Madrid SESSA Conference "Investment for sustainability"

Requiered means and resources for long-term R&D in energy

Foresight and Cleaner Fossil Fuels

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Madrid, 20 May 2005

OUTLINE

1. General Remarks of the world´s energy situation and future trends.

2. Technological innovation in coal-fired power generation.

3. Endesa´s experience.

4. Concluding remarks.

WORLD PRIMARY ENERGY DEMAND (Mtoe)

World's energy consumption will be about 60 % higher in 2030 than today. It will grow 1.7% per year.

	1971	2002	2010	2020	2030	2002 -2030*
Coal	1 407	2 389	2 763	3 193	3 601	1.5%
Oil	2 413	3 676	4 308	5 074	5 766	1.6%
Of which international marine bunkers	*106*	*146*	*148*	*152*	*162*	*0.4%*
Gas	892	2 190	2 703	3 451	4 130	2.3%
Nuclear	29	692	778	776	764	0.4%
Hydro	104	224	276	321	365	1.8%
Biomass and waste	687	1 119	1 264	1 428	1 605	1.3%
Of which traditional biomass	*490*	*763*	*828*	*888*	*920*	*0.7%*
Other renewables	4	55	101	162	256	5.7%
Total	**5 536**	**10 345**	**12 194**	**14 404**	**16 487**	**1.7%**

Source: International Energy Agency

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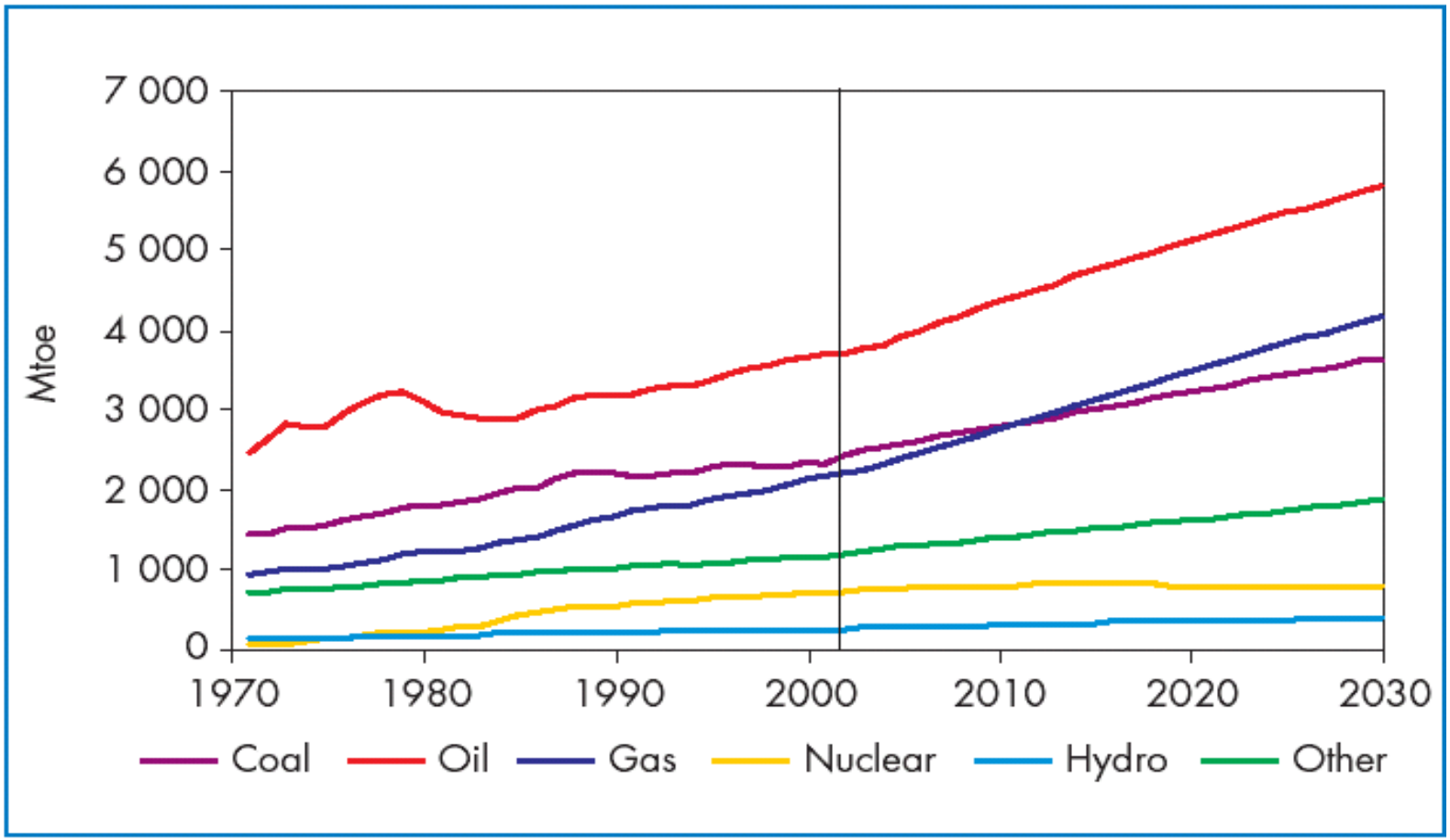
WORLD PRIMARY ENERGY DEMAND (by fuel)

Fossil fuels will still meet most of the world energy demand, accounting 85% of the increase in primary demand.



Source: International Energy Agency

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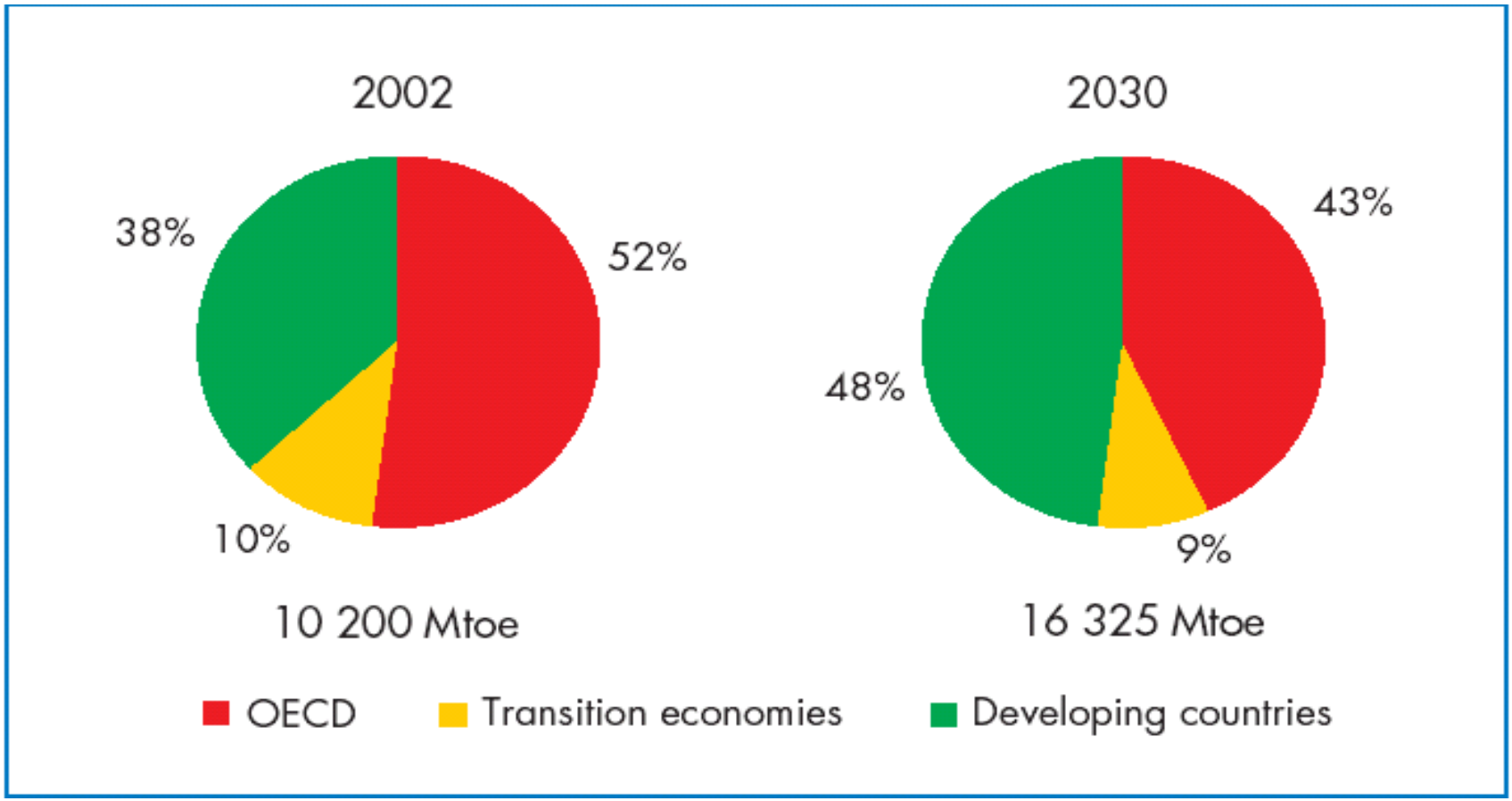
REGIONAL SHARES IN WORLD PRIMARY ENERGY DEMAND

