Energy Consumption of ICT Networks

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SEVENTH FRAMEWORK PROGRAMME

Outline

Part I

Estimation of worldwide energy consumption of ICT networks

- Providing some important building blocks to create the big picture

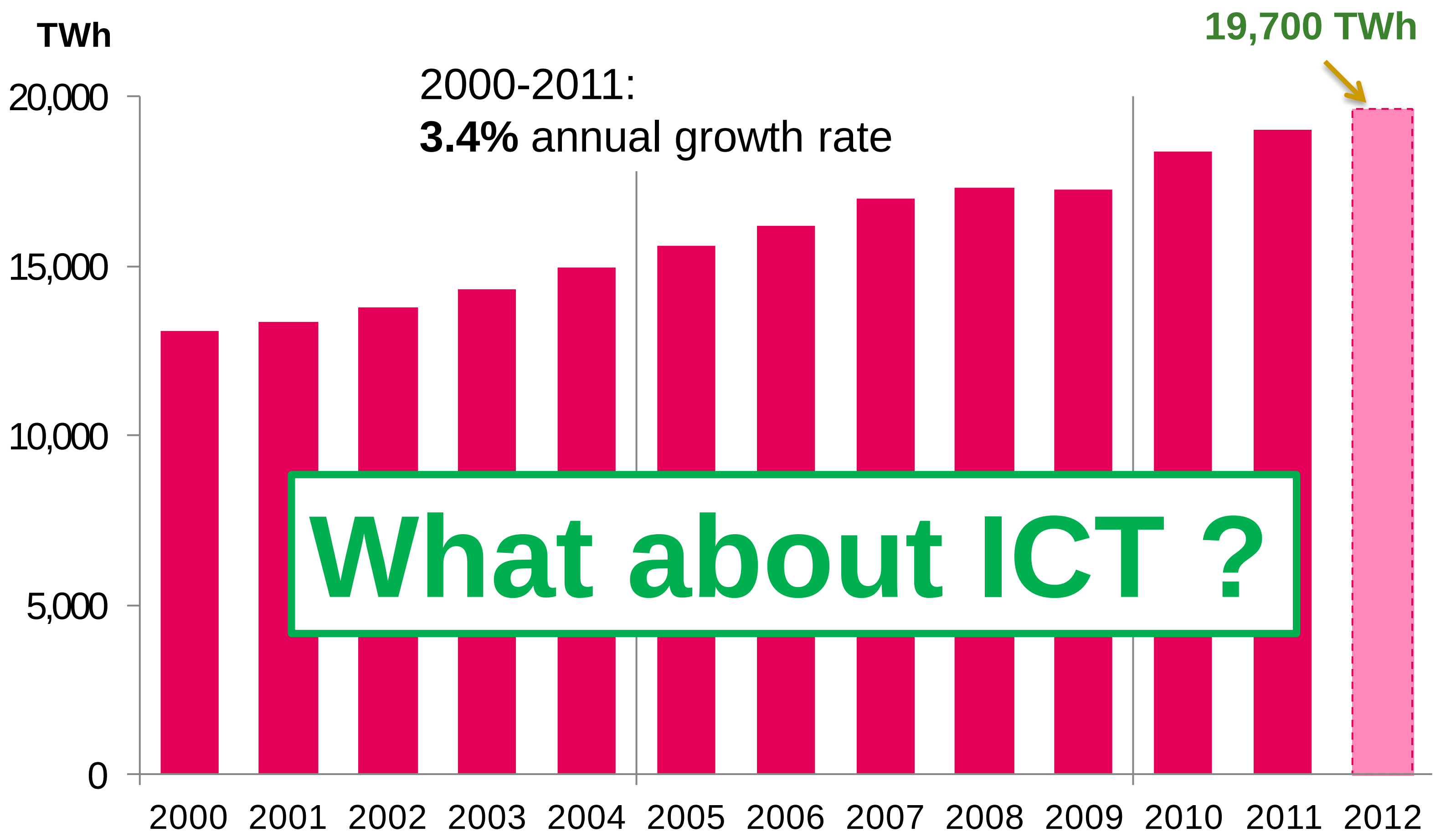
Part II

- Collecting data about energy consumption
  - ➔ Resulting in launch of PowerLib
- Assessing energy-saving potential
  - ➔ Resulting in input towards the big picture

Part III

Evaluating (cost) incentives for implementing energy-saving approaches

Electricity consumption worldwide



Data: based on http://yearbook.enerdata.net

Motivation

- Assess **whether** ICT occupies a major share in human electricity consumption
  - Current situation (2012)
  - Trends in recent past (2007-2012)
  - Insight in the evolution in the near future

- Assess **where** efforts should be concentrated in order to reduce the worldwide ICT electricity consumption

