Energy consumption strategies for optical network

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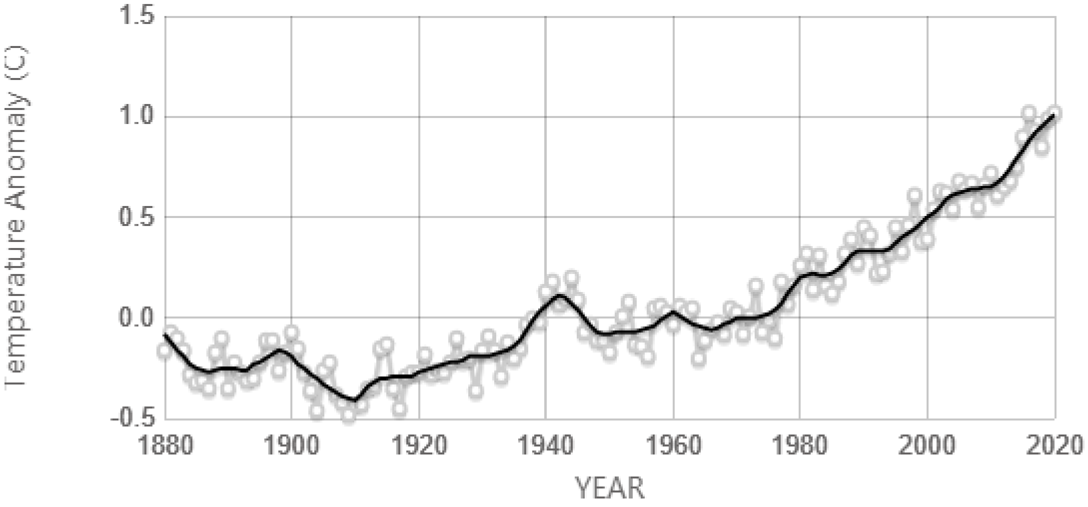
Outline

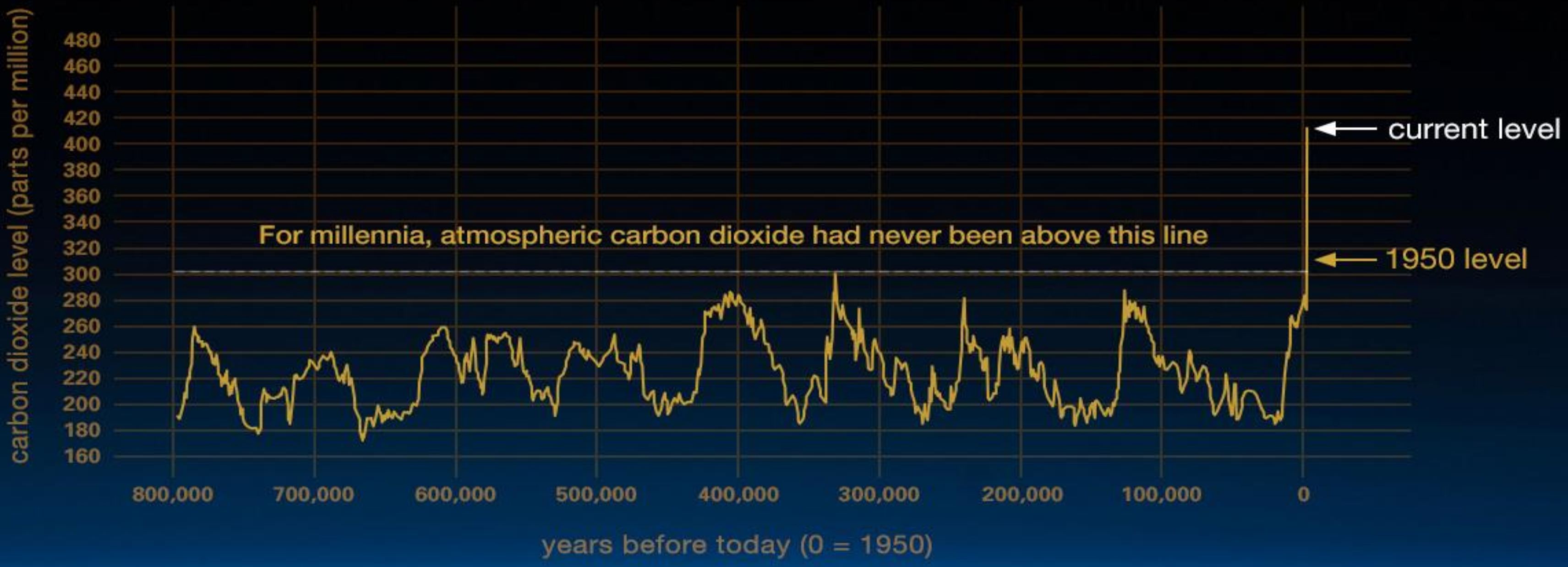
- Energy Problem
- Energy Consumption in Optical Networks
- Data Center Energy Strategy
- Energy Efficiency in Core, Metro and Access Networks

