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System and Network Engineering

Sustainable e-Infrastructures

A short introdcution to my most recent resaerch.

Dr. Paola Grosso

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At the start of this workshop…

Who said this?

People
Energy
People
Expectations
People
Costs
People

You should think of clouds in terms of power not data size…

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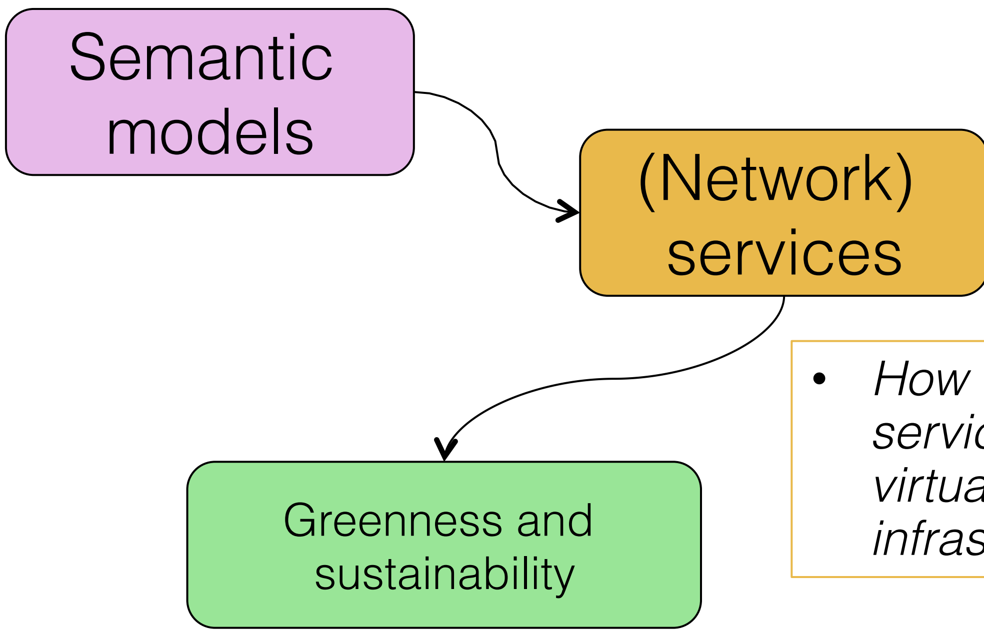
My research

- *How can we represent complex e-Infrastructure?*



- *How can compose end-to-end services that fully exploit virtualized programmable infrastructures?`*

- *Can we use networks to provide support for application that run in a more sustainable manner?*

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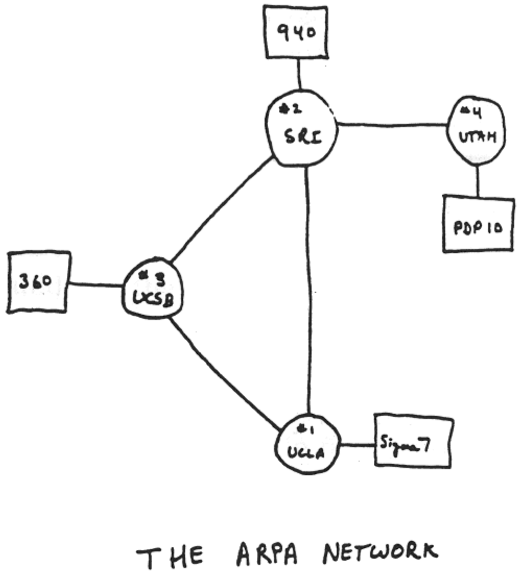
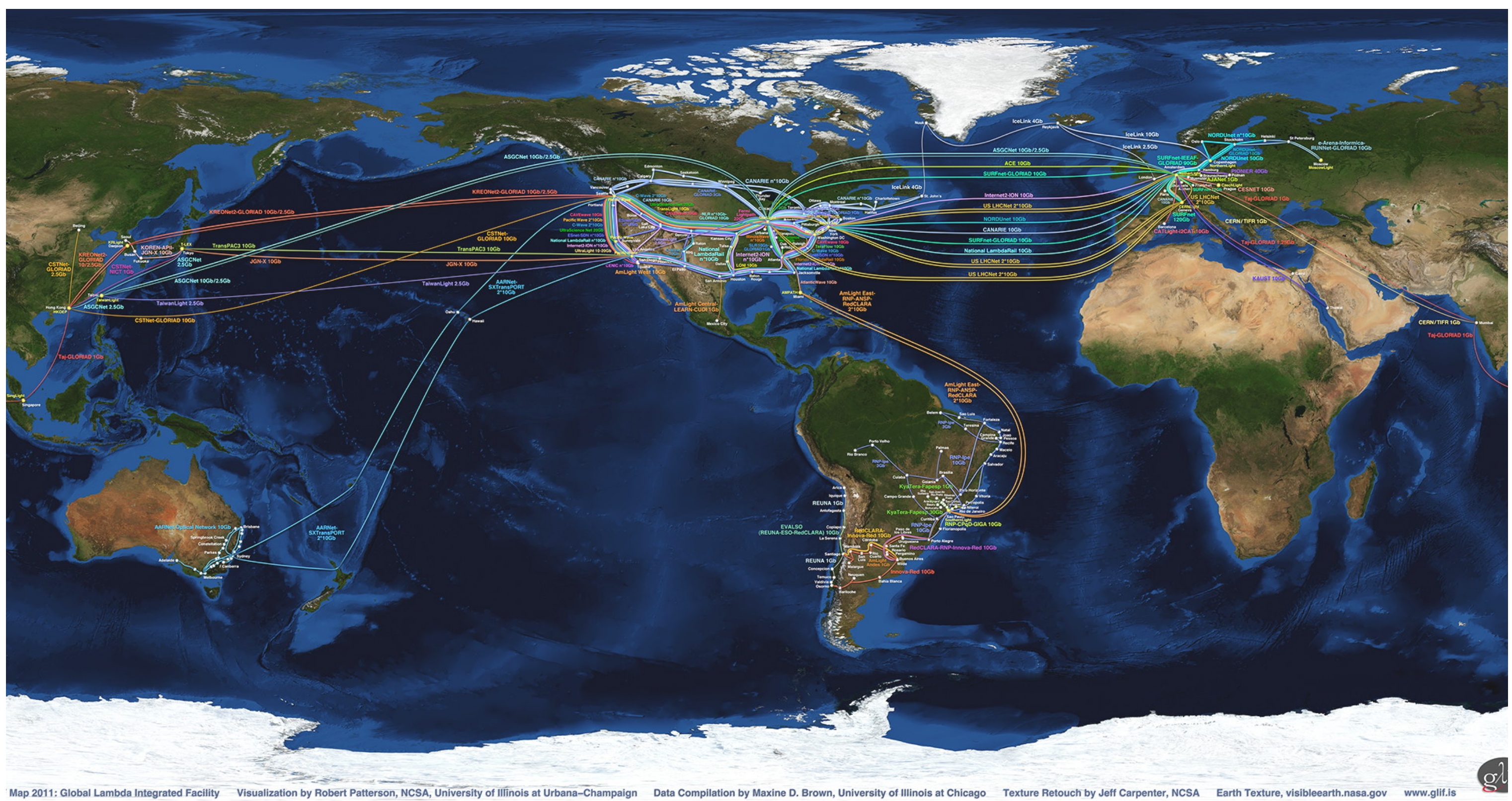
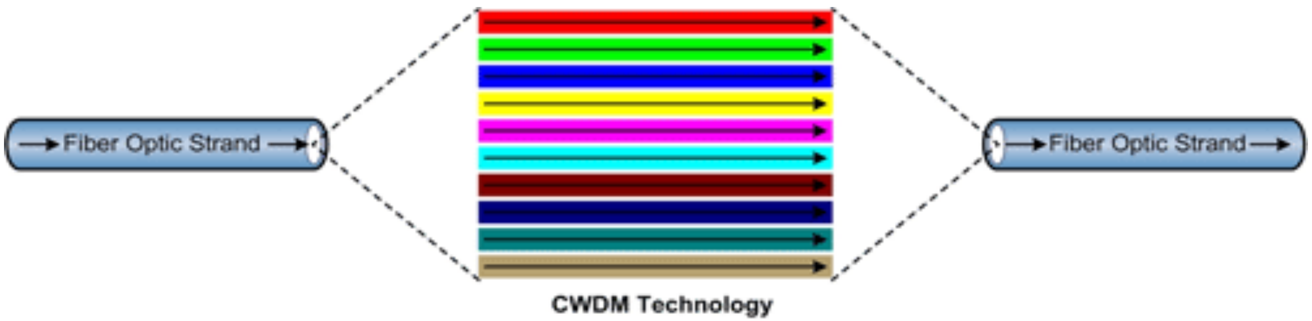