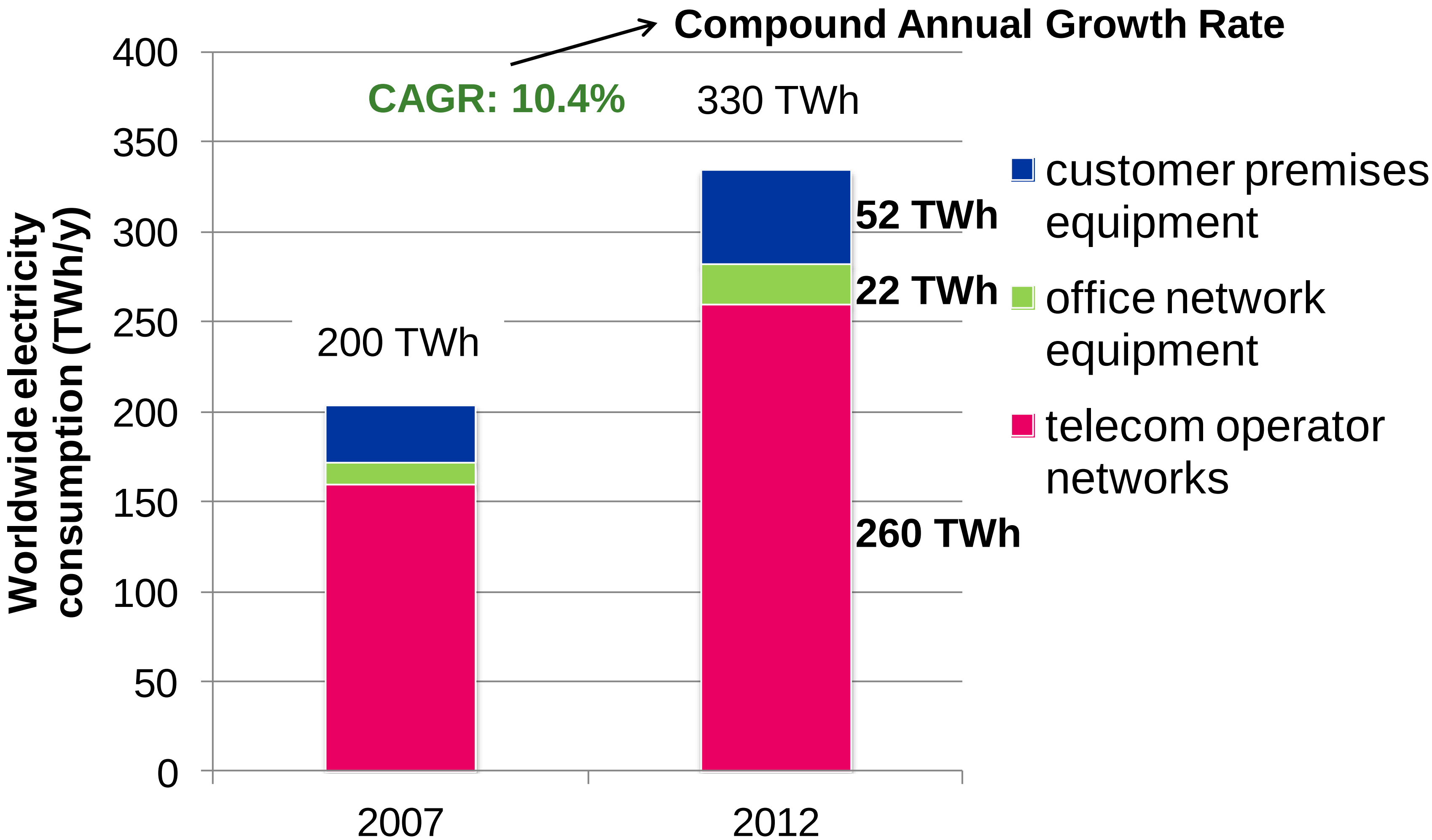
Electricity consumption in ICT: scope

- **Communication networks**
  - Customer Premises Equipment
  - Office networks
  - Telecom operator networks

- **Computers**
  - Desktop / laptops
  - Monitors

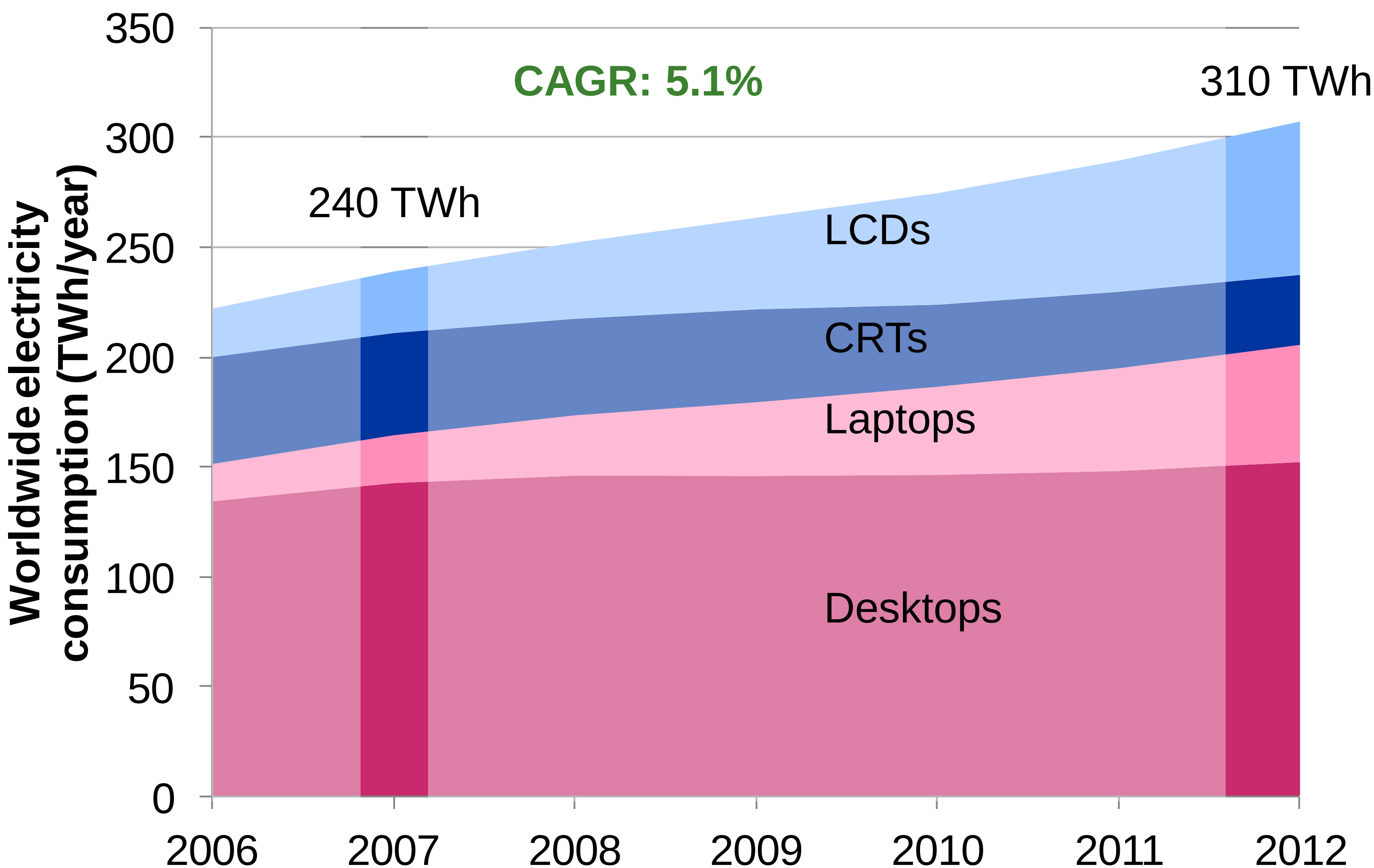
- **Data Centres** (= servers)