Climate Change

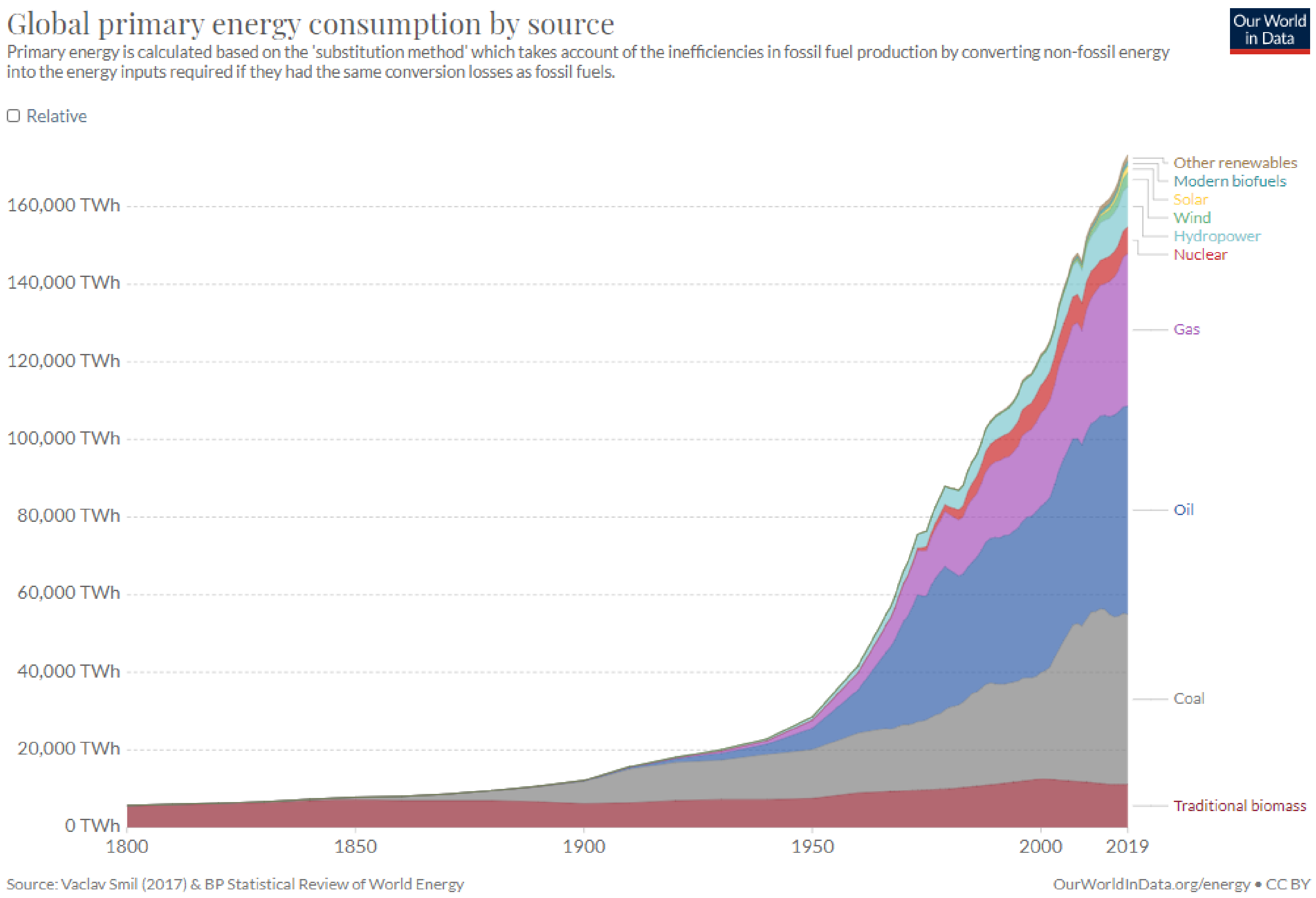
- Average global temperature is up 2.1 degrees F (1.2 degrees C) since 1880.
- The minimum expanse of Arctic summer sea ice has declined 13.1% per decade since satellite measurements began, in 1979.
- Land ice has declined at the poles by 428 gigatons a year since 2002.
- Global sea level has risen 7 inches (178 millimeters) in the past century.
- **Carbon dioxide levels in the atmosphere are 415ppm in 2020, their highest levels in 800,000 years.**



