ESEIA Summer School
SUSTAINABLE SMART METROPOLITAN REGIONS
Energy Efficiency - introduction

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Bibliography

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Energy efficiency

- The current state of the play _ What are we including when measuring EE? The importance of effective implementation. Decomposing EE in demand. How much money is flowing into EE.
- A blue print for an energy-efficient world_Efficient world scenario - methodology and assumptions
- Unlocking energy efficiency at the sectorial level _ Buildings, industry, transport, power generation and electricity demand
- Path ways for EE_ cost and benefits
- Examples of EE and smart Communities

Bill Gates

- **“Never before in history has innovation offered promise of so much to so many in so short time.”**

Adaptado da apresentação de Richard Bendis no MEID

Global Innovation Network

Adaptado da apresentação de Richard Bendis no MEID

Energy efficiency

- *“Energy efficiency is a measure of energy used for delivering a given service. Improving energy efficiency means getting more from the energy that we use.”*
- There are different ways to improve energy efficiency. For example:
    - ‘Innovation’ can lead to the equal or greater output with less energy.
    - ‘Cutting out wasted energy’ reduces energy needed while maintaining output.
    - ‘Heating technologies’, such as heat pumps, can deliver greater output for less supplier energy.

LNEG

Energy efficiency

How much money is currently flowing to EE

- Investments in EE are seldom tracked systematically and no comprehensive estimate is available of global investments
- Investments are made by a multitude of agents and country by country analysis is needed

- As example from OCDE estimates the panorama from a total of 180b$
- such:
  - 76.3% EU 20% USA
  - 30.6% China 18.6% other OCDE
  - 25.1% Other non-OCDE 9.5% India

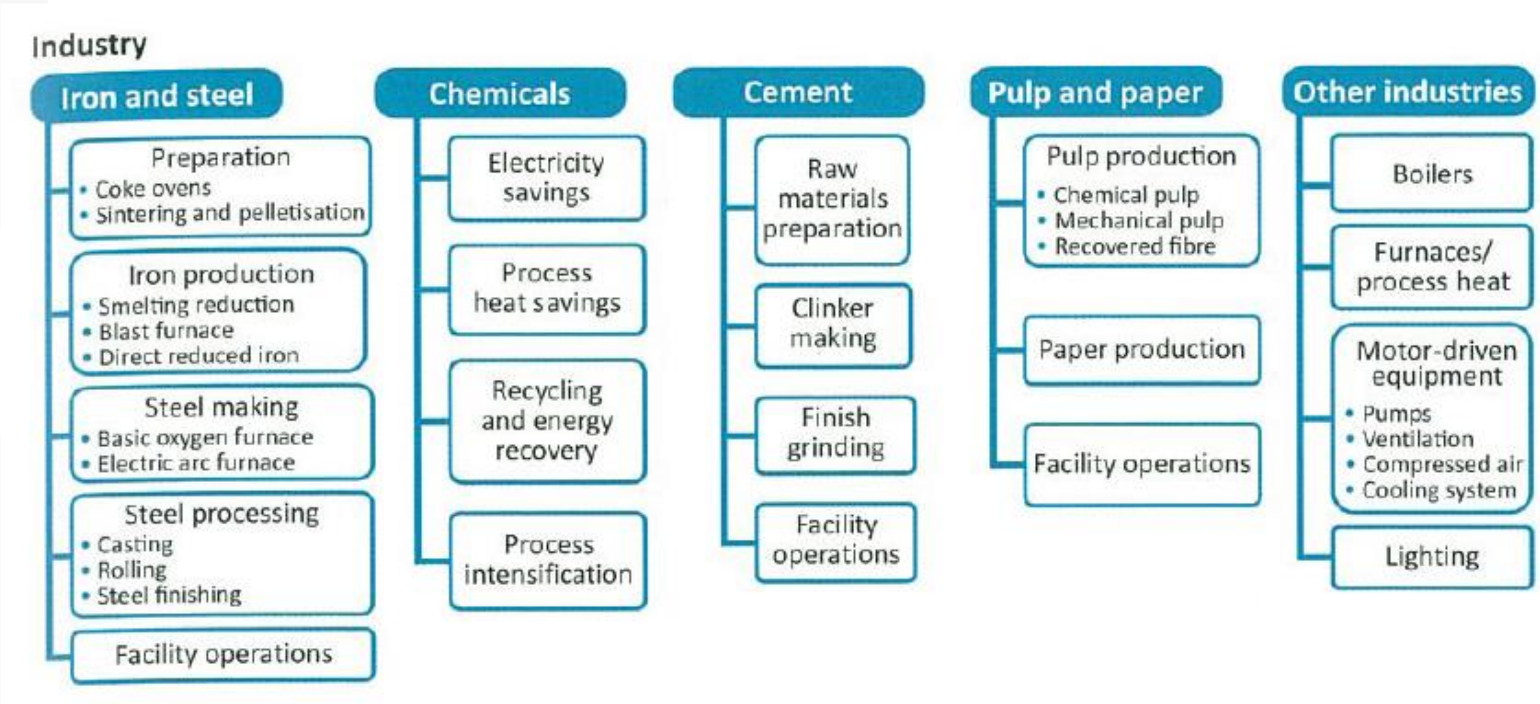
Energy efficiency
Methodology and assumptions

- Efficient World Scenario is that policies are put in place to allow the market to realize the potential of all known EE measures which are economically viable. To calculate the economic potential, which varies by sector and by region, two steps are undertaken
  - Evaluation of technical potentials. Analysis to sub-sectors and technologies by investigating from world-wide data.
  - Identification of economically viable measures. Average payback periods were estimated taking into account the nature of the countries, in general shorter than lifetime of equipment.

