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# Assessment of Energy Options for Development of Greenhouse Gas Mitigation Strategies in Pakistan

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# Contents

- Background Information
- Research Work
  - Estimation of Greenhouse Gas (GHG) Inventory of Pakistan for 2007
  - Development of Reference Energy System of Pakistan
  - Assumptions for the Study
  - Scenarios
  - Modeling of Potential Post-Kyoto Approaches
  - Results
  - Recommendations/Conclusions

# Objective of the Research Study

International Atomic Energy Agency initiated a research project on "Greenhouse Gas Mitigation Strategies and Energy Options" in 2007. Pakistan is participating in this project.

# Background Information of Pakistan

# Population and Energy Consumption

- **Population in Year 2007: 158 million (urban share: 34%)**
- **Per capita GDP (2007) : US $ 925**
- **Per capita primary commercial energy consumption (2007): 0.38 TOE**

  **(World average: 1.68 TOE/capita)**
- **Per capita electricity consumption: 460 kWh**

  **(World average: 2752 kWh/capita)**

Sources: i) Pakistan Economic Survey 2007-08, Government of Pakistan.
ii) Pakistan Energy Yearbook 2007, Government of Pakistan.
iii) Key World Energy Statistics 2009, International Energy Agency.

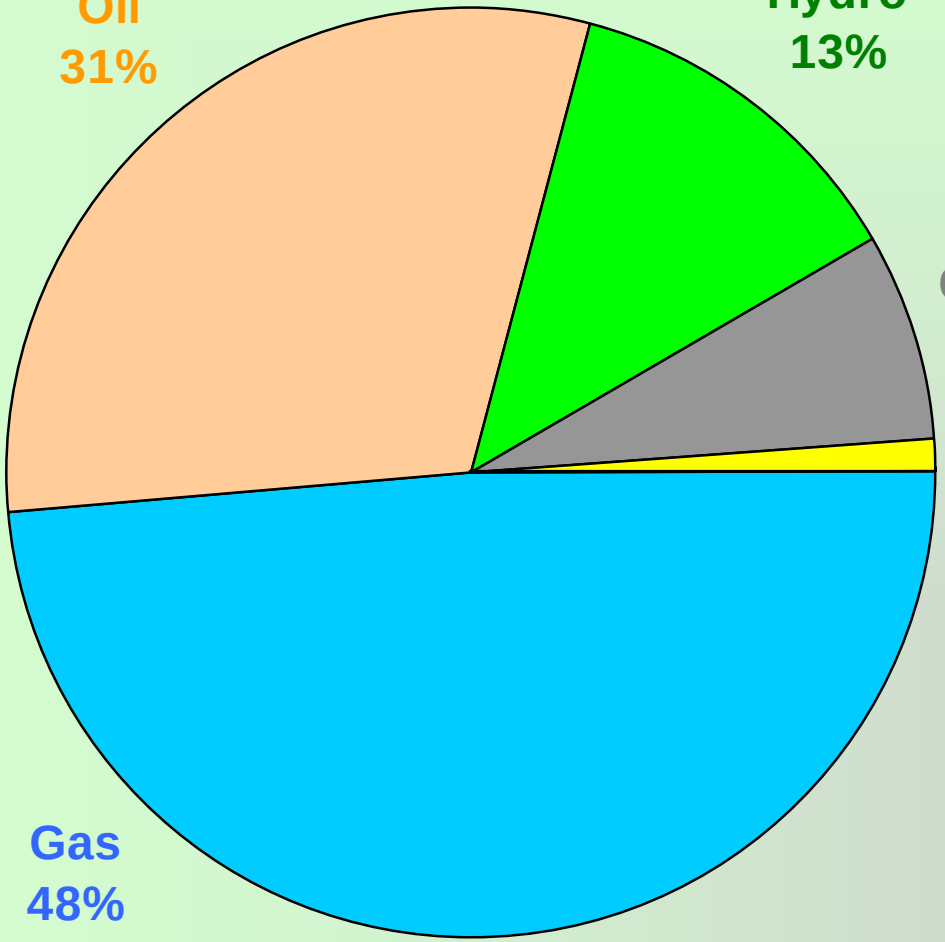
# Sectoral Gross Domestic Product

| Year | 1987 | 1997 | 2002 | 2007 |
|---|---|---|---|---|
| Total GDP (billion Pak. Rupees* in 2007 prices) | 3,157 | 5,056 | 5,956 | 8,257 |
| (average annual growth rate) | | 4.8% | 3.3% | 6.8% |
| Agriculture (share) | 26.6% | 25.7% | 24.1% | 21.8% |
| (average annual growth rate) | | 4.5% | 2.1% | 4.6% |
| Industries (manufacturing construction & mining, etc.) (share) | 17.0% | 16.5% | 15.9% | 19.0% |
| (average annual growth rate) | | 4.5% | 2.6% | 10.6% |
| Services (share) | 49.0% | 49.5% | 52.1% | 52.1% |
| (average annual growth rate) | | 4.9% | 4.4% | 6.7% |
| Energy (share) | 2.5% | 4.0% | 3.0% | 2.1% |
| (average annual growth rate) | | 9.9% | -2.4% | -0.3% |

* 1 US dollar = 60.63 Pak Rupees

Source: Pakistan Economic Survey 2008-09, Government of Pakistan.

