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Joint ICTP-IAEA Advancing Modelling of Climate, Land-use, Energy and Water (CLEW) Interactions

7 - 11 October 2013

Case studies to analyze Climate, Land, Energy, Water (CLEW) interrelations in Cuba

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Joint ICTP/IAEA School on
Advancing Modelling of Climate, Land-use
Energy and Water (CLEW) Interactions

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ICTP, Miramare - Trieste, Italy

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Overview

- Background information
- Current status and projections:
  - Climate
  - Land Use
  - Energy
  - Water
- CLEW project
- Modelling Tools

Policies and Strategies

Guidelines of the Economic and Social Policy of the Government of the Republic of Cuba relative to land use (agriculture), water, energy and climate change (mainly adaptation).

Purpose: to update the Cuban economic model.

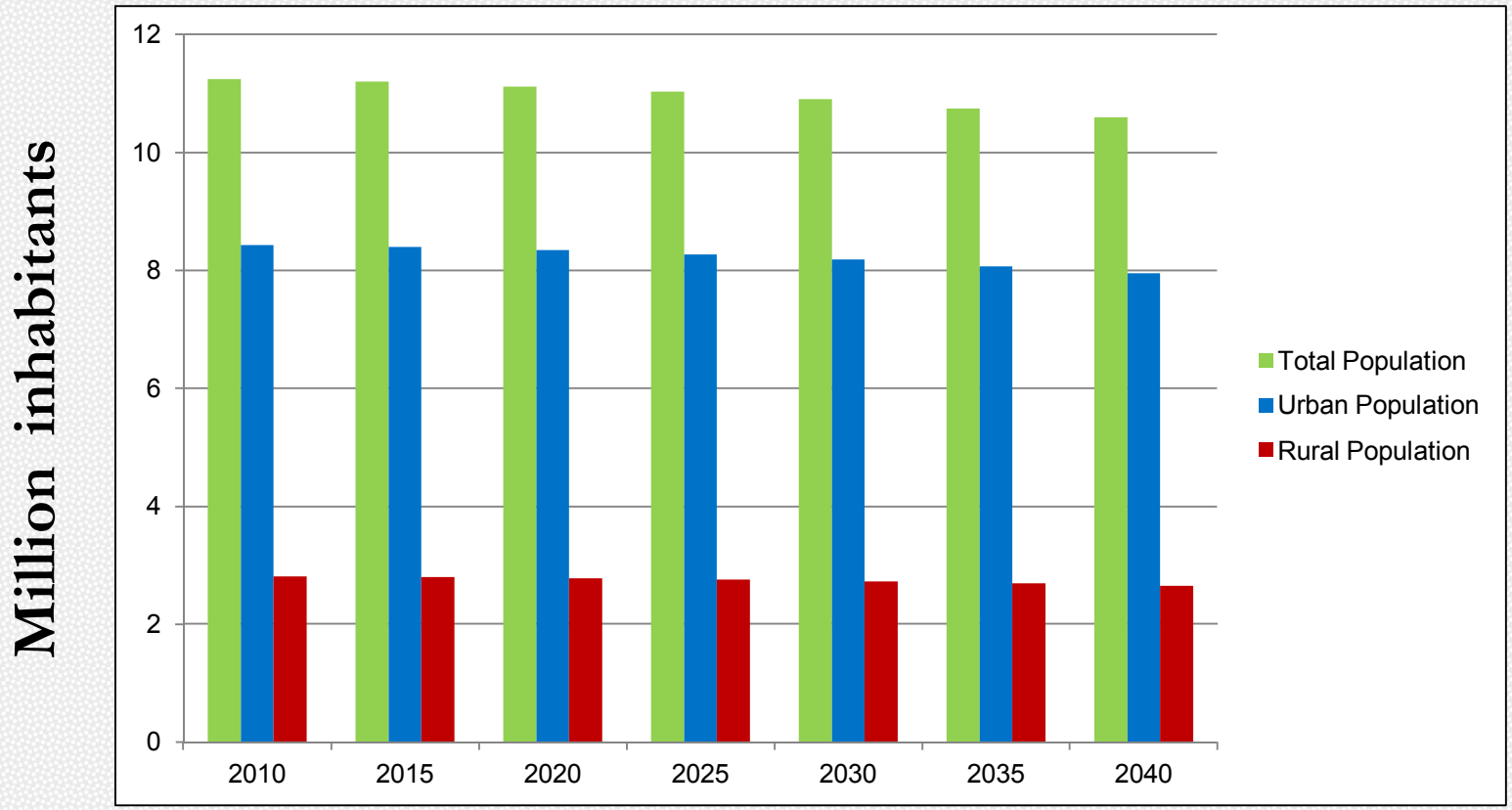
Main aspects: find solutions for sustainable development in the longer term, leading to a higher energy and food self-sufficiency, efficient use of human potential, a high competitiveness in traditional production, and the development of new productions of goods and services.

