Markal Application for China

Wenying Chen
Global Climate Change Institute, Tsinghua University
P. R. China

Markal Application for China

- China Markal model overview
  - Energy
  - Demand sectors and sub-sectors
  - Technologies
    - Conversion (electricity, heat)
    - Process
    - Demand
- Modeling results
  - Baseline
  - SO2 emission constraint
  - CO2 emission constraint

Energy

- Solid fossil fuel (raw coal, washed coal, coke)
- Liquid fossil fuel(crude oil, refined oil products)
- Gas fossil fuel(NG, coal gas)
- Hydro
- Nuclear
- Wind
- Solar
- Geothermal

NG and Oil Supply Limit in 2050

- NG
  - mining: 226Mtce(200Bm^3)
  - import: 385Mtce(375Bm^3)
  - total supply: 611Mtce
- Oil
  - mining: 143Mtce(100Mtoe)
  - import: 445Mtce(311Mtoe)
  - total supply: 588Mtce

Demand sectors and sub-sectors

- Industry sector
  --- IS: Steel
  --- IM: Ammonia
  --- IL: Aluminum
  --- IC: Cement
  --- IP: Paper
  --- IO: Other industry
  --- NY: Non-energy use
- Agriculture sector
  --- AX: Irrigation
  --- AY: Farming
  --- AW: Ago-process
- Residential sector(Urban)
  --- cooking and water heating
  --- space heating
  --- Cooling
  --- Lighting and other electric appliances
- Residential sector(Rural)
  --- cooking and water heating
  --- Space heating
  --- Lighting and electric appliances

Demand sectors and sub-sectors (continued)

- Transportation

  --- T0: Air

  --- T1: Ship

  --- T2: Pipeline

  --- T3: Rail

  --- T4: Automobile

  --- T5: Bus

  --- T6: Truck

- Commercial

  --- C1: Space heating and water heating

  --- C2: Cooling

  --- C3: lighting and electric appliances

Technologies: Conversion(Electricity)

- E01: Coal-fired, 100MW and less
- E02: Coal-fired, 100-200MW
- E03: Coal-fired, 200-300MW with ESP
- E04: Coal-fired, 300MW and above with ESP
- E05: Coal-fired, 300MW and above with ESP and dry FGD
- E06: Coal-fired, 300MW and above with ESP and wet FGD
- E07: Coal-fired, 300MW and above with ESP and combined SOx/NOx removal scrubber
- E08: AFBC
- E09: PFBC
- E0A: IGCC
- E0B: Co-generation
- E0C: Super critical
- E0D: Ultra super critical
- E11: oil-fired traditional plant
- E12: oil-fired combined cycle plant
- E21: conventional gas turbine combined cycle plant
- E22: advanced gas turbine combined cycle plant
- E31: nuclear power generation
- E41: hydropower station
- E51: photovoltaic power station
- E61: geothermal power
- E71: wind power generation

Technologies: Process

- PCW: coal washing
- PCK: coke making
- PCL: coal liquefaction
- PCG: coal gasification
- PCH: hydrogen making
- POR: oil refinery

Technologies : Demand(Industry)

- IS1: Steel (existing)
- IS2: Steel (advanced)

- IM1: Ammonia (using coal as raw material)
- IM2: Ammonia (using oil as raw material)
- IM3: Ammonia (using gas as raw material)

- IL1: Aluminum (existing)
- IL2: Aluminum (advanced)

- IC1: Cement (wet)
- IC2: Cement (dry)
- IC3: Cement (small)

- IP1 :Paper (existing)
- 1P2: Paper (advanced)

Technologies :Demand(Commercial)

- Space heating and water heating
  - District heating
  - Coal-fired centralized boiler
  - Coal-fired scatter boiler
  - Oil-fired boiler
  - Gas-fired boiler
  - Heat pump
  - Gas burner
  - Oil burner
  - Coal-fired centralized boiler + absorption chiller
  - Gas-fired boiler+absorption chiller
  - Oil-fired boiler+absorption chiller
- Cooling
  - Electric chiller
  - heat pump
  - Gas burner
  - Oil burner
  - Coal-fired centralized boiler + absorption chiller
  - Gas-fired boiler+absorption chiller
  - Oil-fired boiler+absorption chiller

Technologies :Demand(Residential)

Urban

- Space heating
  - District heating
  - Coal-fired centralized boiler
  - Coal-fired scatter boiler
  - Oil-fired boiler
  - Gas-fired boiler
  - Heat pump
  - Coal stove
- Cooling
  - Room conditioner
  - Heat pump
- Cooking and water heating
  - Electric stove
  - Coal stove
  - NG stove
  - LPG stove

Rural

- Space heating
  - Coal stove
  - Solar house
  - Biomass stove
- Cooking and water heating
  - Coal stove
  - Biomass stove
  - Biogas stove
  - Solar stove
  - LPG stove
  - NG stove
  - Electric stove