Footprint of communication networks

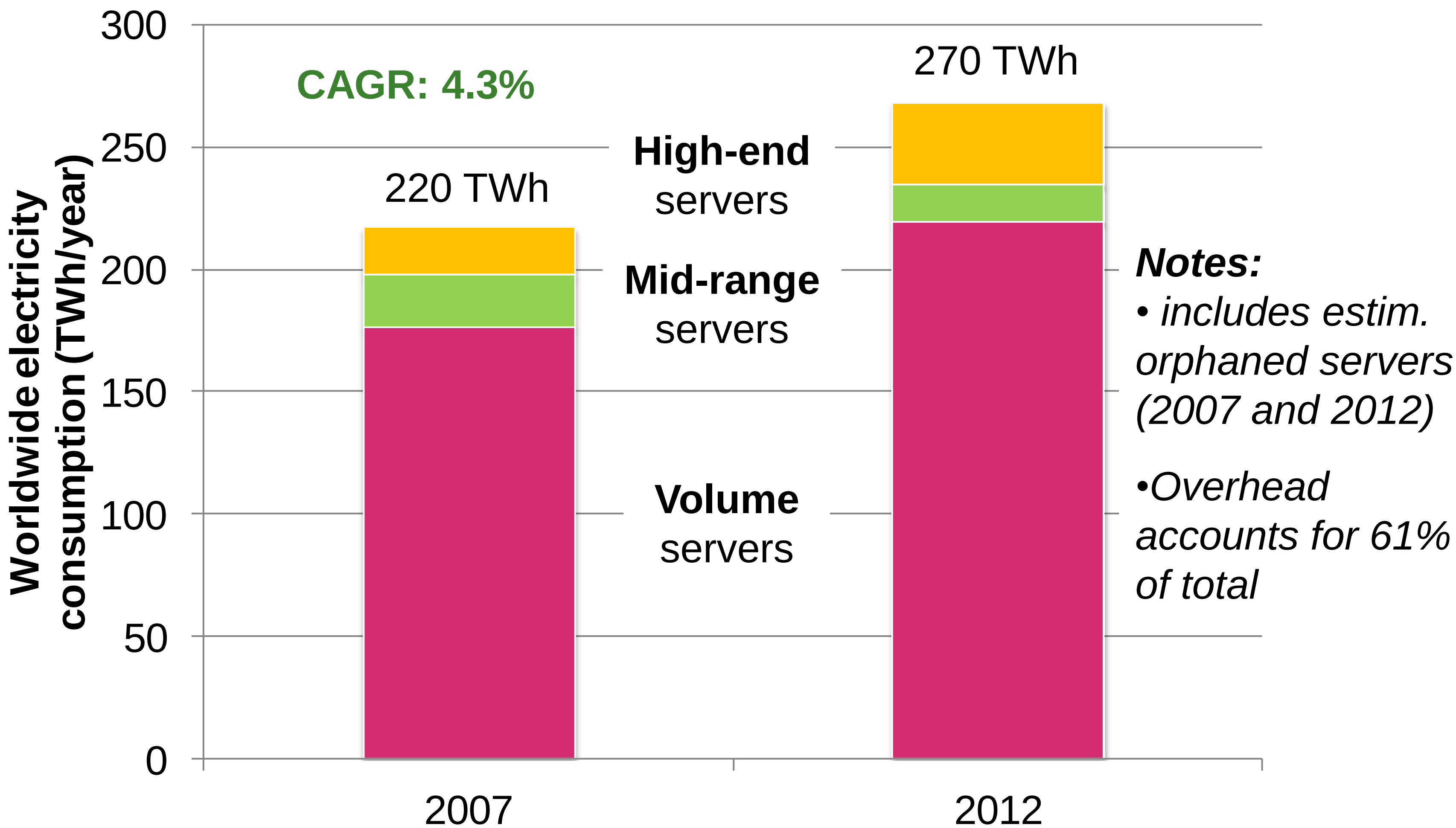


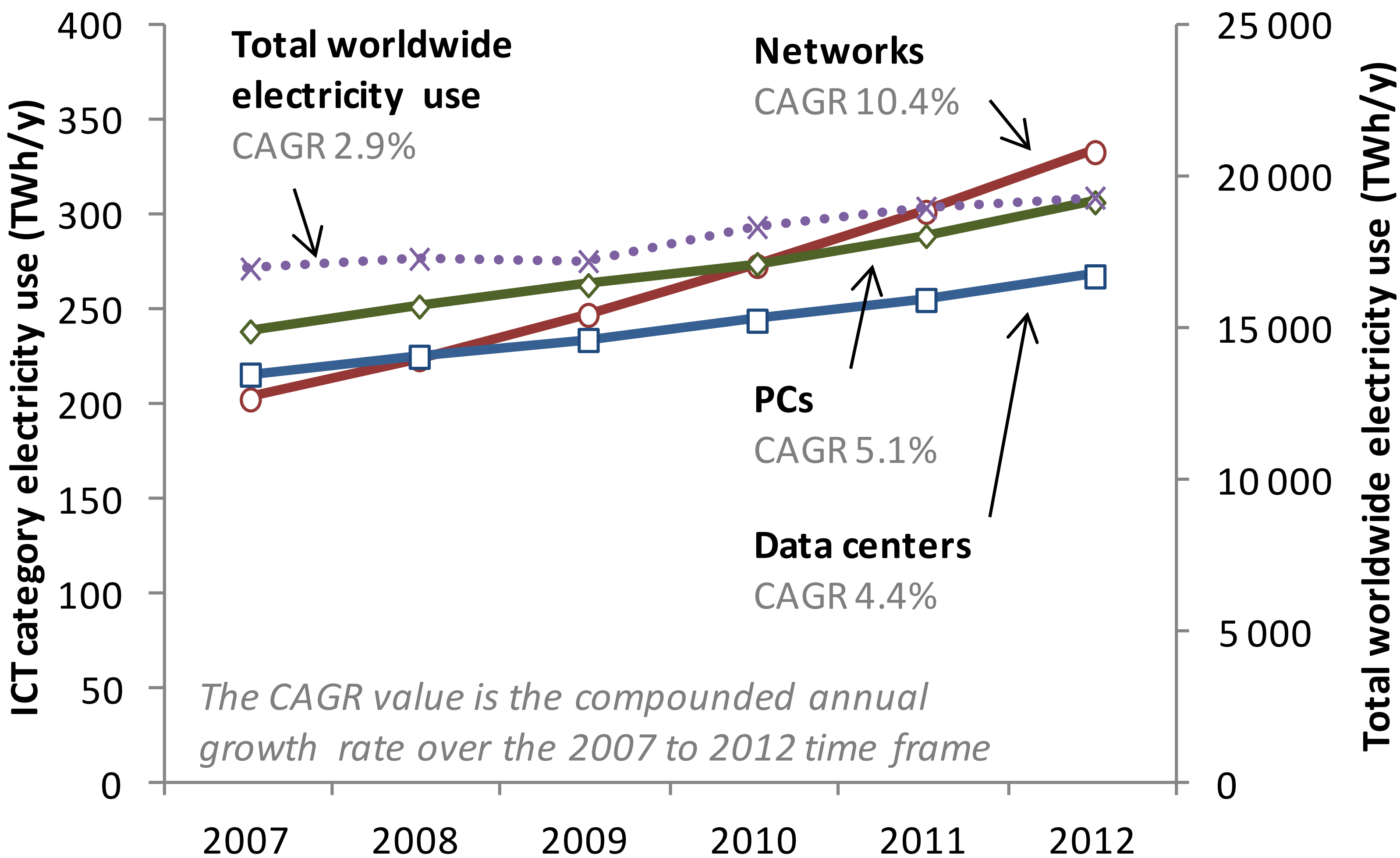
Lambert et al., "Worldwide electricity consumption of communication networks", Optics Express ECOC 2012 Special Issue