2/3 of increase in demand will came from developing countries.



Source: International Energy Agency

PROVEN COAL WORLD RESERVES (Mt)

In the current energy demand scenario, there are proven reserves of coal for 250 years, oil for 70 years and gas for 60 years.

	Hard Coal	Brown Coal	Total
OECD Europe	22 420	17 041	39 461
OECD North America	218 818	35 614	254 432
OECD Pacific	39 677	38 033	77 710
OECD	**280 915**	**90 688**	**371 603**
Transition economies	**208 762**	**38 872**	**247 634**
of which Russia	*146 560*	*10 450*	*157 010*
China	95 900	18 600	114 500
East Asia	3 053	4 330	7 383
South Asia	90 146	5 350	95 496
of which India	*90 085*	*2 360*	*92 445*
Latin America	19 769	124	19 893
of which Brazil	*10 113*	–	*10 113*
Africa	50 333	3	50 336
Middle East	419	–	419
World	**749 297**	**157 967**	**907 264**

Source: International Energy Agency, Spanish Energy Commision

Oil
162000 Mtoe

Natural Gas
160000 MToe

Coal
1,295000 MToe

1Toe=1.43Tce

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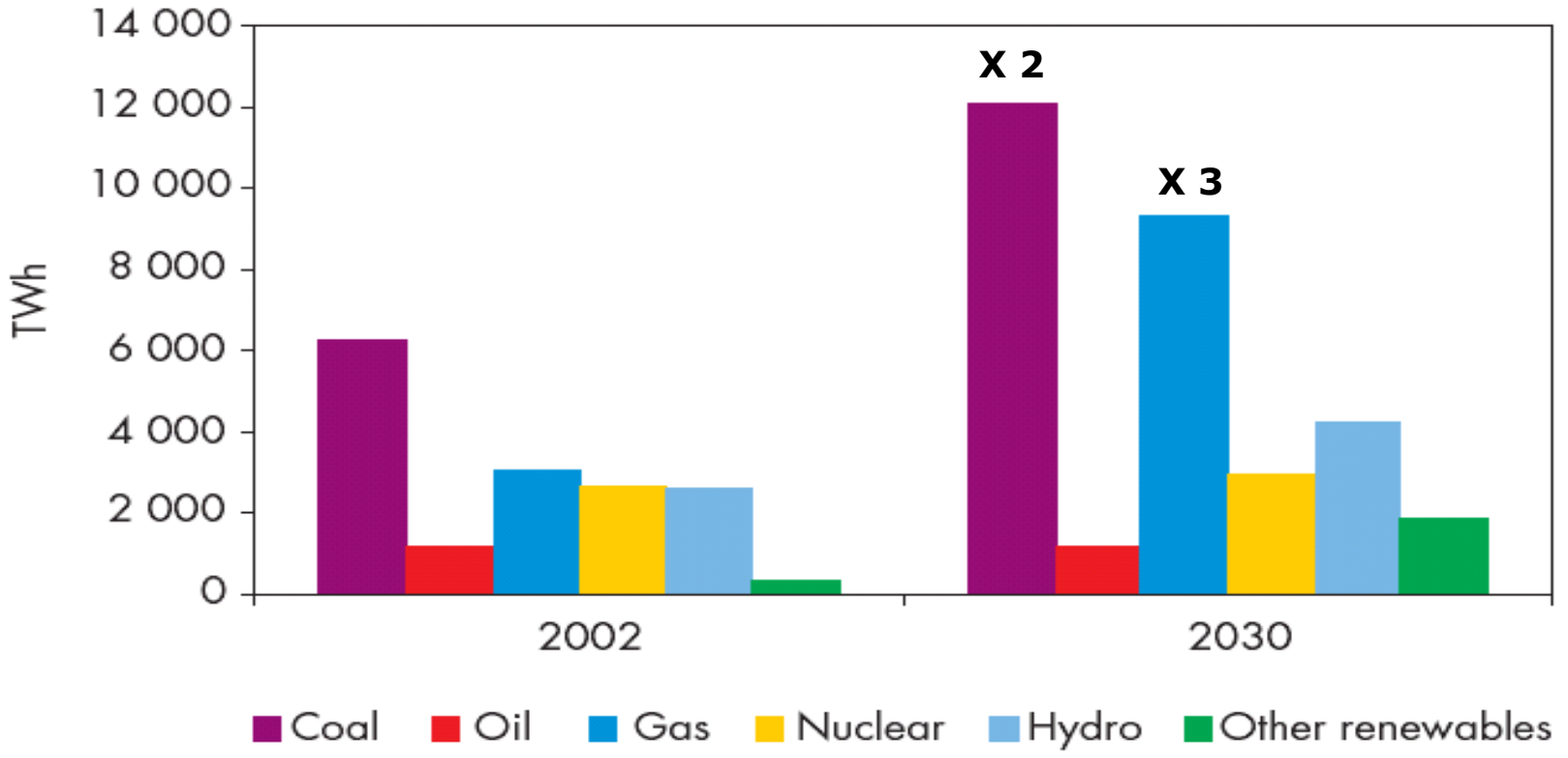
WORLD ELECTRICITY GENERATION 2002-2030

Coal will continue to play a key role in world power generation mix.