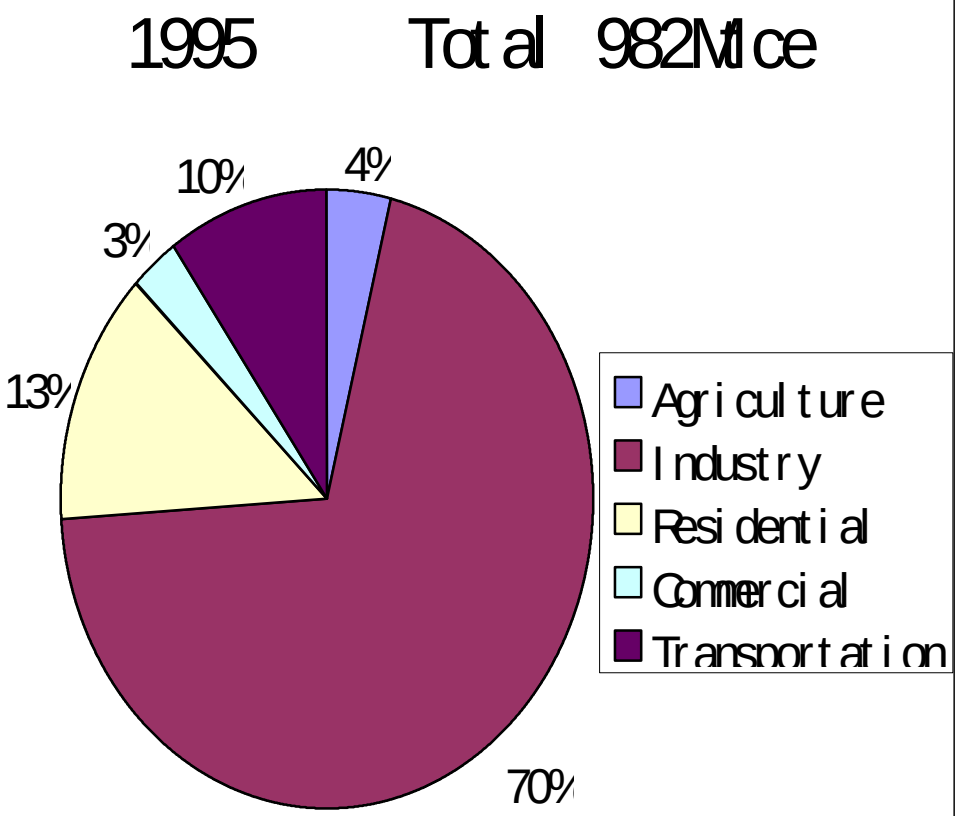
Technologies : Demand(Transportation)

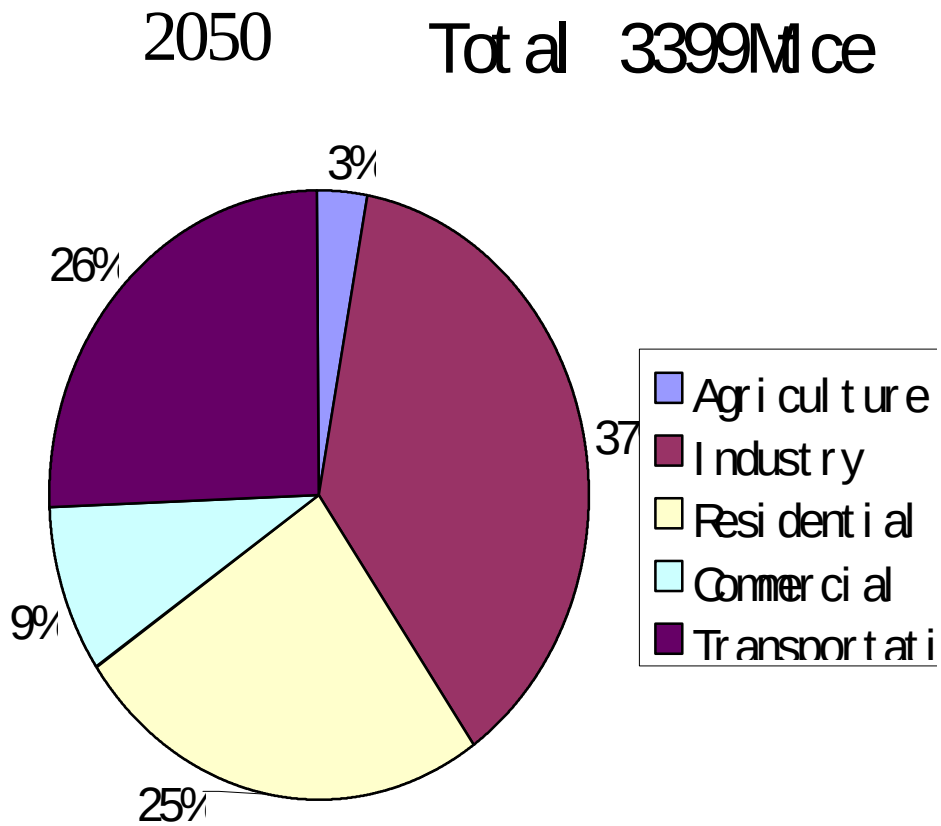
- Railway
  - Steam locomotive
  - Diesel locomotive
  - Electric locomotive
- Truck
  - Gasoline
  - Diesel
  - CNG
  - LPG
  - Fuel cell
  - Methanol + gasoline
  - Methanol + diesel
- Automobile
  - Gasoline
  - CNG
  - Electric
  - Fuel cell
  - Methanol + gasoline
- Ship
  - Diesel
  - Fuel oil
- Pipeline
  - Fuel oil, electricity
- Air
  - Jet fuel

Basic Assumption for Social and Economic growth

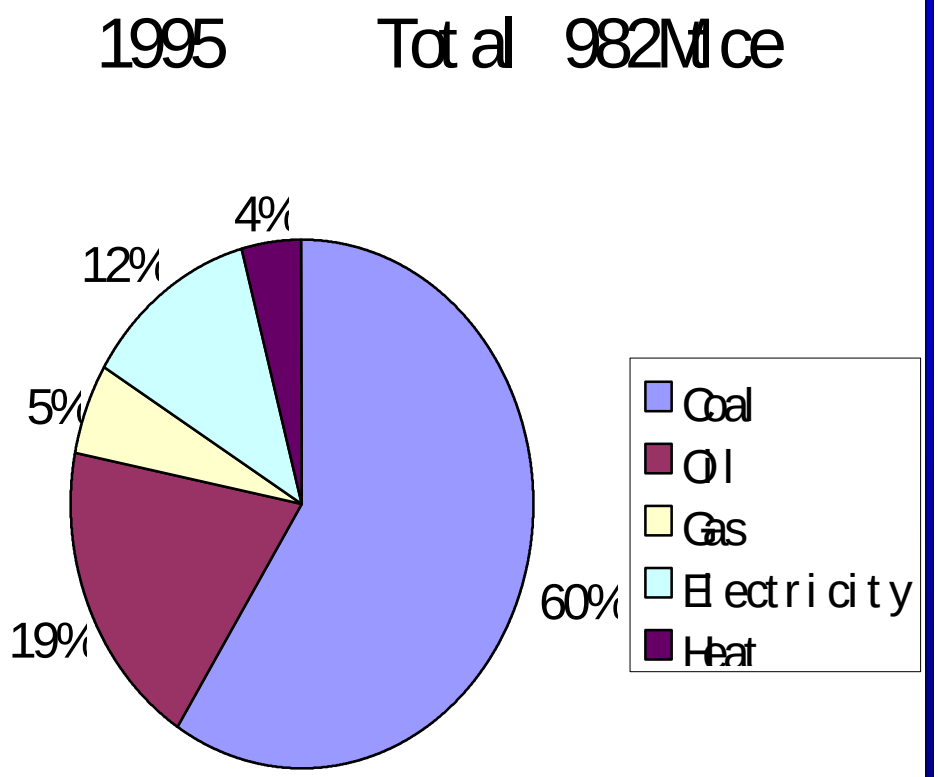
	1995	2010	2030	2050
GDP growth rate(%)		7.5	6.0	4.5
Population(Billion)	1.21	13.86	15.6	15.75
Industrial Structure				
Primary(%)	20.5	15.0	10.0	6.0
Secondary(%)	48.8	45.0	42.0	39.0
Tertiary(%)	30.7	40.0	48.0	55.0

