Global 2050 Calculator: Assessment of Primary and Secondary Energy Supply

Technical workshop on Fossil fuels and Electricity Generation Technologies

23rd - 24th April, 2014

Gurgaon , India

Content of Presentation – Day 1

▶**Session-1: Model Overview & Primary Energy supply**

- Model overview & structure of electricity and fossil fuel sectors
- Pathways of FF extraction efficiency
- Pathways of FF refining efficiency

▶**Session-2 : Fossil fuel based power generation**

- Pathways of split between coal, oil and NG based generation
- Pathways of efficiency of coal, oil and NG based power generation
- Pathway of carbon capture & storage (CCS)

Session-1
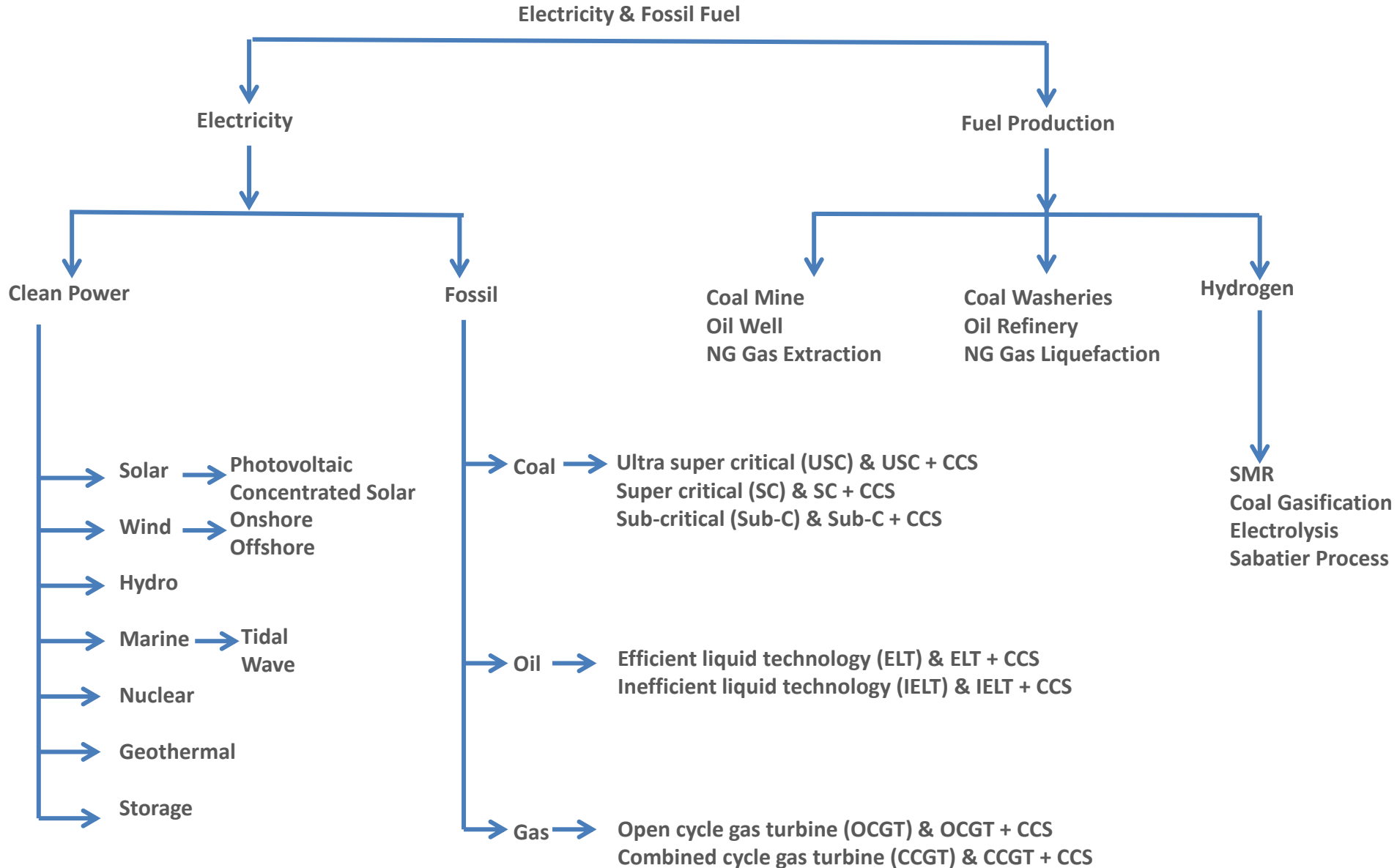
Model Overview &

Primary Energy supply
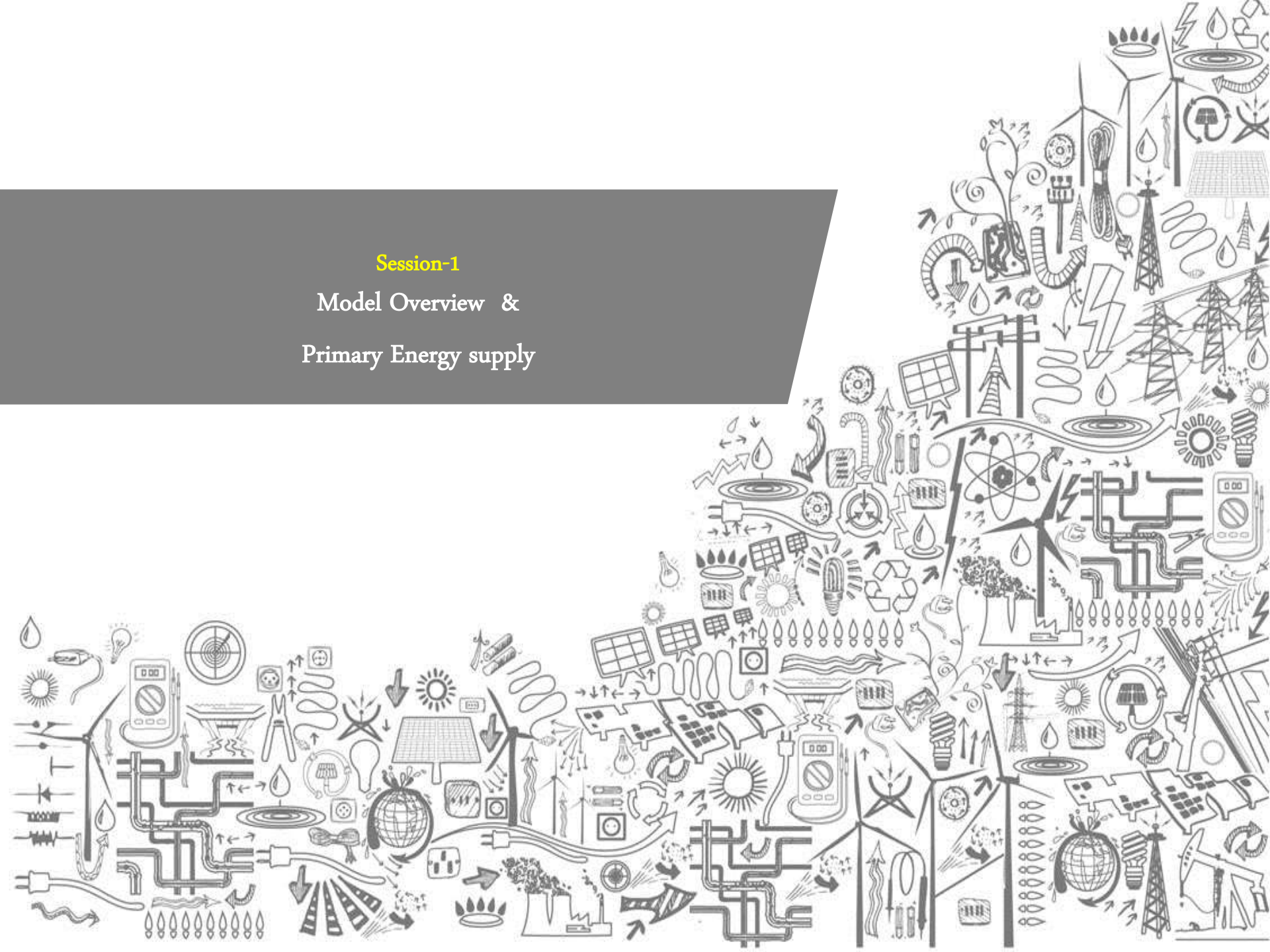
Model Overview

Principles of the Global 2050 Calculator

The Global 2050 Calculator is a simple excel based accounting tool for energy and corresponding emissions which is based only on engineering principle of technology development and adoption and does not contain any constraint in the system during technology deployment.

As a matter of fact this tool provides enormous flexibility to the policy and decision makers at all levels to fit their respective surrounding environments in a diversified information platform which can further help them to take informed decisions.

Technology Mapping

Electricity & Fossil Fuel

Electricity

Fuel Production

Clean Power

Fossil

Coal Mine
Oil Well
NG Gas Extraction

Coal Washeries
Oil Refinery
NG Gas Liquefaction

Hydrogen

Solar → Photovoltaic
Concentrated Solar

Wind → Onshore
Offshore

Hydro

Marine → Tidal
Wave

Nuclear

Geothermal

Storage

Coal → Ultra super critical (USC) & USC + CCS
Super critical (SC) & SC + CCS
Sub-critical (Sub-C) & Sub-C + CCS

Oil → Efficient liquid technology (ELT) & ELT + CCS
Inefficient liquid technology (IELT) & IELT + CCS

Gas → Open cycle gas turbine (OCGT) & OCGT + CCS
Combined cycle gas turbine (CCGT) & CCGT + CCS

SMR
Coal Gasification
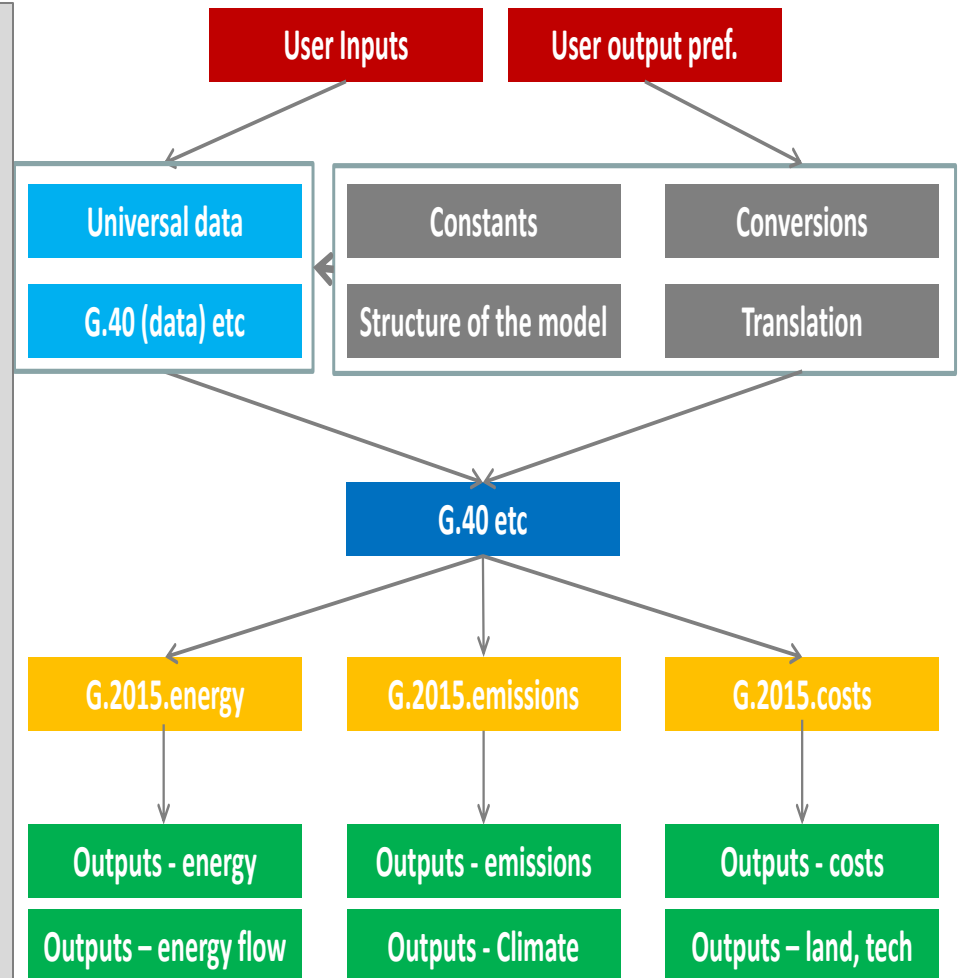Electrolysis
Sabatier Process