Source: climate.nasa.gov

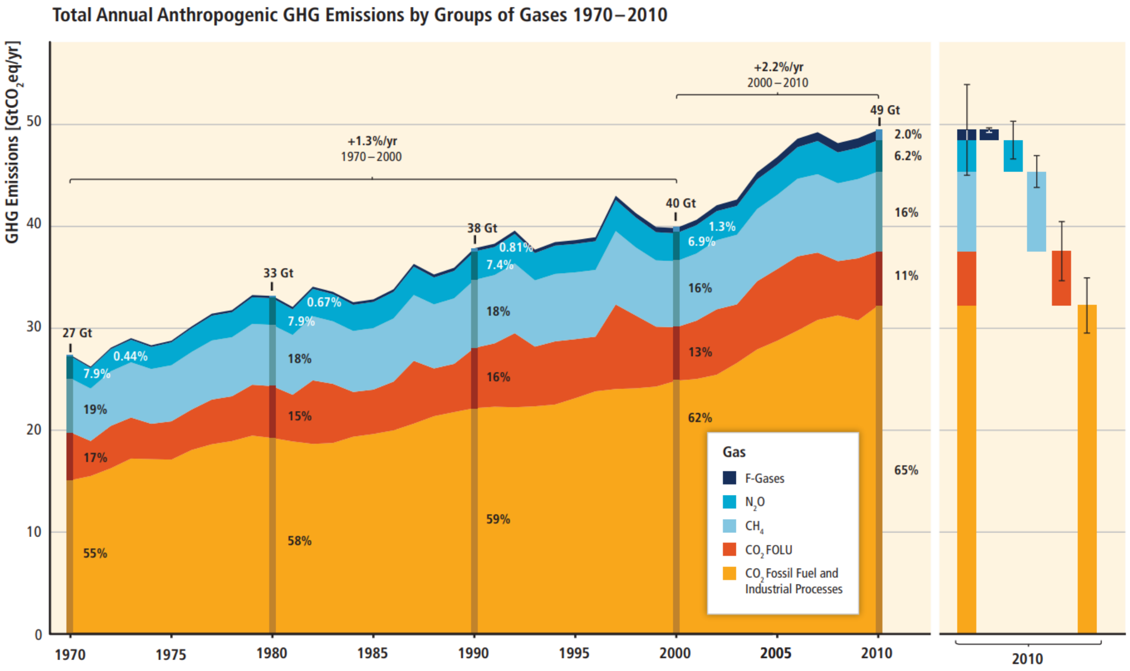


climate.nasa.gov



Global primary energy consumption by source
Primary energy is calculated based on the 'substitution method' which takes account of the inefficiencies in fossil fuel production by converting non-fossil energy into the energy inputs required if they had the same conversion losses as fossil fuels.
Our World in Data
Relative
160,000 TWh
140,000 TWh
120,000 TWh
100,000 TWh
80,000 TWh
60,000 TWh
40,000 TWh
20,000 TWh
0 TWh
1800
1850
1900
1950
2000
2019
Other renewables
Modern biofuels
Solar
Wind
Hydropower
Nuclear
Gas
Oil
Coal
Traditional biomass
Source: Vaclav Smil (2017) & BP Statistical Review of World Energy
OurWorldInData.org/energy • CC BY

GreenHouse Gases Emissions



source:IPCC, 2014: Summary for Policymakers

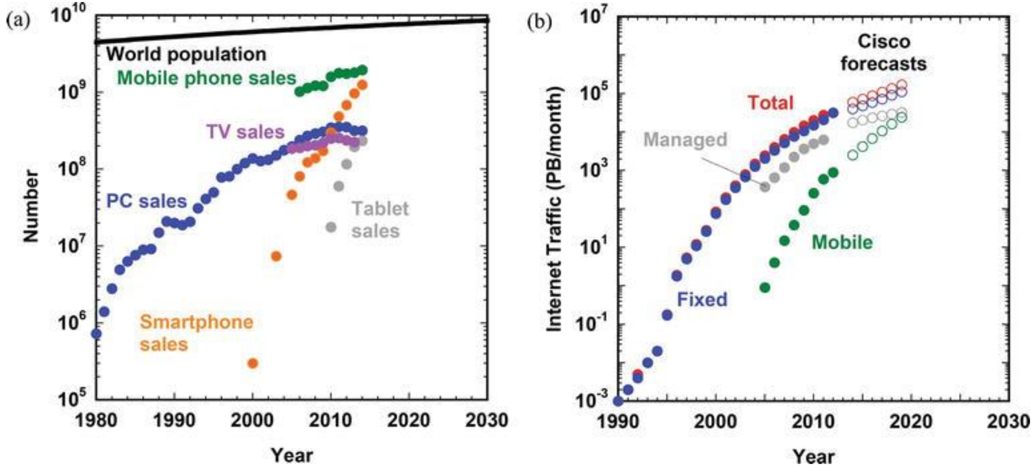
Globally, economic and population growth continue to be the most important drivers of increases in CO_2 emissions from fossil fuel combustion. The contribution of population growth between 2000 and 2010 remained roughly identical to the previous three decades, while the contribution of economic growth has risen sharply.