Footprint of computers

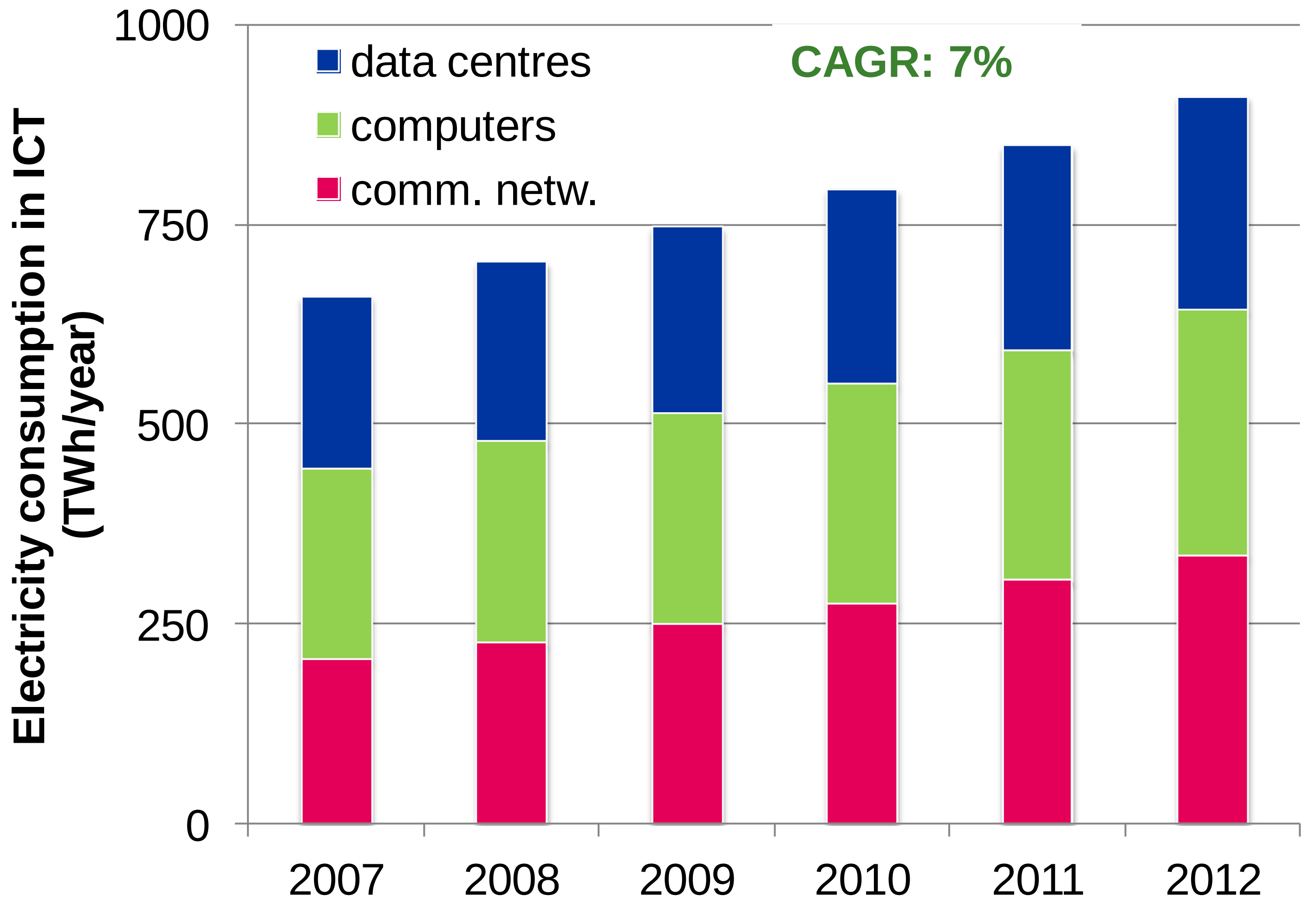


Footprint of data centres

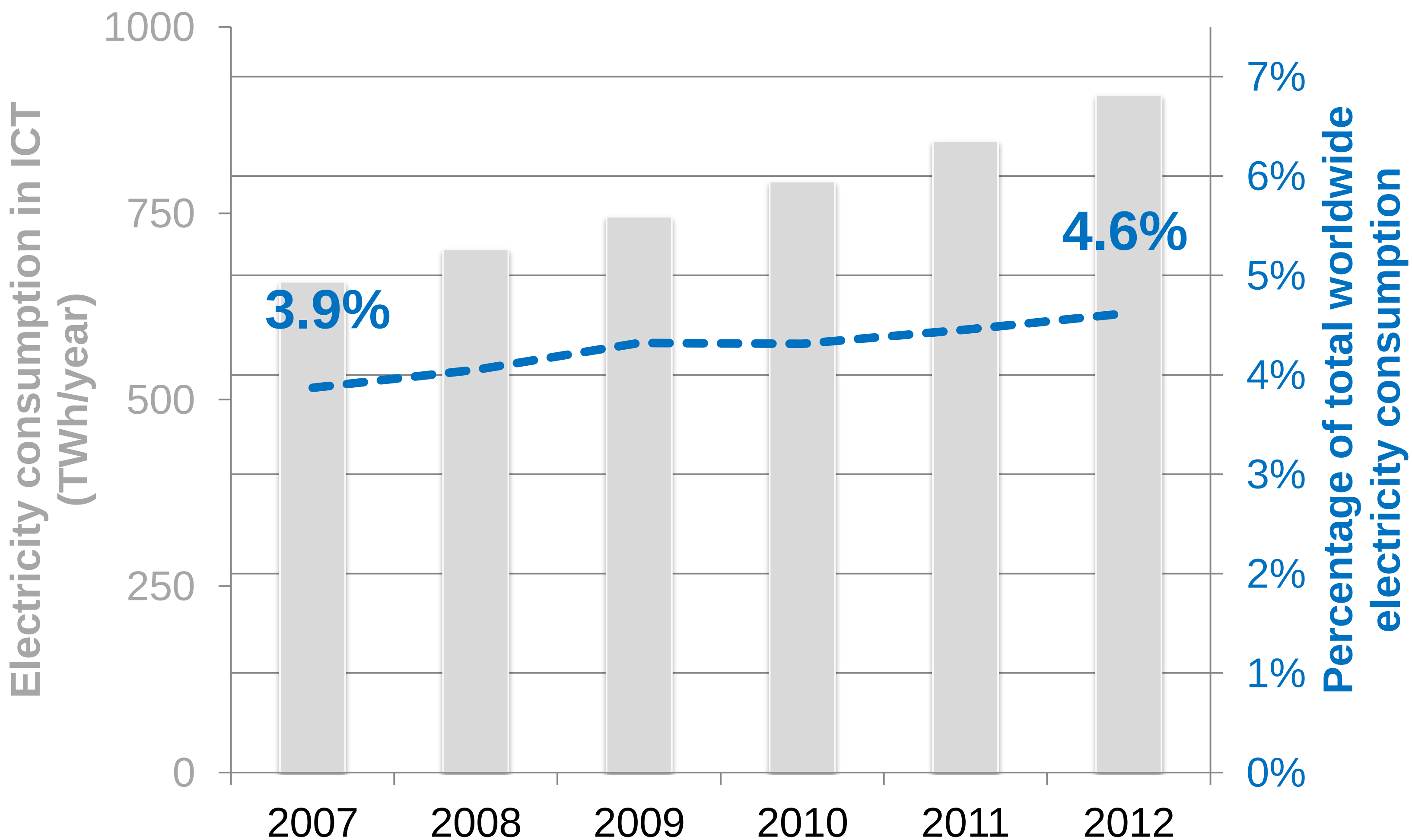



Total worldwide electricity use
CAGR 2.9%
Networks
CAGR 10.4%
PCs
CAGR 5.1%
Data centers
CAGR 4.4%
The CAGR value is the compounded annual growth rate over the 2007 to 2012 time frame