Electricity & Fossil Structure of the Global 2050 Calculator

Indicative flow diagram of the energy system considered in the calculator
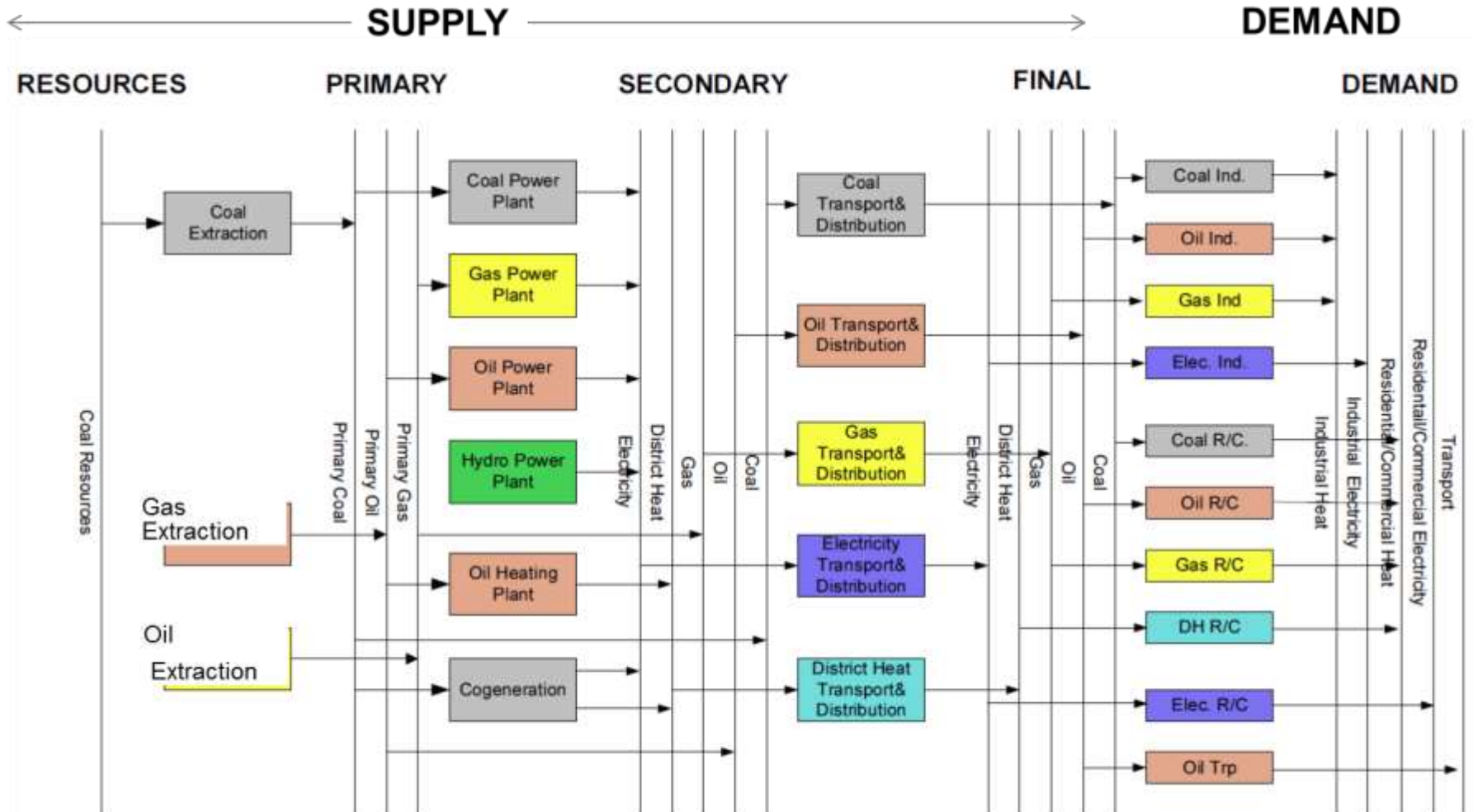
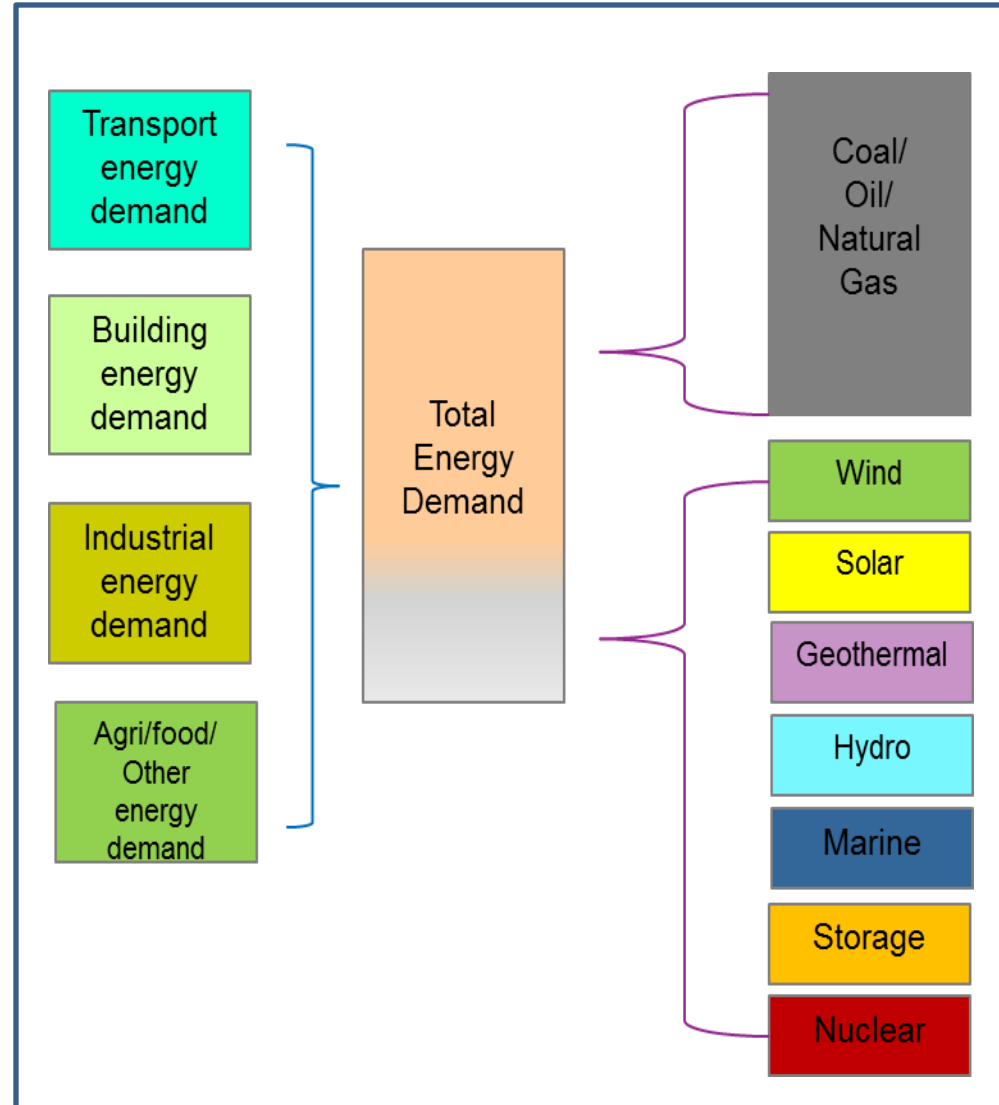# Structure of the Spread Sheets and Linkages

- ➢ Different levels of energy systems converted into excel sheets in the model work book

- ➢ Users get choices to determine the level of activities under each selected technology which are made user defined in the tool.

- ➢ User has options to select levels from 1 energy supply sector (electricity generation) and from 4 different energy demand sectors (transport/ buildings/ manufacturing/ land-food)

- ➢ Users get choices to select output units as well.

- ➢ Model endogenously determines the total energy demand from each demand sector and then determines the total supply required.
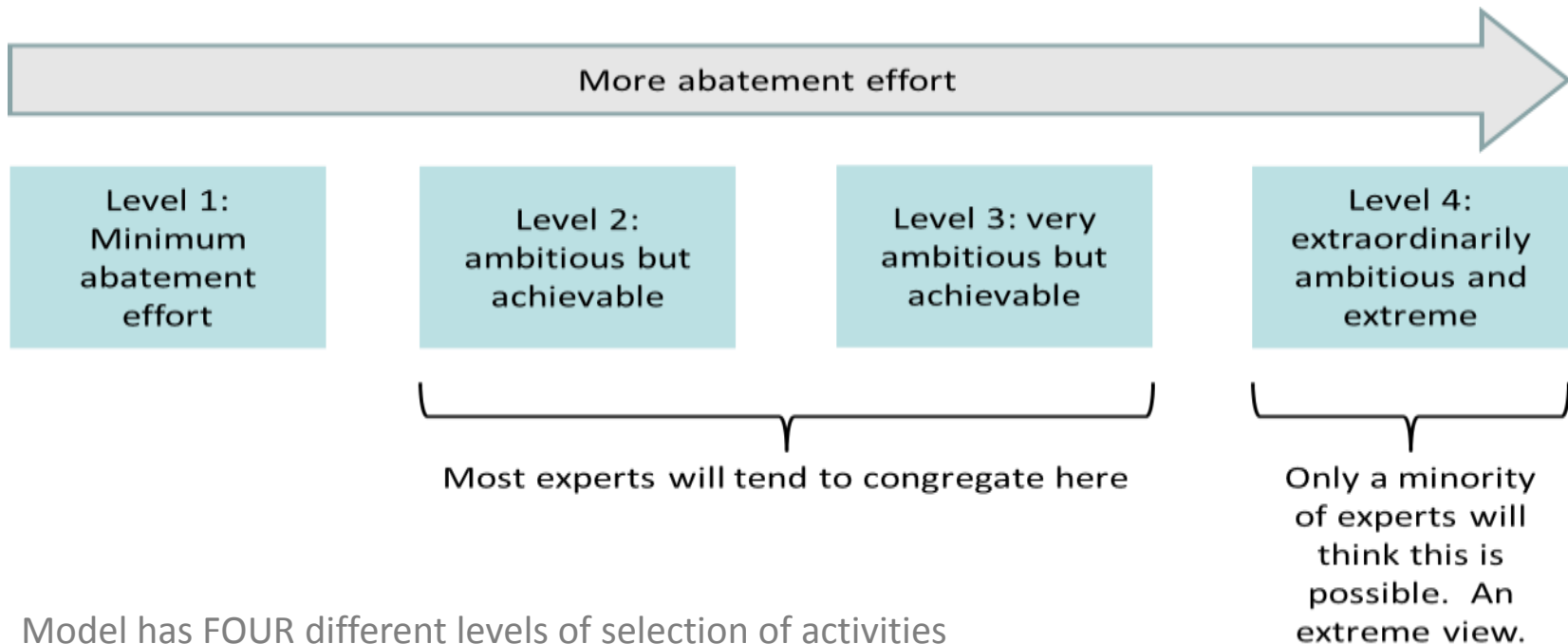
User Inputs	User output pref.

Universal data	Constants	Conversions
G.40 (data) etc	Structure of the model	Translation

G.40 etc

G.2015.energy	G.2015.emissions	G.2015.costs

Outputs - energy	Outputs - emissions	Outputs - costs
Outputs – energy flow	Outputs - Climate	Outputs – land, tech

Basic assumptions of electricity supply sector in the model

- ➢ Demand = Supply

- ➢ Demand meets in a priority order of renewables, nuclear and fossil fuels

- ➢ Primary objective of the supply mix is to reduce GHG emissions

- ➢ Electricity flows freely from one part to another part of the world- existence of global power grid

- ➢ No source of energy is intermittent ..all are firm power

Definition of user defined levels in the model

More abatement effort

| Level 1: Minimum abatement effort | Level 2: ambitious but achievable | Level 3: very ambitious but achievable | Level 4: extraordinarily ambitious and extreme |

Most experts will tend to congregate here

Only a minority of experts will think this is possible. An extreme view.

Model has FOUR different levels of selection of activities

Level-1 : Very pessimistic situation in the future in terms of deploying technology capable of reducing GHG emissions at a global scale.

