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**Joint ICTP-IAEA Workshop on Vulnerability of Energy Systems to Climate Change and Extreme Events**

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# Climate change and extreme events: vulnerability of energy systems in Cuba

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*"Vulnerability of energy systems to climate change and extreme events"*
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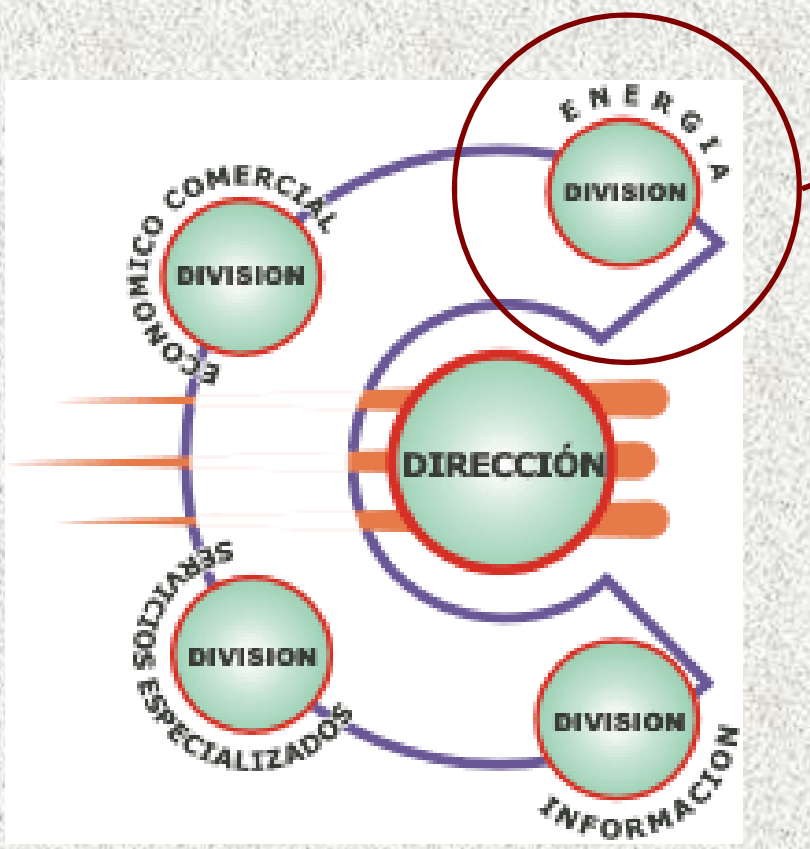
# CLIMATE CHANGE AND EXTREME EVENTS: VULNERABILITY OF ENERGY SYSTEMS IN CUBA

# *CUBAENERGIA*

## *Center for Information Management and Energy Development*




**División de Energía**

- Environmental Impacts
- Energy Planning
- Renewal Energies

# *Background Information*


- Surface extension: 109 866 km$^2$
- GDP 60 806,3 MCUP
- Total population (2008) 11.24 million

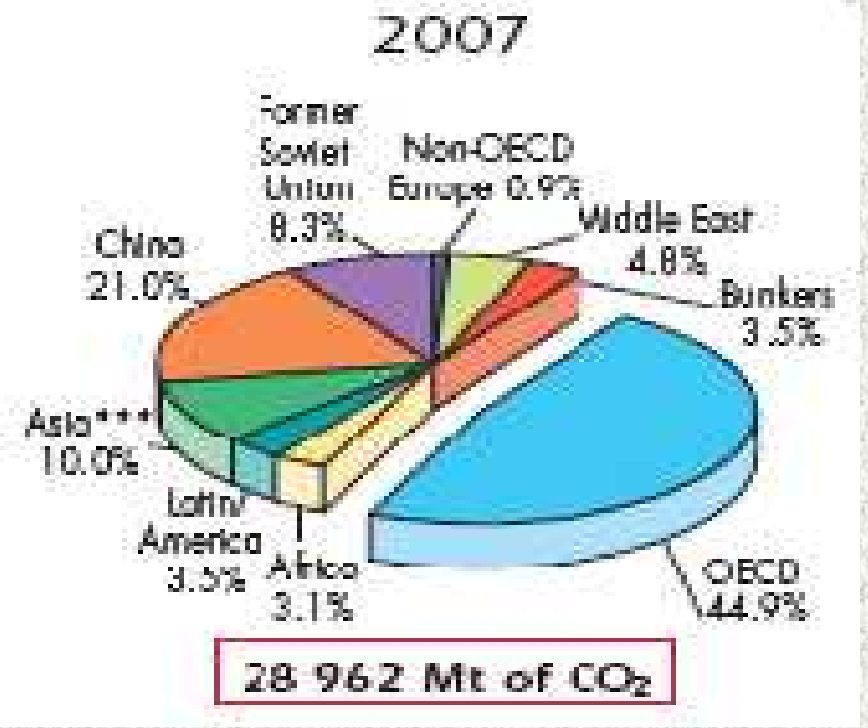
# *GHG Emissions*

# *General Context*

$CO_2$ emissions from fuel combustion for the year 2007

| Region/Country | $CO_2$ Emissions (Mt $CO_2$) |
|---|---|
| World | 28962 |
| OECD | 13001 |
| Middle East | 1389 |
| Former USSR | 2412 |
| Non-OECD Europe | 272 |
| China | 6071 |
| Asia | 2898 |
| Latin America | 1016 |
| Africa | 882 |