Source: International Energy Agency

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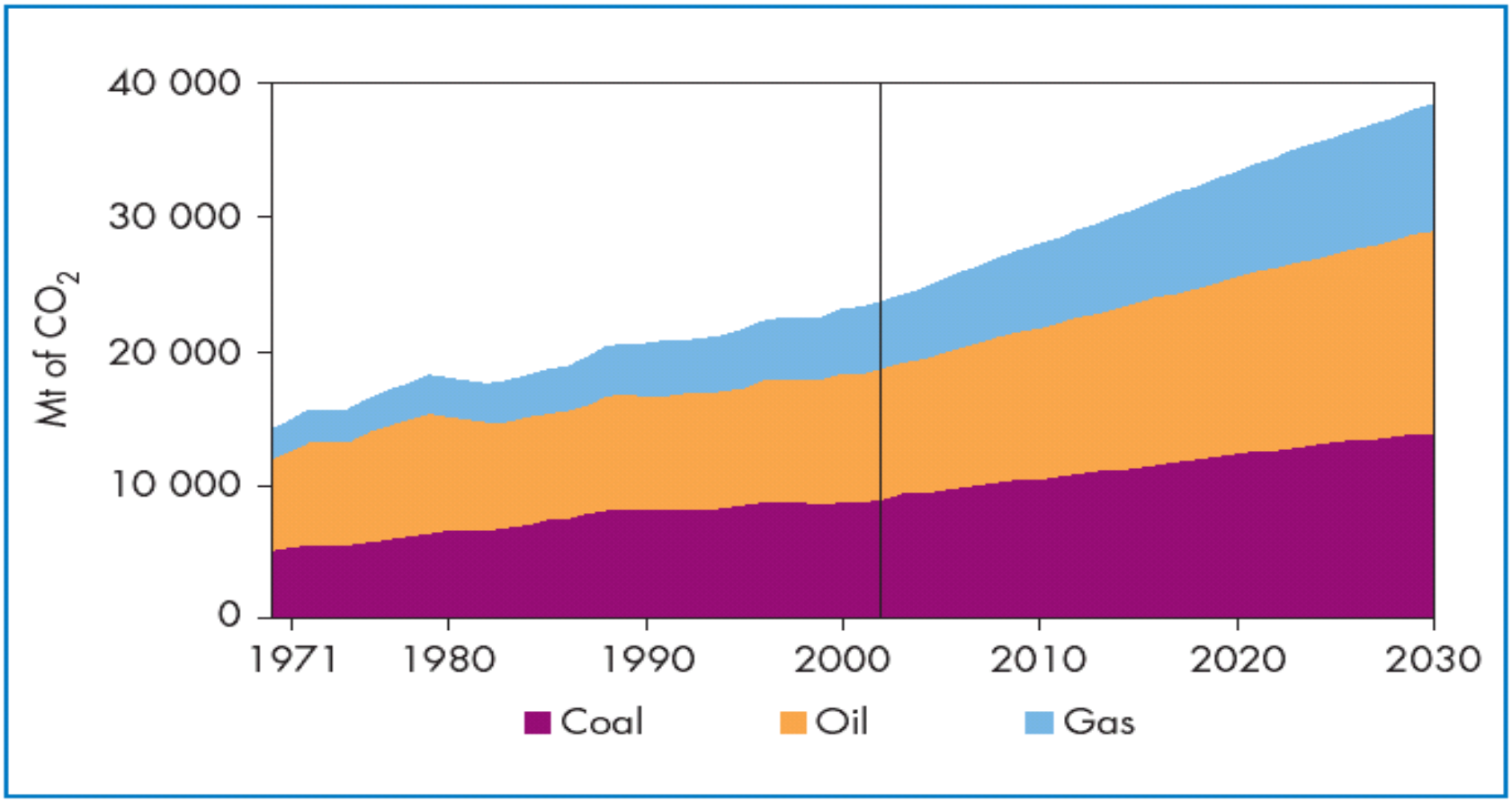
ENERGY-RELATED CO2 EMISSIONS (by fuel)

CO2 emissions will grow marginally faster than energy use. It will rank about 65%.



Source: International Energy Agency

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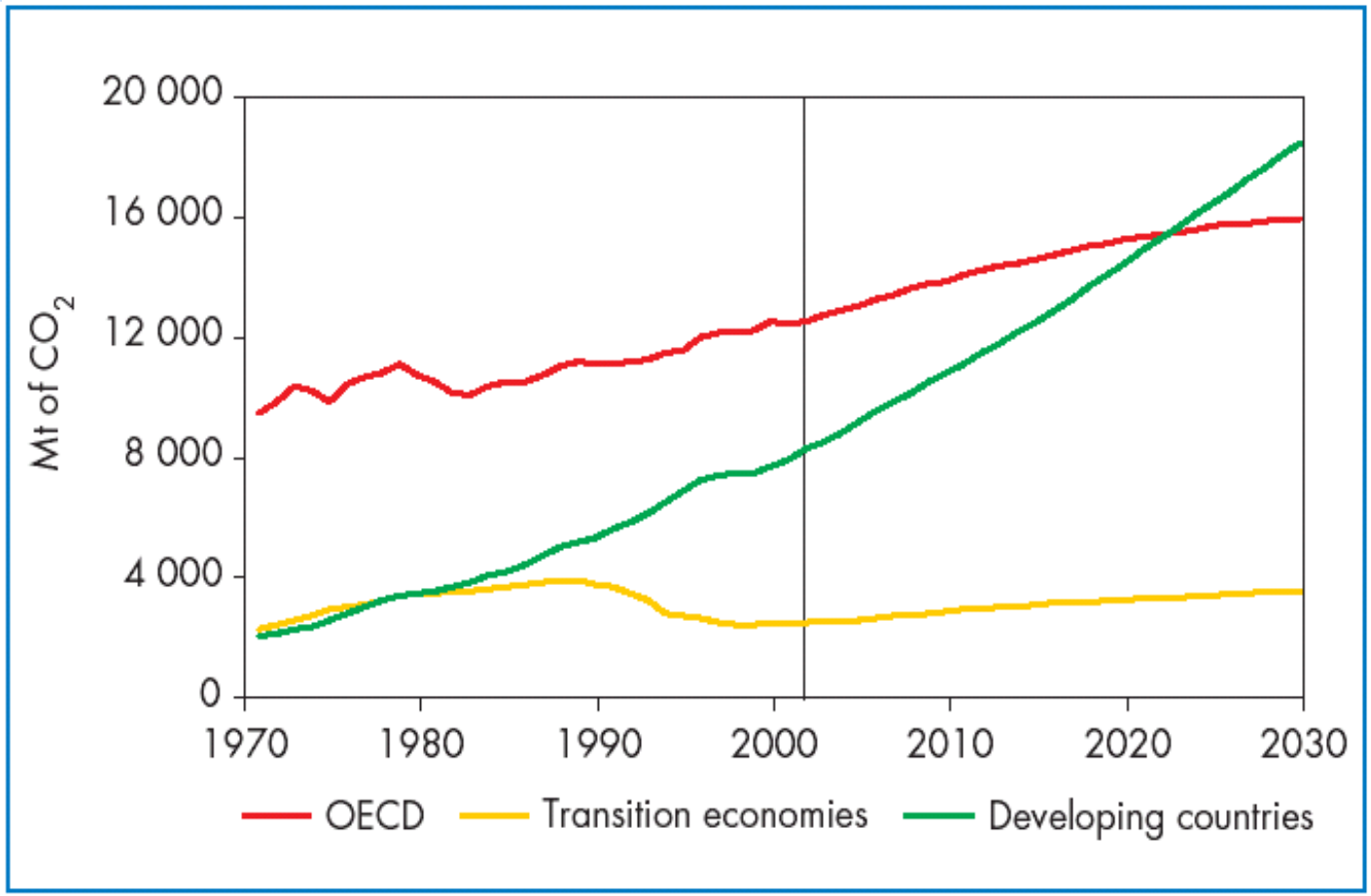
ENERGY-RELATED CO2 EMISSIONS (by region)

This is basically due to fossil fuel consumtion in developing countries.



Source: International Energy Agency

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EMISSIONS AND TARGETS FOR SELECTED COAL-FIRED POWER TECHNOLOGIES

Curret coal-fired power technologies can reduce conventional pollutants to very low levels

Technology	SO_2 emissions (% removal)	NOx emissions (as NO_2, mg/m^3)	Particulates (mg/m^3)
Pulverised Coal Combustion (PCC) with Flue Gas Desulphurisation (FGD)	90–98	100–200 (SCR)	10–50
Circulating Fluidised Bed Combustion (CFBC)	90–98	<200–400	<50
Integrated Gasification Combined Cycle (IGCC)	98–99	<125	<1

