A backgrounder in Green ITC

- For the 2 nd COST 804 Training school on Energy savings in distributed systems, April 2012
- Based in parts on the preparatory course on Green ITC at Copenhagen COP-15 Climate conference for government and industry experts

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aim: zero emissions

Preamble on this Backgrounder on Green ITC

- Facts , methods, issues and approaches
- This is NOT a research presentation
- Help you to put your own research into context
- Sometimes to evaluate the true impact of your own research, or to formulate new research ideas
- Very dense
- To serve as a reference and validation tool

Introduction to the backgrounder

- Facts you need to know about, irrespective of your research in Green ITC
- Open up on highly multidisciplinary issues
- Helping identify where the big energy and emissions savings are
- Survey technical or regulatory approaches (without details, found elesewhere)
- Showing there is no single and no simple solution

ITC roles in sustainable societies

Roles can be classified into 3 groups ALL relying on networks with causal inter-relations :

1. Direct technological effects
2. Indirect contributions through changes in the behavior of individuals and organizations
3. Promotion of the overall decision-making capability of the society

Examples of 2: Telework, telecommuting, sensor networks to monitor the environment,trading of CO_2 emissions rights

Examples of 2: Avg. American uses 30 x more light (in lumens x time) than avg. Indian , and x10 more than a Chinese

Examples of 3: Implement and verify sustainability regulations

Key aspects of Green ITC

- Contribute concretely, by itself or alongside other technologies, to common climate, natural ressource, biodiversity and environmental improvements
- Develop innovative technologies which bring once deployed sustainability benefits
- In so doing, respect and address social, cultural and economic development aspirations, as well as the local usage context
- Evolve regulations, laws and policies whereby Green ITC contribute to the goals above
- Combining ecology and business, to grow new business
- Contribute to european competitiveness

Backgrounder focussing on ..

- Contributions by IT, communications, process control , microelectronics, modelling and storage technologies towards reductions in CO_2 & other emissions via:

1. Energy efficiency
2. Efficient power distribution
3. Electrical energy storage
4. Services and support

, aggregated under the term « ***Green ITC*** »

NOT focussing on

- Climate science
- Environmental sciences
- Waste processing and recovery
- Policy making, developmental and international politics
- Energy supply technologies / markets
- Power generation
- Renewable energy production
- Electrical cars
- Market studies

and a « miss » (by incompetence) : Intelligent transportation systems

STRUCTURE

- 1. Units, climate & energy types
- 2. Methodologies
- 3. Component technologies
- 4. Green Information systems
- 5. Green Communications networks
- 6. Power grids
- 7. Other networks
- 8. Buildings
- 9. Economics, trading and business
- 10. Policies, Regulatory design
- CONCLUSION

THREATS (According to IEA)

Source : World energy outlook 2011

« If we fail to take dramatic action in terms of how we look at and consume energy, we will very soon pass the point of no return where opportunity to repair climate change and global warming has passed »

« For each 1 $ put in energy savings, must be later added 4,30 $ to reduce the higher CO2 emissions »

Notes: 1) 2010 ww CO_2 concentration in atmosphere was 5 % higher than last record in 2008, and 9 % higher than in 1992 (Source UNEP 2011)
2) 2010 *subsidies* to fossil energy worldwide 400 Billion USD
3) « 450 Scenario »: > 450 CO_2 particles per Million ; >50 % probability of atmospheric heating of 2 degrees C
4) In 2035 90% of energy consumption (99 barrels oil equiv. /day/inh.) comes from non OECD countries, of which 75 % fossil

1: UNITS, CLIMATE & ENERGY POLICY TYPES

Power conversion factors

Power	from watts	from kilowatts	from HP (550ft-lb)	from HP (elec)	from BTU/hr	from ft-lb/sec	Power
watt	1	1000	745,6998716	746	0,29307107	1,355817948	watt
kilowatt (KW)	0,001	1	0,745699872	0,746	0,000293071	0,001355818	kilowatt (KW)
Horsepower (550 ft-lb)	0,001341022	1,34102209	1	1,000402479	0,000393015	0,001818182	Horsepower (550 ft-lb)
Horsepower (electric)	0,001340483	1,340482574	0,999597683	1	0,000392857	0,00181745	Horsepower (electric)
BTUs per hour	3,412141633	3412,141633	2544,433578	2545,457658	1	4,626242868	BTUs per hour
foot-pounds per second	0,737562149	737,5621493	550	550,2213634	0,216158128	1	foot-pounds per second

Energy conversion factors

Energy	from erg	from joule	from watt-hour	from KWH	from BTU	from therms	from foot-pounds	from calorie (heat)	from calorie (food)	**Energy**
erg	1	10000000	36000000000	3,6E+13	10550558526	1,0548E+15	13558179,48	41868000	41868000000	erg
joule (watt second)	0,0000001	1	3600	3600000	1055,055853	105480400	1,355817948	4,1868	4186,8	joule (watt second)
watt hour	2,77778E-11	0,000277778	1	1000	0,29307107	29300,11111	0,000376616	0,001163	1,163	watt hour
kilowatt hour (KWH)	2,77778E-14	2,77778E-07	0,001	1	0,000293071	29,30011111	3,76616E-07	0,000001163	0,001163	kilowatt hour (KWH)
BTU	9,47817E-11	0,000947817	3,412141633	3412,141633	1	99976,12898	0,001285067	0,003968321	3,968320719	BTU
therm (US)	9,48043E-16	9,48043E-09	3,41296E-05	0,034129563	1,00024E-05	1	1,28537E-08	3,96927E-08	3,96927E-05	therm (US)
foot-pounds	7,37562E-08	0,737562149	2655,223737	2655223,737	778,1692623	77798350,53	1	3,088025207	3088,025207	foot-pounds
calorie (heat)	2,38846E-08	0,238845897	859,8452279	859845,2279	251,9957611	25193560,71	0,323831554	1	1000	calorie (heat)
calorie (food)	2,38846E-11	0,000238846	0,859845228	859,8452279	0,251995761	25193,56071	0,000323832	0,001	1	calorie (food)

1 PetaJoule (PJ) = 0,278 TeraWatt-hour (TWh)

1 Mtons hard coal eq (Mtoe) = 29,16 PJ

1 Megawatt electric (MW or MWe) =One million watts of electric capacity

Emissions

- Issue 6 gases : CO_2, Methane (CH_4), Nitride (N_2O), Hydrofluorcarbonates (HFC), Perfluorcarbonates (PFC), Sulfur chlorid (SF_6)
- HFC an PFC attack the ozon layer; the other 4 maintain a greenhouse effect; CH_4 is 16 time more « effective » than CO_2

The coal lobby

Sources: BP Statistical Review of World Energy 2011, Coal Initiative Report

REGION	Production (2010, Mtoe)	Consumption (2010, Mtoe)
China	1800	1713 (*)
East Asia & Australia (wo. China)	709	671
North America	591	556
Europe and Central Asia	431	486
Africa	145	95
Latin America	54	24
Middle East	1	9

* : Usage distribution (China) : 55 % Electrical power, 26 % Industry, 4 % Heating, 15 % Misc.

Natural gas as a substitute for petrol

- Issue: some countries and sectors want to use natural gas as a substitute for petrol over time, and indexation of gas on oil prices will vanish; gas is the cleanest fossil energy source,and supplements well wind and sun; it has also the same big advantage as oil in flexible storage
- Prices: now natural gas is cheaper than oil on an energy per BTU basis: 12 USD for 1 MillionBTU for oil, vs. 4 USD for gas
- Specifics: high gas transportation costs lead to different gas prices (even for LNG) in different locations (now largely 3 regional markets functioning separately); gas pipelines are more expensive than oil tankers; disruption coming from increased LNG output from remote fields; disruption from cheap unconventional gas resources; CO_2 emissions from natural gas is 50-70% less than coal
- Approaches: natural gaz combined cycle power plants (50 % less emissions per kWh, compared to coal plants, as electricity is produced both after combustion and after recuperation chamber) ; compressed gas as a substitute for petrol or diesel in transports
- Policy decision: natural gas offers fastest substitute to coal in total emissions wrt, electricity supply
- Research issue: natural gaz as a cheaper alternative medium term to renewables , while cheap electricity from natural gas can make hybrid power plants (Gas/renewables) very attractive also for industry use

Biofuels

- Issue: 1) produce useable liquid diesel fuel (or combustion gas) from plants, biowaste and sewage

  2) adoption of homogeneous quality assurance in view of their big heterogeneity (EU Projetc Bio-NORM)
- 1 st generation : From Oil and sugar in consumable parts of plants(palm, maize, colza,sugar beat, cereals) ; Processes: Fischer-Tropf, Fermentation/ Extraction
- 2 nd generation: From non-consumable plant and tree residues, as well as sewage; Processes: Pyrolysis / Gazeification / Catalytic synthesis , Enzyme based extraction, Supercritical technologies;
- « 3 rd generation »: Algae

Nuclear energy

- 2010: 440 nuclear reactors operating w.w, providing 14-16 % of the world's electricity production , with 340 new being planned (incl. 59 under construction) (Source : Paladin Energy Ltd) ; they consume 170 MLbs/year of natural Uranium

- It is a low carbon energy source on a whole fuel cycle basis , and recycling is being improved in 3 rd generation reactors, leading ultimately to hopes in nuclear fusion (ITER Project, cold fusion research)

Hydro energy

Sources: IAE, Intl Hydropower assn

Hydro electricity (2010)	TWh / y	Notes
China	585	
Canada	383	
Brazil	370	
USA	282	
Russia	167	
Norway	141	Covers 98% domestic demand
India	114	
Venezuela	87	
Japan	83	
Sweden	69	Covers approx. 45 % of domestic demand; rest nuclear

Fossil energy is not renewable

Source: E. Kinderman, H. Crane, SRI Intl

A very… simplified presentation

How to replace *during one year* 1 cubic Mile (4,17 km3) of raw oil (approx. current worldwide energy consumption *per year*)? This can be achieved by installing either :

-104 new coal fired plants, each year for 50 years

-3 new Three Gorges Damms each year for 50 years

-32850 new wind turbines each year for 50 years

-91 250 000 new solar panels each year for 50 years

-52 new nuclear power plants each year for 50 years

Relative production costs of electricity from main energy sources (2010)

Sources: IEA, SIA Conseil ; data are time and location dependent

Production cost (FR)	(Eurocents / kWh)	
Hydro	1,8	
Diesel	5,3	Very variable
Nuclear	4,2	
Gaz plants	6,1	
Terrestrial wind	8,4	
Offshore wind	13,3	50 % less with 7 MW turbines; high OPEX
Biomass & waste	5-50	Depends on raw material and logistics
Photovoltaics	26,4	CAPEX falling fast
Solar energy→H2	?	Photosynthesis

Carbon intensity (CO2) factors of common fuels

(Source : www.bp.com)

Fuel	CO2 : kg CO2/kWh
Natural gas	0,19
LPG	0,21
Heating oil	0,27
Hard coal	0,32
Wood	0
Gasoline / petrol	2,30
Diesel	2,63

Carbon intensity factors and costs of common fuels : there is a lot of debate around this conversion factor ; the BP source uses 0,5460 kg CO2/kWh ; some use 0,53 kg CO2/kWh ; the NEF and the Carbon Trust, plus OFGEM, all use the 0.43 conversion factor (see the calculator in the link below), this also gives the conversion factors for other fuel types; http://www.nef.org.uk/energyadvice/co2calculator.htm

Emissions data

- CO_2: approx 387 ppmillion (2009); ceiling considered by some to be 350 ppm
- Methane : uneven concentration but effect 6-25 times faster than CO_2
- Stratospheric ozone: concentration must be over 276 Dobson units (2009: 283 Dobson)
- Acid oceans (aragonite) : saturation level at max 2,75 (2009: 2,90)
- References: Hadley Centre global environment model HadGEM2-ES, NCAR model

Emissions to air per GJoule of heat output, for different types of emissions

HEATING : emissions to air per GJ of heat output	Primary energy MJ	GWP kg	AD g	VOC mg	HM mg	PM g	To water HM mg
Electric, per GJ	3045	132	784	1147	180	17	6
Gas , 86 % atmospheric	1163	64	19	846			
Gas , 90 % atmospheric	1111	61	18	809			
Gas, 101 % condensation	990	54	16	721			
Gas, 103 % condensation	971	53	16	706			
Oil , 85 % atmospheric	1176	87	110	1519		2	
Oil , 95 % condensation	1053	78	98	1360		2	

GWP: global warming potential (Co2, CO, NOx)
AD: acidification potential (SOx, NOx)
VOC: volatile organic compounds (CxHy)
HM: heavy metals toxicity incl. CO
PM: particulate maters

Basis for nationally targetted reductions: Electrical consumption / inhab. / year (kWh) Source: IEA

NB: average *prices* / kWh across Europe vary by 35 % (min: Scandinavia, Max: Italy)

Country (2010)	kWh/inh./y	Notes
Norway	24 868	98 % comes from 1166 hydro plants; large industrial use
USA	13 843	
Japan	8 331	
France	7 302	Differential to DE due to much larger share of electrical heating; a temperature change of (-1 degree) leads to +500 MW in DE and +2 300 MW in FR
Germany	6 684	
UK	5 996	
South Korea	5 901	
Spain	5 248	
Italy	5 228	
Iceland	4752 (excepting Al industry)	<5 % emissions due to 98 % hydro or geothermal use; location for data farms

Electricity consumption is NOT proportional to GNP, nor inversely ppt. to avg. temperature

Sector targetted reductions:
Case of Norway (Source: SINTEF Gemini)

Sector	1998 Emissions Mton	<2012 Possible reduction Mton	Green ITC share
Oil/ gaz production	17,6	5,0	*
Industry	12,1	8,1	**
Land transport	9,7	2,8	*
Sea transport	3,8	0,8	*
Air transport	1,4	-0,6	
Agriculture	10,8	2,7	
Households	2,4	2,2	**
Offices	6	4	***
TOTAL	63,8	25	

Green ITC contributions can best be achieved in Industry, Offices and Manufacturing

Another segmentation for CO_2 emissions by sources

(Source: Siemens Pictures of the future, Spring 2007, p.83)

Share in CO_2 emissions 2006 (40 Billiontons CO_2e)	**%**
Industry (*direct* emissions from processes and direct primary energy)	23 %
Industry (*indirect* emissions from electric power)	11 %
Buildings and offices (*direct* emissions from primary energy consumption)	8 %
Buildings and offices (*indirect* emissions from electric power consumption)	13 %
Transport	14 %
Forestry	14 %
Agriculture , waste	18 %

Changes in CO_2 emissions by sector

Source: IEA-11

Sector	Average annual CO_2 emissions change (1990-1998)
Manufacturing	0,6 %
Households	0,9 %
Travel	1,8 %
Services	2,0 %
Freight	2,2 %
IT	3,5 %

Seven ways of reducing emissions

1. Technology, and technology transfers
2. Design of products and of their « containers » (buildings etc.)
3. Standards
4. Regulations
5. CO_2 Taxes with re-investments subject to social issues
6. Emission rights (markets or quotas « cap and trade »)
7. Changing behaviors of economic agents

NB: all this in addition environmental protection measures (forests, biodiversity, polution control, recycling..)

« Green ITC » impacts at two levels..

- How to produce and distribute energy efficiently (smart grid, controls for renewable sources, co-generation controls)

- How to save and use energy more efficiently (aircon and heating controls, controls for electrical motors, communication networks, household appliances, lighting systems, rail systems)

But …ITC can contribute to UNsustainability

- Very often ITC can be detrimental to the environment , due to induced side-effects , or cascaded causalities

- *Examples from telework* :

  -actual reduction in transport due to telework is less due to an increase in other non-work commuting travel (such as personal trips during the day, later trips to the office, increase in customized deliveries to teleworkers, etc)

  -increased transport due to wider use of e-commerce for physical deliveries

Distributed systems / networks are everywhere

- Conventional : power networks, communications networks and LAN’s, light distribution networks , signalling and transportation systems, etc.

- High usage / many user new types: homes and offices , home and office appliances & energy controls

Europe’s position

- Europe in 2009 held 45% of worldwide green business, according to Siemens CEO Mr. Löscher

- European environmental industries in 2009 generated sales of 2,2 % of EU’s GDP and employed 3,4 M people (according to EU)

2005 global market for environmental technologies

(Source : Siemens)

Global market segments 2005	BillionEuros	CAGR 2005-2020 (%)
Energy efficiency (process measuring and control, electric motors)	450	5%
Sustainable water treatment & management	290	6%
Energy generation (renewable energies, clean power)	190	7%
Sustainable mobility (alternative drives, clean engines)	170	5%
Natural ressources and material efficiency (biofuels, insulation)	90	8%
Recycling, waste, automatic separation	20	3%
Green ITC	?	?