Energy efficiency

Evaluation of technical potentials – a bottom up approach

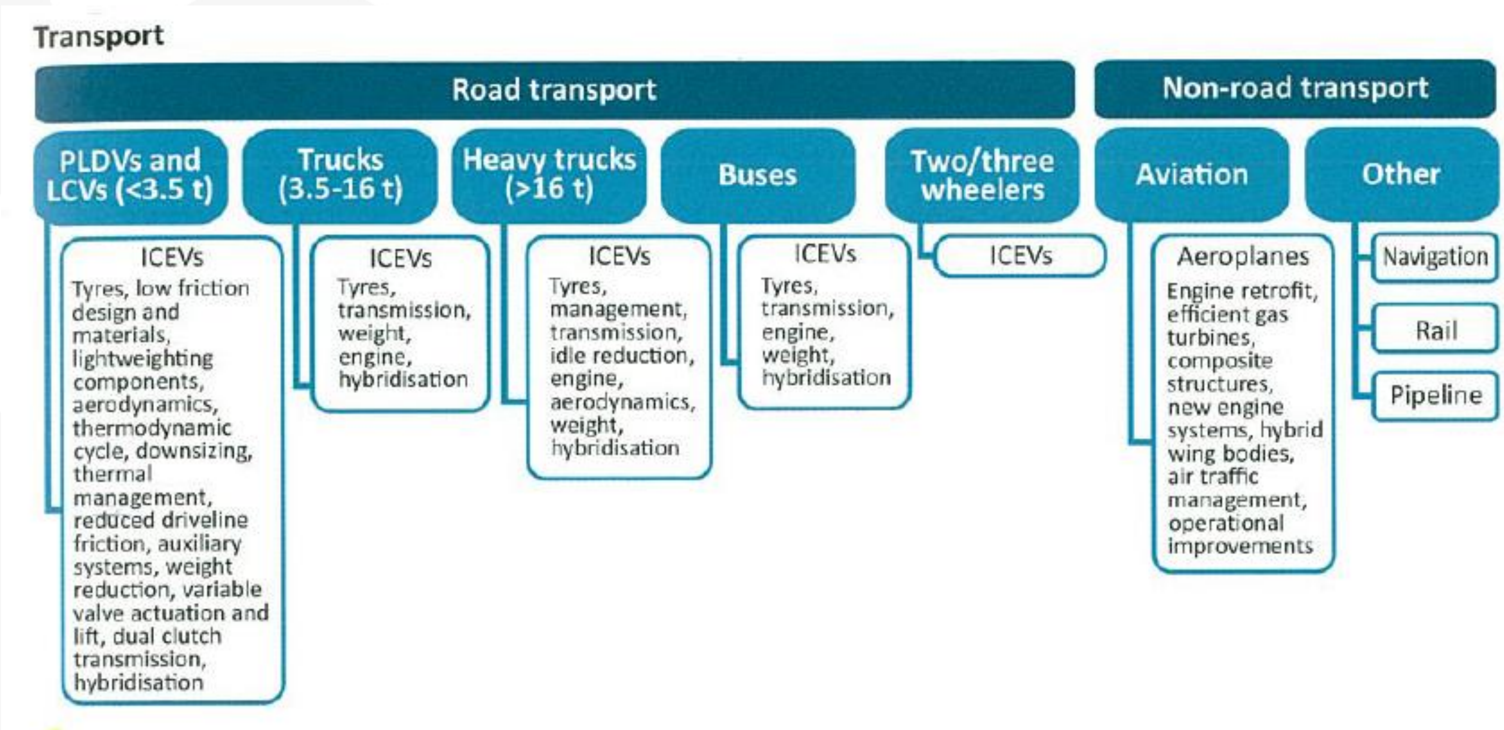
- Industry



Energy efficiency

Evaluation of technical potentials – a bottom up approach

- Transport



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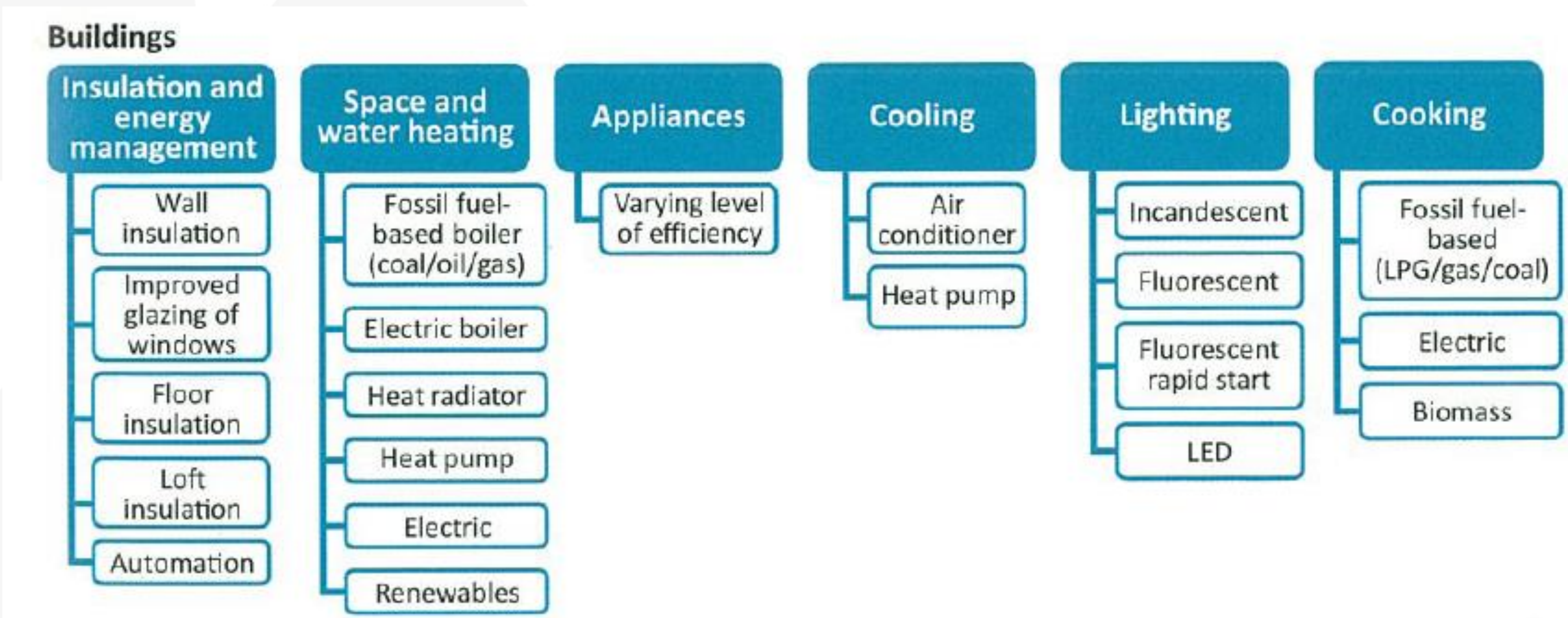
Energy efficiency