Source: Key World Energy Statistics 2009

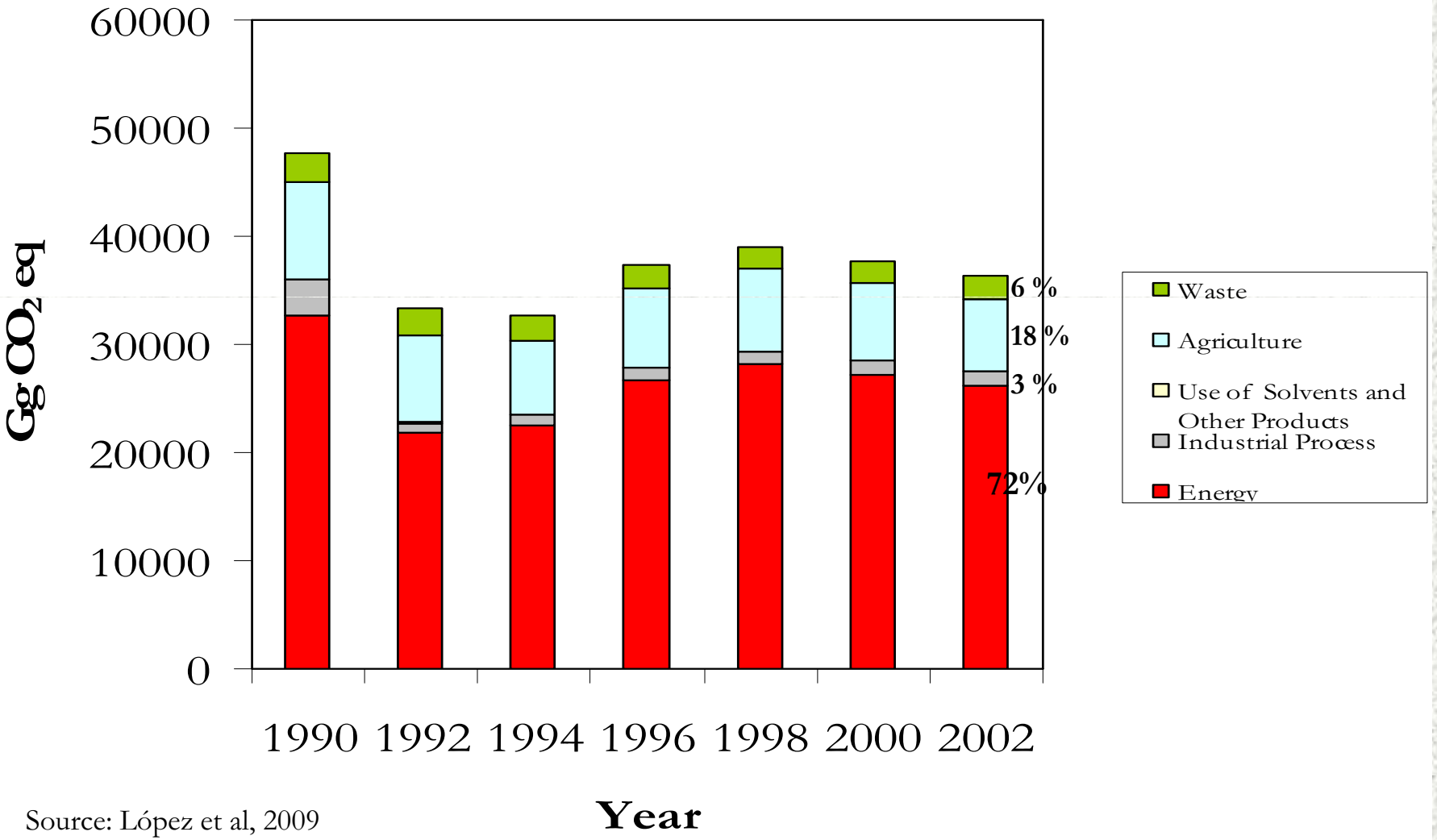



**Cuba: 26.16 Mt $CO_2$**

**2.57 % of the Latin America**

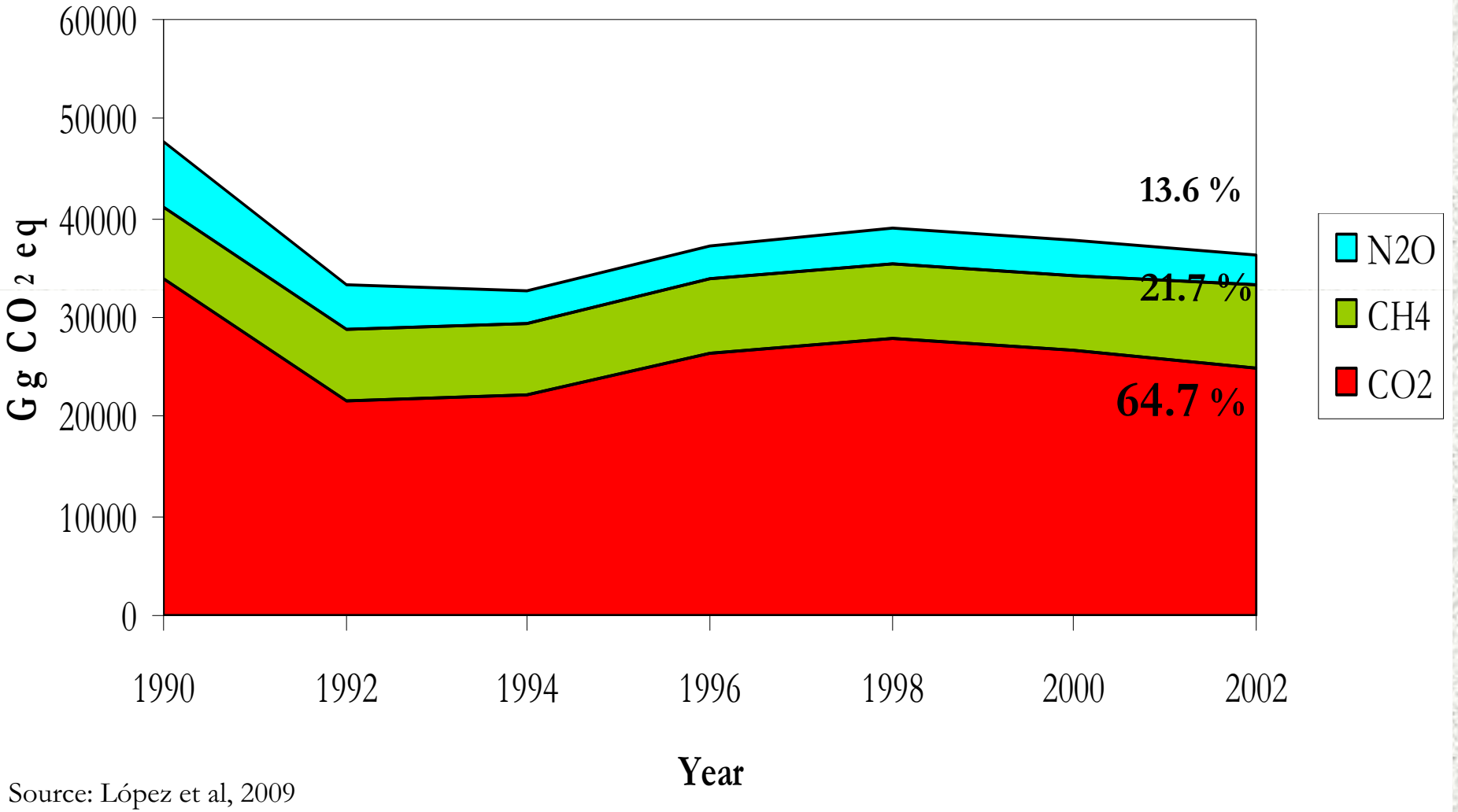
**0.09 % of the World**

# *Gross Emissions by Sector ($Gg\ CO_2\ eq$)*




Source: López et al, 2009

# *Gross Emissions*
# *(Gg $CO_2$ eq)*

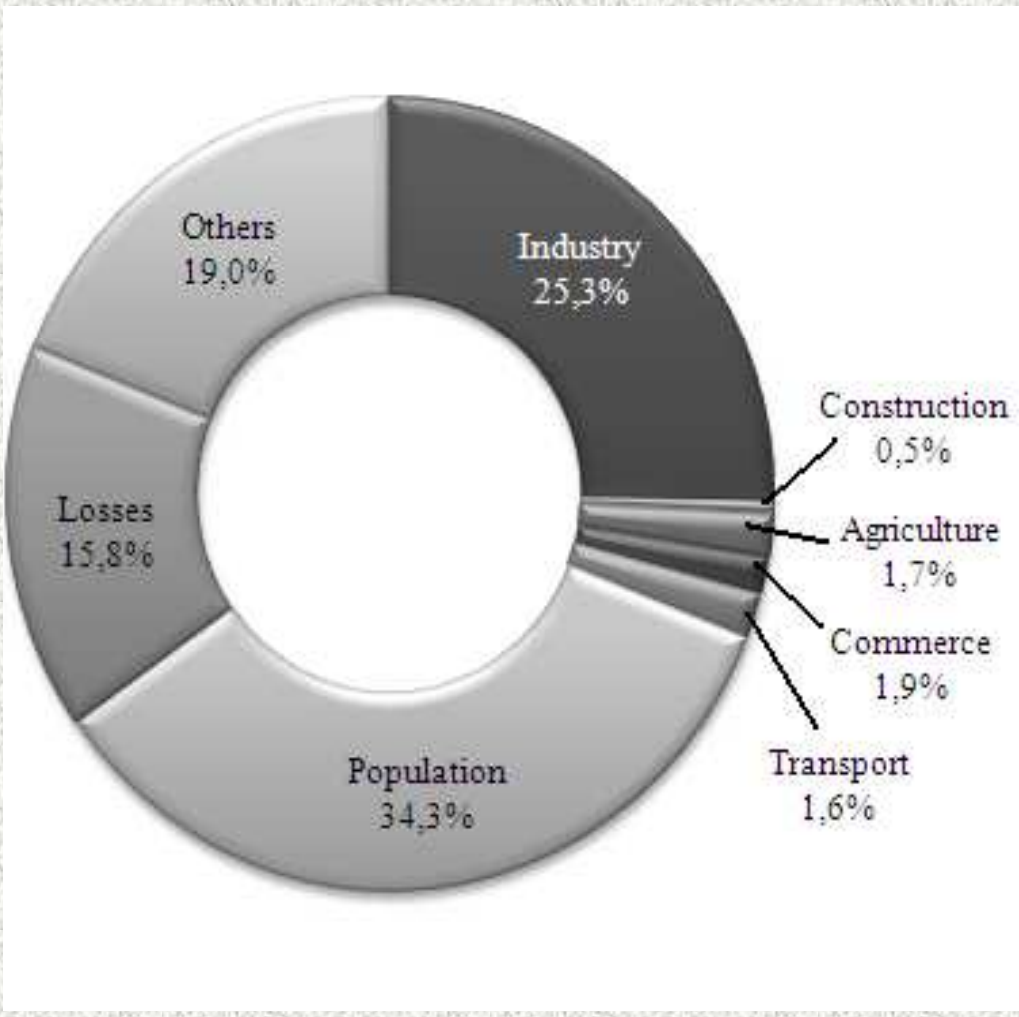



Source: López et al, 2009

# *Energy Policies and Projections*

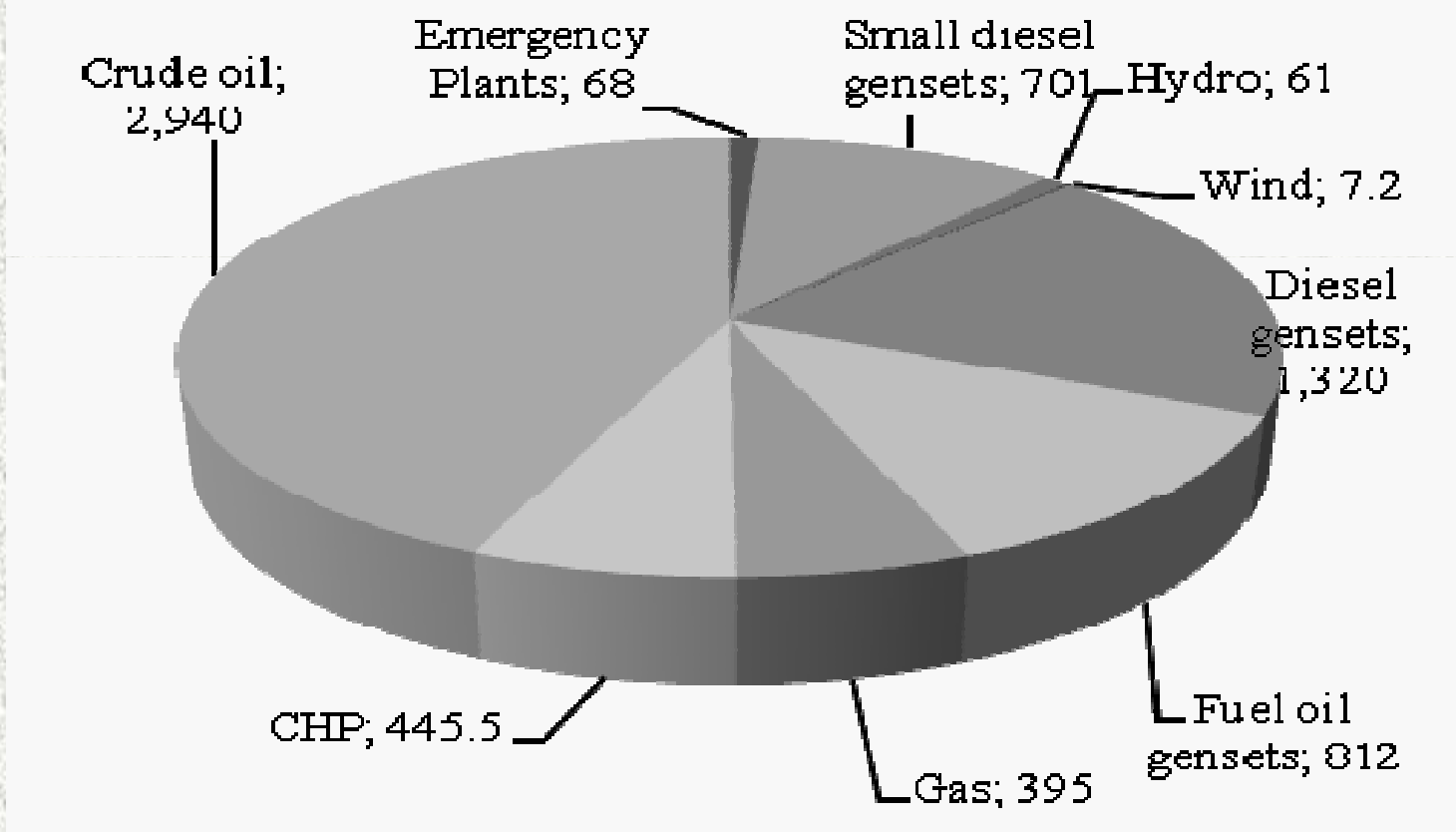
# *Electricity consumption per sectors in Cuba in 2008*

| Energy | 2008 |
|---|---|
| Power installed (MW) | 7690 |
| Access to electricity (%) | 96 |
| Gross Electricity Generation (GWh) | 17661.8 |
| Specific fuel consumption (g/kWh) | 264.2 |
| Electricity consumption (kWh/per capita) | 1571.7 |




Source: Statistical Yearbook of Cuba, 2008

# *Power installed capacity in MW (2009)*




Source: Compilation of the authors

# *Major Energy Transformation*

Frequent interruptions in oil-fired power plants, together with the impact of hurricanes on high-voltage transmission lines, caused an energy crisis in Cuba in the period 2004-2005. To overcome the situation, the Cuban Government launched an initiative called the *Energy Revolution*. Its main goals are to guarantee economic development and the energy invulnerability of the country.