1997 « CCNUCC » UN Kyoto treaty (signed 11/12/1997)

- Decision 1: the industrial countries reduce total emissions by 5,2 % before 2012, compared to 1990 ; developping countries are exempt for the time being; 3 countries may increase their emissions : Iceland (10 %), Australia (8%), Norway (1 %); Russia,Ukraine and New Zealand must stabilize on 1990 levels; 8 european countries must reduce by 8 %(BG, EST, LV,LT, LI, MC, RO,SLO, SLOV, CH, CS); USA must reduce by 8 % , CDN, HU, JP, POL by 6 % ,and CRO by 5 %
- Decison 2: emissions quotas can be traded, but modalities are not given
- Decision 3: common execution is allowed , that is e.g. NO can finance reductions in EST and carry over the reduction in its national accounting
- Decision 4: forest plantings are accepted as CO_2 reductions, but only with new plantations done after 1990
- Decision 5: the agreement is enacted when >55 countries have ratified it, and these countries represent >55% of industrial countries total emissions

NB: A Biodiversity treaty was also signed

History of 1997 UN Kyoto treaty implementation status (due 2012)

- US: Rejection (2001)
- EU, Japan, Canada: legal ratified obligation, enforceable before a national court (or Luxemburg court) ; Canada's conservative govt, opted *out* of agreement 12/12/2011 (having failed to meet -6% emissions objective by 2012)
- BRIC: no action ,no ratification, except benefiting from CO2 emissions credit sales
- Process history: Rio « Earth summit » (2002), COP (Confederation of the parties) annual conferences

Copenhagen COP 15 agreement (Dec 2009)

A very vague 3 page political declaration, without any formal commmitment,with following points

1. The stated goal is to reduce temperature by 2°C (there is no reference date nor means)
2. States can make unilateral propositions on CO2 reduction (for industrial states) or of limitation (developing economies) (some have been made, but cumulated effect is judged insufficient)
3. Additional « fast start » 21 Billion Euros (of which 7,2 Billions by Europe) are promised to poor countries during 2010-2012 to face the consequences of climate change, plus 72 Billion Euros annually before 2020 to be managed by a Green Climate Fund
4. New financing modes will be studied to fund efforts against the climate warming

The developing countries played the « blame game » ….

Cancun COP-16 (2010) and Durban COP-17 (Dec 2011)

Resolutions concerning:

1. Redd+ : deforestation agreement to finance the protection of tropical forests
2. Discussions on the Green Climate Fund governance
3. Discussion on the implementation of the « fast start » funding , and on the origin and the items which could be financed by the 75 Billion Euros annual aid (by 2020)
4. Discussion on verification means of achieved reductions
5. No discussion on the globalization of emissions rights trading
6. In Durban, a toothless meeting, with only support for a working party which would involve China, India etc for a draft reduced protocol in 2015 to get in force in 2020; it would <u>not</u> be legaly binding , but sofar main polluters (US, China, India) intend to join in; the Kyoto agreement stays in place untill replaced
7. Next meetings 20-22/6/2012 « Rio+20 » Earth Summit supposedly organized by UN Commision on sustainable development , and end 2012 in Qatar COP-18

NB: Last International science council meeting (ICSU), made up of 140 scientific national bodies , met in London 03/2012 under name « Planet under pressure » to prepare 7.

Evolution of the climate debate

- GIEC Intergovernmental expert group on climate evolution (Nobel prize) considered by some as reference expertise, but it’s procedures have been criticized
- Higher transparency on data via a new analysis by UK Metoffice of 150 years of ground and sea temperatures ,and opening up this data pushed by Climate Code foundation
- Royal society categorization of issues into consensus issues, debated issues, and little understood aspects
- Multipolar debates on the connections between the climate and policies
- Pragmatic approaches with 3 principles: a) benefits for climate from adapted policies in such fields as health and poverty; b) necessity to encourage public investment in low carbon technologies; c) setting up new institutions and partnerships more diversified than UN

Where it all comes together: megacities

- Case: German city of 10 Minhabitants (with 5,6 M cars) in 2004 required 220 PJ of electrical energy/y (=61 TWh/y), corresponding with german energy mix to 10 GW power plants, which in turn require 670 PJ of primary energy (1120 PJ/y delivered) and produce 35,5 Mtons CO_2 (Source : Siemens Pictures of the future, Spring 2007)
- In this total the following items are related directly to ITC : household electricity (60 PJ), of which ITC 6 PJ (10 %) ; industry and commercial electricity 150 PJ of which 60 % for machines and ITC (90 PJ) ; industrial lighting and commercial signposts 16 PJ (11%) and household lighting 4 PJ(6%)
- Most efficient measures : cutting losses in energy distribution (heat, electricity) (36%) , household space heating , fuels for transportation
- « Model communities » with full or very high energy self-sufficiency (except car fuels) via renewables and waste processing : Samsoe island (DK), Växjö (SE) (80 000 inh.) ,Sanford Walk in London

2: METHODOLOGIES

Key issues in estimating/modelling energy/ emissions in networks

- Issue: Very few models have been calibrated with physical energy and emissions measurements, besides full context and control data
- Key problems :

1. Component / sub-system energy/ emissions are highly non-linear with usage
2. Emissions are NOT proportional to energy consumption , due to side-effects such as gas emissions, particles emissions etc
3. The environment has daily and seasonal variations
4. Usage and human activity have daily and seasonal variations

- Therefore the selection of the integration windows is essential, and misleading results may be obtained (contradicting measurements) if the window is not the largest common denominator
- Case: Boiler emissions study for UK Dept Industry (Imperial College, Building research establishment, Danfoss, Honeywell)

Effect of distributed network control vs. other active and passive mesures

- <u>Methodology</u>: When researching or analyzing a concrete energy savings problem, estimate objectively the relative contributions of :
- 1) distributed network controls
- 2) other active measures on the system
- 3) passive measures on the context
- 4) active measures on the context esp. users/usage
- Also, wen trying to optimize energy savings over usage time and users, beware just doing a sub-optimization , while mapping out the characteristics of all sub-systems is still essential
- <u>Example</u>: data centers facilities rather than an algorithm alone
- <u>Example </u>: impact of a reduction of 70 kWh/m2/y of energy use in buildings qnd offices (compared to average of 260 kWh/m2/y) (42 % of total energy consumption) , compared to investments needed to reduce losses in power grids
- <u>Example</u>: sustainable cities rather than sustainable buildings alone (e.g. Solarsiedlung am Schlieberg, Freiburg, DE)

Common methodologies

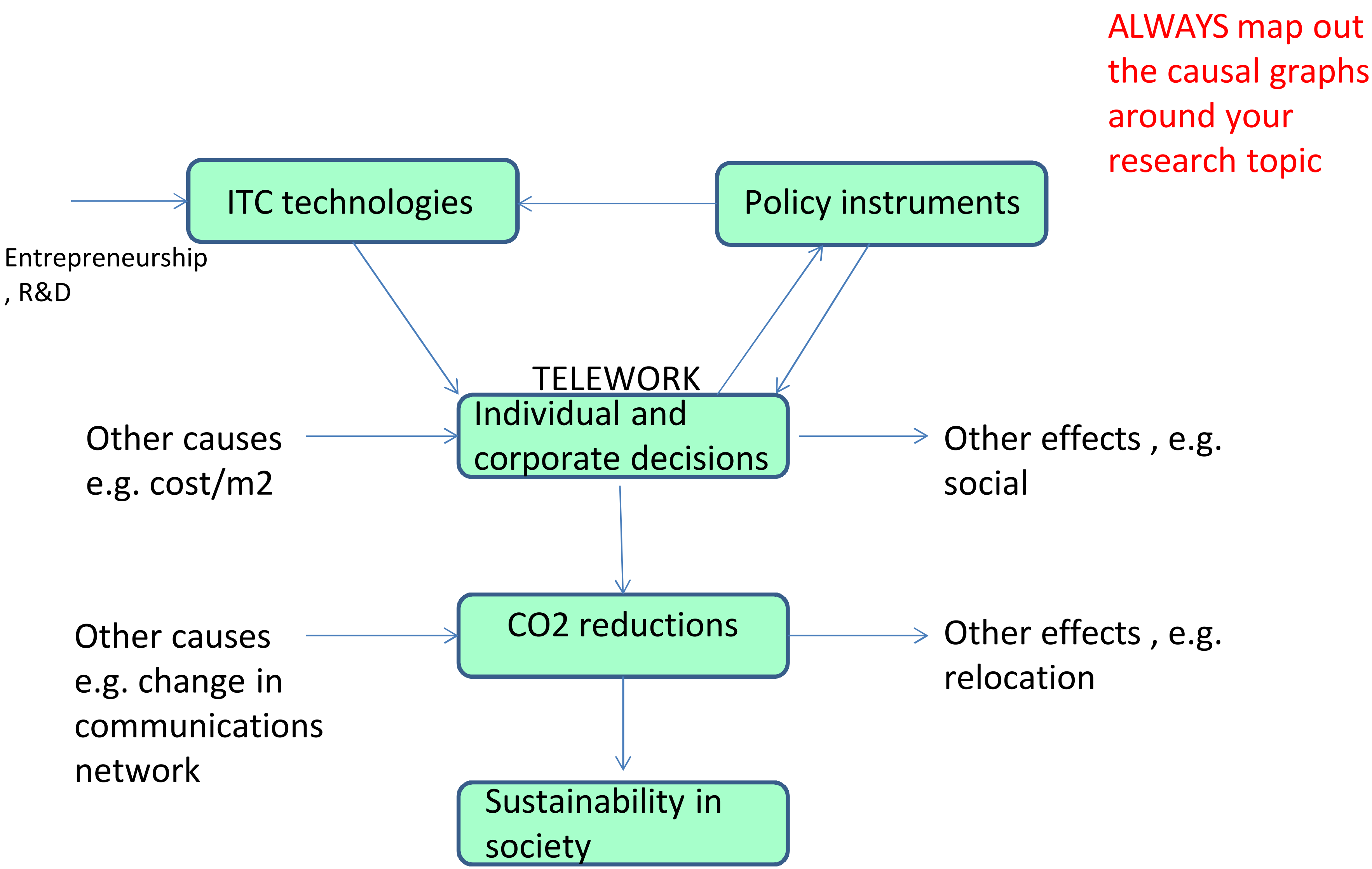
- Labels , certification and standards e.g. ISO 14001: human designed and implemented inspection and evaluation processes
- Causal analysis (multi-factor): determine the net effects of all factors (direct,indirect, physical, human, economic, regulatory) part of, or contributing to, an energy use or emission
- Multi-criteria analysis: use of several quantitative or interval-based scales to compare alternatives , using Pareto or dominance relations
- Life-cycle cost-benefit analysis: over the life-time or a product / service / process, evaluate quantitatively all costs and benefits (direct and indirect), and aggregate them by a metric
- Hierarchical optimization: apply a sequence of optimization algorithms (static, dynamic) to nested system decompositions and metrics leading ultimately to system energy / emissions , while satisfying constraints

But in most cases the issues are so complex and multidisciplinary that the contribution by any methodology by itself is microscopic, and different ones lead to different results

Standards, certification, “labels”, corporate policies and citizen responsibility

- The net effects of normative guidelines : individual behaviors and conduct lead in a faster and cheaper way to end-results , than sometimes costly and slow compliance and auditing schemes
- Compliance to normative schemes must be organized and operated in such a way as to ensure clear stable incentives , rather than appearing as cost/effort elements only
- Independent measurements, verification and audits can be costly, but must also have attached incentives, except areas of absolute necessity (high risks)
- General frameworks like ISO-14001 besides company specific
- Research issue: high life-time, energy savings vs. environmental quality (akin QoS) sometimes contradict each other, or reinforce each other
- Research issue: accreditation processes for certification instances and mutual recognition issues

Example of causality analysis : telework



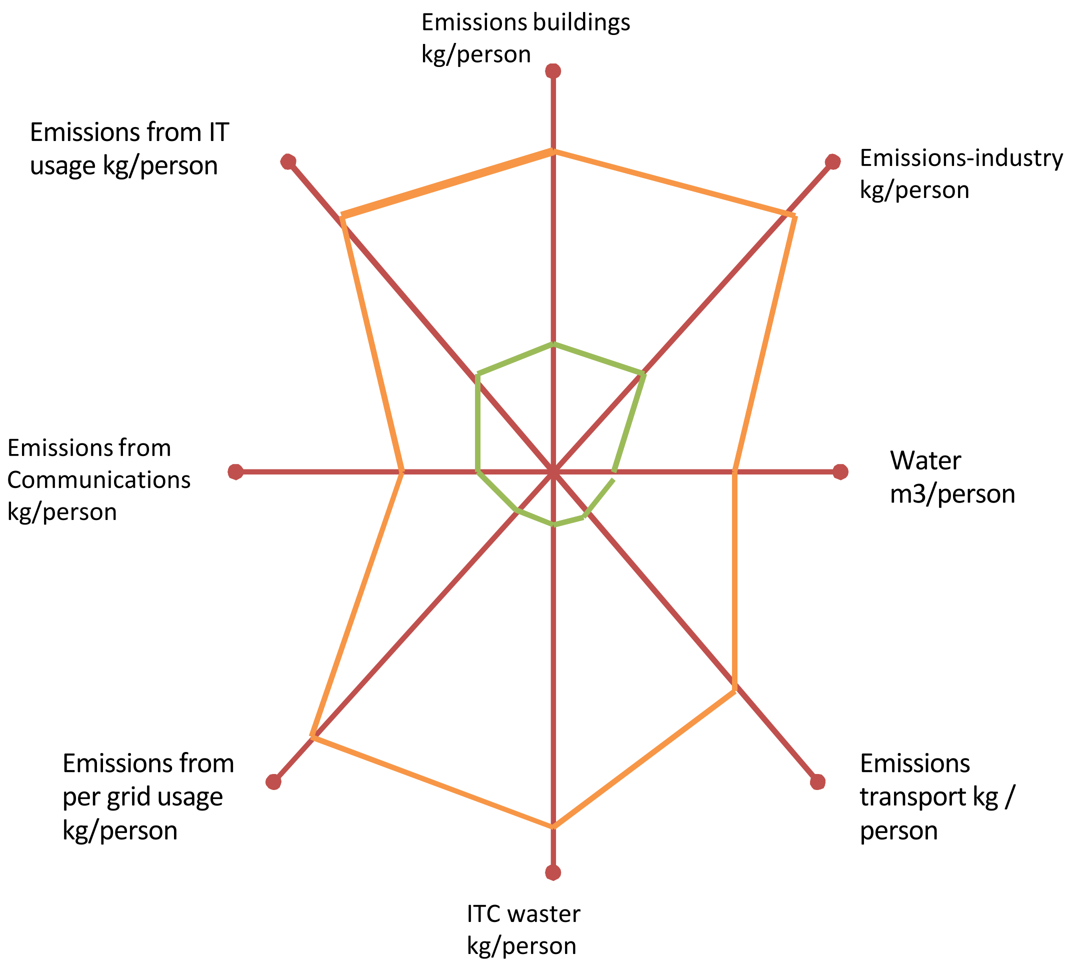
Estimating net effects from causal analysis: example telework (Source: Japan MPT report of May 1998)

Changes in CO_2 emissions due to telework in 2008 in Japan, in ktons CO_2/year

Telework category	Decrease in CO2	Increase in CO2	Net CO2
Home	530	190	-390
Satellite offices	20	0	-20
Video meetings	940	40	-900
Rural offices	360	200	-160
TOTAL	1850	430	-1420

When assessing energy or emissions reductions, ALWAYS account via causal analysis for inverse effects, and estimate net effects