Level -2 : Cautiously optimistic situation in the future in terms of deploying low emission technology at a global scale.

Level -3: Optimistic situation in the future in terms of deploying low emissions technology at a global scale.

Level -4: Very optimistic situation in the future in terms of deploying low emissions technology at a global scale.

User input choices in the electricity sector

Sector	Lever	User defined Level	Limit
Electricity generation	Coal/oil/gas split	1.0	4.0
	Fossil fuel efficiency	1.0	4.0
	Carbon capture and storage	1.0	4.0
	Nuclear	2.0	4.0
	Wind	1.0	4.0
	Hydroelectric	1.0	4.0
	Marine	1.0	4.0
	Solar	4.0	4.0
	Geothermal	1.1	4.0
	Storage and demand shifting	1.0	4.0

Citation

Primary energy extraction efficiency
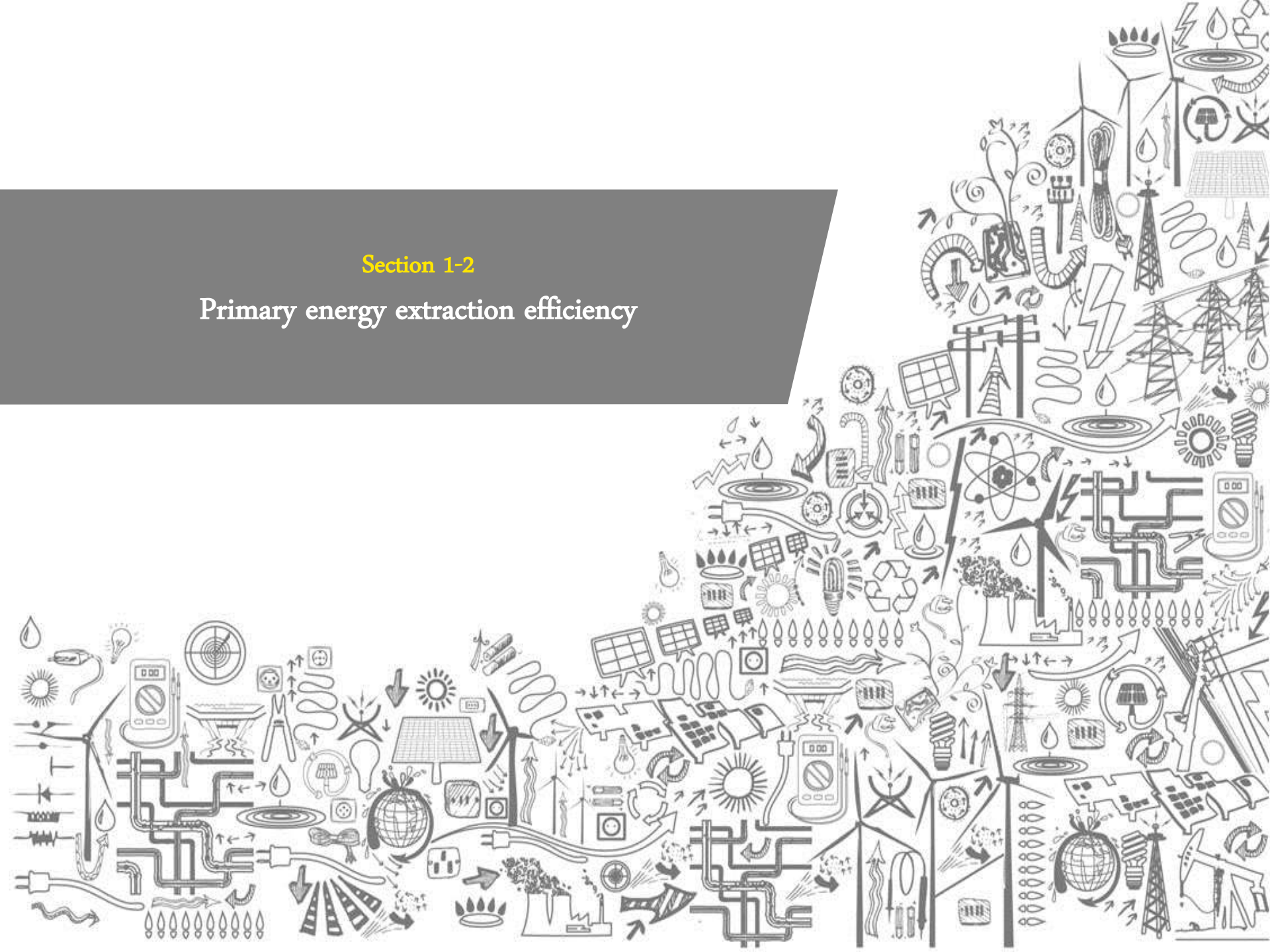
Coal Extraction Efficiency Levels

Global Coal Extraction

Level-4: The coal extraction efficiency is 80% in 2011 which improves to 95% in 2050.

Level-1: The efficiency remains constant at 80% till 2050.
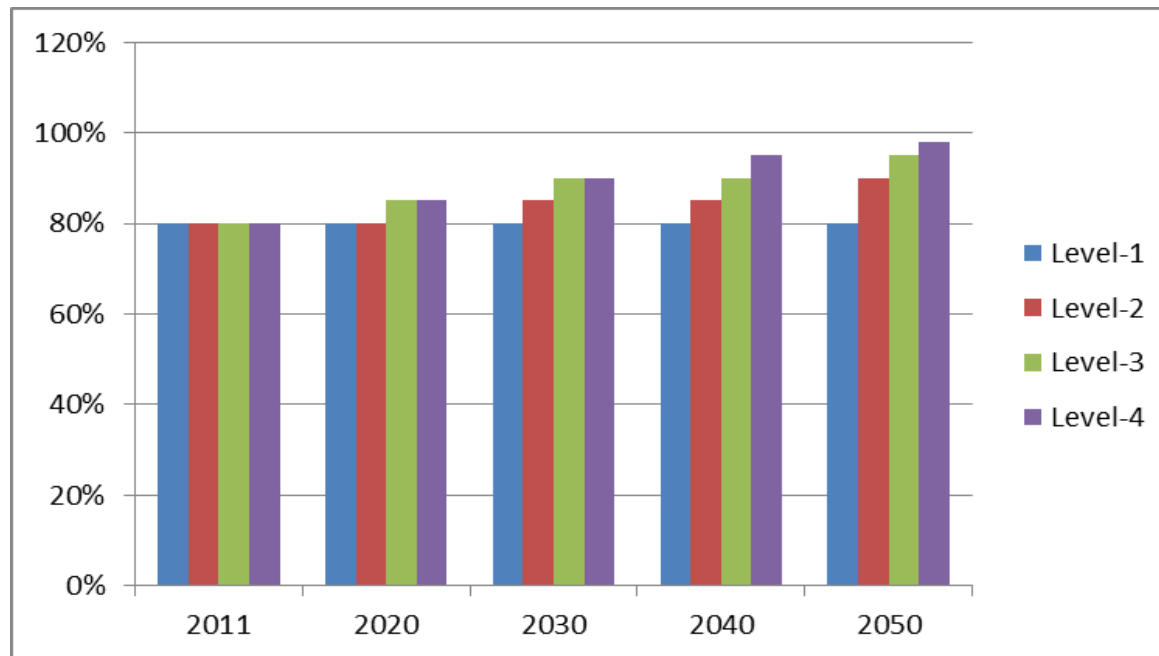
Global Oil Extraction

Level-4: The oil extraction efficiency is 93% in 2011 which improves to 98% in 2050.

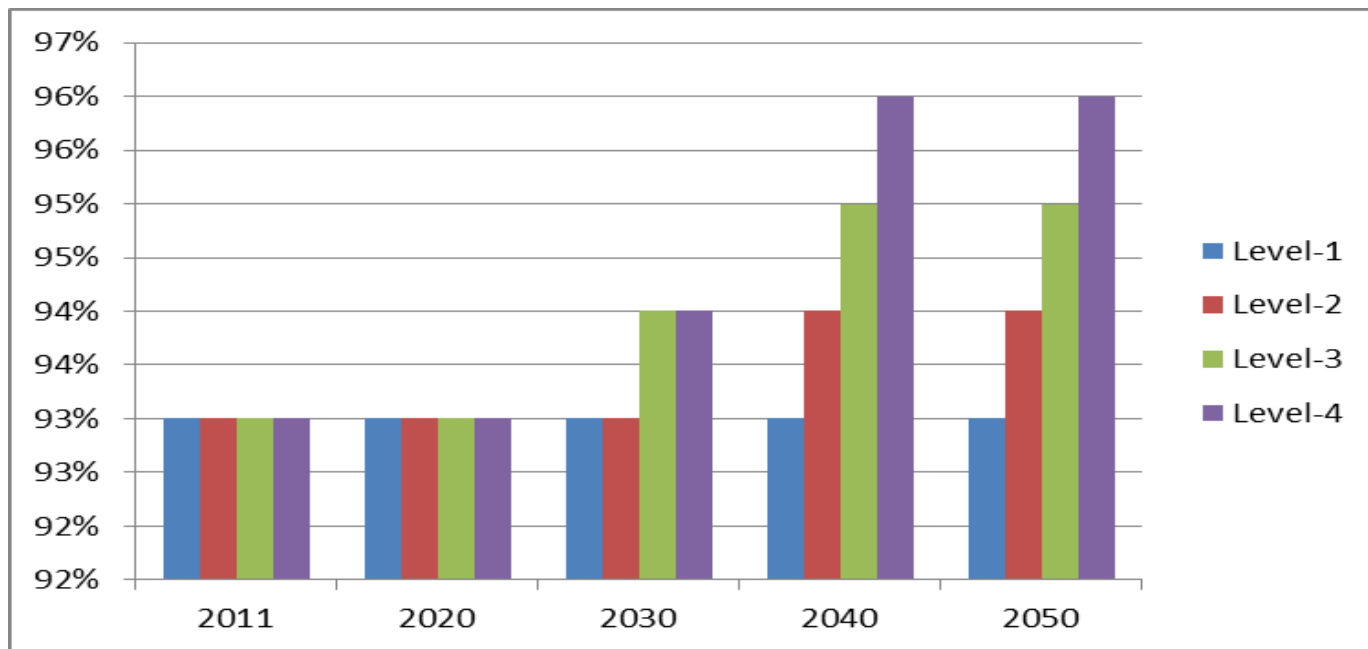**Level-1:** The efficiency remains constant at 93% till 2050.
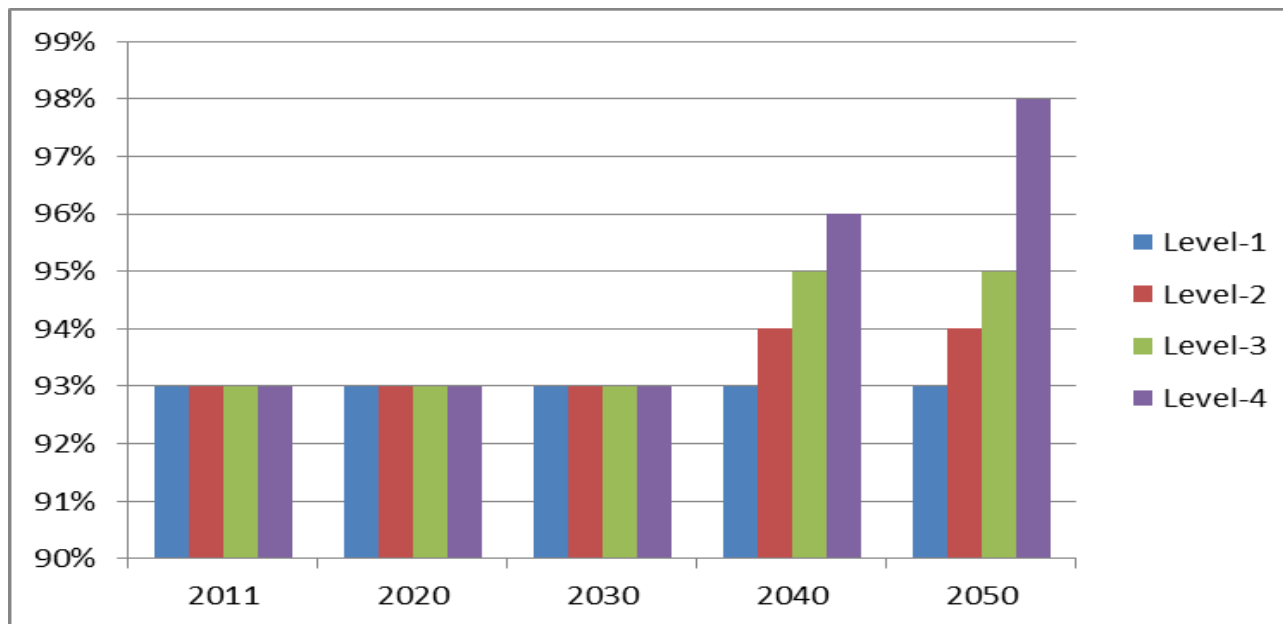
# Natural Gas Extraction Efficiency Levels

Global Gas Extraction

Level-4: The gas extraction efficiency is 70% in 2011 which improves to 90% in 2050.