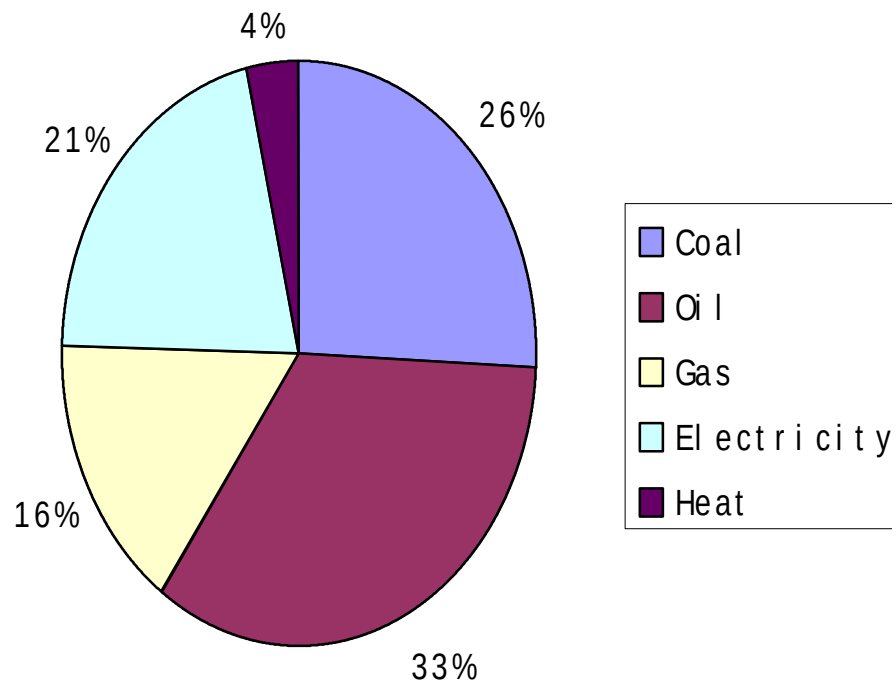
Final Energy Consumption by Sector (Baseline)





Final Energy Consumption by Fuel (Baseline)