ICT category electricity use (TWh/y)
Total worldwide electricity use (TWh/y)
400
350
300
250
200
150
100
50
0
25 000
20 000
15 000
10 000
5 000
0
2007
2008
2009
2010
2011
2012

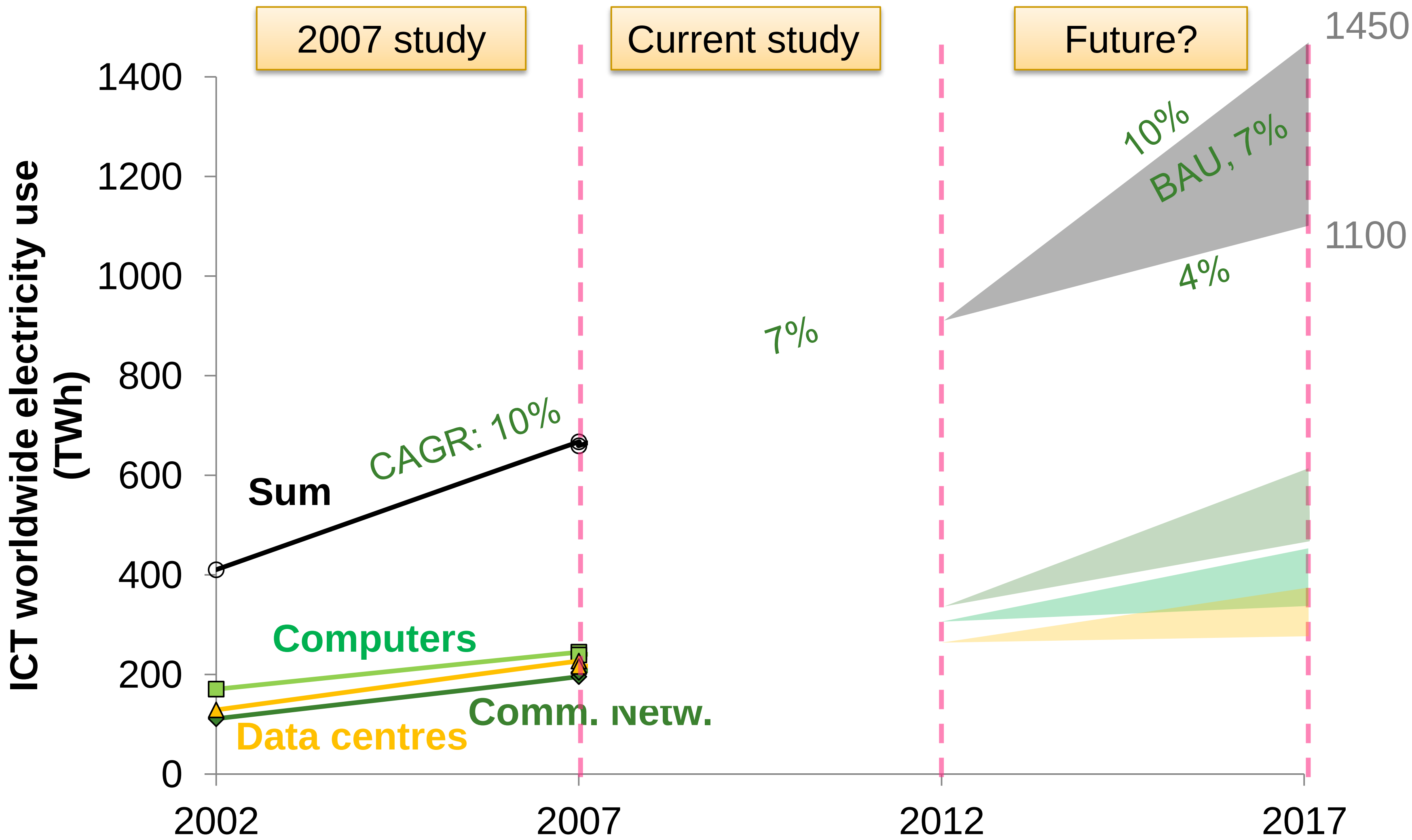
Joint footprint



Joint footprint - % of electr. consumption

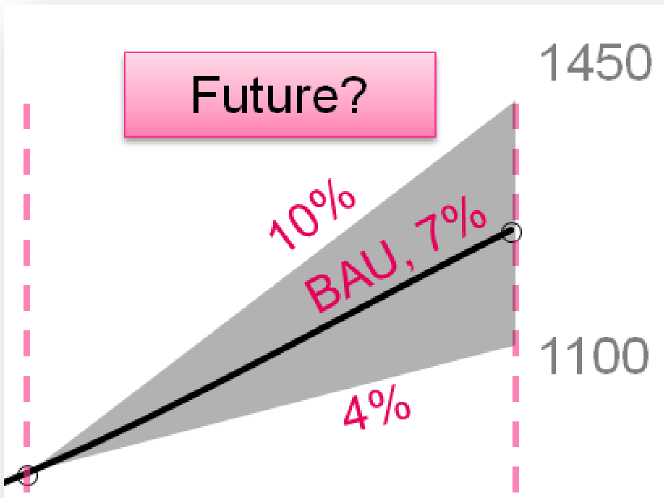


Future trends?



