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# Tutorial: Green Perspectives of Fiber-to-the-Home; Ecology of Scale and Economy of Scale Join Forces

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This tutorial describes important green aspects of fiber to the home (FTTH) deployments. This research provides an extended framework for analysis of the implications of FTTH deployments — both for strategic planners in carrier and technology providers organizations, as well as government employees involved in telecom regulation.

## Key Findings

- Even with relatively conservative traffic forecasts, it is clear that carriers need to significantly lower the energy spent per consumed bit.
- FTTH offers a unique "ecology of scale" as demand for network capacity continues to rise: Above a certain bandwidth threshold, no other existing technology can compete with FTTH on environmental terms.
- FTTH ecology of scale goes hand-in-hand with network economy of scale: Above a certain bandwidth threshold, no other existing access technology can cost-effectively compete with FTTH.
- Regulatory frameworks can be constructed to accommodate the expected growth in network traffic in an environmentally acceptable fashion while also stimulating competition in the broadband market. Specific proposals already exist which can accommodate these requirements and regulators should expect increasing political focus on this issue.

## Recommendations

- Regulatory frameworks should encourage solutions that in the long run can accommodate the expected growth in network traffic in an environmentally acceptable fashion, while also stimulating competition in the broadband market.
- Carriers should evaluate business models and network architectures in the light of possible regulatory scenarios, including the scenario outlined in the previous bullet point. Technology providers must ensure that they stay on top of changes in carriers' requirements and adapt their product portfolio and marketing accordingly.
- Carriers that decide to deploy FTTH should ensure that they market the green aspects of this technology, both to end-users and policymakers.

## WHAT YOU NEED TO KNOW

FTTH has unique ecology of scale characteristics that adds to unique economy of scale characteristics. Increasing political focus on environmental issues, as well as continued focus on the importance of development of broadband infrastructure increase the likelihood of political buy-in to FTTH-friendly regulation. Carriers and technology providers should start to analyze scenarios for the likely impact on business models and network architectures.

## ANALYSIS

# Context

Telecom networks will come to represent an increasing proportion of societies overall energy consumption, as the demand for increasing bandwidth is expected to continue. Therefore, as networks need to handle ever increasing traffic volumes, and the demand for green solutions become the norm rather than the exception, the need for political visions that spans decades rather than a single election period will grow.

# Analysis

## Green Aspects of FTTH — Carrier Perspective vs. Society Angle

Roughly speaking, there are two different angles on the environmental impact from FTTH deployments:

- *Narrow Internal View:* This is defined as the energy consumption of the network itself, including consumption related to the installation and maintenance of the network.
- *Broad External View:* This is defined as the net total effect a FTTH deployment will have on a society. If, for instance, the higher bandwidth of FTTH networks leads to increased telesubstitution (substitution of traditional consumer goods with telecom services), the green impact from this increased telesubstitution will be part of the Broad External View. An example would be increase in video conferences as a substitute for business travel.

Carriers will, at least from an economic standpoint, mainly be concerned with the consumption efficiency of the Narrow Internal View. Policymakers and regulators, on the other hand, should consider both the Narrow Internal View and the Broad External View when evaluating national broadband strategies and associated regulations. In particular, policymakers typically have longer term perspectives on broadband evolution and green initiatives than the business requirements allows carriers to take. It is therefore imperative that regulatory initiatives recognize the different perspectives and shape regulatory frameworks so that the Narrow Internal View of carriers gets aligned with the Broad External View of policymakers.

Note that in this report the differences between various passive optical network (PON) technologies (BPON, EPON, GPON) and point-to-point (PTP) solutions are not treated in detail, so the term FTTH is used without specific reference to any of these technology variants.

## Moore's Law and the Laws of Physics Call for Fundamental Change

Moore's Law states that the performance of an integrated semiconductor circuit at a certain cost point doubles every 18 months. This remarkable example of the "learning curve" effect is at the core of the global progression toward the information age. There are even examples from optical transport networks where traffic growth at least in some periods have outpaced Moore's Law —

as expressed by Gilder's Law ("Bandwidth grows at least three times faster than computer power").

Broadband access is needed to reap the full benefits of the emerging information society, but its development has not matched the progress described by Moore's Law. The limited bandwidth of established transport media (such as copper cables, coaxial cables and microwaves) and the high cost of installing higher-bandwidth transport media (single-mode optical fibers) have been the main inhibitors of ubiquitous deployment of bandwidth-agile broadband access. Without infrastructure limitations, broadband access equipment could easily follow a performance vs. cost curve similar to Moore's Law.