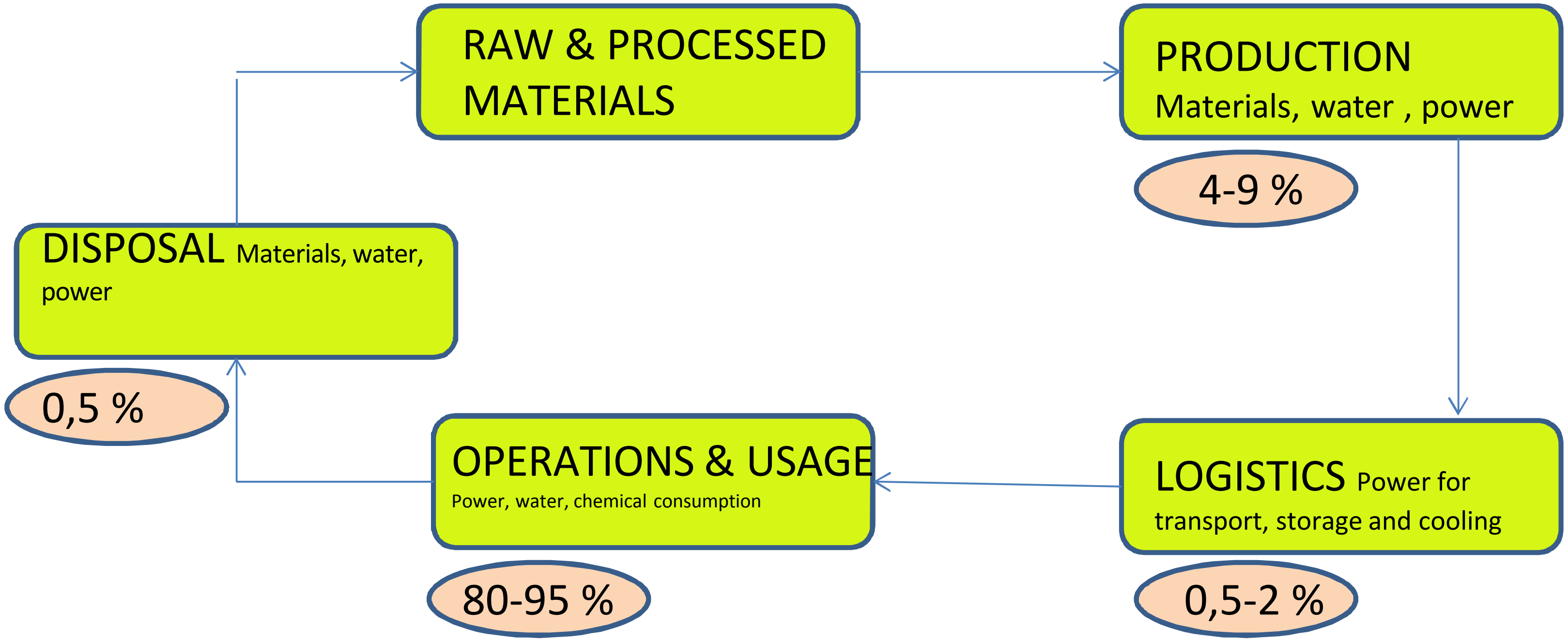
Multiple criteria analysis: Comparative ITC environmental footprints



Life-cycle approach : R&D,architecture, investments, operations and dismantling

- Methodology : in almost all energy savings problems, the life-cycle approach is mandatory and the only meaningful one
- Approaches: life-cycle analysis esp. as for computers and communications, over 80 % of energy used is before it is put in use, while by contrast for a washing machine the opposite is true
- Cases : -GSM networks -low energy construction -electrical power distribution networks in buildings

Looking at complete product life-cycles : the greatest environmental impact is during operations/usage (Source: Bosch & Siemens Hausgeräte)



- CASE : Computing server
- CASE : Tumble dryer appliance
- CASE : 3G base station

Life cycle assessments heighten consumers environmental awareness, and allow to allocate Green ITC efforts

Terminal value

- Issue: End-of life value depends on energy efficiency and constituents
- Cases: -sales value of an energy inefficient building; -sales value of an energy inefficient server
- Effects in theory offset by scrap value, but energy efficient materials often command higher net scrap price
- The slower the improvements in energy efficiency, the slower the reduction in terminl value

  E.g: only approx 7 % annual renewals of office and computing center facilities

Cost-benefit analysis : Metrics to assess the cost of emissions goals

- Methodology : estimate the marginal (also called "shadow") cost of reaching a given emission target, that is the derivative of cost vs. measures and constraints , itself a function of the emissions target
- Tool: Marginal abatment cost curves for CO_2 emissions, per operation and region , for different levels of reductions
- Regulation mechanisms : 1)Computable general equilibrium model: the shadow cost is equal to the tax that would have to be levied on the emissions to achieve the target level , or the price of a traded emissions contract ; the more severe the constraint, the higher the MAC

  2)Bottom up energy models: levying different levels of carbon tax on emissions that result in the different corresponding emission levels
- In all cases, the analysis is fundamentally dependent on underlying energy prices ;thus part of the emission tax is set off by lower energy prices ; also the prevailing energy prices determine the cost of an emission target ; thus reported analysis very often are inconsistent
- For further reading: EU TranSust project

Amortization periods for energy efficient solutions

- Definition : Usage time equivalent of saved energy costs (for prevailing energy tariff at reduced power consumption) when these savings match the additional purchasing cost of an energy efficient version of a system of same performance

Examples	Amortization period
LED vs. Incadescent light	800 hours
LED traffic lights vs. Incadescent	5 years
A++ refrigerator vs. Lower class	4-5 years
Control system at combined cycle power plant	1 year
LTE base station vs. GSM	3 months

Optimization approach hierarchy

MODELLING LEVEL	METHODS/ ALGORITHMS	JUSTIFICATION : e.g.housing case
Top level	Combinatorics	The housing context , equipment choices, fuel choices ,and housing design all are discrete choices addressed by combinatorics
Medium level	Finite elements in time and space	Time sampling is imposed by boiler operations cycles, as well as housing usage. Volumetric sampling is imposed by the interactions between different volumes in different rooms, including walls and separations.
Lowest level	Min Max dynamic optimal control	Taking dynamics in a given time interval and a given volume into account , the maximization of emissions deals with random occurrences due to surroundings , usage (water, people, lighting etc) ,etc under these time and space assumptions .The resulting minimization of emissions is for the dynamic controls applicable to the system . Possibly a cost term to be minimized also would have to do with the thermal comfort for users by minimizing variance from some usage dependent target values

3: COMPONENT TECHNOLOGIES

Power usage in a server (2010)

(Source: Intel Eco-technology program)

Main server components	% of power consumption
CPU	31
Memory	26
Motherboard / voltage regulation	22
Power supply	11
Hard disk	5
Fans	3
PCI Graphics	1
Peripherals	1

« Greening » of Microelectronics

- Issue: innovative architectures, processes, packaging and substrates to reduce power consumption , without limiting too much processing power
- Implementation measures:

1. Migration to 28 and even 15 nm lithographies (-20 % power consumption), but current leakage increases
2. Selected use of graphene, and Si-on-saphire substrates
3. Harmonisation of voltages anc clock speeds
4. At CAD level optimise simultaneously physical properties and thereafter logical properties affecting power consumption (e.g. Mentor Graphics Olympus-SoC tools)
5. At power supply level, increase electrical yield from current 65 % to 90 %

Microcoding and compilers for energy savings

- Issues: a) The more a CPU / ASIC / DSP is in a suspended state, the lower the overall power consumption and eventual drain on a battery

b) The fewer instruction cycles for a given function, the sooner the processor will enter a suspended state

c) Execute in an embedded system periodic functions, optimized for execution speed

- Solution approaches : 1) Assembly microcoding

2) Use optimizing compilers with options

3) In-lining: Insert the entire called function code into the main code body, rather than making a call to an outside function

4) Loop unrolling

5) Remove loop invariant expression from loops

6) Register caching invariant memory references over loops

7) Rotate loop termination tests to the bottom

Powering grid on a chip

- Issue: Supply voltage from outside to a <1 V microelectronic device, requires increasing the input current to more than 100 A per processor ; carrying such high currents around a chip on copper interconnects leads to high conductive power losses ; also a majority of I/O pins (70 %) must be devoted to power distribution with less available for data flows

- Approaches : mixed Si/GaN chips with GaN taking 20 V; shrinking inductors and capacitors (e.g. Cobolt based) in switched mode converters; 3 D designs and converters

Future of low power chips in doubt

- <u>Issue</u>: for lack of theoretical and physical underpinnings of random telegraph noise, there is a problem with the low power regime of small transistors with nanometer thick insulators
- Source: IEEE Spectrum, Aug. 2009, p. 12

Thermal management in high performance computing

- Issue: operators of HPC spend as much removing heat as they do to power the servers; power is 50 % of the cost of a data center; cooling affect the packing density
- Typical processor power (measurements) : Intel core I3/530: 88/133 W ; Intel Core I7/980 X: 147/252 W
- Data(2010) : -7 TeraFlops, in one rack, with 64 servers for 30 kW, power envelope for each chip with 130 W peak

  -Avg. Power efficiency of supercomputers 248 floating point ops./ s / W (Source Top500.org), with much better for MDGRAPE-3 (Riken, J)
- Measure: PUE (total facility power/IT equipment power ratio)
- Approaches: high-k dielectric materials so that power due to leakage is minimized, clock speed adaptation vs. Load, shutting down cores of processors, monitoring of chip temperature / power, reduction of losses in power voltage conversion steps, memory I/O, many disk socket servers, improved fans, « seas of sensors », cryogenic liquids to the chip, supraconducting links

Energy efficiency of semiconductor manufacturing

- Issue: While ignored by computer scientists, energy savings in semiconductor plants and machines are significant and have been reduced fast : facility systems, control of supplies , chillers, variable speed motors for ventilation, frequency controlled vacuum pumps
- SEMI S23 Guide for conservation of energy, utilities and materials

Solar cell efficiencies

- According to NREL (www.nrel.gov) , the best 2010 solar cell efficiencies are:
  - -Three junction concentrators : 40 % (e.g. Boeing Spectrolab)
  - -Single crystal Si : 27 % (e.g. Amonix)
  - -Thin film GaAs : 24 % (e.g. FhG)
  - -Multicrystalline Si: 20 % (e.g. FhG)
  - -Thin film CdTe : 19 % (e.g. NREL)
  - -Thick Si film : 16 % (e.g. Sharp)
  - -Polycrystalline thin-film : 14 % (e.g. United Solar)
  - -Amorphous SiH thin film : 11 % (e.g. Sharp)
  - -Organic cells : 5 %
- While most solar cells are flat, Sphelar solar cells may furthermore use arrays of tiny spheres of Si within a transparent matrix to generate power (e.g. Kyosemi Corp)

Leakage in cables and connectors

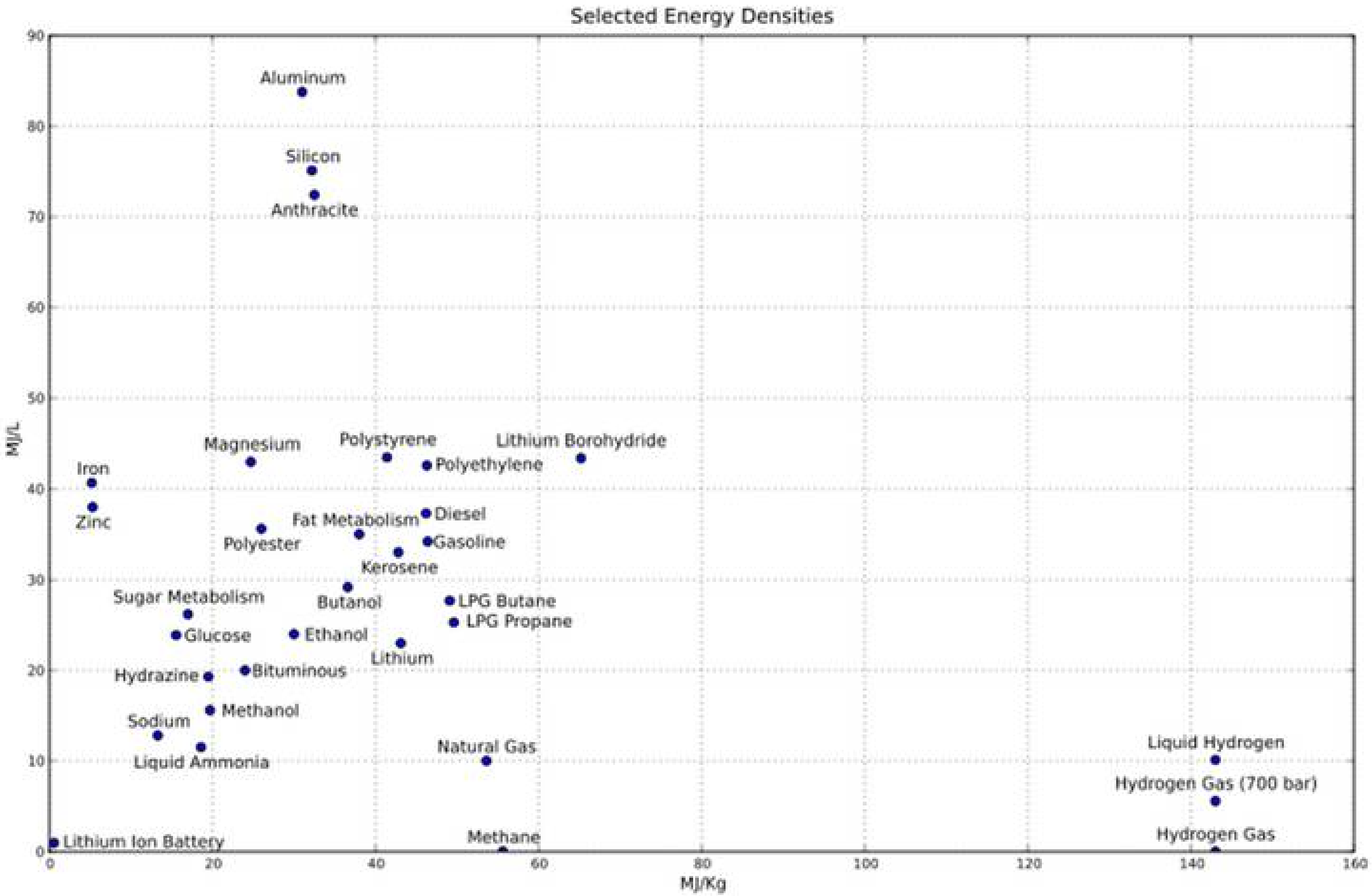
- Issue: * current and shunt capacitance leakage in cables lead (Joule effect) to huge energy losses, esp. if badly insulated and/or at high frequencies (skin effect increasing resistance); furthermore there is intermodulation between cables

  * such losses represent in avg. 2,5 % of total energy consumption
- The typical capacitance of a piece of wire suspended *in free air* is a minimum of 30pF per metre. At 230VAC we need 13.7nF to cause 1mA of current to flow. At 30pF/m and less than 500 metres of wire, the leakage is up to 1mA
- Medium voltage(36kV) grade Cu/XLPE/SC/Cut/PVC/SWA/PVC cables leak 10-15 microamps/meter (to be multiplied by voltage)
- Communications sockets, power sockets and connectors also dissipate 25-500 J
- Approach : always measure and minimize energy losses from static physical connections

Energy density

- Definition: *Energy density* is a term used for the amount of energy stored in a given system or region of space per unit volume. Often only the *useful* energy is quantified. For fuels, the energy per unit volume is sometimes a useful parameter

Energy density



Energy storage

- Issue: for intermittent energy sources, as well as in the power grid and in transport , localized buffer energy storage is needed with low losses and long lifetime
- Many alternative approaches and unknown safety risks / life-time data: flywheels, sodium-batteries,NiH2, Li or Li-Ion battery farms with ceramic membranes, LiMnPO etc…; R&D on fuel-coated nanotubes (MIT)
- Problem: high investments and high costs
- Industrial structure: very competitive and many players with huge funding

Comparison of battery types

Battery type	Energy density Wh/kg	Power density W/kg	Service life in cycles / years
Lead acid	30-50	150-300	300-1000 / 3-5
Nickel metal hydride	60-80	200-300	>1000 / >5
Lithium-Ion	90-150 (300 kWh/m3)	500-2000	>2000 / 5-10
Supercaps (double layer capacitance)	3-5	2000-10000	1 000 000 / unltd
Hydrogen storage	350 kWh/m3		

- In energy storage applications the *energy density* relates the mass of an energy store to the volume of the storage equipment. The higher the energy density, the more energy may be stored or transported for the same amount of volume
- *Power density* (or *volume power density* or *volume specific power*) is the amount of power (time rate of energy transfer) per unit volume; the higher, the faster the battery can be reloaded and the more power it can deliver in use

Energy storage: recycling of batteries and accumulators

- Context: EU 1998 and 2006 directives imposing a unit based recycling rate of 25 % by 2012, and 45 % by 2016; for each recycled battery or accumulator min. 50 % of materials must be reused (Zn, Mg, Co, Li, Fe (inox))

- Processes: chemical and electrochemical recycling by SO2 (e.g.: RECUPYL), far better than physical+ thermal recycling for specific metals / alloys

- Case France: 2009 production of 28 000 tons, with 38 % collection rate

Typical non-invasive energy measurement techniques

- Electrical power meters (Voltage*Intensity)
- Calorimeters (of all sizes) measuring flow and temperature
- Infrared thermography

Chemical products

- High impact of regulations on companies purchasing policies to aim at sustainability
- EU regulations covering product life-cycle: RSE (Social and environmental responsability) , REACH
- Development of auditing sector: SGS, SGS/Eko-Projekt, Intertek, Wethica, EcoVadis, etc
- Problem: to catalog and reference suppliers
- Research question: formalizing product life-cycle compliance and it's reporting

4: GREEN INFORMATION SYSTEMS

US Data centers energy consumption

- While data centers existence and operations has been given for granted by the rest of society until recently, the debate is now emerging as to their huge electricity consumption and sometimes wasteful operations in terms of CO_2 emissions. This feature article reports about some views by Prof. Andy Hopper (University of Cambridge), Microsoft, US Department of energy, Google, Terradata about this issue, back in 2008. As an initial observation it is reported that the approximately 6,000 data centers in the United States, for instance, consumed roughly 61 billion kilowatt-hours (kWh) of energy in 2006; the total cost of that energy, $4.5 billion, was more than the cost of electricity
- Used by all the color televisions in the U.S. in 2006; and , more importantly the US Department of Energy (DOE) reports that data centers consumed 1.5% of all electricity in the U.S. in 2006, and their power demand is growing 12% a year.
- Furthermore,besides power, the same data centers also use resources in terms of cooling , space which both become limiting factors. Several approaches are reported by these parties, as to what they do, or what could be done ; this includes using more hydroelectricity co-located with the data centers, using air cooling, installing personal energy meters, etc. Some industry consortia, like the Green Grid consortium, meet to share best practices.