# *Major Energy Transformation: aspects of this strategy*

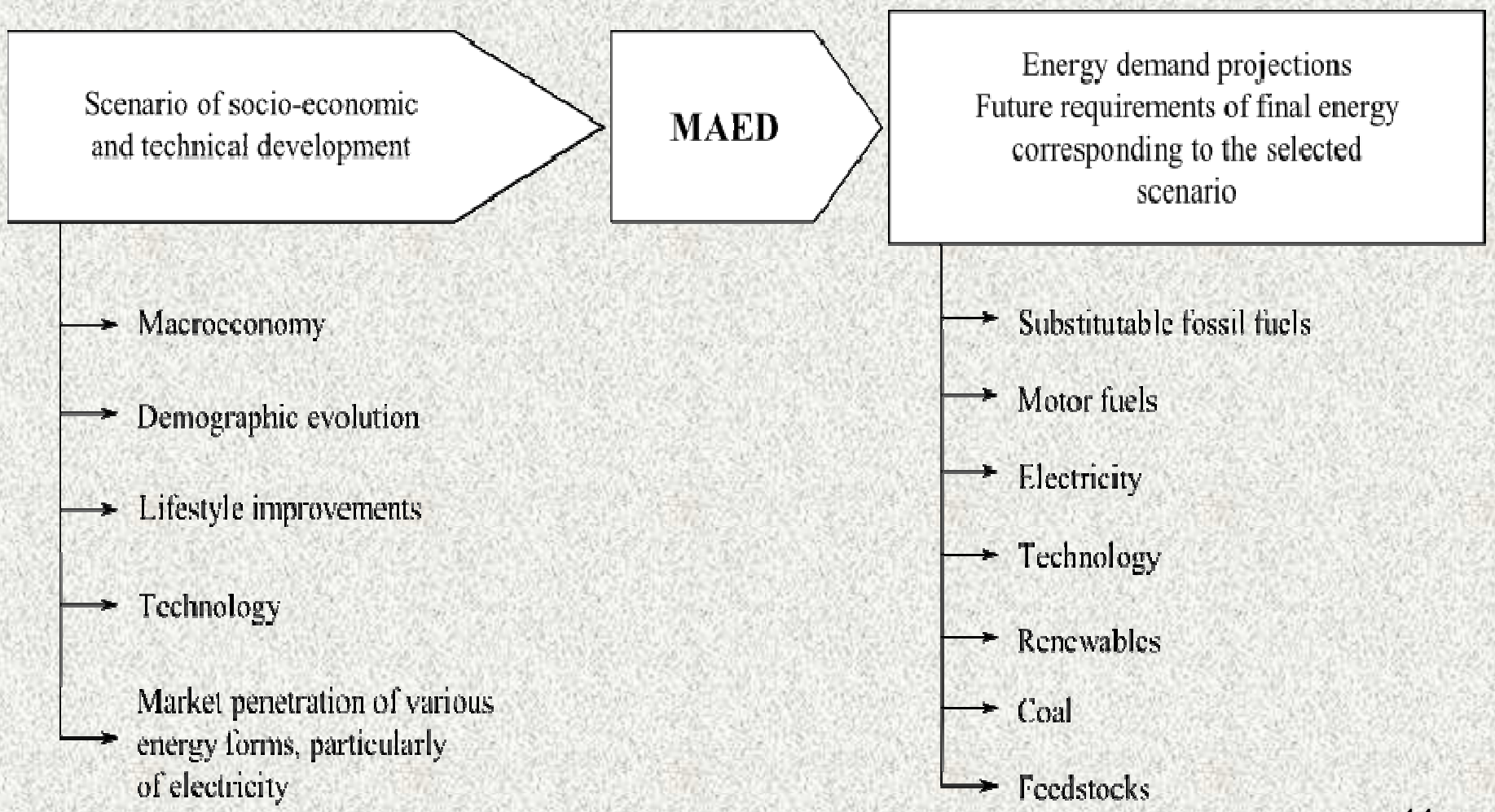
- To accelerate the introduction of renewable energy technologies.
- Distributed Generation (DG) of electricity.
- Changing over inefficient appliances.
- Since 2005, were installed 3,072 MW of new power in diesel and fuel oil generators synchronized to the National Electric System in all the provinces of the country under a DG scheme. Installation of 701 MW of emergency backup generator sets.

# *Future supply scenarios*

- In the frame of the IAEA RESEARCH CO-ORDINATE PROGRAM: “Greenhouse Gas Mitigation Strategies and Energy Options”, using the IAEA tools, MAED and MESSAGE, a set of demand and supply scenarios were developed (reference and mitigation).
- These scenarios take into account the country's energy policy.