Energy problem with ICT

Standard PCs and TVs to be static or decrease

Smartphones and Tablets to grow significantly

Data transmitted by the Internet and communication networks increase



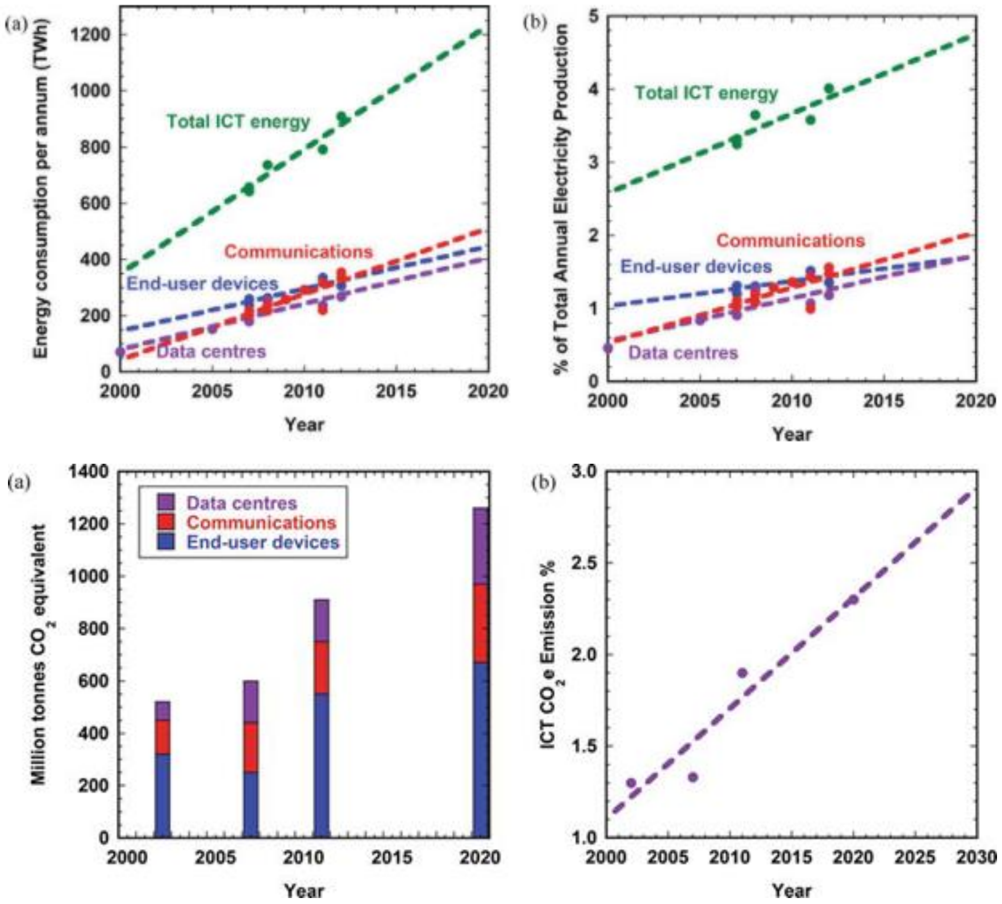
source:Giorgos Fagas et al., 2017: Energy Challenges for ICT