# Primary Commercial Energy Supply in 2007 (60.4 Million TOE)

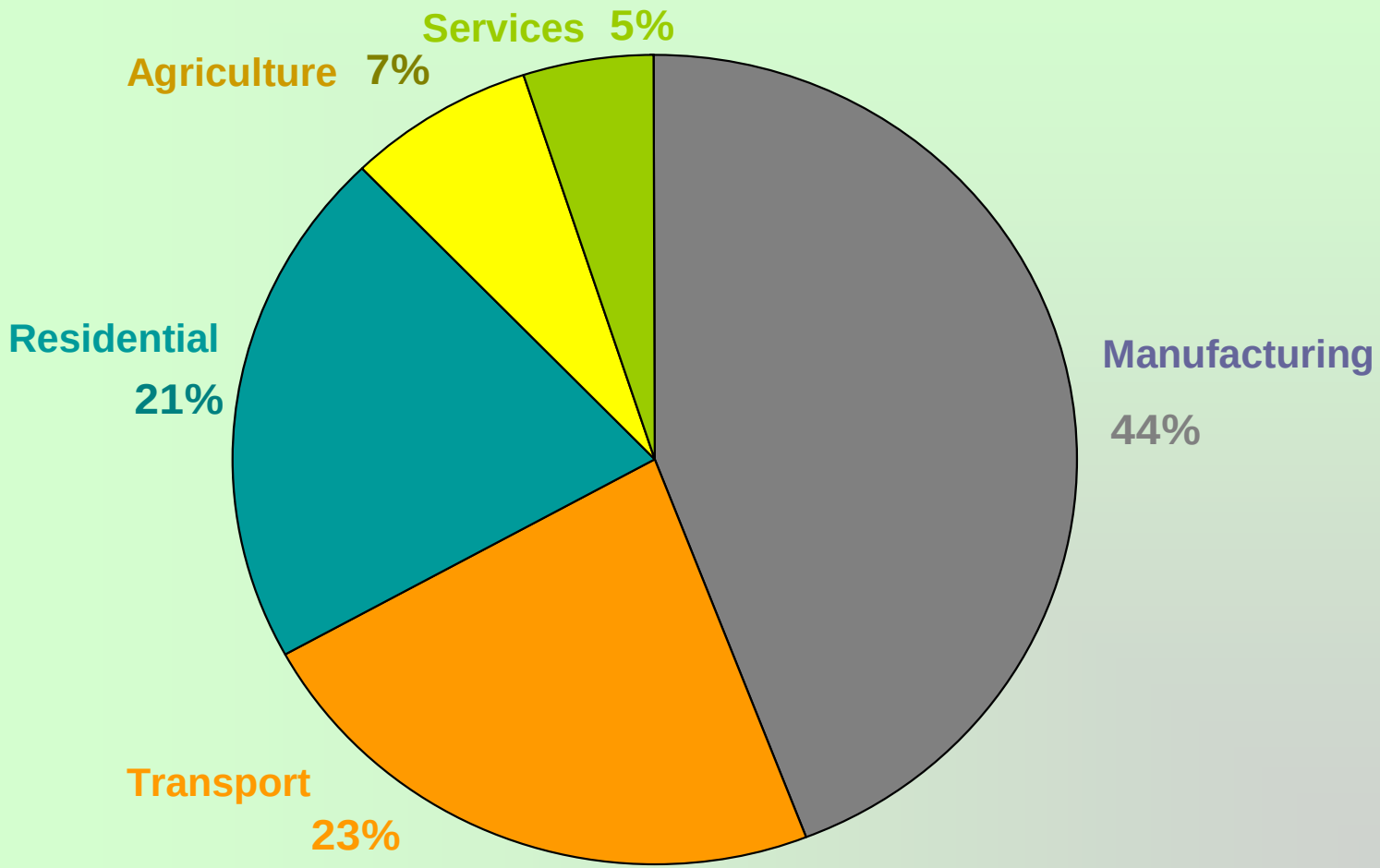



**Per Capita Consumption (TOE)**

| | |
|---|---|
| **Pakistan:** | **0.38** |
| **World average:** | **1.68** |

Source: Pakistan Energy Yearbook 2007, Government of Pakistan.

# Final Commercial Energy* Consumption in 2007 (36.0 Million TOE)




* Non-Energy uses are not included.

Source: Pakistan Energy Yearbook 2007, Government of Pakistan.

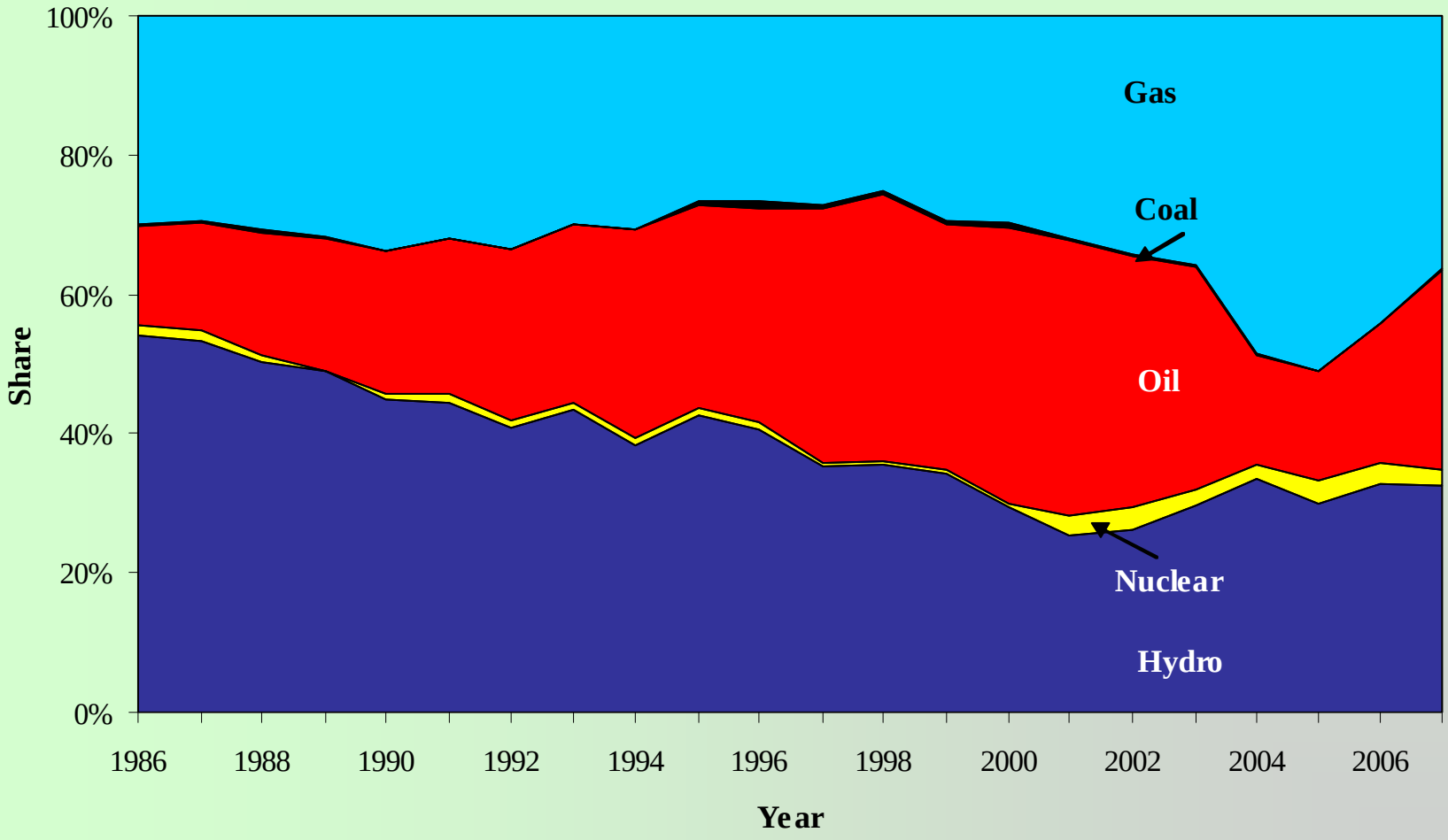
# Fossil Fuel Reserves (million TOE) of Pakistan in 2007

| Fossil Fuels | Pakistan | | World | |
|---|---|---|---|---|
| | Million TOE | R/P ratio | Million TOE | R/P ratio (2006) |
| Oil | 47 | 14 | 168,600 | 42 |
| Gas | 605 | 21 | 162,847 | 63 |
| Coal* | 1,527* | 937 | 426,128 | 147 |
| Total | 2189 | | 757,575 | |
| TOE/capita | 13.8 | | 114.4 | |

* Total resources = 185 billion tonnes

Sources: i) Pakistan Energy Yearbook 2007, Government of Pakistan.
ii) BP Statistical Review of World Energy, June 2008.

# Electricity Generation Mix of Pakistan (98.2 billion kWh during 2007)




Source: Pakistan Energy Yearbook 2007 and earlier issues, Government of Pakistan.

# Electricity Installed Capacity in 2008

| | MW | Shares |
|---|---|---|
| Hydel | 6,480 | 33.4% |
| Gas/Oil | 12,328 | 63.4% |
| Coal | 150 | 0.8% |
| Nuclear | 462 | 2.4% |
| Total | 19,420 | 100.0% |

Source: Pakistan Energy Yearbook 2008, Government of Pakistan.