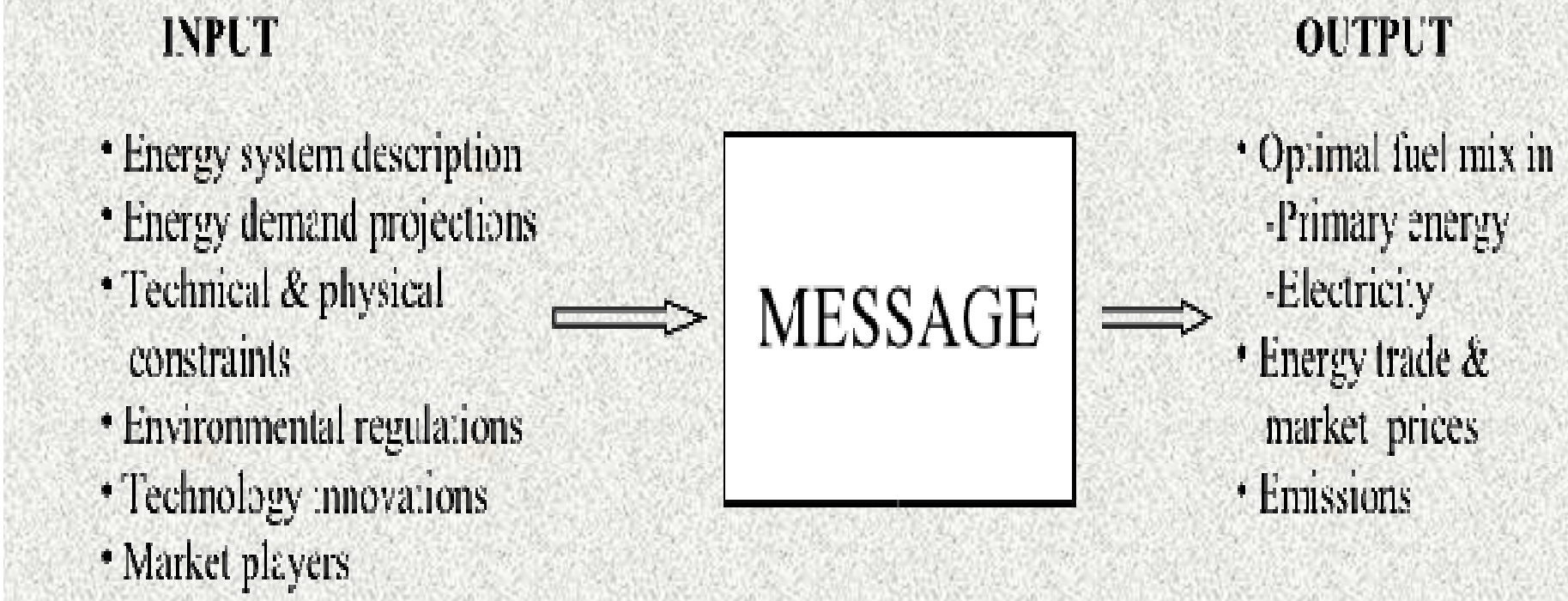
# MAED

## Model for the Analysis of Energy Demand



# *MESSAGE*

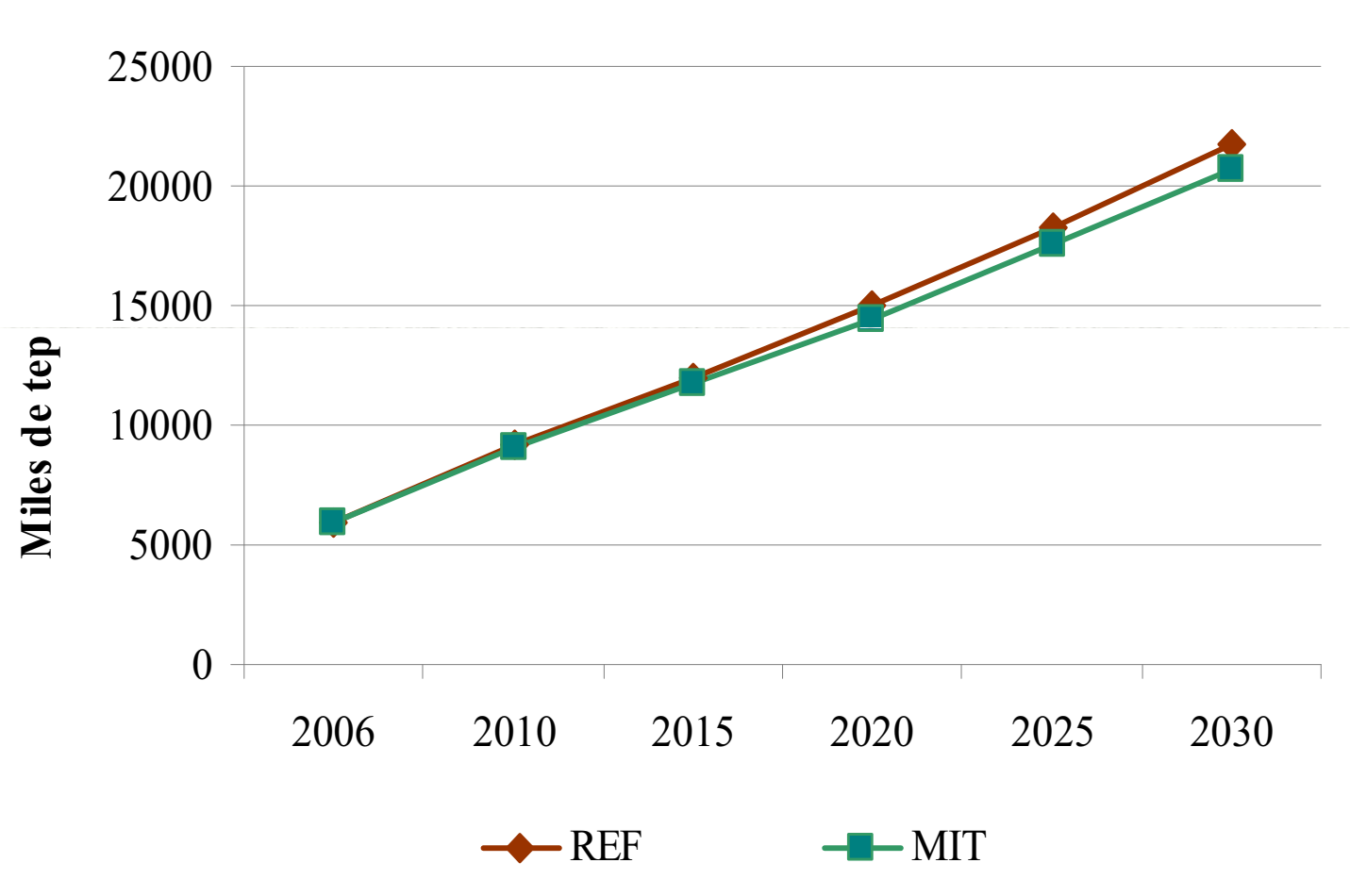
***M**odel for **E**nergy **S**upply **S**ystem **A**lternatives and their **G**eneral **E**nvironmental impacts*



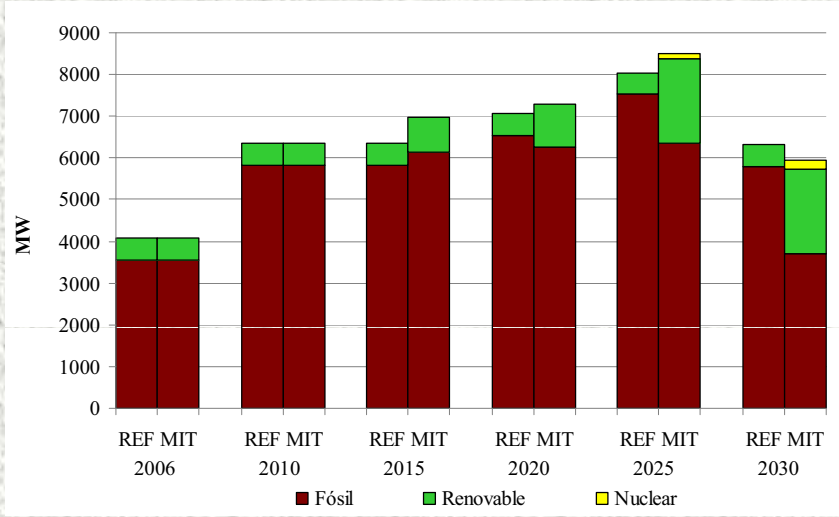
# *Main approaches for scenarios*

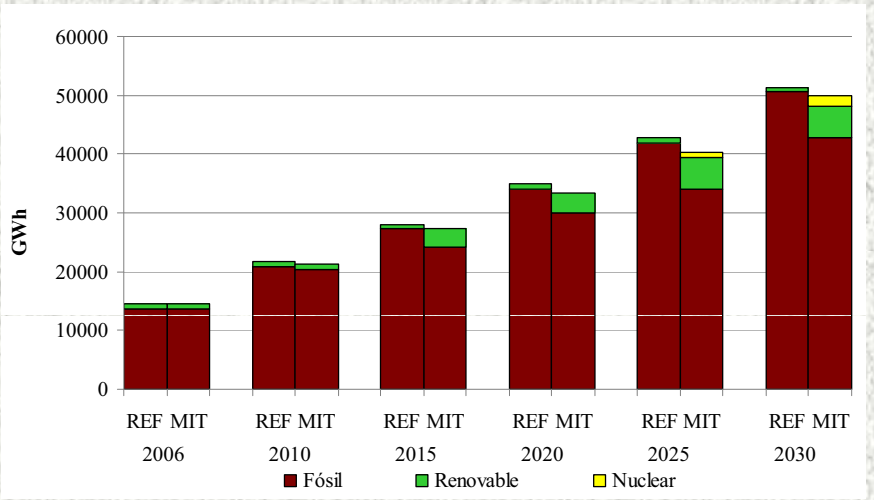
- Increase of Energy efficiency.
- Increment in the renewable energies participation.
- Increment in the use of natural gas for electricity generation incorporating more efficient technologies.
- Introduction of Nuclear Energy.

