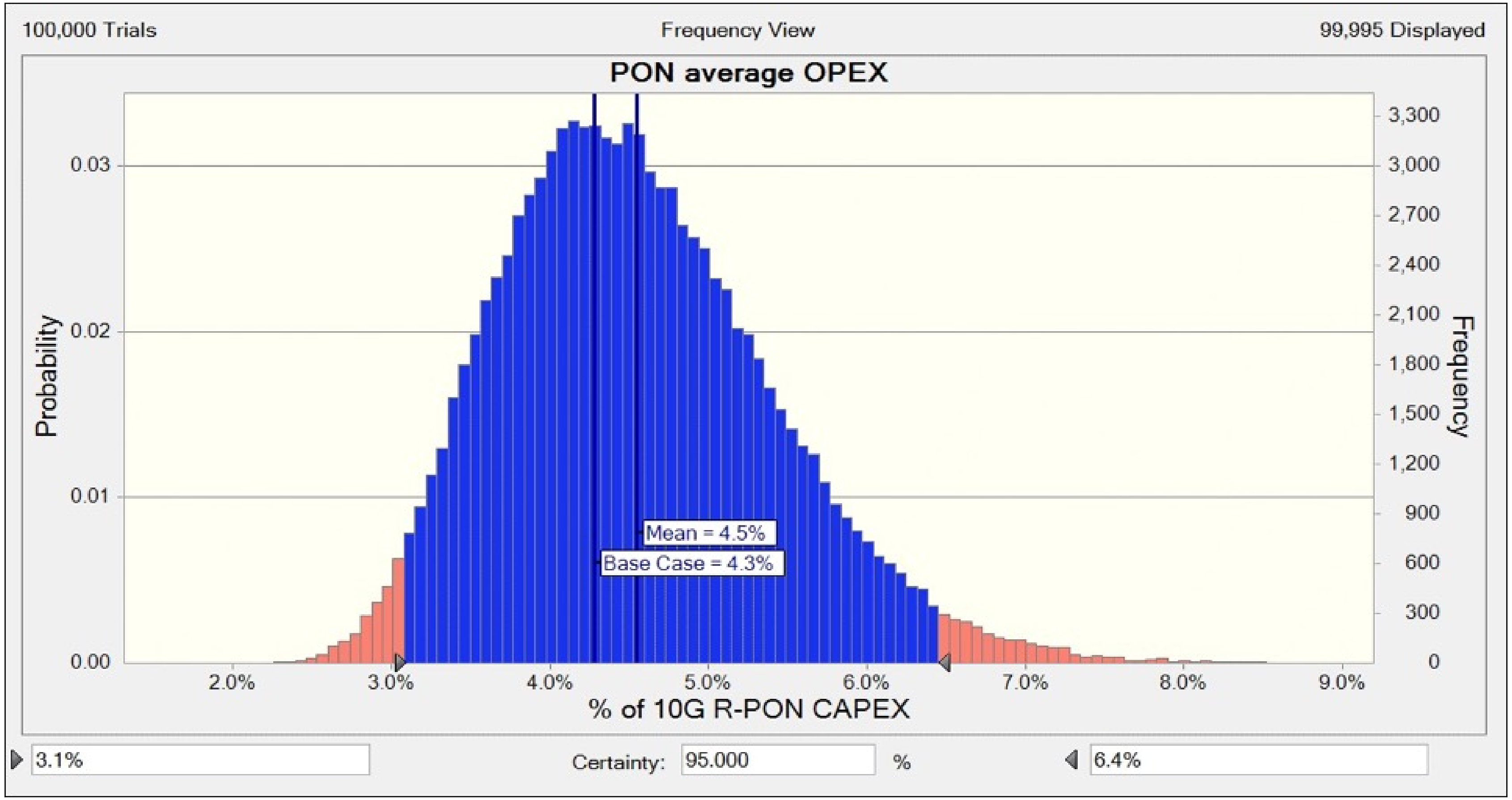
CAPEX; ESD N+5

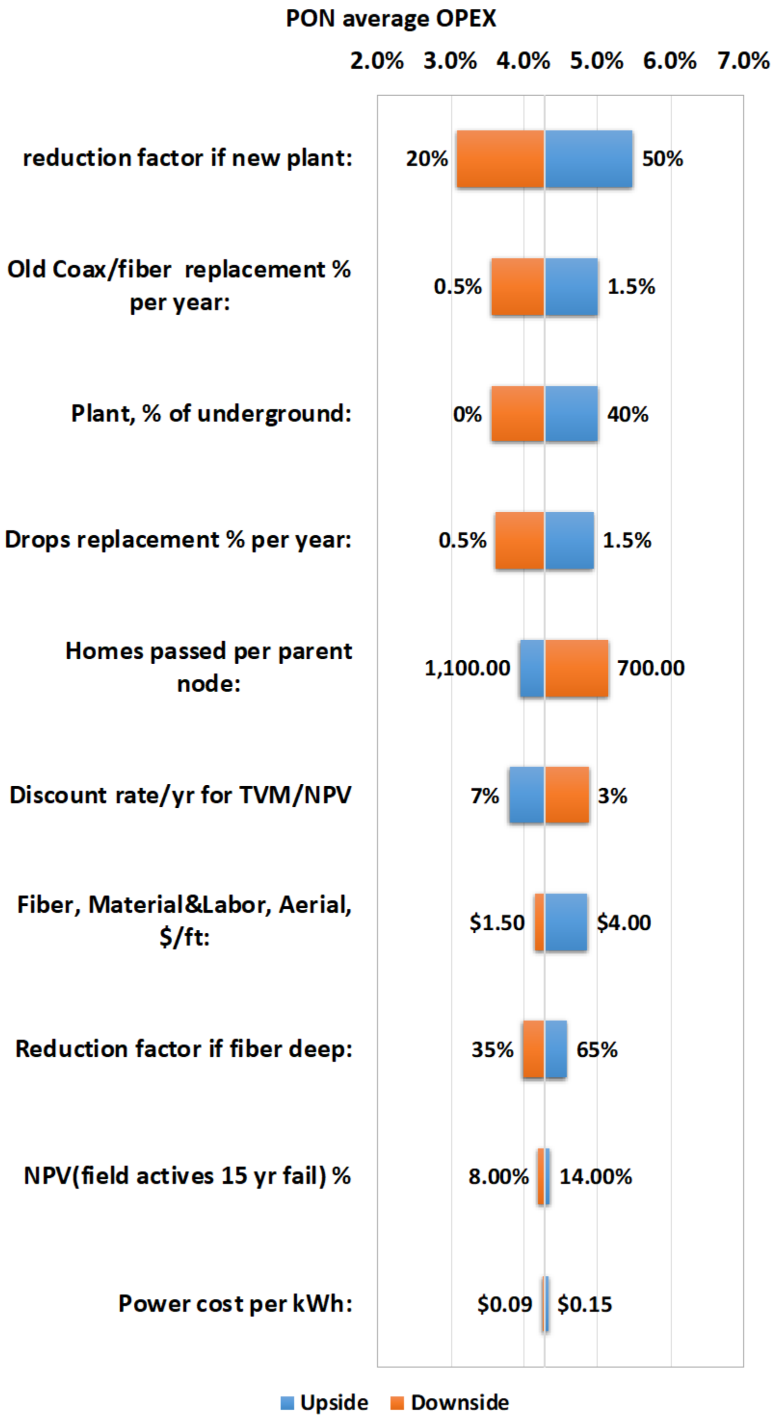

100,000 Trials
Frequency View
100,000 Displayed
ESD N+5 CAPEX
Probability
Frequency
0.03
0.02
0.01
0.00
3,300
3,000
2,700
2,400
2,100
1,800
1,500
1,200
900
600
300
0
Mean = 17.0%
Base Case = 16.5%
13.0%
14.0%
15.0%
16.0%
17.0%
18.0%
19.0%
20.0%
21.0%
22.0%
23.0%
% of 10G R-PON CAPEX
15.0%
Certainty: 95.000 %
19.8%


ESD N+5 CAPEX
12.0% 14.0% 16.0% 18.0% 20.0% 22.0% 24.0%
Homes passed per parent node:
1,100.00
700.00
# of 2-output bridger amps:
8.00
16.00
ESD HW addition factor:
20%
60%
# of 1-output Line Extenders:
25.00
35.00
Labor to replace a complete bridger:
$150
$250
Upside
Downside