Evaluation of technical potentials – a bottom up approach

- Buildings



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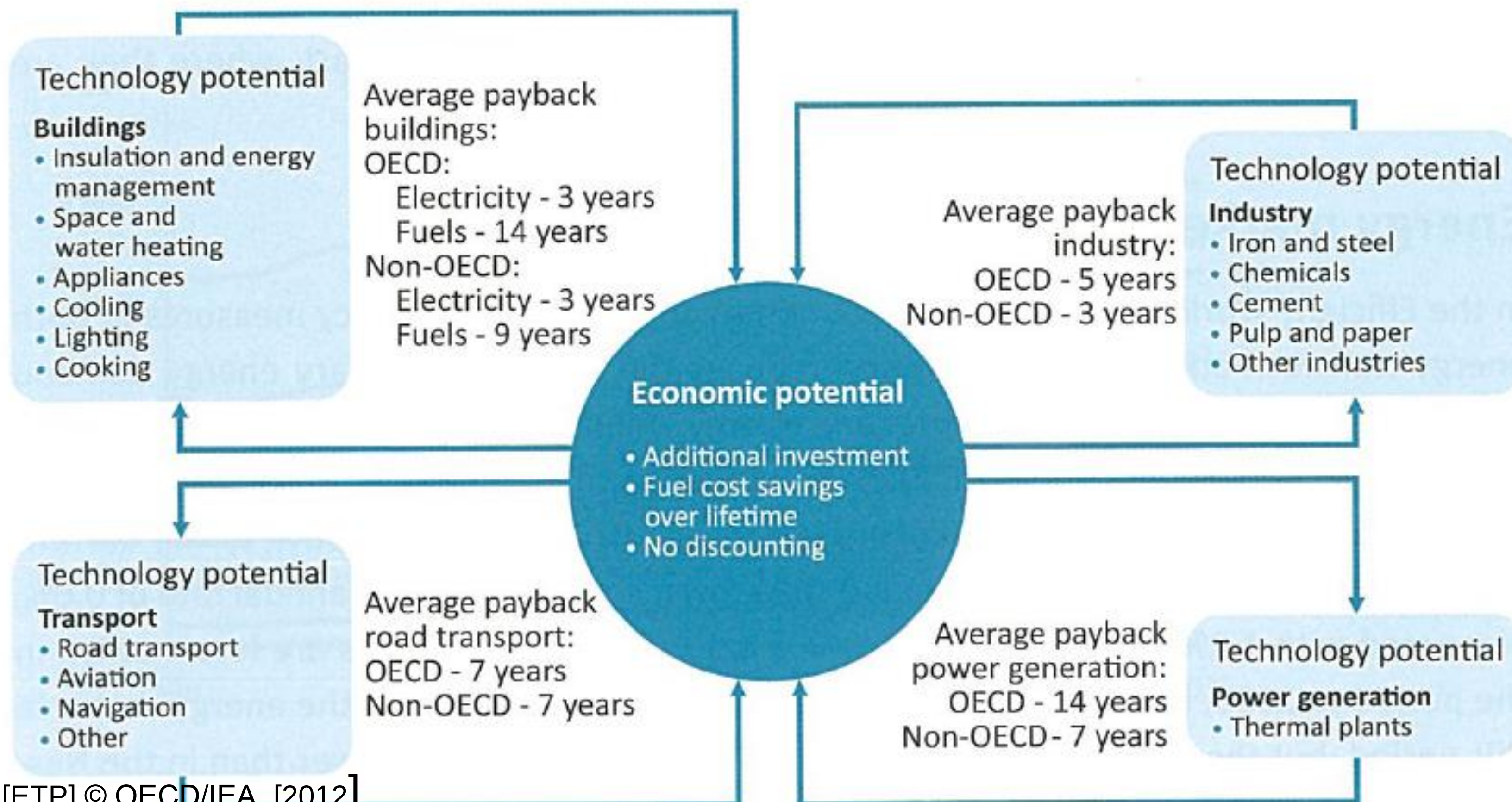
Energy efficiency

Identification of economically viable measures

- Economical analysis



Energy efficiency

Identification of economically viable measures

- Rebound effect
  - Increased efficiency, saving operating costs may lead to increased usage – direct (ex. drive more often an efficient car)
  - Reduced energy expenditures may lead to spend more money on other energy-consuming products (this pushes energy demand)

  - Large uncertainties are related to the evaluation of rebound effect but a significant portion could be avoided by appropriate pricing policy

Energy efficiency

Blue print for EE – hat-trick energy goals

- Make it visible – the energy performance of each end-use service needs to be made visible to the market
- Make it a priority – the profile and importance of EE needs to be raised
- Make it affordable – Create and support business models, financing vehicles and incentives to ensure investors in EE reap an appropriate share of rewards
- Make it normal – EE needs to be normalized if it is to endure
- Make it real – Monitoring, verification and enforcement activities are needed to verify claimed energy
- Make it realizable – achieving the supply and wide spread adoption of EE goods and services depends on an adequate body of skilled practitioners in government and industry

OCDE Scenarios

■ The **6°C Scenario (6DS)** is largely an extension of current trends. By 2050, energy use almost doubles (compared with 2009) and total GHG emissions rise even more. In the absence of efforts to stabilise atmospheric concentrations of GHGs, average global temperature rise is projected to be at least 6°C in the long term.