Pickavet et al., "Worldwide energy needs for ICT: The rise of power-aware networking " ANTS, 2008

Future trends – CAGR?

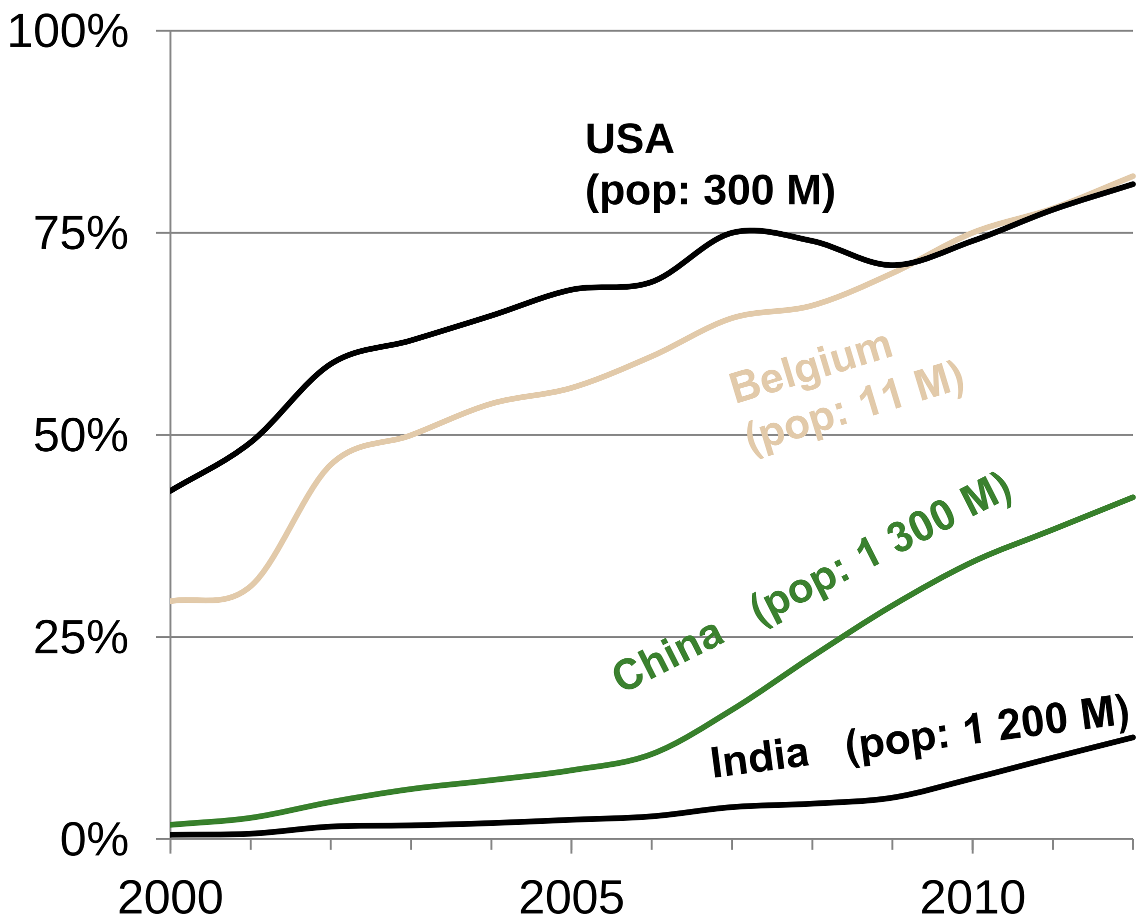


Will the CAGR after 2012 be *higher* or *lower* than in the timeframe 2007-2012?

- Higher CAGR (e.g. 10%)?
  - Temporary effect of crisis disappears
  - Cloud computing
  - Low hanging fruit solutions already accomplished
  - Smart homes (IoT)
- Lower CAGR (e.g. 4%)?
  - CAGR gradually going down during last decades
  - Further intensification of measures and research
  - Shift to smaller/mobile devices

Future trends – Emerging economies

Percentage of individuals using the Internet



China at same level : **+ 500 M** people using the Internet

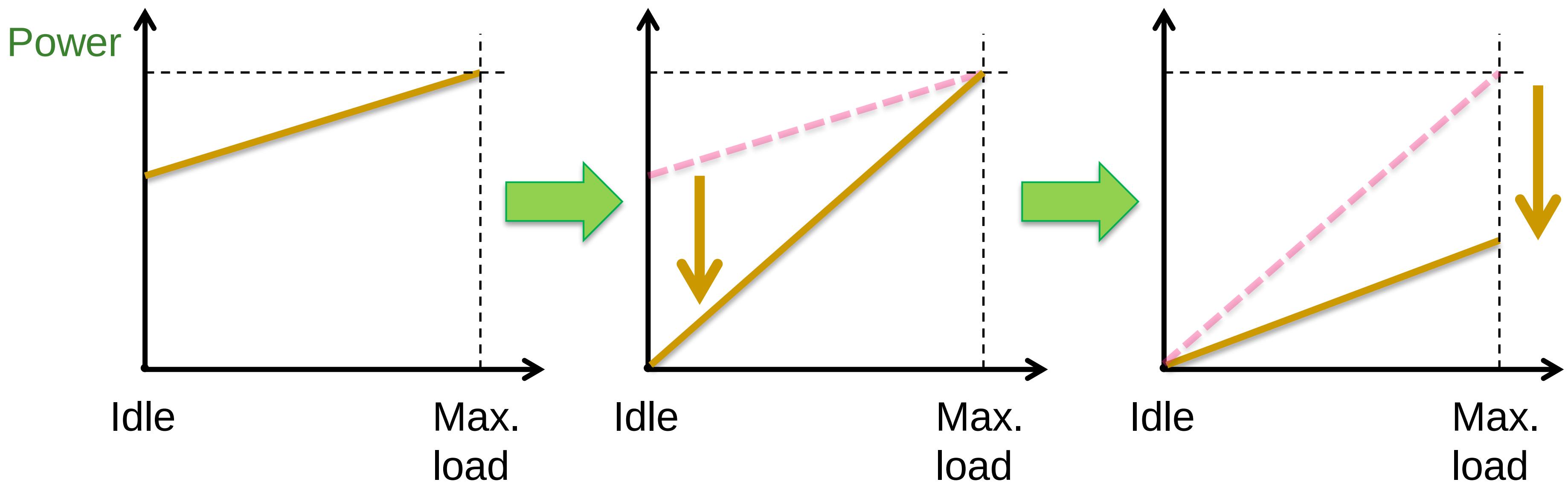
India:
+ 800 M people using the Internet

→ A whole lot of (potential) extra traffic !!