Monte-Carlo variability and sensitivity analysis

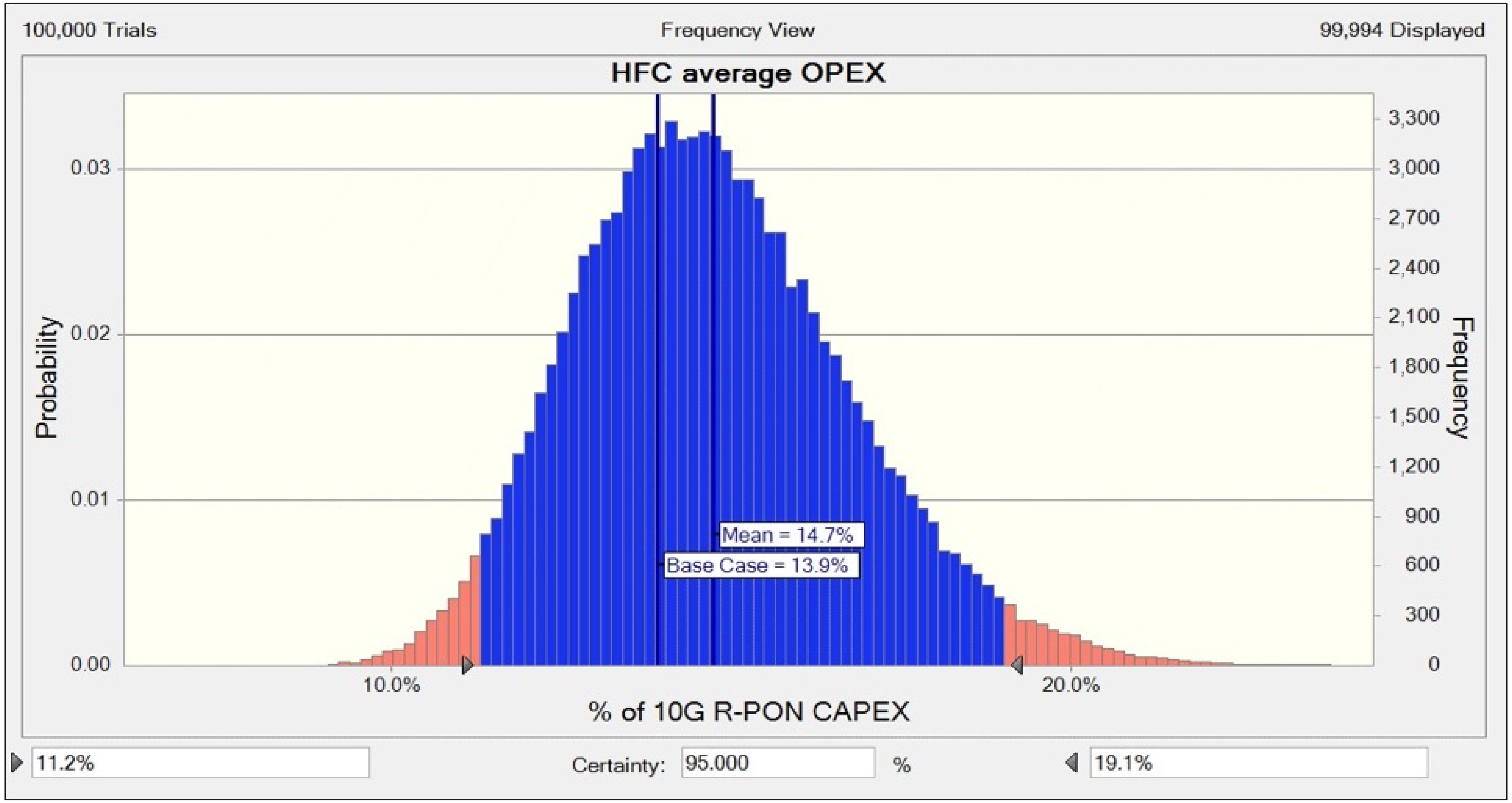
OPEX; PON

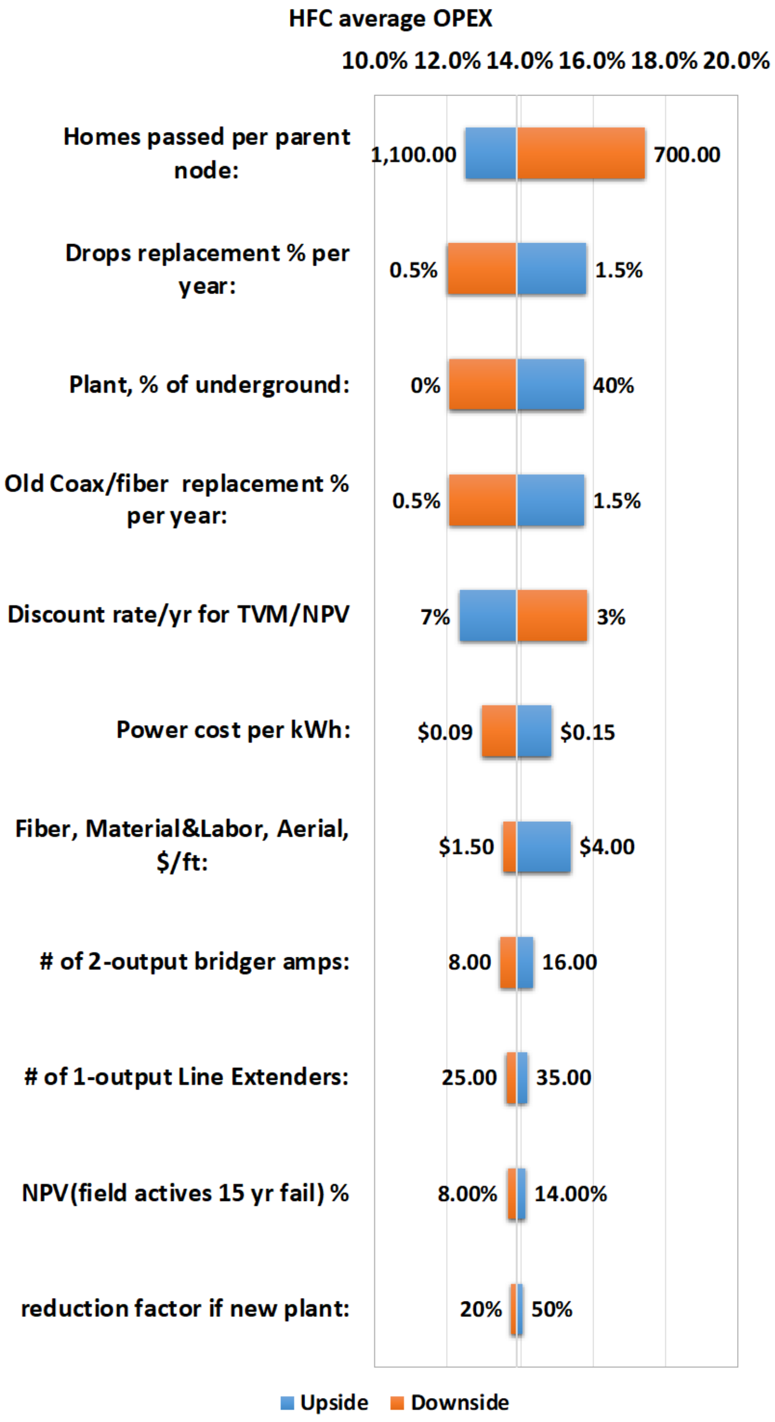