US Environmental protection agency prescription

« US Public Law 109-431 (2007)
SECTION 1. STUDY. Not later than 180 days after the date of enactment of this Act, the Administrator of the Environmental Protection Agency, through the Energy Star program, shall transmit to the Congress the results of a study analyzing the rapid growth and energy consumption of computer data centers by the Federal Government and private enterprise.”

« Recommendations : **EPA Report to Congress on Server and Data Center Energy Efficiency**
A mix of programs and incentives is necessary to achieve a significant portion of the potential savings identified in the energy-efficiency scenarios above. Improvements are both possible and necessary at the level of the whole facility (system level) and at the level of individual components. Although it is not possible to optimize data center components without considering the system as a whole, it is also true that efficient components are important for achieving an efficient facility (for instance, efficient servers generate less waste heat which reduces the burden on the cooling system). Nevertheless, the greatest efficiency improvements will likely result from a comprehensive approach, given that there are opportunities for improvement in many areas of the IT equipment and infrastructure systems “

Data centers with renewable energy: Case of Google's data center at Summa Mill facility in Hamina (FI)

- Transformation cost of 200 Meuro from the former Stora Enso paper mill

- Access to primary nuclear energy, supplemented with Haminan Energy's four on-site wind turbines on site

Data centers with optimized energy use time profiles
Case: Joint venture between Hewlett Packard and EDF Optimal solutions (EOS)

- Joint venture where HP provides IT hardware and software, while EOS supplies electrical /cooling/ control / management

- From an normal energy loss of 50 % of energy consumption, the « solution » is claimed to reduce the loss to 20-25% and the energy bill by 30%

Near optimal case : Thor datacenter / Nordic Performance computing (Iceland)

- 19/4/2012 inauguration of High Nordic Performance computing center (DK, NO, SE, ISL) with the Thor data center , 10 km from Reykjavik, with Hewlett Packard / Intel processing in a container
- 100 % CO2 neutral energy because 98 % of supply is by geothermal electricity, and 2 % from hydro power, both costing 1/10 of avg. EU rate

Original: floating data centers

(Source: Center for networked systems, UC San Diego)

- <u>Issue</u>: power container based data centers aboard special ships, powered in part (50 %) by seawave power, and cooling their heat trap circuits by sea water

Grid computing and cloud services

- Issue: implement services requiring high power computing on distributed nodes with on-demand reliable resource sharing facilities (incl. storage)
- Grid computing comes out of the scientific HPC computing field (e.g. CERN LHC data)
- Cloud services offers users processors and storage space to be billed per unit time, with a wide choice of configurable virtual clusters (e.g. : 128-2000 cores) with different pricing structures (e.g. Amazon Elastic Compute cloud EC2); they are partly a business model and partly a usage model
- This may require : cluster management software that resizes the cluster depending on the queued tasks and content management access; shared libraries (e.g. DOE Argonne Lab Nimbus toolkit) ; node-to-node link bandwidth interconnect adaptation ; application software configuration and parallelization
- Scale-up (sprint) applications vs. Scale-out (marathon) applications
- Problem areas: energy usage, power failures, security, liability issues, privacy

Simple Energy savings by timing usage of IT according to service usage

Simple processes:

1. automatic programmable clocks on most non-essential peripherals , such as printers, photocopiers
2. human presence / motion detectors

Energy reductions in server grids

- Issue: to adapt computing ressources to computational needs, and power-down lasting unused nodes
- Approaches : measuring and prediction of reduced computational loads from time-patterns; ressource reservation ; trust delegation to idle nodes; scheduling

Data mining for emissions savings

- Issue: Data mining algorithms and tools applied to supply-chain wide emissions data (materials, products, logistics) ; support for decision analysis

- Case : SAP data mining of Danone’s yoghurt production (from the cow to recycled yoghurt packages)

Home IT & electronics : the threat from growing usage and low costs

- Claim : « 200 EPR nuclear reactors will be needed by 2030 to cater for home IT and entertainment « (« Gadgets and Gigawatts, IEA, 2009)
- Drivers:* information, services and entertainment growing very fast and used by many more people, with no saturation in sight

  * cheap device prices
- 2010 situation (worldwide): 1 Billion PC's, 5 Billion mobile phones , 2,3 Billion TV's (used many hours: 8 h /day in OECD), 1 Billion MP3 players, represent 15 % of household's energy consumption in OECD
- IEA Director Nobuo Tanaka calls for government action to curtail service and usage growth via minimal energy efficiency of devices , information campaigns on cost to users , and mandating automatic dimming of displays according to ambient natural light

5: GREEN COMMUNICATIONS NETWORKS

Green telecom networks

- Issue: Reduce emissions from electrical power usage throughout the design, installation, operations and service usage in telecommunications networks and access terminals , as well as the controlled temperature they need; infrastructure typically represents 80 % of emissions above; emissions above represent approx 2 % of global emissions (according to Alcatel Lucent) ;energy is approx, 10 % of total network OPEX (in emerging markets 15-20%)
- Methodology: only holistic approaches produce gains , not site-by-site or device-by-device measures; as a result suppliers as well as operators run knowledge-intensive consulting and planning units devoted to environmental and cost gains
- Approaches: improved device technologies (e.g. low temperature power amplifiers), electronic design esp. of switches/ routers/base stations, universal charger (with 50 % reduction in standby power), use of renewables, reduce network inefficiencies, better back-up power, remote radio heads, better power amplifiers, technology upgrades, removing shelters with aircon,

Green wireless networks standard

- ITU has adopted in 2011 the methodology / best practice collection standard ITU-T L.1410 « Methodology for environmental impact assessment of ICT goods, networks and services » » , proposed by GSMA
- It includes aggregate benchmark figures (« Mobile energy efficiency (MEE) network benchmarking » for some wireless network energy efficiencies, recognized by 35 worldwide operators
- The determination of MEE is offered as a service by GSMA called « MEE Optimisation »

Telecoms and Internet CO2 emissions

- Estimate 2009: 183 Mtons worldwide (0,7 % of worldwide global emissions) from a sector weighing 2 % of world GNP ; or: one user of telecoms and Internet emits 17 kg CO_2/year or about the same of 111 km in a car (Source: IDATE , 2010)
- Trend (average) : (-20 %) power consumption in networks every 18 months , insufficient to compensate the faster increase in traffic !
- Implementations at terminals' level :

1. Change design and power-off/backlighting-off modes; average rate of decrease of 6 %/year
2. Solar power add-on (Samsung Blue Earth/Solar Crest , LG, ZTE (2009) : 10 min loading for 3 min talk)
3. Partially recyclable materials (Nokia 3110 Evolve (2007), Sony Ericsson NAITE
4. Reducing waste in packaging of terminals
5. Universal USB charger (2011)
6. Copper sink for human heat loading a thermogenerator in the terminal (Nokia E-Cu)

Spectral and link efficiency

- Issue: These 2 efficiencies dictate the power needed to service a given set and volume of user requests, these parameters have a high impact on energy efficiency
- *End user measure* (at operator and user levels) : Mbit/s and Erlangs/ kWh
- The *link spectral efficiency* of a digital communication system is measured in *bit/s/Hz*, or, less frequently but unambiguously, in *(bit/s)/Hz*. It is the net bitrate (useful information rate excluding error-correcting codes) or maximum throughput divided by the bandwidth in hertz of a communication channel or a data link
- In digital wireless networks, the *system spectral efficiency* or area spectral efficiency is typically measured in (bit/s)/Hz per unit area, (bit/s)/Hz per cell, or (bit/s)/Hz per site. It is a measure of the quantity of users or services that can be simultaneously supported by a limited radio frequency bandwidth in a defined geographic area. It may for example be defined as the maximum throughput , summed over all users in the system, divided by the channel bandwidth. This measure is affected not only by the single user transmission technique, but also by multiple access schemes and radio resource management techniques utilized. It can be substantially improved by dynamic radio resource management
- Examples: 3 G cellular : 0,51 ((bit/s)/Hz per site); IEEE 802.11n : max 2,4 ; DVB-T : 0,55

Coding-linked efficiency

- Issue: Multiplexing technology has a significant contribution to electrical consumption in networks
- Case: Interdigital & Arthur D Little claim that TDD (Time division multiplexing) offers 20 % energy savings over FDD (Frequency division duplex), for same bandwidth usage (e.g. 5 MHz), by allowing simultaneous transmission / reception and reduced intra-cell noise

Energy efficient bandwidth allocation

- Issue: Improvements to existing static and dynamic price-based bandwidth allocation algorithms and protocols, get extended to include the energy cost component needed to power the link of stated bandwidth
- Approaches : Parallel Jacobi model for bandwidth adjustment with energy dissipated by link
- Problems : architecture where to execute allocation: in network management (with good computational means), or at link level (low level protocols) ; in practice , only static models are relevant in view of overcapacity in most fixed networks

Energy and cost optimisation in wireless sensor networks

- Issue : tradeoffs and improved protocols to mitigate network coverage and service lifetime with bounded energy storage at each node

- Approaches: lot's of theoretical optimizations using flow redirection and path lifetime ; idle mode powering ; labeling subcluster head nodes; burst modes

- Very little industry and defense uptake due to better technologies, besides deployment and interoperability constraints

6: POWER GRIDS

Electricity supply network

- Four main components :

1. Generation (from coal, gas, nuclear, renewables, etc.)
2. Transmission (long range, to distribution systems)
3. Distribution
4. Customers

- Many such systems are antiquated (e.g. : in USA, over 50 years old)

Power grid transmission losses

- High thermal losses in transmission lines, and transformers, supplemented by current leakage
- Wordlwide loss: 1 342 Mwe (2000) (Source:OECD)
- OECD losses: 6,5 % of power production
- Developing countries: up to 27 % losses (India)
- Supraconducting power transmission (HTSL, <500 m) reduce enormously the losses (Nexans, Trithor), as do supraconducting generators (Siemens, American Superconductor (36 MW))

Power grid blackouts

- Blackouts can be accidental, accidental despite time-dependent load predictions, climate driven (+ 30 % cold temperature peaks in Europe over 10 years), or programmed (maintenance operations, withdrawal of coal fired plants, etc.)
- In case of blackout, AC frequency falls (50→49 Hz), Voltage can be reduced a little in transport networks, customers / network parts have to be cut off, and expensive international grid exchange acquisitions have to take place (e.g. France imports more than it exports approx. 80 days/year, a 10 fold increase in 10 years)
- Long term effects of biased appliance policies (like in favor of electrical heating in nuclear electricity countries seeking users of excess capacity)
- Commercial strategies of voluntary reductions by big consumers shutting down a proportion of high usage facilities at forecasted peak dates/hours, against a financial compensation by the supplying utility ; e.g. in France: EJP (« effacement jours de pointe ») contracts for 2 TeraW/year

From electricity supply to smart electric grids

Issues: 1) Under deregulation, an existing electricity grid is shared between suppliers, and users become eventually suppliers to the grid (e.g. with renewable or storage sources)

2) Implement two-way communication among all the elements , so that information about the grid's condition can be shared and acted upon ; roots in IT network monitoring and communications network management platforms

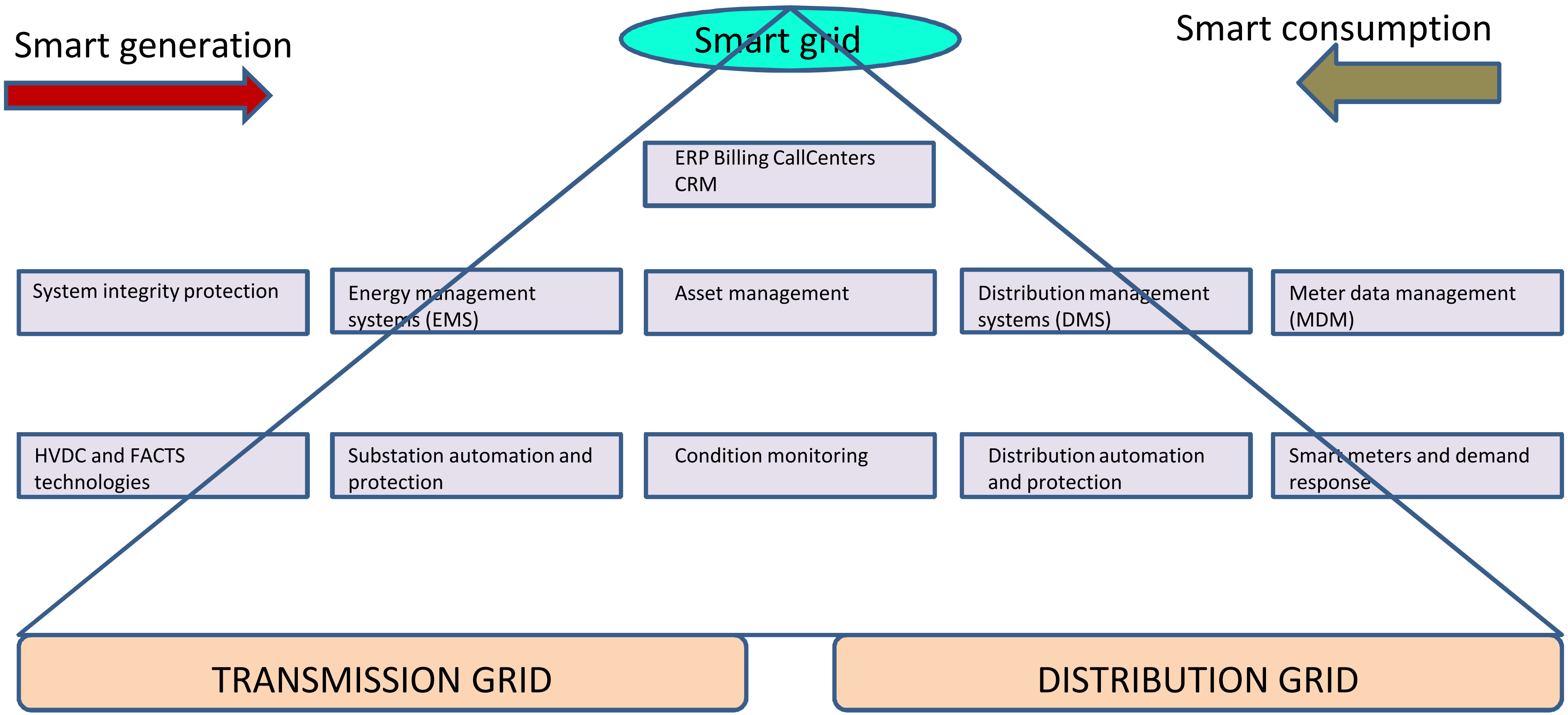
- Problem: Inability to predict demand; when demand spikes, an overloaded system may fail, resulting in denial of supply to other suppliers, as well as denial of service by some users ; difficulties in most solutions to achieve linear scalability
- Sector with problems: charging of electrical cars ,esp. AC Level 2 chargers (J1772 standard) for 240 V/3 hours/ 6,6 kW , burning street level transformers (claim of US power industry) (see IEEE Spectrum, Jan 2010, 13-14)
- Sector with minimal problems: renewable sources as their production rate changes are smooth
- Approaches : implement a large number of sensors, control functions, modems and transmission links ; implement SLA (service level agreement) IT platforms with suppliers and some users to throttle back on non-essential energy during peak demand in exchange for payment (e.g. EnerNOC Inc., SilverSpring Networking , BaseN Corp.(FI))

Certificate trade for suppliers

Issue: Incentive schemes have to be designed, whereby power suppliers, when they operate outside their normal field of intervention, can buy energy savings / emissions certificates from associations (or local governments) which implement energy savings measures, Suppliers can offset their regulated energy savings / efficiency obligations by such purchases certificates. Each year, regulator assigns an energy savings / efficiency goal to each regulated supplier, corrected by its market share. The certificates are issued by Ministry of Industry or equivalent public body.