# Research Work

## Estimation of GHG Inventory of Pakistan for 2007

**GHG Inventory for 2007 was estimated using:**

- **The national statistics of different activities leading to GHG emissions,**
- **2006 IPCC Guidelines for National Greenhouse Gas Inventories, and**
- **UNFCCC's Non-Annex I National Greenhouse Gas Inventory Software, Version 1.3.2, 2005-06**

# Activities Considered for GHG Inventory (1/2)

**Energy and Non-Energy related activities**

**I. Energy Related GHG Emissions**

- **Energy Industries**
- **Manufacturing and Construction sectors**
- **Transport sector**
- **Commercial, Residential and Agriculture sectors**

**II. Non- Energy Related Emissions**

**a) Industrial Process**

- **Cement production**
- **Steel production**

# Activities Considered for GHG Inventory (2/2)

- Soda ash production
- Urea fertilizer production and use
- Asphalt use in construction industry

## b) Agriculture Sector

- Animals related:
  - (i) Enteric fermentation and
  - (ii) Manure management
- Rice cultivation
- Crop residues burning

# Greenhouse Gas Inventory in 2007 (thousand tonnes)

| Sector | $CO_2$ | $CH_4$ | $N_2O$ | CO | NMVOC | Total $CO_2$ eq |
|---|---|---|---|---|---|---|
| Energy Sector | 132,208 | 154 | 3 | 183 | 105 | 137,653 |
| i). Energy Related (fuel combustion) | 132,208 | 12 | 3 | 183 | 105 | 134,100 |
| Power Sector | 43,813 | 1 | 0.2 | 12 | 5 | 43,948 |
| Manufacturing | 42,963 | 2 | 0.4 | 11 | 22 | 43,224 |
| Transport | 30,151 | 7 | 2.3 | 156 | 76 | 31,572 |
| Other sectors | 15,282 | 2 | 0.1 | 4 | 3 | 15,357 |
| ii). Fugitive Emissions | | 142 | 0 | 0 | 0 | 3,553 |
| Non-Energy Related | 17,309 | 3,592 | 35 | 163 | 147 | 118,457 |
| i). Industrial Processes | 17,309 | | 35 | 0 | 147 | 28,322 |
| ii). Agriculture | | 3,592 | 0 | 163 | 0 | 90,135 |
| Total | 149,518 | 3,746 | 38 | 346 | 252 | 256,110 |

- Global warming potentials for $CH_4$, $N_2O$, CO and NMVOC are taken as 25, 298, 1.9 and 3.4 respectively (IPCC 4th Assessment Report).

# Growth of Greenhouse Gases

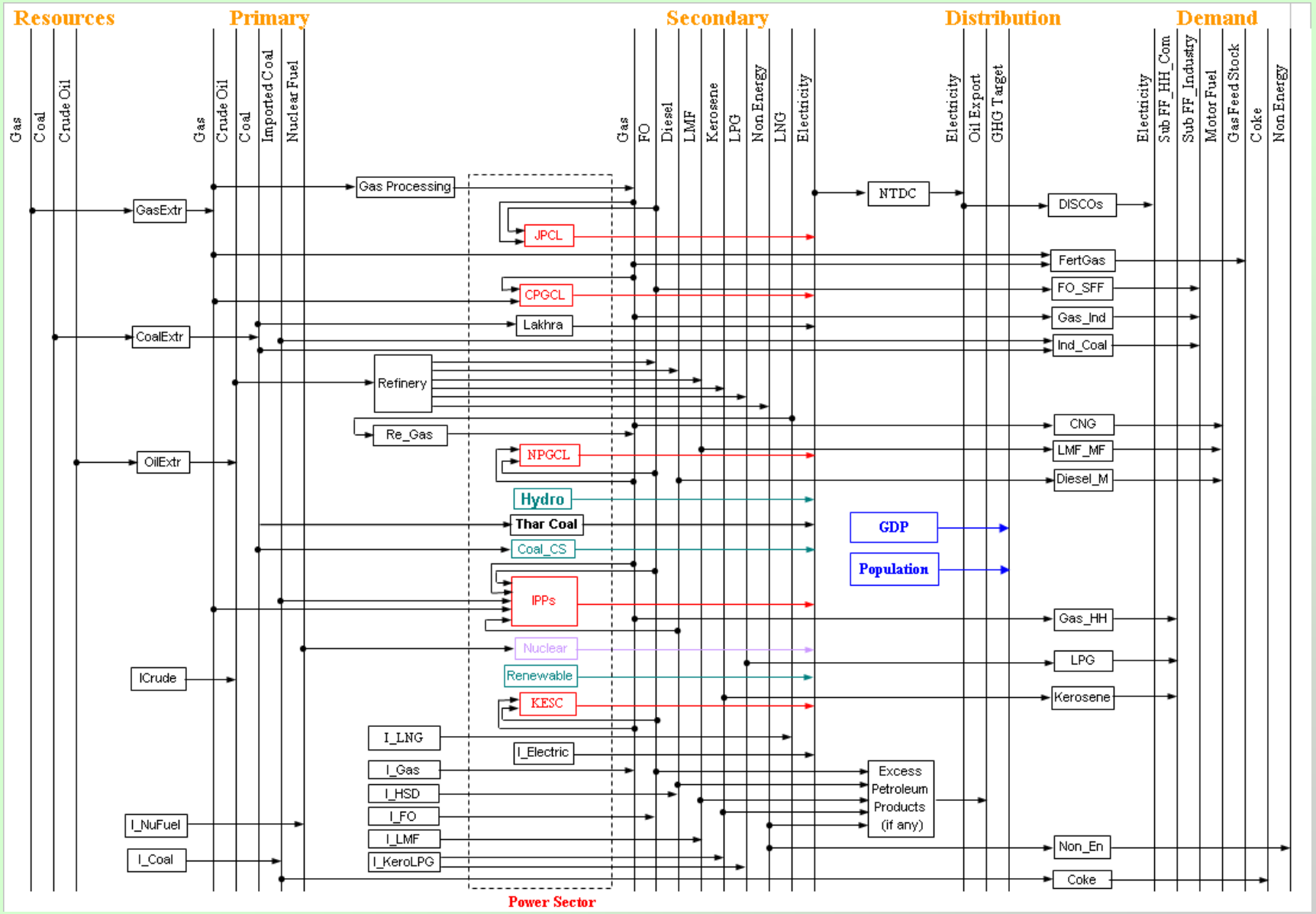
| | $CO_2$ eq of GHG Emissions (Thousand tonnes) | | |
|---|---|---|---|
| | 1994* | 2007 | Growth rate (%) |
| A. Energy Sector | 85,816 | 137,653 | 3.7% |
| 1. Fuel Combustion | 78,898 | 134,100 | 4.2% |
| Power sector | 21,651 | 43,948 | 5.6% |
| Manufacturing | 25,113 | 43,224 | 4.3% |
| Transport | 19,848 | 31,572 | 3.6% |
| Other sectors | 12,286 | 15,357 | 1.7% |
| 2. Fugitive Emissions | 6,918 | 3,553 | -5.0% |
| B. Non-Energy Sector | 84,929 | 118,457 | 2.6% |
| 1. Industrial processes | 13,297 | 28,322 | 6.0% |
| 2. Agriculture | 71,632 | 90,135 | 1.8% |
| Total | 170,745 | 256,110 | 3.2% |

* Pakistan's Initial National Communication on Climate Change to UNFCCC, November 2003.

# Methodology

**IAEA's Model for Energy Supply Strategy Alternatives and their General Environmental Impacts (MESSAGE) was used in the study for modeling the energy system of Pakistan and two post-Kyoto climate protection approaches.**

# Development of Reference Energy System of Pakistan



# Assumptions for the MESSAGE Model

**Planning Horizon:** 2007 to 2030

**Discount Rate:** 10%

**Division of the Year:** Six seasons and four parts of the day

**Load Curve:** for Electricity Demand

**Seasonal Availability Factor:** for Hydro Power

# Fuel Prices Assumed

| | In Physical Units | US $/million BTU | US $/TOE |
|---|---|---|---|
| Imported Crude Oil | US $ 75/bbl (FOB) | 14.2 | 595 |
| Domestic Crude Oil | US $ 67.8/bbl (85% of imported) | 12.1 | 505 |
| Furnace Oil | US $ 503 tonne | 11.7 | 489 |
| HSD | US $ 835/ tonne | 20.9 | 877 |
| Gasoline | US $ 705/ tonne | 17.9 | 750 |
| Kerosene | US $ 830/ tonne | 20.4 | 856 |
| Domestic Natural Gas | US $ 5306/million CFT# | 5.6 | 234 |
| Imported Natural Gas | US $ 5760/million CFT# | 6.1 | 254 |
| LNG | - | 8.7 | 364 |
| Thar Coal | US $ 60/ tonne | 3.15 | 132 |
| Imported Coal | US $ 80/ tonne | 2.90 | 121 |