Monte-Carlo variability and sensitivity analysis

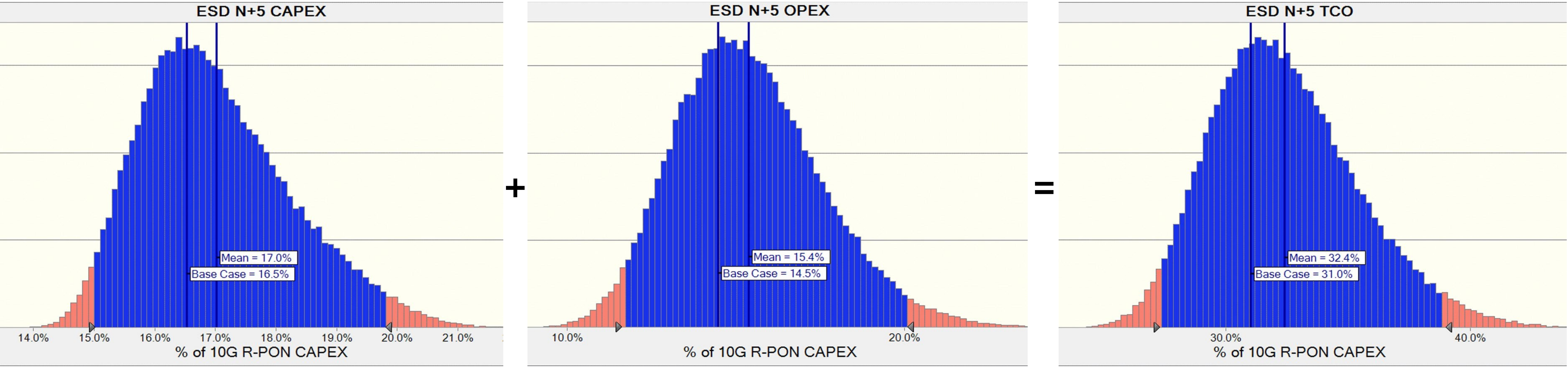
OPEX; HFC METHODS ON AVERAGE