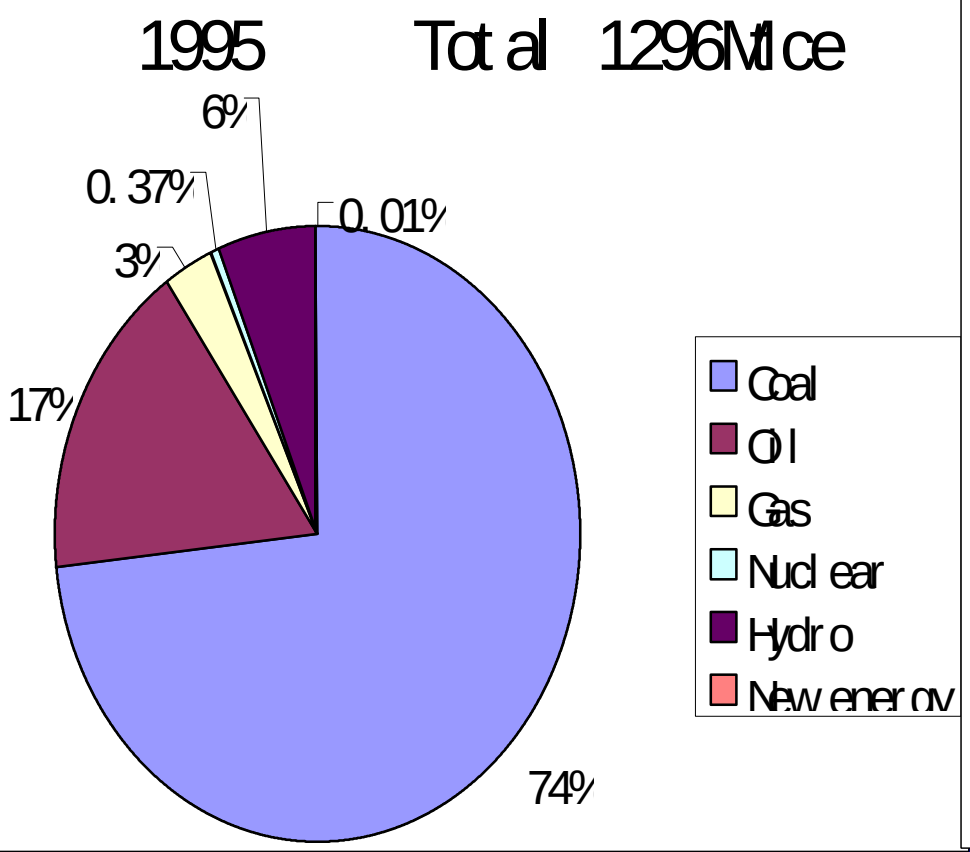


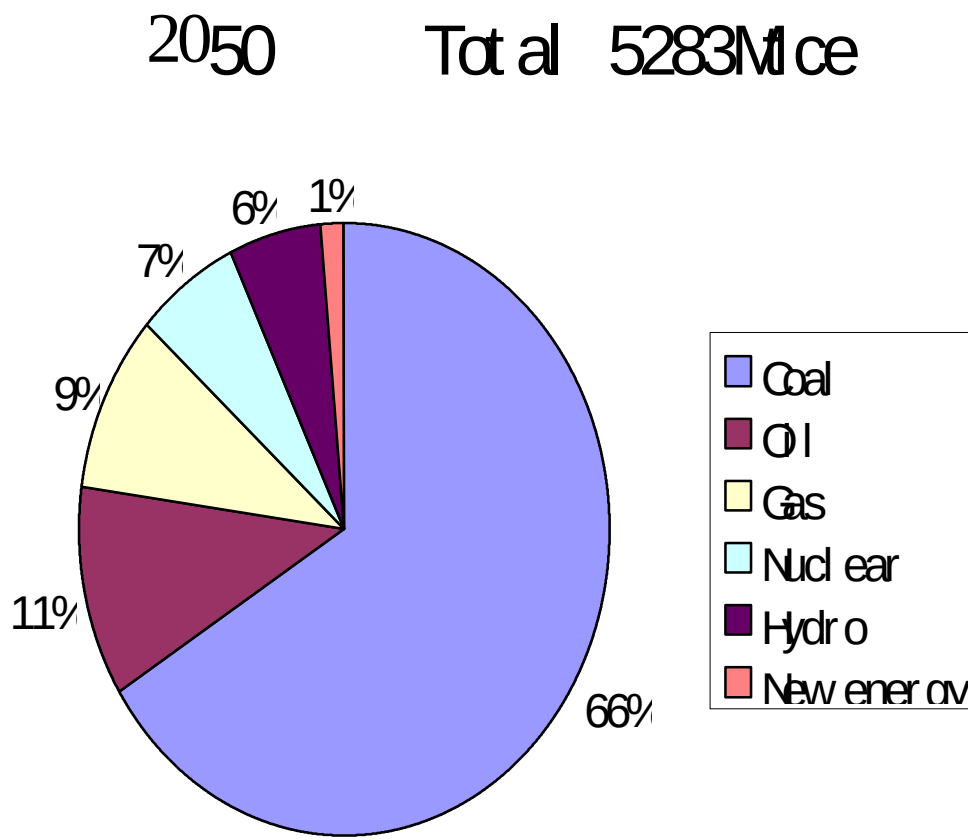


Oil demand in 2050 : 1150Mtce

Gas demand in 2050: 500Mtce

Primary Energy Consumption Mix (Baseline)



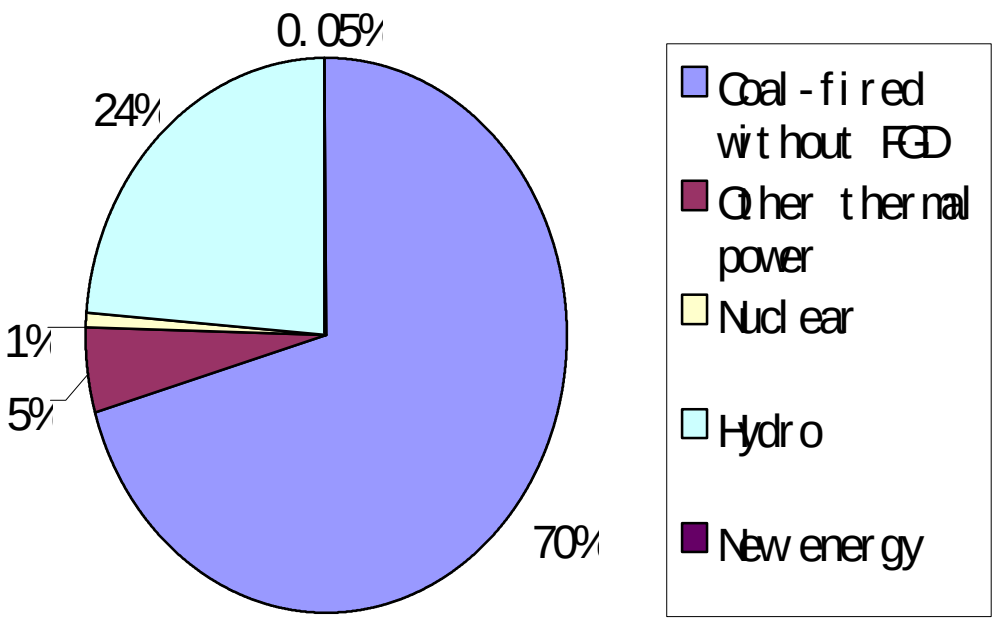


Coal liquefaction capacity in 2050 : 500Mtce

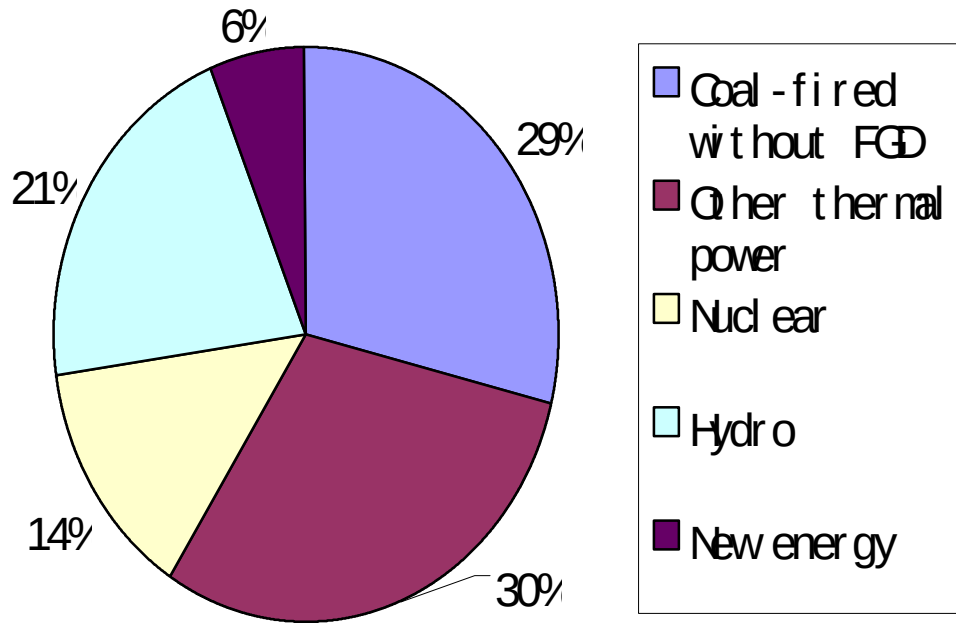
Hydrogen making capacity in 2050 : 130Mtce