# Calorific value of 950 BTU/CFT

# Data of Future Power Plants

| Plant Type | Overnight Investment Cost ($/kW) | Variable O & M Cost ($/kWyr) | Fixed O & M Cost ($/kWyr) | Plant Factor (fraction) | Construct. Period (Year) | Efficiency (%) |
|---|---|---|---|---|---|---|
| Furnace Oil, (Steam) | 1100 | 4.78 | 11.75 | 0.75 | 4 | 40.0 |
| Combined Cycle | 877 | 17.5 | 11.7 | 0.75 | 3 | 55.0 |
| Combustion Turbine | 604 | 27.2 | 10.5 | 0.25 | 2 | 35.0 |
| Coal (Steam) | 1923 | 39.4 | 27.5 | 0.75 | 4 | 38.0 |
| Coal CCS* | 2872 | 56.3 | 35.0 | 0.75 | 4 | 34.0 |
| Nuclear, PWR | 2700 | 4.2 | 66.0 | 0.80 | 6, 5 | 33.0 |
| Hydro | 1500-2500 | 0 | 11.2 | 0.50 | 4-8 | |
| Wind | 1797 | 11 | 30.3 | 0.28 | 3 | |
| Solar Thermal | 5750 | 0 | 11.7 | 0.35 | 3 | |

* with carbon capture and storage

# Load Curve Data for Electricity Demand

| Season | Load Curve | | | | Total |
|---|---|---|---|---|---|
| | Night | Morning | Daytime | Evening | |
| Winter1 (Jan-Feb) | 3.62% | 2.21% | 5.09% | 2.75% | 13.66% |
| Spring (Mar-Apr) | 4.38% | 2.40% | 5.58% | 2.88% | 15.24% |
| Dry Summer (May-Jun) | 6.00% | 3.14% | 7.76% | 3.52% | 20.42% |
| Wet Summer (Jul-Aug) | 5.96% | 3.03% | 7.49% | 3.54% | 20.02% |
| Autumn (Sep-Oct) | 5.05% | 2.58% | 6.12% | 3.26% | 17.01% |
| Winter2 (Nov-Dec) | 3.59% | 2.18% | 5.03% | 2.85% | 13.64% |

## Hydro Electricity Availability

| | Winter1 | Spring | Dry Summer | Wet Summer | Autumn | Winter2 |
|---|---|---|---|---|---|---|
| % | 7.7 | 8.4 | 20.6 | 28.3 | 23.3 | 11.5 |

# Final Commercial Energy Demand of Pakistan

| | 2007 | | 2020 | | 2030 | |
|---|---|---|---|---|---|---|
| | MWyr | (000 TOE) | MWyr | (000 TOE) | MWyr | (000 TOE) |
| Electricity | 8,300 | 5,922 | 17,421 | 12,428 | 35,433 | 25,279 |
| Industry Fossil Fuel | 18,501 | 13,199 | 38,395 | 27,392 | 96,197 | 68,629 |
| Residential and Services Fossil Fuel | 8,037 | 5,734 | 15,286 | 10,905 | 24,882 | 17,752 |
| Transport Motor Fuel | 13,777 | 9,828 | 22,863 | 16,311 | 42,524 | 30,337 |
| Transport CNG | 1,851 | 1,321 | 4,716 | 3,365 | 9,337 | 6,661 |
| Feed Stocks (gas) | 4,191 | 2,990 | 5,385 | 3,842 | 7,992 | 5,702 |
| Feed Stocks (coke) | 286 | 204 | 1,697 | 1,211 | 4,376 | 3,122 |
| Non-Energy Oil | 839 | 599 | 1,398 | 997 | 2,069 | 1,476 |
| Total Commercial | 55,784 | 39,797 | 107,160 | 76,450 | 222,810 | 158,957 |

**Final energy demand is based on 6.5% average economic growth rate during the study period.**

# Scenarios

| | Hydro | Coal | Import of Natural Gas | Nuclear | GHG Emission Limit |
|---|---|---|---|---|---|
| **Baseline** | High | High | High | Medium | No limit |
| **CaC** | Same as in Baseline scenario. | | | Medium | Equal per capita emission to keep GHG at 450 ppmv level by the year 2050. |
| **GIT** | Same as in Baseline scenario. | | | Medium | GHG intensity reduction by 2% per annum |
| **GITN** | Same as in Baseline scenario. | | | High | Same as in GIT scenario |

CaC: Contraction and Convergence scenario

GIT: GHG Intensity Target scenario

GITN: GIT with high Nuclear scenario

# Approaches Modeled in MESSAGE

| | |
|---|---|
| **Contraction and Convergence** | **The safer level of stabilization of GHG concentration is 450 ppmv by the year 2050. Beyond 2010, all countries would adopt the global pathway of equal per capita emissions which will converge to the level of 2.0 t $CO_2$-eq per capita by 2050.**<br>**A 450 ppm $CO_2$-eq stabilisation target would be extremely demanding, requiring emissions of greenhouse gases to peak within the next few years followed by annual reductions of 6% or more. Average annual per-capita $CO_2$-eq emissions would need to fall to around 2 tonnes by 2050 (WEO, 2008).** |
| **Intensity Target** | **Targets are in terms of reduction in GHG emissions per unit of GDP. A 2% to 4% decrease in global emission intensity per year on average is required if it is applied to all countries to reach stringent environmental goals.** |

## Contraction and Convergence

$$\sum_{i=1}^{N} T(i) \times E(i) \; - \; POPL \times PCE \; \leq \; 0$$

**where for a certain year,**

**N = number of technologies,**

***T (i)* = activity of technology (MWyr) emitting GHG,**

***E (i)* = emission factor (thousand tonnes $CO_2$-eq /MWyr)**

**POPL = population, (thousands),**

***PCE* = Per Capita Emission, (tonnes/capita),**

# GHG Intensity Target

$$\sum_{i=1}^{N} T(i) \times E(i) \quad - \quad GDP \times GHG\,\text{int} \quad \leq \quad 0$$

**where for a certain year,**

***N* = number of technologies,**

***T(i)* = activity of technology (MWyr) emitting GHG,**

***E (i)* = emission factor (thousand tonnes CO2-eq /MWyr)**

***GDP* = gross domestic product, real, (million US $),**

***GHGint* = GHG intensity, (tonnes/thousand US $),**

# GHG Data used for the Approaches

| | Contraction and Convergence | | | | GHG Intensity Targets (2% reduction per year) | | | |
|---|---|---|---|---|---|---|---|---|
| | Population (million) | World per Capita (tonne/ capita) | Path for Pakistan | | GDP (billion US $) | | GHG Intensity (Tonne of CO2-eq / thousand US $) | |
| | | | Energy Related Emission (share) | Energy Sector (tonne/ capita) | Total | Excluding Agriculture | With Total GDP and Emissions | Excluding Non-energy emissions |
| 2007 | 158.2 | 5.32* | 57.1% | 3.04 | 136 | 106.5 | 1.8 | 1.33 |
| 2010 | 166.1 | 5.32 | 57.4% | 3.05 | 154 | 122.4 | 1.8 | 1.33 |
| 2015 | 180.2 | 4.87 | 57.9% | 2.82 | 202 | 163.3 | 1.7 | 1.23 |
| 2020 | 195.4 | 4.00 | 58.4% | 2.34 | 275 | 227.2 | 1.5 | 1.08 |
| 2025 | 212.0 | 3.56 | 58.9% | 2.10 | 390 | 329.0 | 1.4 | 0.93 |
| 2030 | 230.0 | 3.17 | 59.4% | 1.89 | 580 | 498.5 | 1.2 | 0.79 |