Source: International Energy Agency

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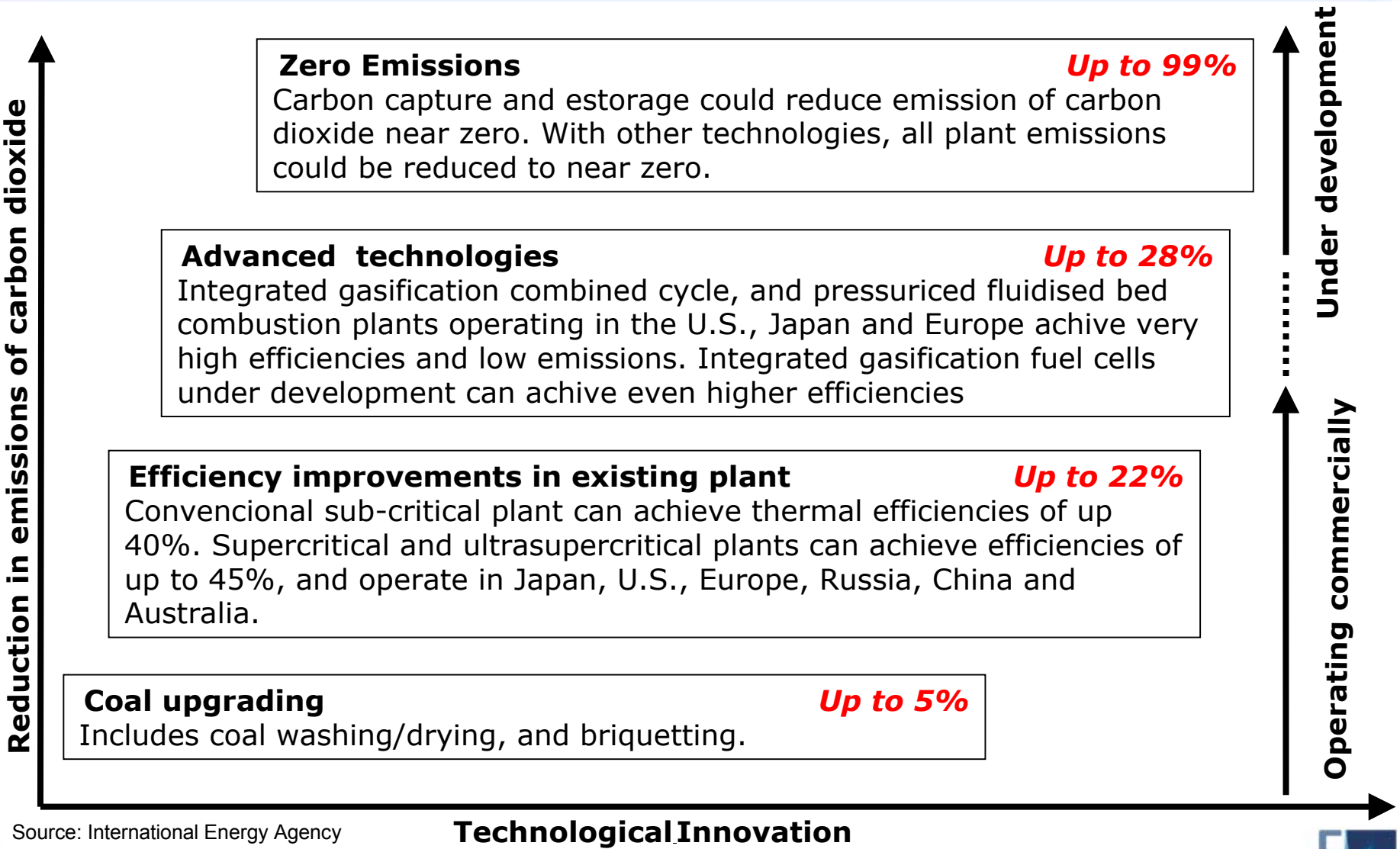
THERE ARE MANY ROADS TO PROVIDE CLEANER POWER WITH FOSSIL FUELS



Zero Emissions ***Up to 99%***

Carbon capture and estorage could reduce emission of carbon dioxide near zero. With other technologies, all plant emissions could be reduced to near zero.

Advanced technologies ***Up to 28%***

Integrated gasification combined cycle, and pressuriced fluidised bed combustion plants operating in the U.S., Japan and Europe achive very high efficiencies and low emissions. Integrated gasification fuel cells under development can achive even higher efficiencies

Efficiency improvements in existing plant ***Up to 22%***

Convencional sub-critical plant can achieve thermal efficiencies of up 40%. Supercritical and ultrasupercritical plants can achieve efficiencies of up to 45%, and operate in Japan, U.S., Europe, Russia, China and Australia.

Coal upgrading ***Up to 5%***

Includes coal washing/drying, and briquetting.

Source: International Energy Agency

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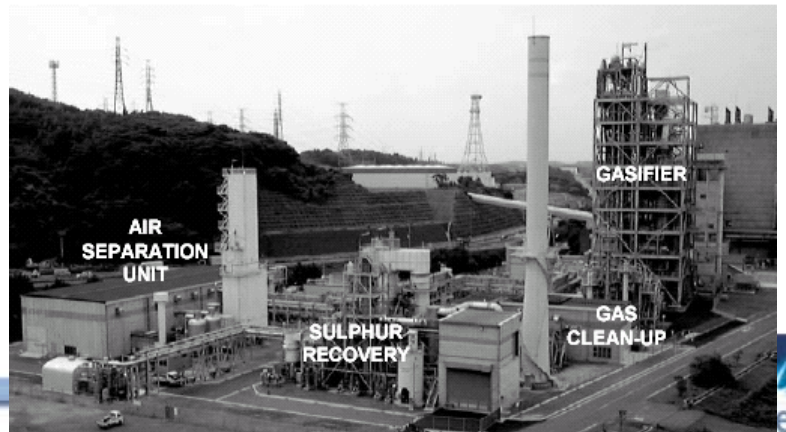
CURRENT STATE-OF-THE-ART IN CLEAN COAL POWER TECHNOLOGIES

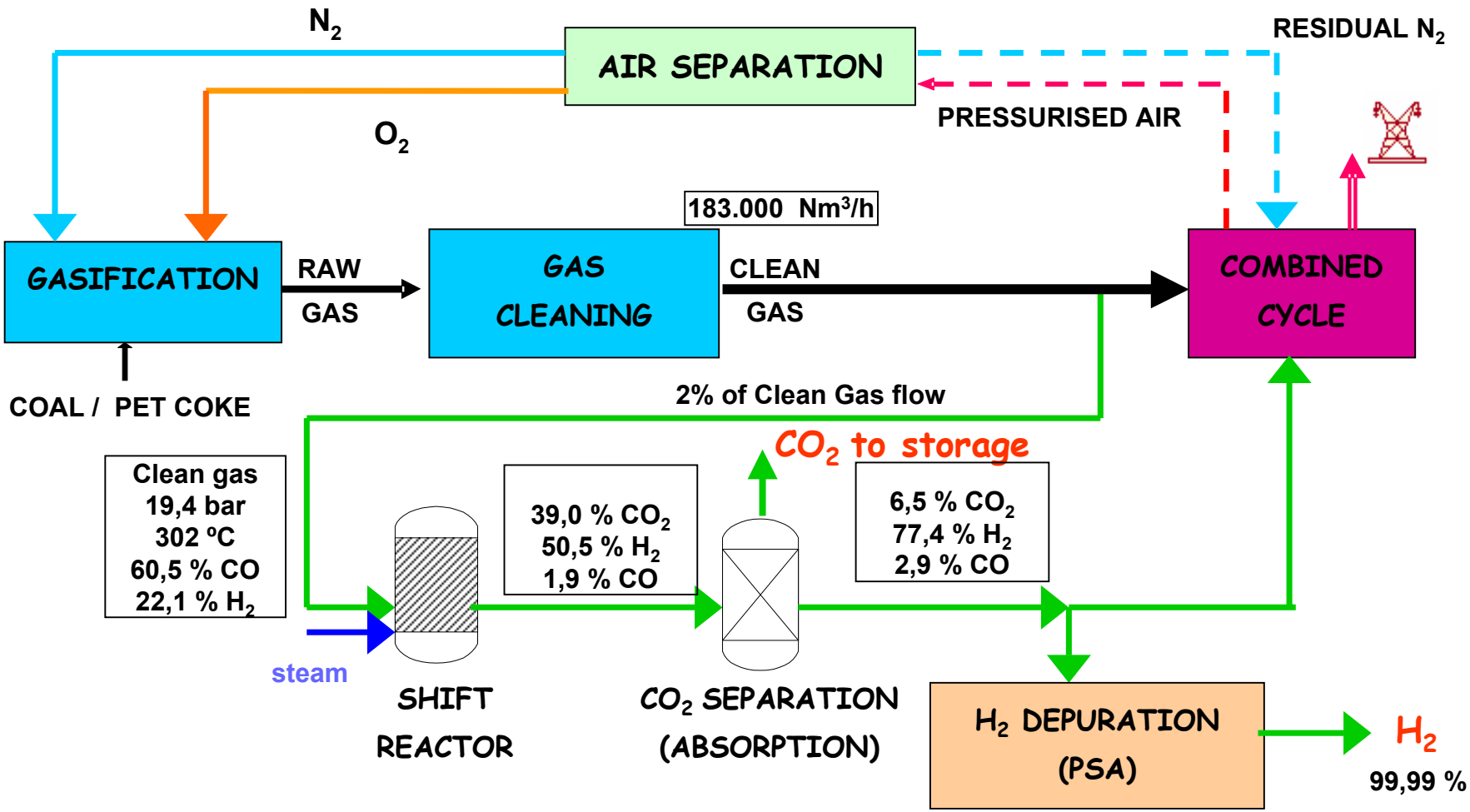
- There are may to choose from. Some are based on combustion and others on gasification of coal. No single system will be capable of meetin all future requirements, so a portfolio is needed (different countries and regions and different leves of development)
- **The most relevant advanced technologies are:**
  - **Supercritical Pulverised Coal Combustion (PCC)**
  - **Circulating fluidised Bed Combustion (CFBC)**
  - **Integrated Gasification Combined Cycles (IGCC)**
- Future: the Zero Emission Tecnologies (ZET) and the capture and storage of CO2. At present, the most likely to provide the ZET are supercritial PCC and IGCC.
  - ZETs based on PCC has more importance in countries such as China and India (they have growing PCC generation).
- Economic considerations: PCC plant capital costs would be 56-82% greater than current systems. IGCC plant capital costs would 27-50% higher than now (A large proportion of this difference is associated with the capture of CO2)

