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Perspectives on the Development of Energy & Environmental Technology

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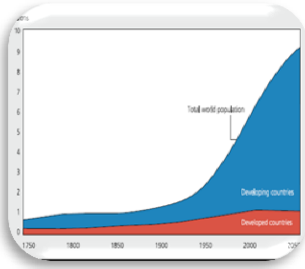
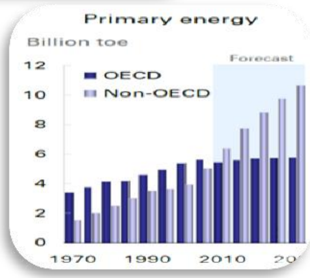
Global Issues on Energy & Environment

Population



Drastic Population Increase

Energy

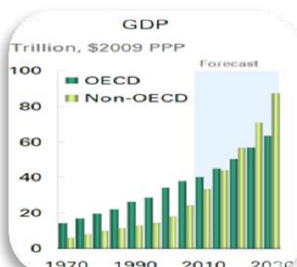


Energy Consumption Increase

Environment

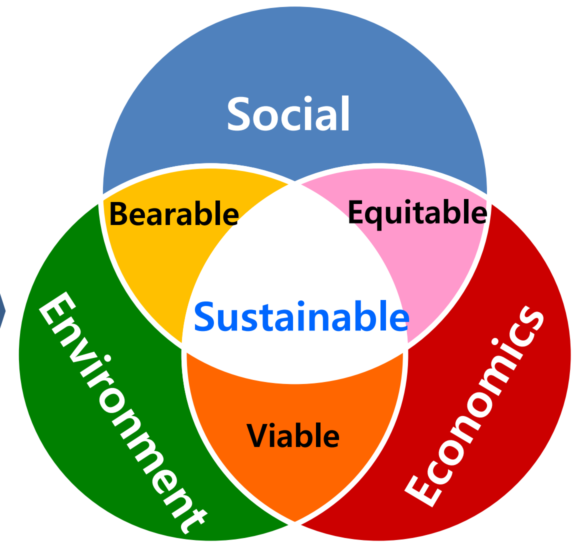
Climate Change

Economic Growth



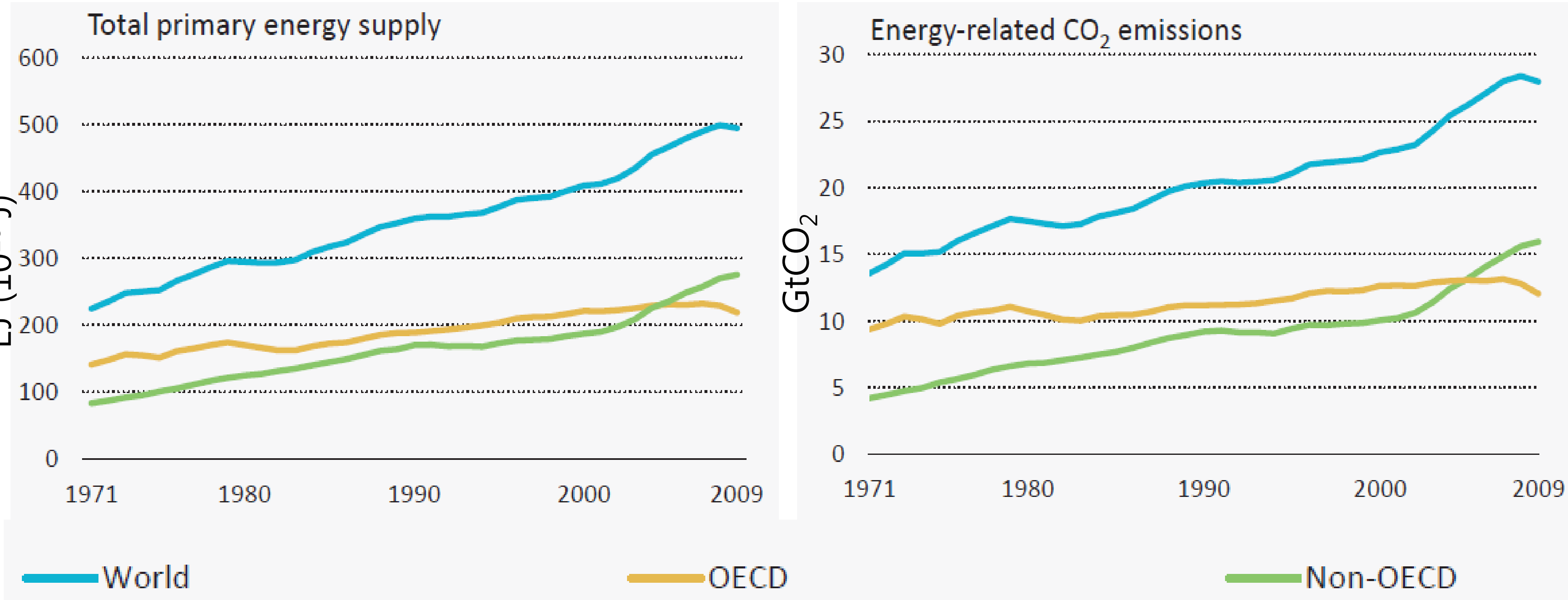
GDP Increase

Sustainable



Development

World Energy Demand And Emissions



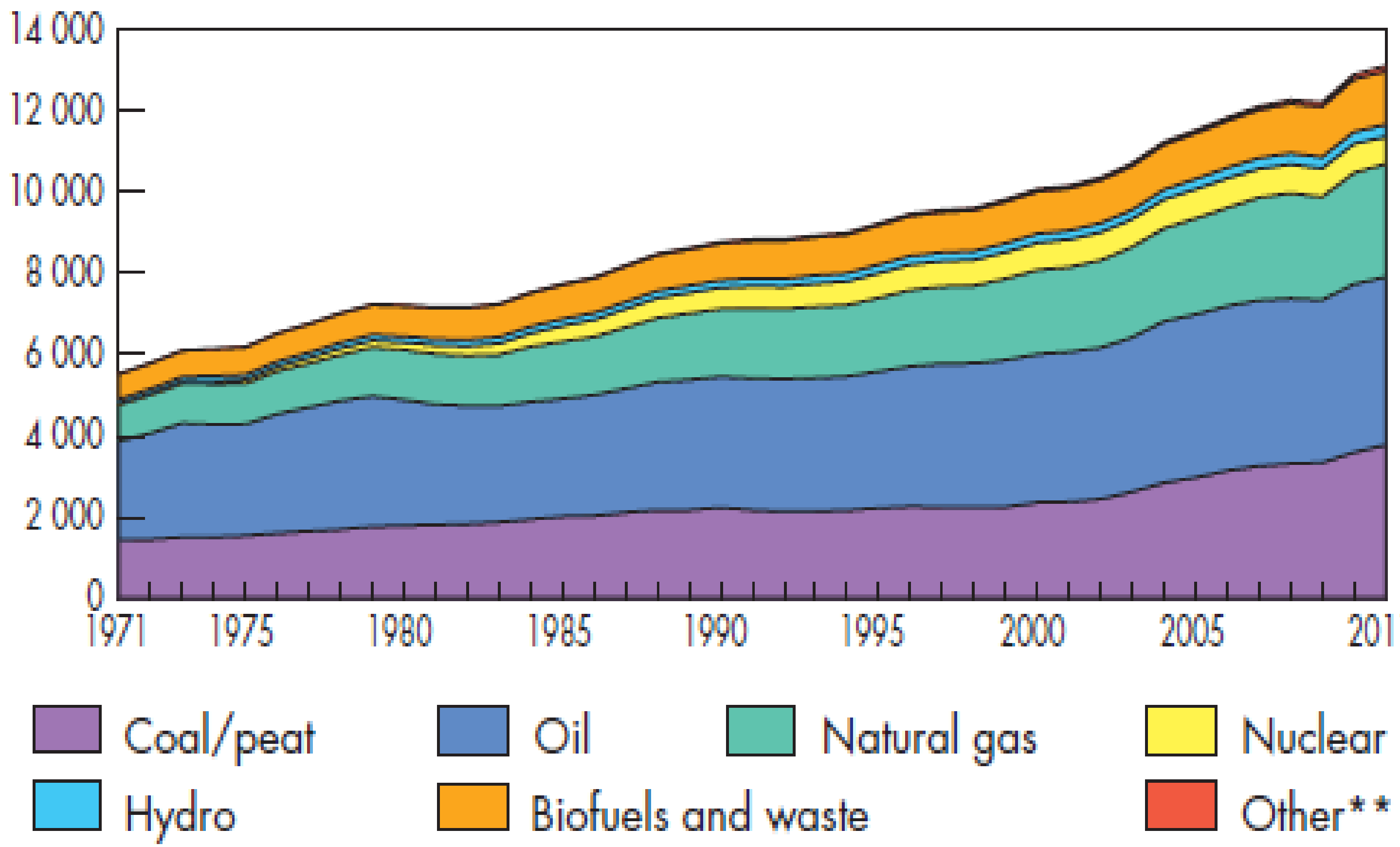
- ***From 6,000 Mtoe to 12,000 Mtoe***
- ***Rapid growth outside OECD after 2000 is remarkable***

- ***CO_2 emissions from 14Gt to 30Gt***
- ***Since 2005, non-OECD countries emit more than OECD***

Source: IEA , ETP 2012

World Energy Supply by Fuel

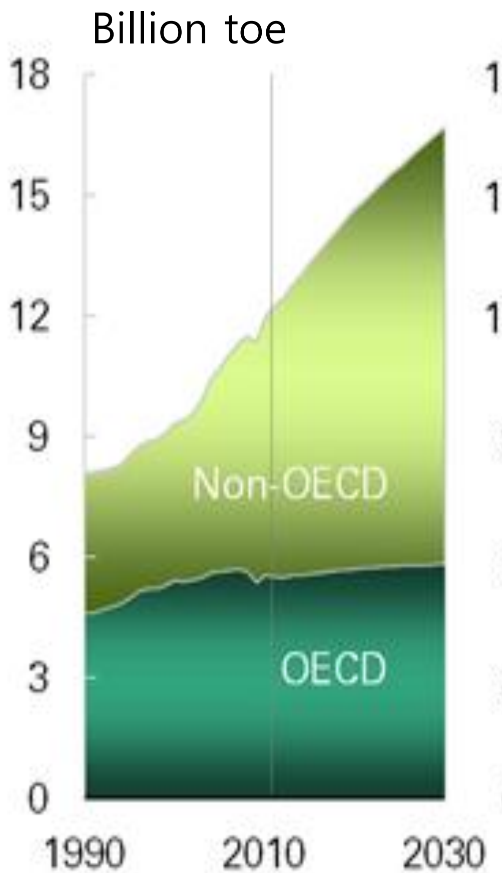
World total primary energy supply from 1971 to 2011 by fuel (Mtoe)