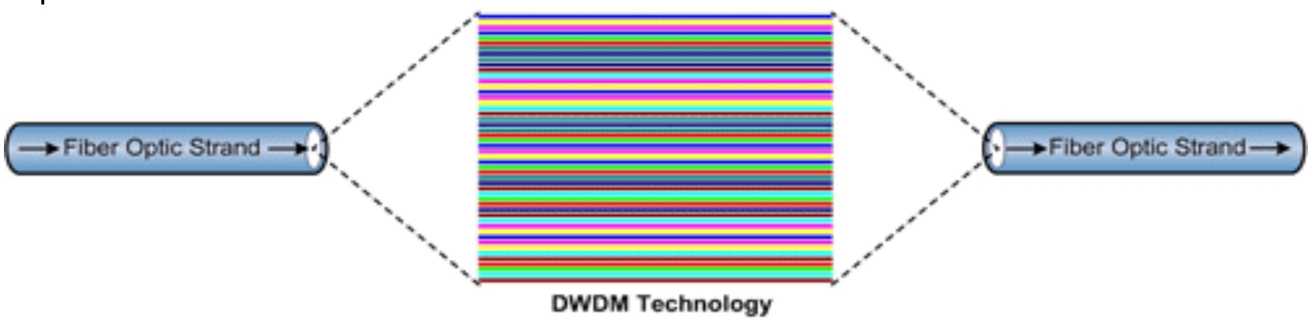
Complex (network) infrastructures

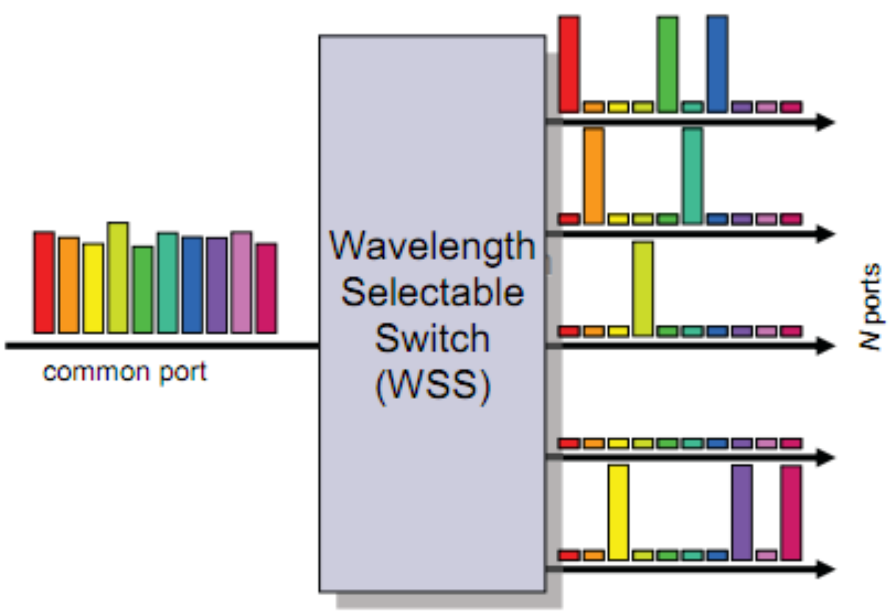


...with more possibilities



Optical transmission

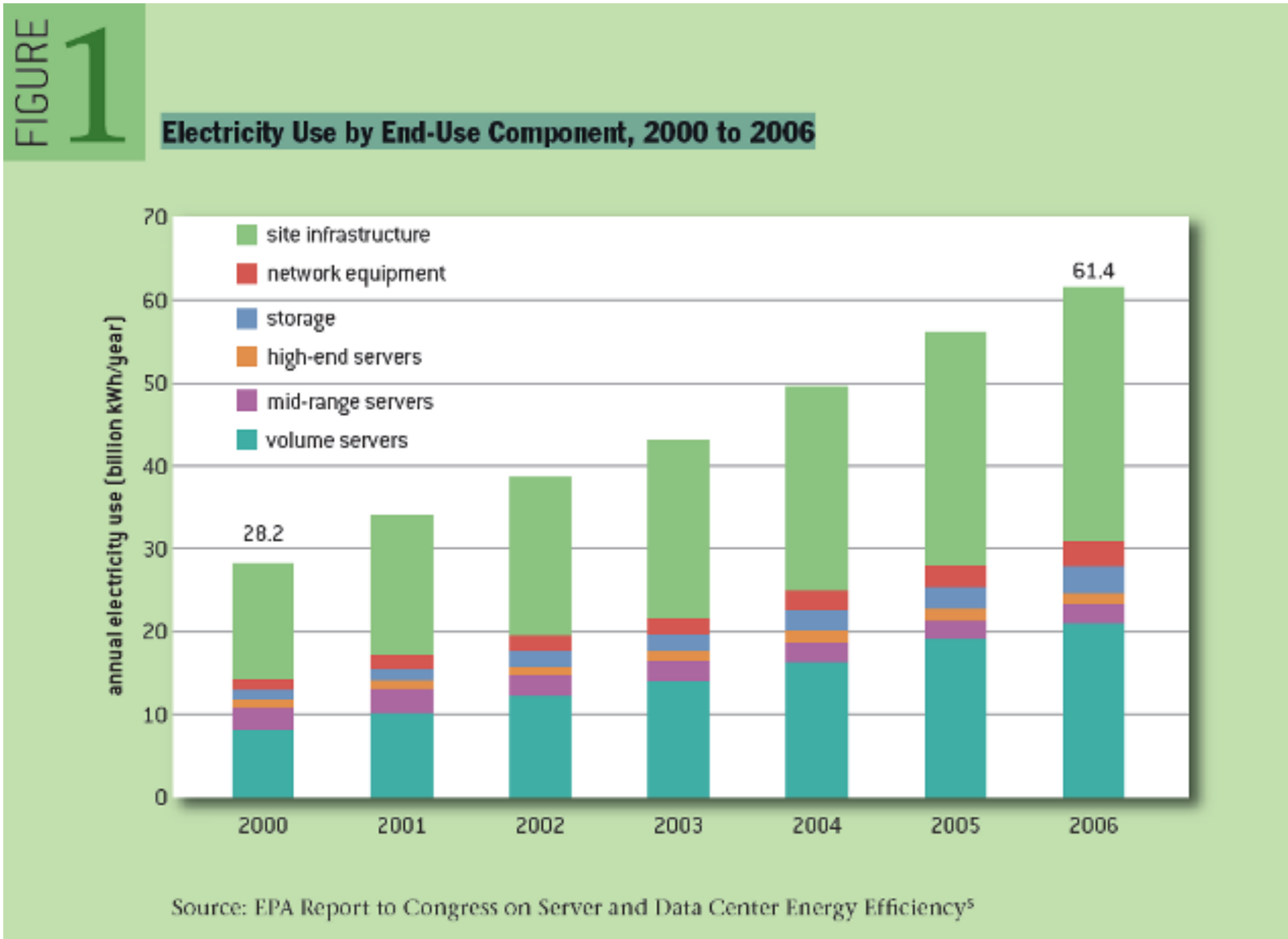




Virtualization

Greening

"….the cloud model provides also **benefits** *from the* **environmental perspective***…."*

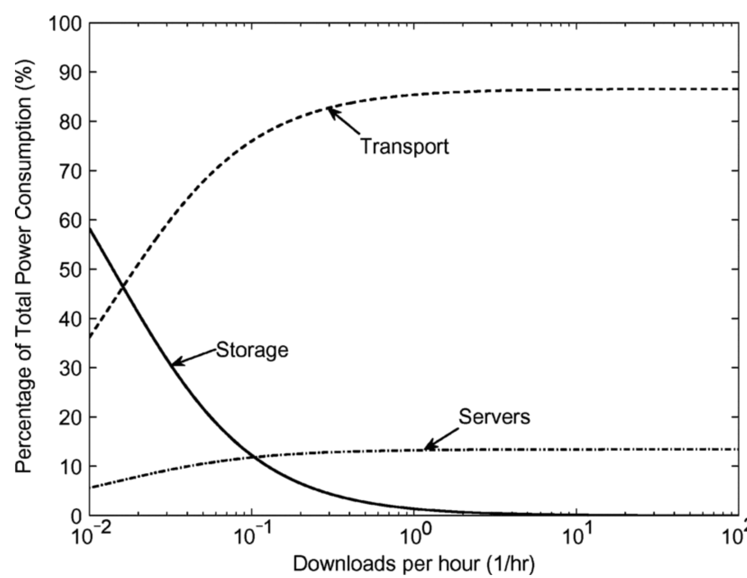


D. Brown and C. Reams
Towards energy-efficient computing
Communications of the ACM Volume 53 Issue 3, March 2010 Pages 50-58

Clouds: green or gray?

Complex question.