INTERNATIONAL DEVELOPMENTS

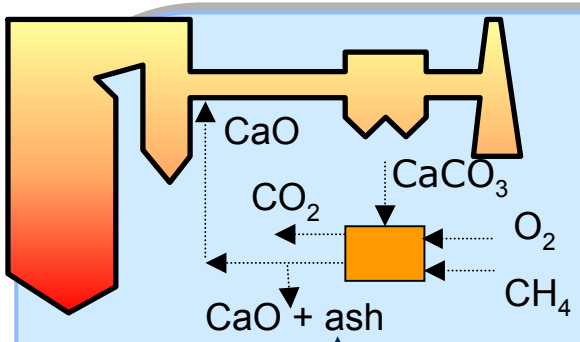
- **United States :**
  - **Coal-based, zero-emissions electricity and hydrogen power plant called FutureGen**. This project is designed to reduce dramatically air pollution and capture and store greenhouse gas emissions.
  - Carbon Sequestration Leadership Forum.
  - International Partnership for the Hydrogen Economy (IPHE) Inaugural meeting of the IPHE November 18-21, 2003 in Washington, D.C.
- **Japan :**
  - **Japan Coal Energy Centre** (http://www.ccuj.or.jp/): develop clean coal combustion projects: **EAGLE**
    - Coal-based, zero-emissions electricity and hydrogen power Integrated gasification combined cycle fuel cell in Japan.8 MW pilot plant at Wamasaku. Oxygen-blown, two stage, entrained flow gasifier.Generate electricity in a solid oxide fuel cell fed with hydrogen from the coal gasifier.
- **Europe :**
  - VI **Framework Program.**
  - Research Funding For Coal And Steel.
  - Spanish initiative: **ELCOGAS.**



ELCOGAS: A SPANISH CO_2 TECHNOLOGICAL PLATFORM



SPANISH CO_2 TECHNOLOGICAL PLATFORM



In duct capture of CO_2 in the existing pulverised coal Andorra Power Station

Gas without CO_2

CO_2 to Storage

Carbonator

650-700 C

CaO

$CaCO_3$

Calciner

850 C

Heat

Combustor

T > 1000 C

$CaCO_3$

Combustion gases

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R&D PROGRAMS

EUROPEAN PROGRAMS	**VI FRAMEWORK PROGRAM**
	RESEARCH FUNDING FOR COAL AND STEEL (RFCS)
NATIONAL PROGRAMS	**TECHNOLOGICAL PLATFORMS**
	PROFIT
REGIONAL PROGRAMS	**XUNTA DE GALICIA R&D PROGRAM**

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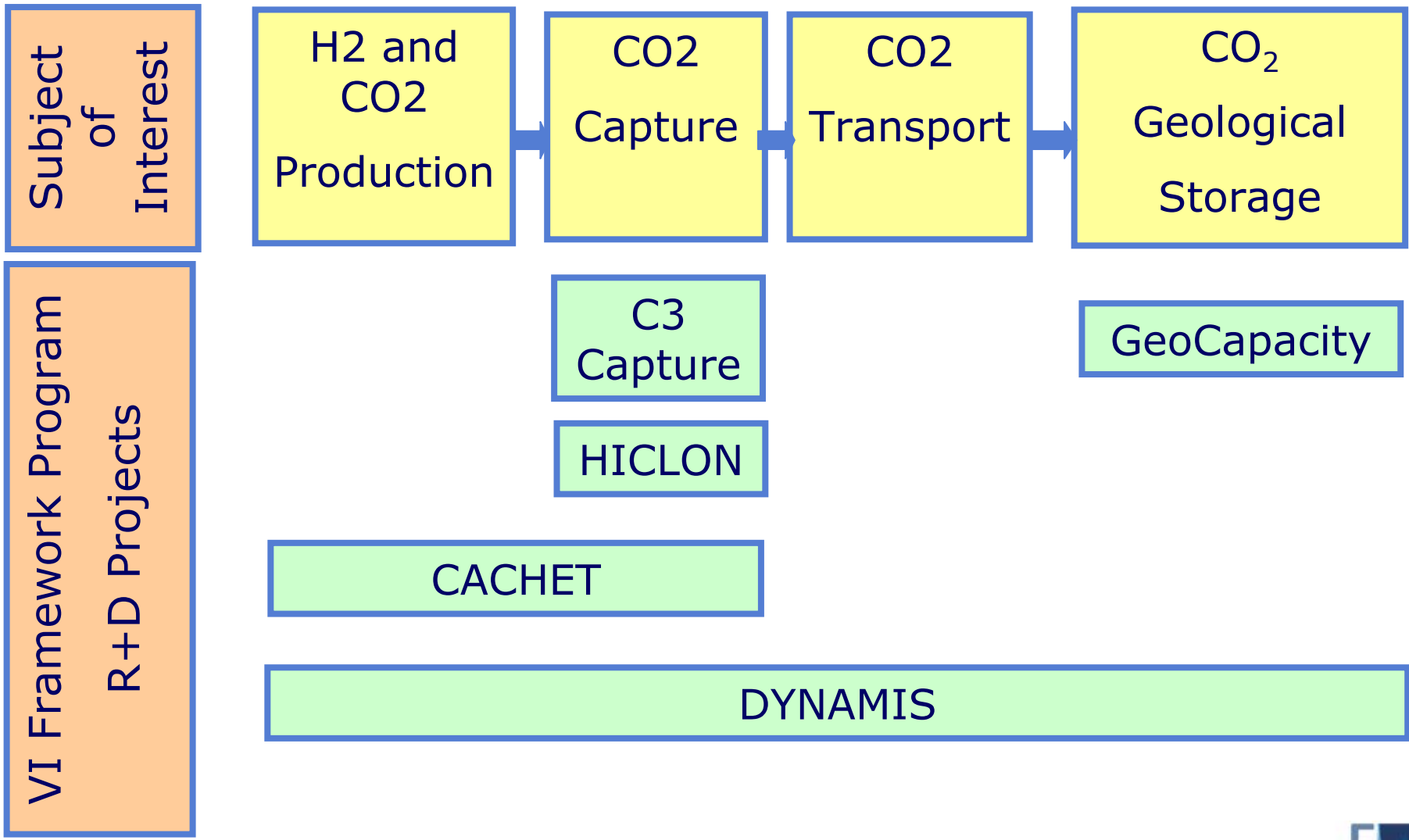
ENDESA Project Participation VI FrameWork Program