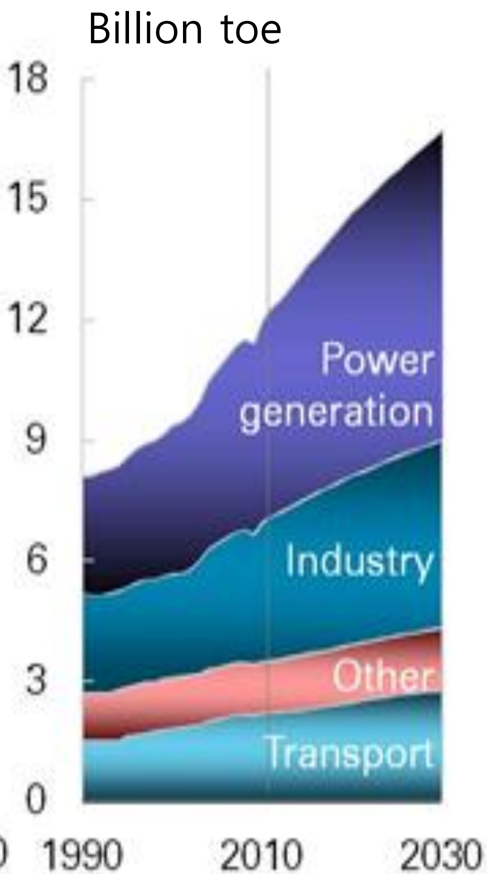
Source: IEA, 2013 Key world energy statistics