- Need knowledge of the carbon footprint
- Need knowledge of all contributing components, also of the network contribution between clouds, between user and cloud center



Baliga, J.; Ayre, R.W.A.; Hinton, K.; Tucker, R.S.
Green Cloud Computing:
Balancing Energy in Processing, Storage, and Transport
Proceedings of the IEEE , vol.99, no.1, pp.149-167, Jan. 2011

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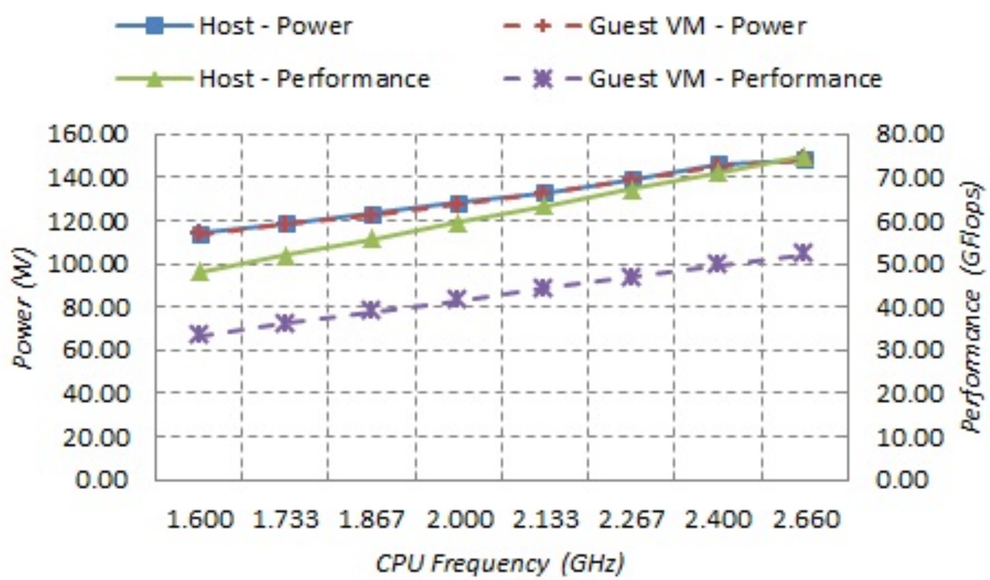
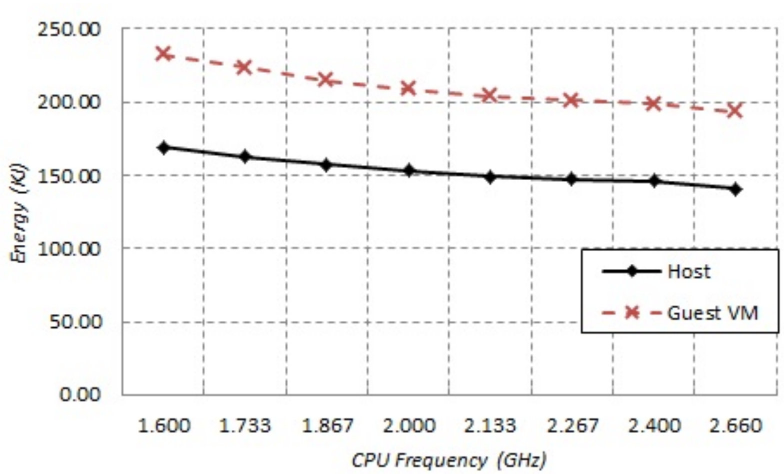
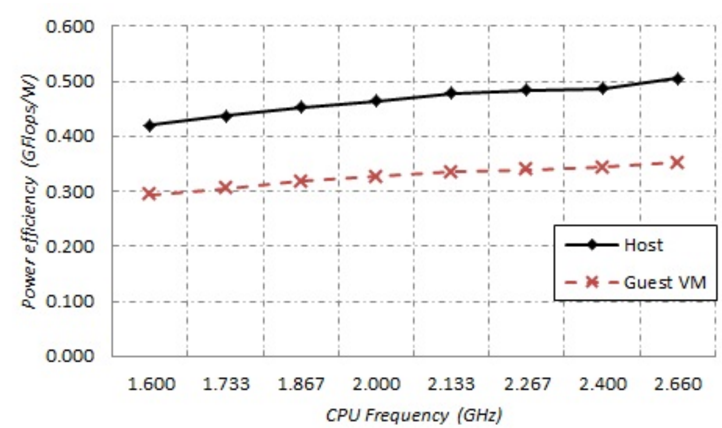
Energy saving in clouds



Quantifying the energy performance of VMs is the first step toward energy-aware job scheduling.

Q. Chen, P. Grosso, K. van der Veldt, C. de Laat, R. Hofman and H.Bal.
Profiling energy consumption of VMs for green cloud computing
In: International Conference on Cloud and Green Computing (CGC2011), Sydney December 2011





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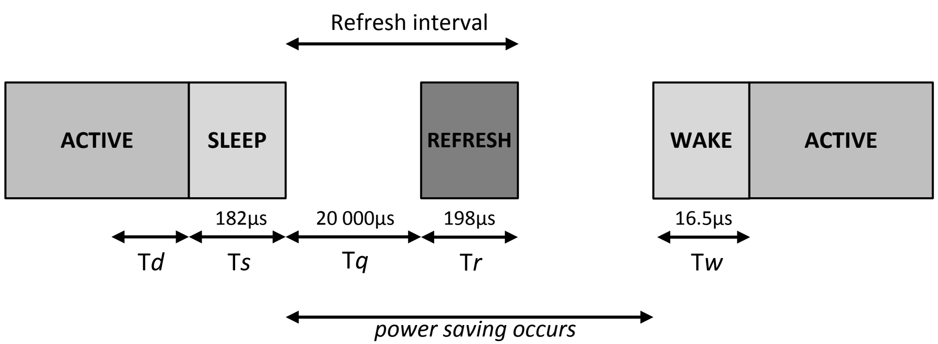
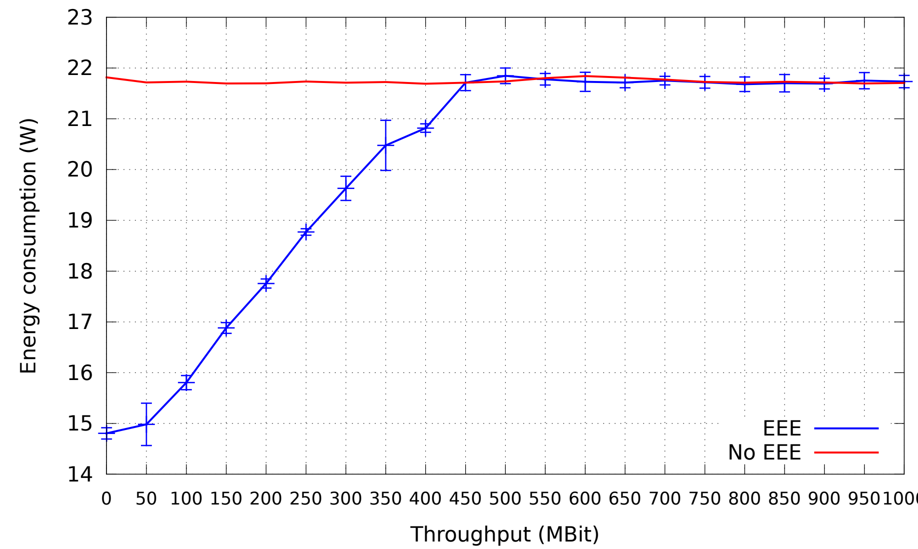
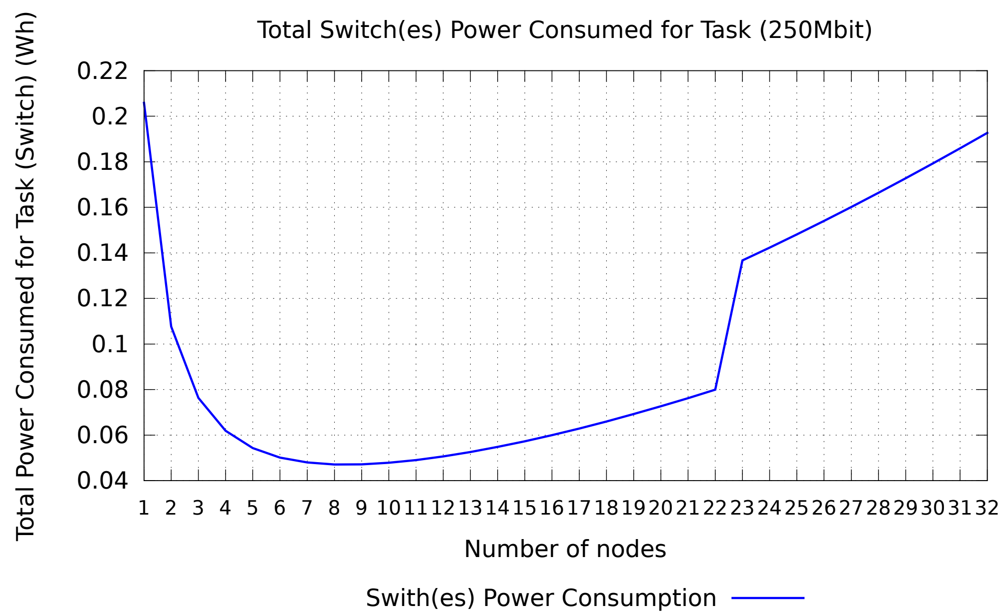
Energy Efficient Ethernet (802.3az)

