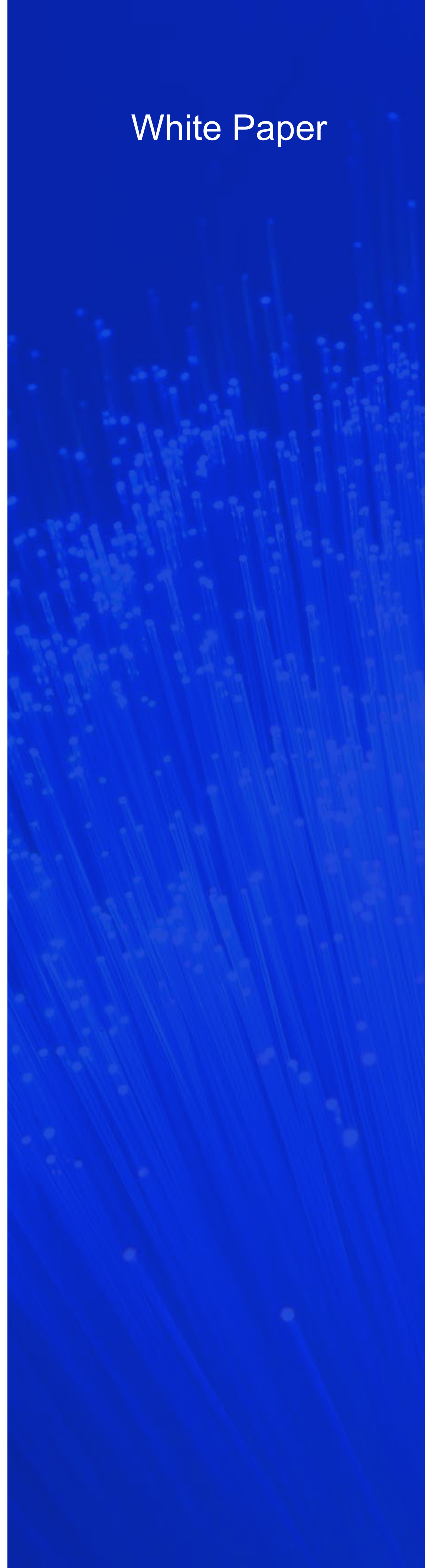


Powering the Plant: HFC versus FTTH

JEFF BROWN

Director, Product & Segment Marketing, Calix

JACK BURTON

Principal, Broadband Success Partners

I. INTRODUCTION

As subscribers continue to demand more and more network bandwidth, operators of hybrid-fiber-coax (HFC) networks have some big decisions to make. Should they upgrade their plant to a next-generation HFC architecture, or deploy a Fiber-to-the-Home (FTTH) architecture leveraging passive optical networks (PONs)?

Over the last 12-18 months, adoption of 10G XGS-PON has grown at a 4x-5x rate year over year as operators are increasingly choosing to deploy fiber-based PON networks. We see operators deploying 10G PON in a greenfield mode for new markets/coverage areas, or as an overlay in an existing market to address near-term network needs while future proofing the network and facilitating ther migration from HFC over time.

With this explosive level of adoption taking place, operators are clearly making the decision to place big bets on FTTH & PON as the access technology of choise for the coming decades.

But pulling the trigger and making these investments require solid business cases and ROI justification. Beyond the technology benefits driven by FTTH PON, there must be compelling economic factors motivating aggressive moves by large numbers of operators.

While much has been written about the comparative capital costs of constructing these upgrades and new networks, less has been discussed documenting the ongoing operating costs, which over the life of the investment make up the bulk of the overall network expense. We all know, intuitively, that fiber should cost far less than metallic networks in terms of maintenance. However, the largest difference in operating expense is in an area which may surprise you: powering the plant.

HFC networks, old and new, require power to run the nodes and the amplifiers. Because these elements are located in the outside plant, a distributed power solution is required. Power supplies are distributed throughout the plant, with each serving a cluster of nodes and/or amplifiers. In most cases, back-up batteries protect against outages in the commercial power source. These batteries have a finite life and require periodic replacement.

In contrast, PONs are by definition “passive”. An Optical Line Terminal (OLT) located in a central office or headend feeds the fiber plant. There are no amplifiers or other electronics in the plant, so there is nothing to power.