Energy problem with ICT

ICT energy consumption increases

4% of the electricity generated worldwide consumed by ICT devices

1 billion tons CO_2 equivalent, about 2.3% of the global emission of CO_2



source:Giorgos Fagas et al., 2017: Energy Challenges for ICT

ENERGY CONSUMPTION RATE IN OPTICAL NETWORK

CORE NETWORK

DATA CAPACITY:
92Tbps

ENERGY CONSUMPTION:
1020kW

CORE ROUTER

DATA CAPACITY:
1.2Tbps

ENERGY CONSUMPTION:
2.5kW

OPTOELECTRONIC SWITCH

Image courtesy: cisco.com

ENERGY CONSUMPTION RATE IN OPTICAL NETWORK

CORE NETWORK...*cont'd*

DATA CAPACITY:
4.25Gbps

ENERGY CONSUMPTION:
228W

OPTICAL CROSS-CONNECT

Image courtesy: pressebox.de

DATA CAPACITY:
3.2Tbps

ENERGY CONSUMPTION:
10.8kW

WDM TRANSPORT SYSTEM

Image courtesy: halfinn.com

ENERGY CONSUMPTION RATE IN OPTICAL NETWORK

CORE NETWORK...*cont'd*

DATA CAPACITY:
40Gbps

ENERGY CONSUMPTION:
73W

WDM TRANSPONDER

Image courtesy: cisco.com

DATA CAPACITY:
N/A

ENERGY CONSUMPTION:
8W

EDFA AMPLIFIER

Image courtesy: cisco.com

ENERGY CONSUMPTION RATE IN OPTICAL NETWORK

METRO NETWORK

DATA CAPACITY:
160Gbps

ENERGY CONSUMPTION:
4.21kW

EDGE ROUTER

Image courtesy: cisco.com

DATA CAPACITY:
95Gbps

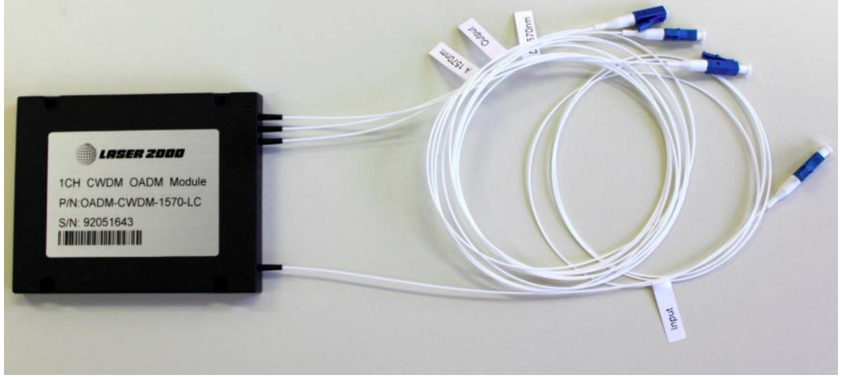
ENERGY CONSUMPTION:
1.2kW

SONET ADM

Image courtesy: cisco.com

ENERGY CONSUMPTION RATE IN OPTICAL NETWORK

METRO NETWORK...*cont'd*



DATA CAPACITY:
N/A

ENERGY CONSUMPTION:
450W

OADM

Image courtesy: wikipedia.com

DATA CAPACITY:
8Gbps

ENERGY CONSUMPTION:
1.1kW

NETWORK GATEWAY

Image courtesy: itechdiscount.com

ENERGY CONSUMPTION RATE IN OPTICAL NETWORK

METRO NETWORK...*cont'd*

ETHERNET SWITCH

DATA CAPACITY:
72-Gbps

ENERGY CONSUMPTION:
3.21kW

Image courtesy: cisco.com

ENERGY CONSUMPTION RATE IN OPTICAL NETWORK

ACCESS NETWORK

DATA CAPACITY:
1Gbps

ENERGY CONSUMPTION:
100W

OLT

DATA CAPACITY:
1Gbps

ENERGY CONSUMPTION:
5W

ONU

Image courtesy: wikipedia.com

Image courtesy: itechdiscount.com

ENERGY CONSUMPTION RATE IN OPTICAL NETWORK SUMMARY

TYPICAL ENERGY CONSUMPTION DATA OF DIFFERENT COMPONENTS IN TELECOM NETWORKS.

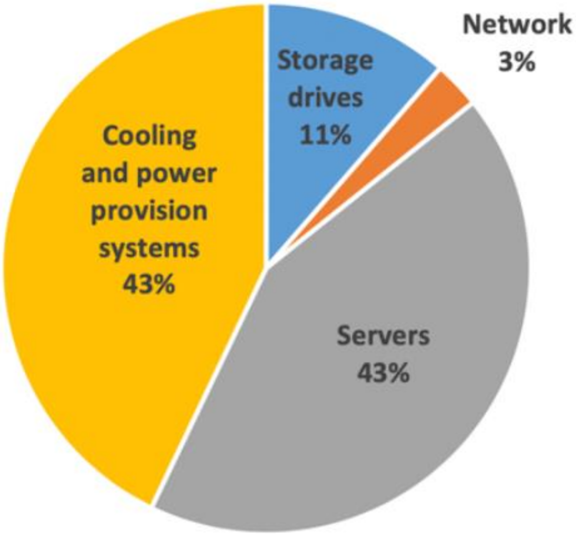
Network Domain	Component	Capacity	Energy Consumption
Core Network	Core Router (Cisco CRS-1 Multi-shelf System)	92 Tbps	1020 kW [26]
	Optoelectronic Switch (Alcatel-Lucent 1675 Lambda Unite MultiService Switch)	1.2 Tbps	2.5 kW [27]
	Optical Cross-Connect (MRV Optical Cross-Connect)	N/A	228 W [28]
	WDM Transport System (Ciena CoreStream Agility Optical Transport System)	3.2 Tbps	10.8 kW [24]
	WDM transponder (Alcatel-Lucent WaveStar OLS WDM Transponder)	40 Gbps	73 W [29]
	EDFA (Cisco ONS 15501 EDFA)	N/A	8 W [29]
Metro Network	Edge Router (Cisco 12816 Edge Router)	160 Gbps	4.21 kW [30], [31]
	SONET ADM (Ciena CN 3600 Intelligent Optical Multiservice Switch)	95 Gbps	1.2 kW [32]
	OADM (Ciena Select OADM)	N/A	450 W [33]
	Network Gateway (Cisco 10008 Router)	8 Gbps	1.1 kW [31]
	Ethernet Switch (Cisco Catalyst 6513 Switch)	720 Gbps	3.21 kW [26], [31]
Access Network	OLT (NEC CM7700S OLT)	1 Gbps	100 W [34]
	ONU (Wave7 ONT-E1000i ONU)	1 Gbps	5 W [34]

Data Center energy strategy

What is the role of the data center in networks?

Data Center: “Brain” of the internet
compute, process, store, and disseminate data

The Concept of Digital Brain: Abstraction of Functional Artificial Intelligence in the Data Center.
Shehabi 2016.



The key components: routers, switches, firewalls, storage systems, servers, and application-delivery controllers.

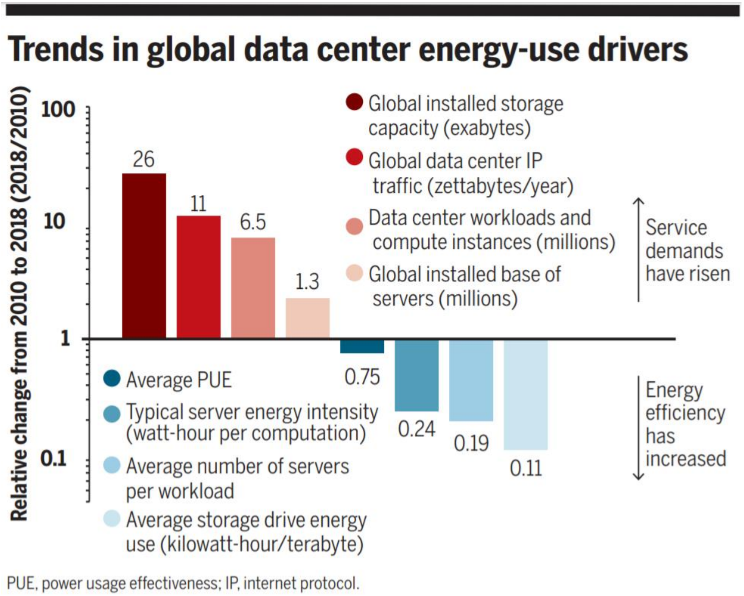
All of the components are electrically powered.