Source: ITU, percentage of individuals using the internet, http://www.itu.int/en/ITU-D/Statistics/Pages/stat

Research directions: general approach

General approach remains: **More power proportional (components and systems)** **More energy efficient**



Conclusions

- Joint CAGR: **7%** (doubling per decade)
- Vs. global electricity consumption: **5% share** and growing
- But**: lower CAGRs than before 2007**.
  → Some (unintentional?) energy-efficiency effects seem to have an impact (e.g. data centers, PCs)
- All three considered categories – communication networks, computers and data centers – represent an **equal share** in the total electricity consumption
- 5-yearly updates needed to see where we are headed, and evaluate efforts

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Part III

- Evaluating (cost) incentives for implementing energy-saving approaches

Incentives for energy-efficient networks

- General and practical guidelines to improve energy-efficiency and carbon footprint in networks.
- Identification of major societal and economic challenges
- Provide **economic incentives** to induce energy-aware behaviours of:
  - Users
  - Equipment manufacturers
  - Operators

Two use cases considered

- Use case 1: Fiber to the Home with home router virtualization as EE solution
- Use case 2: Wireless access with network sharing as EE solution

Motivation

Use case 1: wired access – FTTH

- Initial observation
  - A lot of energy consumption goes to the CPE
  - This is paid for by the consumer, but the CPE choice is mainly influenced by the operator
  - The operator has no initial incentive to reduce this consumption

- Goal
  - Internalize the energy consumption for CPE into the objective function of the operator

Options to reduce energy

Use case 1: wired access – FTTH

- Possible schemes for energy reduction at CPE:
  - Sleep mode operation
  - Proportionality to network load
  - Home router virtualization
  - Open access – shared infrastructure
- Two categories of EE techniques at CPE side
  - (+) Options leading to lower costs for the operator
    ➔ in real interest of the operator [first focus]
  - (-) Options leading to higher costs for the operator
    ➔ can be enforced by regulation / taxes

Methodology

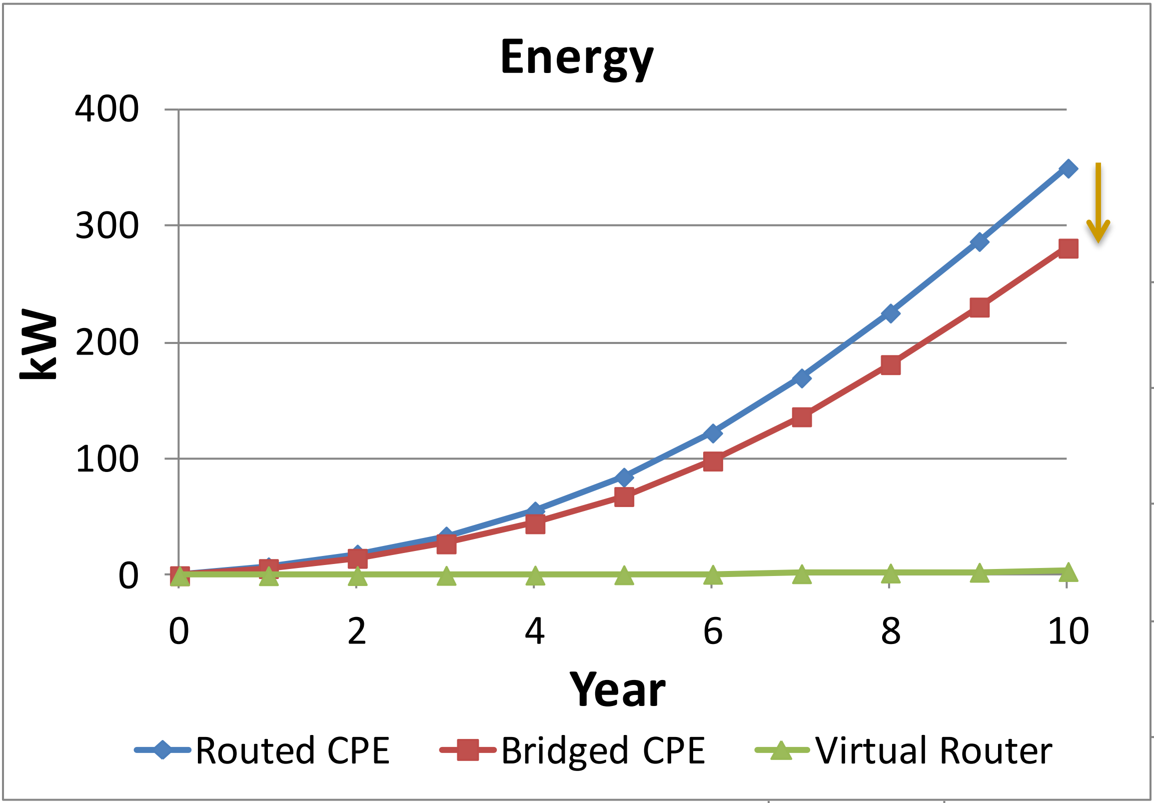
Use case 1: wired access – FTTH

- Scenario for quantifying home router virtualization
  - GPON technology, 1 operator
  - Time frame of 10 years
  - Routed home gateway vs.
    bridged home gateway (+virtual router at operator side)