When adding PON as an overlay network to eventually replace an existing HFC network, it is desirable to make as much use of the installed fiber as possible. Installed spare fiber counts are probably far short of what is required for a PON. A remote OLT (ROLT) solution can serve to multiply these fibers to provide PON service without large-count extensions. In this case, power in the field will be required. How does that power requirement impact the savings of PON versus HFC?

Let us quantify the power used for HFC networks, and see what could be saved if the same plant geography was instead served by a fiber-based PON network.

II. BASIC ASSUMPTIONS

What power does a node or amplifier use?

The first bit of information we will need is an estimate of the power used by various HFC plant elements.

1. Nodes

A look at the most popular 2x2 (two service groups) and 4x4 (four service group) analog nodes shows that each consumes between 80 and 120 watts.

Next-generation distributed access architecture (DAA) nodes consume at least this much. Not because the electronics are less efficient, but because new nodes frequently include the high-level RF outputs necessary for extended spectrum plant. A system already using DAA has probably already made a decision on next-generation HFC plant, so we will not analyze DAA power consumption further.

Electricity costs can vary even more around the world than they do in the US. Let's look at some countries that have HFC networks.

2. Amplifiers

Line extender amplifiers, along with mini-bridger amplifiers are exclusively used in short-cascade HFC plant, while older plant uses a combination of trunk amplifiers (with built-in bridger amps) and line extenders. For each of the trunk amps, we can expect 80 to 120 watts, and for the line extenders or mini-bridgers 35 to 50 watts.

What does electricity cost? US, Europe, Africa, LATAM

1. United States

Electricity costs can vary tremendously from state to state. Below, we list the average price for residential service per kilowatt hour. Commercial prices should be similar.

Most Expensive States	**$ / kWh**
Hawaii	$ 0.30
Connecticut	$ 0.24
Alaska	$ 0.23
Rhode Island	$ 0.22
Massachusetts	$ 0.22
California	$ 0.21
Vermont	$ 0.20

Least Expensive States	$ / kWh
Kentucky	$ 0.11
Utah	$ 0.11
Missouri	$ 0.11
Oklahoma	$ 0.11
Mississippi	$ 0.11
Arkansas	$ 0.11
Tennessee	$ 0.11
Idaho	$ 0.10
Washington	$ 0.10
Louisiana	$ 0.10

Source: September 2020 – GPP- ©Statista 2021

The US average is $0.15 per KWh.

2. Around the Globe

Electricity costs can vary even more around the world than they do in the US. Let's look at some countries that have HFC networks.

Most Expensive Countries	US $ /kWh	
Germany	$	0.36
Denmark	$	0.33
Belgium	$	0.30
Portugal	$	0.27
Ireland	$	0.27
Japan	$	0.26
United Kingdom	$	0.26
Italy	$	0.26

Source: September 2020 – GPP- ©Statista 2021

Some of the least expensive countries might surprise you:

Least Expensive Countries	US $ /kWh	
Turkey	$	0.09
India	$	0.08
Mexico	$	0.08
China	$	0.08
Nigeria	$	0.06
Argentina	$	0.06
Russia	$	0.06
Saudi Arabia	$	0.05
Qatar	$	0.03
Iran	$	0.01

What do standby power batteries cost?

Typical CATV power supplies contain three or six batteries. Capacity specifications for these batteries are typically around 100 Ah. They must operate in an uncontrolled environment and be capable of deep cycles. Batteries can be expected to last about four years. These are specialty batteries, which are similar to an auto battery but emphasizes continuous run time rather than “cold cranking amps”.

Each battery can cost between $100 and $200, so this replacement effort can get expensive. Just initially installing batteries for the 500-plus power supplies in a 100,000-home system could cost hundreds of thousands of dollars. The battery replacement effort itself requires a truck roll and up to an hour on-site for the operation.

Source: Toner Cable

Monitoring discussion and cost

Because replacing batteries strictly on a time-in-service basis can be costly, most systems employ status monitoring equipment that can remotely test the batteries and determine when each requires replacement. Status monitoring equipment adds a bit to the cost of a power supply, but operationally someone must manage the database of supplies and monitor the data within the status monitoring system. We will assume monitoring would pay for itself versus time-in-service battery replacement.