Monte-Carlo variability and sensitivity analysis

TCO; ESD N+5



Monte-Carlo variability and sensitivity analysis

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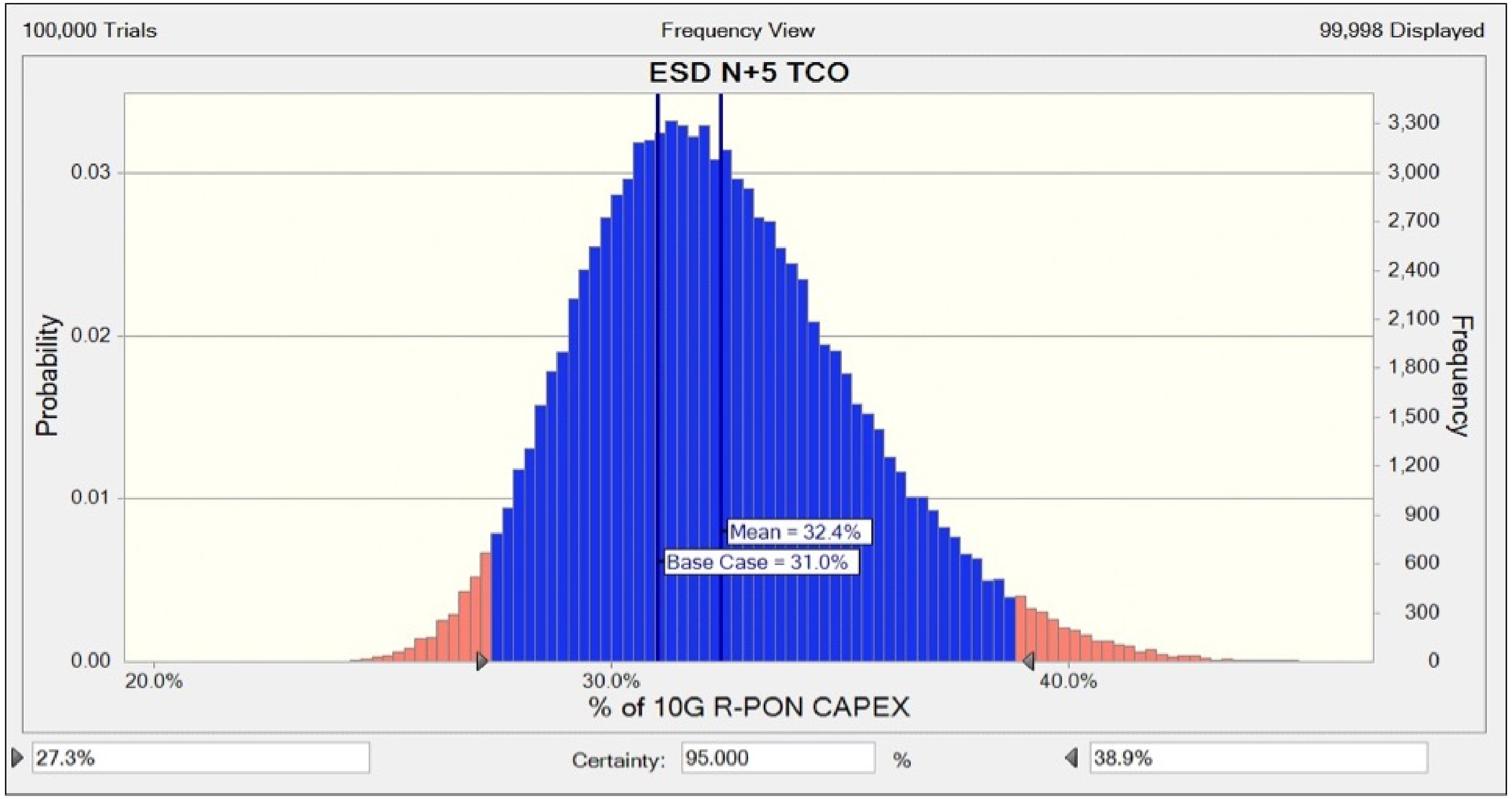
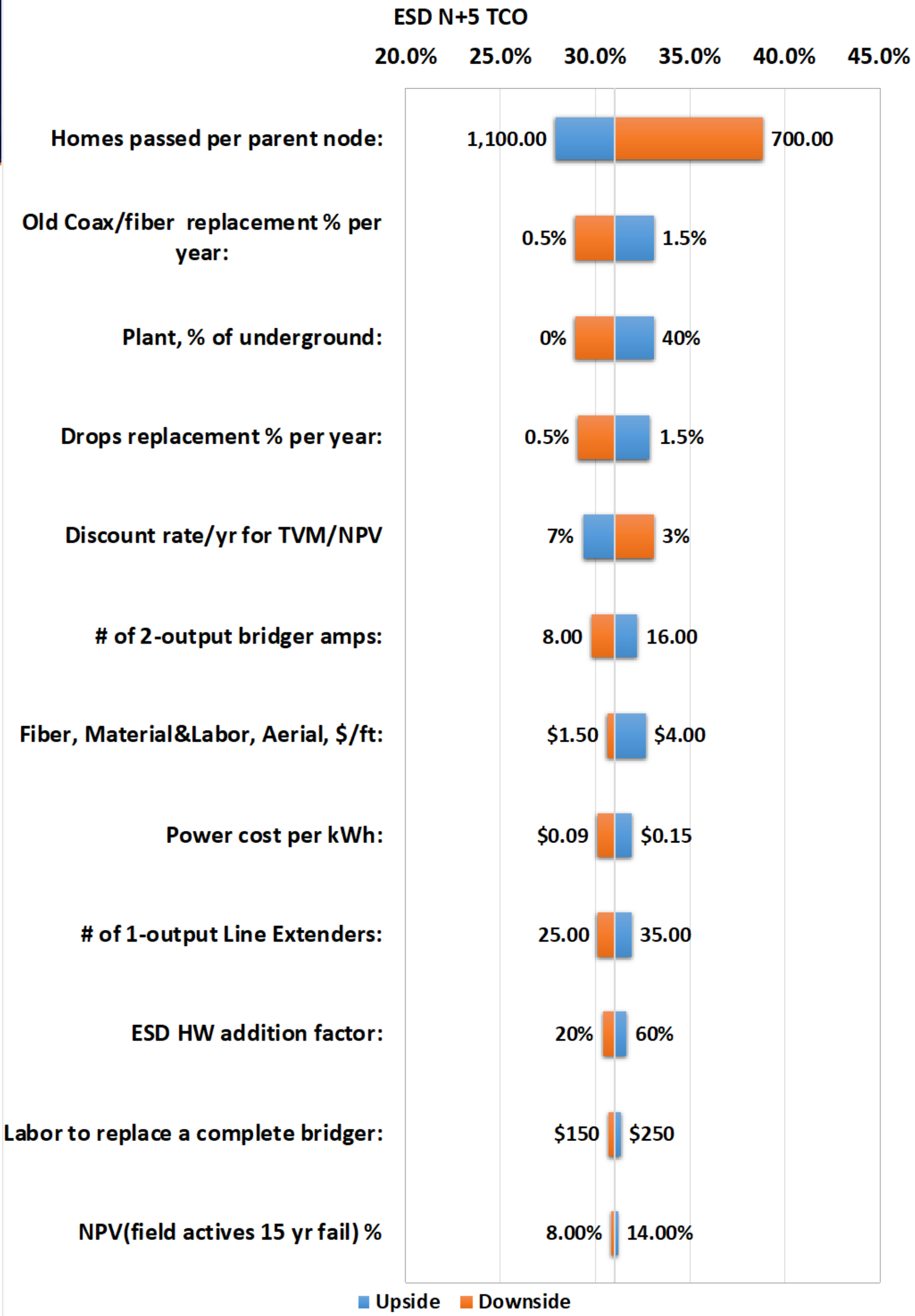
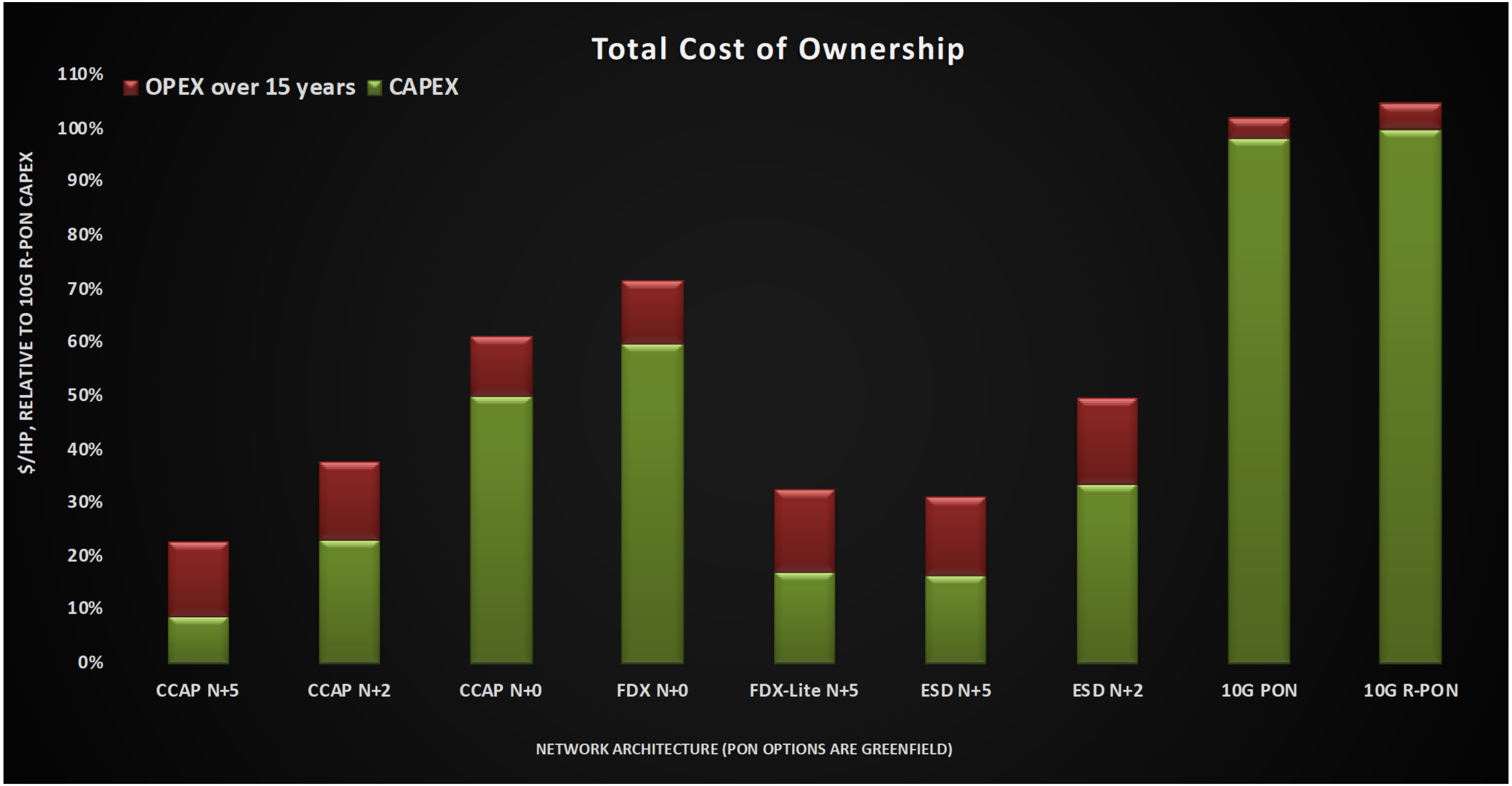