Energy Outlook 2030

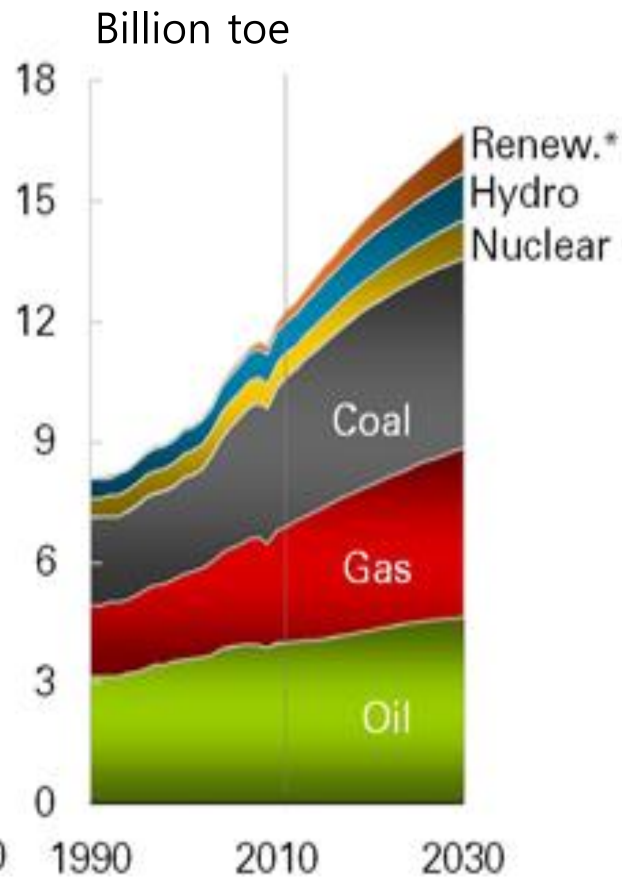
By region



By primary use

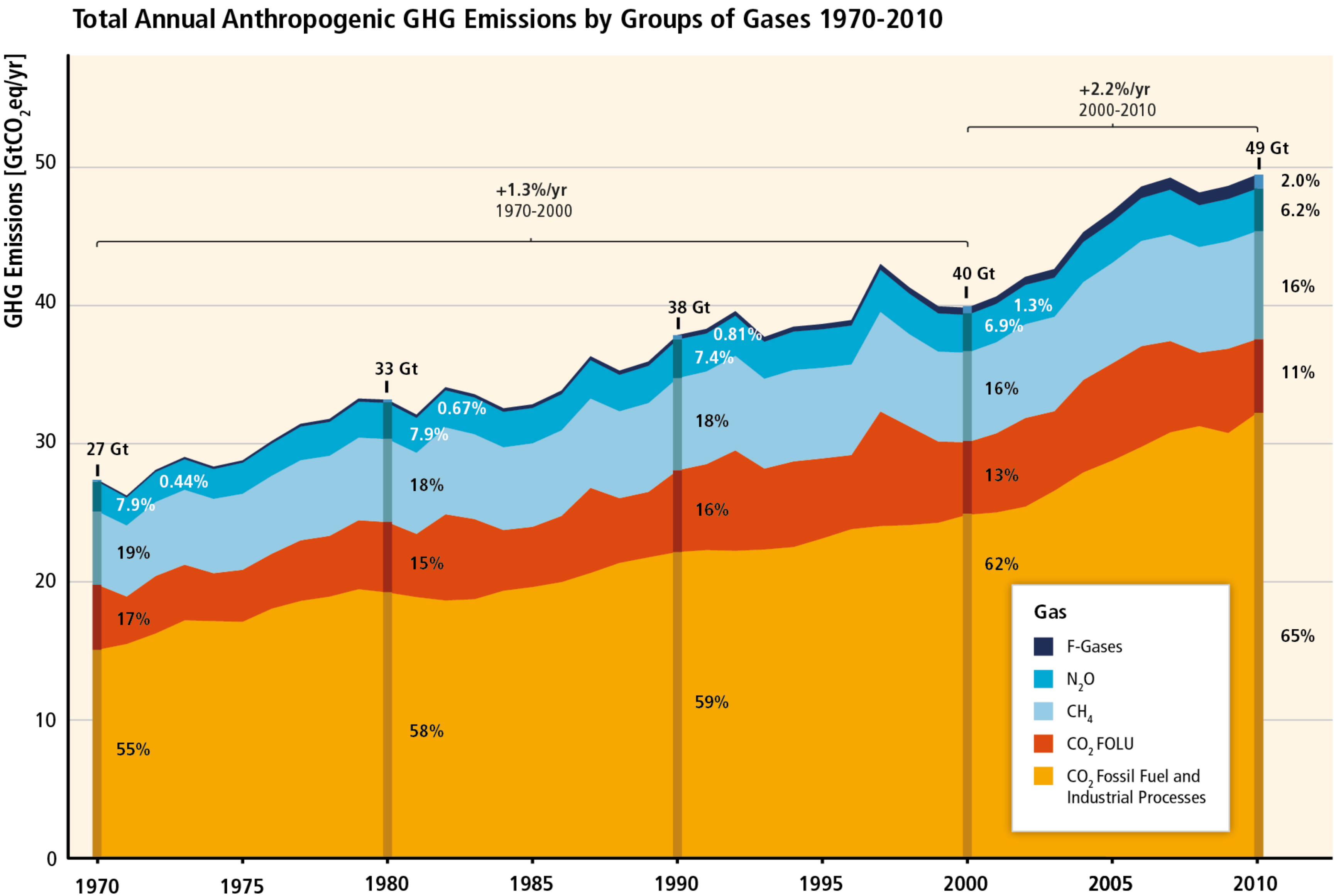


By fuel



Source: Energy Outlook 2030, BP 2013

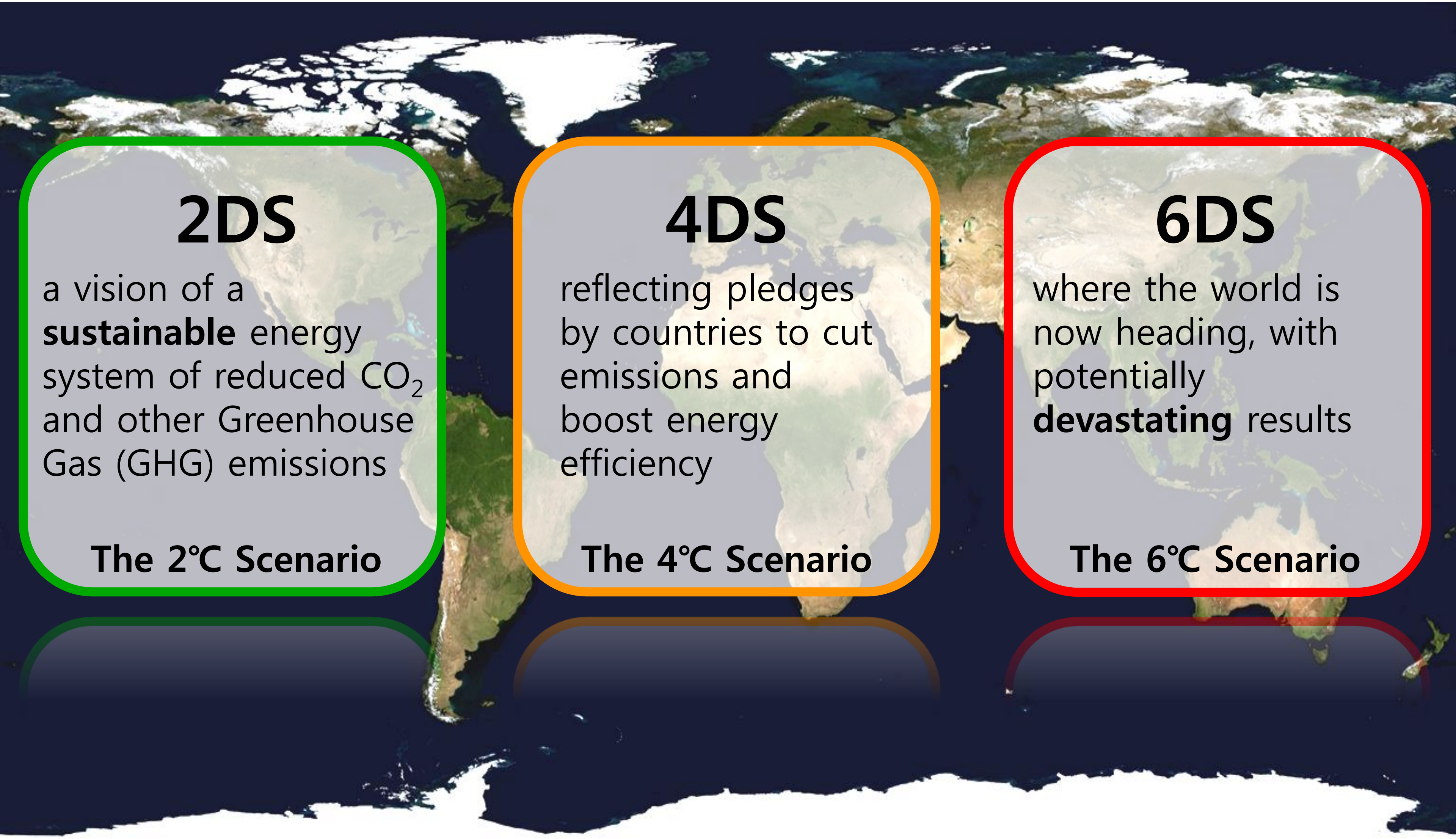
Greenhouse Gas Emissions



* FOLU : Forestry and Other Land Use

Source: IPCC, 2014

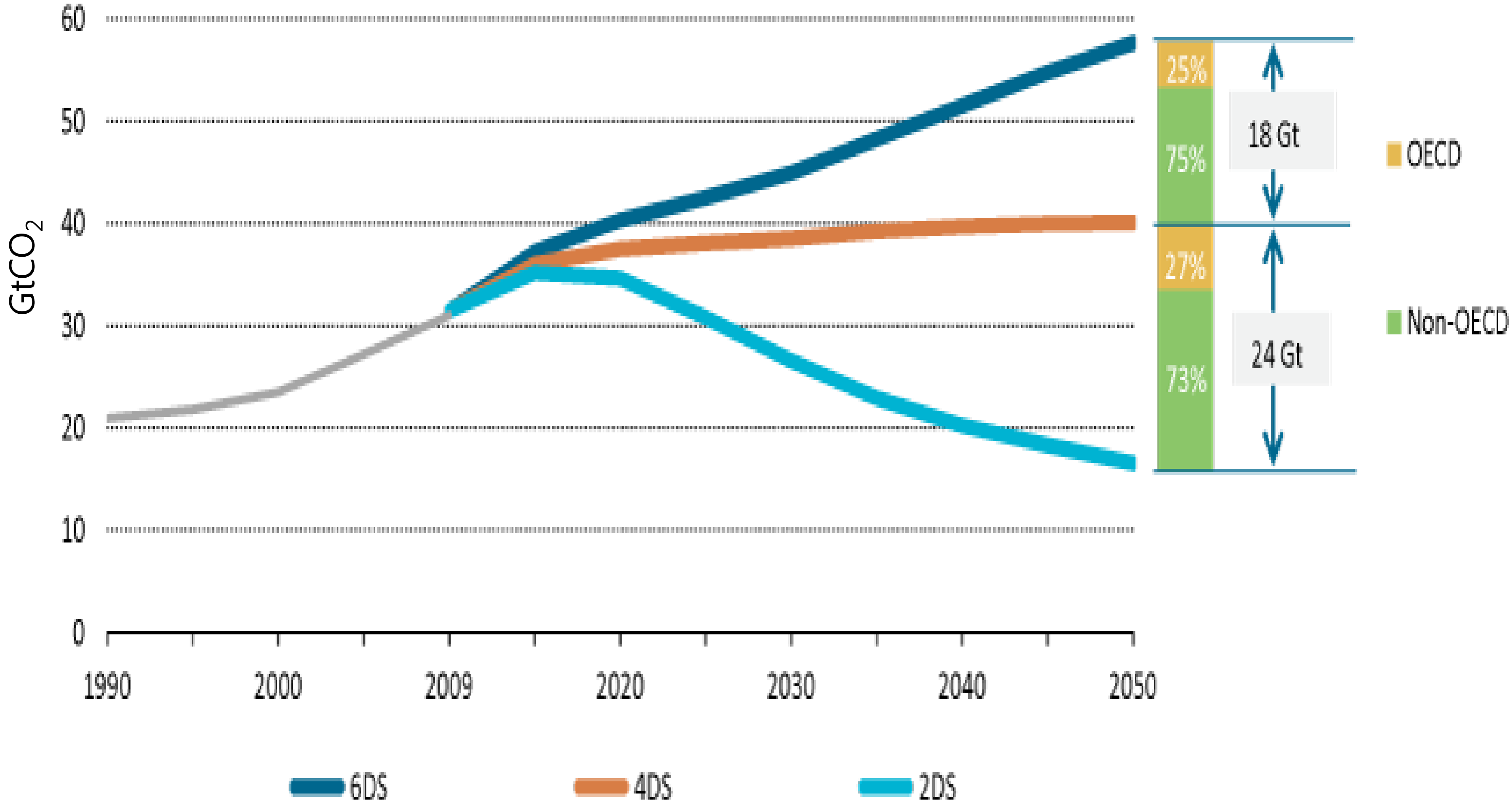