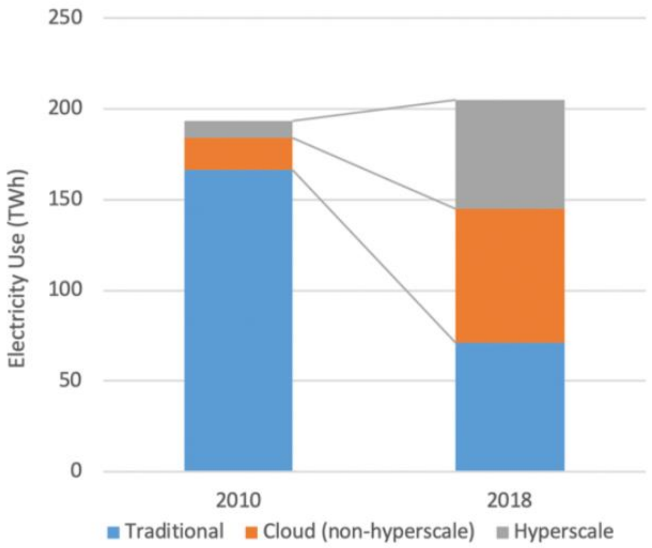
Cooling them also needs electricity.

100 WM = 80,000 U.S. households

Data Center energy strategy

Global Data centers consume how much energy every year?





2010 to 2018:

Global storage capacity increased 26 times
Global data center traffic increased 11 times
Global data center workloads and compute instances increased 6.5 times

How?

2010 to 2018:

Energy consumption only increased by 6%

Masanet et al., recalibrating global data center energy-use estimates, 2020.

Data Center energy strategy

Approches to reduce DC energy consumption

Information technology infrastructure

- Server virtualization(In 2011, virtual server : physical server = 6.3:1)
- Decommissioning inactive servers(8%-10% servers run with no use)
- Better Management of Data Storage(Data Compression, Deduplication)

Airflow management

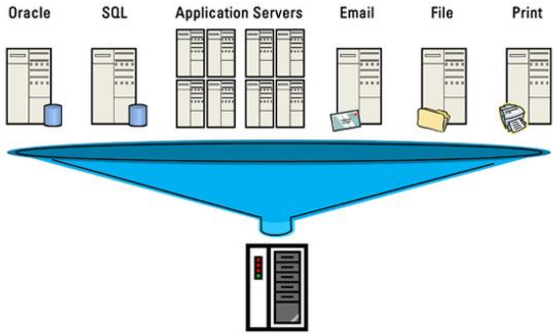
- The fronts of the servers face each other. The backs of the server racks should also face each other.
- Use flexible strip curtains to minimize mixing of cold ("supply") air and hot exhaust air

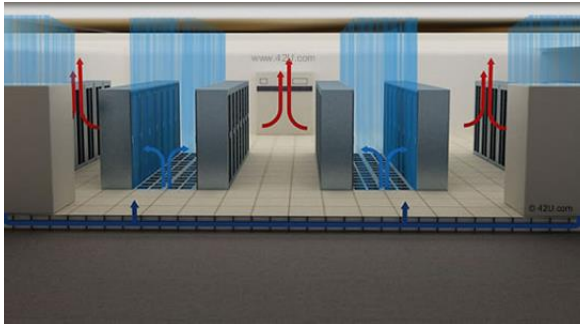
Managing air conditioning

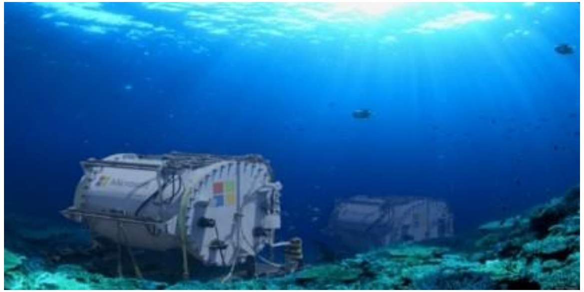
- ASHRAE increased the recommended temperature and humidity range(1℃ increase can bring 4% cooling cost saving)
- Google deepmind AI reduce the amount of energy used for cooling by up to 40%

Using natural climate

- Google's DC in Hamina, Finland
- Microsoft's DC on the sea floor near Scotland's Orkney Islands







https://www.energystar.gov/products/low_carbon_it_campaign/12_ways_save_energy_data_center
https://blog.cloudware.bg/en/did-microsoft-go-crazy-sinking-their-data-centers-undersea/