# Energy demand projection



# *Installed Capacity and Generation*




**Electricity Installed Capacity**

**Electricity Generation**

**Higher participation of the renewal energy sources**

- Increment in the use of wind energy and hydro
- Increment in the use of biomass for electricity production

**Introduction of the Nuclear Energy**

Fossil fuel participation will decrease from 97% in the Reference Scenario to 81% in the Mitigation Scenario

# *Energy System and Climate Change*

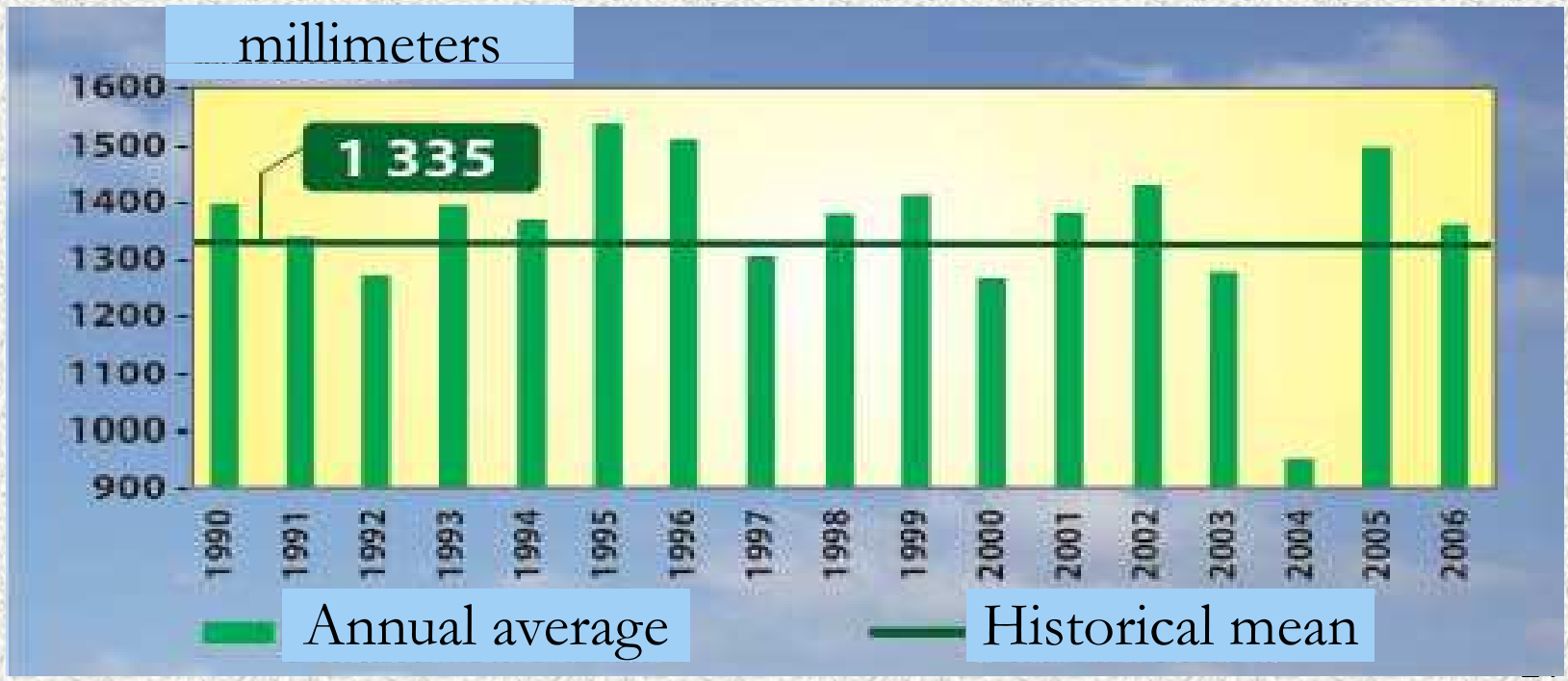
Extreme events affect the entire economical sector, include of energy sector. Depending on the kind event an energy source can be more affected than another.

# Temperature

- Recent studies show that annual and seasonal ocean surface and island air temperatures have increased by 0.6 to 1.0℃ since 1910.
- For the Caribbean, analyses shows warming ranged from 0 to 0.5°C per decade for the 1971-2004. The percentage of days having very warm maximum or minimum temperatures has increased considerably since the 1950s, while the percentage of days with cold temperatures has decreased.

# *Precipitation*

In the Caribbean, the maximum number of consecutive dry days is decreasing and the number of heavy rainfall events is increasing.



# *Sea level*

- The Caribbean region experienced, on average, a mean relative sea-level rise of 1mm/yr during the 20th century.
- Considerable regional variations in sea level were observed in the records; these were due to large-scale oceanographic phenomena and tectonic movements.
- Preliminary analysis foresee the lost of the 6% of the coastal area by 2050 in Cuba.

# Tropical cyclones

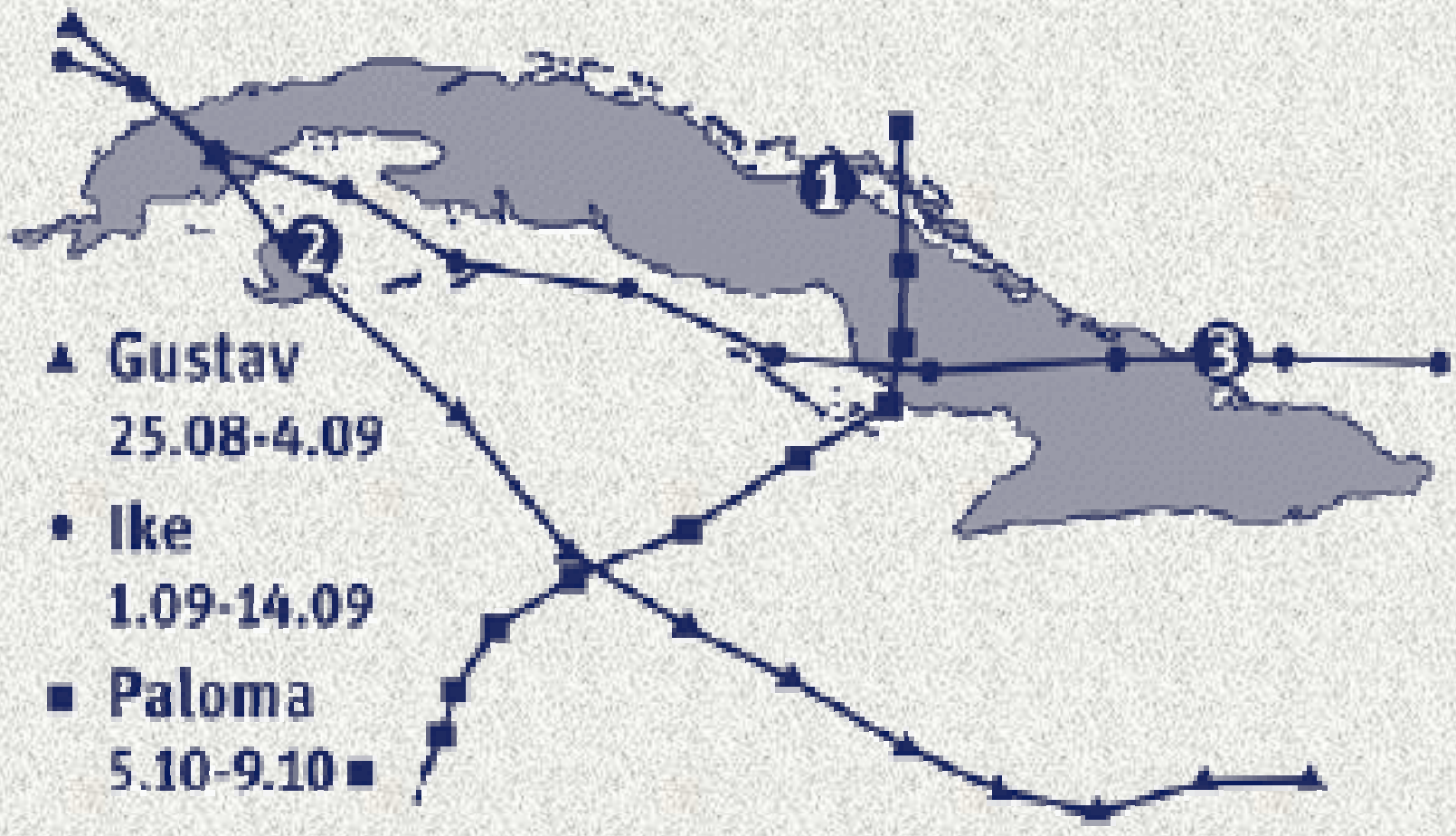
- Tropical cyclones: risk by strong winds, severe rains and coastal storm surges.
- It is expected with the increment in the sea surface temperatures, favorable conditions for the formation of vigorous tropical hurricanes. Variations in tropical and extra-tropical cyclones, hurricanes in many small-island regions are dominated by ENSO and decadal variability which result in a redistribution of tropical storms and their tracks, so that increases in one basin are often compensated by decreases in other basins.