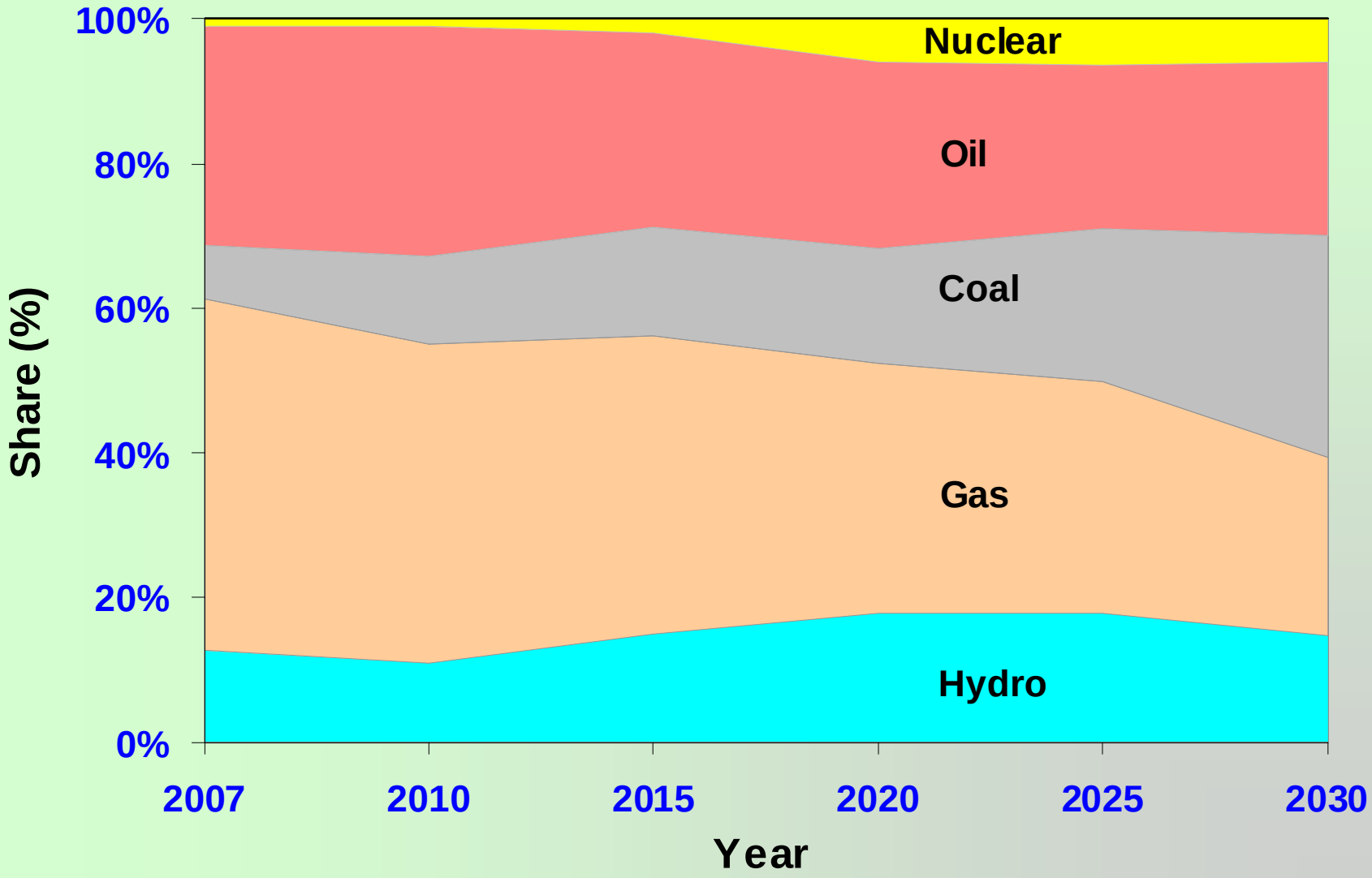
* World data for the year 2004

## Bounds on Additional Capacities for Electricity Generation (MW)

| | | 2010 | 2015 | 2020 | 2025 | 2030 | Total |
|---|---|---|---|---|---|---|---|
| Hydro | In all scenarios | 265 | 4,549 | 8,758 | 5,732 | 6,103 | 25,407 |
| Renewable (Wind) | In all scenarios | 50 | 650 | 1,300 | 1,500 | 1,500 | 5,000 |
| Renewable (Solar) | In all scenarios | | | 20 | 30 | 100 | 150 |

# Results of the MESSAGE Model

# Primary Commercial Energy in Base Case



## Energy Import Dependence

**Share of energy imports in primary commercial energy would increase from the present 30% to about 35% in all the scenarios**

# New Installed Capacity in Base Case (MW)

| | Hydro | Gas CC* | Coal | Nuclear | Ren. (Wind) | Total |
|---|---|---|---|---|---|---|
| 2010 | 265 | 1,880 | - | - | 50 | 3,317 |
| 2015 | 4,548 | 285 | 1,200 | 600 | - | 6,633 |
| 2020 | 8,142 | - | 1,200 | 3,300 | - | 12,642 |
| 2025 | 6,348 | - | 4,956 | 2,000 | - | 13,305 |
| 2030 | 3,681 | - | 13,776 | 2,000 | - | 19,457 |
| Total | 22,984 | 2,165 | 21,133 | 7,900 | 50 | 55,354 |

* Combined Cycle

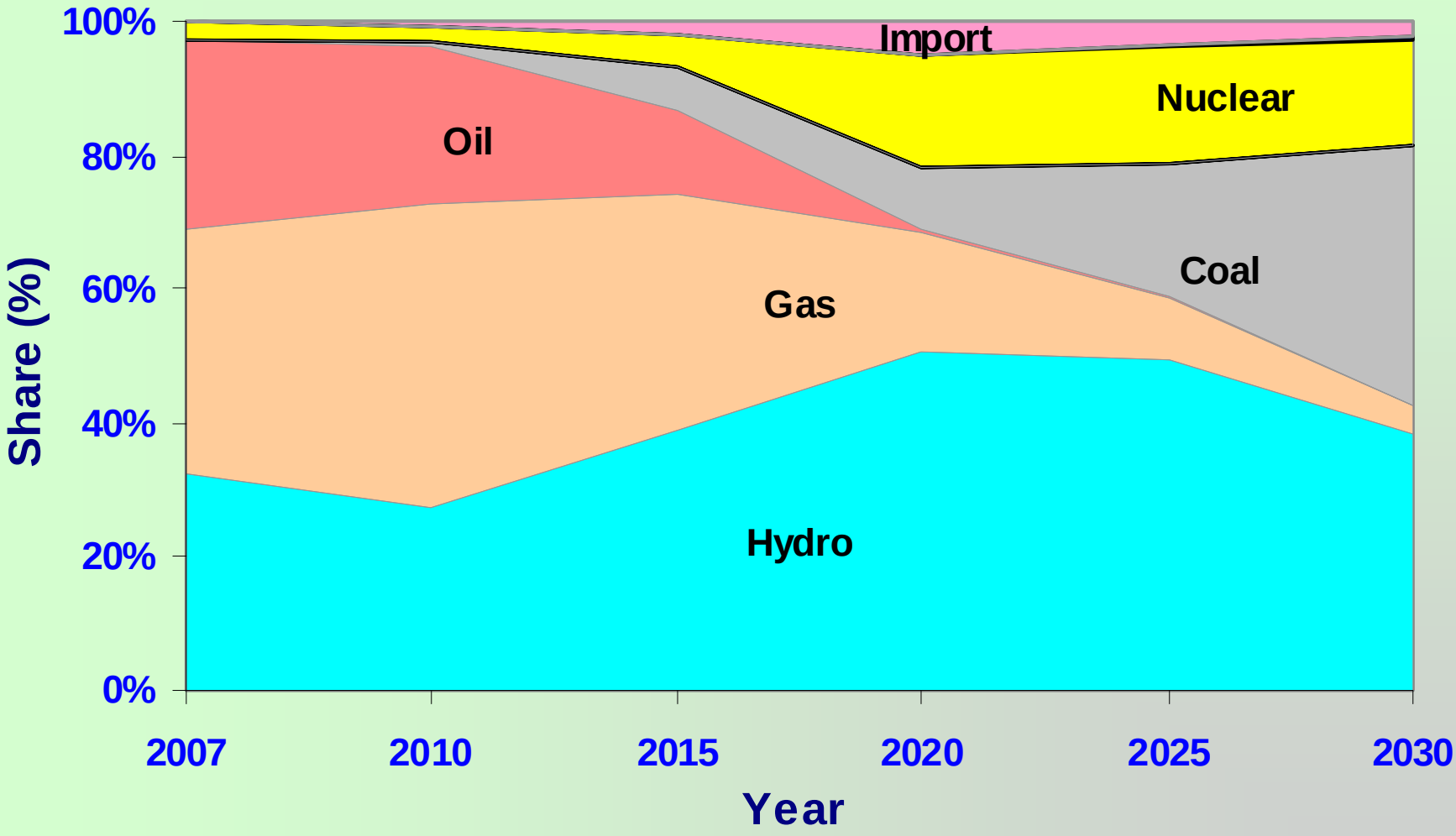
# New Installed Capacity in Alternative Scenarios (MW) (1/2)