Source: Universal Battery

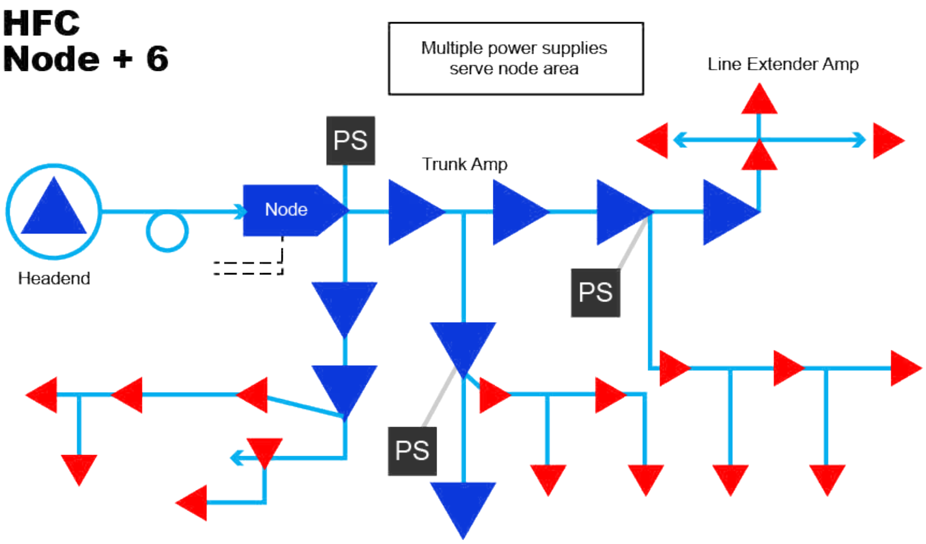
III. HOW MANY NODES OR AMPLIFIERS ARE REQUIRED?

What are typical system sizes?

If we start with the number of homes per node in a typical system, we can arrive at estimates for varying system sizes. For our example, we will use a 100,000-home-passed network, but will provide per-home costs that can be extended for larger or smaller systems.

What are typical HFC network architectures?

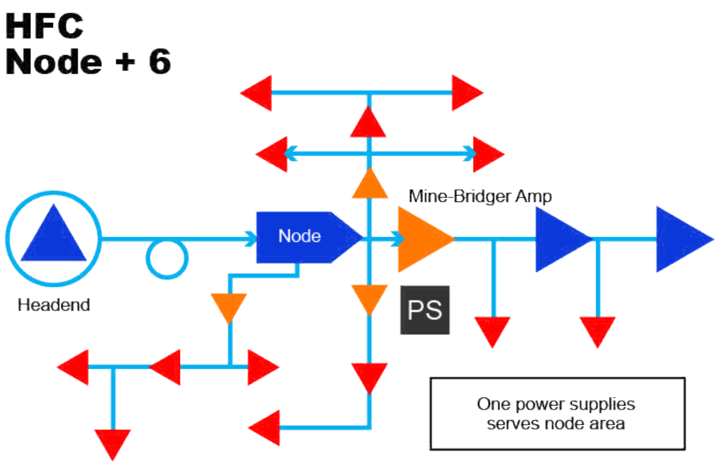
1. Node + 6 System



Note: diagram does not show all described items for clarity

In a conventional node + 6 system (500 homes per node), one node might feed an average of 38 amplifiers. Let us assume that eight of the amplifiers are trunk/bridger units and 30 are line extenders.

2. Node + 3 System



In a more modern node + 3 system (150 homes per node), the number of amplifiers per node will be lower (up to 20), and all would be line extenders or mini-bridgers.

What power does each component consume?

Individually, the consumption of the elements of the HFC network are fairly low.

Power per Unit Assumption	
Item	Power (W)
Node	100
Trunk Amp/Bridger	100
Line Extender/Mini Bridger	40

How many components per system?

By dividing the total homes passed by the design target for number of homes per node, we can determine the approximate number of nodes in the system. We take this number and multiply the power total for a single node to obtain the total system power requirement.

Now we can calculate the power across the system, and adjust for power supply efficiency and estimate the entire power usage. We can then take that number of kilowatts and multiply by the number of hours in a day, and days in a year, to arrive at the kilowatt hours of energy used annually.

We will assume 80% power supply efficiency. That is to say that 20% of the electricity purchased is used for running status monitoring and charging batteries, and wasted in heating the power supply. The rest powers the nodes and amplifiers.