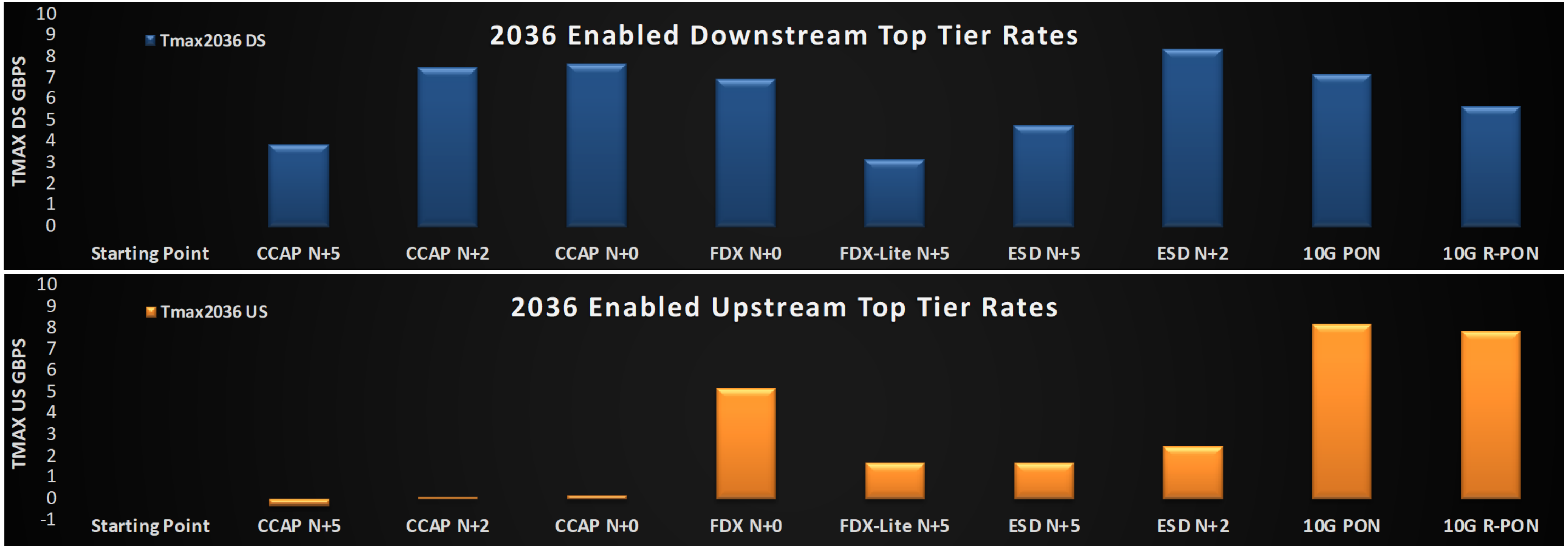


Total cost of ownership (TCO = CAPEX + OPEX)