Data Center energy strategy

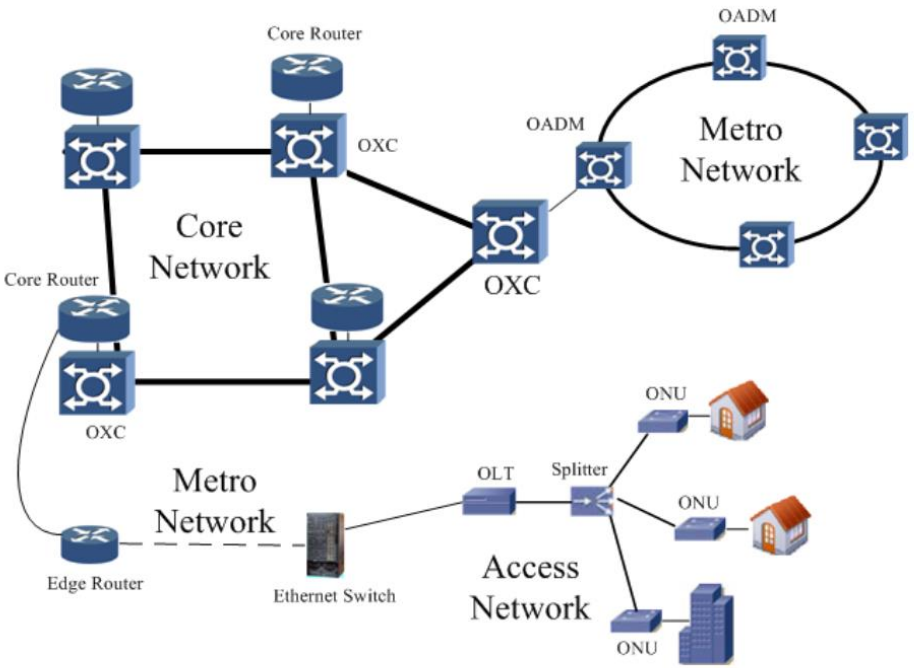
How can the heat generated by DC be reused?

- Excess heat can be used to heat nearby swimming pools during the winter. This may seem like a logical solution.
- Ducts running out of the heat exhaust systems can be directed into nearby buildings, thus providing them with heat when colder temperatures prevail. The heat supplied can be controlled through the use of pneumatic baffles.
- Telecity, a data center in Paris uses waste heat to provide heat to an on-site Climate Change Arboretum, where the effects of future climate change are studied.
- The Notre Dame Center for Research Computing uses the heat to maintain warm temperatures at a local municipal greenhouse.

https://www.datacenterknowledge.com/sites/datacenterknowledge.com/files/wp-content/uploads/2010/02/Telecity-Paris.jpg

Energy Efficiency In Core,Metro and Access Networks

[a]



Addressing the Energy Consumption Problem

[b]

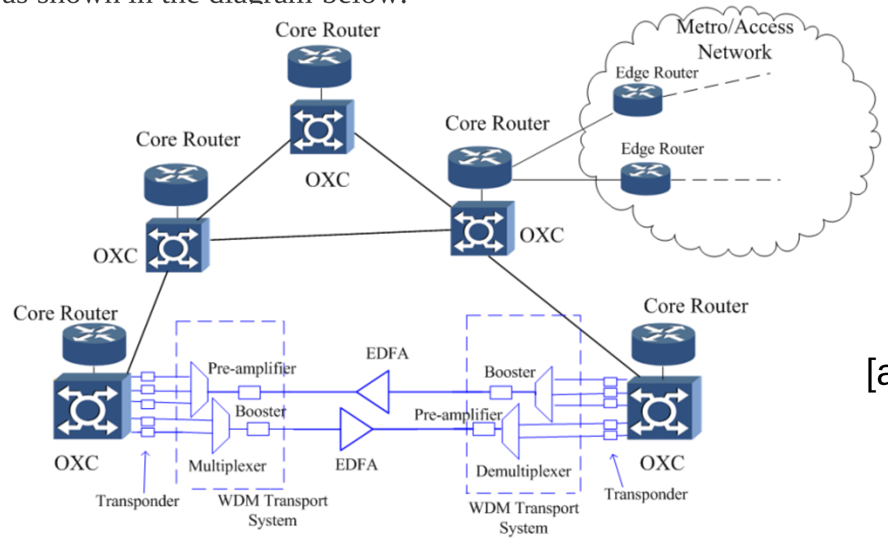
Generally two directions are being taken to address this problem:

1. Use of Renewable energy
   renewable energy is being harnessed to replace traditional hydrocarbon energy. This not only gives the opportunity to reduce the carbon footprint, but also it paves the road towards a sustainable and environment-friendly societal development . this involves the use of solar panels , wind turbines etc to power network components.

1. Smart schemes to reduce the energy consumption of components

Core Network

As core networks exhibit multilayer network architectures, energy consumption of the core network should be considered at both of the network layers, i.e., the optical layer and the electronic layer. Considering IP over WDM, energy consumption of its network components can be found in the switching (routing) level and also in the transmission level. In the switching (routing) level, the main energy consumers are Digital Cross-Connects (DXC) and IP routers for switching electric signals at the electronic layer, while Optical Cross-Connects (OXC) are used to switch optical signals in fibers at the optical layer. In the transmission systems, WDM is a technology which multiplexes multiple optical carrier signals on a single optical fiber by using different wavelengths of laser light to carry different signals. this consumes energy . EDFA’s are also involved as shown in the diagram below.