# *Tropical cyclones (cont)*

Quantity of hurricanes that have affected the island by region

| Period | Cuba | Western | Central | Eastern |
|---|---|---|---|---|
| 1800-2006 | 110 | 80 | 62 | 42 |

# *Tropical cyclones 2008*



# *Tropical cyclones*
# *Saffir-Simpson classification*

| Category | Central pressure, hPa | Maximum wind speed, km/h |
|---|---|---|
| 1 | 980 | 118-153 |
| 2 | 965-979 | 154-177 |
| 3 | 945-964 | 178-209 |
| 4 | 920-944 | 210-250 |
| 5 | < 920 | > 250 |

# *Electricity grid system*

Electricity grid system has been the more affected by the hurricanes in Cuba.


SEA

# *Solar*

- The use of solar energy for thermal purpose is getting importance in Cuba, and it is expected an increment by 2010, reaching a share of 20 % and 30% in 2030 in residential and services sector respectively.
- Solar energy is extremely vulnerable to tropical storm due the damage to the solar facilities. During 2008 and as consequence of the impact of the hurricanes Gustav and Ike, one of the most demonstrative project of the use of solar energy for thermal propose was severe affected.



Solar Heater

# *Wind*

- It is expected an increment in the use of wind energy. In the projected scenarios wind energy was evaluated considering available up to its maximum potential (1200 MW of installed capacity).
- Wind energy is vulnerable to the change in the wing patterns and to the occurrence of tropical storm due the damage to the wind power generators. During 2008 and as consequence of the impact of the hurricanes Gustav and Ike, some of the wind facilities were affected. Maximums winds were 15% higher that the reported by the manufacturer.

Before new contingencies it is suggested:

To design and to improve the mechanism of bladed immobilization to avoid their rotation, and to reinforce the protection of the external cover.

# *Hydro*

- It is expected an increment in the use of Hydro energy. In the projected scenarios hydro energy was evaluated considering available up to its maximum potential (360 MW of installed capacity).
- The hydropower generation potentials are seriously affected by the drought and by the occurrence of tropical storm due the damage to the facilities.
- During drought 2004-2005, the hydro potential was reduced in a 15%.

# *Biomass*

- Biomass potential is affected by the drought and by the occurrence of tropical storm due the damage to the facilities.
- It is expected to increment of the Biomass use in electricity generation with the introduction of more efficient bagasse power plant (100 kWh per tonne of sugarcane crushed)
- Nowadays the biomass potential increase after the Sugar Industry recovery

# *Fossil fuels*

- Fossil fuel facilities, include electricity and fuel prospecting, are affected by the increment of the sea level because most of the them are located in the coastal areas.
- Also are affected by the occurrence of tropical storm due the damage to the facilities.
- The increment of temperature and hot waves, reduce the thermoelectric power production efficiency.

# *ADAPTATION OPTIONS AND POLICIES: Results*

During the 2008 hurricanes, in spite that the damages to the power plants installation were high, the fuel oil and diesel engines installed did not have serious affectations and its use allowed to support essential activities for the human life in the most affecting areas.

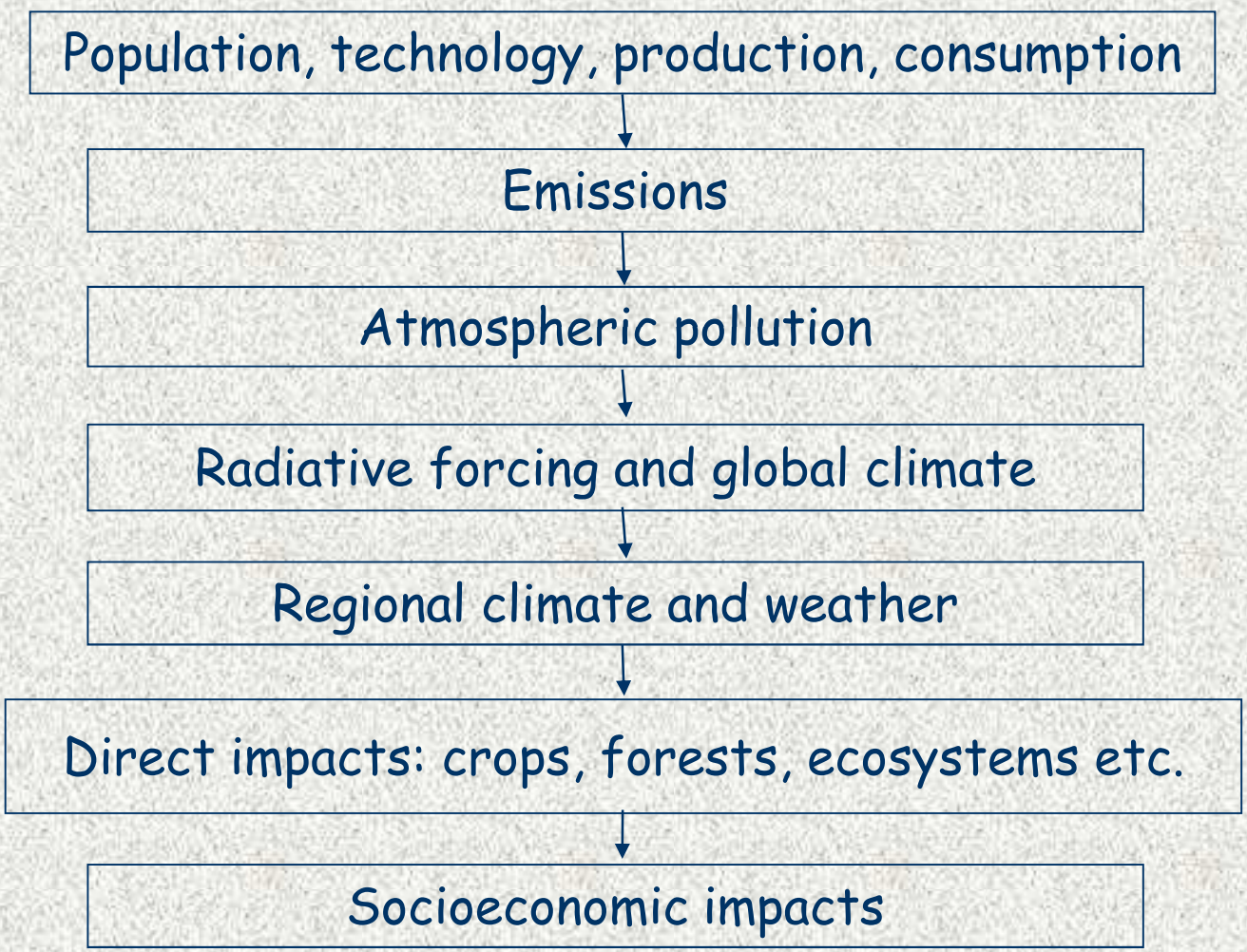
# *Climate change: Integrated Assessment Models*