| | Scenario | Hydro | Gas CC | Nuclear | Coal | Oil | Coal CCS | Ren-ewable | Total |
|---|---|---|---|---|---|---|---|---|---|
| 2010 | Base | 265 | 1880 | 0 | 0 | 1,122 | 0 | 50 | 3317 |
| | CaC | 265 | 1880 | 0 | 0 | 1,122 | 0 | 50 | 3317 |
| | GIT | 265 | 1880 | 0 | 0 | 1,122 | 0 | 50 | 3317 |
| | GITN | 265 | 1880 | 0 | 0 | 1,122 | 0 | 50 | 3317 |
| 2015 | Base | 4548 | 285 | 600 | 1200 | 0 | 0 | 0 | 6633 |
| | CaC | 4548 | 655 | 600 | 1200 | 0 | 0 | 0 | 7003 |
| | GIT | 4548 | 1961 | 600 | 1200 | 0 | 0 | 0 | 8309 |
| | GITN | 4548 | 1631 | 600 | 1200 | 0 | 0 | 0 | 7979 |
| 2020 | Base | 8142 | 0 | 3300 | 1200 | 0 | 0 | 0 | 12642 |
| | CaC | 7715 | 0 | 3300 | 1200 | 0 | 0 | 0 | 12215 |
| | GIT | 7595 | 0 | 3300 | 0 | 0 | 0 | 0 | 10895 |
| | GITN | 7595 | 0 | 3300 | 330 | 0 | 0 | 0 | 11225 |

# New Installed Capacity in Alternative Scenarios (MW) (2/2)

| | Scenario | Hydro | Gas CC | Nuclear | Coal | Oil | Coal CCS | Ren-ewable | Total |
|---|---|---|---|---|---|---|---|---|---|
| 2025 | Base | 6348 | 0 | 2000 | 4956 | 0 | 0 | 0 | 13305 |
| | CaC | 6775 | 0 | 2000 | 3813 | 0 | 0 | 0 | 12588 |
| | GIT | 6895 | 248 | 2000 | 2400 | 0 | 0 | 0 | 11543 |
| | GITN | 6895 | 0 | 4000 | 655 | 0 | 0 | 0 | 11550 |
| 2030 | Base | 3681 | 0 | 2000 | 13776 | 0 | 0 | 0 | 19457 |
| | CaC | 5853 | 0 | 2000 | 0 | 0 | 13148 | 4950 | 25951 |
| | GIT | 5853 | 0 | 2000 | 0 | 0 | 20101 | 4950 | 32904 |
| | GITN | 5853 | 0 | 4000 | 0 | 0 | 15834 | 4950 | 30637 |
| Total | Base | 22984 | 2165 | 7900 | 21133 | 1122 | 0 | 50 | 55354 |
| | CaC | 25156 | 2535 | 7900 | 6213 | 1122 | 13148 | 5000 | 61074 |
| | GIT | 25156 | 4089 | 7900 | 3600 | 1122 | 20101 | 5000 | 66968 |
| | GITN | 25156 | 3511 | 11900 | 2185 | 1122 | 15834 | 5000 | 64708 |

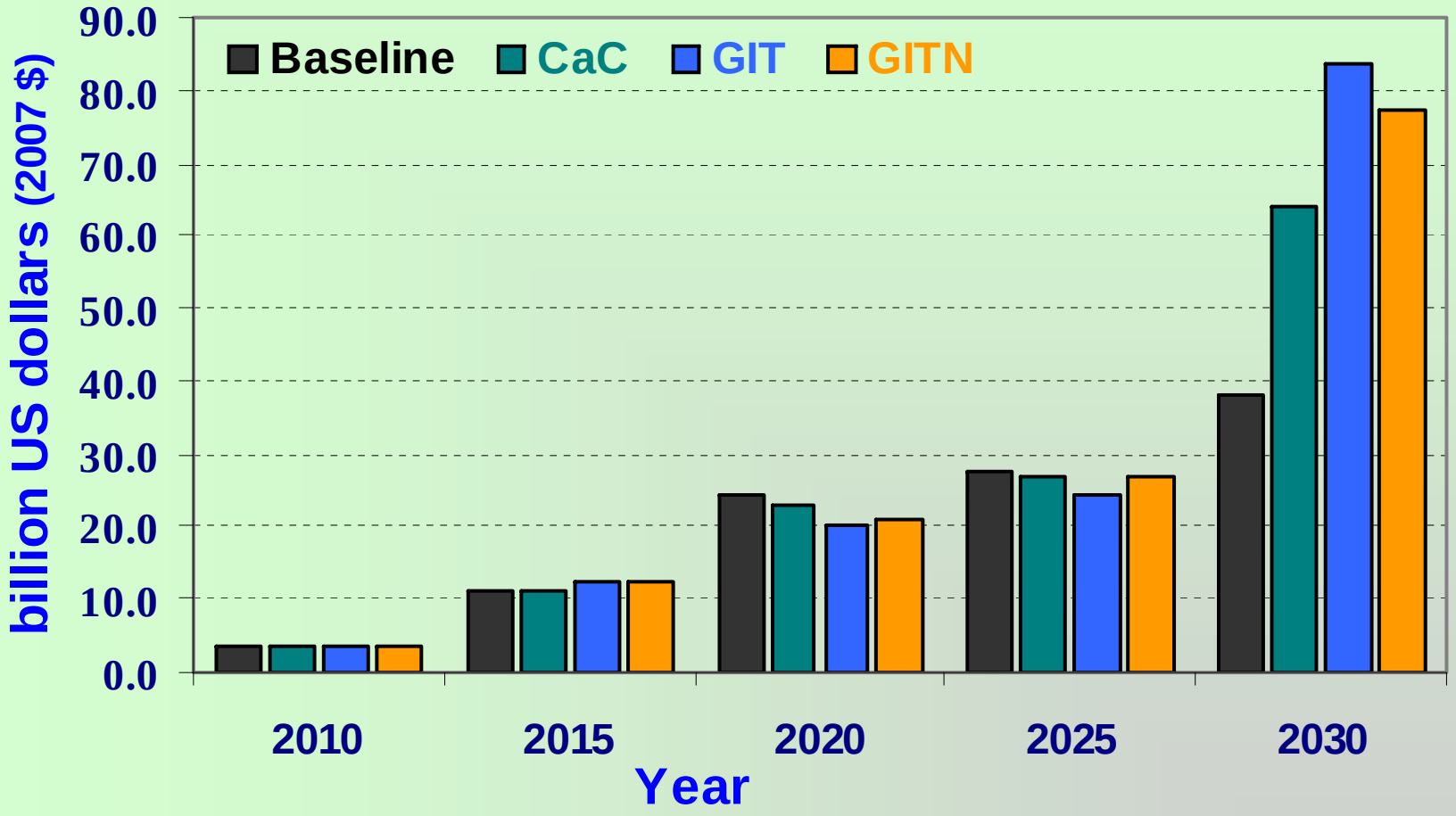
# Electricity Generation Mix in Base Case