■ The **4°C Scenario (4DS)** takes into account recent pledges made by countries to limit emissions and step up eff orts to improve energy effi ciency. It serves as the primary benchmark in *ETP 2012* when comparisons are made between scenarios. Projecting a long-term temperature rise of 4°C, the 4DS is broadly consistent with the *World Energy Outlook* New Policies Scenario through 2035 (IEA, 2011). In many respects, this is already an ambitious scenario that requires significant changes in policy and technologies. Moreover, capping the temperature increase at 4°C requires significant additional cuts in emissions in the period after 2050.

OCDE Scenarios

The **2°C Scenario (2DS)** is our objective

■ The 2DS describes an energy system consistent with an emissions trajectory that recent climate science research indicates would give an 80% chance of limiting average global temperature increase to 2°C.

■ It sets the target of cutting energy-related CO2 emissions by more than half in 2050 (compared with 2009) and ensuring that they continue to fall thereafter. Importantly, the 2DS acknowledges that transforming the energy sector is vital, but not the sole solution: the goal can only be achieved provided that CO2 and GHG emissions in non-energy sectors are also reduced.

Note: The 2DS is broadly consistent with the IEA *World Energy Outlook* 450 Scenario through 2035.

The global outlook – a Low carbon future

■ **Create an investment climate that builds confidence in the long-term potential of clean energy technologies.**

Industry is key to the transition. Common goals supported by stringent and predictable policies are essential to establish the necessary credibility within the investment community.

■ **Level the playing field for clean energy technologies.**

Governments should commit to, and report on, progress on national actions that aim to appropriately reflect the true cost of energy production and consumption.

Pricing carbon emissions and phasing out of inefficient fossil fuel subsidies, while ensuring access to affordable energy for all citizens, are central goals

■ **Scale up efforts to unlock the potential of energy efficiency.**

The IEA and EU have developed several energy efficiency recommendations to help governments achieve the full potential of energy efficiency improvements across all energy-consuming sectors. Committing to application of these recommendations would form a good basis for action and accelerate results.

■ **Accelerate energy innovation and public research, development and demonstration.**

Governments should develop and implement strategic energy research plans, backed by enhanced and sustained financial support.

The global outlook – a Low carbon future

- *Additionally, governments should consider joint RD&D efforts to co-ordinate action, avoid duplication, and improve the performance and reduce the costs of technologies at the early innovation phase, including sharing lessons learned on innovative RD&D models.*

Key findings

■ **Energy use and CO_2 emissions will almost double by 2050 if current trends persist. This would put the world on the path towards a 6°C rise in average global temperature.** *The energy technologies exist to stave off that threat. The current relationship between economic growth, energy demand and emissions is unsustainable.*

■ **ETP 2012 unveils three dramatically diff erent energy futures:** *the 2°C Scenario, a vision of a sustainable energy system; the 4°C Scenario, an assessment of what announced policies can deliver; and the 6°C Scenario, which is where the world is now heading, with potentially devastating results.*

■ **Progress in rolling out clean technologies has been too slow and piecemeal.** *Too little is being spent on clean energy technology. Investment in fossil fuel technologies is still outpacing low-carbon alternatives.*

■ **A low-carbon energy system is likely to provide a higher level of energy security,** *primarily through reduced dependency on energy, greater diversity of energy sources and technologies, and lower risks related to climate change.*

■ **The cost of creating low-carbon energy systems now will be outweighed by the potential fuel savings enjoyed by future generations.** *A sustainable energy system will require USD 140 trillion in investments to 2050 but would generate undiscounted net savings of more than USD 60 trillion.*

■ **The biggest challenge to a low-carbon future is agreement on how to share the uneven costs and benefi ts of clean technology across generations and countries,** *not the absolute cost or technological constraints. Governments must address these distributional issues.*

■ **Substantial opportunity exists to increase energy savings, effi ciency and know-how across sectors and technologies,** *such as those between heat and electricity, or among transport and industry applications.*

■ **A sustainable energy system is a smarter, more unifi ed energy system. Complex and diverse individual technologies will need to work as one.** *Technologies must be deployed together rather than in isolation. Policies should address the energy system as a whole, rather than individual technologies.*

Opportunities for policy action

■ **Governments must outline a coherent vision for a clean energy future, backed by clear goals and credible policies.**

It is is vital to establish the necessary investment climate for clean energy to thrive and to stimulate the development of breakthrough, low-carbon technologies. Ensuring that the true cost of energy is refl ected in consumer prices, that non-economic barriers for energy efficiency are removed, and that clean energy research, development and deployment is accelerated are three key steps for governments to take.

■ **Governments must collaborate to achieve a low-carbon future.** *Governments need to show determination and courage to transform the energy system by making the right choices.*

Cooperation and collaboration at home and abroad will be vital to achieve this.