Power savings techniques in hardware can be leveraged in architecturing communication patterns in data centra

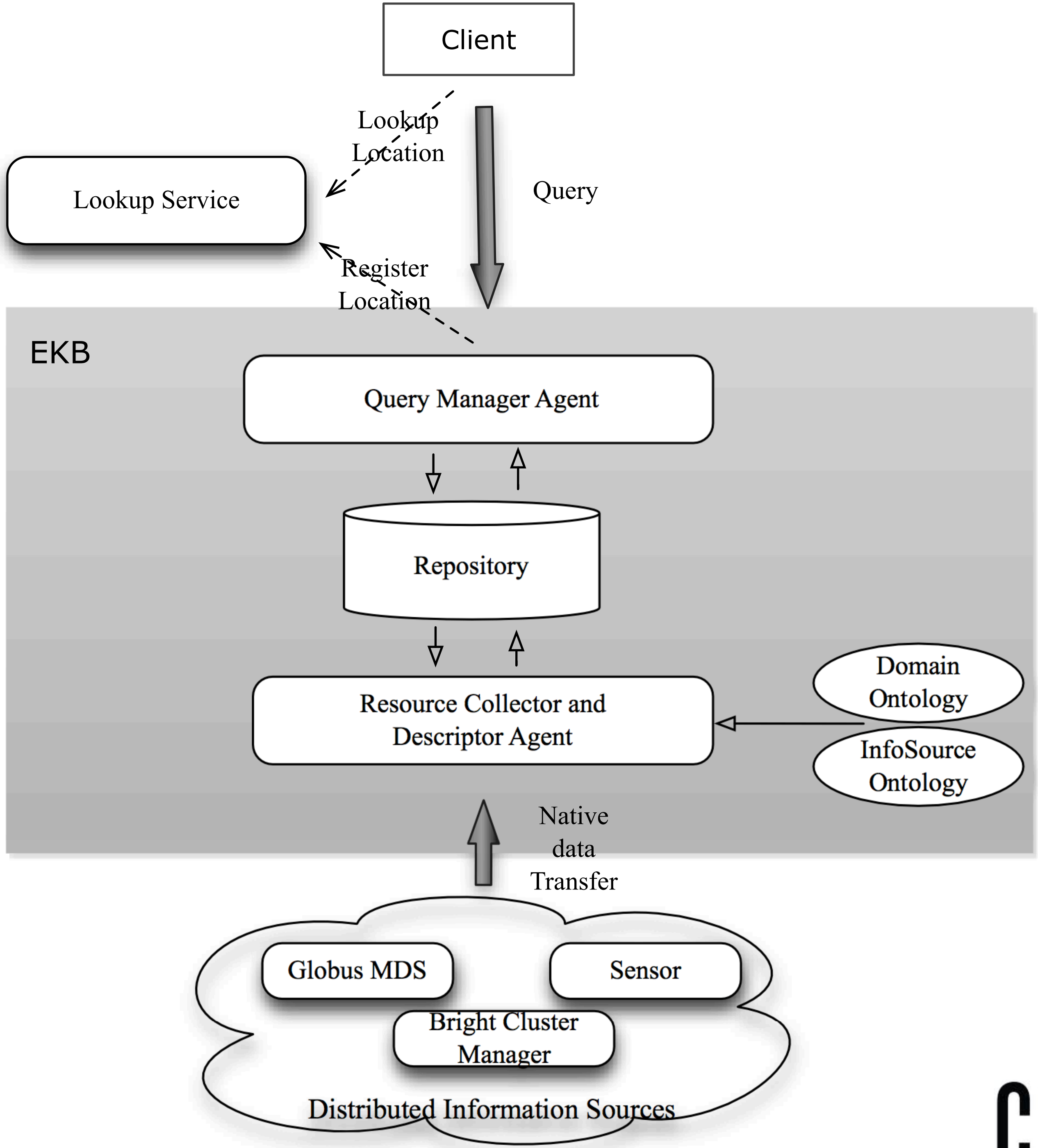






D. Pavlov and J. Soert and P. Grosso and Z. Zhao and K. van der Veldt and H. Zhu and C.de Laat
Towards energy efficient data intensive computing using IEEE 802.3az
In: DISCS 2012 workshop - Nov 2012

EKB


Client
Lookup
Location
Query
Lookup Service
Register
Location
EKB
Query Manager Agent
Repository
Domain
Ontology
Resource Collector and
Descriptor Agent
InfoSource
Ontology
Native
data
Transfer
Globus MDS
Sensor
Bright Cluster
Manager
Distributed Information Sources

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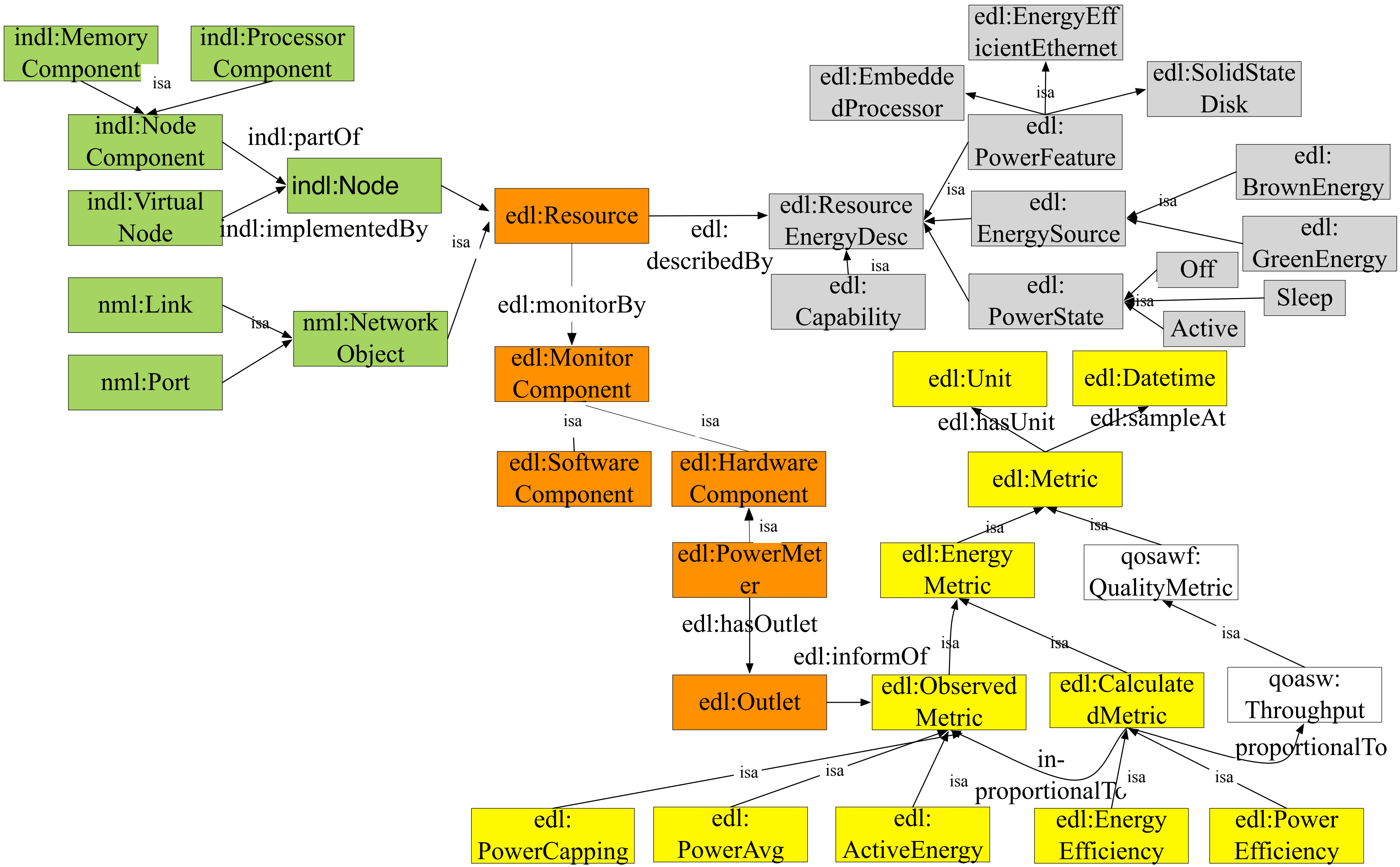
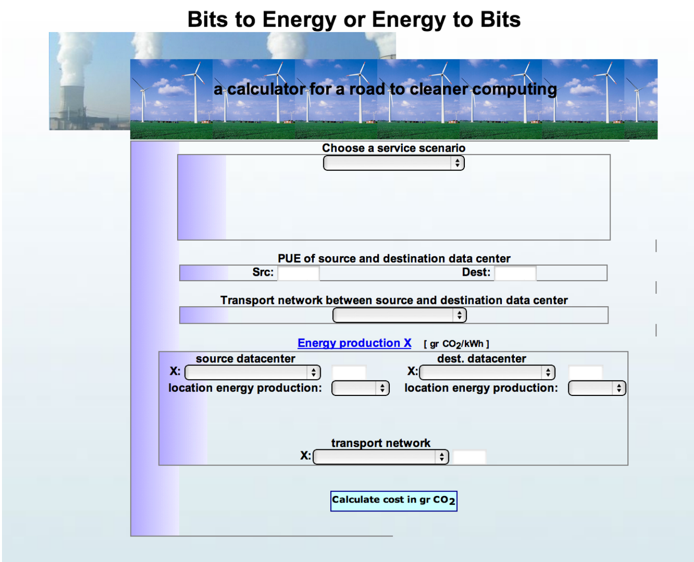
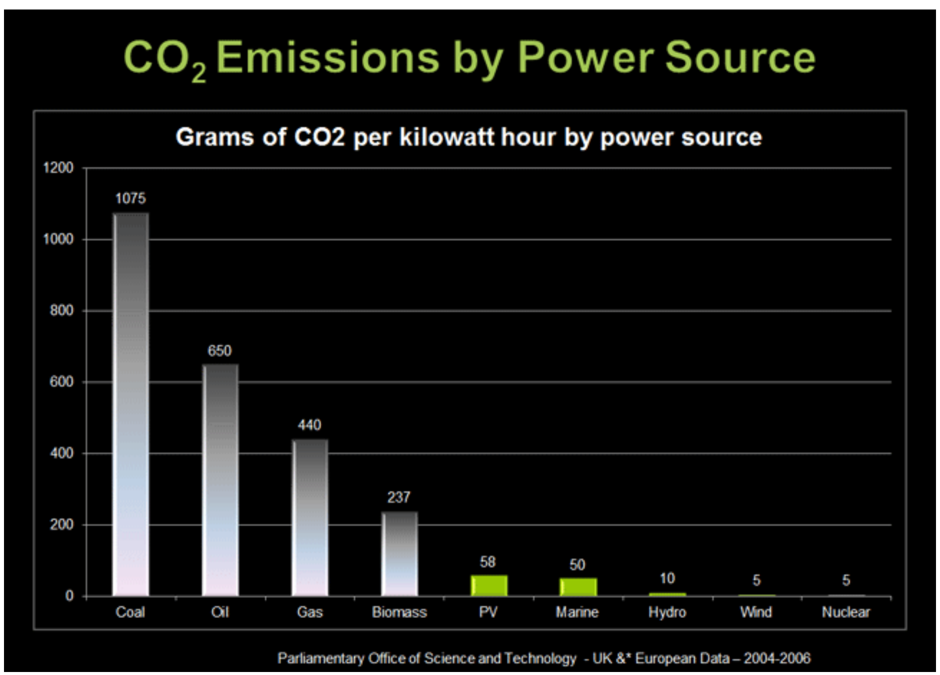
Energy Description Language - EDL