Power Capacity Mix (Baseline)

1995 Total 219GW

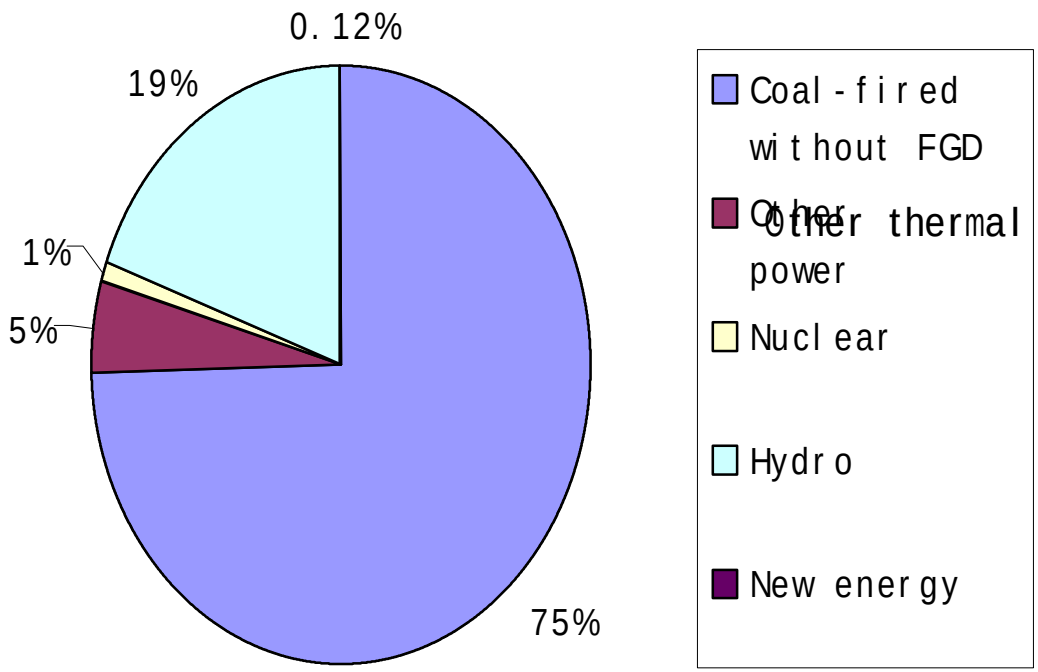


2050 Total 1169GW

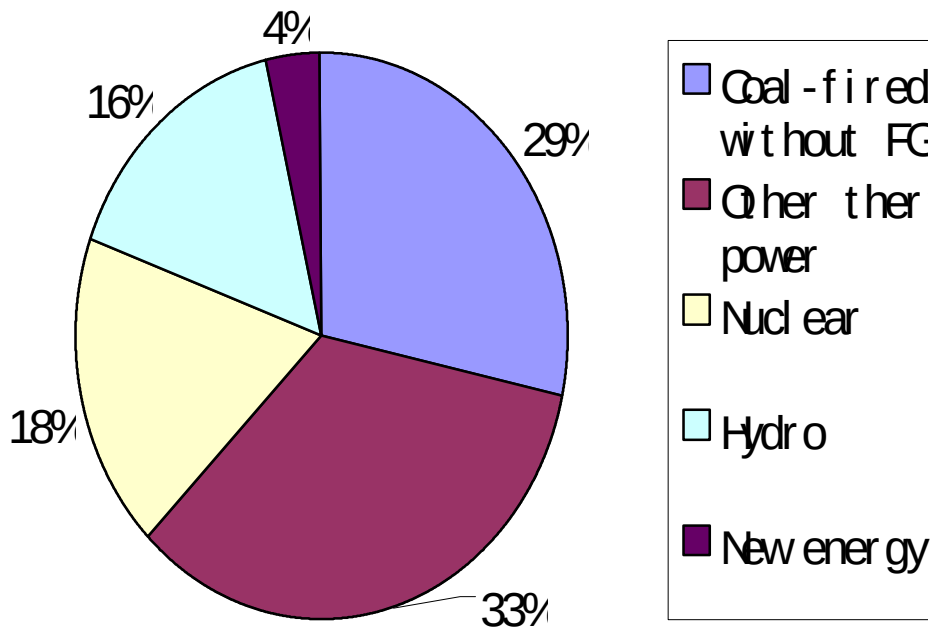


Power Generation Mix (Baseline)