# Electricity Generation (billion kWh)

| | Scenario | 2007 | 2015 | 2025 | 2030 |
|---|---|---|---|---|---|
| Hydro | Baseline | 32.0 | 52.1 | 121.2 | 137.2 |
| | CaC, GIT, GITN | | 52.1 | 121.2 | 146.1 |
| Gas | Baseline | 35.8 | 47.6 | 22.5 | 14.2 |
| | CaC | | 49.1 | 28.3 | 4.9 |
| | GIT | | 55.5 | 43.9 | 0.0 |
| | GITN | | 55.5 | 39.2 | 0.0 |
| Oil | Baseline | 28 | 16.6 | 0.6 | 0.0 |
| | CaC | | 15.1 | 2.3 | 0.0 |
| | GIT, GITN | | 8.7 | 3.9 | 0.0 |
| Coal | Baseline | 0.1 | 8.6 | 48.3 | 138.8 |
| | CaC | | 8.6 | 40.8 | 40.8 |
| | GIT | | 8.6 | 23.7 | 0.0 |
| | GITN | | 8.6 | 14.4 | 0.0 |
| Coal CCS | Baseline | 0.0 | 0.0 | 0.0 | 0.0 |
| | CaC | | 0.0 | 0.0 | 86.4 |
| | GIT | | 0.0 | 0.0 | 132.1 |
| | GITN | | 0.0 | 0.0 | 104.0 |
| Nuclear | Baseline, CaC, GIT | 2.3 | 6.7 | 43.2 | 57.2 |
| | GITN | | 6.7 | 57.2 | 85.2 |
| Renewable | Baseline | 0.0 | 0.1 | 0.1 | 0.1 |
| | CaC, GIT, GITN | | 0.1 | 0.1 | 12.3 |
| Import | All | 0.2 | 2.6 | 8.8 | 8.8 |
| Total | All | 98.4 | 134 | 245 | 356 |

# Investment Cost in Power Sector




| | Baseline | CaC | GIT | GITN |
|---|---|---|---|---|
| Total Investment Required (billion US $) | 104.5 | 128.6 | 144.9 | 140.4 |

# Investment Cost on Electricity Generation Technologies (billion US dollars of 2007)

| | GDP (billion $) | Baseline | | CaC | | GIT | | GITN | |
|---|---|---|---|---|---|---|---|---|---|
| | | billion $ | GDP share | billion $ | GDP share | billion $ | GDP share | billion $ | GDP share |
| **2010** | **154** | **3.6** | **0.8%** | **3.6** | **0.8%** | **3.6** | **0.8%** | **3.6** | **0.8%** |
| **2015** | **202** | **11.1** | **1.2%** | **11.4** | **1.3%** | **12.5** | **1.4%** | **12.2** | **1.4%** |
| **2020** | **275** | **24.3** | **2.0%** | **22.9** | **1.9%** | **20.3** | **1.7%** | **20.9** | **1.8%** |
| **2025** | **390** | **27.5** | **1.7%** | **26.8** | **1.6%** | **24.6** | **1.5%** | **26.6** | **1.6%** |
| **2030** | **580** | **38.0** | **1.6%** | **64.0** | **2.6%** | **84.0** | **3.5%** | **77.1** | **3.2%** |
| **Total** | | **104.5** | | **128.6** | | **144.9** | | **140.4** | |

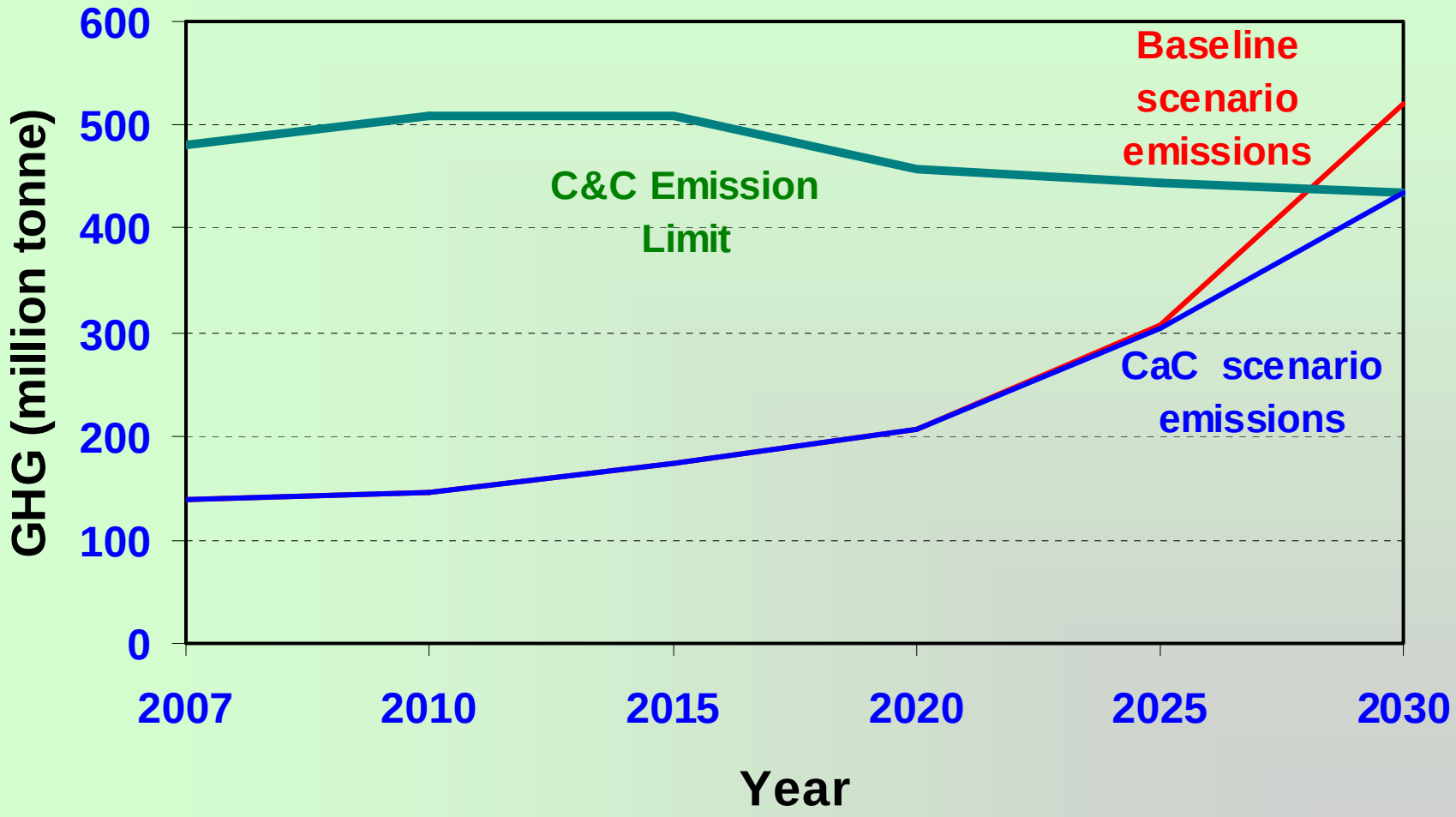
# GHG Intensity of Electricity Generation (grams of GHG /kWh)

| | Baseline | CaC | GIT | GITN |
|---|---|---|---|---|
| 2007 | 450 | 450 | 450 | 450 |
| 2010 | 389 | 389 | 389 | 389 |
| 2015 | 307 | 304 | 291 | 292 |
| 2020 | 165 | 171 | 155 | 160 |
| 2025 | 205 | 194 | 168 | 130 |
| 2030 | 337 | 98 | 0 | 0 |