Background Information

- Surface extension: 109 866 km^2
- GDP (2011) 48 745 MCUP
- Total population (2011) 11.24 million

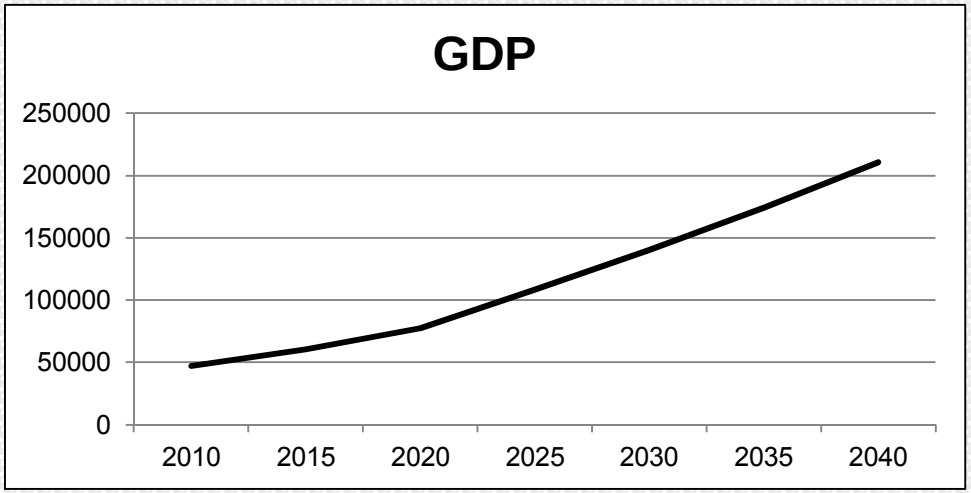
Source: ONE, 2012

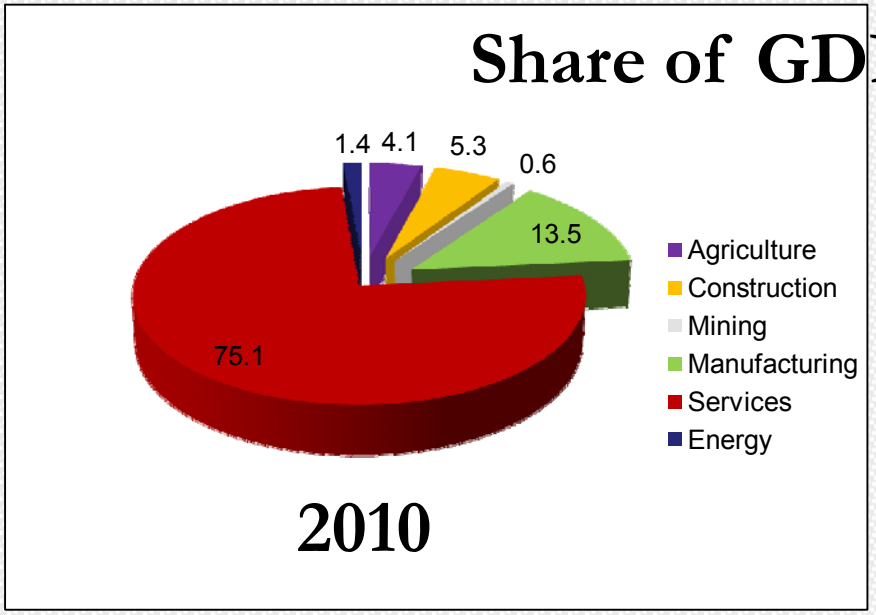
Population Projection

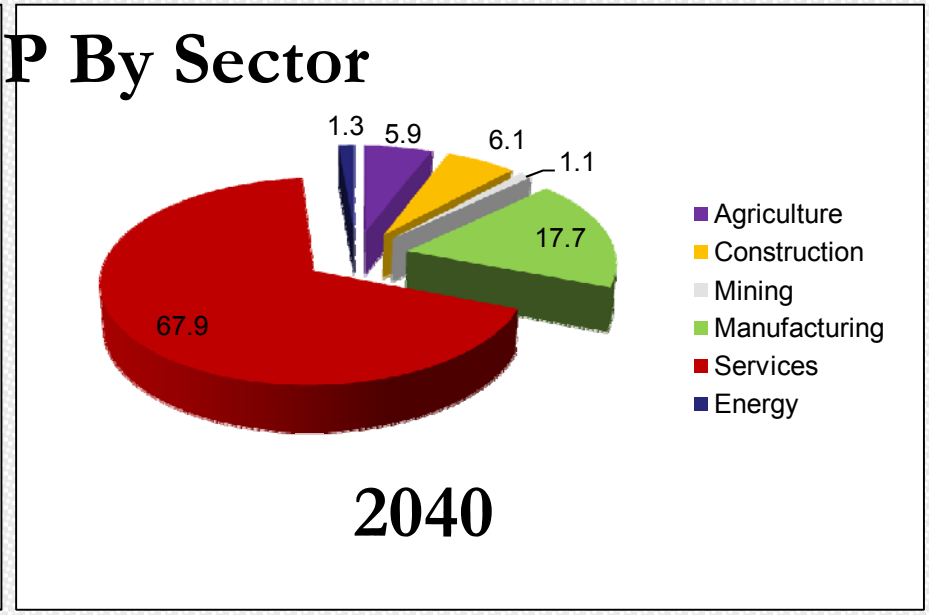


Source: Perez. D, et al 2012

GDP Projected (MCUP)







Source: Perez. D, et al 2012

Climate

"Cuba geographic characteristic, lengthened and narrow, makes it especially vulnerable to the effects of climate change, sea level rise and extreme weather"

Temperature

Absolute maximum and minimum recorded

Region	Maximum	Minimum
Western	38.1 ^{0}C	0.6^{0}C
Central	38.5 ^{0}C	0.8^{0}C
Eastern	38.8 ^{0}C	3.0^{0}C