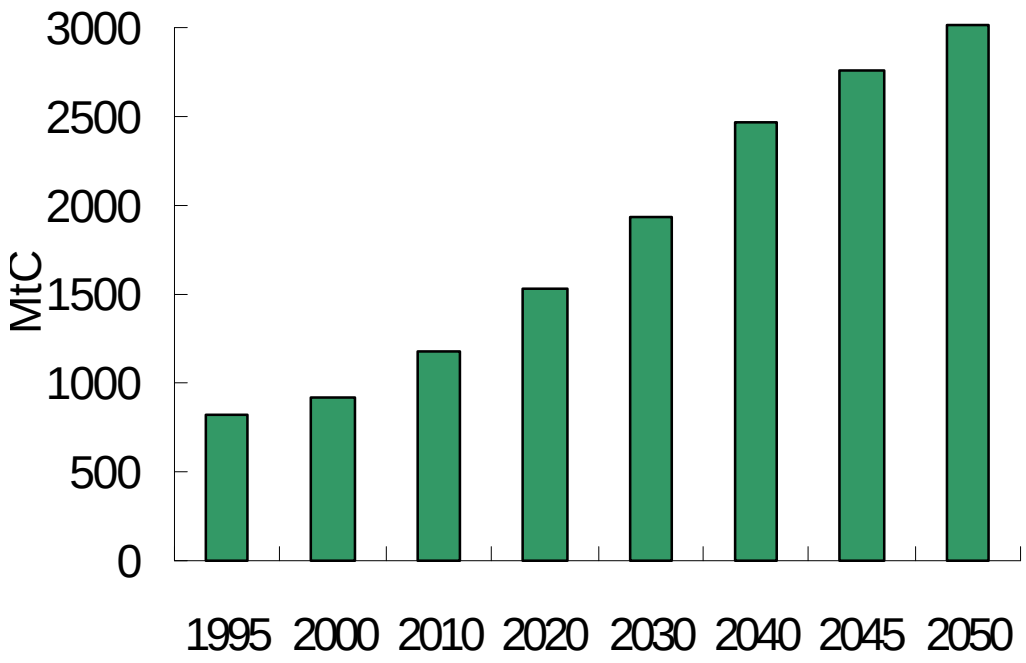
1995 Total 1039TWh

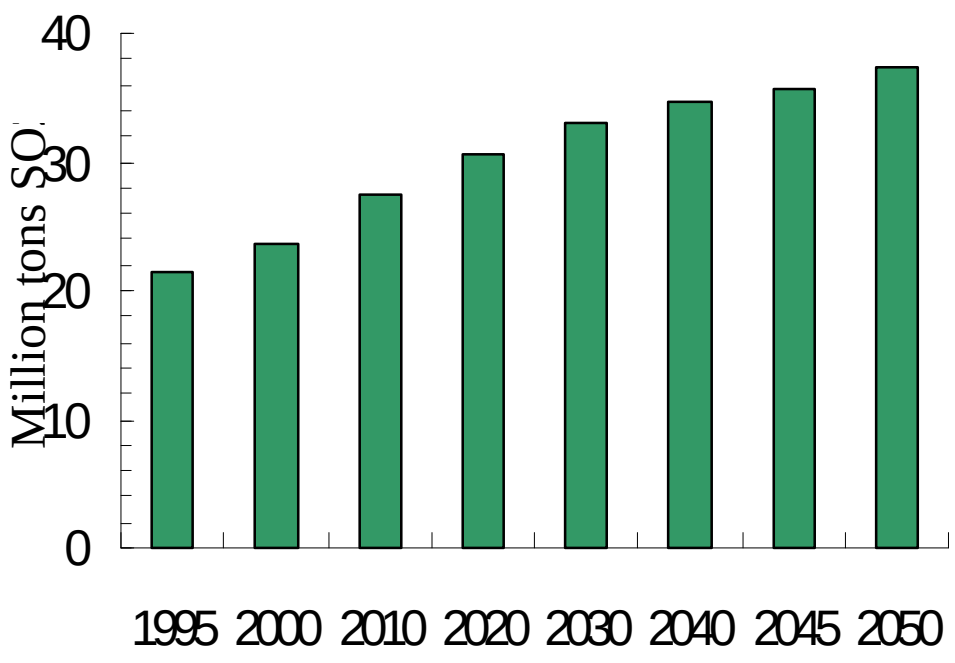


2050 Total 6132TWh



SO2 and CO2 Emission (Baseline)

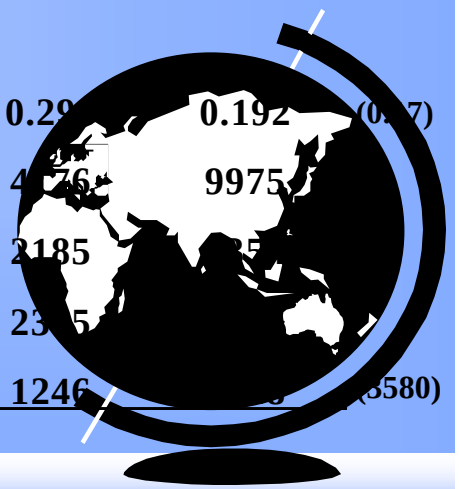




- **CO2 emission is 816MtC in1995,and it will be 3021MtC in 2050.**
- **SO2 emission is 21.38Mton in 1995, and it will be 37.47Mton in 2050.**