Also included in this chart is the calculation for number of power supplies in the system and number of batteries, discussed below.

100,000- home system						
Item	Quantity per Node		Count per System		Power per System (W)	
	Node + 6	Node + 3	Node + 6	Node + 3	Node + 6	Node + 3
Homes per Node			500	150		
Nodes			200	667	20,000	66,667
Trunk Amps/Bridgers	8	0	1,600	-	160,000	-
MiniBridger/Line Extender	30	20	6,000	15,000	240,000	600,000
Power Supplies	2.5	1	500	667		
Batteries (6 per supply)	15	6	3,000	4,000		
Total Power (kW)					420	667
Total Power at	80%	Efficiency (kW)			525	833
Total Energy at 24 hours * 365 days (kWh)					4,599,000	7,300,000

What does it cost to power a system?

Now that we have a number for the energy usage, it is straightforward multiplication by the price of electricity in order to determine the annual cost.

Annual Cost for 100,000-home system	$/KWh		Node+6		Node+3	
Cost of Electricity at:	$	0.10	$	459,900	$	730,000
	$	0.15	$	689,850	$	1,095,000
	$	0.20	$	919,800	$	1,460,000
	$	0.25	$	1,149,750	$	1,825,000
	$	0.30	$	1,379,700	$	2,190,000
Annual Cost per Home in 100,000-home system	**$/KWh**		**Node+6**		**Node+3**	
Cost of Electricity at:	$	0.10	$	4.60	$	7.30
	$	0.15	$	6.90	$	10.95
	$	0.20	$	9.20	$	14.60
	$	0.25	$	11.50	$	18.25
	$	0.30	$	13.80	$	21.90

In the United States, averaging $0.15 per KWh, powering the HFC plant can cost more than $700,000 each year for a 100,000-home system.

IV. WHAT ARE THE ANNUAL BATTERY MAINTENANCE COSTS?

Battery Count

We made our power calculations based only on node and amplifier consumption. In order calculate the number of batteries, we will need to know the number of power supplies. In the Node + 6 system, we will estimate approximately 2.5 power supplies per node, while for the Node + 3 system, we will assume one. That yields 500 power supplies for Node + 6, and 667 power supplies for Node + 3.

In all cases we are assuming six batteries per power supply. This will allow a run time of at least four hours under typical loads. This may be a regulatory requirement in some areas for provision of voice services.

The total battery requirement assuming six batteries per power supply is as follows:

Node + 6: 500 power supplies, 3,000 batteries

Node + 3: 667 power supplies, 4,000 batteries

Maintenance Cost

We will assume that each battery requires replacement on average every 4 years. With the cost of these batteries at $120 each and with an average labor cost of $500 per operation including truck roll, we are talking about $465,000 to $620,000 per year.

Battery Replacement Years: 4			Node+6	Node+3
		units	750	1,000
	$120	unit cost	$ 90,000	$ 120,000
	$500	unit labor	$ 375,000	$ 500,000
Total			$ 465,000	$ 620,000
Total per home			$ 4.65	$ 6.20

This does not include administrative and overhead costs such as warehousing, disposal, scheduling, etc.

V. TOTAL COST – ELECTRICITY AND BATTERY MAINTENANCE

Adding up the cost of electricity and battery maintenance, the annual cost per home could range from $9.25 to $28.10, depending on the cost of electricity.

Total Annual Cost for 100,000 home system		Node+6	Node+3
Cost of Electricity at:	$ 0.10	$ 924,900	$ 1,350,000
	$ 0.15	$ 1,154,850	$ 1,715,000
	$ 0.20	$ 1,384,800	$ 2,080,000
	$ 0.25	$ 1,614,750	$ 2,445,000
	$ 0.30	$ 1,844,700	$ 2,810,000

Total Annual Cost per Home		Node+6	Node+3
Cost of Electricity at:	$ 0.10	$ 9.25	$ 13.50
	$ 0.15	$ 11.55	$ 17.15
	$ 0.20	$ 13.85	$ 20.80
	$ 0.25	$ 16.15	$ 24.45
	$ 0.30	$ 18.45	$ 28.10

We have not included the cost of maintaining the power supplies themselves, which could add a slight amount to the overall maintenance costs.

