# Sustainable Energy Efficiency Index: A case Study of SAARC countries

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# Outline

- World Energy Outlook
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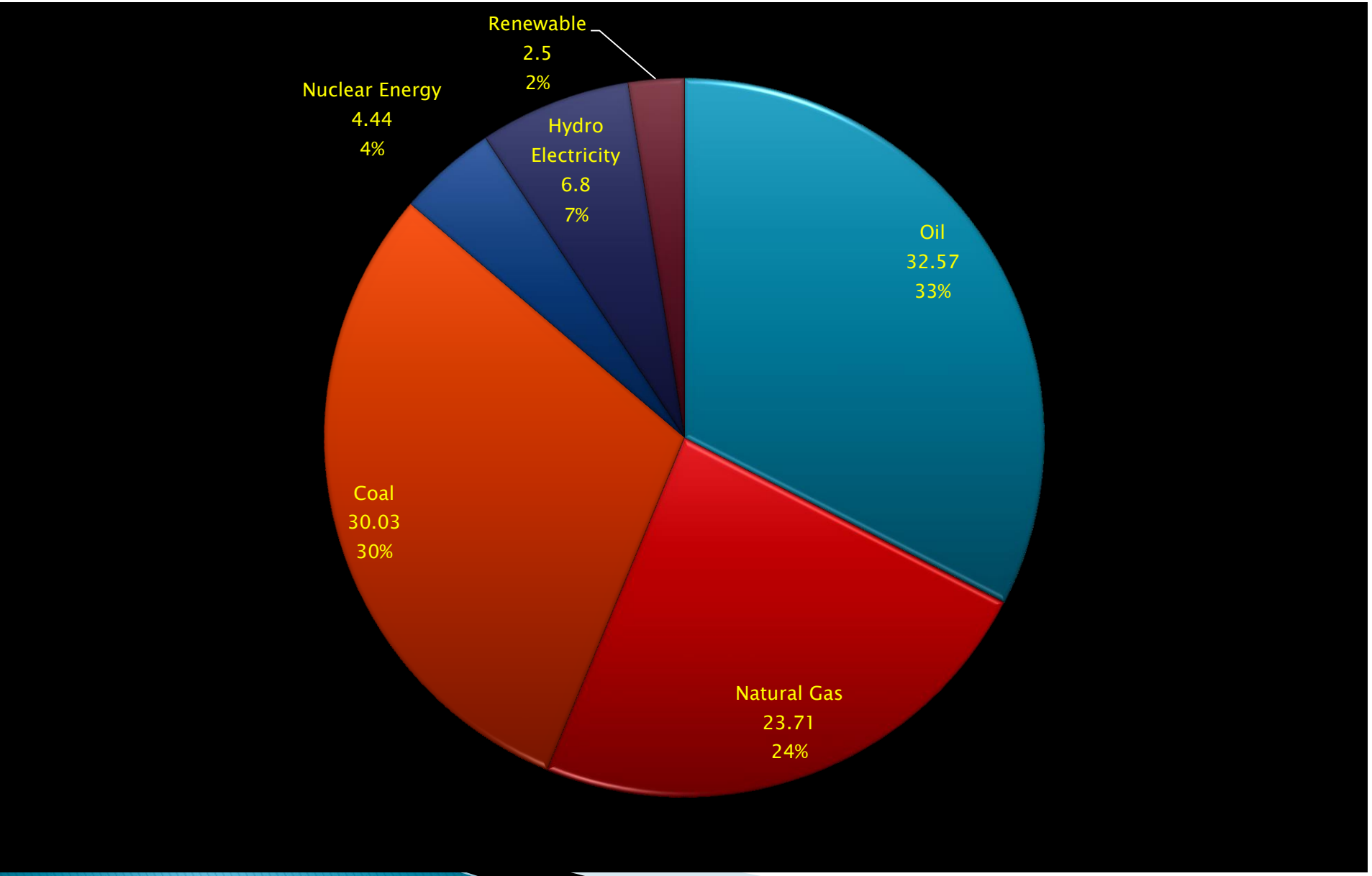
# World Energy Outlook

## Highlights

- Projected Global Energy demands to grow by 33% higher by 2040.
  - OECD
  - Non-OECD
- Major role players: India, China, Africa, the Middle East & South-East Asia.
- Reduction in annual growth rate.
- 17% of the global population – remain without electricity.
- Energy-related Carbon emissions projected to be 16% higher by 2040, increasing at the rate of 2.4% per year since 2000.