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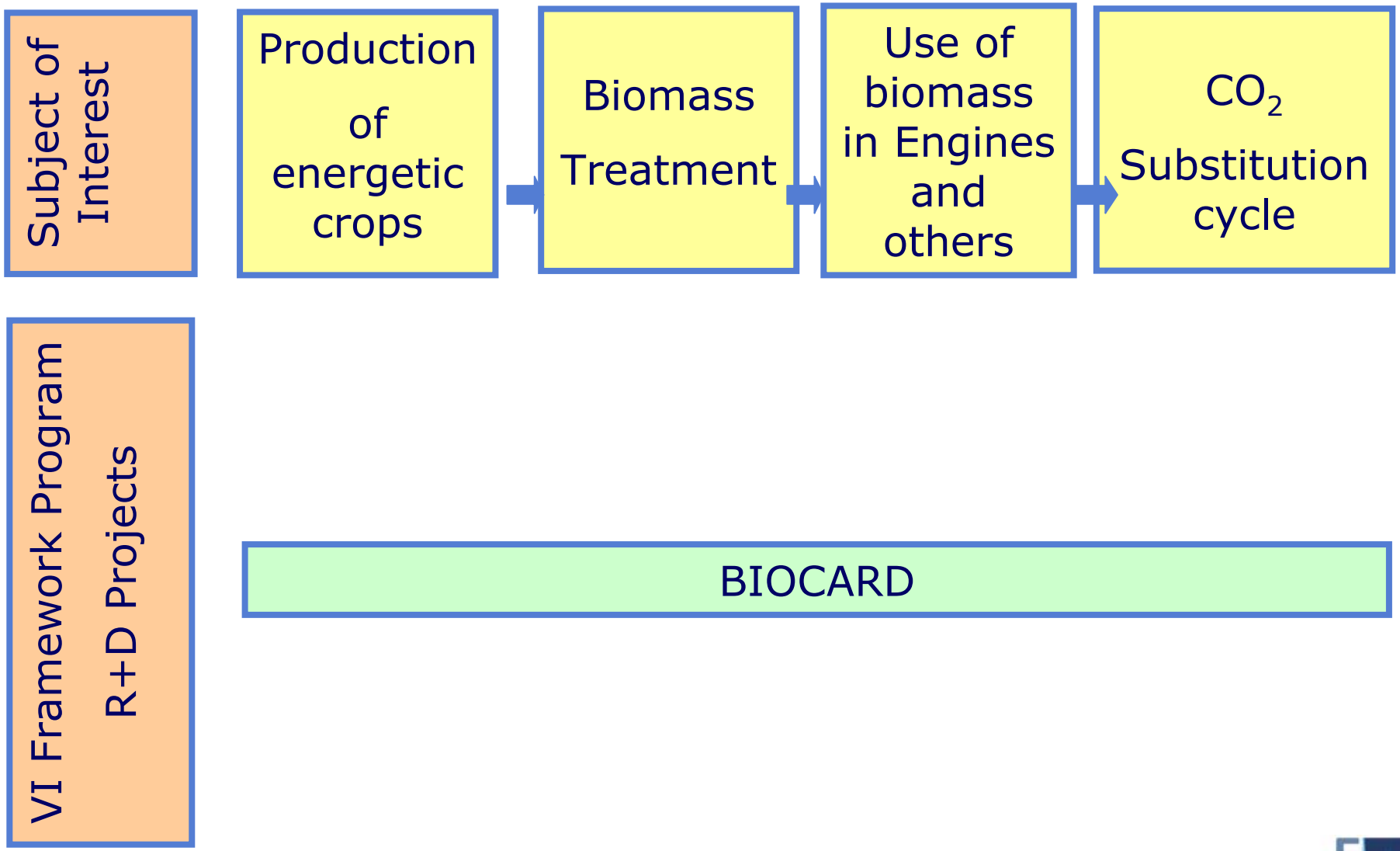

ENDESA Project Participation VI FrameWork Program

- **DYNAMIS.** Towards hydrogen production with CO_2 management
  - ✓Research paths for H2 production in big scale, for electric power generation or other social benefits and improvements.
  - ✓Studies of treatment, storage and transmission of CO2.
  - ✓Make engineering studies and designs for future H2 power plants.
  - ✓Other participants: Statoil, BP, Siemens, Alstom, E.ON UK, IEA, Ecofys
  - ✓Duration: 5 years.
- **CACHET.** Carbon dioxide Capture via Hydrogen Energy Technology
  - ✓Develope effective methods of H production from Natural Gas and CO2 capture, decreasing the CO2 storage and capture costs to 20-30 €/ton.
  - ✓Develop enginnering studies to build a power plant in the future, with gas turbines and power cells, that would combine H2 and CO2.
  - ✓Other participants: BP, Alstom, E.ON UK, Shell, Siemens, Texaco.
  - ✓Duration: 5 years.
- **HICLON.** Cost-effective and energy efficient decarbonisation technology
  - ✓Develope technologies to produce air with high levels of O2, and the capture, storage and separation on CO2 in post-combustion stages, at low temperatures.
  - ✓Evaluate the economic impact of different separation processes.
  - ✓Other participants: Alstom, Institute Fracais du Petrole.
  - ✓Duration: 3 years.

ENDESA Project Participation VI FrameWork Program

- **GEOCAPACITY.** Assessing European Capacity for Geological Storage CO_2
  - Map the main sources and fonts of emissions in 13 countries of Eastern Europe. Revise the emissions in other 4 and actualizing data of other 5 in OECD.
  - Evaluate potential CO2 geological storages in all these countries.
  - Other participants: IGME, Institute Francaise du Petrole, Vattenfall.
  - Duration: 3 years.
- **C3 CAPTURE.** Calcium cycle for efficient and low cost CO2 capture
  - ✓Research and develop the capture process of CO2 through the calcination/carbonization in fluidizied bed combustion an pulverized coal power technology.
  - ✓Evaluate the option of integrate this method with the capture of emissions of CO2 in power plants
  - ✓Other participants: University of Stuttgart and other European schools.
  - ✓Duration: 3 years.
- **BIOCARD.** Process to Improve Cynara cardunculus Explotation
  - ✓To demonstrate the technical an economical opportunity of the cardoom as a fuel for its industrial use in power plants.
  - ✓Evaluate the use of the cardoom mixed with coal in the PPC, and its opportunity as biodiesel fuel in combustion engines.
  - ✓Other participants: MAN B&W, UPM and other universities.
  - ✓Duration: 3 years.

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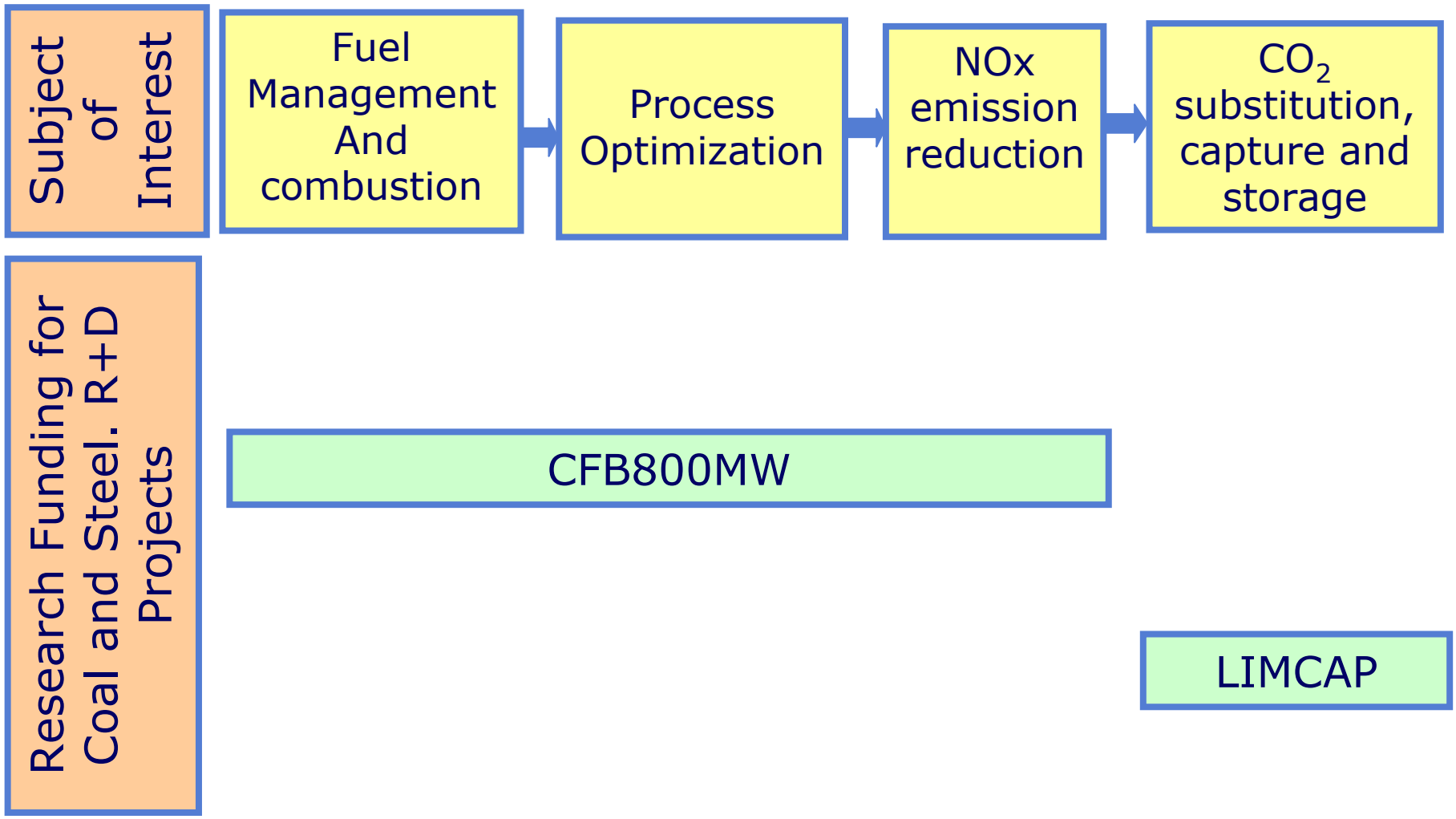
ENDESA Project Participation
Research Funding for Coal and Steel