Level-1: The efficiency remains constant at 70% till 2050.

15
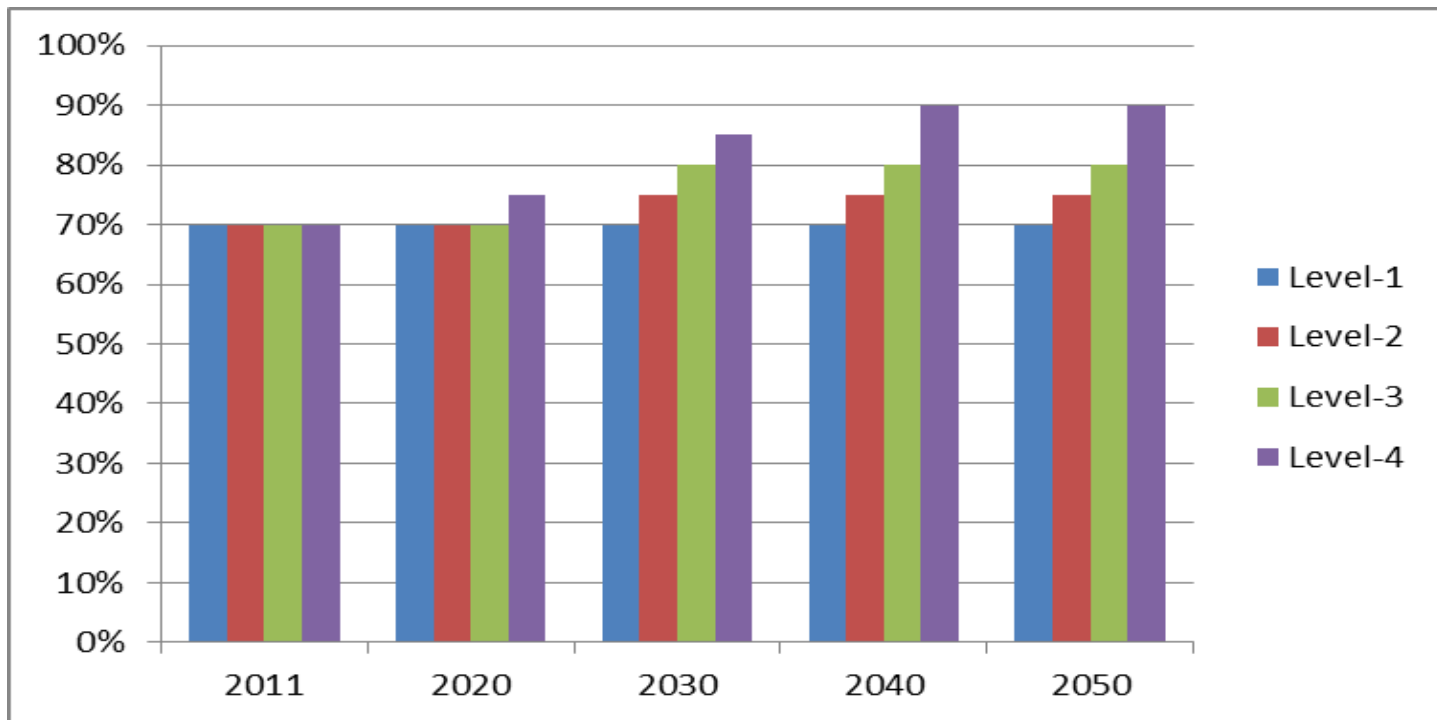
Primary energy refining efficiency
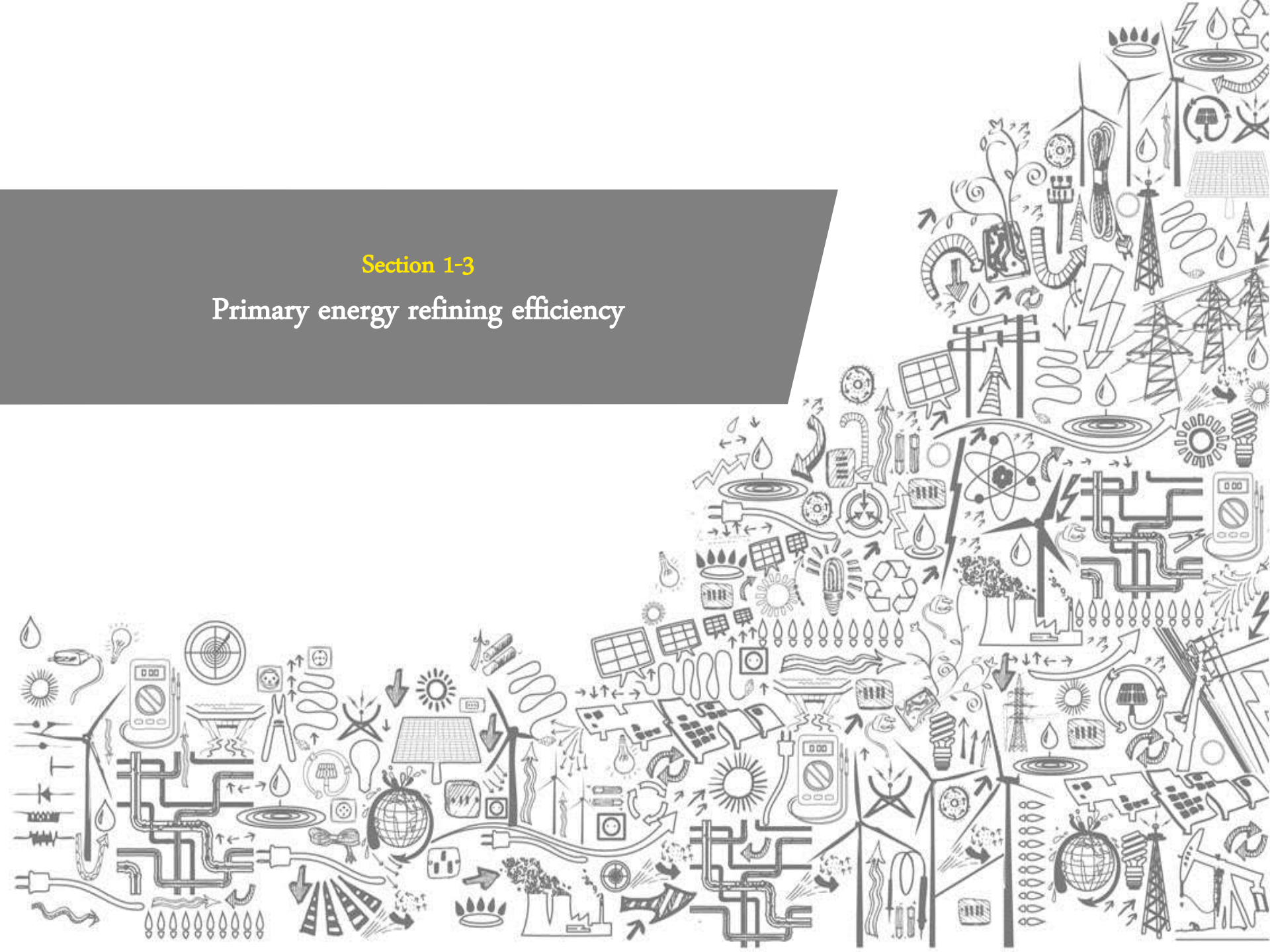
Coal Washing Efficiency Levels

Global Coal Washery

Level-4: The coal washery efficiency is 95% in 2011 which improves to 97% in 2050**.**

Level-1: The efficiency remains constant at 95% till 2050.
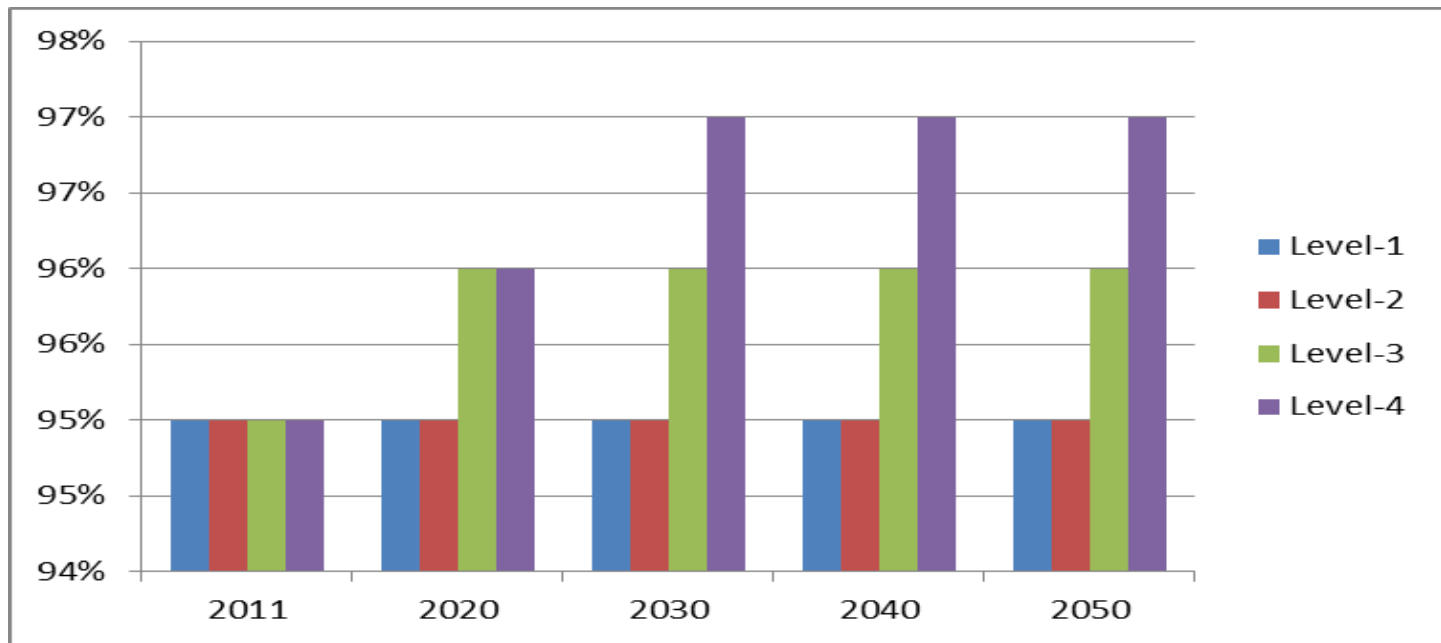
Global Oil Refinery

Level-4: The oil refinery efficiency is 93% in 2011 which improves to 96% in 2050.

Level-1: The efficiency remains constant at 93% till 2050.

Natural Gas Processing Efficiency Levels

Global Gas Processing

Level-4: The gas processing efficiency is 98% in 2011 which improves to 98% in 2050.