ETP 2012 – Choice of 3 Futures



Source: IEA , ETP (Energy Technology Perspectives) 2012

2DS : Need to Halve CO_2 by 2050

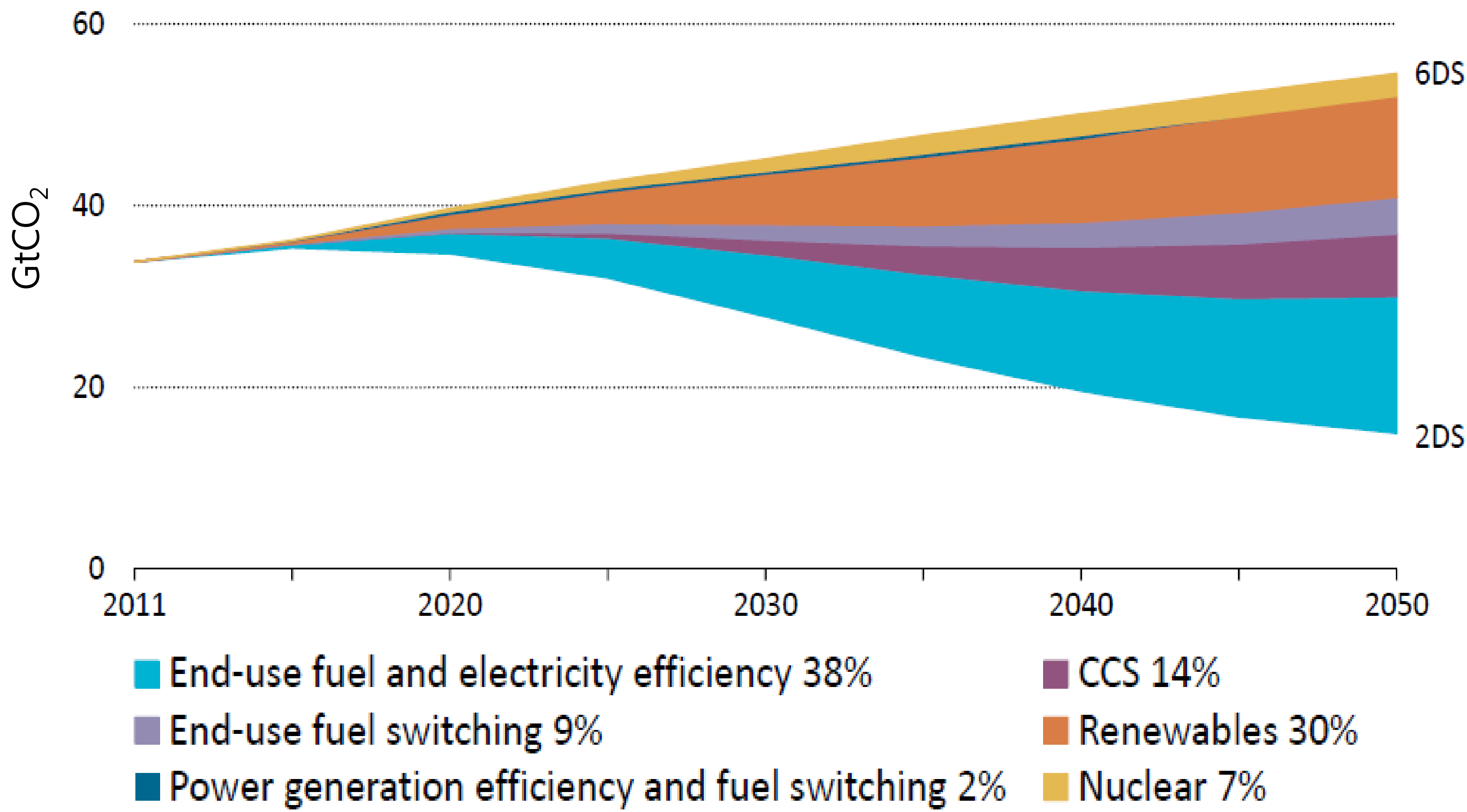
CO_2 emissions by scenarios



Source: IEA , ETP 2012

A Transformation Is Needed

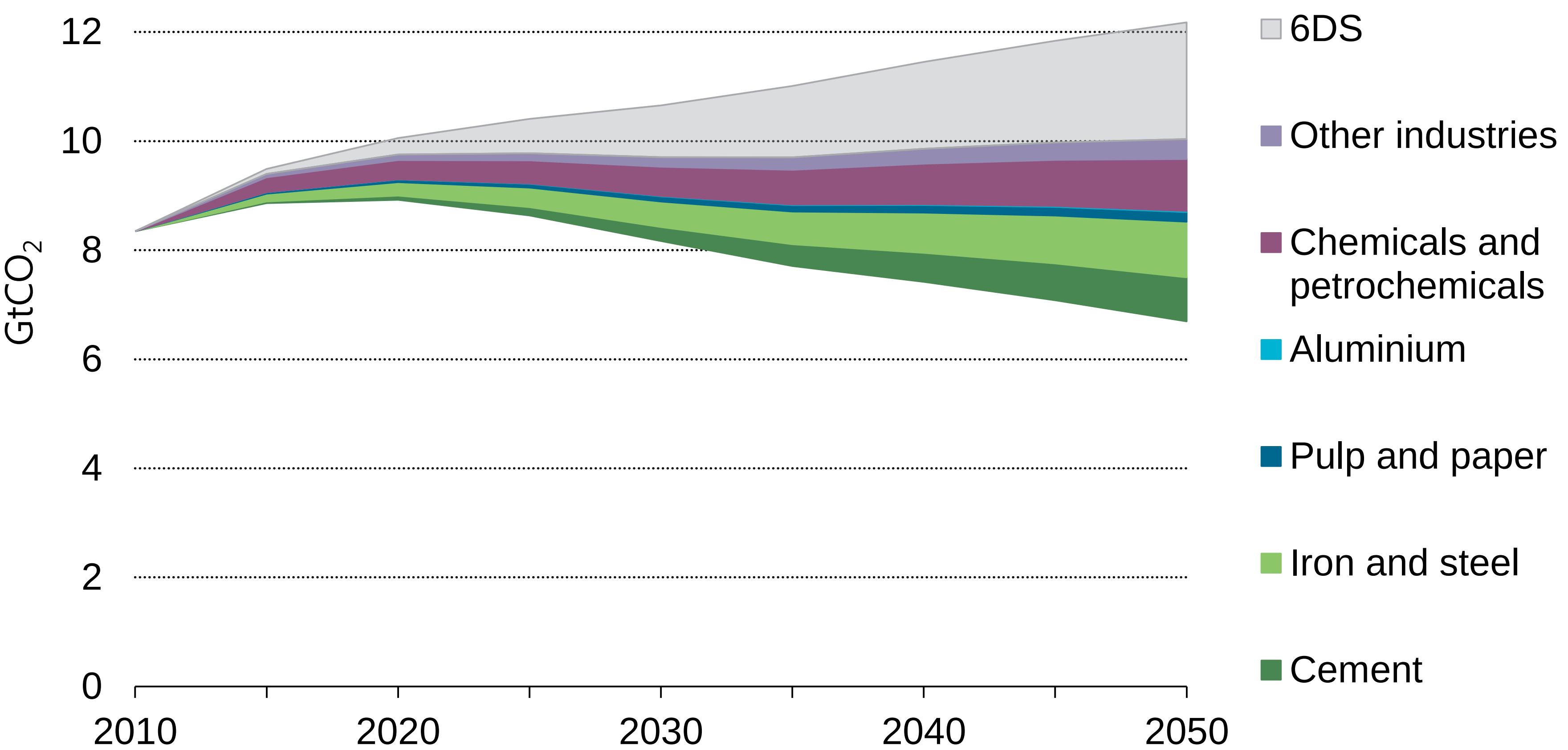
Contribution of technologies to meet the 2DS target