Case: France : Penalty for each kWh by which target is missed is 0,02 Euros

Smart power grid



NB: but this is still the old centralized pyramid ….

The facts behind the fancy words « smart grids »: US Case

Sources: US DOE Energy information administration, North American Electric reliability Corp

- <u>Issue</u>: the electrical power industry has been one of the lowest spenders on R&D (1995-2000: <0,3 % of revenue; total 2010 less than 180 MUSD) and transmission investments since long; also: starting in 1995 the amortization and depreciation has exceeded utility construction expenditures ; result is a stressed grid

- US network outages are in avg. 92 min/year in Midwest and 214 min/y in Northeast compared to Japan 4 min/y

Smart Grid Deployment phases: European Cases

PHASES

1. Intelligent meter refurbishment (communicating, with open interfaces due to deregulation(*)) (Italy 30 M meters/ ENEL since year 2000, Sweden, France / ERDF 35 M meters since year 2007, etc)
2. Reduce utility's metering costs (IT: -10%)
3. Utilities, with solutions provided by IT industry, implement « demand response » systems, esp. for peak load management, and will reduce investments in occasional peak supply plants (thermal)
4. Strengthen competition, by user profile driven offers
5. Consumers as actors by own savings / production profiles (distributed sources, buildings as sources, as well as local storage such as vehicles)

(*): EU Project « Open public extended network metering » (OPEN)

Evolution of Aggregating utility metering

- Issue: Consider using cloud computing, instead usual of centralized relational data base systems (RDBMS) , to retrieve data from metered access points, allocate consumption to contract owner, and offset losses / errors
- Sizing: typical access point samping rate of 15 min
- Approaches: using distributed file systems , and parallelizing the allocation algorithms
- Case: Pacific Gas and Electric's Smart Meter program with its distributed ORACLE RAC (Real application clusters) system and Knowledge global environmental management system , with data compression (see Oracle Magazine, Jul 2008)
- Case: ABB Process data management platform in pulp and paper
- Problems: little use as the same RDBMS platforms are used also for CRM and billing ; also for energy savings feedback/control loops must be implemented

Energy data management systems

(also branded by some as «FACTS Flexible AC transmission »

- Issue: Sensors, software, controllers,solid-state switches coupled to capacitors, and user interfaces for real-time energy meter data management (EDM) in deregulated power (electricity, gaz) markets, and for measurement data warehousing , as well as balance settlement+reconciliation calculations between network operators
- Case: FORTUM(FI) deploying 550 000 smart energy meter and smart grid software (from Echelon)
- Data collection by wired or wireless automatic data management (AMM) systems ; data transmission by power wires or wireless; cheap solutions (PLC+OFDM chip+Zigbee+mesh protocol)
- Examples: Telvent (ESP), Siemens , ABB, Schneider, ITRON(USA), Echelon (USA), General Electric, Process Vision Ltd(FI), Wirecom (FR),Voltalis (FR), YIT (FI),Vizelia, etc

Smart grids and renewable sources

- Issue: Energy conservation measures require utilities to get energy from renewable sources,and thus to manage them as part of a smart grid

- Problems: As many renewable sources operate intermittently , they put at risk the smart grid's stability and integrity at transmission and distribution levels

- Approaches: detecting and containing power outages by real-time data, and re-routing distribution to minimize customers affected

Smart grid standards

- NIST Smart grid interoperability standards roadmap
- IEEE P2030 Smart grid interoperability of energy technology and information technology operations
- IEEE P1901 for communications over power lines
- IEEE P1901,2 for low frequency (<500 kHz) narrow band AC/DC power line communications for smart grid applications and devices
- IEEE PC37.118.1 Draft standard for synchrophasor measurements for power systems
- IEEE PC37.118.2 for synchrophasor data transfer for power systems
- IEEE PC37.238 for use of IEEE 1588 precision time protocol in power system applications
- IEEE/IEC P1547 on interconnecting distributed power system resources
- IEEE P2030,1 on 2-way power flow and communications between plugged-in electric cars and the grid
- Over 100 additional IEEE, IETF, IEC standards , incl. for interoperability between the grid and appliances

Smart power grid evolution

Source: EPRI

V1 : Advanced metering infrastructure (AMI) (200-300 $/household and 10 % for communications)	V2: Consumer-grid connectivity	V3: Supply/demand integration
Enterprise operations • Data management • Device programming • Demand response	Smart energy service • Enterprise service • Unified customer operations • Multi-service offerings	Sustainability • Supply balancing • Time-allocation • ECO-credits
AMI Networks • Standard protocols • Public /private WANs • Wide coverage	Multi-service networks • Broadband grid • Community / Home	Max. capacity • Matrix grids • QoS • Load balancing • Energy storage
Utility managed • Critical peak pricing • Read advanced meter • Load control • Control thermostats	Consumer oriented grid • Consumer energy efficiency • Smart appliances • Account info service • 1-Way smart charging	ECO-community • Distributed power generation • 2-Way charging • Affinity groups

High voltage direct-current transmission (HVDCT)

- Issue: Low loss low-current high voltage (>500 kV) transmission lines for distant power transmission , but also short ranges; much more efficient than AC transmission lines (which has 13 % losses);financially viable for >600 km on-land and >60 km undersea ;used also for offshore wind farms ;can also be used back-to-back to link networks of different voltages on a given site

Microgrids

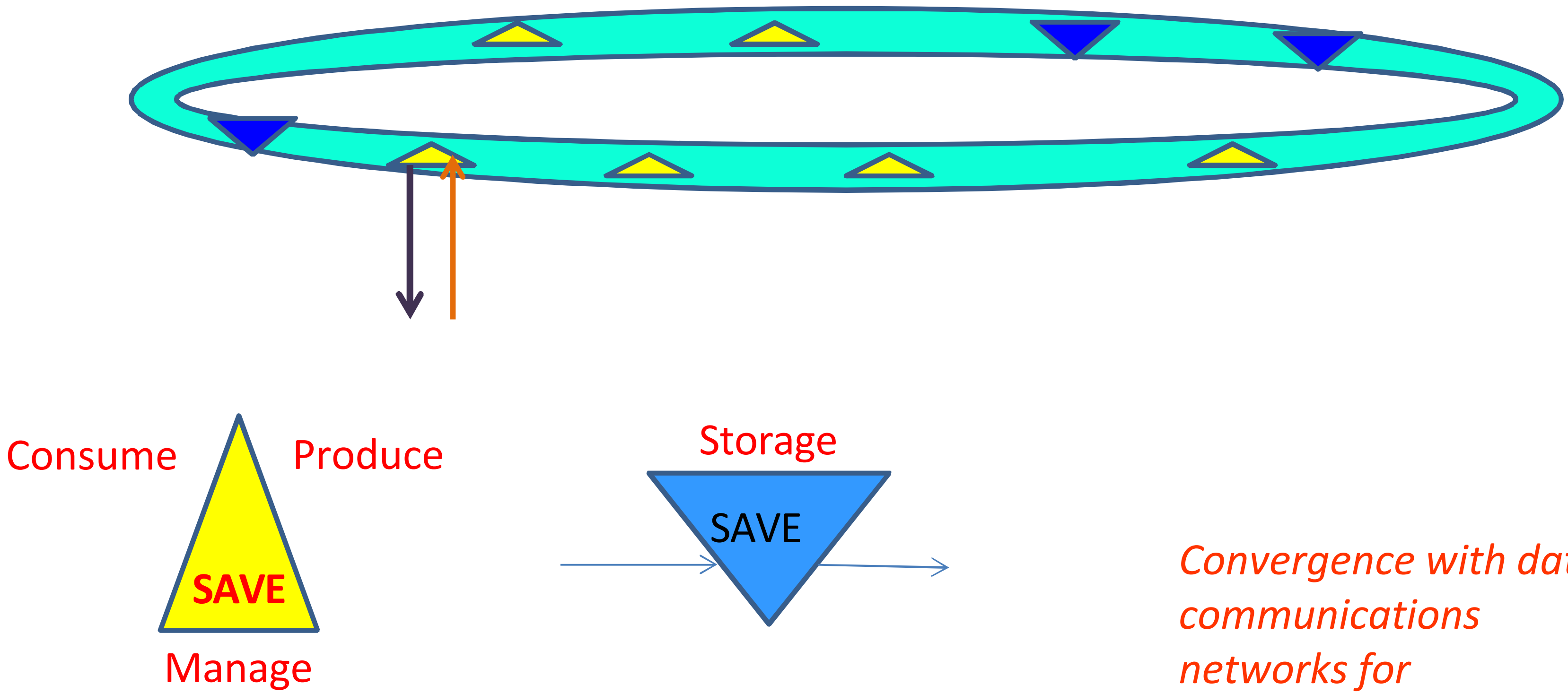
- Approaches: micro-combined heat and power systems , or other cogeneration (from biomass) systems, at user premises with slow dynamics
- Example: Pannonpower / Velolia 182 MW cogeneration plant in Pécs (HU), plus hot water production

- Issue: microgrids may provide localized network support in times of stress by relieving congestion and aiding restoration after faults; they may also reduce the demand for distribution and transmission facilities in backbones

“Smart” smart grids & Virtual power plants

- Approach: network all energy sources and sinks, under one single control system reacting centrally and locally to usage rates and rates; rather than having n small sources of p , you have one flexible reactive virtual utility of power (n x p)
- Case: Bornholm island (DK): EcoGrid project (Siemens, Energinet.dk) (21 Meuros) connects 2000 households to an island wide grid enabling them to cut back electricity usage at times of peak demand using gateway controllers, and sell unused Watts back to the grid at market rates. Grid includes 36 MW wind power, 16 MW biomass plant, electrical cars, and a software control system (virtual power plant)

The new flat distributed Smart grid



Convergence with data communications networks for management, coordination !!

Grid of grids (Europe)

- In 1999, the major power operators in Europe have united in order to harmonize access and use of electricity across 490 M users consuling 3 200 TeraWh/year. The association is callled ETSO.

- The high voltage lines (400 kV and 230 kV) across Europe in this grid of grids represent 290 000 km (high voltage in US is 500 kV and even 1150 kV in Kazakhstan). Secundary transmissions run at 10-30 kV .

7: OTHER NETWORKS

Green public transport networks

- Issue: reengineer transport platforms and their management, to reduce energy consumption in public transport networks

- Implementation measures:

1. New transport platforms(small busses, trams, metros, trains, scooters, bicycles) with braking energy feedback (Oslo Metro, Lisbon / Nice trams)
2. Roadpricing (Oslo, Singapore)
3. GPS based positioning and tracking
4. Software sends estimated bus arrival times to LED displays at solar powered bus stops (San Francisco)
5. Bicycle or hybrid shared rental schemes (»Vélo bleu » (FR), Zipcar (US), MIT Media Lab « Smart cities »)
6. Ads' companies co-fund solar powered shelters
7. Projected cost of Li-Ion batteries for cars : 2010: $ 800/kW/h 2020: $ 150-200 kW/h

- Calculation tools : www.ecotransit.org (CH)

Lighting networks

- Issue: Forced adoption of light source technologies, transformers, and light management for minimal emissions , safe viewing and long usage life ; lighting consumes approx, 19 % of all electricity (1,6 Billiontons CO2)
- Approaches : 1) LED's, LED arrays, coupled to solar panels 2)EU regulations (2008) progressively banning >60 W incadescent lamps
- Units: 100 W filament lamp corresponds to approx, 1300-1400 lm (lumens)
- Efficiency : LED's approx 75 lm/W, incadescent 12 lm/W , OLED 25 lm/W (prototypes)

Light source type	Power usage compared to incandescent filament of same Lumen	Life time	Typical cost
Halogen	-30-40%	3 y	3 Euros
8899-- Fluocompact (Hg)	-80%	6-15 y	7 Euros
LED (no Hg)	-80%	>15 y	>10 Euros
Future LED & OLED	-90%	>15 y	5 Euros

Digital television networks

- OFCOM (UK,2009) has established that the terrestrial TV transmission networks are only about 2 % of all TV equipment emissions (dominated by receivers, displays , operations and stand-by power)
- If satellite broadcast totally supplanted digital terrestrial TV, the resulting emissions would be approx. 50 % higher due to higher energy use to install satellite dishes and their cabling, besides higher consumption by satellite set-top boxes
- <u>Approaches</u> :Energy Star standard (US EPA 1996) of 1 W in standby; limit of 115 W per 42 inch TV in operations (California);hot cathode fluorescent backlighting; ambient lighting matching

8: BUILDINGS

Transmission energy loss for buildings (approximation)

$$Q = U \times S \times HGT \times (24/1000)$$

Q: energy loss (KWh per year) (to be matched by energy supply for temperature balance)

U: material dependent transmission loss coefficient (W/m2. degree K)

S: surface (m2) (eventually corrected by ceiling height)

HGT: number of heat degree-days for a given base temperature (location & climate dependent) (degrees Kelvin x days Year) ; it is the integral of a function of time which varies with temperature (see e.g.: www.**degreedays**.net)

24: correction for hours/day 1000: correction for W/kW

Data examples:

HGT Bern for 20 degrees inner temperature and 12 degrees external temperature : 4044/y

U(old wooden window): 2,25

U(plastic window): 1,40

Zero-energy buildings as receptacles to IT activities

- Issue : for a given IT technology subject to given environmental constraints , consumptions and emissions, how to mitigate these dynamically at container level

- Definition : German DIN standards define a passive house : < 15kWh/m2/y in heating energy, and total energy consumption must be <120 kWh/m2

- Passive zero/positive -energy building components: building shape and orientation, windows shape and orientation, triple glazed windows, materials and insulation (300-500 mm)

- Active building components: moving screens, embedded photovoltaic thin films (in roof tiles and windows), embedded hot air recirculation in roof tiles Soltech Energy systems (SE), storage of excess heat, heat pumps, ventilation with heat recovery , ventilation with wireless synchronization, heat and energy distribution pipes embedded into the walls, PV panels, horizontal wind turbines, active energy management architectures

- Problem: Incremental cost due to inconsistent regulations: 15 % (Source: Terra Natura)

- Leading actors: Saint-Gobain, Schüco, Rockwool , Schneider EcoStruxure ,Vallox Oy, Walter Meier, Daikin, Mitsubishi

Autonomous positive-energy buildings as receptacles to IT activities

- Issue: consumption of less than 5 kWh/m2/year , fully autonomous in energy, with minimal CO_2 emissions, and own power sources (Photovoltaics, Wind, Hydrogen Fuel cells, double flow ventilation)
- Approaches: IT heat emissions used to heat the building; use of wireless building control system to coordinate in real time all subsystems (e.g. Siemens APOGEE)
- Cases: a) Abalone Group headquarter building (Nantes, FR) ; cost of equipments: 4 MEuros b) Green Office (Meudon,FR) built by Bouygues (5000 m2 of solar panels producing 390MWh +440MWh cogeneration facility)