Level-1: The efficiency remains constant at 98% till 2050.
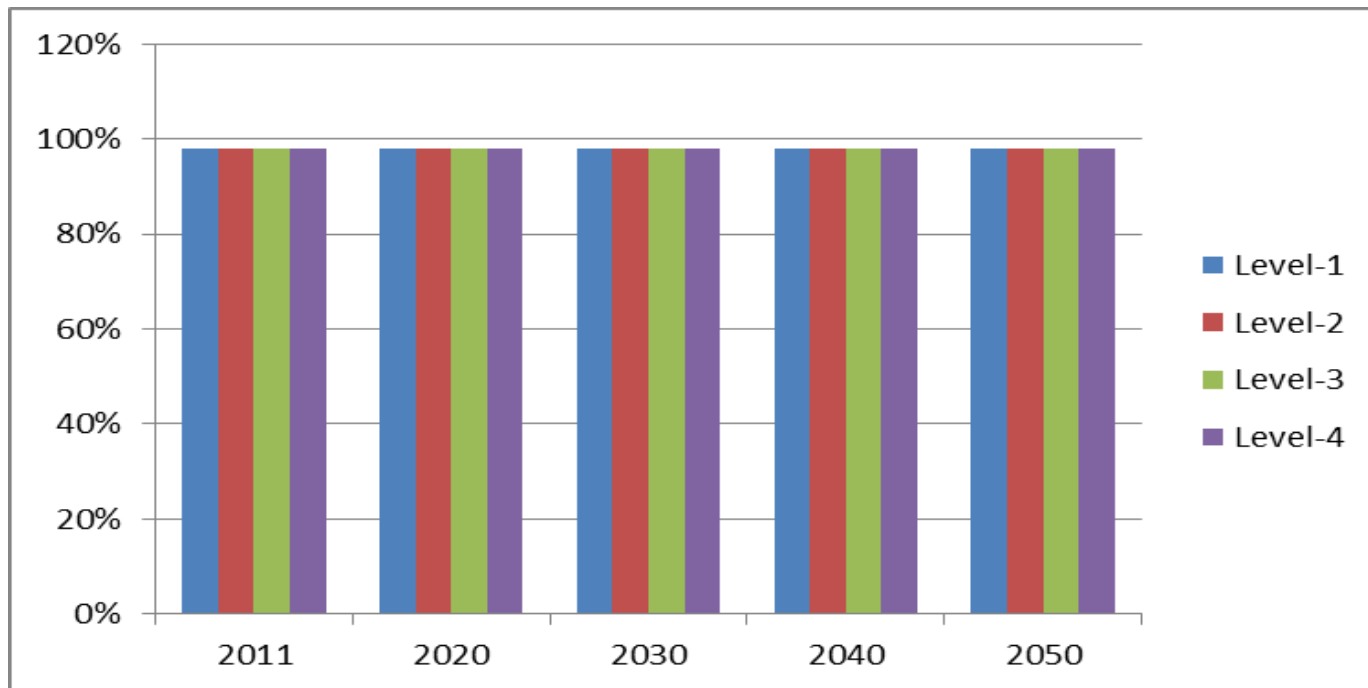
Section 2

Fossil fuel based power generation
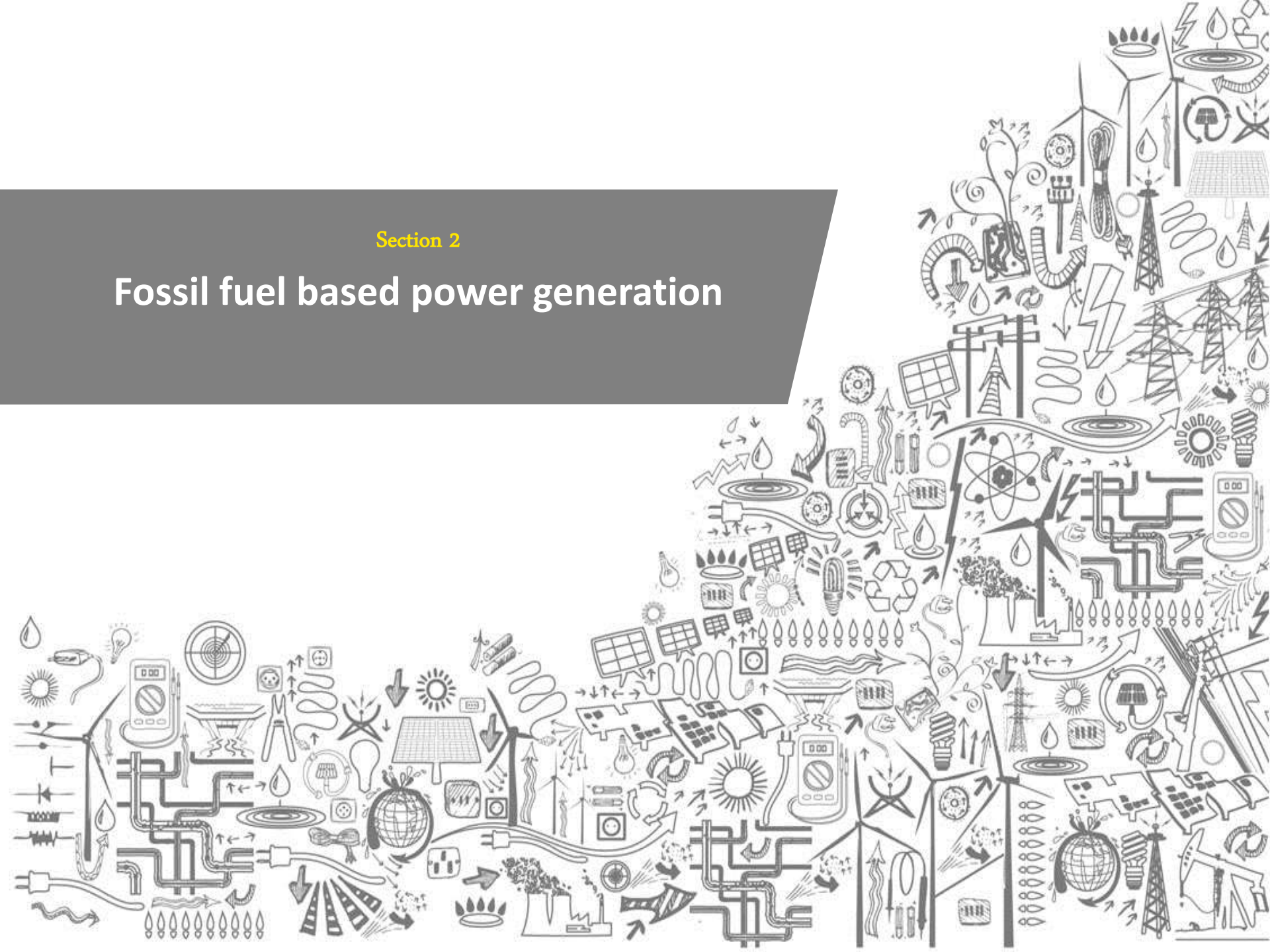
Section 2-1

Future pathway of split between coal, oil and NG based generation

Fossil fuels proportional split

Methodology

▶ Regional/country reserve and resource allocation. Historical and future estimates were mapped.

▶ Regional/country level production and consumption trends were recorded.

▶ Studied production and generation technologies deployed and under development globally.

▶ Analyzed variables which drive primary energy demand like industry, transport, etc.

▶ Analyzed variables which have a bearing on secondary energy like capacity factor, efficiency, demand load, etc.

Proportional split of hydrocarbons stations (solid/liquid/gas)

Assumptions

1. Coal based power generation will dominate if no additional measures are taken due to its easy and abundant availability at low cost.

2. Oil use tends to increase under L1 scenario due to its ready to use, low cost proven technology available across the world.

3. To increase gas based generation, world needs certain policy push and extra initiatives.

4. In Level -4 we assume new gas reserves are available at low cost (shale gas pitched in) , gas transport facilities improved (LNG facilities and pipelines commissioned)

Proportional split of hydrocarbons stations (solid/liquid/gas)
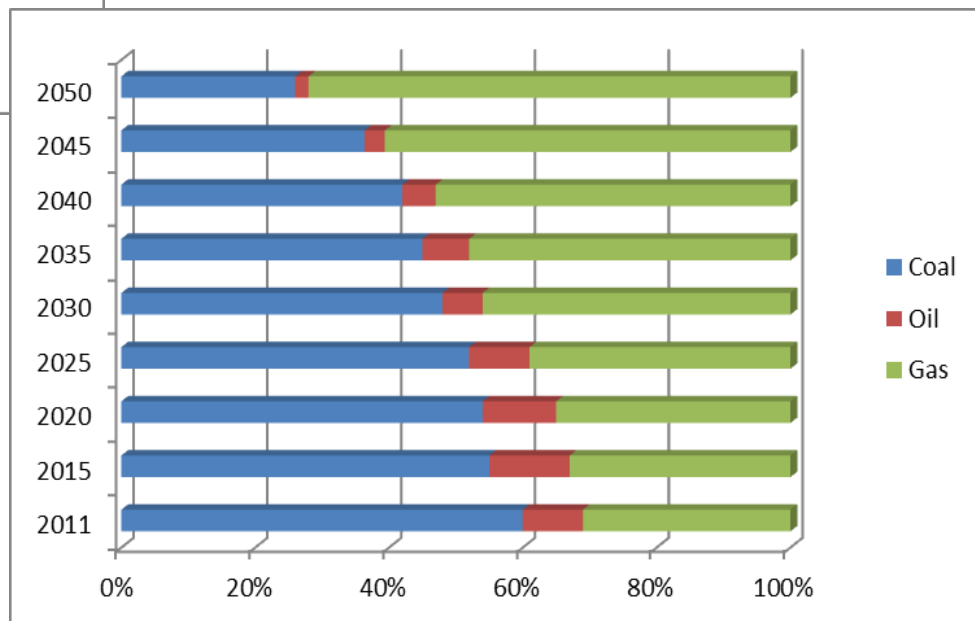
Level-1
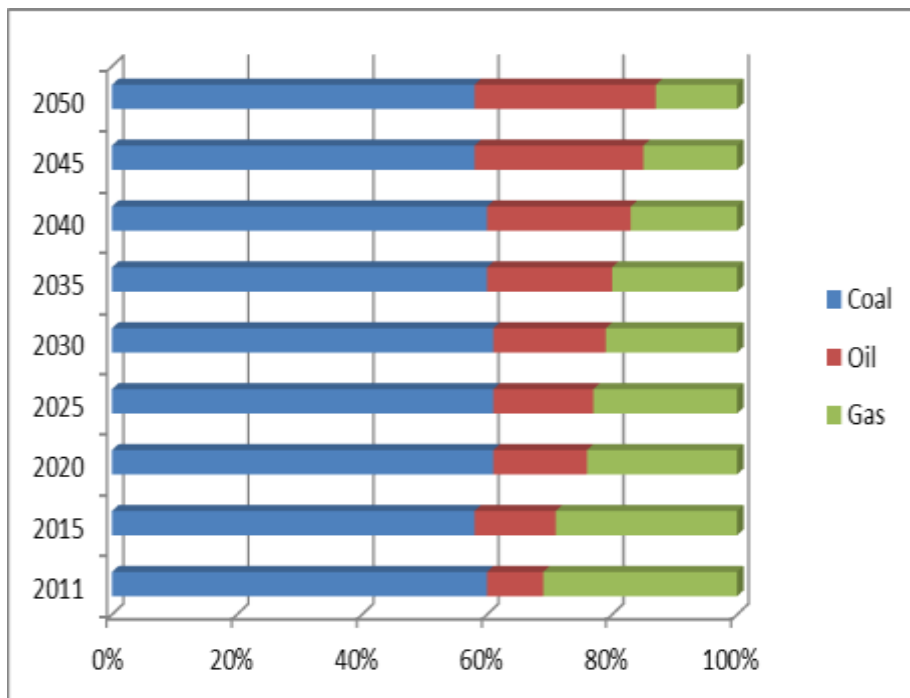
Level-2
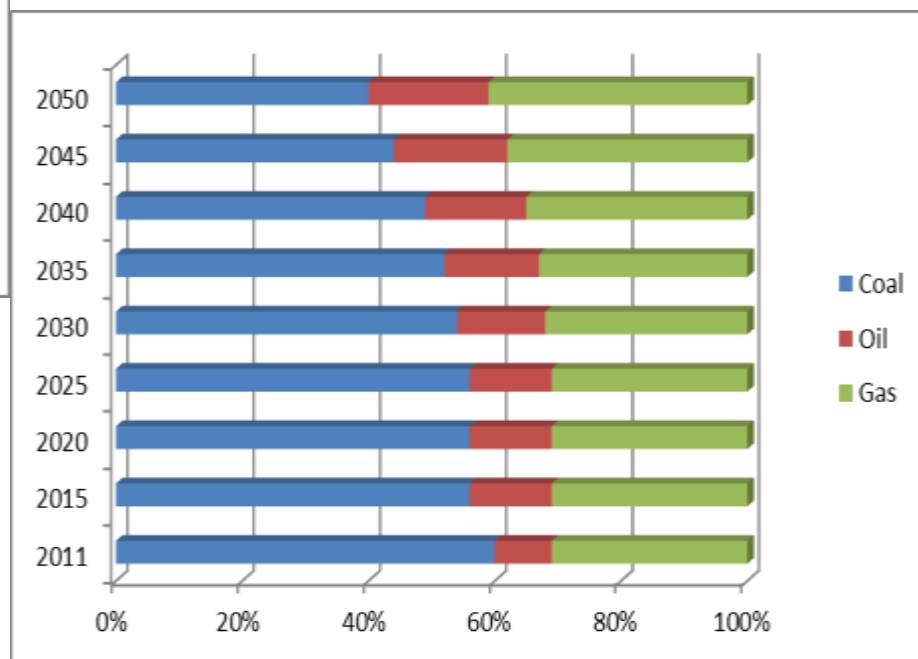
Proportional split of hydrocarbons stations (solid/liquid/gas)