Source: IEA , ETP 2014

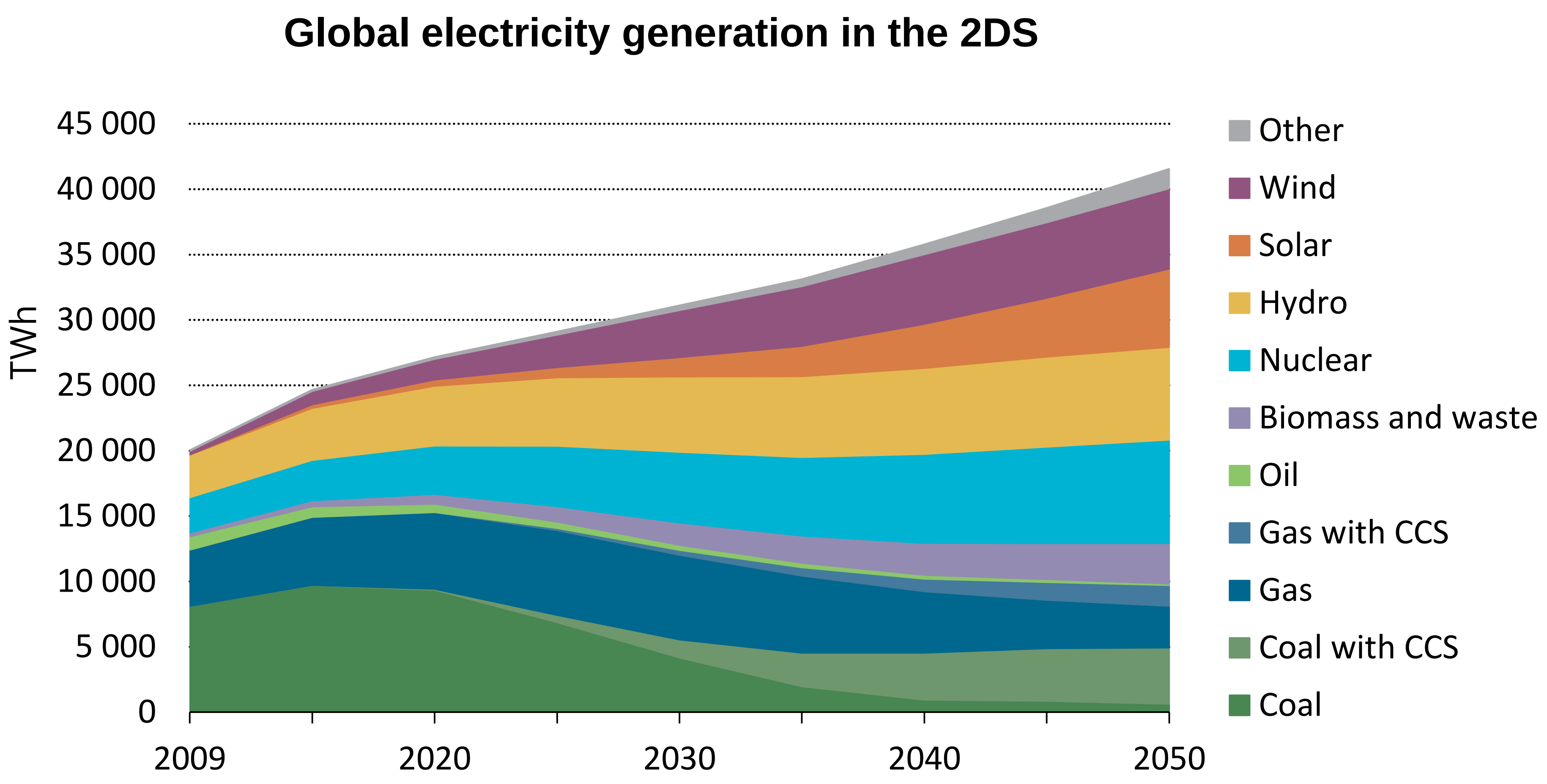
Industry Must Become More Efficient

Contribution of the industrial sectors



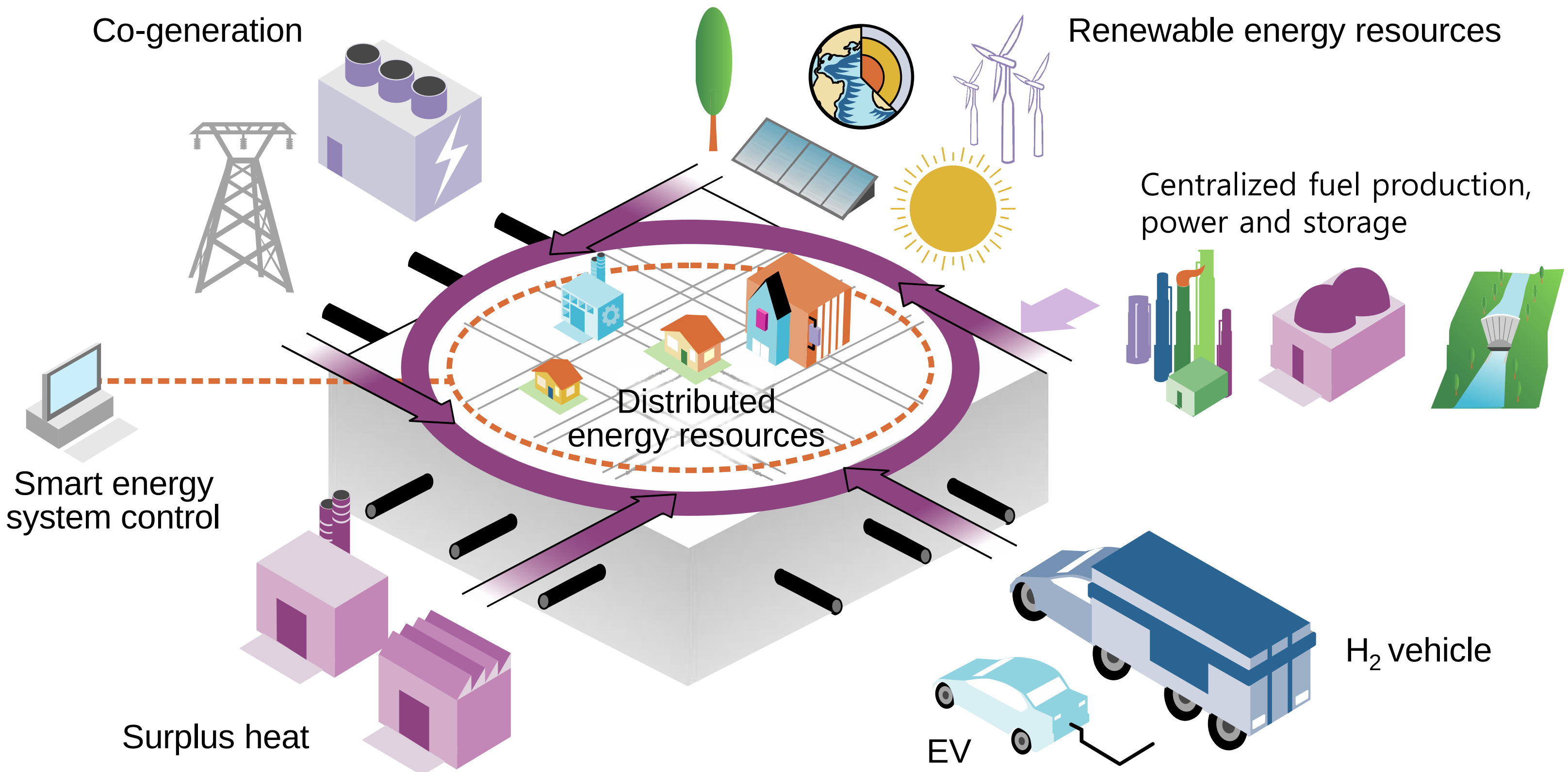
Source: IEA , ETP 2012

Low-Carbon Electricity : a clean core



Source: IEA , ETP 2012

Target : a smart, sustainable energy system



Source: IEA , ETP 2012

To get on track to a sustainable future

Energy Efficiency
- Power, Industry, Transportation, Heating & cooling

Environment

CCS, CCU

Clean Coal

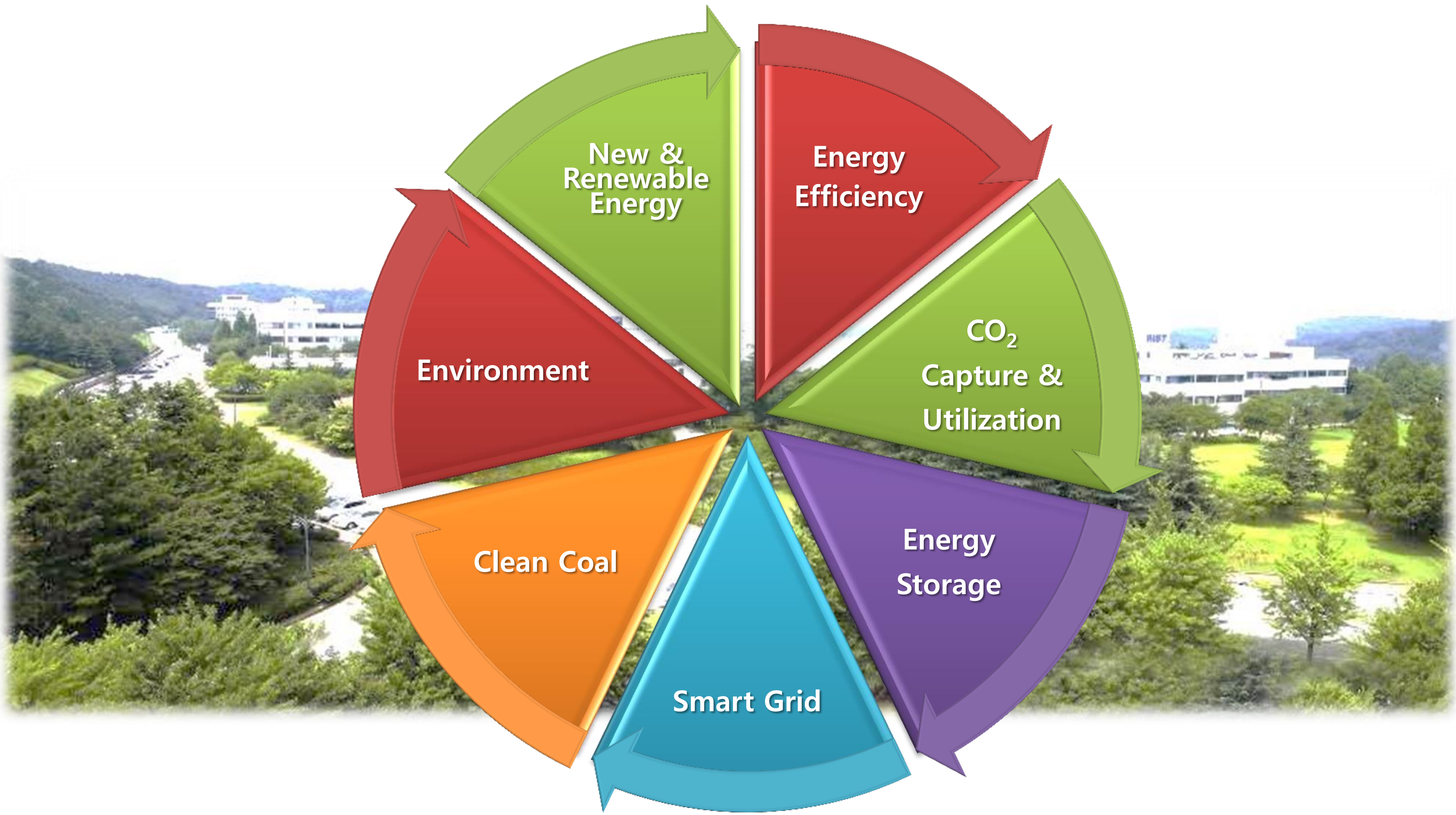
Energy Management / Smart Grid

Storage

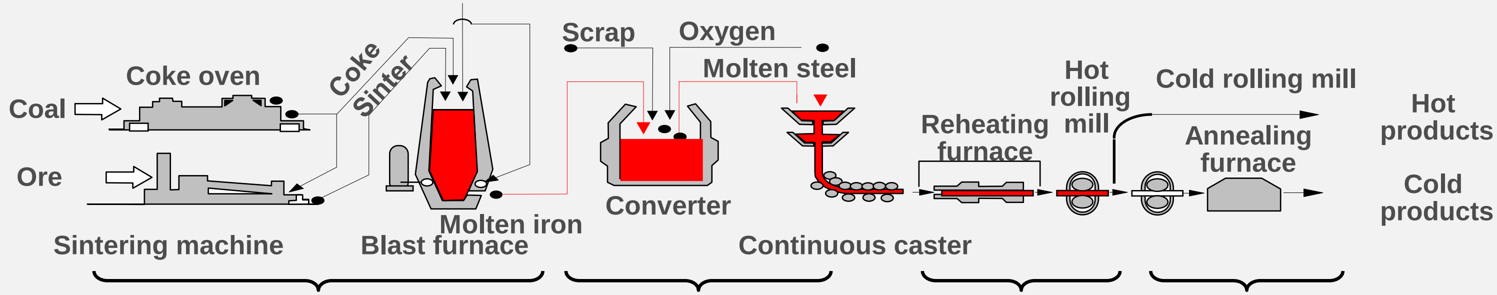
Renewables

Recycling

Energy & Environmental Research at RIST



Energy and CO_2 in the Iron & Steel Industry



CO_2 Emission: ~87% ~5% ~5% ~3%

$$Fe_2O_3, Fe_3O_4 + \text{Carbon} \rightarrow Fe + CO_2$$

√ *Features of iron & steel-making*

- *energy-intensive: ~ 25 GJ/t-steel*
- *high burden: ~ 2t-CO_2/t-steel(~5% of global emissions: 6.5Mt-CO_2/yr)*

√ Activities for CO_2 Reduction

- *Routes for CO_2 reduction at iron and steel industry*

Carbon -free	•Hydrogen •Renewables
Carbon -lean	•Energy efficiency improvement •Waste heat recovery
CCUS	•CO_2 capture and storage •CO_2 utilization

Regional programs;

√ ULCOS (Europe)

√ AISI CO_2 BP (US)

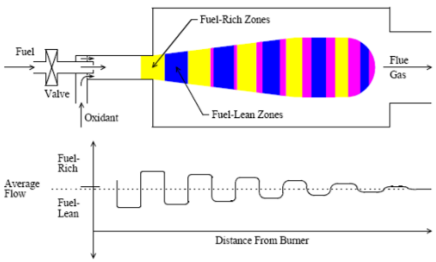
√ COURSE50 (Japan)

√ POSCO CO_2 BP (Korea)

…

Energy Efficiency

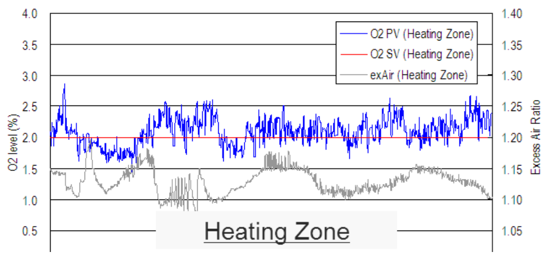
- **Oscillating Combustion : Control fuel lean & rich to induce mild combustion**



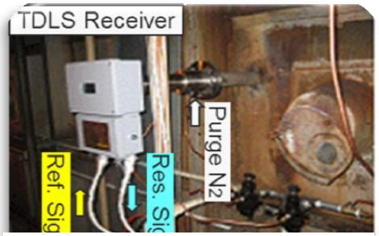
Major Achievements

- **Application to radiant tube burners for indirect heating furnace ('09~'10)**
  ~30% NOx reduction & 3% fuel saving
- **Demonstration for large scale direct heating burners ('12~)**

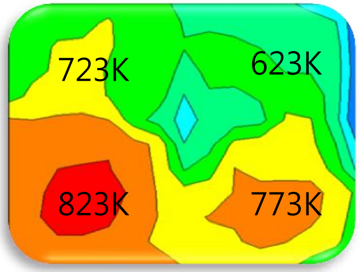
- **Oxygen control using TDLS (tunable diode laser spectroscopy)**



Control Performance at reheat furnace



Mount 1x1 TDLS at RF



2D T-profile by 3x3 TDLS

Major Achievements

- **Automatic combustion control was enabled by using TDLS oxygen sensing**
- **Application :** Reheat & forge furnaces
  ~5% energy saving and prevention of ~ 20% scale loss

Waste Heat Recovery

Waste heat

The recovery of waste heat below 300°C is very restricted by lack of technology.
Total amount of world-wide waste heat being able to recover is 1,109GW ('11, Wasabi co.).
Market forecasts of power generation using waste heat ('17) : 65.0 billon won/yr

Waste heat power recovery

ORC
- Technically mature
- Commercially available

Kalina cycle
- R&D in progress (long term run-test)
- Commercially available

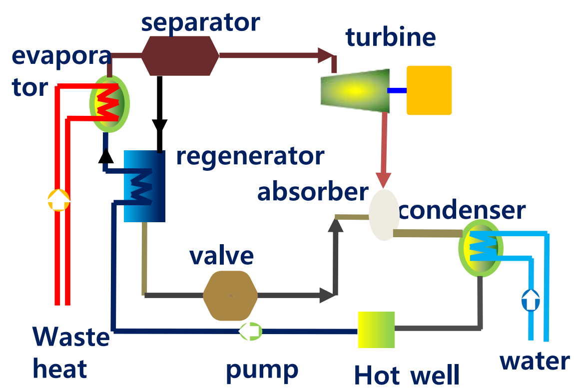
TPG (Thermoelectric power generation)
- R&D in progress
- Modular/Compact

Kalina cycle power generation

Characteristics

- ➢ Working fluid is NH_3/water mixture with low boiling point

Kalina cycle & pilot plant

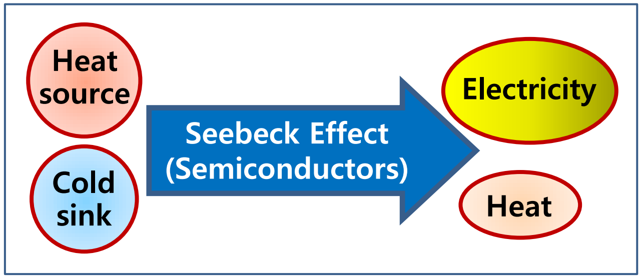


Major Achievements

- ➢ Pilot-plant(600kW) operation and process optimization ('13)
- ➢ Demo plant underway for geothermal generation (Pohang, '15~)

● Thermoelectric power generation

Thermoelectric generator produces electricity using semiconductors through a temperature difference (Seebeck effect)