Energy bill split in a typical office building

(Source: www.esope-sas.com)

Function	% of power bill	
Heating and aircon	>50 %	
Lighting	15 %	
Data center	40 %	
Ventilation	10 %	
Restaurant	10 %	

Energy savings by refurbishing a 20 000m2 4 year old office building (Source: Vinci Energies)

Actions	Electricity MWh	Heating MWh	Water m3	2009 annual savings (Euro)	2009 Investment (Euro)	Breakeven period
Change in power supply contract				6236		0
Condensers				6861	11000	1,6 y
LED lighting	78,6			5787	8000	1,4 y
150 W halogens instead of 300 W	48,4			3563	600	<1 y
Change iced water supply	98,4		2000	12222	11000	<1 y
Cap ventilation duration	30,1	52		5688		0
Heat catch and speed varystor on air ventilation circuit	81,2	90		10055	25000	2,5 y
Water flow reducer			790	2140	1290	<1 y
TOTAL				52552	56890	1,1 y

Facility modelling

(There are hundreds of model instances: www.eere.energy.gov/buildings/tools_directory/countries.cfm)
They help architects, engineers and data center managers fulfill the demands of the EU Energy performance of buildings Directive (2006)

- Configuration data :

1. Boiler , radiator/ convector, aircon, cooling, het pump equipment locations
2. Hot water distribution network
3. Cool fluids distribution networks (5 degrees C)
4. Ventilation inlet/outlet/ducts
5. Window locations, types and sizes
6. Density map of human activity

- ICT equipment locations, dynamic heat dissipation, power consumption dynamics, and display/lighting emissions

- Equations :

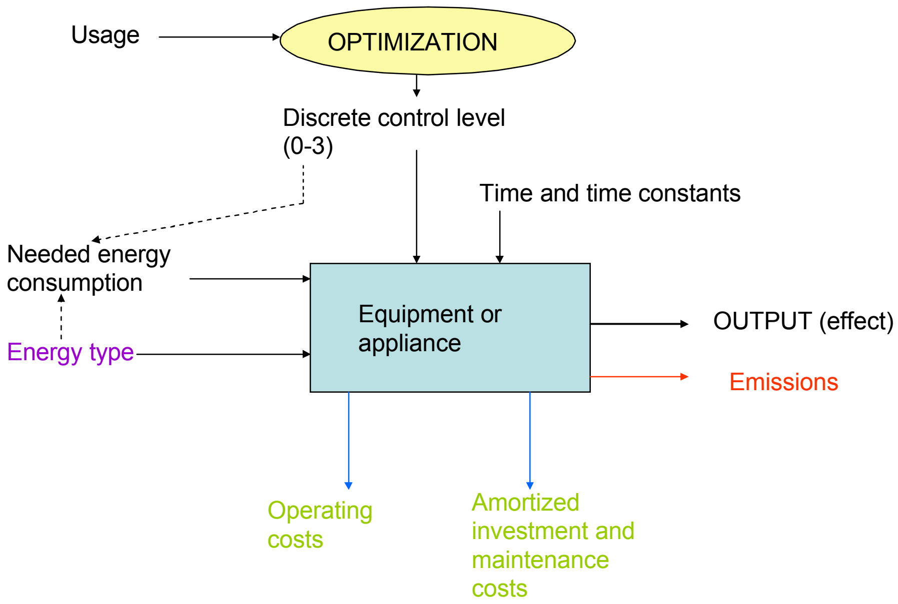
1. Heat balance, with heating demand / supply , and distributred transmission losses, ventilation losses , minus solar and internal gains
2. Thermal mass estimation or calculation from materials and surfaces
3. Non-controlled radiator cool-down profiles
4. Heat and cold distribution loss, taking outside and volume temperatures into account
5. Heat transfers between volumes
6. Ventilation flows between volumes
7. Boiler’s Stefan-Bolzman convection and radiation equation
8. Hot / cold water usage from facility usage
9. Lighting dynamics
10. Human activity sensor outputs

- Algorithms : partial differential equations and hierarchical optimization
- Examples of energy efficient facility modelling companies: Rockwool BuildDesk , Schneider

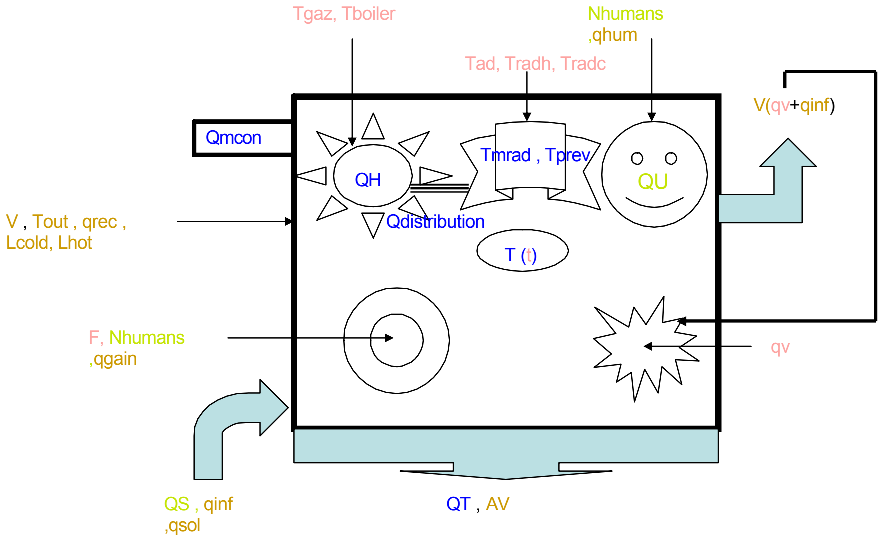
Intelligent materials

- Issue: for passive energy savings affecting receptacles, novel materials and materials refurbishment offer effects often higher than active measures;many novelties are enabled by nanomaterials and processing at particle level;some materials are even interactive
- Approaches: lighting concrete with integrated optical fibers,BFUHP concrete with integrated plastics for flexible structures, plaster with polymeric integrated capsules with phase change for thermal regulation in the walls (BASF,MateriO),active windows with adaptive transparency or liquid crystals (Pilkington, Saint Gobain with its OLED small windows)

Equipment or appliance plant model

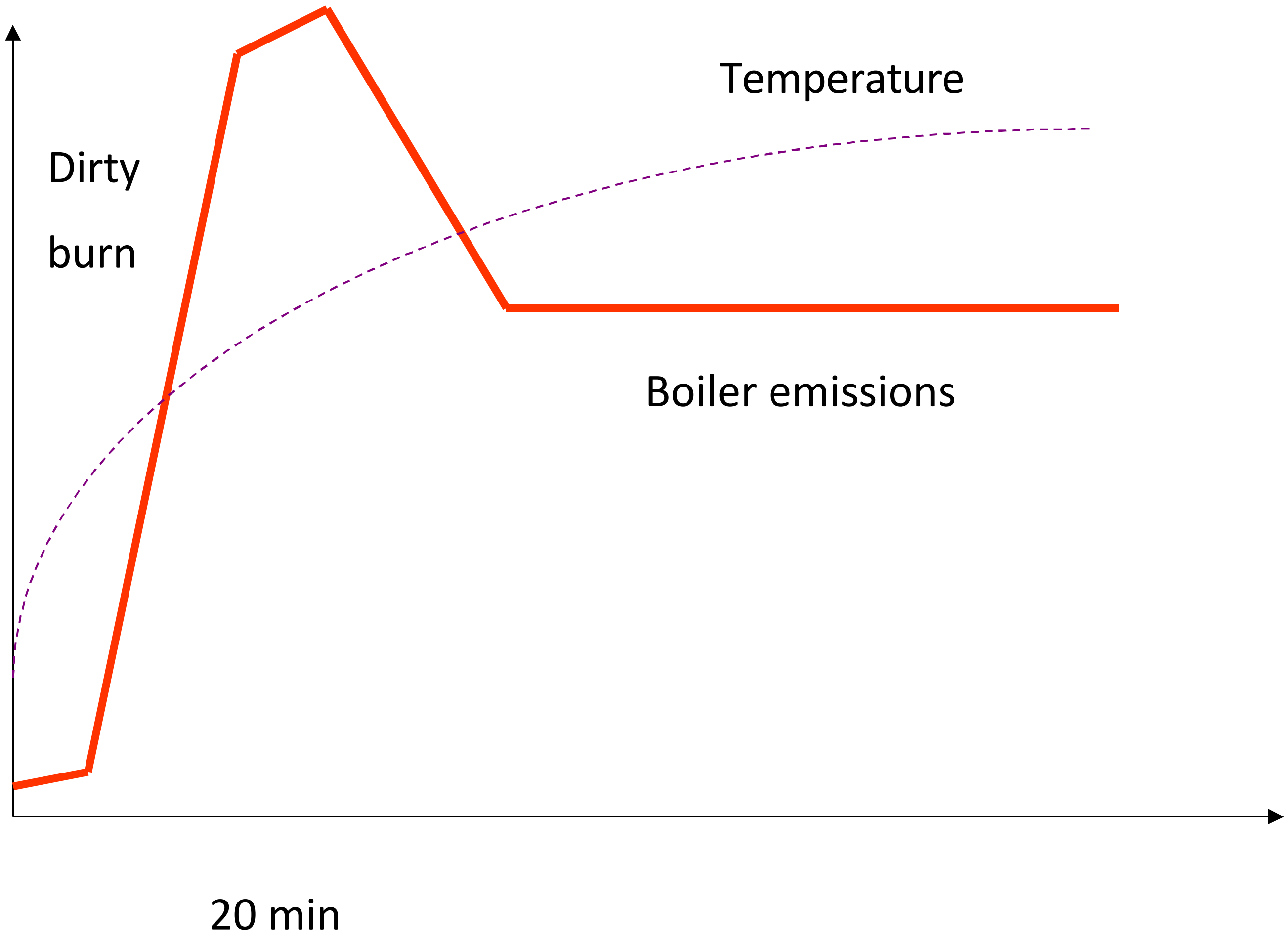


Heat balance in a building

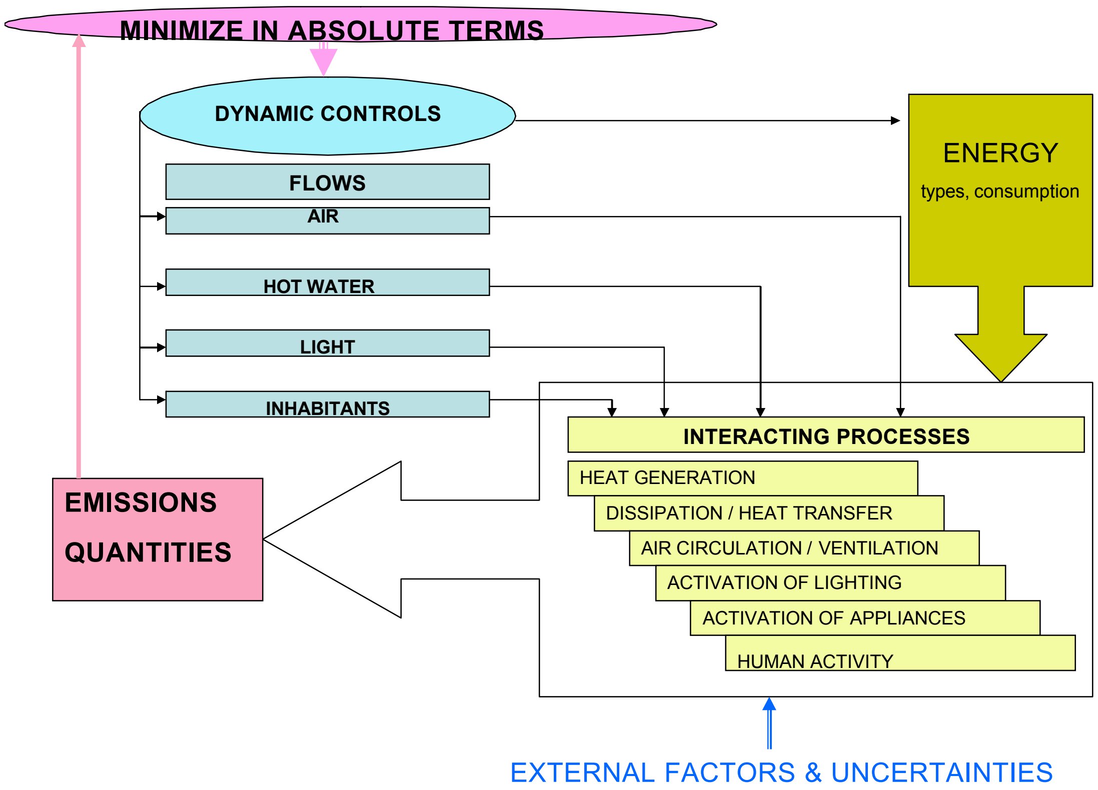


- Heat balance model for a given volume V ; the volume contains a heat source , distribution pipes, appliances , radiators , ventilator, and people and their interaction results in an indoor temperature T(t) at time t ; the airflow is mostly recuperated and walls / windows have thermal inertia
- With low temperature systems (heat pumps with water), temperature gradients are minimized across heating / cooling / ventilation (REHACTS technology)

BOILER EMISSION DYNAMICS (Proprietary source)



Flows, interaction processes, and the emissions optimization affecting the dynamic controls

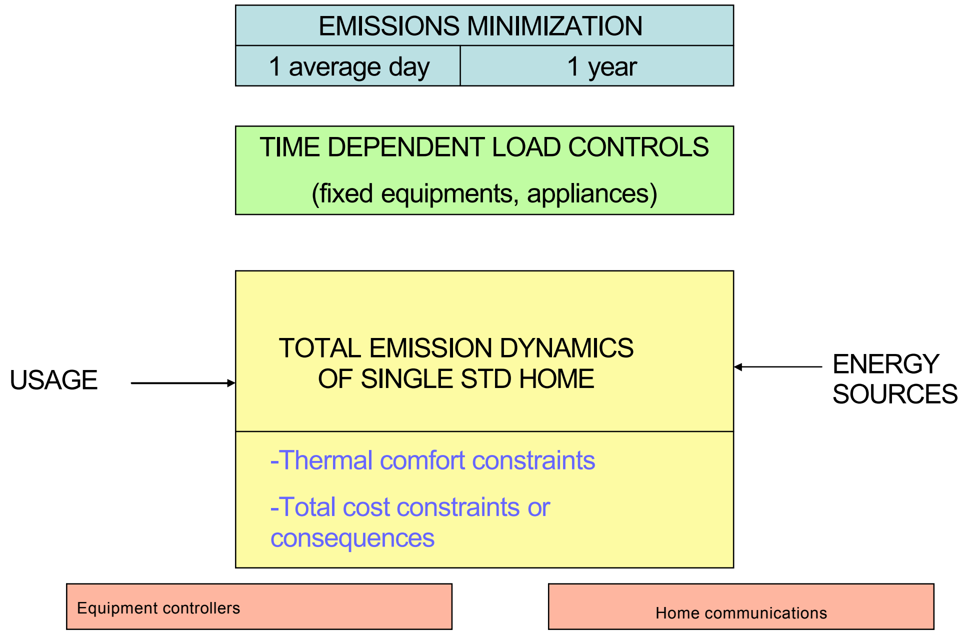


The daily usage and annual emissions optimization problems

EMISSIONS OPTIMIZATION PROBLEM	Time horizon	Specification	Data and control sampling rate
Daily usage cycle	1 day	Average emissions per day over 12 days of the year spread over 12 months	1 minute
Annual cycle	1 year	Integrated emissions over the year	1 day

Household emission optimization

Physical or usage flow medium	Common prime effect
Indoor air	Room temperature and comfort
Hot water	DHW (Domestic hot water)
Light	Lighting
Inhabitants	Home and appliances utilisation



Recycling energy in hot water distribution networks

- Issue: capture used warm water to heat buildings or power selected functions

- Approach : use of heat exchangers connected to used warm water circuits , and transport of calories to heat pump,or reuse into power

- Case: Suez Environnement: Levallois Perret (FR) swimming pool with -24% energy and -66 % emissions

Cooling from renewables

- Issue: usage of compressors linked to thermal solar power, to generate cold
- Example: Cooperative of wine producers in Banyuls(FR) , with Solarclim process, using 130 m2 of solar panels to cool 3 M bottles on 3500 m2 (www.pole-derbi.fr)