VI. COMPARISON OF HFC WITH TRUE PON

With a PON using no field-mounted OLTs, the power and battery cost is zero. So, all of the above can be considered saved expense when comparing PON versus HFC.

VII. REMOTE OLT PON

In a greenfield situation, we can plan to run enough fiber out of each hub or headend to feed all of the PON splitters. However, we are talking about a brownfield HFC network where we would probably want to use available fibers in order to minimize construction. That would require the use of remote OLTs.

Remote OLTs require power, and each conventional cabinet or shelter mounted remote OLT requires substantially more power than an HFC node or amplifier. There are, however, fewer required.

While each remote OLT can feed a number of PONs, even more fiber efficiency can be achieved by layering Dense-Wavelength Division Multiplexing (DWDM) to feed several remote OLTs on a single fiber, using inexpensive colorized pluggable optical modules.

Let's look at two possible architectures for Remote OLT PON.

Centralized – Remote OLT serves 10,000 homes

This approach is more typical of a greenfield architecture adapted to reduce transport fiber counts, or allow for long distances from the headend or central office. Here, the Remote OLT is provided with 48v DC power from a standard telco supply with battery back-up. Eight or more batteries might be required to run on backup for an extended time, or fewer batteries to simply hold the load as a standby generator starts. There would only be up to ten of these sites for our sample 100,000-home system.

We will assume that a single remote OLT site, feeding 10,000 homes, consumes 1,800 watts. In practice, the number of homes in the cabinet service area will vary.

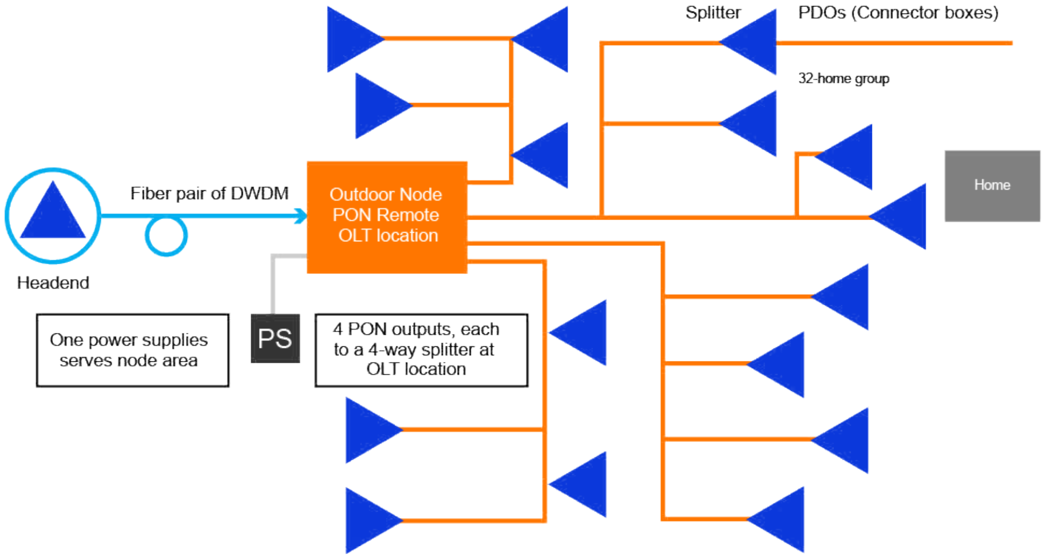
De-centralized – Remote "Node PON" OLT serves 500 homes

This would be the case if we overlay a conventional HFC Node + 6 system with two remote OLTs covering each existing 500-home HFC node location, or with one half of the existing node locations for a Node+3 system serving 125 homes per node. We could use a strand-mount remote "Node PON" OLT fed by a cable power supply or even existing HFC plant power if enough excess power is available. (The power consumption of a typical Node PON OLT is up to about 120 watts.)

Because of the lower load, reducing the battery count could be considered. In order to keep comparisons consistent, we will continue to assume six batteries per power supply. If six batteries power a single Node PON OLT, run time in excess of six hours is likely to be expected.

Though they may have different names, "Node PON" is available from many of the major HFC node and PON manufacturers, and is an integral part of the "Generic Access Platform" under development at SCTE/ISBE.