<Thermoelectric Generator Schematic>

Development of TEG system

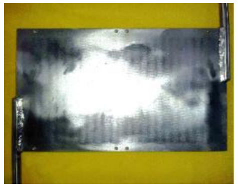
Characteristics

- ➢ To enhance power output with compact design → stacking technology

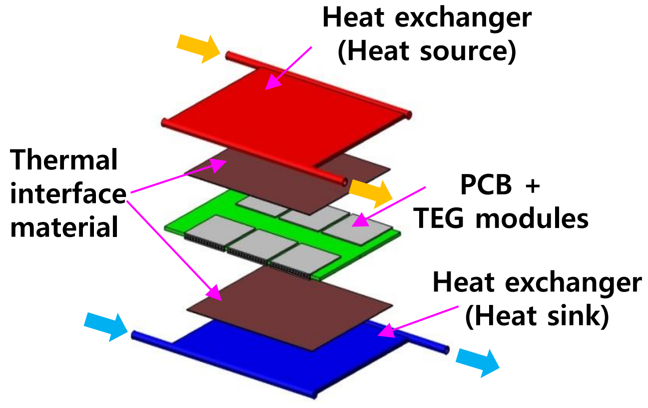
TEG module

PCB+TEG modules

Heat exchanger



TEG Unit Package



TEG Unit Stack

Major Achievements

- ➢ Development of TEG unit stack: 235W with 4 packages stacked (△T=150℃)
- ➢ Power density > 23.5kW/m^3, Net power ratio > 50%
- ➢ Field test of pilot scale (5kW) system using furnace exhaust gas ('14.12~)

CO_2 Capture Using Aqueous Ammonia

● CO_2 Capture

CO_2 capture is the term of technologies aimed at capturing carbon dioxide emitted from industrial and energy-related sources before it enters the atmosphere

Ref) http://www.nanocat.co.in/co2-capture-and-conversion.html

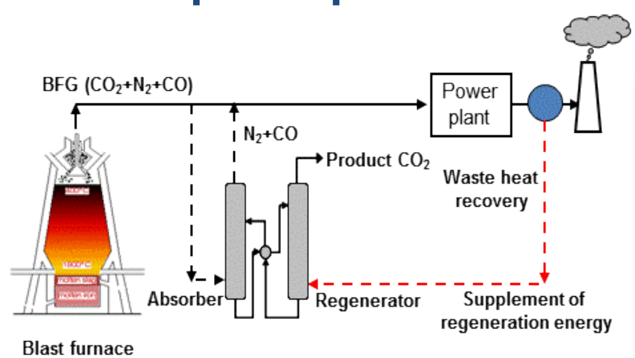
● Type of CO_2 Capture

Absorption
- Amine, **ammonia**, …
- Technically mature

Adsorption
- Pressure/Temp swing
- Limited application

Membrane
- Polymeric, inorganic, …
- R&D at early stage

RIST capture process



Aqueous ammonia-based CO_2 capture utilizing waste heat from boiler stacks

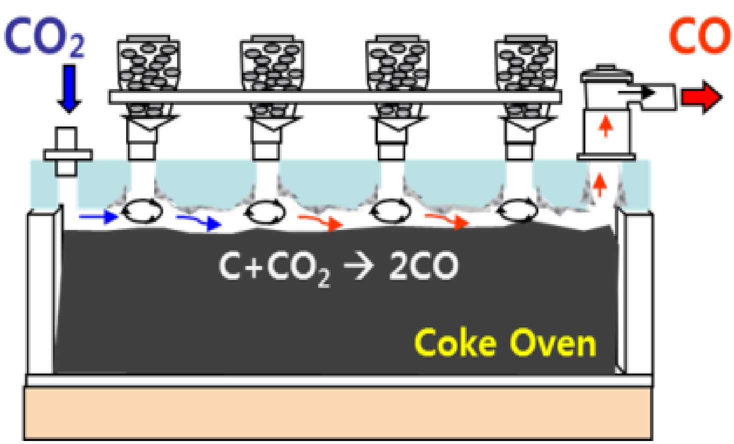
CO_2 Capture Pilot Plant (10 t-CO_2/d) @ POSCO-Pohang Works

Major Achievements
- ➢ Absorbent regeneration at low temp (~80 °C) utilizing waste heat (~150°C)
- ➢ CO_2 capture pilot operation at 90% removal w/ 99.8% purity
- ➢ Commercial design (1kt/d) completed

CO_2 Utilization : Conversion into CO

CO_2 conversion using coke oven: steel-industry specific CO_2 utilization tech.

CO_2 utilization means the conversion of CO_2 into CO, fuel, other valuable chemicals. We develop the conversion technology of CO_2 into CO via Boudouard reaction utilizing waste carbon and heat in the coke-making process.



Boudouard reaction

$$C + CO_2 \xrightarrow[\Delta H]{} 2CO$$

- C : Waste carbon in coke oven
- CO_2 : Captured from steel industry
- ΔH : Waste heat in coke oven (900~1,000^{o}C)

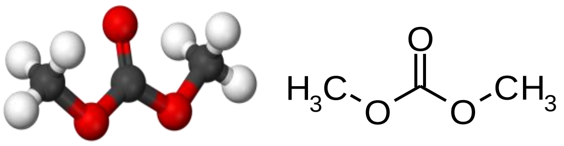
Major Achievements

- CO_2 conversion to CO: ~65%
- COG (Coke Oven Gas) production amplification: 10%
- Pilot testing at POSCO: optimization & long-term operation

CO_2 utilization : DMC Synthesis

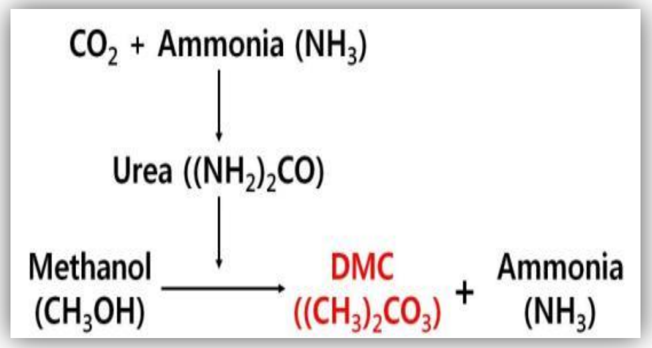
DMC(dimethyl carbonate)

DMC is used for
- Raw material for engineering plastic (Polycarbonate): 1 Mt/yr
- Potential fuel additive for MTBE substitute : 7~8 Mt/yr

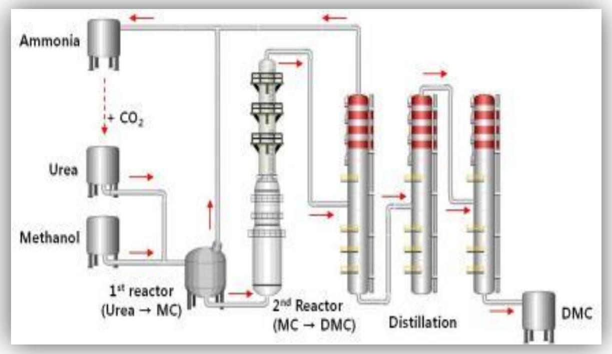


[chemical structure of DMC]

RIST DMC process



[DMC synthesis]



[DMC process]

[Pilot plant]

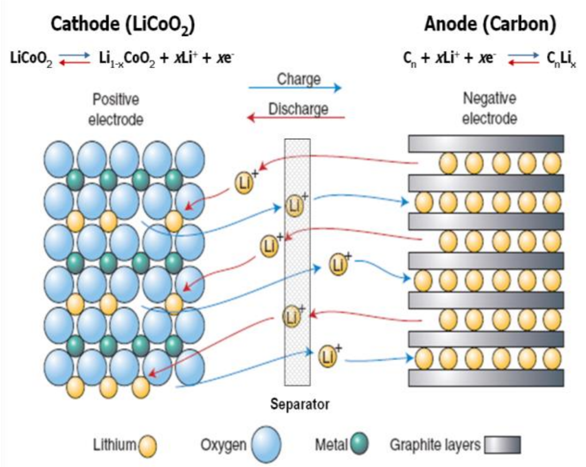
Major Achievements

- Lab ('11~'12): feasibility study for a new catalytic synthesis system
- Pilot ('12.7~present): pilot-scale (30 ton/yr) operation and process optimization
  - Continuous operation: 600 hrs
  - DMC Yield: 85%, Purity: 99.9%
- Chemical utilization of CO_2 : **0.5 t-CO2/t-DMC**

Energy Storage : Lithium-ion Battery

Lithium-ion battery (LIB)

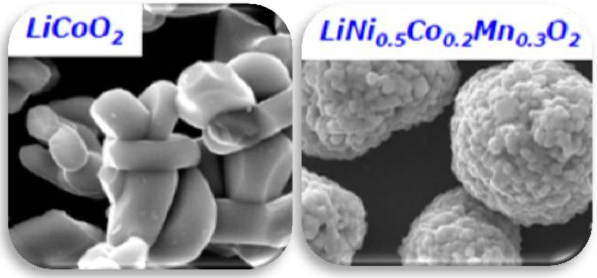
LIB is a rechargeable battery based on Li intercalation reaction.
It has much higher energy density and longer life cycle compared to the conventional Pb or Ni batteries.
LIB will be used for next generation EV and/or mobile devices



<Schematic reaction diagram of LIB>

Cathode development

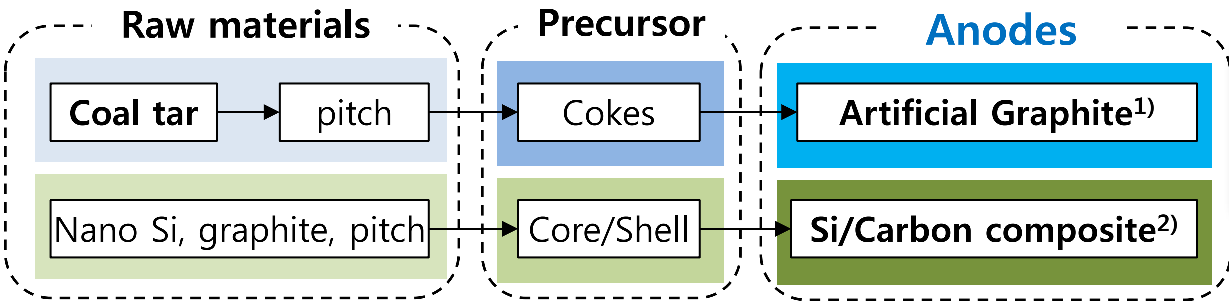
Raw Material	Precursor	Cathode
Li Extraction from Brine Ni/Mn/Co Ore Smelting	Ni/Mn/Co Compound Li Compound	Oxide Synthesis
• Smelting Technology	• Powder Technology	• Composition & Size Control

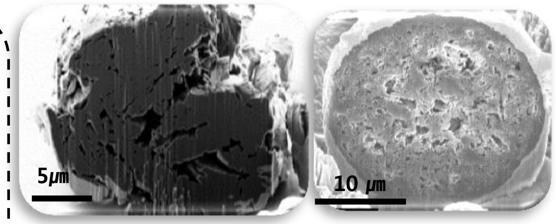


Major Achievements

- High capacity & high stability cathode materials (Ni-rich Gradient NMC)
- Enhanced the life cycle of cathode materials through coating method

Anode development





1) Graphite   2) Si/C comp.