Efficiency vs. sustainability





- <u>Energy efficiency:</u>

  Reduce the amount of energy used to provide services, power devices

- <u>Sustainability:</u>

  Use of renewables energy sources and reduction of carbon footprint.

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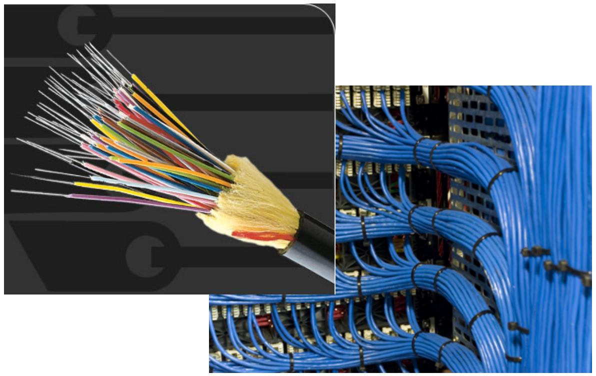
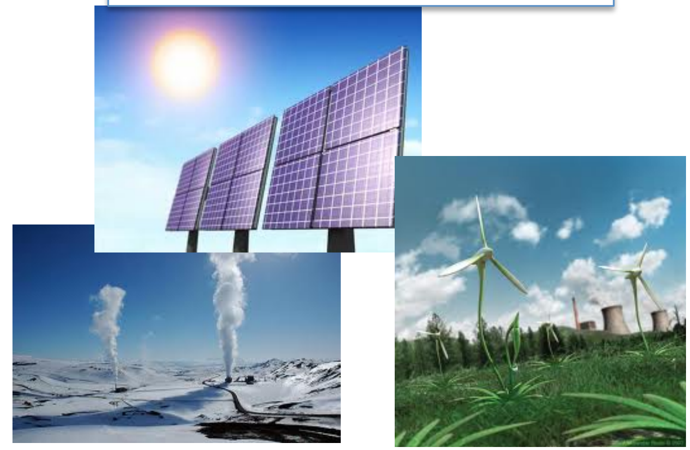
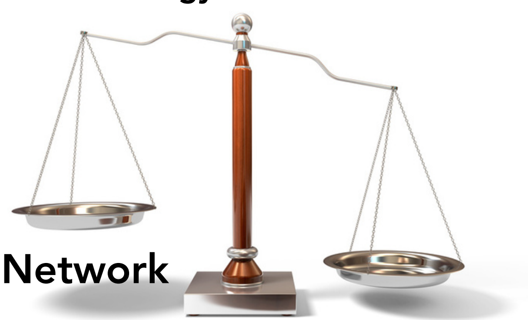
Green scheduling

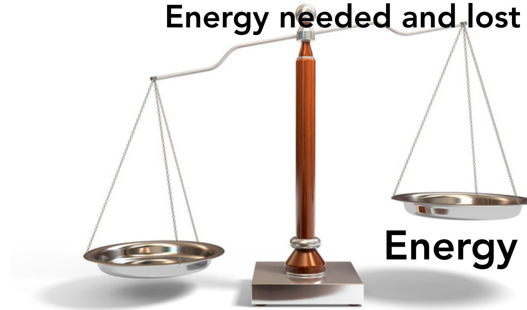
Network infrastructures



Green energy sources







Bits to energy!

Energy to bits!

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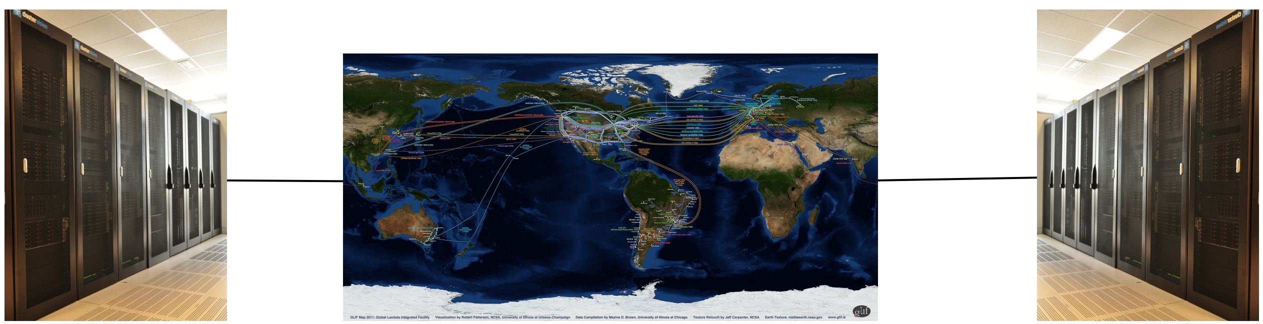
Bits-to-nets cost

$$Q = 1KWh \sim X\ gr\ CO_2$$

Three components:

- Cost of local network at source data center
- Cost of local network at destination data center
- Cost of transport network



Local data center

Remote data center

$$Cost_{bits-to-nets} = Cost_{LAN-source-data-center} + Cost_{transport-network} + Cost_{LAN-destination-data-center}$$