Node PON



Power required for remote OLT

For our sample 100,000 home system, we will look at 10 Cabinets of Centralized Remote PON, 400 Node PON units at 64 homes per PON, and 200 Node PON units at 128 homes per PON. This is what we can expect for annual electricity cost:

Electricity $/kWh	Cabinet	Node PON 64 homes	Node PON 128 homes
$ 0.10	$ 19,710	$ 65,700	$ 32,850
$ 0.15	$ 29,565	$ 98,550	$ 49,275
$ 0.20	$ 39,420	$ 131,400	$ 65,700
$ 0.25	$ 49,275	$ 164,250	$ 82,125
$ 0.30	$ 59,130	$ 197,100	$ 98,550
	Cost per Home		
$ 0.10	$ 0.20	$ 0.66	$ 0.33
$ 0.15	$ 0.30	$ 0.99	$ 0.49
$ 0.20	$ 0.39	$ 1.31	$ 0.66
$ 0.25	$ 0.49	$ 1.64	$ 0.82
$ 0.30	$ 0.59	$ 1.97	$ 0.99

Battery maintenance

In the case of the cabinet or shelter-based PON, there are only up to 10 sites with which to be concerned. This is a small battery maintenance consideration. We will budget $20K/year for our sample system, or $0.20 per customer.

For the Node PON with conventional four 64 home PONs per unit, or 250 homes per housing, we can estimate battery maintenance as follows:

NodePON Battery Repl. Years			4 years	
	64 Home PON			
	600	units		
	120	unit cost	$	72,000
	500	unit labor	$	300,000
Total			$	372,000
Total per home			$	3.72

And for higher split-ratio deployments leveraging four 128 home PONs per unit, or 500 homes per housing:

128 Home PON				
	300	units		
	120	unit cost	$	36,000
	500	unit labor	$	150,000
Total			$	186,000
Total per home			$	1.86

VIII. COMPARISION OF HFC WITH CABINET REMOTE OLT AND NODE PON

Cabinet Remote OLTs use very little power – pennies a year on a per-subscriber basis even when battery maintenance costs are included.

We add the battery maintenance assumption to the cost of electricity, and for the 10,000-home cabinet we can save almost all of the power cost versus HFC:

This is the total annual cost per home:

Electricity		HFC Node + 6		Cabinet		Savings versus HFC
$	0.10	$	9.25	$	0.40	96%
$	0.15	$	11.55	$	0.50	96%
$	0.20	$	13.85	$	0.59	96%
$	0.25	$	16.15	$	0.69	96%
$	0.30	$	18.45	$	0.79	96%

For 64 home per PON Node PON, adding the battery maintenance to the annual electricity cost works out to $4.05 to $4.71 per home per year, as compared to $9.25 to $18.45 per home per year for HFC Node + 6. That is quite a difference! Although not shown in the table, comparison with HFC Node + 3 produces an even greater difference.

The table also shows what savings a 128 home per PON Node PON could produce.

Total annual cost per home:

Electricity		HFC Node+6		NodePON		Savings versus HFC	NodePON		Savings versus HFC
$/kWh				64 Home PON			128 Home PON		
$	0.10	$	9.25	$	4.05	56%	$	2.52	73%
$	0.15	$	11.55	$	4.21	64%	$	2.85	75%
$	0.20	$	13.85	$	4.38	68%	$	3.17	77%
$	0.25	$	16.15	$	4.54	72%	$	3.50	78%
$	0.30	$	18.45	$	4.71	74%	$	3.83	79%

IX. SUMMARY AND CONCLUSION

Anecdotally, we've heard blended operators (those who run both coax and fiber networks) express the sentiment that a fiber-based PON network costs one-tenth as much as their HFC networks to operate. This cost study validates that and provides specific documentation other operators can use as they build out their network planning business cases. Even with the ROLT deployment model, the operator can expect to save anywhere from 60% to upwards of 80% annually on power costs versus HFC networks.

Broadband Service Providers who operate in countries with high electricity costs would experience ever greater annual cost savings by migrating to a fiber-based PON network.

The dramatic savings in operating expense is a factor behind why operators are aggressively choosing to deploy FTTH PON networks, often with 10G XGS-PON. As operators look to build greenfield network in new markets or communities, or look to blended networks to help facilitate their eventual migration from HFC to fiber, power savings are a material factor driving their decision to deploy fiber-based PON architectures.