Major Achievements

- High capacity and cyclic life of artificial graphite anode
- Si-carbon composite anode with higher capacity than natural/artificial graphite

Performance comparison of developed materials

<Posco Gradient-NMC vs conventional NCA>

Cathode Mat'ls	Discharge capacity (0.1C)	Cap. retention @ 50 cycles
PG-NMC (Ni 80%)	**209 mAh/g**	**98 %**
NCA (Ni 80%)	194 mAh/g	95.8 %

Higher performance than conventional one

<Artificial graphite vs commercial one>

Anode Mat'ls	Discharge capacity (0.1C)	Efficiency(%)
Developed	**357 mAh/g**	**92 %**
Commercial	355 mAh/g	94 %

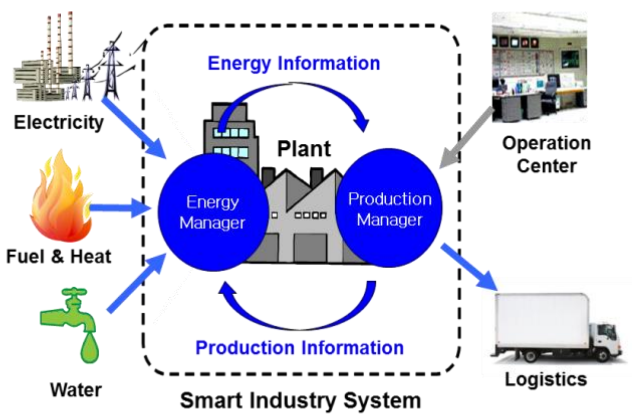
Similar performance with lower price

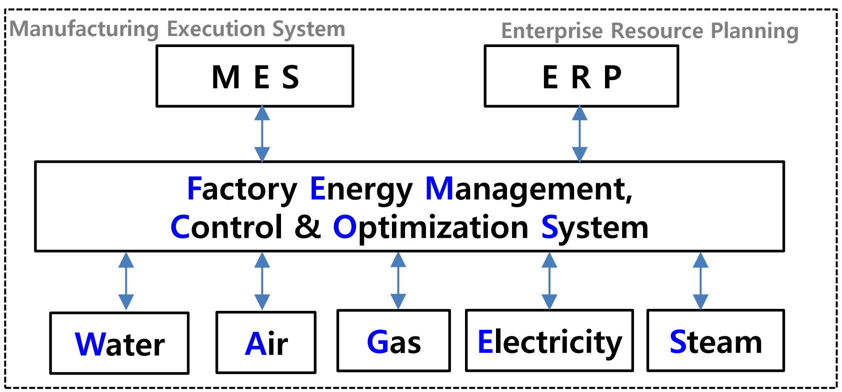
Smart Industry

Smart industry

System-wide energy efficiency improvement by optimizing energy and production process with sensor network and IT system based on the smart grid methodology

Technology progress of Smart Industry





Major Achievements

➢ **Demo stage research and application**

- New concepts establishment for the industrial system(POSCO)
- Energy demand prediction & efficiency evaluation of energy facilities
- Application of energy saving solutions
- Achievement of 2 million $/year energy cost reduction

Clean Coal Technology

Coal to Fuel and Chemicals

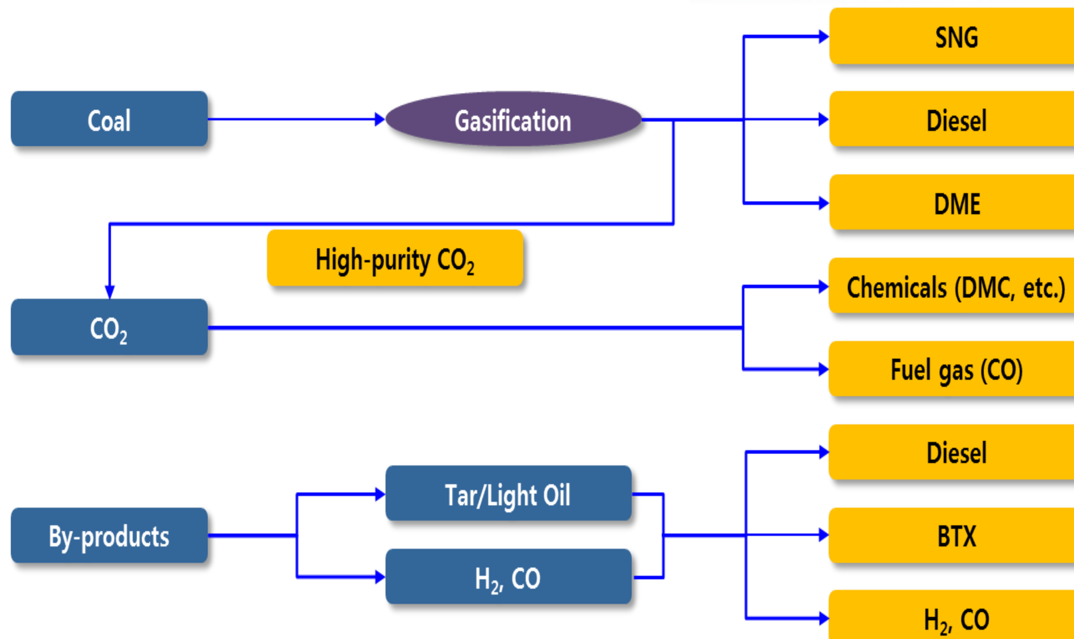
Coal to SNG(Synthetic Natural Gas), Diesel & DME
CO_2 to Chemicals and Fuel Gas
Steel By-products (Tar, Light Oil, By-product Gases) to Diesel & Chemicals

Type of Coal to Fuel / Chemicals

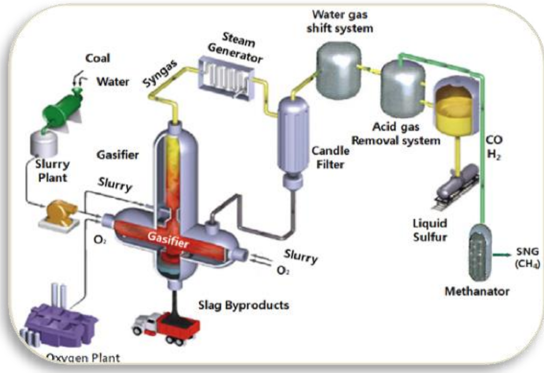
SNG (Synthetic natural gas)
- Similar property of natural gas(LNG)

CTL (Coal to liquid)
- Liquid fuel like gasoline and diesel

DME (Dimethyl-ether)
- Substitute for propane in LPG



Technology progress of SNG development



[SNG Process Scheme]

[Catalyst for SNG]

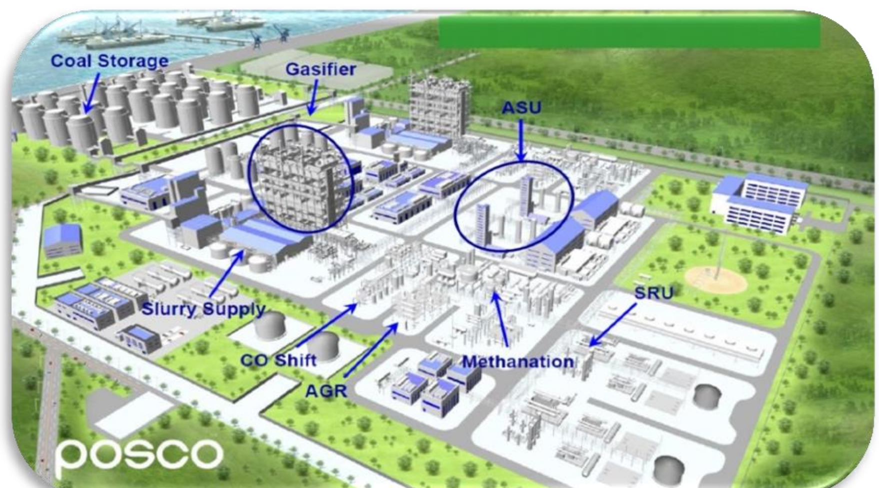
[Pilot plant]

Major Achievements

- Catalyst : High performance catalyst for SNG synthesis (847 L/kg.cat-h)
- Pilot plant : High performance reactor(6→4ea) (capacity : 5,000 Ton/yr)

Business Activity

- The First SNG plant in Korea (~ '15.5)
- Location : Gwangyang (POSCO site)
- Capacity : 500,000 ton of SNG /year



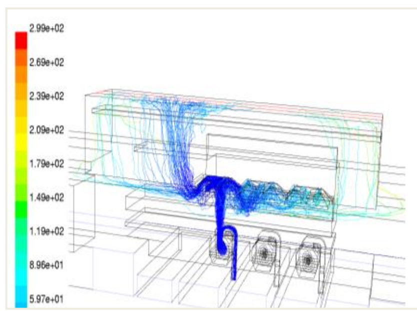
[Commercial plant of SNG]

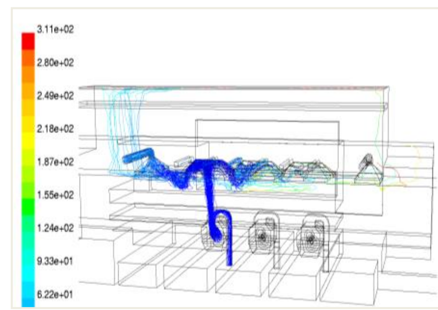
Environment : Air Pollution Prevention

Air Pollution Prevention

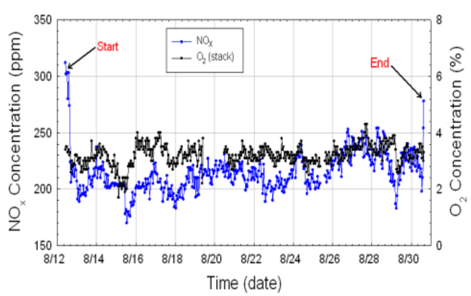
Air pollution includes particulates, NOx, SOx and VOC etc. in the effluent gas.
Measurement, modelling, treatment and engineering of facility is necessary for preventing air pollution.