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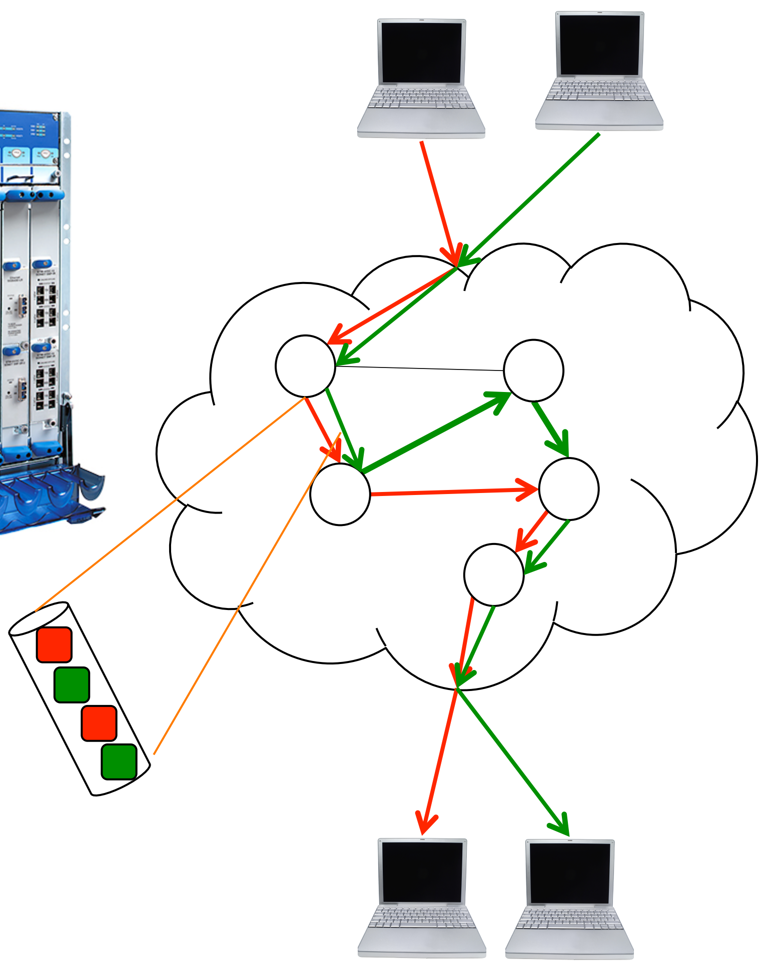
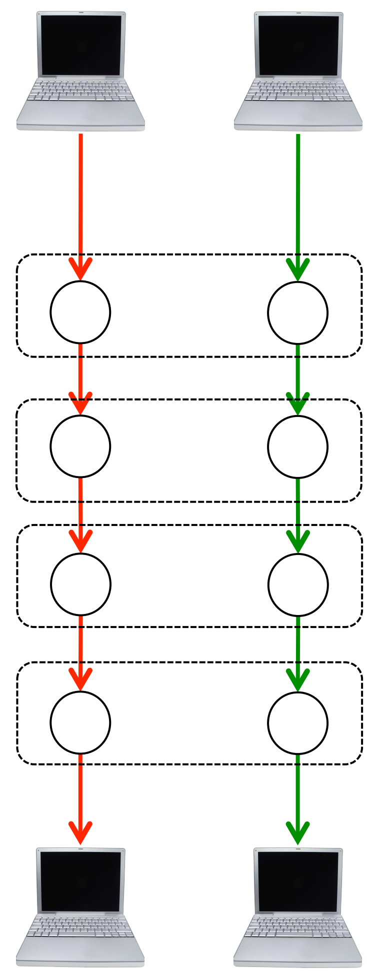
$$Cost_{bits-to-nets} = Cost_{LAN-source-data-center} + Cost_{transport-network} + Cost_{LAN-destination-data-center}$$

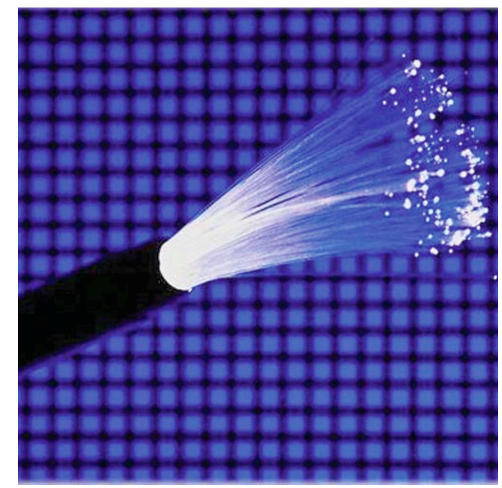
Hybrid networks

- Internet



- Circuits/lightpaths





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$$Cost_{bits-to-nets} = Cost_{LAN-source-data-center} + Cost_{transport-network} + Cost_{LAN-destination-data-center}$$

Internet

Oversubscription factor: 1/5

Short distances: 1 or 2 hops

Long distance: 3 or 4 hops

Lightpaths

Oversubscription: none

Short distance: direct connection

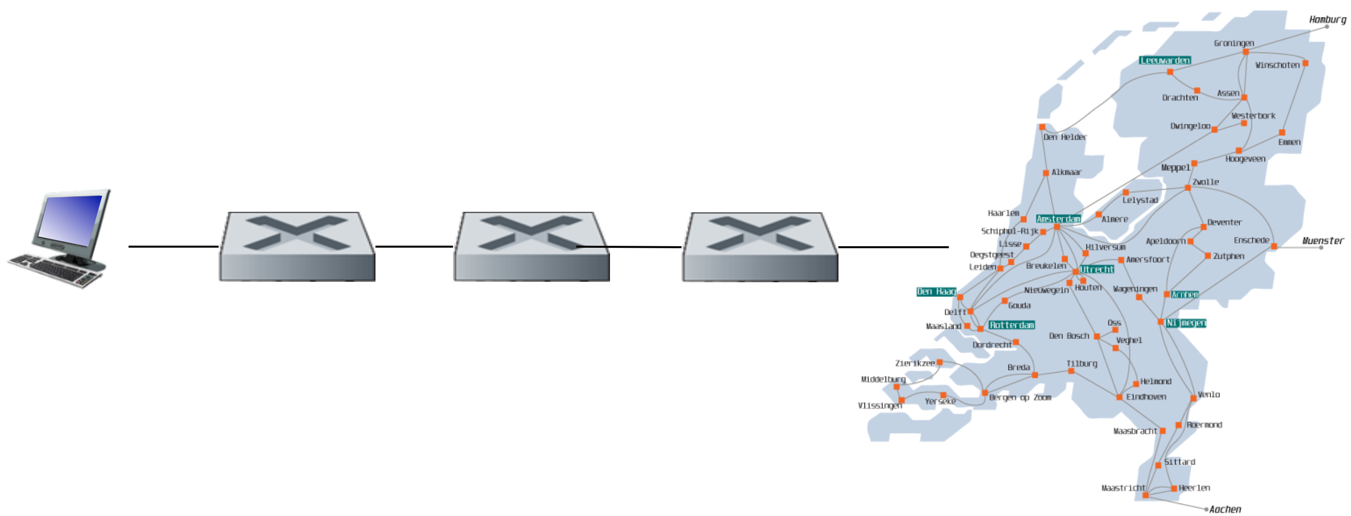
Long distances: 1 or 2 devices in between

Internet Short distance	Lightpaths Short distance	Internet Long distance	Lightpaths Long distance
Transport network:	**Transport network:**	**Transport network:**	**Transport network:**
Switch 2x20%x 10 Gbps	Switch 2x 10 Gbps	Switch 2x20%x 10 Gbps	Switch 2x 10 Gbps
DWDM 20%x 10 Gbps	DWDM 1x 10 Gbps	DWDM 20%x 10 Gbps	DWDM 1x 10 Gbps
DWDM 4x20%x 1 Wavelength	DWDM 4x 1 Wavelength	DWDM 4x20%x 1 Wavelength	DWDM 4x 1 Wavelength
DWDM 20%x 10 Gbps	DWDM 4x 1 Wavelength	DWDM 20%x 10 Gbps	DWDM 4x 1 Wavelength
Switch 2x20%x 10 Gbps	DWDM 1x 10 Gbps	Switch 2x20%x 10 Gbps	Switch 2x 10 Gbps
Router 2x20%x 10 Gbps	Switch 2x 10 Gbps	Router 2x20%x 10 Gbps	DWDM 4x 1 Wavelength
Switch 20%x 10 Gbps		Switch 20%x 10 Gbps	DWDM 4x 1 Wavelength
DWDM 20%x 10 Gbps		DWDM 20%x 10 Gbps	Switch 2x 10 Gbps
DWDM 4x20%x 1 Wavelength		DWDM 4x20%x 1 Wavelength	DWDM 4x 1 Wavelength
DWDM 20%x 10 Gbps		DWDM 20%x 10 Gbps	DWDM 4x 1 Wavelength
Switch 2x20%x 10 Gbps		Switch 2x20%x 10 Gbps	DWDM 1x 10 Gbps
		Router 2x20%x 10 Gbps	Switch 2x 10 Gbps
		Switch 20%x 10 Gbps	
		DWDM 20%x 10 Gbps	
		DWDM 4x20%x 1 Wavelength	
		DWDM 20%x 10 Gbps	
		Switch 2x20%x 10 Gbps	
		Router 2x20%x 10 Gbps	
		Switch 20%x 10 Gbps	
		DWDM 20%x 10 Gbps	
		DWDM 4x20%x 1 Wavelength	
		DWDM 20%x 10 Gbps	
		Switch 2x20%x 10 Gbps	

$$Cost_{bits-to-nets} = Cost_{LAN-source-data-center} + Cost_{transport-network} + Cost_{LAN-destination-data-center}$$