# World total energy Consumption by fuel in 2014



# Energy Sector of Pakistan

- Total Primary Energy Consumption:  38.8 MTOE

- Fuel contribution:
  - Natural Gas: 43.2%
  - Oil: 29%

# Significance of the Study

- Climate Summit in Paris (COP21)
- Pakistan: a minor contributor but a worst victim of Climate Change.
- Contributes 0.8% of total global GHG emission and 0.5% of total Carbon emission.
- Widening Deficit in supply and demand of energy

# Objectives of the Study

- **Overall Objective:**
  - Analyze the role of energy sector in Environmental degradation and Economic growth
- **Explicit Objectives:**
  - Develop Sustainable Energy Efficiency Index
  - Estimate Scale efficiencies
  - Analyze the patterns of change in efficiencies over time
  - Policy formulation

# Data Collection

- The present study is based on the secondary source of data consisting annual observations on SAARC countries for the years 2004-2007.
- **INPUT:** Energy use per capita (E)
- **OUTPUT:** Gross Domestic Product per capita (GDP) & $CO_2$ emissions per capita (C)
- **SOURCE:** World Development indicators

# Variables

- Energy use in kg of oil equivalent per capita
- GDP per capita (current US$)
- $CO_2$ emissions (metric tons per capita)

# Energy Sustainable Index

- **Energy sustainability :** A guarantee that the energy resources are preserved for the coming generations.
- **Methods for assessing Energy Sustainability**
  - Aspect of Sustainability
  - Type of data Employed
  - Time Span

# Measuring Efficiency

- **Uni-dimensional Methods:**
  - Performance Indicators
- **Mutli-dimensioanl Methods:**
  - Frontier Approaches
    - Stochastic Frontier Analysis — Parametric Approaches
    - Corrected Ordinary Least Squares — Parametric Approaches
    - Data Envelopment Analysis — Non-Parametric Approaches
    - Malmquist Productivity Index — Non-Parametric Approaches

- Non-Frontier Approaches
  - Linear Programming
  - Econometric Methods
  - Growth Accounting Equation
  - Divisia Index
  - Exact Index
  - Tornqvist Index

Parametric Approaches

Non-Parametric Approaches

# Energy Sustainability Index

- Energy efficiencies obtained using the output oriented models estimated such that for the given levels of energy input:
  - maximizes the economic growth
  - minimizes the carbon emissions at the same time.

# Methods Employed in Study

- **Which:**
  - Data Envelopment analysis
  - Malmquist Productivity Index
- **Why:**
  - Incorporate multiple inputs and outputs
  - Does not require functional form
  - Variables can have different units of measurements
  - Provide direct comparison by the means of peers

# Data Envelopment Analysis

- Introduced by Farrell (1957)
- Estimate productivity efficiency taking into account all the inputs.
- Based on linear programming for assessing the relative efficiency of DMUs.
  - **DMU:** Decision Making Units that operates a production process that converts inputs into outputs.

# Basic DEA Models

- A basic DEA model assumes K inputs and M outputs on each of N DMUs.
- **Constant Return to Scale (CRS) Model**
  - Introduced by Charnes, Cooper and Rhodes (1978)
  - Based on the Radial minimization of all inputs and maximization of all outputs.
  - Assumes an environment of Constant return to scale.
  - Provides an estimate of Technical efficiency

- **Variable Return to Scale (VRS) Model**
  - Introduced by Banker et al. (1984)
  - Provides estimates of the Pure Technical Efficiency.
  - Impose a convexity constraint on the CRS model

- **Scale Efficiencies:**

$$\text{Scale Efficency} = \frac{TE_{CRS}}{TE_{VRS}}$$

# Malmquist Productivity Index (MPI)

- Introduced by Fare et al. (1994, 1996)
- Measures Productivity Growth as the weighted sum of the sectoral rates
- Assumes the inputs are explicitly known and efficiently allocated among the sector.
- Output Based MPI is given as:

$$M_0(t, t+1) = \left[ \frac{D_0^t(x^{t+1}, y^{t+1})}{D_0^t(x^t, y^t)} \frac{D_0^{t+1}(x^{t+1}, y^{t+1})}{D_0^{t+1}(x^{t+1}, y^{t+1})} \right]^{\frac{1}{2}}$$