Energy Systems Thinking

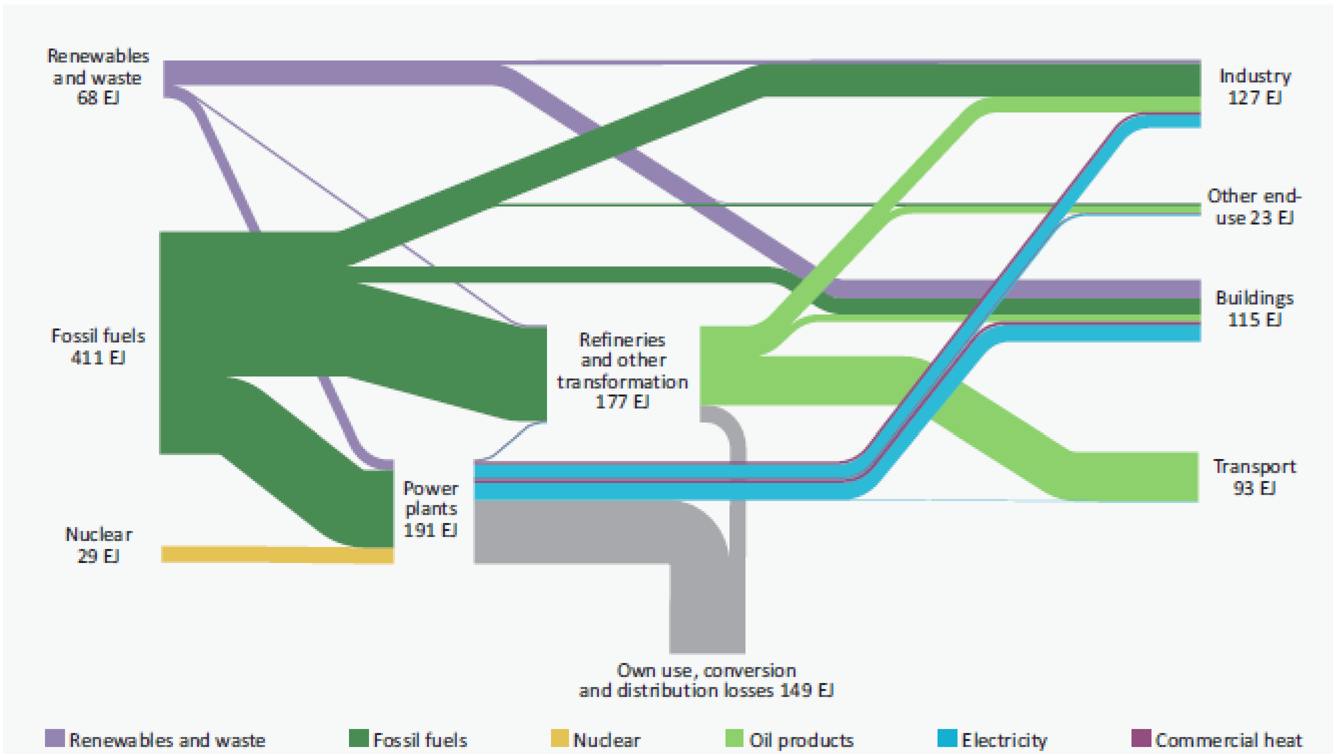
■ The current energy system is dominated by large, centralised generation based mainly on fossil fuels. The low-carbon energy system of the future will be characterised by greater diversity of technologies and fuels, more renewable energy, and increased complexity across the entire infrastructure (Figure ES.2). Managing energy effectively –

which implies reducing costs and increasing effi ciency while, also ensuring reliability and security – will require a highly inter-related system in which every piece fits together.

■ A systems approach to energy must carefully examine the existing divisions between energy sources and end uses, with the aim of identifying potential synergies that allow for more effective use of each element. The following highlight innovative ideas about unlocking the benefits within targeted areas, and moving towards a more unified energy system overall in the context of the *ETP 2012* 2oC Scenario (2DS) and *ETP 2012* 4oC Scenario (4DS).

Energy Systems Thinking

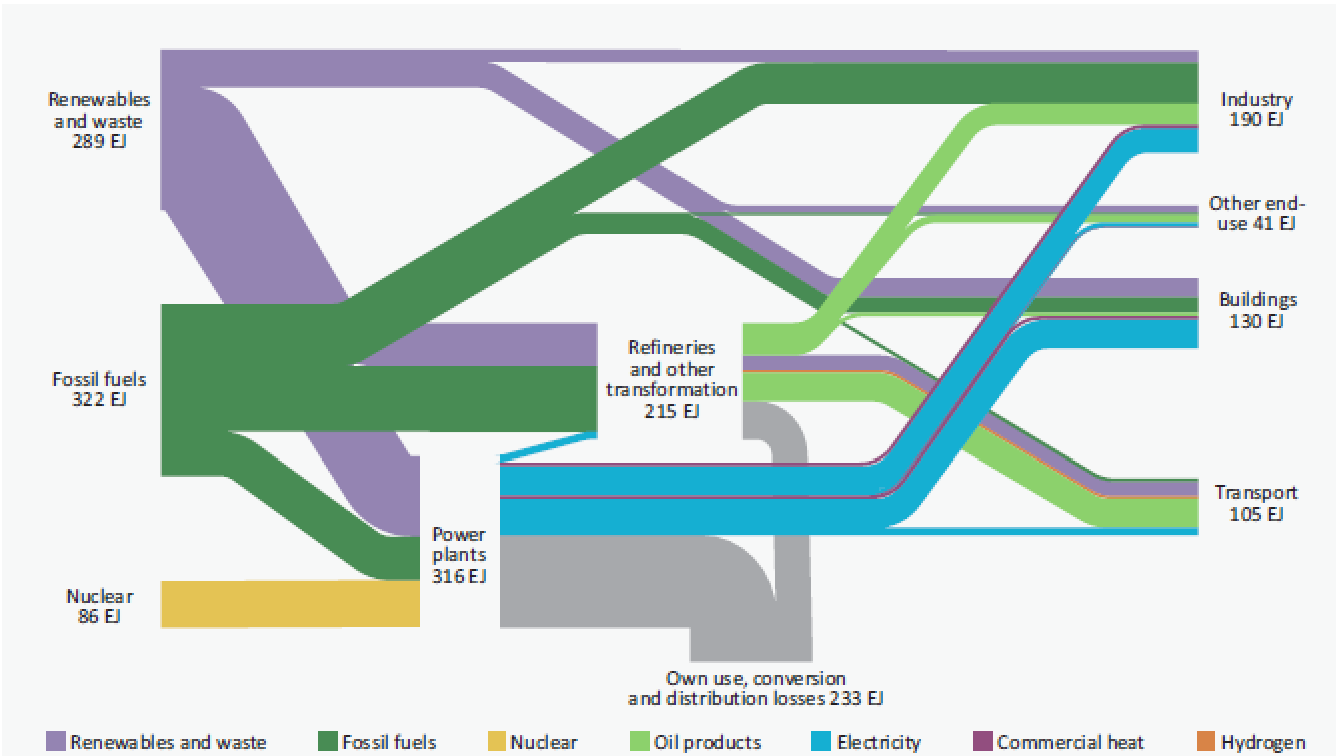
- Global energy flows in 2009



Key point Fossil fuels dominate the current energy system across all sectors.