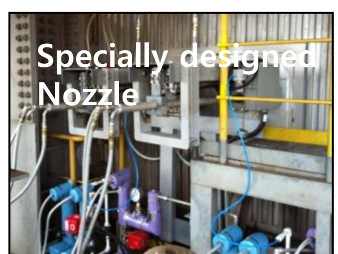
Particulate removal modeling Using CFD





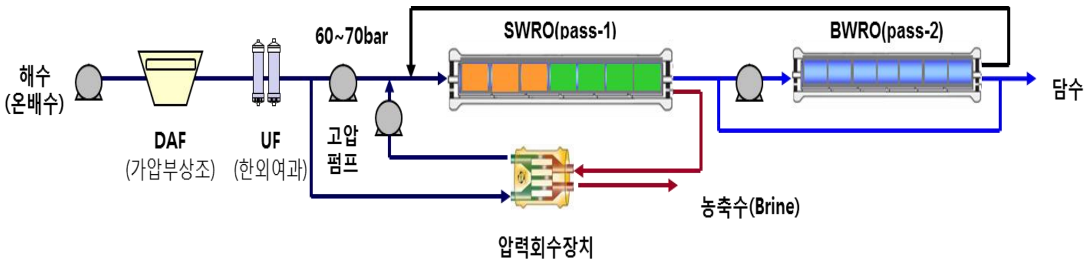
Improvement of De-NOx, De-SOx Efficiency





Environment : Water Supply & Clean Tech.

- **Wastewater Reuse and Seawater desalination**



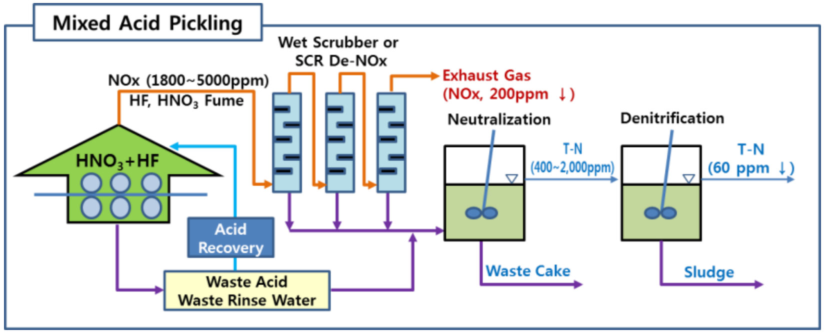
[Seawater desalination process]

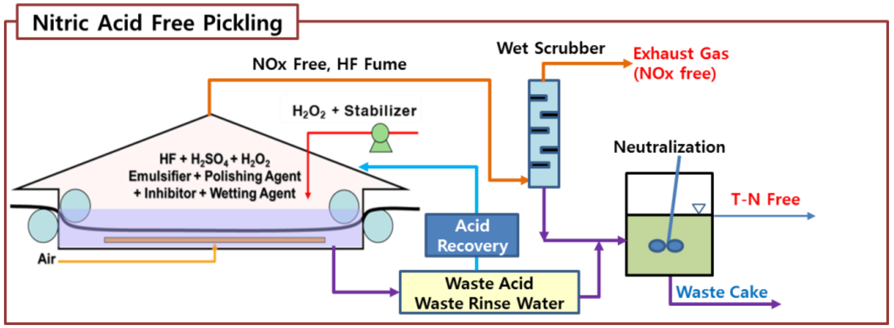
[Commercial plant near Gwangyang Works(30,000t/d)]

Major Achievements

- **ISD(internally staged design) improved the recovery to 55% (45% is typical)**
- **Operational energy is reduced to below 3.0 KWh/m³ (4.0 is typical)**

- **Nitric Acid Free Pickling Technology of Stainless Steel**





Major Achievements

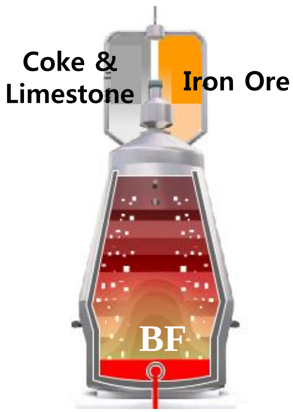
- **NOx emission prevented by blending H_2O_2 in pickling solution instead of HNO_3**
- **Commercial application to STS pickling plants of POSCO SS and DKC.**

Environment : By-product Reuse

Slag from steel industry

Slag is a by-product from blast furnace and steel-making process.
It is composed of silicon/calcium/aluminum and other metal oxides.

Type of Slag and Its Application



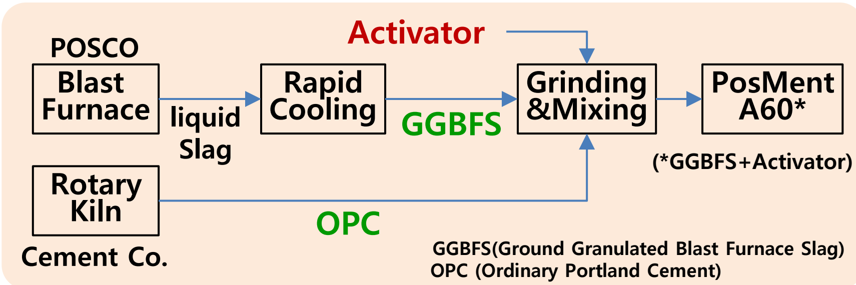
BF Slag

Granulated BF Slag

Air Cooled BF Slag

BOF Slag

PosMent® (Posco CeMent : slag cement with higher content BF slag)



Materials flow in PosMent manufacturing

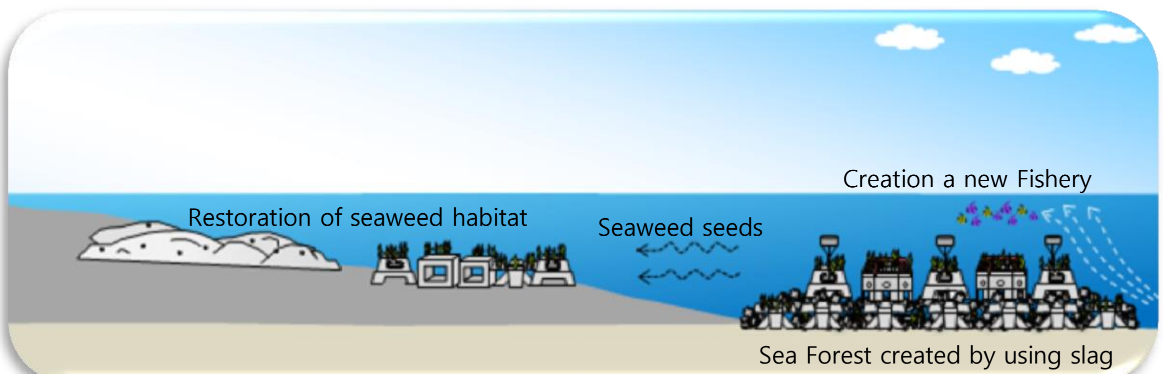
Application to mass structure and apartment construction.

O Development of high volume slag cement

-Mixing ratio of BF slag : Conventional Slag Cement(40%) → PosMent A60(60%)

O Commercialization: 530kT in 2013. (Use; Mass/Mat concrete, Soil Improvement, Building, etc.)

Sea Forest



Artificial Reefs made of slag(TRITON®)

Sea Forest (Yeosu, Southern Sea of Korea)

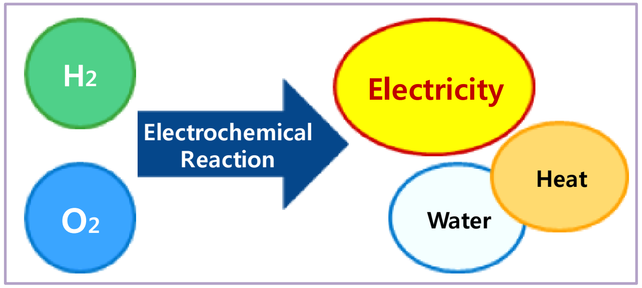
O Utilization of slag as seaweed reefs for overcoming desertification in coastal area

O Application : Participation in national marine afforestation projects since 2010

New & Renewable Energy : Fuel Cell

● Fuel Cell

Fuel cell produces electricity using electrochemical reaction of fuel (H_2) and air (O_2), with by-products of heat and water without CO_2 production



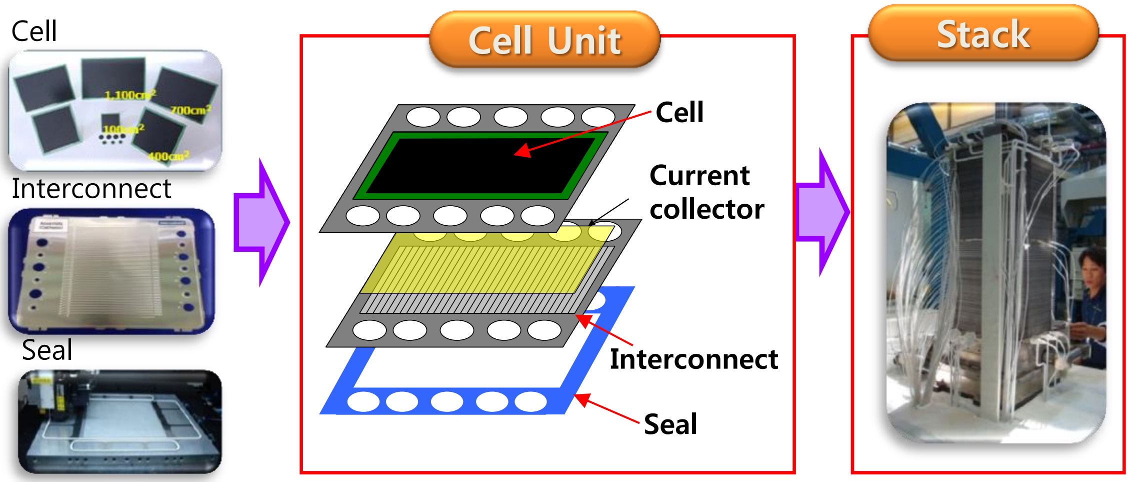
<Fuel Cell Schematic>

● Fuel cell type

	Power	Application
PEMFC	1~200KW	House, Building, Automobile
MCFC	1~200kw	Power generation
SOFC	1~100KW 300~MW	House, Building, Power generation

● Technology progress of SOFC

➢ High Efficiency, wide range of power generation



Major Achievements

➢ Cell unit : WB-class size and performance achieved (1,100cm^2, 0.44W/cm^2 : 480W/Cell

➢ Stack : >13kW with 96 cells stacked, 50% or higher efficiency

Concluding Remark