Level-3

Level-4

1. What do you think about our level 4 on FF supply mix inclined more towards NG based generation by 2050 ?

2. What do you think shale gas can influence the mix in future ?

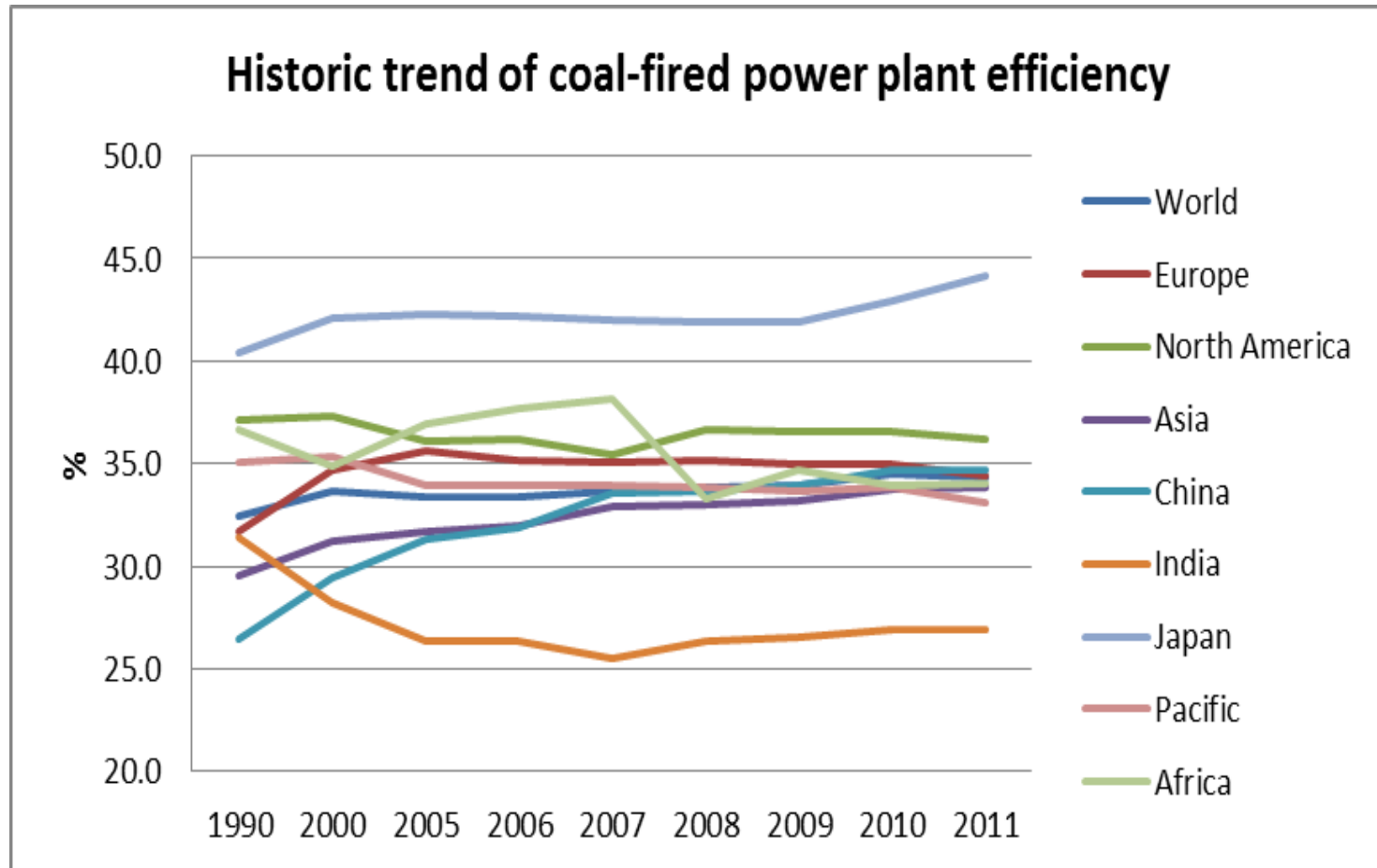2. What is your opinion on making supply mix coal free by 2050?

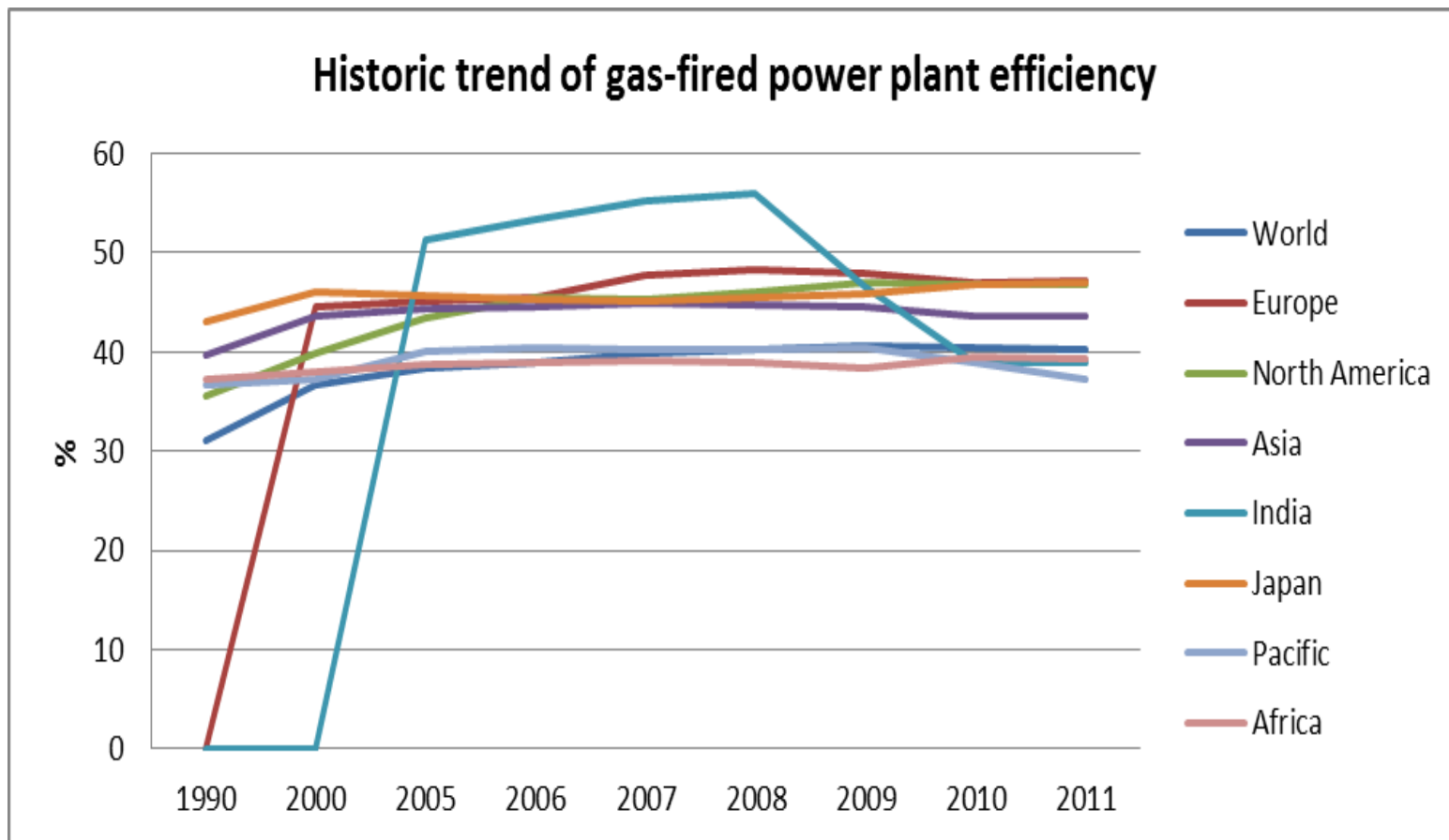# Future pathway of efficiency improvement in coal, oil and NG based generation
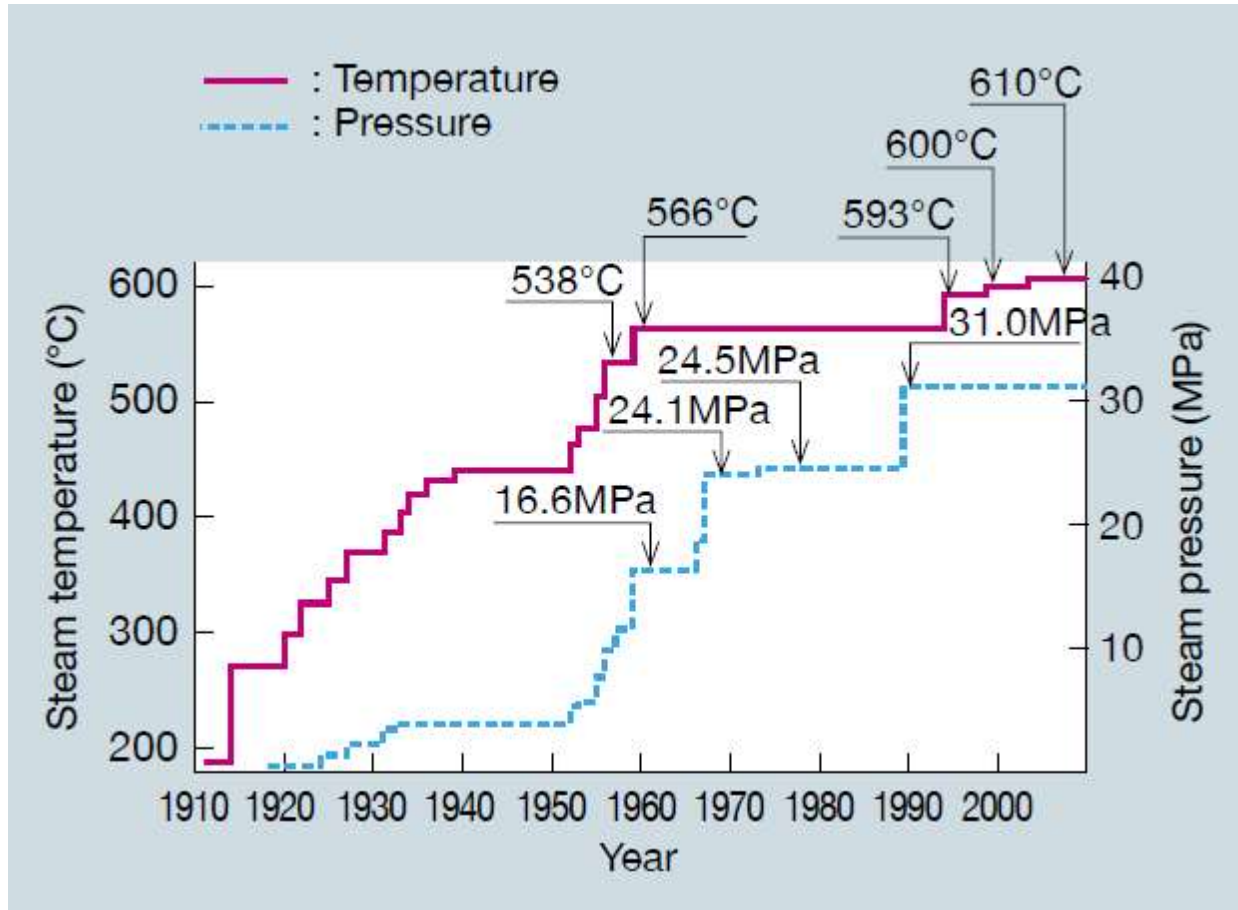
Historic trend of coal-fired power plant efficiency