Energy Systems Thinking

- Global energy flows in 2DS in 2050



Key point To meet global climate goals, the current energy system will evolve and use greater amounts of renewable energy and a wider range of energy carriers.

[ETP] © OECD/IEA, [2012]

Energy Systems Thinking
Energy sector interfaces

- Look to existent infraestruture and optimize new investments
- Flexibility to accomodate an increasing share of variable renewable investments
- A large untapped resource on the demand side exists, which needs to be unlocked through increased deployment of smart grids, and this will require new technology, stakeholder involvement and business models
- Such changes will be challenging for both energy providers and customers, but by considering opportunities throughout the system, cities, regions and countries can choose the best solutions to match their specific circumstances and resource endowment, optimising investments.

Energy Systems Thinking

- **Heating and cooling -** developing a locally based merit order of energy sources that addresses the particular characteristics of local energy demands.
  - **District heating and co-generation of heat and power**
  - **Heat pumps**
  - **Industrial co-generation and waste heat**
  - **Geothermal heat**
  - **Solar heating and cooling**
  - **Bioenergy for heat generation**

Energy Systems Thinking

Heating and cooling recommendation

Thorough understanding of systems integration is essential and the skills of practitioners at all decision levels need to be improved.

- To achieve a highly efficient and low-carbon system for heating and cooling requires **integrated planning** across three levels: **the overall system**, **local communities** (*e.g*. cities or neighbourhoods) and **individual buildings**.
- At the **overall system level**, procedures should be put in place that allow decisions to be informed by developments and operation at the regional and individual building scales.
- Local heating networks and individual micro-generation systems will require real-time information on the carbon intensity of the electricity grid, the load on the local network and the electricity prices.
- These activities require more sophisticated levels of monitoring and control, beyond the reach of current roll-out programmes for smart meters and building scale energy management system.

Energy Systems Thinking

Heating and cooling recommendation

- At the **community level,** sources of locally available heat should be assessed and matched against demand. Planning procedures and policies should be put in place that give adequate incentives to integrate the system cost-effectively, for example by using excess heat from industry or power plants, geothermal heat and heat from waste, as well as other renewables exploiting solar and biomass resources. New permitting procedures, building codes and market mechanisms that provide direct economic incentives for more building codes and market mechanisms that provide direct incentive mechanisms for more efficient use are all needed to realise the vision of an integrated system. At present, the complexity of the regulations and incentives in the heating and cooling markets is a barrier for the diffusion of low-carbon technologies and system integration. Policies and incentives need to be simplified and focused towards end objectives rather than particular technologies.

Energy Systems Thinking

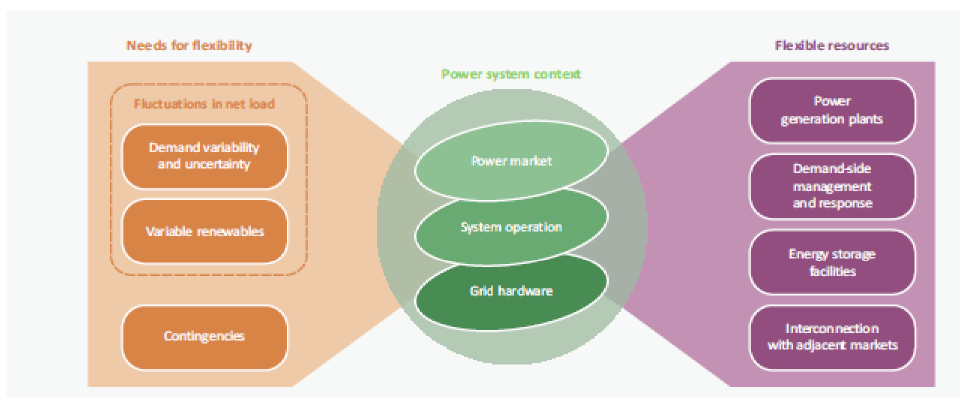
Heating and cooling recommendation

- At the **individual building level**, policies should ensure that practitioners adequately consider the relative practicality and economic eff ectiveness of all available low-carbon options in a holistic manner, in view of local conditions: the standards of the building envelope; the existing heating system; access to existing infrastructure including district heating or gas networks; the occupational profi le of the building; whether there is available space for storage or an individual heating system; and the capacity of the local electricity network. The skills required to integrate and deploy low-carbon heating and cooling technologies successfully are beyond the current levels generally available from fragmented markets of electricians, plumbers and other installers. Furthermore, incentives should align with longer-term planning and objectives. For example, technology that might deliver partial savings today (*e.g.* sub-standard insulation or a co-generation unit fuelled by gas) might be inadequate in a future system with more ambitious targets.

Energy Systems Thinking

Flexible electricity

- Power system flexibility "expresses the extent to which a power system can modify electricity production or consumption in response to variability, expected or otherwise. In other words, it expresses the capability of a power system to maintain reliable supply in the face of rapid and large imbalances, whatever the cause. It is measured in terms of the MW available for ramping up and down, over time (—MW/time). For example, a given combined cycle gas turbine (CCGT) plant may be able to ramp output up or down at 10 MW per minute". Electricity systems need flexibility and employ a range of resources to meet it within their technical, regulatory and market frameworks.