Macro Indices of CO_2 Emission

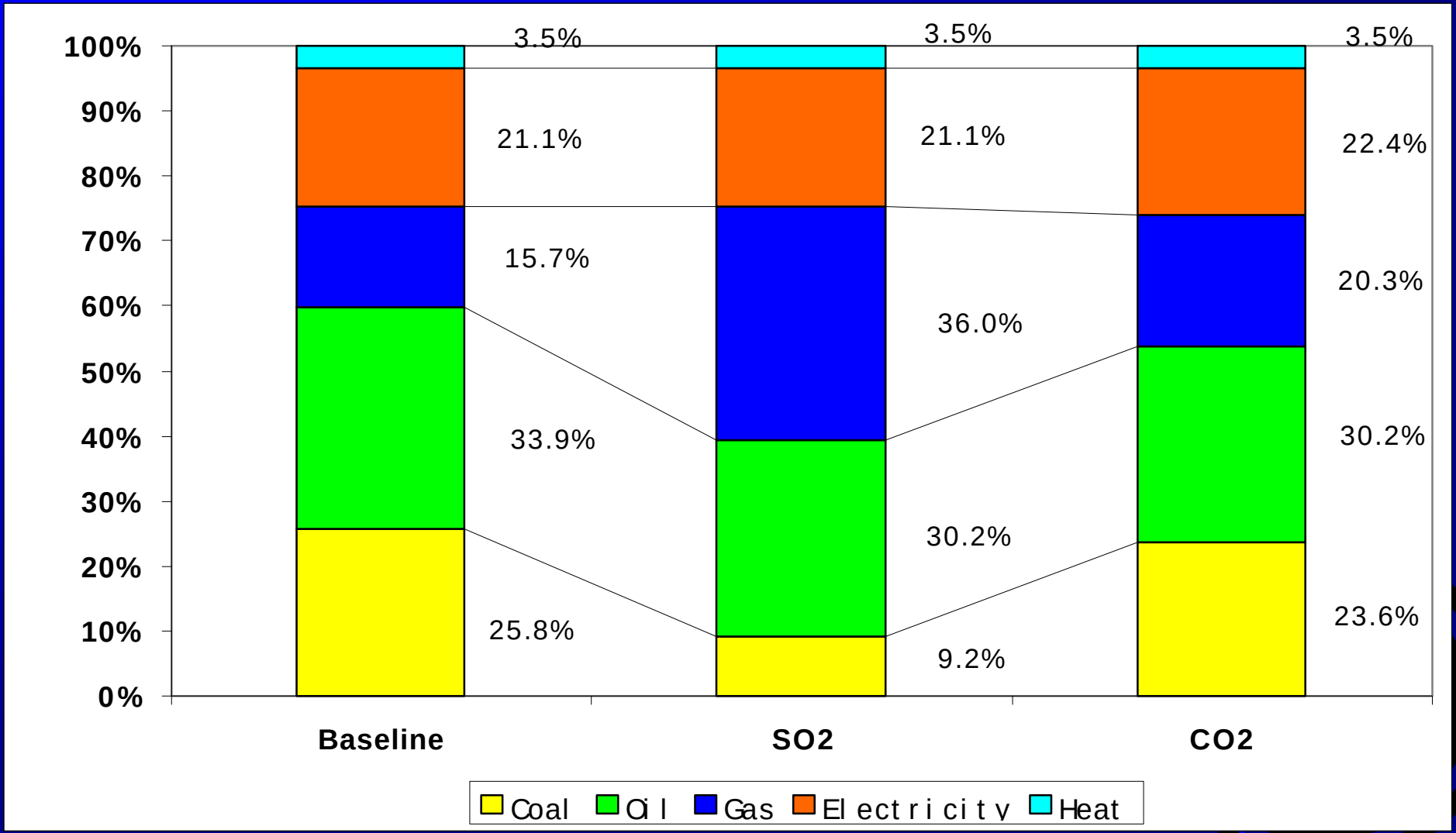
	1990	1995	2010	2030	2050	
Population (Billion)	1.143	1.211	1.386	1.56	1.575	
GDP(Billion US$ 1990 price)	355	627	2031	6515	15711	
Primary energy consumption (Mtce)	987	1286	2041	3409	5283	
Electricity consumption (TWh)	623	1007	1898	3596	6132	
CO_2 emission (Mt-C)	621	816	1179	1943	3021	
Energy intensity per GDP (kgce/US$)	2.778	2.051	1.005	0.523	0.336	(0.36)
Electricity intensity per GDP (kWh/US$)	1.753	1.606	0.935	0.552	0.390	
CO_2 emission intensity per energy consumption (kg-C /kgce)	0.629	0.635	0.578	0.570	0.572	(0.46)
CO_2 emission intensity per GDP (kg-C /US$)	1.748	1.302	0.580	0.29[illegible]	0.192	(0.[illegible]7)
Per capita GDP (US$)	311	518	1466	4[illegible]76[illegible]	9975[illegible]	
Per capita energy consumption(kgce)	864	1062	1473	2185	[illegible]	
Per capita electricity consumption(kWh)	545	832	1370	23[illegible]5	[illegible]	
Per capita CO_2 emission (kg-C)	543	674	851	1246	[illegible]	(3580)



Basic Assumption for SO2 and CO2 Emission Constraint Scenarios

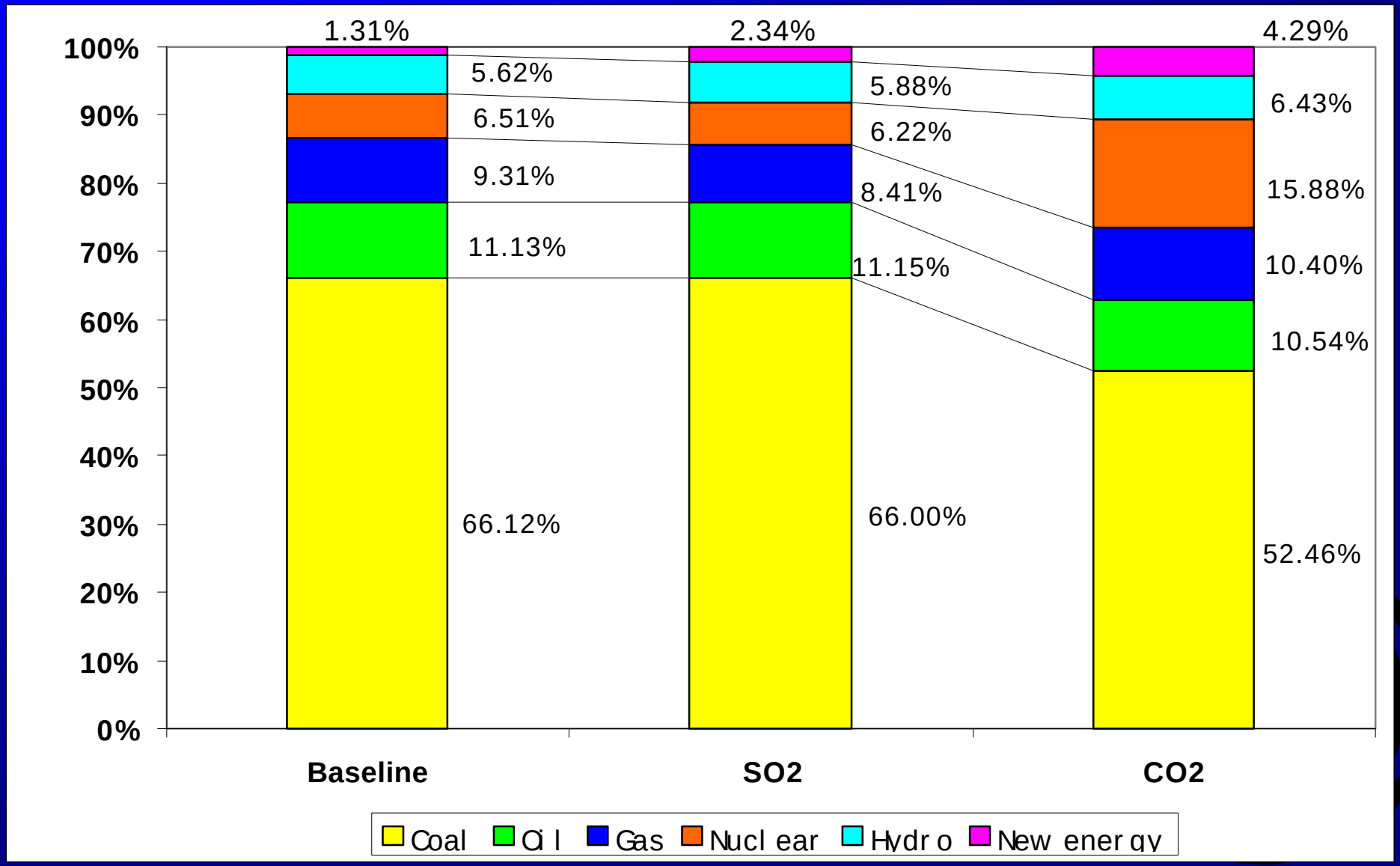
- **SO2 emission constraint**
  - **National SO2 control target: 22.5, 20.6,18.45,16.48Mton for 2005, 2010, 2015, 2020 respectively.**
  - **14.45Mton for 2025 and 12.22Mton for 2030,then maintain 10Mton after 2035.**
- **CO2 emission constraint**
  - **Reduction rate 20% (2050: 2417Mt-C)**