- MPI $>$ 1 indicates Positive TFP growth
- MPI can be represented as the geometric mean of the effect of the technological change.

$$M = TE \times TC$$

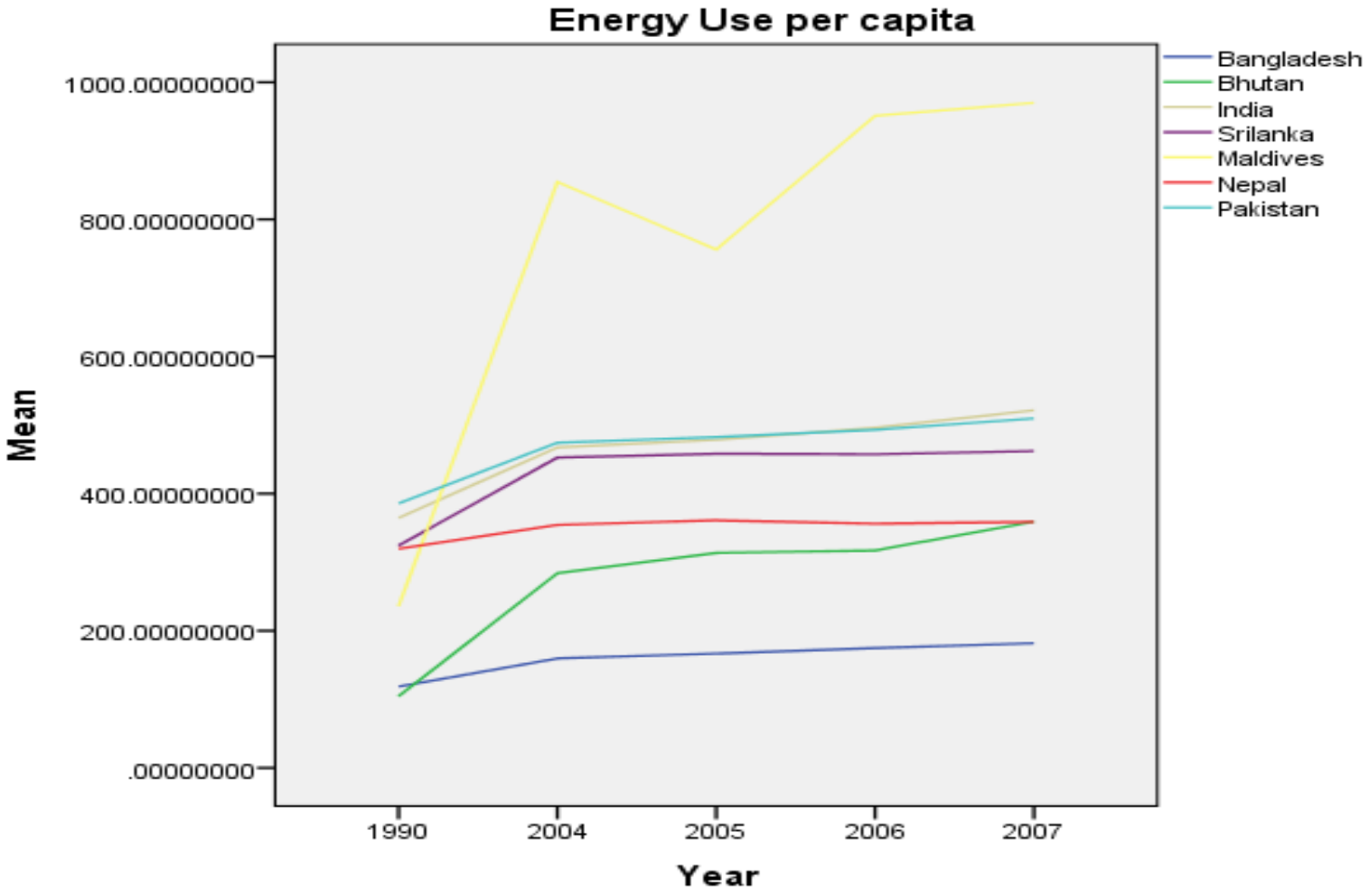
Where TE = Technical efficiency

TC = Average Technological Change over Time.