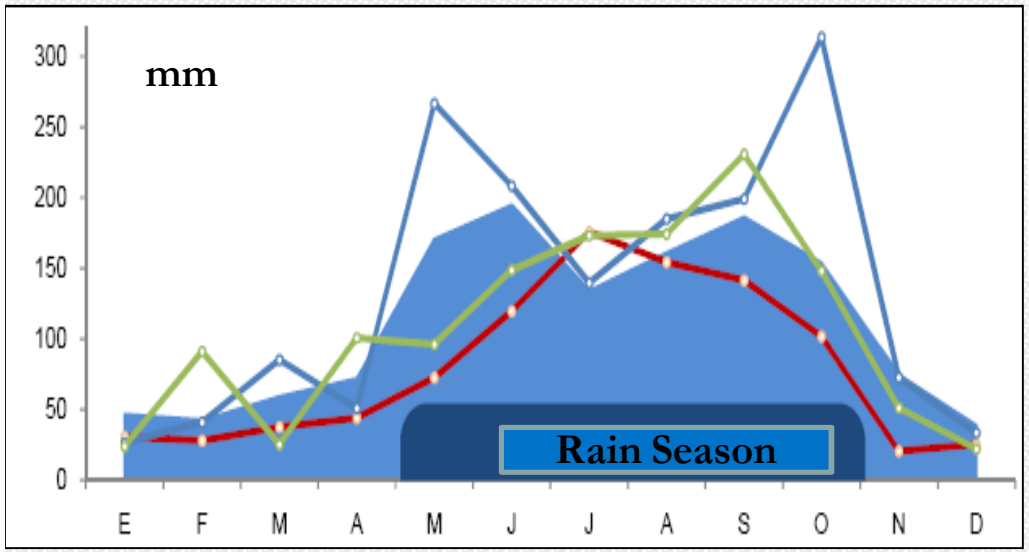
Source: ONE,2010

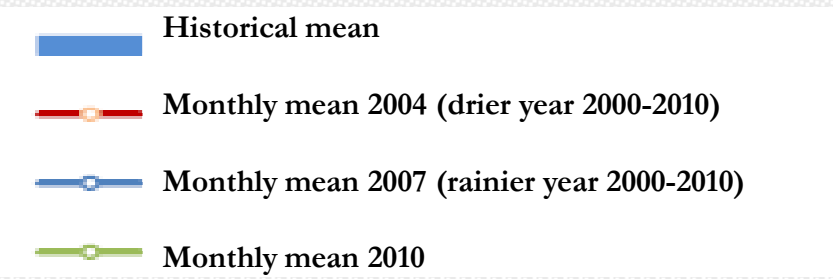
Temperature

- From 1951 to 2010, average increment of 0.9 °C in media temperature and in 1.9 °C in the minimum.
- The percentage of days having very warm maximum temperatures has increased considerably since the 1950, while the percentage of days with cold temperatures has decreased.

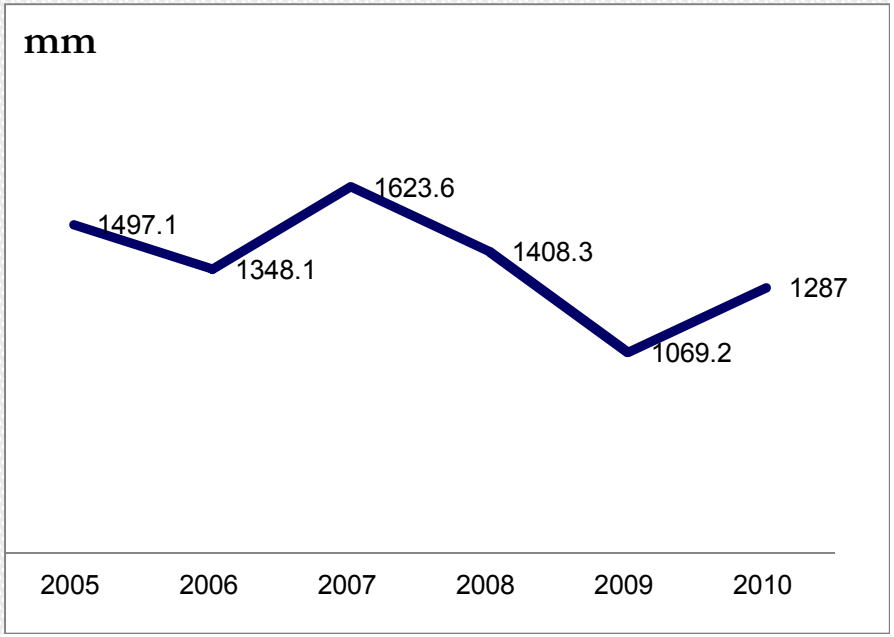
Source: IPCC, 2007

Mean Monthly & Total Rainfall





- The maximum number of consecutive dry days is decreasing.
- The number of heavy rainfall events is increasing
- Increment of the drought lengthy and intensity (May, 2003 to May 2005)



Source: ONE,2010

Sea level

- On average, a mean relative sea-level rise of 1.43 mm/yr during the last 40 year of the 20th century, with maximum of the 2.14 mm.
- Preliminary analysis foresee the lost of the 6% of the coastal area by 2050 in Cuba.

Climate Variations in the Caribbean Region

Climatic variables	Climatic scenario
Temperature	Increment from 0,8 ^{0}C to 2,5 ^{0}C in 2050 and from 0,9 ^{0}C to 4 ^{0}C in 2080
Precipitation	Variation Range from -36.3% to 34.2% in 2050 and from -49,3% to 28,9% in 2080
Sea level rise	Increment of 35 cm during the century
Extreme events	Increment of the frequency from 5% to 10% during the century

8- 44cm 2050

20-95cm 2100

- Persistent increment of events climatic extreme as tropical hurricanes.
- Increment of the rains in 10%
- Increment in the number of serial dry days