World Energy Council , 2013

Historic trend of gas-fired power plant efficiency

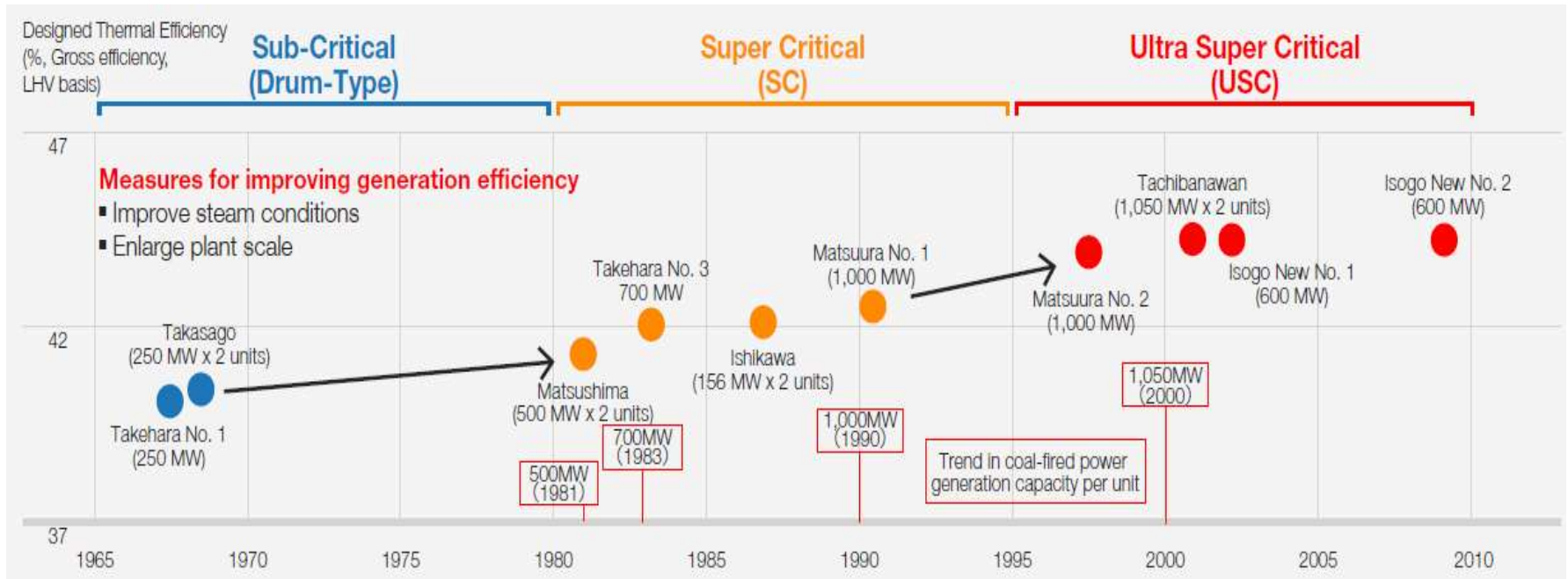Historic trend of gas-fired power plant efficiency

World Energy Council , 2013

Historic trend of steam conditions in thermal power plants

Historic trend of efficiency improvement in thermal power generation in Japan

Assumptions of pathways of coal based power plant split

1. For Level-1 we assume situation did not improve in terms of improving thermal efficiency and moving more towards super critical or ultra supercritical.. Case of India where efficiency declined.

2. Level-4 is considering the growth rate of Japan thermal efficiency improvement

Technology Spilt for Coal Based Generation (Level-4)

Technology	2011	2050	Growth Rate
Ultra Super critical	8%	23%	2.74% CAGR
Super Critical	17%	32%	1.63% CAGR
Sub-Critical	75%	45%	-1.30% CAGR

Technology Spilt for Oil Based Generation (Level-4)

Technology	2011	2050	Growth Rate
Liquid Fuel Efficient Plant	30%	71%	2.23% CAGR
Liquid Fuel Inefficient Plant	70%	29%	-2.23% CAGR

Technology Spilt for Gas Based Generation (Level-4)

Technology	2011	2050	Growth Rate
Open Cycle Gas Turbine	35%	7%	-4.04% CAGR
Combined Cycle Gas Turbine	65%	93%	0.92% CAGR

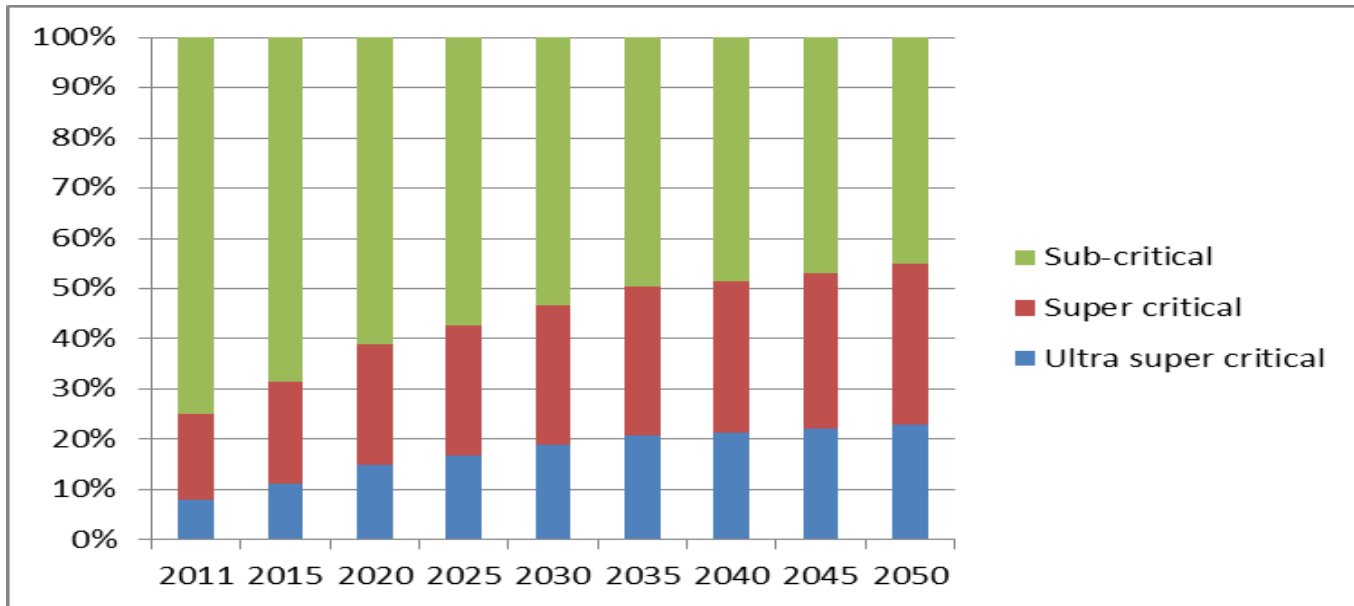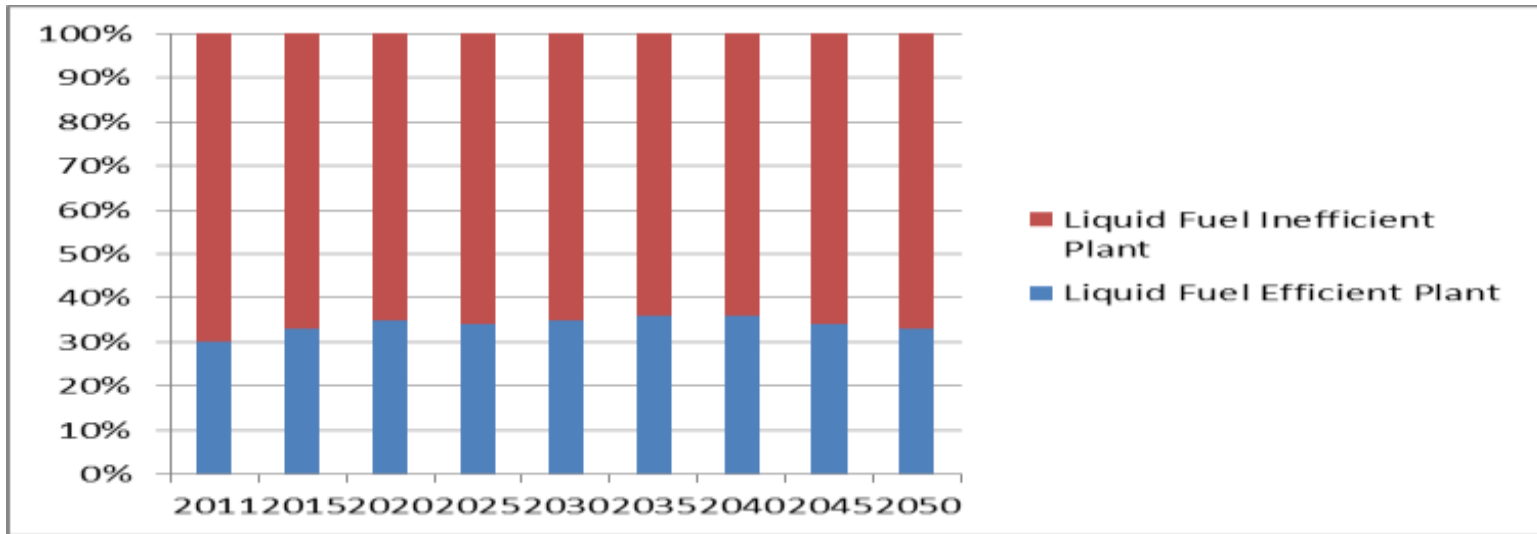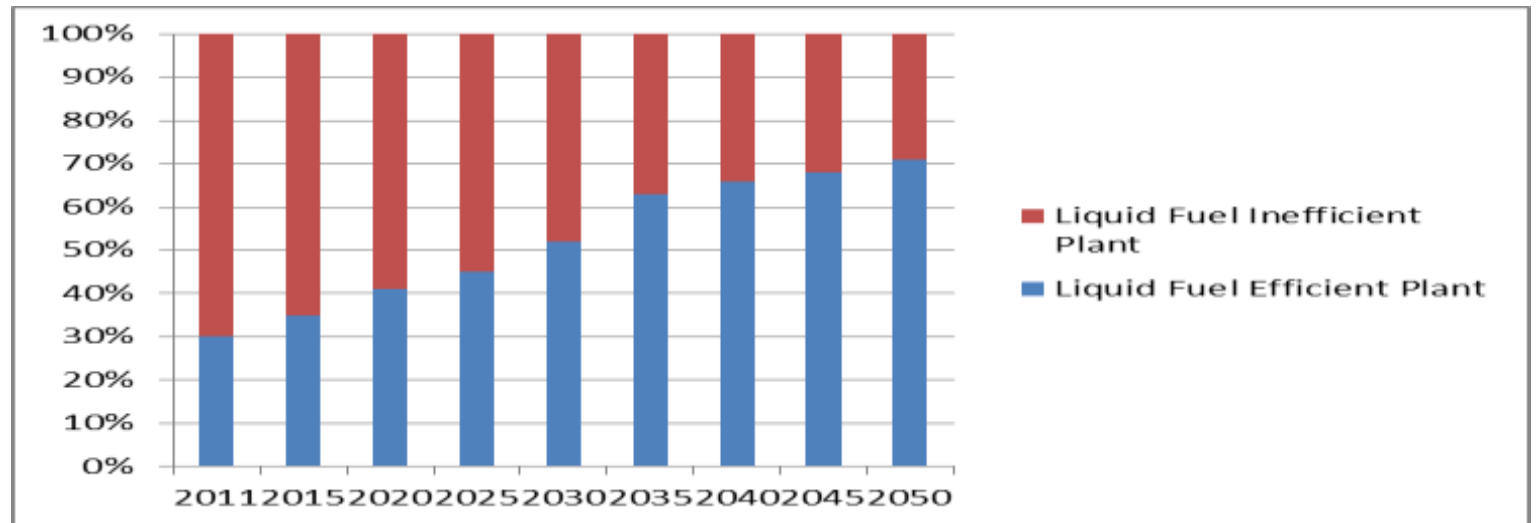# Split of Coal Based Power Generations
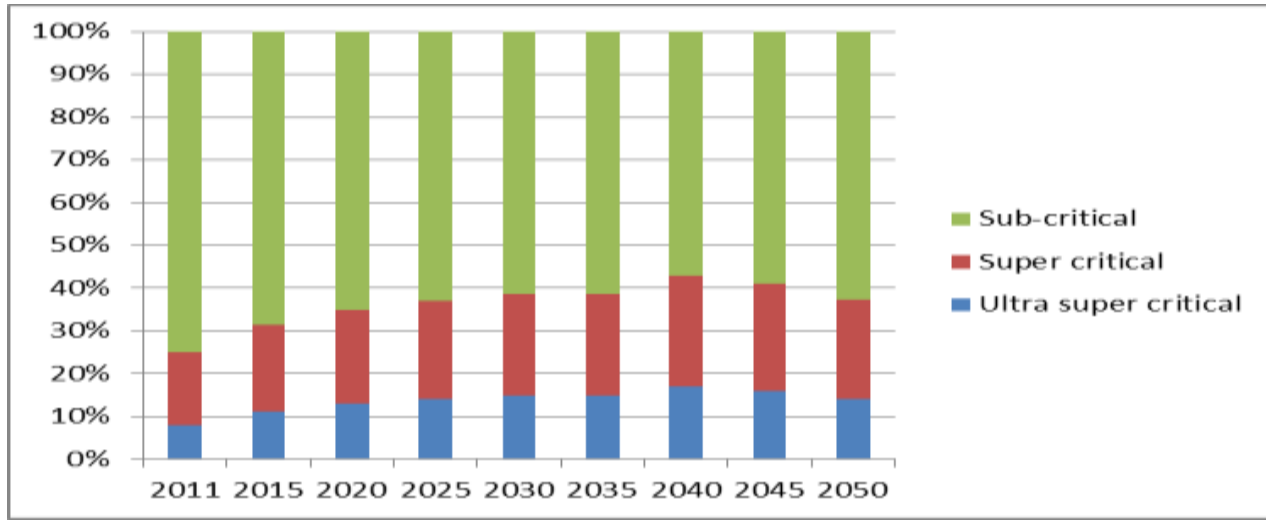
Split of Liquid Fuel Based Power Generation