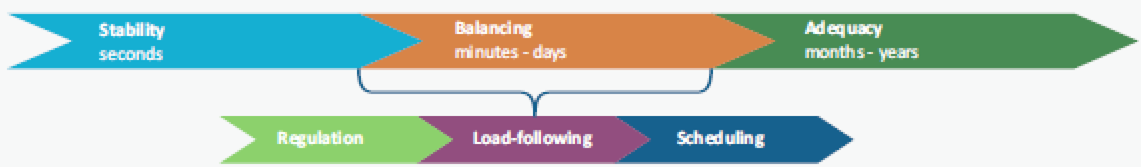


Key point *The need for flexibility, resulting from variable renewables, demand and contingen cies, can be met by four flexible resources: generation, demand response, storage a interconnections.*

Energy Systems Thinking

Flexible electricity – ancillary services

- Non-energy services that are necessary to support the generation and delivery of electricity. These include, but are not limited to: regulation, spinning or operating reserves, voltage support, and black-start capability. Ancillary services are typically provided as a by-product of electricity generation but can be supplied by a range of technologies and approaches such as generation, storage, demand response and interconnection with other regions or electricity systems.



Notes: As in the previous IEA analysis, focus will be on the balancing time frame, and using the terminology commonly associated with ancillary services.

Key point *Flexibility for balancing is divided into regulation, load-following and scheduling to allow quantification of need and evaluation of appropriate technology.*

Energy Systems Thinking

Flexible electricity - Generation technologies

Centralised

Representative values for different power plant flexibilities show that their range varies considerably . Hydro generation can respond more quickly than all others listed, but even technologies that typically provide base-load generation offer some flexibility, especially over longer time periods. Both new coal and nuclear plants are being designed with increased flexibility capabilities and older plants are being retrofitted to increase their flexibility potential.

	CCGT	OCGT	Coal (conventional)	Hydro	Nuclear
Start-up time (hot start)	40-60 minutes	<20 minutes	1-6 hours	1-10 minutes	13-24 hours
Ramp rate	5-10% per minute	20-30% per minute	1-5% per minute	20-100% per minute	1-5% per minute
Time from zero to full load	1-2 hours	<1 hour	2-6 hours	<10 minutes	15-24 hours
Minimum stable load factor	25%	25%	30-40%	15-40%	30-50%

Note: Biomass and biogas are increasingly being used in CCGT, OCGT and coal plants.
Sources: IEA, 2012; Siemens, 2011; VGB, 2011; and expert opinion.

*CCGT – combined cycle gas turbine
**OCGT – open-cycle gas turbine

Energy Systems Thinking

Flexible electricity - Generation technologies
Distributed

- Power generation is becoming increasingly distributed10 as a wide range of technologies are deployed to tap into diverse resources. Back-up generation, self-generation (more common in industry), co-generation11 and micro-generation can use fossil fuels, biofuels, and variable renewables using solar and wind energy among others. While there are many advantages to distributed generation, the lack of centralised (or co-ordinated) monitoring and control of medium and low-voltage networks makes it difficult to manage the generation across the power system.

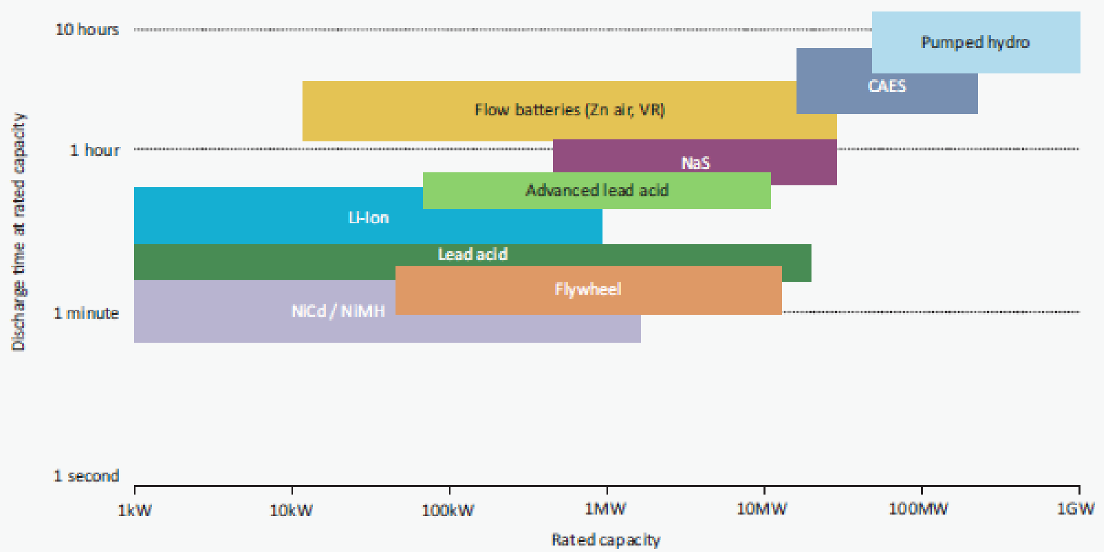
	CCGT	Co-generation		Diesel and CCGT standby	Bio-energy	Wind	PVs	Hydro
		Large	Micro					
	> 100 MW	1 – 100 MW	1-5 kW	<50 MW	1- 100 MW		<100kW	>1 MW
Frequency	Yes	Limited	No					Yes
Reserve	Yes	Possible	Possible at high penetration	Yes	Possible	Possible	Possible	Possible
Reactive	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
Network support	Yes	Yes	Possible at high penetration	Yes	Yes	Yes	Limited	Yes

Note: The ability for wind to provide ancillary services will be affected by the specific generator technology deployed.
Source: Adapted from Degner, Schmid and Strauss, 2006.

Energy Systems Thinking

Flexible electricity - Storage

- Storage technologies distinguish between energy and capacity. Energy (in kWh) is the fundamental quantity delivered, while the rated capacity (in kW) of a facility determines the maximum rate at which stored energy can be delivered to an electricity system. Thus, storage technologies have two fundamental characteristics that determine their suitability for a particular application: the capacity at which they can discharge stored energy (in kW); and the time it takes to fully deplete the energy store at this capacity level (the discharge time). Storage technologies can be categorised by the range of rated capacities of installations and their associated discharge times.