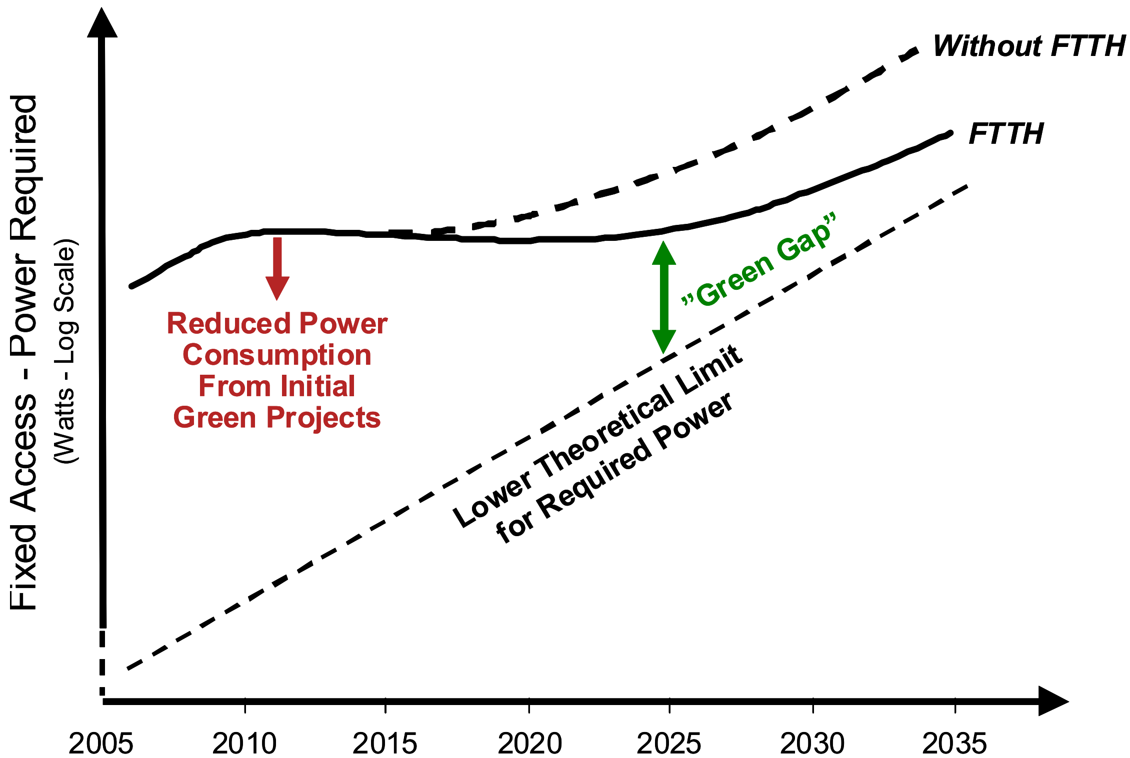
FTTH offers bandwidth scalability that can match Moore's Law, but FTTH business cases are very sensitive to regulatory conditions. This economy of scale aspect of FTTH is described in detail in "Governments Can Bring Moore's Law to Broadband Access (February 2006 Update)." This note also discusses sharing of physical infrastructure by several network service providers, which can further enhance the economy of scale aspect of FTTH and also have positive environmental implications.

However, an important implication derived by combining the laws of physics and information theory is that there is a lower theoretical limit for the amount of energy required to transmit one bit of information between two arbitrary points A and B. Extending this finding to the real-life situation of billions of subscribers and multiple networks with increasingly sophisticated feature sets, it is clear that for any given communication scenario (number of users, user locations, number of networks, services in use, usage patterns, functions enabled and so on) there is a theoretical lower limit for the power required to run the networks supporting this scenario.

Today's networks are far away from this lower limit, and therefore there is plenty of room to make networks more green, and it may even be possible to lower the overall power consumption by replacing power hungry equipment by new and greener solutions.

However, as traffic increases over time, the number of bits that need to be transported increase, and therefore the lower theoretical limit for the required power also increases over time. In the long run, the actual power requirements will increase as continued traffic growth is expected, despite efforts to find ever greener implementations. The long-term objective should therefore be to — in a scalable fashion — lower the "green gap" between the lower theoretical limit for the required power and the power that is needed in practice — as illustrated in Figure 1.

**Figure 1. Illustration of the Long-Term Objective of Reducing the "Green Gap" Between Theoretical and Actual Power Consumption.**




Note: This figure is meant as an illustration only, it is not driven by real data.

**Source: Gartner (December 2008)**

The implication from Figure 1 is that while reduced power from initial green projects is important in the short term, the long term imperative for governments and regulators is to establish regulatory frameworks and incentives that help and encourage carriers to implement network solutions that will lower the "green gap" between theoretical and actual power consumption while allowing network capacity to scale.

Figure 1 may wrongly be interpreted to suggest that broadband evolution is at odds with environmental requirements. However, this is only true within the Narrow Internal View discussed in the previous section. As telesubstitution is expected to continue as bandwidth increases, an evaluation of the green impact of the broadband evolution should also embrace the Broad External View.

## Ecology of Scale in FTTH networks

The low-loss nature of optical fibers gives FTTH networks an "ecology of scale" advantage over alternative solutions. Three factors contribute to this advantage:

- The low loss in the fibers means that relatively small amounts of energy is wasted while the bits are transported. To illustrate the low loss nature of optical fibers, consider a small boat at sea by the Marianas Trench. If sea water had the same transparency in the visible spectrum as standard single-mode optical fibers have in the part of the infrared spectrum that is used in fiber optics, it would be possible to see straight to the bottom of the Marianas Trench from the boat on the surface.