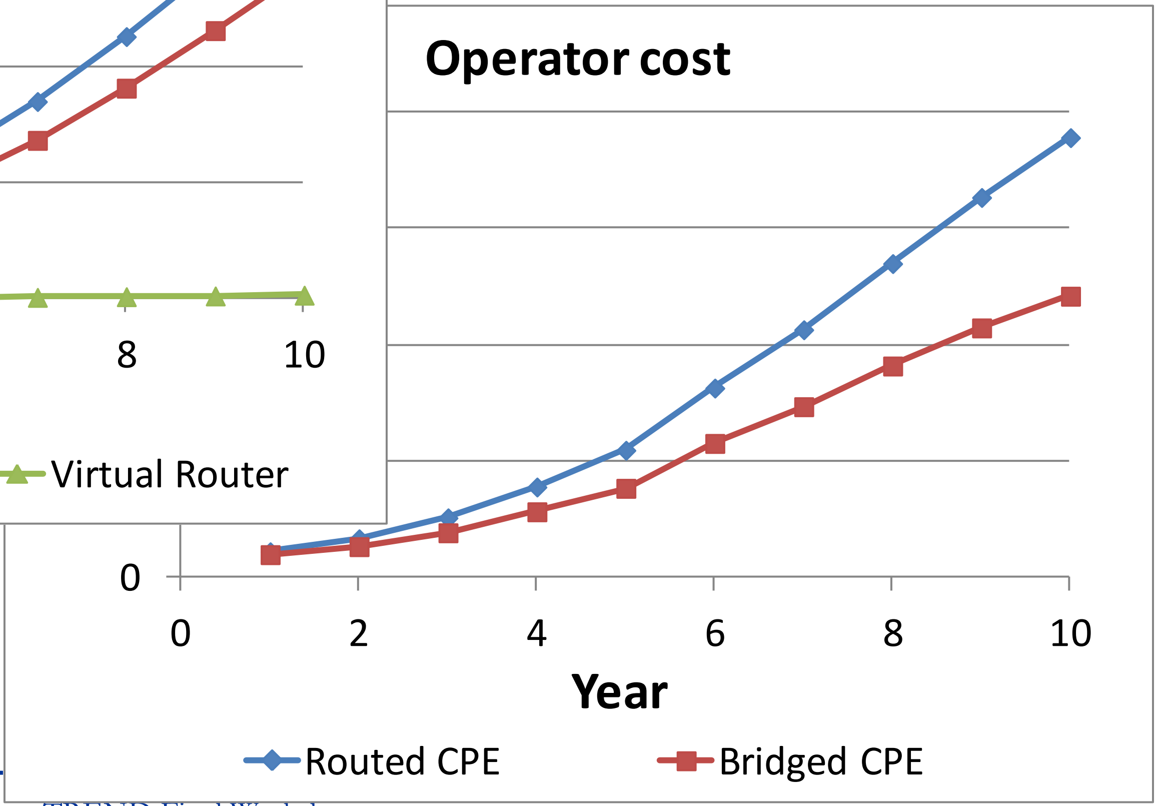
- Total Cost of Ownership (TCO) model, including:
  - Equipment cost of home gateway
  - Operational gains to verify the incentives for introducing home router virtualization
    - Maintenance (reducing number of faillures, affecting operator's OpEx)
    - Energy consumption (mainly affecting customer side)

Results

Use case 1: wired access – FTTH



20% reduction
(ca. 22k users connected in Y10)



Motivation

Use case 2: wireless access

- Initial observation
  - A lot of energy goes to base station
  - The operator is directly interested to reduce the consumed energy at the BS
  - The vendor should develop hardware that supports the reduced energy consumption

Options to reduce energy

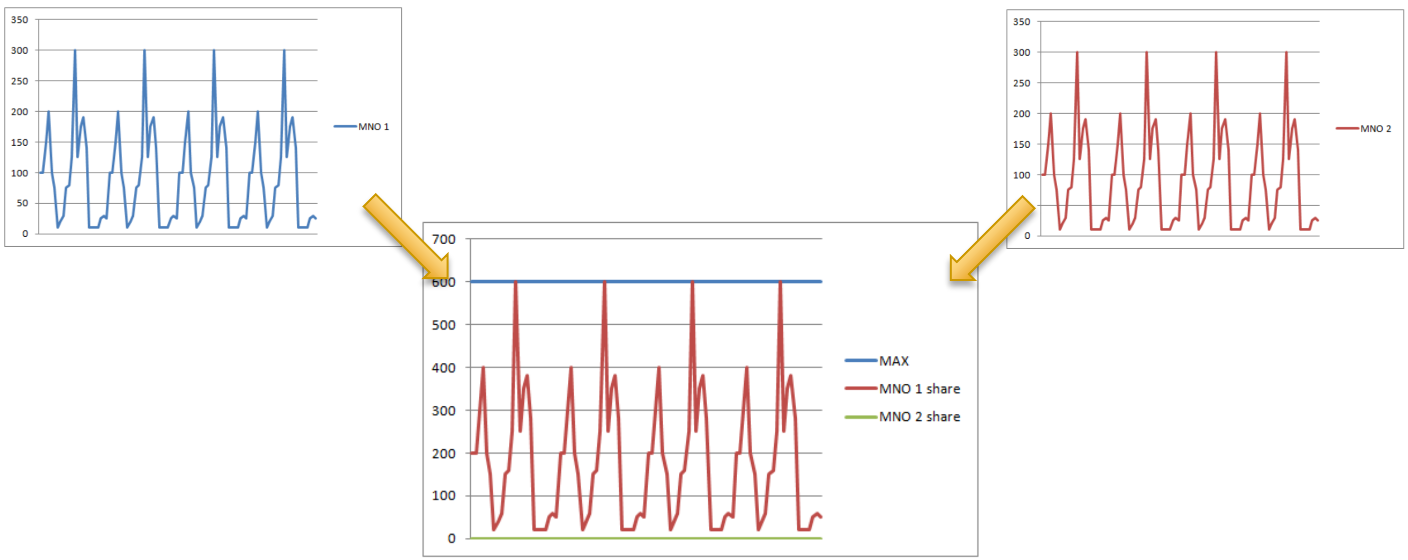
Use case 2: wireless access

- Possible schemes for energy reduction at BS:
  - Sleep mode operation
    - Coverage holes can be a problem
    - You need technology that can be switched off safely
  - Network sharing
    - Incentive is that you have no problem with coverage holes, leading to increased QoS
  - Optimal network deployment
  - Heterogeneous networks (macro / micro / femto)
  - Hardware optimizations
    - Lowering the power consumption at zero load

Methodology

Use case 2: wireless access

- Combine traffic of multiple MNOs on 1 network (if possible)



- Calculate energy consumption and cost

$$C_n(f_i(t)) = \begin{cases} a_n \cdot U_n(f_i(t)) + b_n, BS \quad is \quad on \\ 0, BS \quad is \quad off \end{cases}$$

Game theoretic evaluation

Use case 2: wireless access

- Game theoretic simulation to evaluate competition between operators sharing their networks
- Is network sharing sustainable?
  - What are the dominant strategies?
  - What is the optimal strategy?

		MNO1		
		Roaming price 1	Roaming price 2	Roaming price 3
MNO 2	Roam	payoff MNO 1, Payoff MNO 2		
	Do not roam			

Results

Use case 2: wireless access

- Nash & Pareto optimal solutions
  - Nash: High price is dominant strategy for MNO 1
  - Pareto (social optimum): network sharing is desirable

		MNO1		
		Roaming price L	Roaming price M	Roaming price H
MNO 2	Roam	-11.95 ; -0.85	-4.34 ; -8.46	71.80 ; -84.59
	Do not roam	-10.86 ; -10.86	-10.86 ; -10.86	-10.86 ; -10.86

- Incentives to roam
  - Divide cooperation benefits between operators
  - Regulation on roaming price could be beneficial

Conclusions

- Several energy efficiency solutions can also lead to lower costs for the operator
  - Home router virtualization in fibre-to-the-home

    ➔ Reduced maintenance: main driver

    ➔ Reduced energy "as a bonus"
  - BS sharing in wireless access

    ➔ Some cooperation benefits possible for host and roaming MNO

    ➔ Regulation can help to enforce roaming & reduce energy