ENDESA Project Participation
Research Funding for Coal and Steel

- **CFB800MW.** Utility Scale CFB for Competitive Coal Power
  - ✓Increase the power of the fluidizied beds up to 800 MW in supercritic combustion cycles.
  - ✓Evaluate and study the technology of supercritics fluidizied beds from a technical and economical view.
  - ✓Determine the potential reduction of emissions.
  - ✓Other partners: Siemens, Foster Wheeler Energy, CIRCE
  - ✓Duration: 3 years.

- **LIMCAP.** Lime-based CO_2 Capture Retrofit Options for Low Capture Costs
  - ✓Evaluate some different schemes of capture and storage of CO2 with limestone, and the future designs of power plants, studing the impact in some operating parameters, such as flexibility, avaliability and manteinance.
  - ✓Other partners: CSIC, University of Stuttgart, CIRCE.
  - ✓Duration: 3 years.

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NATIONAL TECHNOLOGICAL PLATFORMS

Strategic Actions

- They are promoted by the Spanish goverment through some national agencies. A National Plan has been made (2004-2007)
- Definition: group of activities and projects of R&D&I higly coordinated to achieve some common objects very well defined in the short-term.
- The goals are very clear and concrete. The national plan develops the strategic actions requiered.

Many different projects and singular actions

- Biofuels.
- CO2 capture and storage.
- Electric power generation with H2 & windpower & power cells.
- ELCOGAS.
- IGME (Geologics and Minering Spanish Institute).
- CIEMAT (Power Technologies Spanish Center) – El Bierzo
- Carbonated/calcinated cycles.
- Land-power crops: production, combined use electrical and termical

ENDESA IS ANALIZING SOME PROJECT PROPOSALS FOR OTHER PROGRAMS

PROFIT National Program

Renewable energy	Quality of supply	Distributed Power Generation
Ciclonic generator	Trials of Power Quality	Proposal to produce H_2 with wind power
		Inertia wheels

Xunta de Galicia Regional Program

- **As Pontes Power Plant Coal Combustion**
  - Optimization the combustion process in those boils, recoverting them through CFD simulation.
  - Defining new strategies and techniques of combustion.
  - Other partners: Universidad de Santiago de Compostela

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CONCLUDING REMARKS

- **Fossil fuels will remain the main pillar of the world´s energy supply for decades to come. Achieving a sustainable energy system will call for tecnologycal change in the way to produce and use energy.**

- **In this same period, CO2 constraints are likely to become an even greater feature of energy policies.**

- **Zero Emission Technologies are the only option available today that have the potential to respond these.**

- **These technologies will be introduced through Supercritical Pulverised Coal Combustion (PCC), Circulating fluidizied Bed Combustion (CFBC), and Integrated Gasification Combined Cycles (IGCC)**

- **Hydrogen is consider to have the potential to provide the cleanest energy, but there are many technical and economic challenges to be overcome before it becomes a practical source of fuel**
  - ✓ **The transition will be provided by fossil fuels (coal and natural gas) coupled with CO2 capture and storage.**

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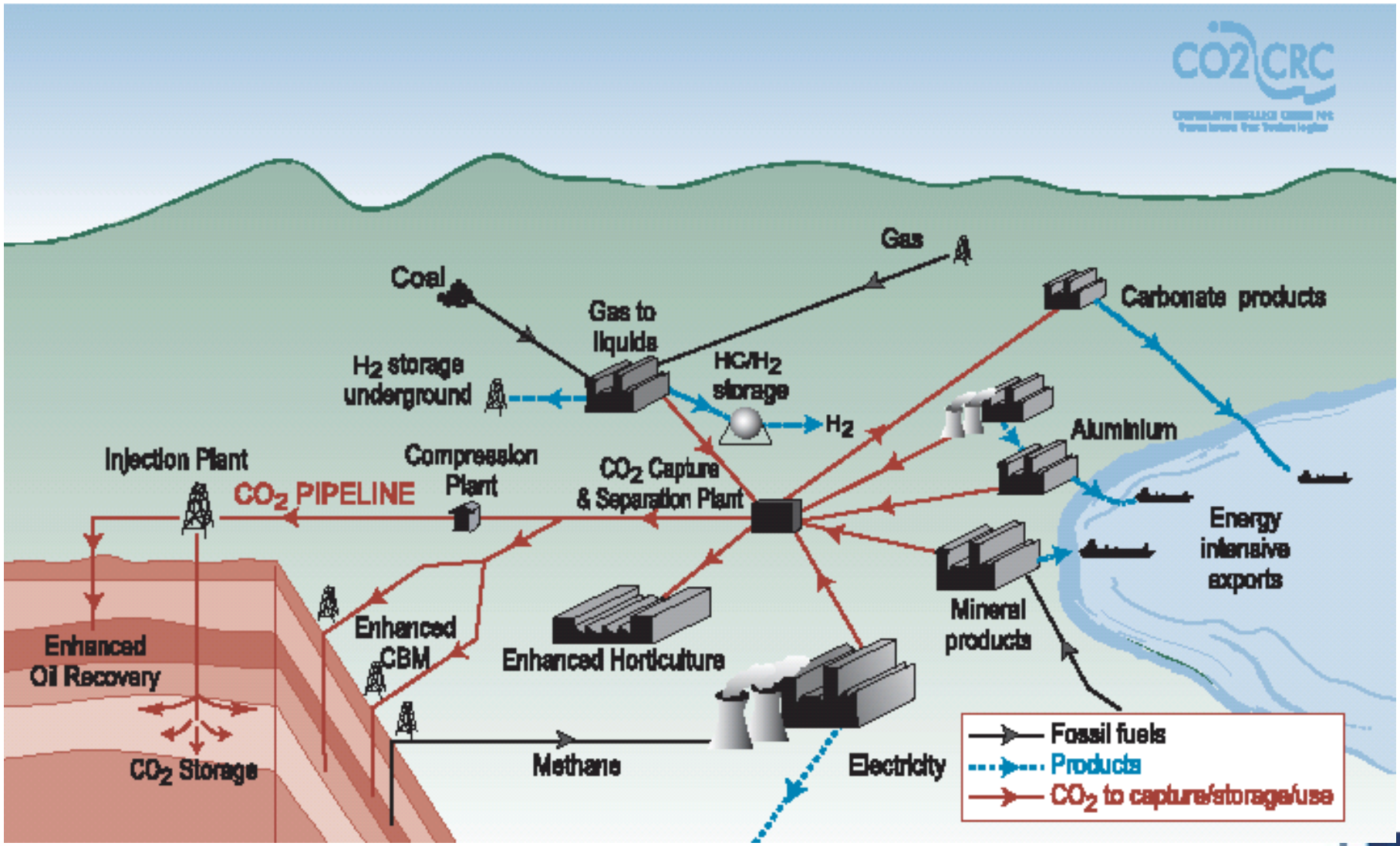
AN EMISSION-FREE VISION FOR THE FUTURE