Source: IPCC, 2007 and CEPAL 2010

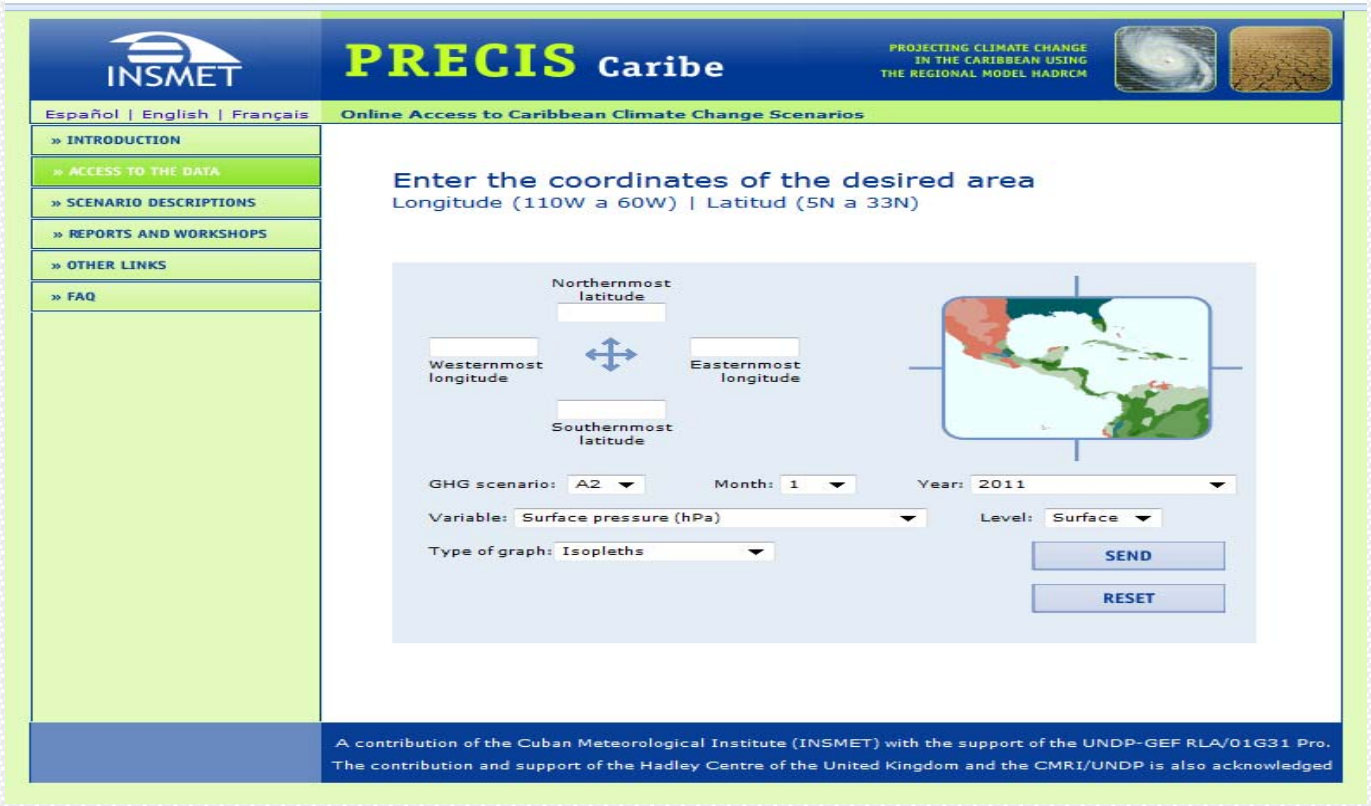
Previous Cuban studies

1. National studies on Disaster Risk, Exposure and Vulnerability:
   - Flooding by heavy rains
   - Floods by sea penetrations
   - Strong winds
   - Wildfires
   - Landslides
   - Droughts