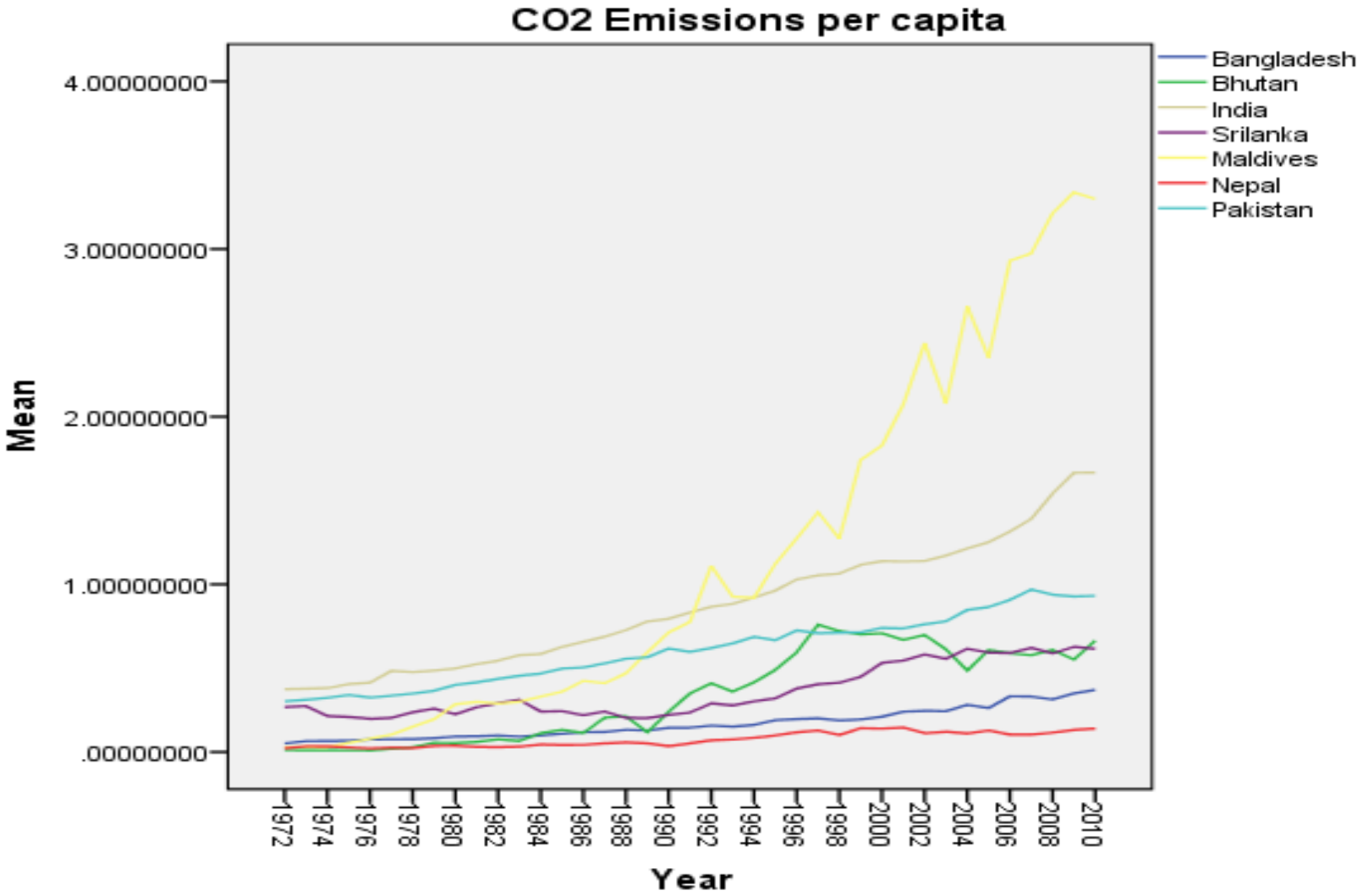
# Results & Discussion

- Descriptive Analysis
- Energy Sustainable Index
- Patterns of Change in efficiencies