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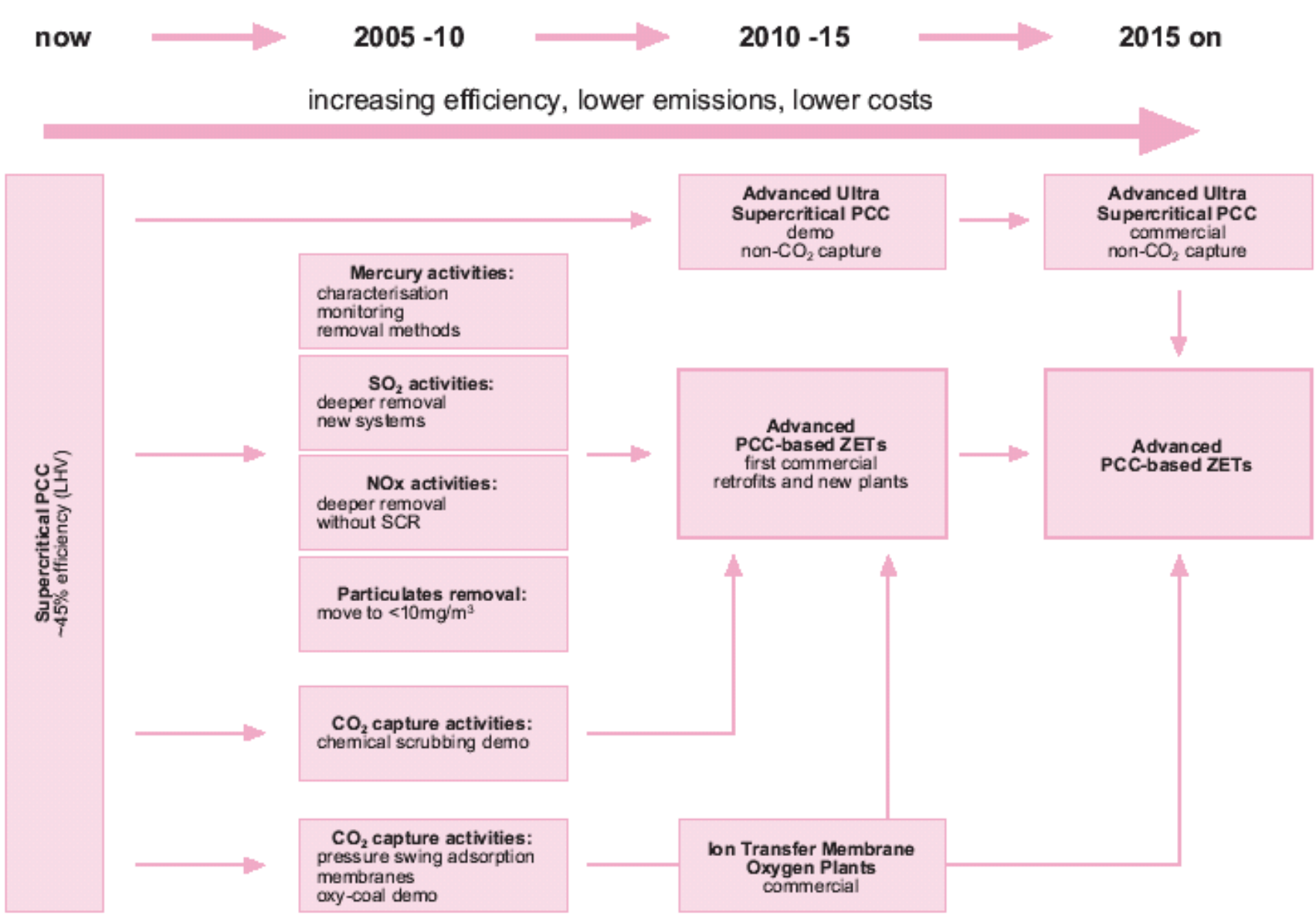
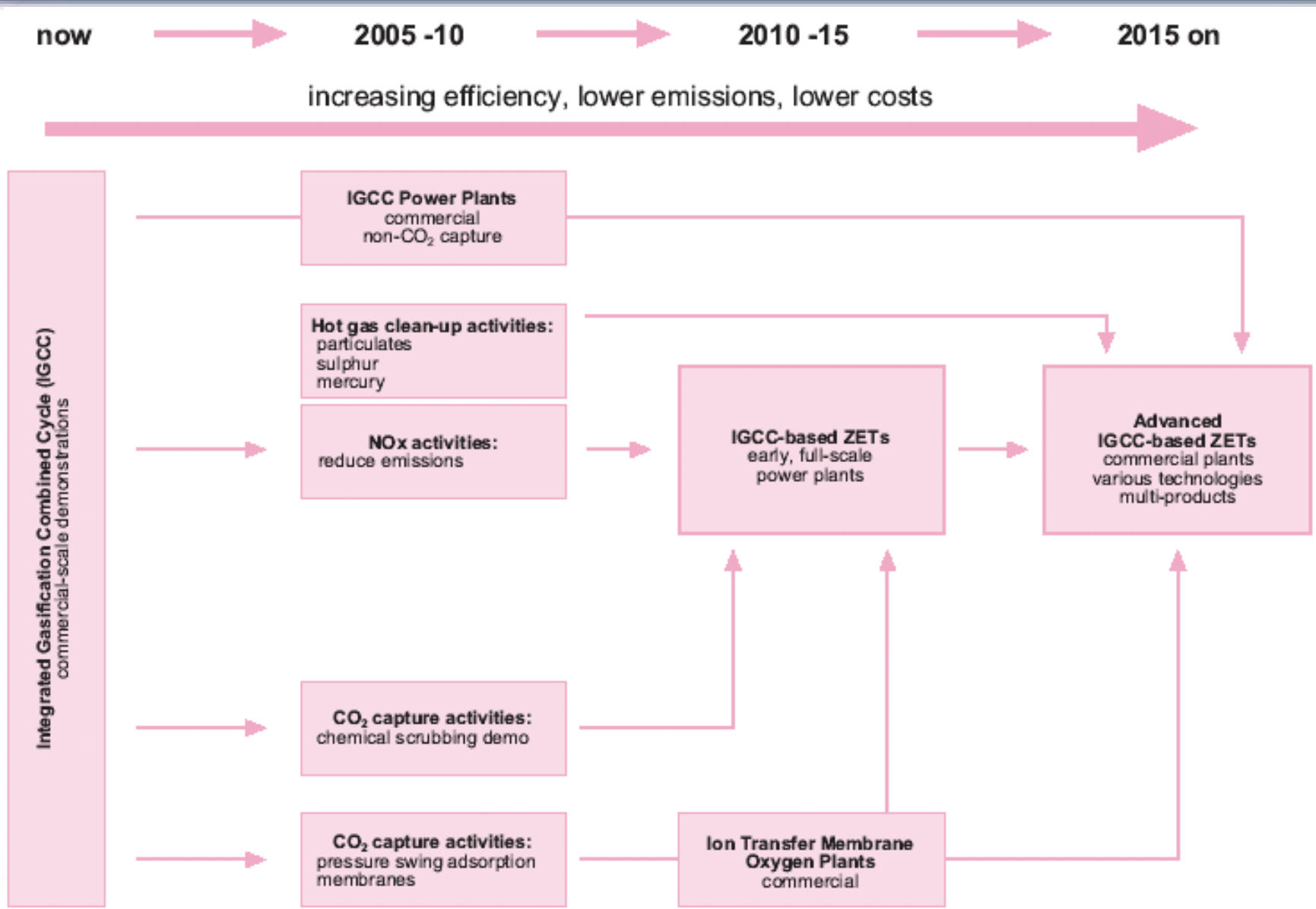
PCC-BASED ZET PATHWAY



IGCC-BASED ZET PATHWAY



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