Final energy consumption by fuel under different scenarios

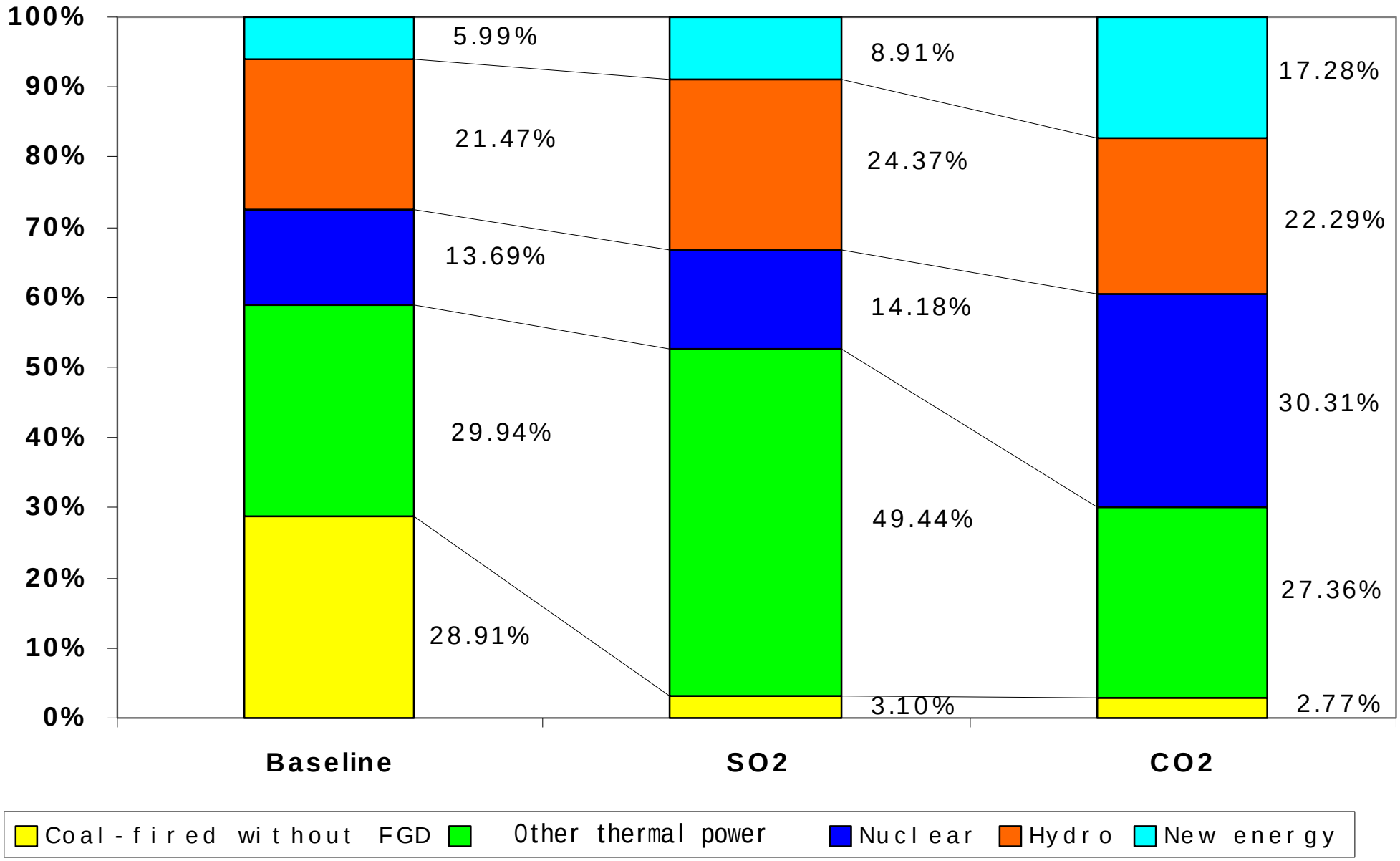


Coal gasification capacity for SO2 scenario: 980Mtce

Primary Energy mix under different scenarios



Power capacity mix under different scenarios



Conclusions

- In 2050 China's primary energy consumption will hit 5.283Btce .
- To fill the huge gap between limit resources and sharp rising demands for oil and gas could rely on coal, the richest resource in China, with the application of coal gasification and liquefaction.
- To reduce SO_2 emission will mainly rely on mass use of urban clean energy (NG and coal gas))and popularization of advanced thermal power generation units with desulfuration, while CO_2 emission control strategies will largely lie on vast exploitation and utilization of new and renewable energy.