[a]

Efficient Energy Use In The Core Network

Selectively Turning Off Network Elements
This approach involves shutting down links and nodes when they are idle or the traffic passing through them is below a certain threshold value. Also a certain percentage of nodes can be shut down during less busy hours of the network (eg in the night).

Energy efficient network Design
lightpath non-bypass and bypass. Under lightpath non-bypass, all the lightpaths incident to a node must be terminated, i.e., all the data carried by the lightpaths is processed and forwarded by IP routers. But the lightpath bypass approach allows IP traffic, whose destination is not the intermediate node, to directly bypass the intermediate router via a cut-through lightpath. Results show that lightpath bypass can save more energy than non-bypass. This approach endeavours to keep the network as transparent as possible as OEO conversions consume energy.

Energy Aware Routing
In the presence of multiple routes, the energy consumed by each route is taken into account and thus the route with the smallest consumption is chosen. Taking into account parameters like link length (number of amplifiers), modulation and number of hops.

Metro Network

There is limited research on energy conservation in metro networks mostly because it accounts for a small percentage of the total energy consumption in the network. Three architectures for a unidirectional WDM ring network,can be considered i.e., FG (First Generation) optical network, SH (Single-Hop) network, and MH (Multi-Hop) network. In a FG optical network, every node must electronically process all the incoming and outgoing traffic, including the in-transit traffic. In a SH optical network, every node electronically processes only the traffic that goes into or out of the network at that node. A MH network lies somewhere between the FG and SH networks. SH has the least energy consumption. This is similar to the lightpath bypass and non pass case in talked about in the core network.

Access Network

Adoption of passive optical networking
The absence of active elements within the link means less energy consumption. This is energy efficient and reduces the absolute total energy consumed.

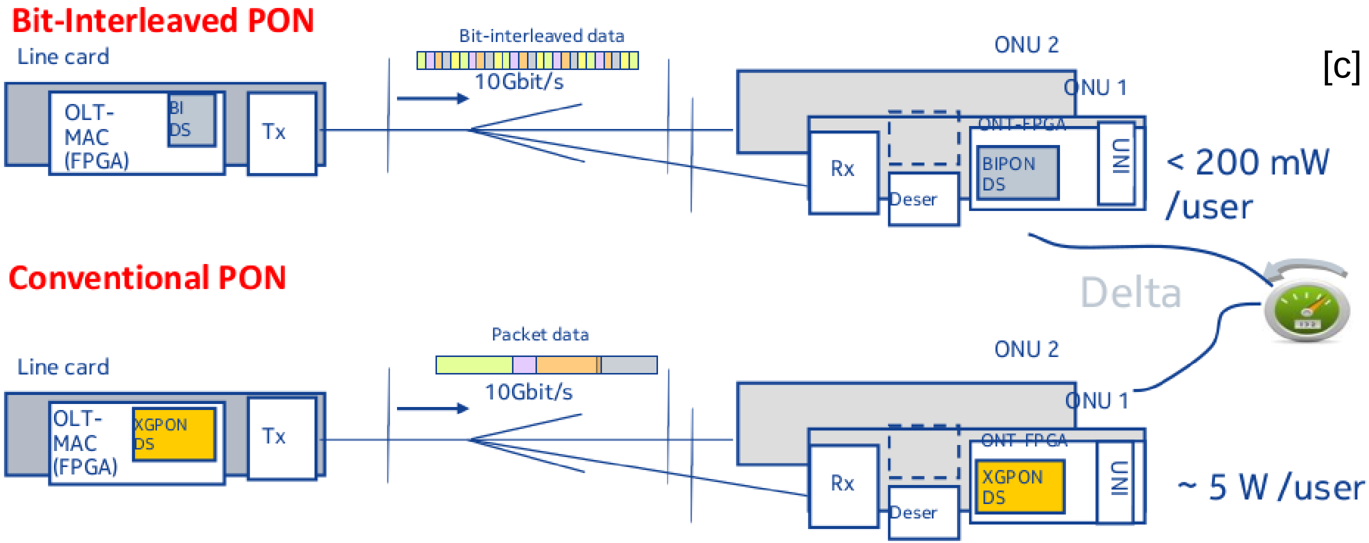
ONT sleep mode scheduling
The ONT goes into sleep mode after being active for a certain period of time to reduce power consumption and also the avoid the near far effect (where near ONUs with stronger transmissions produce noisy signals when not transmitting thereby crowding the weaker signals from farther ONUs). To put some perspective on energy gain:

Active ONU power consumption : 10.5W

ONU sleep mode power consumption : 0.8W

Bit Interleaved PON

Interleaving the bits imply that at the ONU, the sampling scheme used involves a lower rate . say we have 10gbps downlink rate with bit interleaving, this meaning each ONU receiver would be sampling at the rate of 1gbps which leads to a smaller energy consumption (5W to <200mW) compared to the conventional packet interleaving used today.



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[b]https://www.istockphoto.com/fr/photo/image-of-the-renewable-energy-gm586163548-100594001

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