- A consequence of the low loss of optical fibers is that the distance between the end user and the first active network node can be increased significantly compared to existing solutions. This has a significant impact on the number of active node elements, as the number of active nodes are roughly proportional to the inverse square of the distance between the end user and the first active node. As an example, consider a situation where the distance between the end user and the first active node increases by a factor of five — this would reduce the number of active nodes by a factor of 25. The benefits of having fewer active nodes includes savings on supplying the nodes with power as well as operational savings, and maintenance efforts typically scales in proportion to the number of active nodes in the network.
- Single-mode optical fibers have a wide low-loss spectral window of operation. It is in principle possible to handle more than 1 Tb/s of data, even over extended distances as seen in transport applications. This means that as more capacity is needed in a fiber network, the power efficiency (or energy required per transported bit) does not deteriorate. In contrast, when capacity needs to be increased over other types of infrastructure (for example, copper wires or wireless), trade-offs related to the capacity constraints of the transmission medium results in the active nodes getting closer to the end-user. As a result, when more capacity is added to network based on these types of infrastructures, the power efficiency is reduced as the average energy consumption per bit increases. This may not be significant when thinking about the next upgrade, but when viewed in the context of multiple upgrade cycles this could become a decisive factor.

However, it is important not to ignore the issue of installing a FTTH network, which of course comes at an environmental cost — both considering materials used and energy spent in the process. In fact, the "green case" of FTTH is quite similar to the business case of FTTH: the investment needs to be considered from a long-term perspective, to recoup the initial spending — but when evaluated from a long-term perspective, FTTH compares favorable to alternative infrastructures in particular with respect to the ecology of scale which increases in importance as network traffic continues to grow.

## Vision: Ultra-High Bandwidth and Competitive Broadband Market Based on Green Networks

The significance of broadband networks as part of a nation's infrastructure will continue to increase, and environmental issues are unlikely to fade from the political agenda anytime soon. Telecom networks will come to represent an increasing proportion of societies overall energy consumption, as demand for increasing bandwidth is expected to continue. Therefore, as networks need to handle ever increasing traffic volumes, and the demand for green solutions become the norm rather than the exception, the need for political visions that span decades rather than a single election period will grow.

As described above, it is possible to create regulatory frameworks that — in a competitive environment — will pave the way for ultra-high bandwidth green fiber optical access networks, with bandwidth scalability and ecology of scale that will last for decades. By appropriate planning it is even possible to use such networks to solve the increasingly important backhaul bottleneck of mobile networks, as these networks migrate via third generation (3G) rollouts toward Long Term Evolution (LTE), thus sustaining ever increasing mobile bandwidth. And it is based on proven technology that already are used commercially in today's telecom market.

In reality, the interplay between regulatory frameworks, carriers business models and network technologies and architectures is quite complex. It is unlikely that there will be a "one size fits all" solution for the exact implementation of forward looking regulatory frameworks, and different countries and regions should be expected to move at different times and at different speeds. Faced with all these caveats, it is important to emphasize the bottom line of the above analysis: FTTH networks have — thanks to the unique physical properties of optical fibers — two unique attributes that over time will gain increasing importance:

- **FTTH economy of scale:** Above a certain bandwidth threshold, no other existing technology can cost-effectively compete with FTTH. Nor are there any technologies on the horizon that will change this picture, as the economy of scale attribute of FTTH networks is derived from the unique physical properties of optical fibers.
- **FTTH ecology of scale:** Above a certain bandwidth threshold, no other existing technology can compete with FTTH on environmental terms. Nor are there any technologies on the horizon that will change this picture, as the ecology of scale attribute of FTTH networks is derived from the unique physical properties of optical fibers.

The bandwidth thresholds will vary between networks, but they will be located at the bandwidths where existing infrastructures start to struggle with bandwidth upgrades.

Carriers should take these properties of FTTH networks into account when updating their network strategies, and technology providers should anticipate that carriers — when faced with appropriate regulatory frameworks — over time will become increasingly tempted to invest in FTTH networks, despite of the capital expenditure-intensive nature of these networks. Technology providers should look beyond the technology and architecture implications and also try to understand the business models that are likely to evolve as carriers migrate toward ultra-high bandwidth green fiber optical access networks.

## Key Facts

- FTTH offers unique economy of scale: Above a certain bandwidth threshold, no other existing technology can cost-effectively compete with FTTH.
- FTTH offers unique ecology of scale: Above a certain bandwidth threshold, no other existing technology can compete with FTTH on environmental terms.
- It is possible to create regulatory frameworks that stimulate a competitive, state-of-the-art broadband market while taking long-term environmental concerns into account.

### RECOMMENDED READING

"Magic Quadrant for Fiber-to-the-Home Equipment"

"Governments Can Bring Moore's Law to Broadband Access (February 2006 Update)"

"A Business Model for Next-Generation Broadband Access (February 2006 Update)"

"Choose the Right Topology for Your Fiber-to-the-Home Network"

"Funding FTTx and Expanding Your Marketplace"

"Why Governments Should Care About Fiber-to-the-Home"

"'Green' IT: Cut Your Travel Costs and Carbon Footprint With Web Conferencing"

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