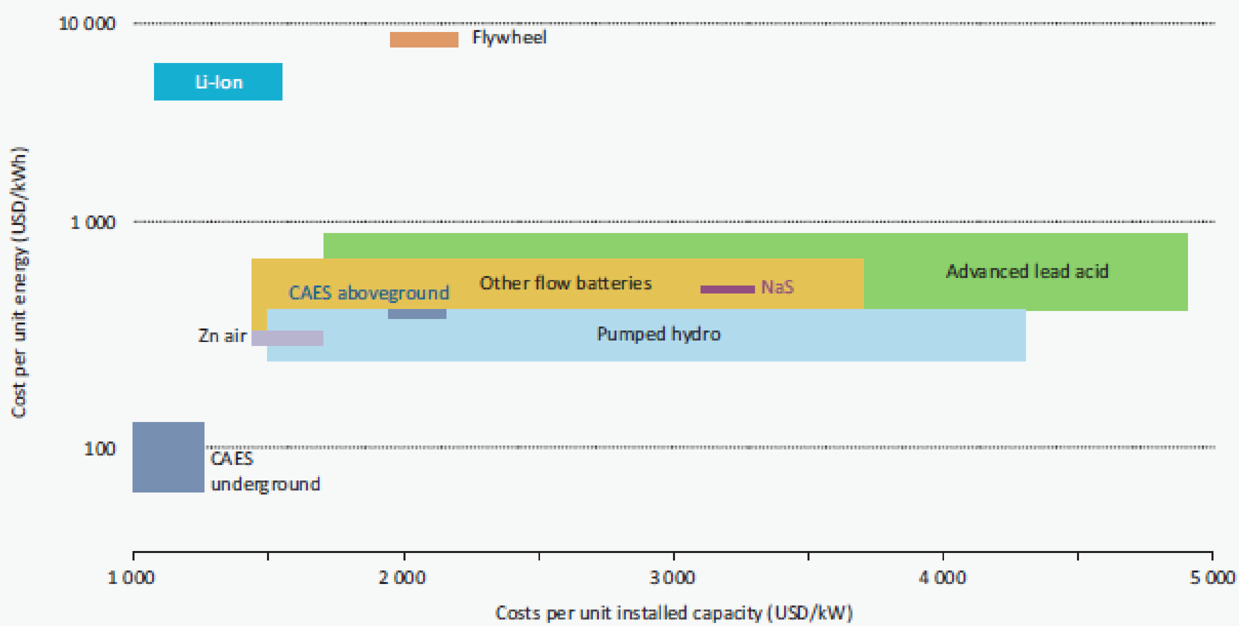
Source: EPRI, 2010b.

Key point *The technical applicability of storage technology depends on both rated capacity and discharge time at rated capacity.*

Energy Systems Thinking

Flexible electricity – Storage (barriers)

- All storage technologies are characterised by relatively high capital costs compared to conventional generation technologies. Combined with the conversion energy losses, this creates a significant barrier to wide-scale deployment.



Notes: Values include both battery and balance of system costs for applications, including system support, frequency regulation and renewable integration applications. For above ground CAES technology, data for utility transmission and distribution grid support applications are plotted. Commercially-deployed cost data is used where possible. Where data was not available from reliable sources, technologies are omitted from the graph.
Source: Data from EPRI, 2010b.

Key point *The cost of storage technologies varies widely; determining appropriate applications is vital to financially sustainable deployment.*

Energy Systems Thinking

Flexible electricity – Storage (barriers)

- Cost reductions are critical if storage is to play a large part in future electricity systems. To date, much of the analysis values only energy arbitrage, although valuation of other storage applications is ongoing – particularly its flexibility (Ma *et al.,* 2011; Lannoye, Flynn and O'Malley, 2012).
- Because the characteristics of storage are so different from conventional generation, some institutional barriers exist (as is true of demand response) which are being addressed by the modification of market rules. Cost targets for research programmes can be used as a proxy for future cost trends.
- The two main forms of storage deployed commercially today, pumped hydro and CAES (compressed air), depend on the availability of suitable geological structures, which may have already been exploited or may not be available in some regions. Historically, the environmental impact of such developments had a lower level of public opposition. Some battery technologies depend on the availability of specialised materials. In the case of lithium-based battery technologies, the sufficiency of the economically recoverable resource has been called into question (Sims *et al.,* 2011). Other battery technologies, notably NaS and advanced lead acid, have a limited number of charge and discharge cycles before performance is materially impaired, restricting their suitability for some applications.

Energy Systems Thinking

Hydrogen in the ES context

■ **Transport**. As a transport fuel for FCEVs, including passenger cars, trucks and buses, and possibly even ships. In the near term, car and bus fl eets are likely to be the main focus of demonstration projects and could be important early adopters of commercially available hydrogen.

■ **Industry** and **transformation** sector. Increasing demand as a feedstock in the refining and chemical industries, due to lower crude-oil quality and the need for cleaner petroleum based fuels,2 as well as increasing demand for fertilisers. Hydrogen may also eventually be used as reductant in the steel industry.

■ **Buildings**. Decentralised co-generation, using stationary fuel cells. Excess electricity could be used for grid stabilisation. In the near term, natural gas can be blended with hydrogen and used with the current infrastructure. As an intermediate energy carrier, hydrogen could also play a signifi cant role for:

■ **Energy storage**. As countries ramp up renewable, variable energy sources (*e.g.* wind turbines and solar photovoltaic), excess electricity might need to be stored for a few hours or in some cases for days, weeks or months. Since electricity can be used to create hydrogen via electrolysis and the hydrogen can later be converted back to electricity, hydrogen storage provides an option for large-scale and long-term energy storage.

Thank you

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