Home electronics , Whitewares and their recycling

- Issue: individual home electronics & whiteware appliances are becoming networked, and represent high usage / high diffusion / short life-time energy consumption sources
- Regulatory framework:- EU and national directives on disposal of electronics & appliances , and eco-taxes (e.g. 0,5-1 %)

  -Pedagogical initiatives and « community campaigns »
- Approaches : remote controls for networks of household appliances (see e,g, demos at CeBit); Powersaver units plugged into power distribution sockets, which detect remote control's Infrared standby orders and shuts off the corresponding appliances; embedded power modulation detector chips powering down appliances (General Electric (US), Watteco (FR))
- Problems : slow technological progress on pumps and electrical motors, slow change in structural materials, wider specialization and diffusion esp, in developing countries , handling difficulties of bringing to recycling stations

Home appliances and ITC

Appliance	% of avg. Household energy use (Source: ADEME)
Cooling , freezer	32 %
Lighting	14 %
Drier	14 %
Dish washer	14 %
Home IT and electronics	12 %
Washing machine	7 %
Misc.	7 %

Appliance consumption and usage

(Source: ww.sbi.dk Report Sbi 2006:06)

Appliance	Typical number	Energy usage/unit
Stove	1	600 W , 1 h /day
Microwave oven	1	300 W , 1 h/day
Freezer	1	250 W , constant
Washing machine	1	500 W , 100 W standby , 2 x 2 h/week
Dish washer	1	500 W , 100 W standby , 3 x 2 h /week
TV	1	130 W / standby 6 W , 3 h / day
DVD	1	200 W , 2 h/day
PC	2	300 W , 50 W standby , 5 h/day
Light bulbs	10	5 W/m2 , 15 h/day
Spot lights	3	1 W/m2 , 3 h/day

Efficient energy savings steps in housing

1. Energy diagnostic balance analysis (in view of possible classification and to identify remedies)
2. Insulation of roof and floor surfaces first, then walls (inner or outer insulation) (50 % savings)
3. Double flux ventilation (25 % savings over mechanical ventilation)
4. Double glazing windows
5. More efficient heating (or cooling) systems

Evolution of building regulations

- Some countries have embarked into enforcing long term, via building regulations, lower emissions from both commercial and residential buildings, aiming at a renewal of the building stock
- <u>Case</u> France :

1. from any commercial building permit filed since 1/1/2011, the building code RT2012 limits average commercial building emissions at max, 50 kWh/year/m2 (vs, prior 120 kWh/year/m2 under RT2005, despite the heterogenoeity of that group (e.g. hotels vs. offices)
2. Residential buildings are subject to RT1973
3. For all buildings theoretical reference emissions are abandonned in favour of individual measured/ audited individual building consumptions
4. Problems remain in the tradeoff between constraints on emissions and usage constraints (safety, labour law, insurance code)

Residential Building energy labels and certification

* Five energy label levels for granted building permits (approx 40 % of total energy use):

- BBC-Low consumption buildings: mandatory for new residential buildings, < 50 kWh/m2/year (modulated by a climatic and altitude coefficient)
- THPE EnR: Very high energy performance-Renewable energies : +30 % improved performance over BBC , plus use of either: solar energy, biomass, renewable electricity, heat pumps
- THPE : +20 % improved performance over BBC
- HPE-EnR: High energy performance-Renewable energies : +10 % improved performance over BBC, plus use of either biomass for over 50 % of the building's energy use, or connection to a heat network supplied by >60 % by renewable energies
- HPE: +10% improved performance over BBC

* Public agencies, or audited independent institutions, issue the energy labels

* In some countries, maximum energy consumption ceilings exist in connection with delivering building permits and they may relate to the chosen energy source: e.g. < 130 kWh/m2/year for combustible fuel energy , and < 250 kWh/m2/year for electrical heating

International standardisation of Residential Building energy labels and certification (Source: Verein Minenergie)

Certificates	Country	Since	Link
MINENERGIE	Switzerland	1998	www.minenergie.ch
DGNB (Deutsches Gütesiegel Nachhaltiges Bauen)	Germany	2009	www.dgnb.de
LEED (Leadership in energy and environmental design)	USA	1998	www.usgbc.org
BREEAM (Building research est, environmental assessment method)	UK	1990	www.breeam.org
GREEN STAR	Australia	2007	www.gbca.org.au
Haute Qualité environnementale	France	1990	www.assohqe.org
CASBEE (Comprehensive assessment system for building environmental efficiency)	Japan	2002	www.ibec.or.jp/CASBEE /english

9: ECONOMICS, TRADING and BUSINESS

Some macroeconomic data

(Sources: Global subsidies initiative, IMF, IEA, World Bank State and trends of the carbon market (2008), Danish national bank)

2006 data	Billions USD	% of global GNP
Subsidies to fossile energy and energy use (e.g. heating price/m2)	600	1,2
EU total energy taxes	210	0,5
Assistance to economic development	105	0,22
Subsidies to renewable energy	25	0,05
OPEC oil exports	605	1,3
OPEC balance of payments surplus	340	0,7
USA balance of payments deficit	810	1,7
Total petroleum markets with oil at 100 $/t	3000	6,2
CO2 rights trade volume	31	0,05

Input-output tables

- <u>Issue</u>: apply statistical estimation and matrix inversion calculations to equation :

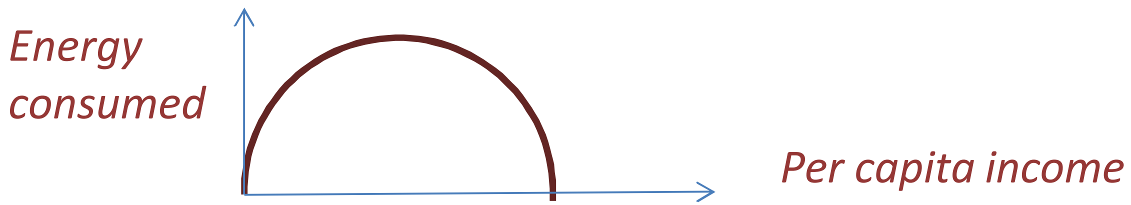
  ProductOutput = A * Input

  where: ProductOutput is the vector of product value-add /volumes (or value-add by product sectors) , and Input is the vector of all constituent raw material inputs, including primary energy

- <u>Case</u> : Denmark (2005) spends 2,9 % of value-added from machine sector on primary energy (compared to OECD: 4,8 %) giving a competitive advantage (Source: Danish National Bank
- <u>Case</u>: ST Microelectronics has done similar calculations at company level

Environmental Kuznets curves (Nobel prize 1971)

- Issue: The environmental Kuznets curve (EKC) refers to an inverted U-shaped relationship between some polluant level (including energy used) and per capita income; i,e, the environmental quality deteriorates at early stages of economic growth and subsequently improves at later stages ,Although there is no conclusive proof, EKC emerges as an empirical regularity



- Survey paper: M. Kijima,K. Nishide, A. Ohyama, Economic models for the environmental Kuznets curves: a survey, J. economic dynamics and control, 34 (2010), 1187-1201
- Research issue: Nothing is known on the evolution of the pollution/emissions as the aggregation of microeconomic activityn ; nothing is known either on the turning point in income level at which degradation starts to improve : need to identify factors

Peak energy supply, e.g. « peak oil »

- Issue:As most sectors in society depend on energy, should future investments (incl. on energy savings) and operating budget forecasts rely on peak , average or price trend values of energy supply quantities (as they subsequently impact prices) ?
- According to peak oil theory (Kjell Aleklett, Uppsala), energy consumption is correlated to growth in the global economy, so if supply decreases after its peak, growth will be negative
- According to opponents, there is no risk of recession as the growth of consumption in emerging countries is non-linear and temporary (growth followed by stable 19 barrels oil/person/day in avg.), and innovation will allow to match the later slow changes in energy demand
- According to all, price based regulation mechanisms for energy have stopped working, as it is pure supply which is the dominant driver now

2010 Oil consumption Mill Barrels/ day (Source: BP)	
Asia	25
North America	23
Europe	15
Middle East	15
Latin America	6
Russia	4
Africa	3
Australia Oceania	1

Consumer behavior vs. prices

-Oil prices: unregulated, but heavily taxed, and petrol distribution is a no-margin business
-Electricity prices: mostly regulated, and often taxed
-Gaz prices: mostly regulated, and not taxed much

So , it is not surprising consumers ONLY see energy battles at the petrol station, and

Raw energy prices will play an even greater role in end price formation, even when heavily taxed, and

Electricity savings only is a largely biased debate

Taxes on emissions

- Issue: change economic agents energy consuming behaviour, while leaving choice of decisions, by taxing main CO_2 emissions linked to use of fossil fuels, electricity , and energy spending appliances & IT to change the demand curves ; this tax is added to other existing taxes (like on fuel for transportation)
- Sub-issue: it is impossible to impose such a tax on imported CO_2 in imported products
- Theoretical basis: A. Pigou (1920) proposing an environmental tax on production and consumption; OECD recommends this
- Calculation basis : very different from country to country, if used at all; average : nom. 32 Euros/ton CO_2 in EU (Sweden since 1991: 27 Euros/ton CO_2 now worth 108 Euros, yielding emissions reductions of 9 % ; Australia 17 Eur/ ton CO_2); Australia grants back 50 % in income tax reductions…
- Energy Tax income : from 3 % of State income (Belgium) to 8 % (Bulgaria) ;if reassigned to investments in emissions savings measures, added growth may occur
- Opposition's arguments: Emissions reductions enabled here benefit others, and harm own competitivity and labour ; all incentive subsidies (e.g. public transport, renewables) must be stopped

Summary of energy taxes: Case Sweden

In theory, the market price should be equal to the total marginal costs in the network

Tax category	2011 Tax (approx. 9 SEK/Euro)	Tax before deregulation
Energy tax	0,283 SEK/kWh	0,09 SEK/kWh
Electricity certificates (NO,SE)	0,03- 0,06 SEK/kWh (2/3 for certificate, 1/3 for utility's transaction costs)	Paid by consumer ; price for renewables less
Emissions taxes	0,11 SEK/kWh	
Sale of certificates	0,17-0,25 SEK : KWh	
Sale of guaranteed wind production	0,005 SEK/kWh	

MARKETS:
-Physical market NORDPOOL for spot (per hour, 24 h in advance) (1996: NO, SE, FIN, DK and basis electricity supply (1 h in advance) (same countries, plus DE, EST)
-Financial market Nasdaq OMX Commodities (Scandinavia) , which enters clearing contracts on Nordpool

Energy tax reductions when electricity is sole energy source

- Issue : in some countries, the energy tax is reduced for housing (or secundary housing) where electricity is the sole energy source and consumption exceeds e.g 4000 kwH

- NB: houses must be registered

Funding technology changes via incentive loans

- Issue: granting lower interest rate eco-loans, where borrowers would finance interest cost by energy cost savings, and borrowers finance capital needed by deferred investments in added energy production capacity
- Zero-cost to public finances, but needed regulatory changes in banking ; no impact on users purchasing power
- Cases: France (eco-prets), New Zealand ; no reported cases worldwide for Green ITC ; however, incentive loans are *sanctioned*, due to claims of higher risks by financial institutions or by high charges for intelligent meters.

« Green ITC » modelling as a service business

- Issue : the multidisciplinarity and data needs for Green ITC modelling open opportunities for many advisory or consulting business models
- Coupling to 3-D models / maps and on-line optimisation
- Examples of focus areas: data distribution between clients/ suppliers, document management, electronic ticketing, process control industries, ESCO processes in hospitals, supply chains
- Examples of players: ABB Energy management and optimization solution (SE/CH), Veritas (NO),Battelle (USA), Enertech (F) , EnviroScopy (CH), Quantis Intl (CH), Schneider Electric Buildings business (global), Panasonic (J) ,ATOS (Europe)

Climate « rents »

- Definition: a « *climate rent* » occurs if the price paid for an emissions right (e.g. measured in $/ton) is much larger than the actual emissions reductions costs

- Incentives to emissions rights purchases are driven by the marginal reductions costs in industrialized countries,but may be higher than the total reductions costs elsewhere

- Case: China has had to introduce punctual special tax on companies (e.g. agricultural companies) selling too expensively emissions rights

Trading in CO_2 emissions rights (I)

- Issue: organize markets for rights achieve specific CO_2 (or other, e.g. SO_2) emissions reduction targets
- Evolution:

1. Opening of markets: UK, Denmark (2000): 34 « seed » companies commited on a voluntary basis to reduce emissions in 2006 to 4 Mtons in less than their average levels over 1998-2000; in exchange they shared a public subsidy of 310 Meuros ,or were exposed to penalties if goal was not met;
2. All companies in these countries were mandated to achieve emissions reductions ; any company which would perform better would receive emissions rights , which could be resold on a market to lesser performing ones (to avoid the penalties or 80 % of the taxes on energy consumption)
3. From 2005, the market has become European, for emission quotas set by each member country and covering approx. 5000 polluting european sites (steel mills, refineries, power plants, etc) ; contracts are for 8 % average reductions over 2008-2012 compared to 1990, for subsidies of 1,3 BillionEuros/year
4. Few other markets: Japan, US Regional greenhouse gas initiative (10 States incl, California)

NB: the EU potential is about 2 Billion tons CO_2 , much smaller than US with 5,5 Billion tons

Trading in CO2 emissions rights (II)

- ETS (Emissions trading Scheme) Market operations : prices of 3-13 Pounds/ton
- There are 2 Mton/day and 20 Mton/day spot markets
- 2010 ETS market volume across EU(+EFTA) : 80 BillionEuros, covering 12 000 installations across EU representing 50 % of EU's greenhouse gas emissions
- Problems : market is illiquid and has too few transactions ; the initial 34 companies had targets easy to reach , thus there were too many emission rights to sell ; as the many smaller companies' goals are only evaluated once per year, there are few buyers; companies have lied on their emissions to save on taxes
- Case: security attacks on european emissions rights market (Jan 2011) , due to 2 M allowances to emit CO2 were stolen in Czech republic ; effect on market credibility; only 13 of EU's members have secure national registries for the transactions; traders have also played on different VAT rates to siphon off millions

Fundamental flaw in emissions permits trading concept

- All market based machanisms still allow to pollute beyond the turning points in concentrations of emissions which have non-reversible consequences

- It is impossible to set the marginal price on the last ton of CO2 emissions before that turning point

- In economic history, rationing has proven more efficient , and faster, than taxation and markets ; this would lead to emissions quotas but with security implications

Green Metrics for management

- Issue: include environmental goals for the appraisal of managers (and sometimes their bonus)
- Regulatory basis: Since 2001, national laws on sustainability policies in some countries , excluding even from some procurement processes
- High level of support in general for these measures from company Boards and top management, with focus on clients; bad response though from investors (Source: Study on 850 companies in 100 countries by Accenture for UN Global compact)
- Case : 37 % of CAC40 companies have metrics including Social responsability, into which goes environmental issues (Sources: RiskMetrics, MACIF Gestion); e.g. Danone where 900 managers have bonus linked to CO_2 + H_2O+recycling targets
- Problems: lack of specific measurements, lack of budgets for corporate sustainability, leading to very subjective assessments

Case: IT investments in supply chains with green side-effects

- Case Global brands/ Local markets: Pernod-Ricard (F) uses:
- river barges rather then trucks for champagne supply chains to Le Havre harbour ; reduction of air and road freight
- Investment in 8 demand prediction IT systems for fast-moving consumer goods (FMCG) with ERP, BI and sales forecasting tied to above new logistics routes
- Branding of green supply routes helps in the consumer market place
- Better real-time product tracing
- Similar cases: General Mills UK, JAE, etc

- Problem area: hazardous materials handling

- Research issue: real-time information systems for measuring each product's CO2 footprint; additional modules to ERP systems; switching on of these modules driven by regulations rather than by costs and benefits
- Research issue: standardisation of exchange of environmental data across a supply chain, and to trace the eco-footprint of a given bill of materials
- Research issue : reverse logistics of the end-of-life of a product in terms of disposal and logistic costs

Energy and poverty

- Issue: -How can poor and needy cater for higher energy costs and the social pressure to use more power hungry services and devices ? Or social action vs. Environmental sustainability (first: Rio 2 nd Earth Summit, 1992; since: all the COP battles; also EU SPARK-Net project/ database)

- What is the lasting impact of low thermal insulation constructions ?
- How can poor owner occupants upgarde their properties ?