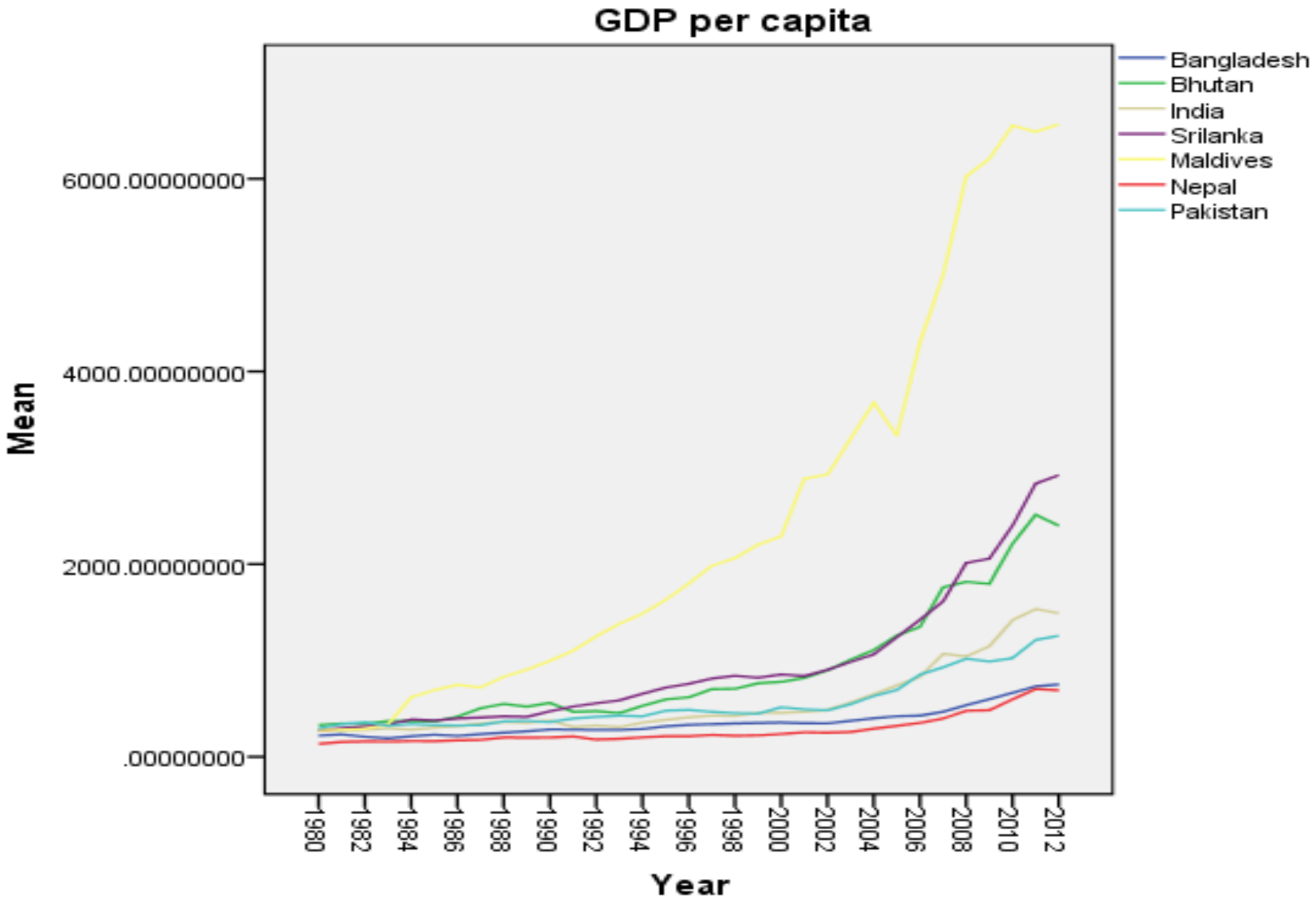
# Energy Use Per Capita



# Carbon Emission per capita



# GDP per capita



# Efficiency Summary for 2004

| Country | CRS Efficiency | VRS Efficiency | Scale Efficiency | Peers |
|---|---|---|---|---|
| **Bangladesh** | 1 | 1 | 1 | |
| **Bhutan** | 1 | 1 | 1 | |
| **India** | 0.345 | 0.356 | 0.969 | Maldives, Nepal, Bangladesh |
| **Maldives** | 1 | 1 | 1 | |
| **Nepal** | 1 | 1 | 1 | |
| **Pakistan** | 0.341 | 0.369 | 0.924 | Maldives, Bangladesh, Nepal |
| **Srilanka** | 0.591 | 0.62 | 0.954 | Maldives, Bangladesh, Nepal |
| **Mean Efficiency** | 0.754 | 0.764 | 0.978 | |