Data center cost

- Given a typical data center network:



And known power (P) and capacity (C) of the devices in the topology:

$$Cost_{LAN-source-data-center} = \frac{P_{host}}{C_{host}} + \frac{P_{switch}}{C_{switch}} + \frac{P_{firewall}}{C_{firewall}} + \frac{P_{router}}{C_{router}}$$

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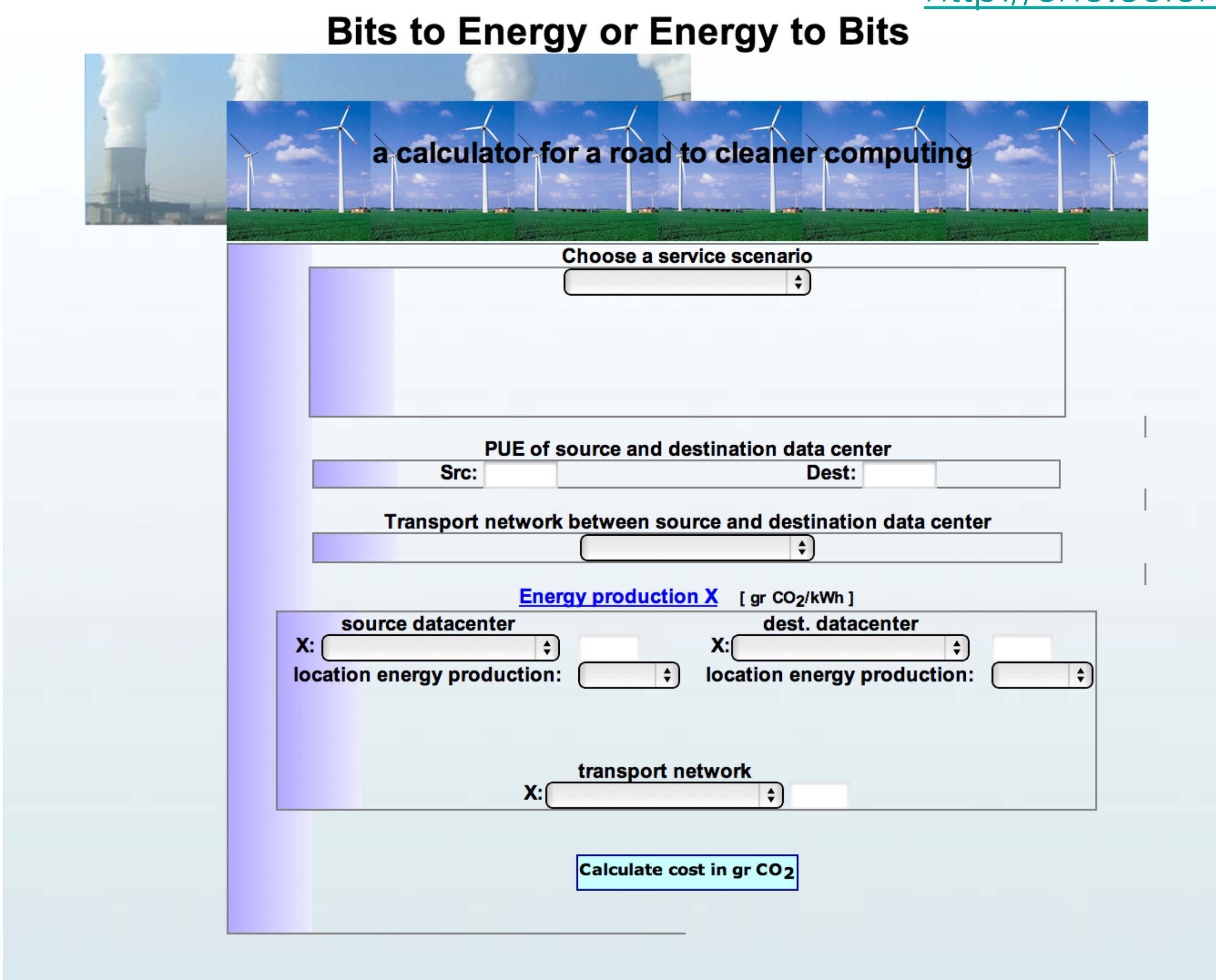
Bits-Nets-Energy

http://sne.science.uva.nl/bits2energy/



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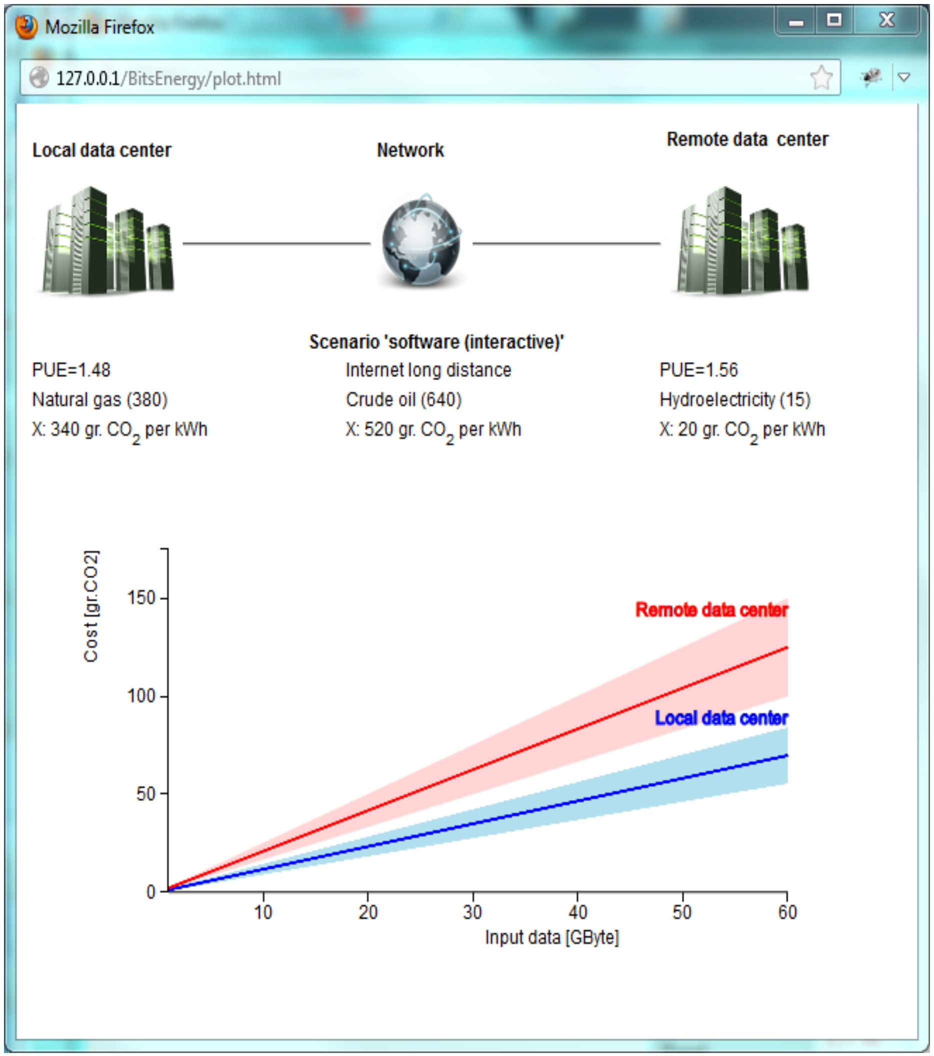
The output



Scenario 'software (interactive)'

PUE=1.48
Natural gas
380 gr. CO_2 per kWh

Internet long distance

526 gr. CO_2 per kWh

PUE=1.56
Hydroelectricity (15)
15 gr. CO_2 per kWh

Cost local data center	
	g CO_2 (kWh)
CPU	48.09 (0.1265)
LAN (output data)	2.27 (0.0060)
Energy prod. loss	2.03 (0.0054)
Total	52.39 (0.1325)

Cost to remote data center	
	g CO_2 (kWh)
LAN local (input data)	14.65 (0.0385)
Network (input data)	23.12 (0.0439)
LAN remote (input data)	0.61 (0.0406)
CPU remote	2.00 (0.1334)
LAN remote (output data)	0.09 (0.0063)
Network (output data)	3.58 (0.0068)
Energy prod. loss	0.11 (0.0073)
Total	44.16 (0.2769)