Split of Gas Based Power Generation
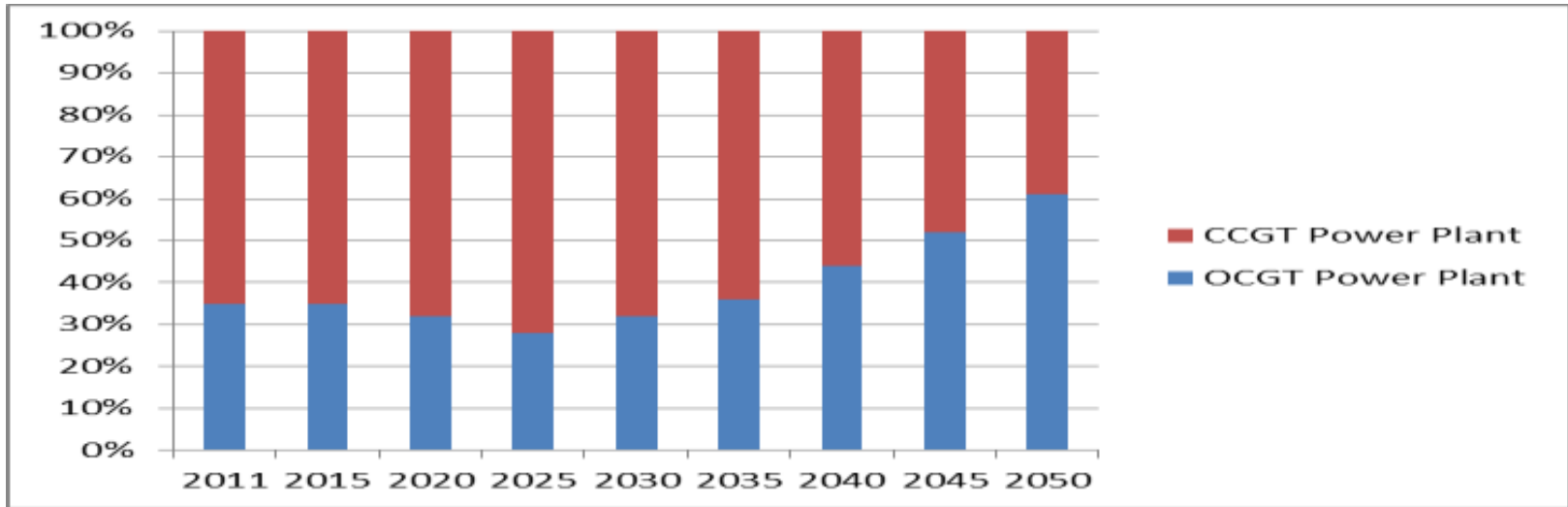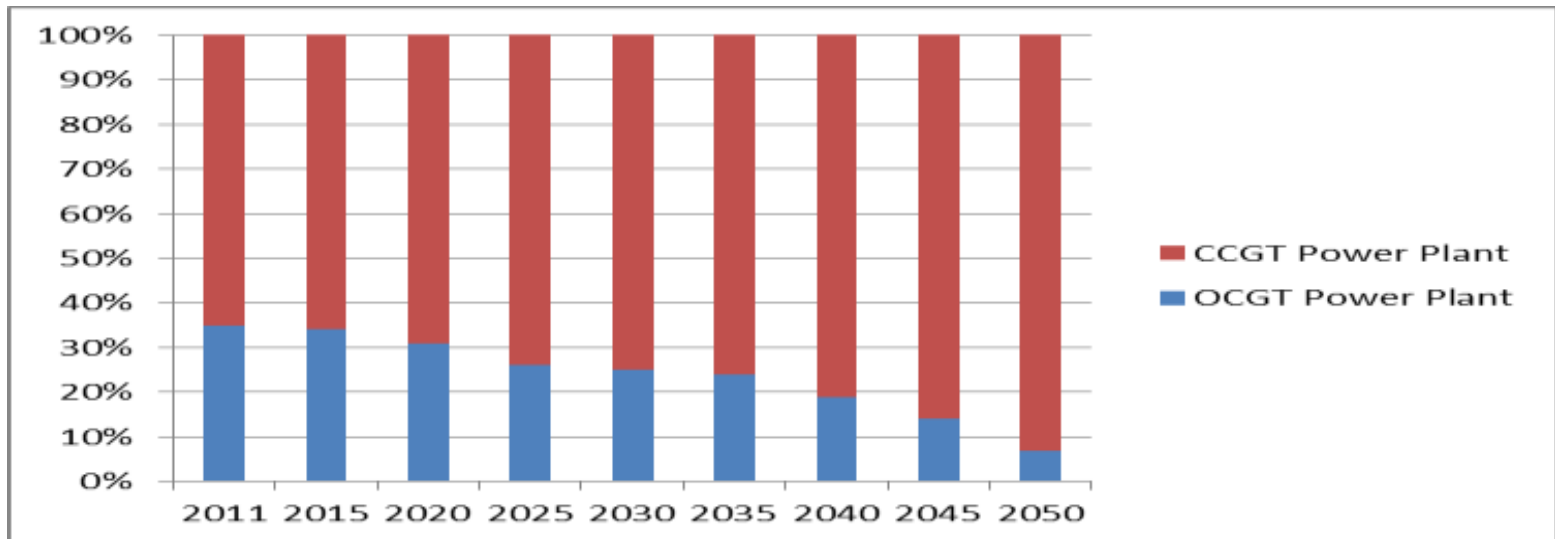
1. What do you think about our level 4 on thermal efficiency improvement target adopted following Japanese example by 2050 ?

2. Can world follow the Japanese case in terms of converting to super critical stations ?

2. What is your opinion about CCGT adoption at a global scale following Japanese example ?

Carbon Capture & Storage

Growth assumptions for estimating potential of CCS

►Worldwide, 120 GW of electrical storage and nearly 0 GW (pilots or very small scale) of carbon capture storage (CCS) was online in 2011.

►**Built rate of levels for CCS**

Level-4: In 2050 there is 3700 GW equivalent of installed CCS capacity. The average built up rate is more than 100% (42.2 GW/year) till 2020, 12.79% (88.7GW/year) till 2030, whereas 6.96% (121.6GW/year) till 2040 and 4.07% (121.7GW/year) up till 2050.

Level-1: It initially builds at a high rate from 0 GW in 2011 to 16 GW till 2020 and then remains stagnant till 2050.

Levels for Carbon Capture & Storage (GW)

►Initial deployment of CCS is considered mostly in OECD countries and developing nations would largely contribute around 2025.
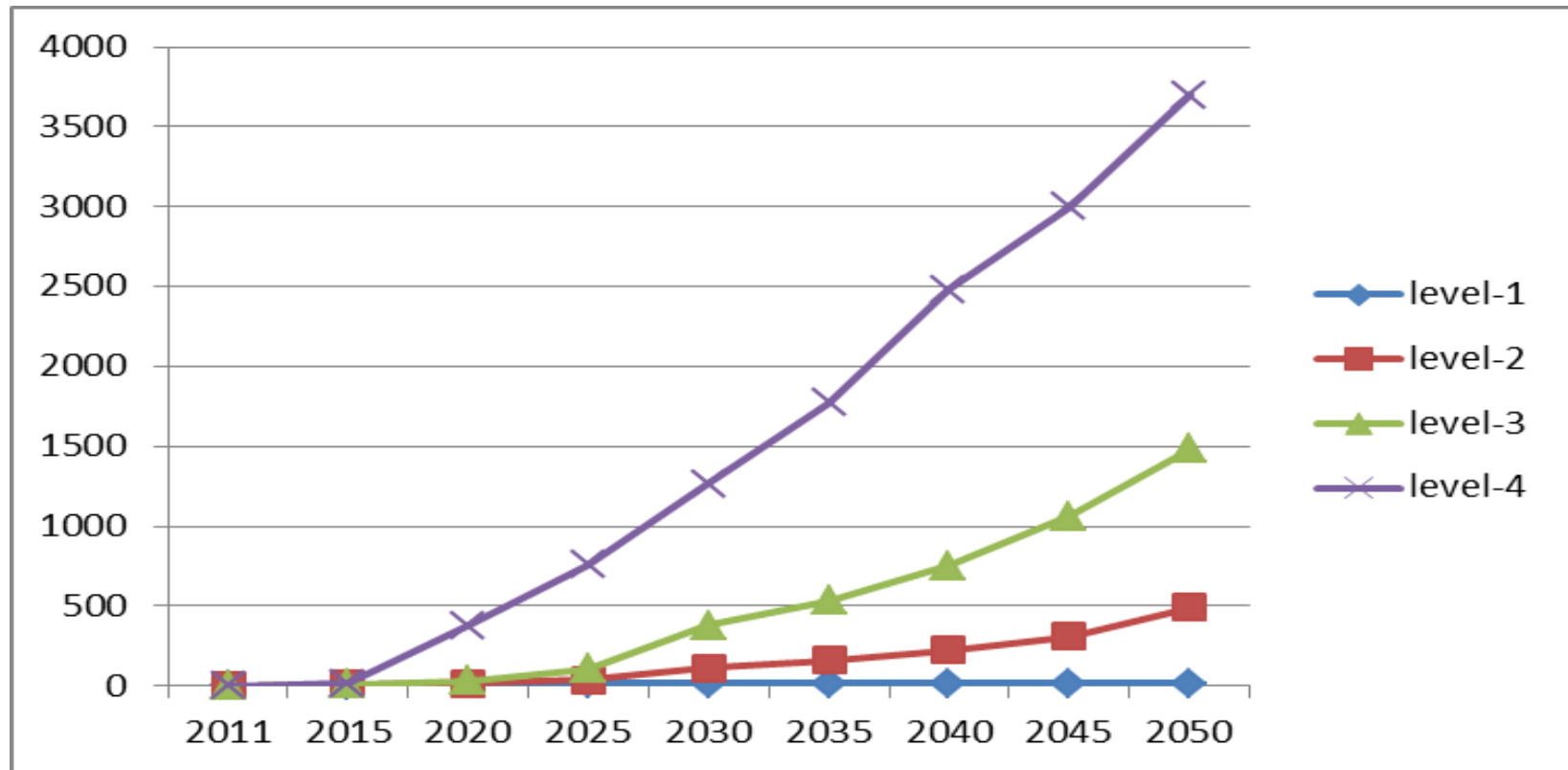
Questions to experts on CCS

1. Do you think our Level -4 built rates are achievable / reasonable / undermined ?

2. What is your opinion on world can achieve by 2050 closest possible range?

Thank You