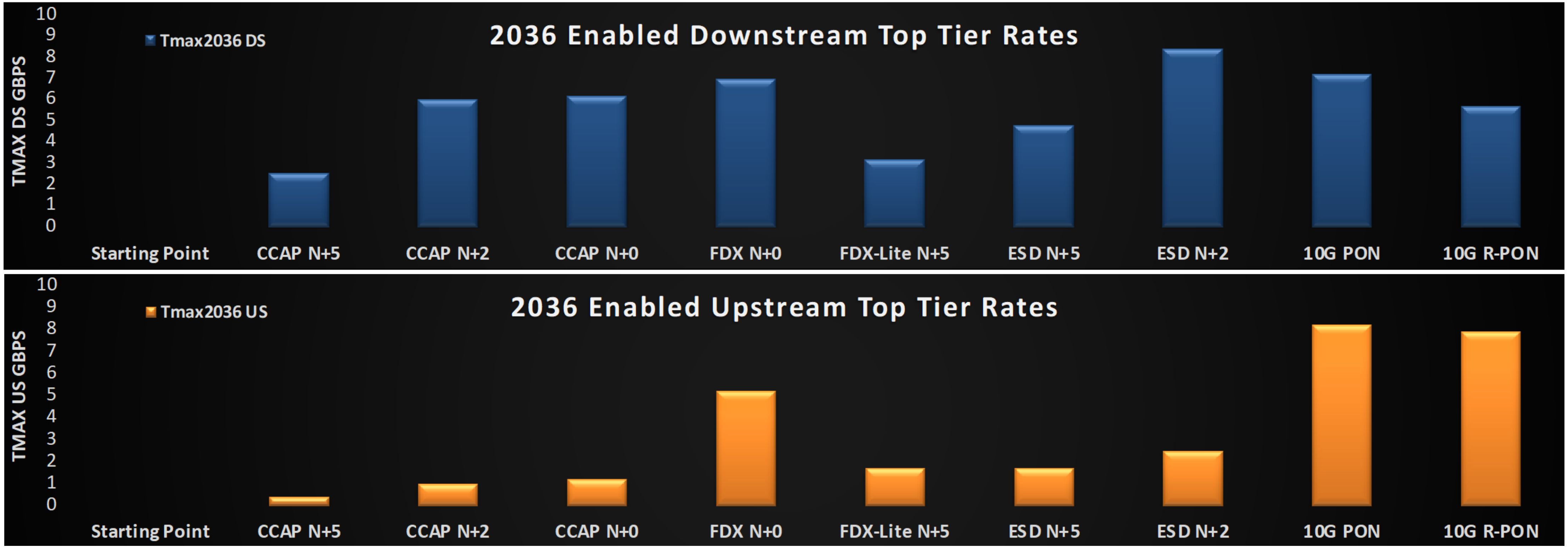


Maximum rates enabled for the nine upgrade paths

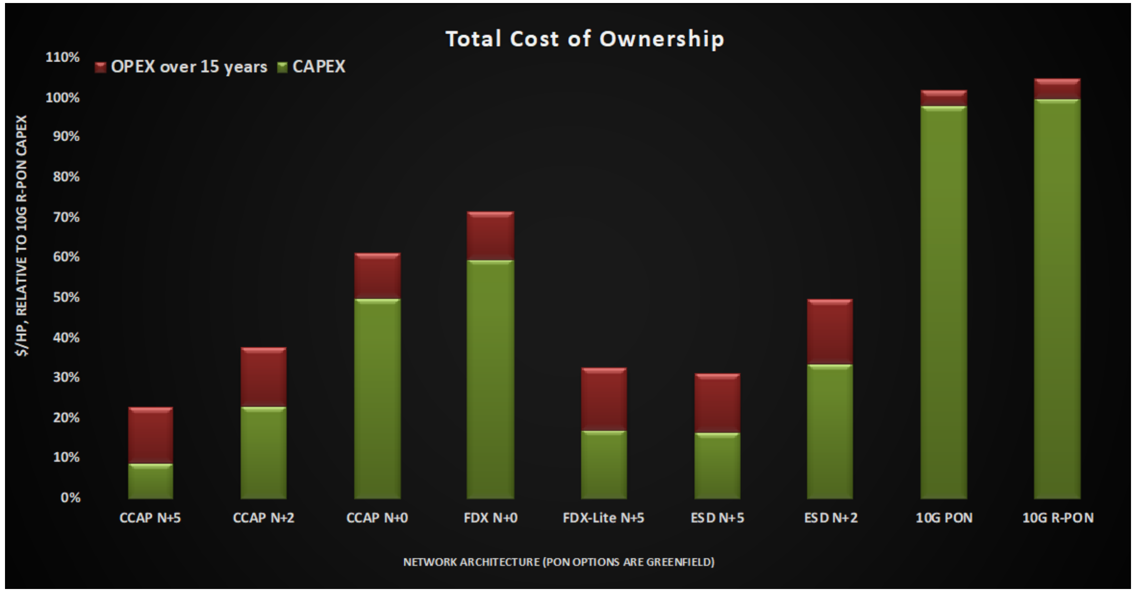
Mid-Split; Tmax_max = (C – Nsub * Tavg) / K

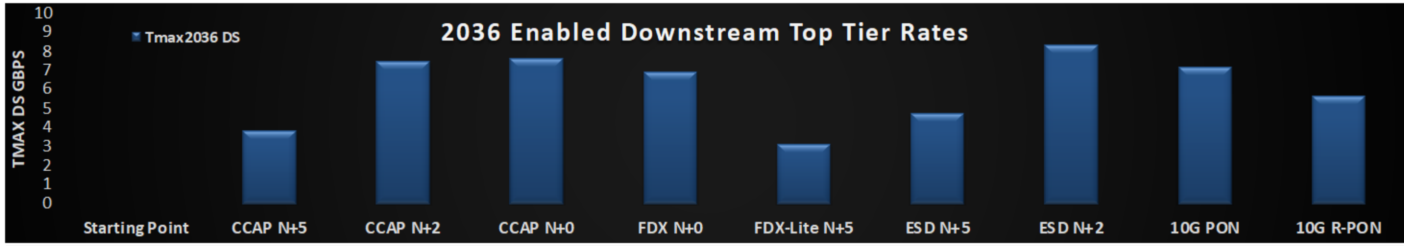


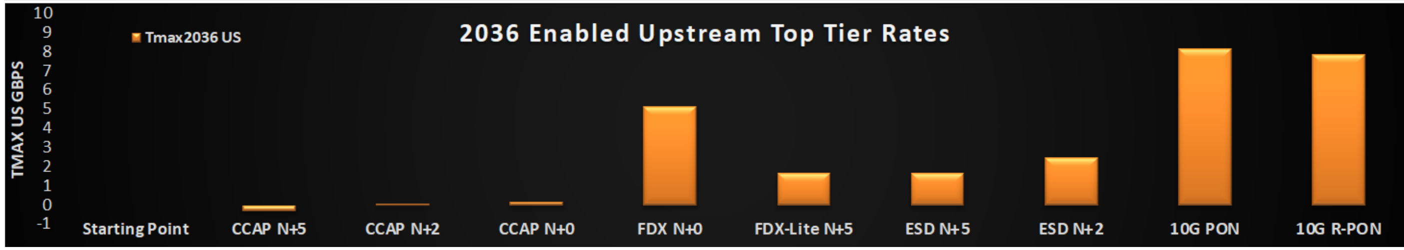
High-Split; Tmax_max = (C – Nsub * Tavg) / K