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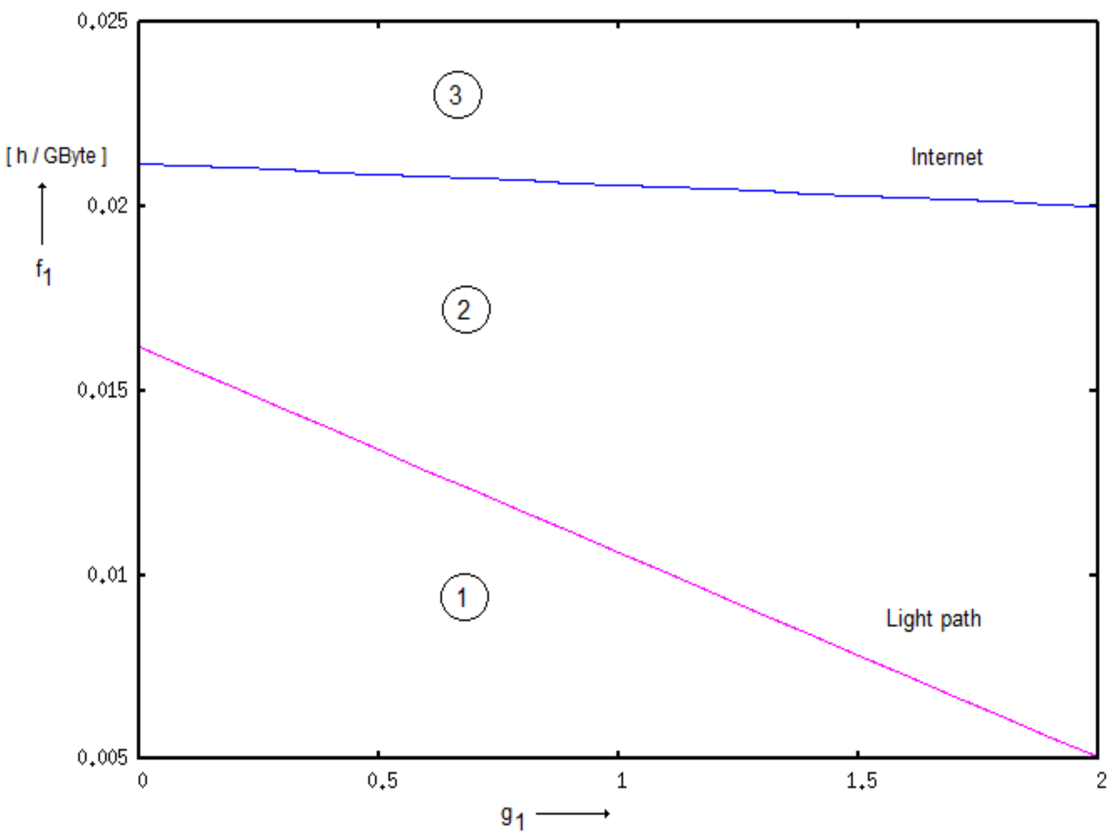
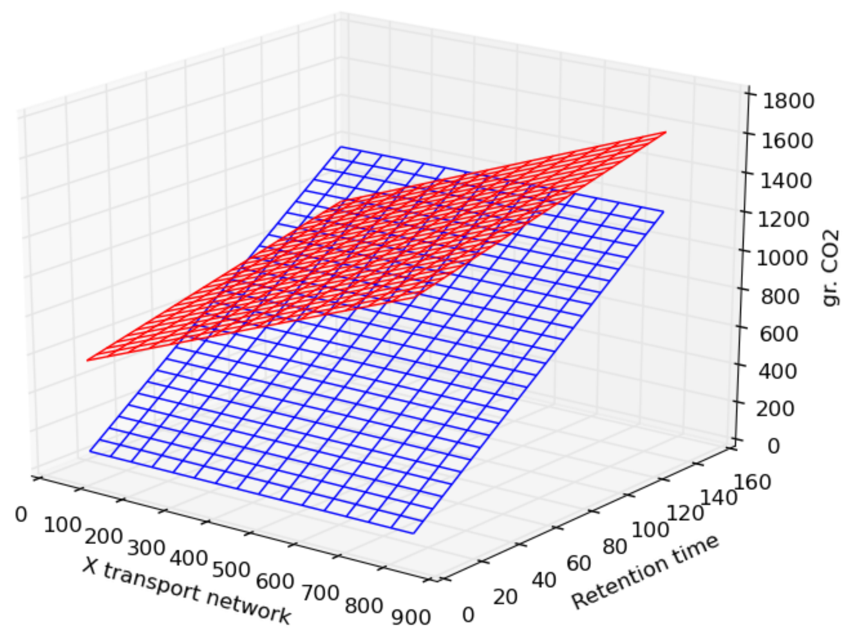
"Fresh from the press"



Given different network paths what are the decision boundaries as function of the task complexity.

Storage to energy: when should you move hot or cold data to a green remote data centra for storage?



More information

- Email: p.grosso@uva.nl
- URL: http://staff.science.uva.nl/~grosso/

Calculator is online:

http://sne.science.uva.nl/bits2energy/

Final report on this research:

http://www.surf.nl/nl/publicaties/Pages/TransportingBitsorTransportingEnergy.aspx

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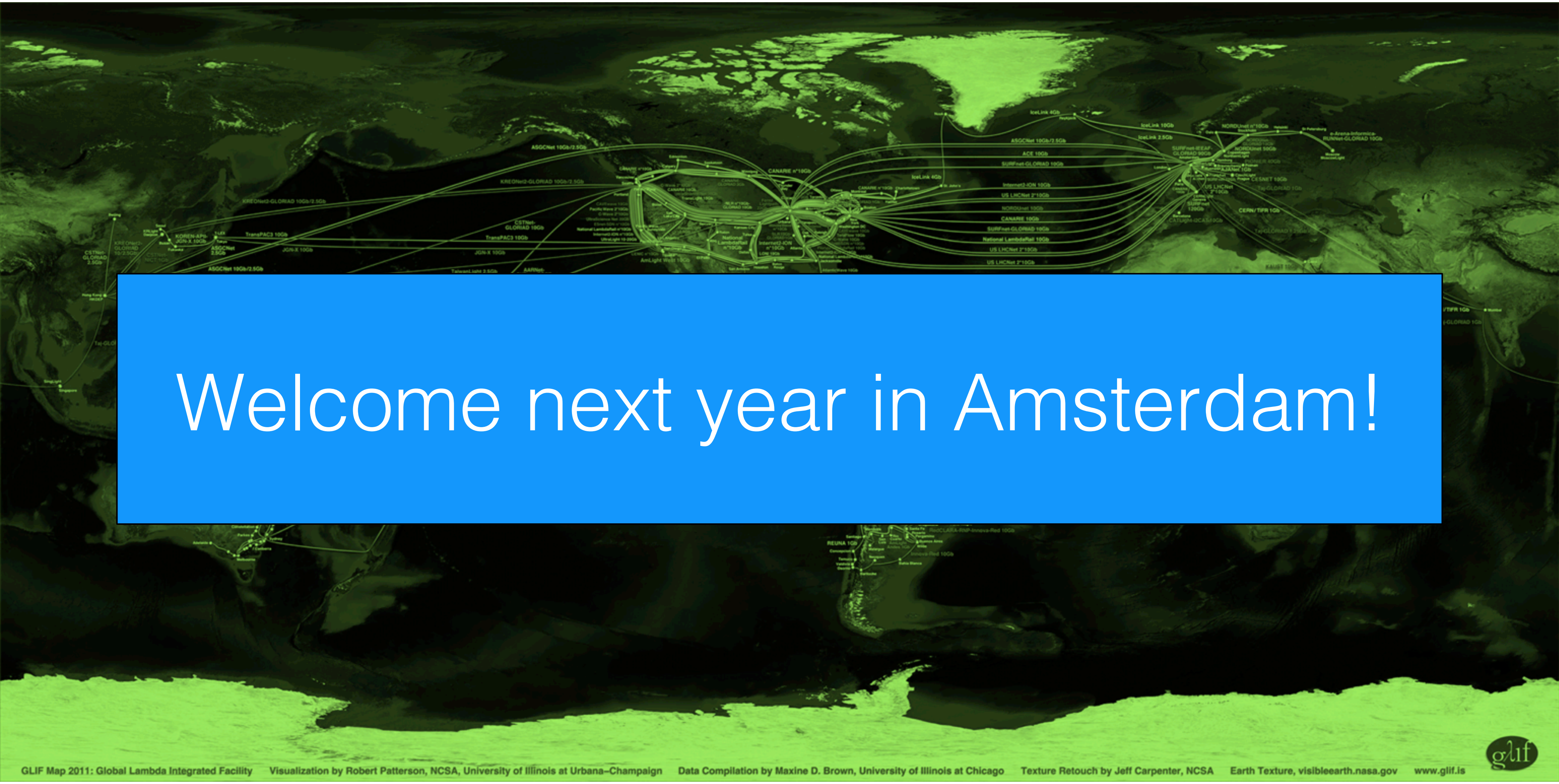

Welcome next year in Amsterdam!

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