- Regulations: * some countries include social justice , dignity, economic progress into their environmental charters

  * some countries define and enforce social energy tariffs

- Case: in France in 2009: 5 M households had difficulties paying their energy bills (Source: RAPPEL); 3,4 M households are under energy precarity (>15 % revenue used on energy); 300 000 households benefitted from the National energy solidarity fund (FSL) managed by the national districts; note GDF Suez/ Emmaüs partnership

Health implications of energy saving initiatives

- Issue: Energy saving projects which simultaneously improve the inner climate in buildings and hospitals, reduce the spread of some infectious diseases (e.g. pneumonia)

- Case: After installation of a distributed ventilation & heat recovery system, Aalborg Hospital (DK) reduced some infections occuring there by 35 %

« Greenwashing »

- Issue: marketing techniques aiming at wrongly « greening » a product or service
- WWF/HEC survey in 2007 of 17129 visual ads, of which 508 on green issues, with >17 % greenwashing cases
- Controlling parties: Profesional media/ advertising National regulator , NOG's
- EU 1999 regulation on posting CO2 emissions of cars, has not entered many national legislations
- Moderating instruments: Self-regulating « Charters » by ad's industry

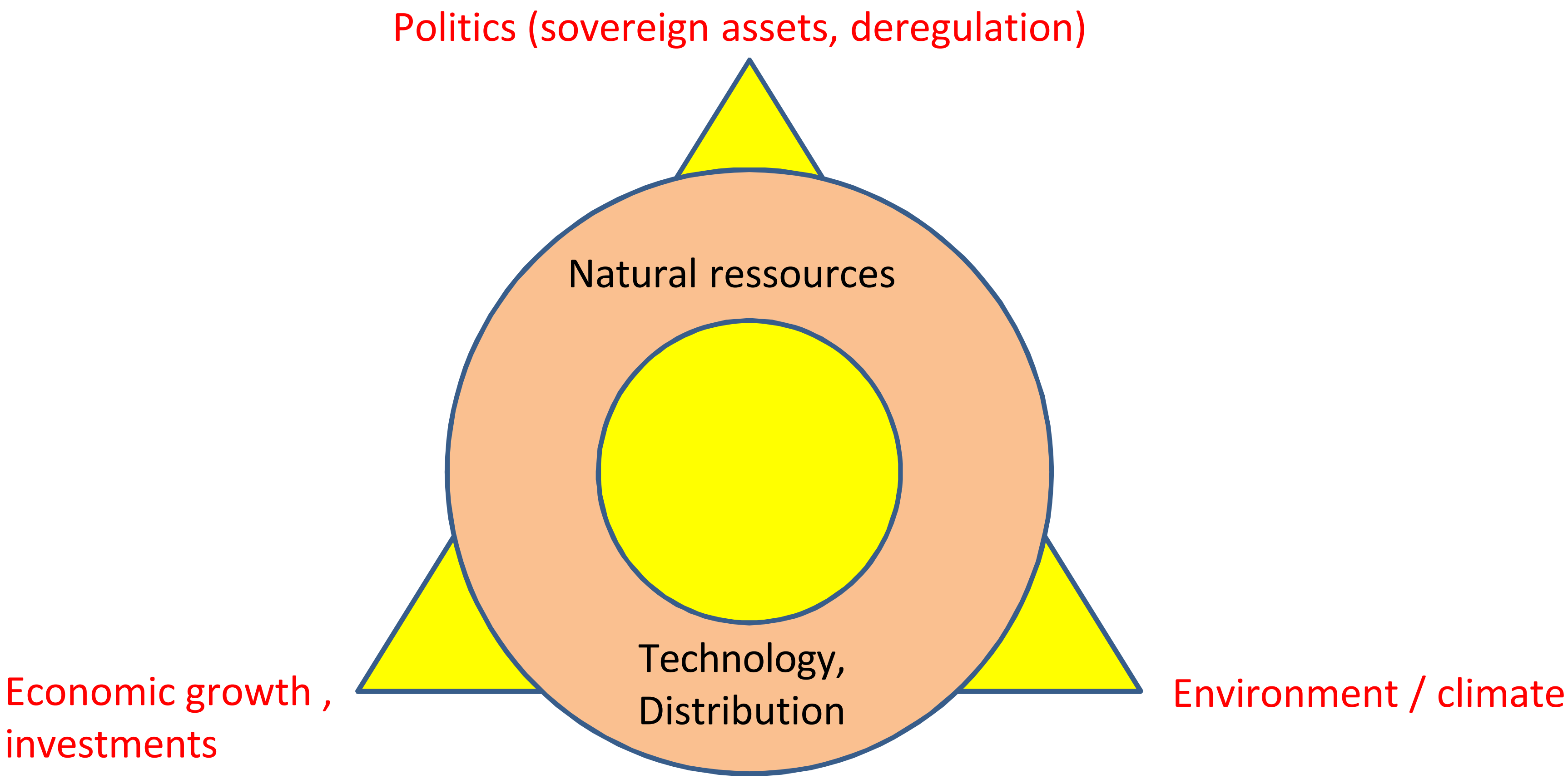
- Examples: -BMW: « pleasure is a renewable energy »

  -Total: « your energy is our energy »

- Problem: lack of clear criteria

10: POLICIES & REGULATORY DESIGN

The eternal « violent » triangle of energy and energy savings



Policies

- Policies set by political powers drive regulations, investments, regulated industry structure, taxes but also behaviors. According to EU's BARENERGY project :

1. The same barriers are relevant for energy savings, increasing efficiency and new technologies
2. Only a mixture of measures focussing on broad institutional changes and targeted at individuals can overcome the above existing barriers
3. For energy savings, a lack of knowledge is an essential barrier blocking behavioral change; any steps to reduce consumption must not compromise significantly comfort or personal status
4. Clear and reliable product information, also around eventual subsidies, is needed to create trust in energy efficiency processes and products

- Across Europe, two policy types co-exist: market and supply driven only, regulated with varying types of incentives with energy / emissions performance measures (e.g. « Grenelle »(FR))

European Energy Community

-<u>Issue</u>: There are differences and limits in national policies, and lack of flexibility, energy security & critical mass, Some political forces have proposed in 2012 to replace the unmanaged non-solidarity interdependencies, by a European Energy Community with associated investment capabilities and market integration mechanisms.

Why regulations and Green ITC are mutually relevant in terms of energy savings?

- Cost basis for energy is enhanced or damaged by regulations, so that incentives or taxes on energy / emissions get irrelevant or critical
- All distributed systems depend on regulated markets: electricity, gas, water, telecoms
- Data center operators are / become themselves monopolists, or oligopolists
- Regulations affect not only grid operating costs , but also reliability (via investment policies), and security of supply (via market mechanisms)
- Green ITC technologies can be disruptive in some cases as to the operating cost basis in regulated markets

Why regulate?

- Networks are natural monopolies

–Investors and consumers need protection under private ownership

- Why privatise?

–Separate competitive services from network

- Competition reduces costs, transfers gains

–Competition difficult under public ownership

- Cross-border trade: public and private utilities

– Regulation + restrictions on state aid to avoid distortions

- Regulation to protect against subsidy

Un-bundling (Legacy issues in presence of an incumbent)

Local loop unbundling (LLU or LLUB) is the regulatory process of allowing multiple operators to use connections from the local edge node to the customer's premises. The physical wire connection between the local edge node and the customer is known as a "local loop", and is owned by the incumbent. To increase competition, other providers are granted unbundled access.

Regulation: the challenge

- Regulator appointed by Government , or by Parlament, with / without judicial control

- Regulator represents in principle the community

–grants access rights, franchise, social balance

–wants guaranteed supply at low prices

- Utility makes « sunk investments »

–wants secure future profit

–has huge potential market power

–will not invest without assurance

Regulatory acronyms

- CC: Competition Commission
- CEC: Commission of European Communities
- CEGB: Central Electricity Generating Board
- COLS: Corrected ordinary least squares
- CRS: Constant returns to scale
- DEA: data envelopment analysis
- Disco: Distribution company
- DOJ: US Dept of Justice
- ESI: Electricity supply industry
- G: generation
- HHI: Hirschman-Herfindahl Index=sum of squared market shares
- PDV: present discounted value
- PUC: Public Utility Commission
- RAB: regulatory asset base
- REC: Regional Electricity (Distribution) Company
- RPI: Retail Price Index
- rTPA: regulated Third Party Access
- T: Transmission
- WACC: weighted average cost of capital

Electricity regulation

- Why regulate?

– Public vs private ownership and interstate trade

- Objectives and challenges of regulation

– Credibility and institutional requirements

- Unbundling electricity –what to regulate?
- How to regulate:

–US rate-of-return vs price cap regulation policy

- Many other regulatory policies (see later slides)

Example : The UK model: incentive regulation

- European regulation and cross-border challenges

The regulatory trap

- Sunk investment (cables, servers, masts, etc) are exposed to "regulatory opportunism" : hold down prices to benefit consumers
- Utility may then underinvest
- Underinvestment precipitates nationalisation

Inability to restrain regulatory opportunism may make state ownership (de jure or de facto) the only solution

Regulation

- Transfers efficiency gains R to consumer C:

  $R = bR + (1-b)C$

- *b* is « *power of incentives* » , R is value of efficiency gains, and C is purchases by consumers (companies and households)
- -high “power” = strong efficiency incentives

  -low “power” = “rent transfer”
- Conflict between incentives and transfers

Applies for public ownership and regulation

Accounting for the utility's cost

- Very often , purchases by consumers C are for theoretical purposes made equal to cost of utility (apart from regulated or capped profit margin)

- Full cost *C* is operating expenditure, OPEX *, plus* return ***on*** and ***of*** capital:

  $C(t)= OPEX(t)+ rB(t)+ D(t)$, *r* is cost of capital

- Regulatory Asset Base (RAB) = *B(t) (sunken assets)*

  $B(t+1)= B(t)+ I(t)-D(t)$

where *D(t)*is depreciation, I(t) investments

(for each asset *j in RAB installed over time : Sum(d(j,t))= k(j),*is its initial cost)

« Rate-of-return » regulation

- Regulator sets all prices p(i) for all utilities I, to cover utilities' costs
- Regulator determines "fair rate of return", *f* > *r*
- Regulatory asset base B(t,i) normally written down to book value over life-time T
- Utility i meets demand *q(i)* at these prices *p(i)*

$$\Sigma\,(p(i) \times q(i)) = R(i) = OPEX(t,i) + fB(t,i) + D(t,i),$$

with f , and ultimately B ,fixed by regulator

- Utility decides ***how*** to produce the output

→***Incentives to over-invest and to gold-plate***

« Rate of return » regulation

- US Constitution entitles utility to “fair return upon the value of that which it employs for the public convenience‟ (1898)

- “Rate of return” will be adequate to attract new investment if it is „used and useful‟ and not „imprudent‟

→ ***« Low powered » regulation***

« Price-cap regulation »

- Designed by Littlechild for BT

– mimics the effect of competition

- Regulator collects data from utility:

– forecast of efficient operating costs *OPEX(t)**

– asset value, investment plans *B(t)*

– demand forecasts

– calculates weighted average cost of capital WACC = *r*

- Regulator determines revenue required:

$$R(t) = OPEX(t)^* + rB(t) + D(t)$$

« Competition »

Prices set individually by competitors (e.g. Argentina)

- increased profits require cost cuts
- competition transfers gains to investors and/or consumers
- innovation rewarded, not impeded
- incompatible with central state ownership

« Regulatory equilibrium »

- This Regulatory policy reflects a (political) balance between interest groups
- Conflicts lead often to inefficiencies : cross-subsidy, costly investment, costly raw materials / logistics / energy / processes and machines
- A "regulatory equilibrium" is normally remarkably stable, hard to reform
- Technical change and new players may alter the balance and may precipitate a new structure :

–new entrants or technologies (telecoms, renewables, GreenITC); loss of "economies of scale"

➔ ***Privatisation changes balance of power particularly if at least one utility is restructured***

Case: Google Energy

- Under the regulatory equilibrium principle, GOOGLE has been awarded a power distribution license in USA to purchase wholesale electricity for its own use, and even to resell it

« Yardstick » regulation

- Needed: a set of comparable companies
  - e.g. 12 distribution companies with unit costs c(.)

- Estimate the average unit costs of ***other*** firms *co(.)*

- Price cap for firm *i* is *p(i,max)=* (1-*b*)* *c(i)+ b* Average(co(.))*

- "Power of yardstick" is *b*

→***What if other companies face different costs?***

« Structural remedies »

- Structural remedies mean a set of processes forced by regulator, such as mergers, site co-locations, affecting the operating costs and investment costs of the regulatory asset base
- To implement such remedies is often ineffective
- Structural reforms disturb interest groups:
- Regulatory inefficiencies to be reduced wherever possible

→Competition where feasible, regulation to mimic competition where not

« Benchmarking »

- Objective: to set and maximize *R*=efficiency gains
- Need: a set of comparable companies, and enough data to identify important cost drivers
- Carry out regression analysis
- Identify « efficiency frontier », i.e. changes of R with design and operating parameters chosen by utility
- Determine distance of each utility company from frontier
- *Investments and costs* set by regulator for the utility to catch up the frontier
- Predict rate of movement of frontier

What makes regulation credible

- Ideally self-enforcing: if the cost of breaking the regulatory framework is high, the cost of consumers losing confidence in the utility is high because:
  - -high need for future investment (rapid demand growth)
  - -investment and newt technology require private management/finance
  - -high cost of poor service (few alternatives)

- External enforcement needs institutions: regulatory independence, legal enforcement

- Regulatory framework is threatened if:
  - – technical progress
  - - alternatives are cheaper
  - – investment needs fall

Incentives vs credibility

« Rate-of-return » or « cost-of-service » regulation:

• Either party can request a “rate review”

• Limits excess profits and losses

• Price-caps set by regulator for e.g. 5 years (sometimes with right of appeal if costs rise > 10%)

• If variability of profits is larger, windfall taxes may be defined

→***Better have incentives at expense of reduced credibility***

Restraining « regulatory opportunism »

- US system:

–Constitutional guarantees

–Separation of powers: DoJ, FCC, PUCs

–Administrative law to challenge regulatory discretion

- European system: national Parliament is sovereign

- need to restrain Government
- licences upheld by courts
- but frequent oligopolies (e.g. Germany, Spain), or single party domination (France)

- Other systems:

-Australia: national wholesale electricity market (since 1998)

Case: Licenses and Legislation in UK

- Primary legislation contains a framework

–duties of regulator, requirements for licencees

–dispute resolution

- Details contained in licences; like contracts, upheld by courts

- Licence modification by consent or reference to Competition Commission

→***Costly for either party to deviate***

Case UK: Creating credibility

Regulator has a duty to ensure that investment can be financed

- Price controls reset every 5 years

–but changed only if “in the public interest”

- Utility can appeal against new price control

–appeal considered by Competition Commission

–and subject to Judicial Review

–disputes costly for both parties

Case UK: Power Transmission adequacy

- National Grid Ltd. has incentives for reliability and investment
  - –to reduce the cost of ancillary services
  - –to reduce interruptions and increase availability
  - –has invested hugely in distribution and transmission (since 1990 : £16 billion)

- But average transmission system reliability has gone DOWN with competition (Source: National Grid data)

EU Energy Directives

- Electricity: 96/92/EC (Feb 1999)

- Gas: 98/30/EC (Aug 2000)
  –justified by experience in UK, Norway, Chile

- Increased role of Commission

- De-politicises national energy policies

- Energy policy to be made “market friendly”

→***Aim: create a competitive single energy market***

New EU Directive (2000)
(but markets only opened 2007)

For electricity *and* gas:

- « regulated » not « negotiated » access to grids
- tariffs *or* methodology published *ex ante*
- sector-specific regulator
- legal (but not ownership based) unbundling of generation and transmission
- no single buyer model
- 2007 all gas + electricity markets "fully open" (i.e. Swedish operator may operate in Germany)

Rising prices prompted frequent inquiries!!!

→Remember the California melt-down (1998-2001) : prices above competitive levels were due to both higher production costs and higher mark-up from market power

European developments in Energy field

- *« Energy Sector Inquiry »* completed :concern over market power (some companies unbundle Generation & Transmission)

- Gradual move to cooperation between national regulators

- Aim to improve power to get information: slow progress on market surveillance

- ***Inadequate attention to mergers***

CONCLUSION

The perfect energy savings and enjoyment with zero emissions (in operations) can be achieved