# *Climate Change Externalities*

- Climate change can be considered as an externality associated to GHG emissions since it is expressed in costs that are not assumed by those who generate the emissions. However, it has some essential characteristics who distinguish it from other externalities, for instance: its causes and consequences are global, impacts are at long term and they remain for long periods of time, uncertainties and risks of impacts are the key of the assessments
- The Impact Pathway Methodology, widely applied to the externalities assessment of the air pollution at local and regional scales, is also valid to estimate the global impact due to GHG emissions.

# *Impact Pathway Methodology*

## *Global Atmospheric Pollution*



# *INTEGRATED ASSESSMENT MODELS*

## *GENERALITIES*

- Modelling the monetary impacts of climate change globally is very challenging: it requires quantitative analysis of a very broad range of environmental, economic and social issues. Integrated Assessment Models (IAMs), though limited, provide a useful tool
- There are several IAM, with differences in the scope and the level of detail
- PAGE2002, RICE and FUND. referenced in important studies like the IPCC Third Assessment Report, the Stern Review and the ExternE project

# *INTEGRATED ASSESSMENT MODELS*
## *GENERALITIES (Cont)*

- The results from the models depend of the considerations used, mainly: 1) how are assessed the costs in poor regions? and 2) what are the assumptions concerning the societies capability for reducing the costs by the adaptation to the climate change?
- In all the IAM, the input and outputs are given by regions and globally. The costs estimated are subtracted from the GDP projected.
- The projections obtained illustrate the risks involved, even though the uncertainties are high.

# *MAIN INTEGRATED ASSESSMENT MODELS*

- PAGE2002
  - Policy Analysis of the Greenhouse Effect 2002,
  - Chris Hope, Cambridge University
- DICE y RICE
  - Dynamic Integrated model of Climate and the Economy
  - Regional dynamic Integrated model of Climate and the Economy,
  - William Nordhaus, Yale University.
- FUND
  - Climate Framework for Uncertainty, Negotiation and Distribution,
  - Richard Tol, Hamburg University,

# *The FUND Model*

- Even though no model is absolutely superior to the others, each one has strengths and weakness and, under similar conditions, they predict comparable results; we identified the FUND model as the best option for Cuba.
- FUND include a more detailed impact assessment
- A FUND version for country is under development necessary for evaluated the impact on the climate change costs of local strategies.

# FUND Model

## Impact assessment module

Model has methodologies to estimates the impact of the Climate Change in:

- Agriculture
- Forestry
- Ecosystems
- Water resources
- Energy consumption
- Sea level rise
- Human health: Diarrhoea
- Human health: Vector-borne diseases
- Cardiovascular and respiratory mortality
- Extreme events (Tropical storms)

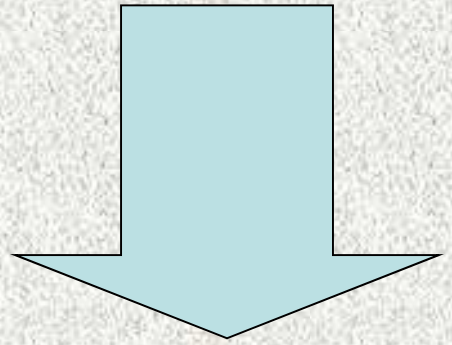
# FUND Model

## Current options for its implementation

Its not possible to separate a country from the FUND regions

- To select among the emission scenarios included in the FUND input data those with similar growth rates to our scenarios, and to modify them with the emissions reduction resulting of our mitigation scenario and to evaluate the impact of the mitigation
- To generate the emissions scenarios for a longer period beyond 2030, estimating data for the whole region
- To consider the GHG reductions as a negative addition in the add.dat file

# *Main difficulties for the adoption of a model in the region*



***To be carry out in the frame of the Second National Communication to UNFCCC***

- They are global or regional models, their input data and parameters used in the main equations are established for the regions that each model provides.
- Models created from the perspective of developed countries.
- Regions
  - There are differences (socioeconomic, geographical, etc.) among the countries that form a region.
- Review the settings of scenarios to use, if these coincide with the forecasts for the region.
- Caribbean and Cuba Emissions could be very small depending on the region.

- Precipitation are not modeled, nor the impacts associated with changes in this variable such as droughts and floods.
- Change in the wind regimes are not modeled.
- Most of the model does not take into account the impact of extreme events, except FUND 3.3 that evaluates tropical storms.
- Take into account other important impacts for the region that are not included.
  - Consequences for renewable energies of the changes in precipitation and wind patterns
- Given the importance of adaptation for Cuba and the region, needs to improve its modeling.

# *Conclusions*

- Energy projection have taking into account the current energy policies.
- Nowadays tropical cyclones are weather events that most affect the island.
- Fuel oil and diesel engines installed allowed to support essential activities for the human life in the most affecting areas by cyclones during 2008 season.

# *Conclusions (cont)*

Nowadays is not possible, without making great efforts, to adopt a comprehensive IAM to assess the impact of mitigation and adaptation. Work continues in this way to adapt existing methodologies and models according to the particularities of the Caribbean

***Thank you***

# *Affectations provoked by the hurricanes Gustav and Ike to the solar heaters installed in the territories of the Youth's Island and Pinar del Rio*


EN
CADA
CUADRA
UN
COMITE
EN
CADA


aquapla

# General recommendations

***STAGE 1***

- ***To execute the projects correctly.***
- ***To settle and to anchor the equipment and the pipes appropriately.***

***STAGE 2***

- ***To keep the tanks full with water.***
- ***To retire the solar heaters.***

Back