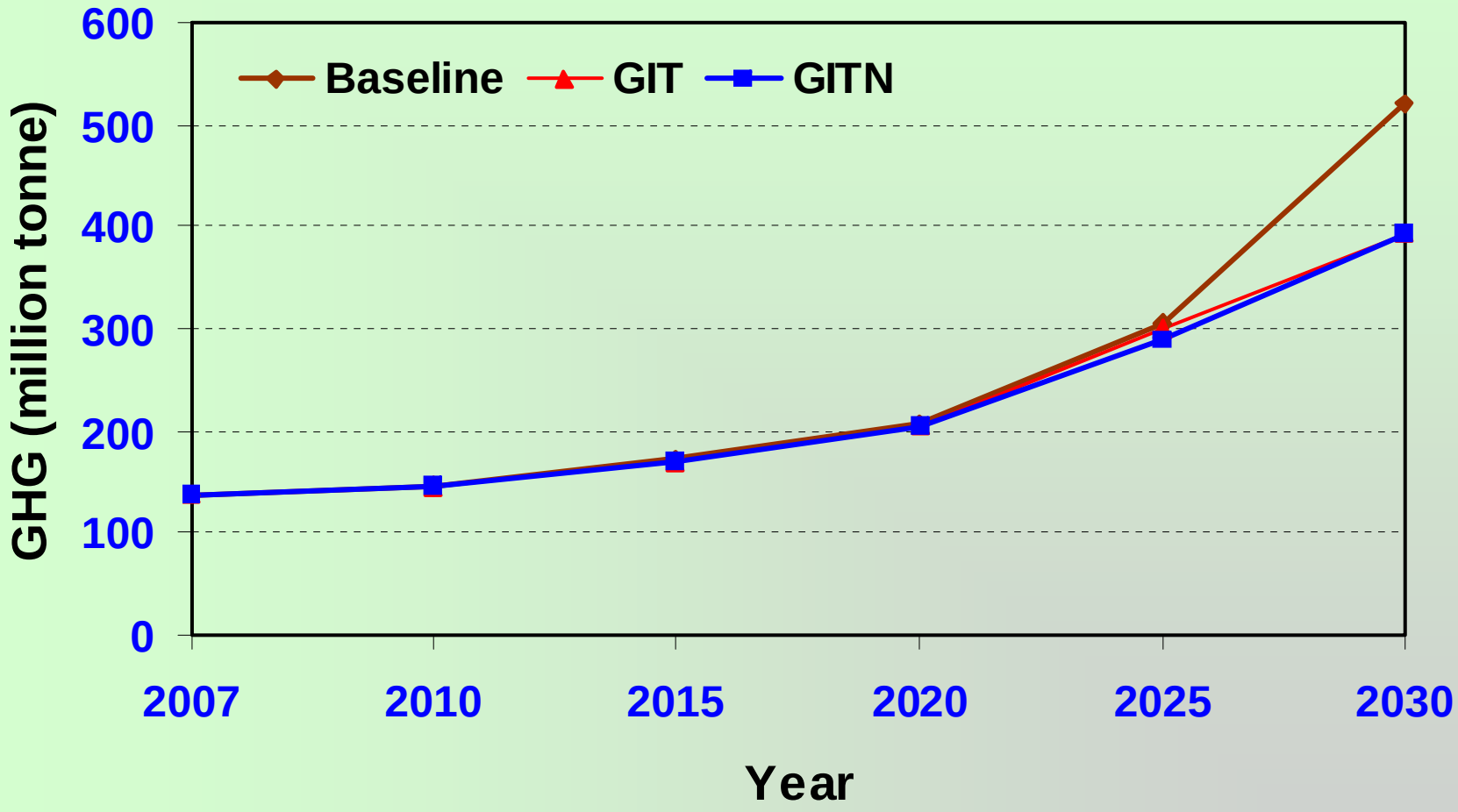
# GHG Emissions from Energy Sector and GHG Intensity of Primary Energy

| | Baseline | | CaC | | GIT | | GITN | |
|---|---|---|---|---|---|---|---|---|
| | GHG (million tonne) | Intensity (tonne/ TOE) | GHG (million tonne) | Intensity (tonne/ TOE) | GHG (million tonne) | Intensity (tonne/ TOE) | GHG (million tonne) | Intensity (tonne/ TOE) |
| 2007 | 138 | 2.29 | 138 | 2.29 | 138 | 2.29 | 138 | 2.29 |
| 2010 | 145 | 2.22 | 145 | 2.22 | 145 | 2.22 | 145 | 2.22 |
| 2015 | 173 | 2.07 | 172 | 2.07 | 171 | 2.02 | 171 | 2.02 |
| 2020 | 206 | 1.73 | 207 | 1.74 | 205 | 1.72 | 205 | 1.73 |
| 2025 | 305 | 1.87 | 304 | 1.88 | 300 | 1.90 | 290 | 1.82 |
| 2030 | 521 | 2.31 | 435 | 1.90 | 394 | 1.73 | 394 | 1.73 |

# GHG Emissions of CaC scenario



# GHG Emissions of CaC scenario



## Electricity Generation Cost (cents/kWh) in Alternative Scenarios

| | Baseline | CaC | GIT | GITN |
|---|---|---|---|---|
| 2010 | 6.1 | 6.1 | 6.1 | 6.1 |
| 2015 | 5.3 | 5.2 | 5.1 | 5.1 |
| 2020 | 5.1 | 5.1 | 5.1 | 5.1 |
| 2025 | 5.7 | 5.7 | 5.6 | 5.6 |
| 2030 | 6.3 | 7.1 | 7.5 | 7.3 |

# GHG Abatement Cost of Power Sector during 2025-30

| | Baseline | CaC | GIT | GITN |
|---|---|---|---|---|
| Power sector emissions (million tonnes) | 120 | 35 | 0 | 0 |
| System generation cost (million US $*) | 22,067 | 24,840 | 26,192 | 25,293 |
| GHG mitigated (million tonnes) | | 85 | 120 | 120 |
| Additional generation cost (million US $) | | 2,769 | 4,121 | 3,223 |
| GHG abatement cost (US $/tonne $CO_2$) | | 32.5 | 34.3 | 26.9 |
| Carbon abatement cost (US $/tonne C) | | 119 | 126 | 98 |

* Dollar of 2007.

# Conclusions and Recommendations (1/3)

➲ **For the economic development of Pakistan at 6.5% per year, the expansion of energy and electricity system will require the maximum exploitation of indigenous energy resources i.e. hydro, oil, natural gas, coal and nuclear to keep import dependence at level of one-third of the total energy supply.**

➲ **The contraction and convergence (C&C) approach requires about 84% of the electricity generation capacity on carbon free or low carbon energy technologies (hydro, nuclear, wind, coal CCS) by 2030 to achieve the global objective of keeping GHG concentration at 450 ppmv by 2050. It will involve additional investments of US dollar 24.1 billion and increase annual electricity generation cost by US dollars 2.77 billion in 2030.**

- **The GHG stabilization level at 550 ppmv by 2050 with C&C approach, will soften the limit of GHG emission for hardly a few years. In case of low to medium development of indigenous energy resources, utilization of wind and coal CCS technologies would be required during 2025-30.**

## Conclusions and Recommendations (2/3)

➲ **GHG Intensity target approach with even 2% per annum reduction in GHG intensity needs whole of the electricity generation from carbon free or low carbon technologies by the year 2030.**

i. **The total investment cost is increased by US dollars 40.4 billion for capacity additions on coal CCS and wind during the last period.**

ii. **The annual electricity generation cost would be increased by US dollars 4.12 billion in 2030.**

iii. **Additional 4,000 MWe nuclear capacity in the GHG intensity reduction approach, would save US dollars 4.5 billion in the total investments for power capacity additions and US dollars 0.9 billion in the annual cost for electricity generation by 2030.**

## Conclusions and Recommendations (3/3)

- Freezing of nuclear based capacity in the power generation system of Pakistan increases the GHG intensity of electricity generation in the range of 98 - 130 grams/kWh during the period of 2020-30 and annual generation cost of the system is increased by US dollars 0.31 billion annually by 2030.
- The carbon abatement costs of the two climate protection approaches is in the range of US dollars 32 - 34 per tonne of CO2 (US dollars 119 - 126/tC) in 2030.
- In long term, GHG mitigation under these approaches can only be committed if the Annex-I Parties to UNFCCC support Pakistan financially and through effective transfer of clean technologies including the nuclear power plants.

# Thank You