# Efficiency Summary for 2005

| Country | CRS Efficiency | VRS Efficiency | Scale Efficiency | Peers |
|---|---|---|---|---|
| **Bangladesh** | 1 | 1 | 1 | |
| **Bhutan** | 1 | 1 | 1 | |
| **India** | 0.379 | 0.38 | 0.995 | Maldives, Bangladesh, Nepal |
| **Maldives** | 1 | 1 | 1 | |
| **Nepal** | 0.945 | 1 | 0.945 | |
| **Pakistan** | 0.368 | 0.389 | 0.944 | Maldives, Bangladesh, Nepal |
| **Srilanka** | 0.678 | 0.691 | 0.982 | Maldives, Bangladesh, Nepal |
| **Mean Efficiency** | 0.767 | 0.78 | 0.981 | |

# Efficiency Summary for 2006

| Country | CRS Efficiency | VRS Efficiency | Scale Efficiency | Peers |
|---|---|---|---|---|
| **Bangladesh** | 0.995 | 1 | 0.995 | |
| **Bhutan** | 1 | 1 | 1 | |
| **India** | 0.386 | 0.396 | 0.975 | Maldives, Nepal, Bhutan |
| **Maldives** | 1 | 1 | 1 | |
| **Nepal** | 1 | 1 | 1 | |
| **Pakistan** | 0.408 | 0.429 | 0.951 | Maldives, Bhutan, Nepal |
| **Srilanka** | 0.729 | 0.757 | 0.963 | Maldives, Nepal, Bhutan |
| **Mean Efficiency** | 0.788 | 0.798 | 0.983 | |

# Efficiency Summary for 2007

| Country | CRS Efficiency | VRS Efficiency | Scale Efficiency | Peers |
|---|---|---|---|---|
| **Bangladesh** | 0.948 | 1 | 0.94 | |
| **Bhutan** | 1 | 1 | 1 | |
| **India** | 0.411 | 0.417 | 0.984 | Maldives, Nepal, Bhutan |
| **Maldives** | 1 | 1 | 1 | |
| **Nepal** | 1 | 1 | 1 | |
| **Pakistan** | 0.379 | 0.396 | 0.958 | Bhutan, Maldives, Nepal |
| **Srilanka** | 0.714 | 0.737 | 0.968 | Maldives, Nepal, Bhutan |
| **Mean Efficiency** | 0.779 | 0.793 | 0.98 | |

# Patterns of Change in Efficiency (2004–2007)

| Country | Technical Efficiency Change, TE | Technological Change, TC | VRS Technical Efficiency Change | Scale Efficiency Change | Malmquist Productivity Index |
|---|---|---|---|---|---|
| Bangladesh | 0.982 | 0.976 | 1 | 0.982 | 0.959 |
| Bhutan | 1 | 1.055 | 1 | 1 | 1.055 |
| India | 1.06 | 1.061 | 1.052 | 1 | 1.124 |
| Maldives | 1 | 1.062 | 1 | 1.008 | 1.062 |
| Nepal | 1 | 1.021 | 1 | 1 | 1.021 |
| Pakistan | 1.03 | 1.048 | 1.045 | 1 | 1.085 |
| Srilanka | 1.065 | 1.056 | 1.064 | 0.991 | 1.125 |
| Mean Efficiency Change | 1.02 | 1.039 | 1.023 | 1.001 | 1.06 |

# Conclusion

- **Year-wise Energy Sustainability Indices**
  - Most Efficient Countries: Bhutan, Maldives
  - Least Efficient Countries: Pakistan, India
- **Change in Productivity over time**
  - MPI suggests an overall positive change (1.02%) in TE of the region.
  - An increase in Technological Change (1.04%)
  - Region is more inclined toward Technological improvement rather than Technical improvements.

- MPI reveals progress in terms of environmental related energy efficiency for the whole region except Bangladesh.
- India and Srilanka have shown highest progress in this regard.
- The highly efficient Maldives owes it efficiency to the  Technology.

# Policy recommendations

- SAARC countries need to divert towards technical efficient paradigm for a sustainable economic growth.
- Pakistan has a long struggle ahead in energy-enivronment-growth nexus.
- Pakistan needs to adapt the policies by its peer indicated by the analysis.
- The energy sector of Pakistan needs institutional reforms to increase the energy efficiency via technological achievements

Thank You