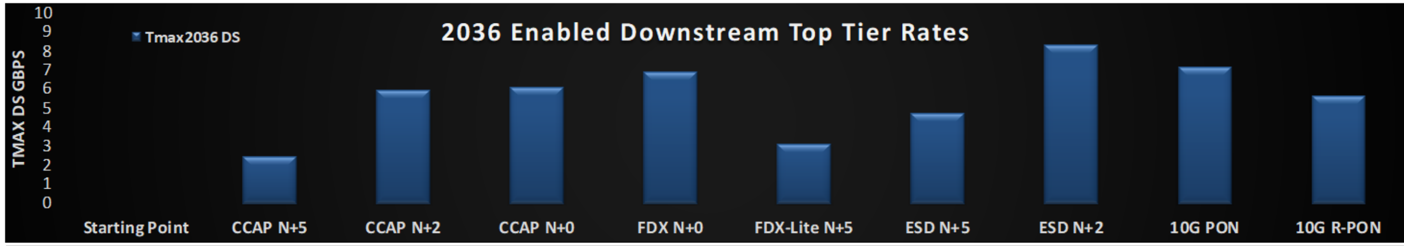


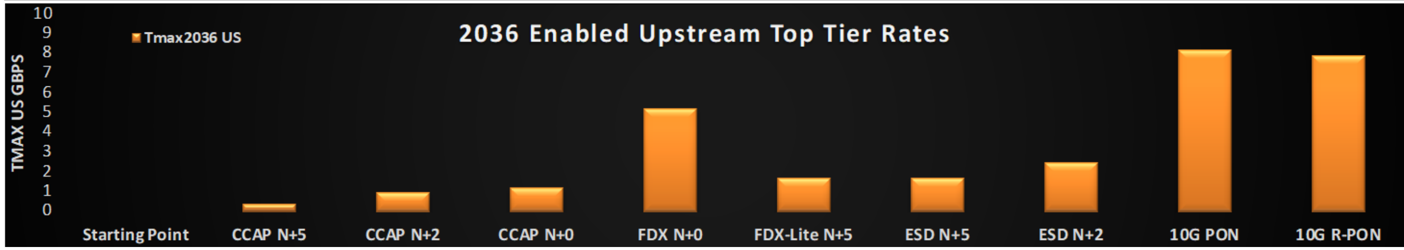
Total cost of ownership and what it buys



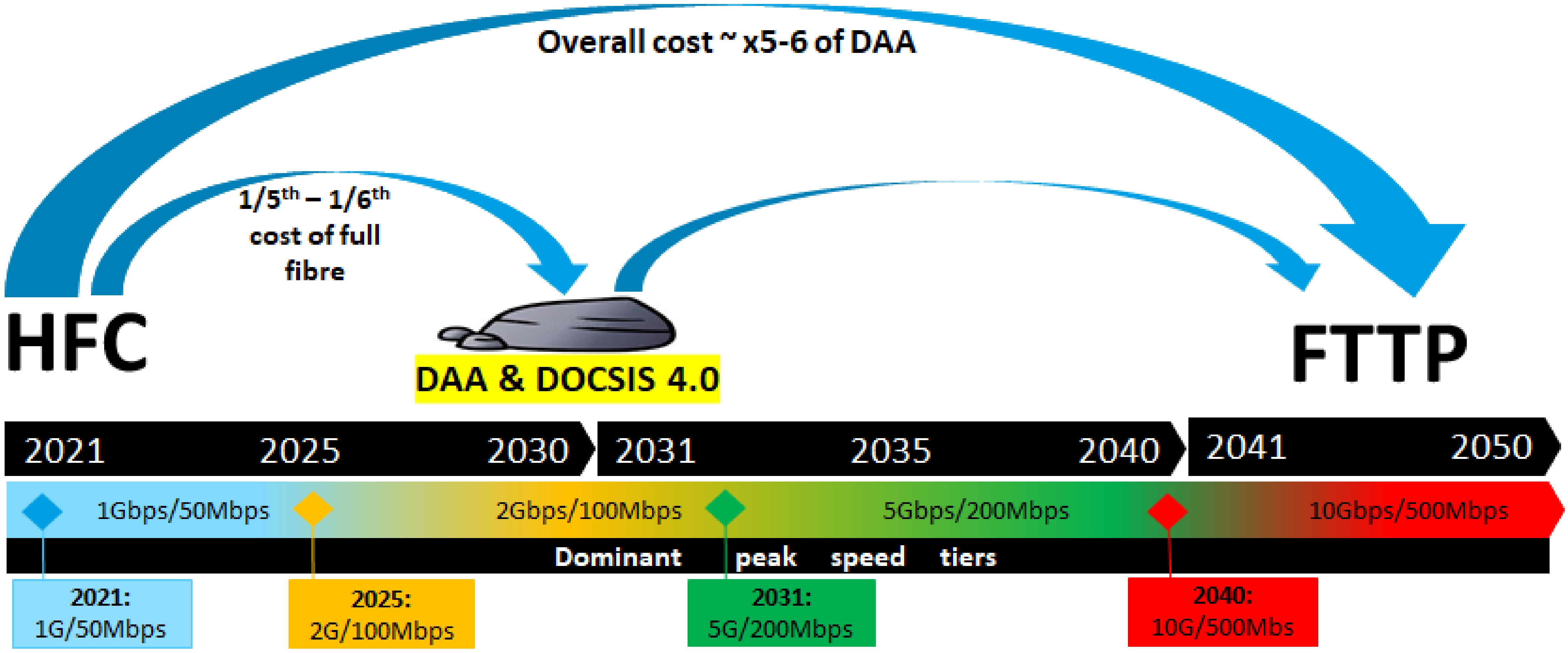








The way of nbn™



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Summary / Conclusions

FTTP or DOCSIS or both?

Fiber all the way day one?

- If greenfield – definite YES
  - CAPEX on par; OPEX 3x lower for FTTP
  - Comes down to the operations folks to implement new fiber-only processes
- Otherwise, if:
  - # of plant miles per node lower
  - # of HP/node higher
  - $/foot for fiber construction lower
  - Can leverage the existing fiber routes
  - Can leverage innovative approaches

If DOCSIS, D3.1 or D4.0?

For markets where HFC network already exist:

- D3.1 will provide good ROI into the late 2020s and early 2030s- enabling Gigabit rates - even in upstream if high-split
- D4.0 coupled with DAA will enable even higher data rates, into the late 2030s and beyond
- Each D4.0 technology (FDX and ESD) come with its unique set of strengths and weaknesses

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Thank You!

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