Previous Cuban studies

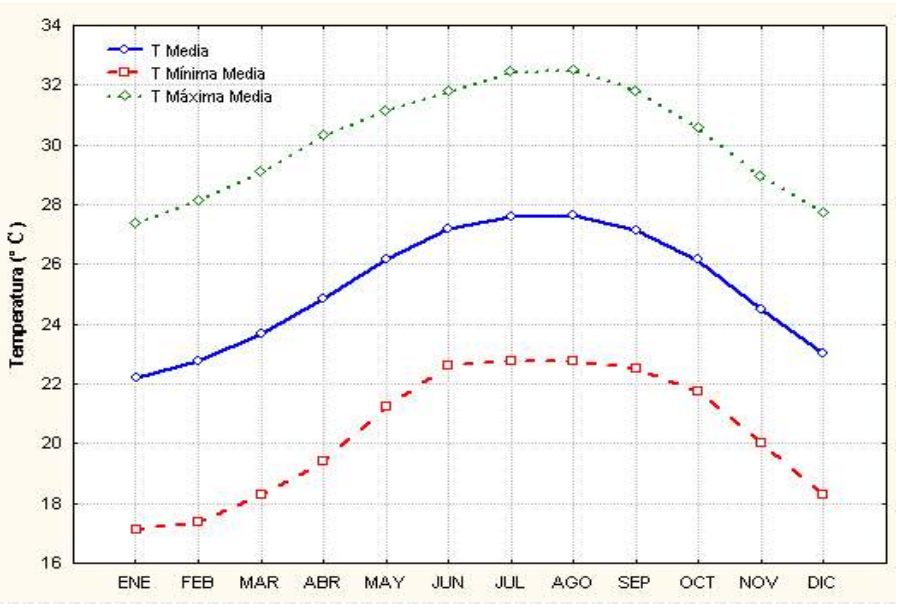
2. I and II National communications to UNFCCC,
3. Impacts and adaptation studies,
4. **PRECIS** Regional Climate Model for Central America, Mexico and the Caribbean

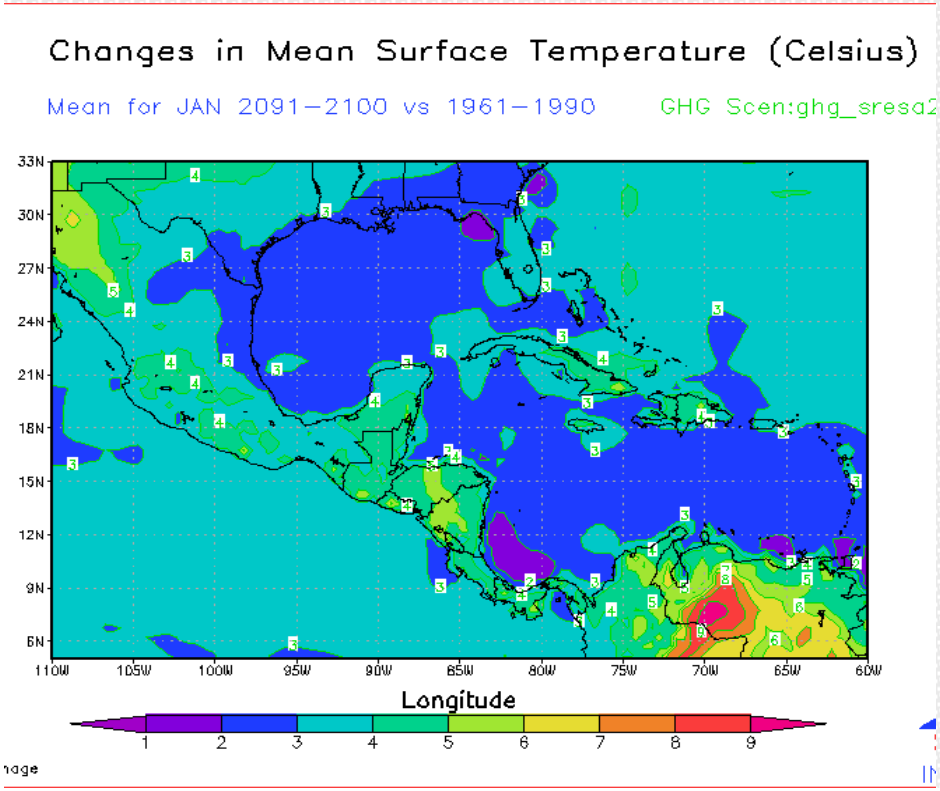
PRECIS (Providing REgional Climates for Impacts Studies)

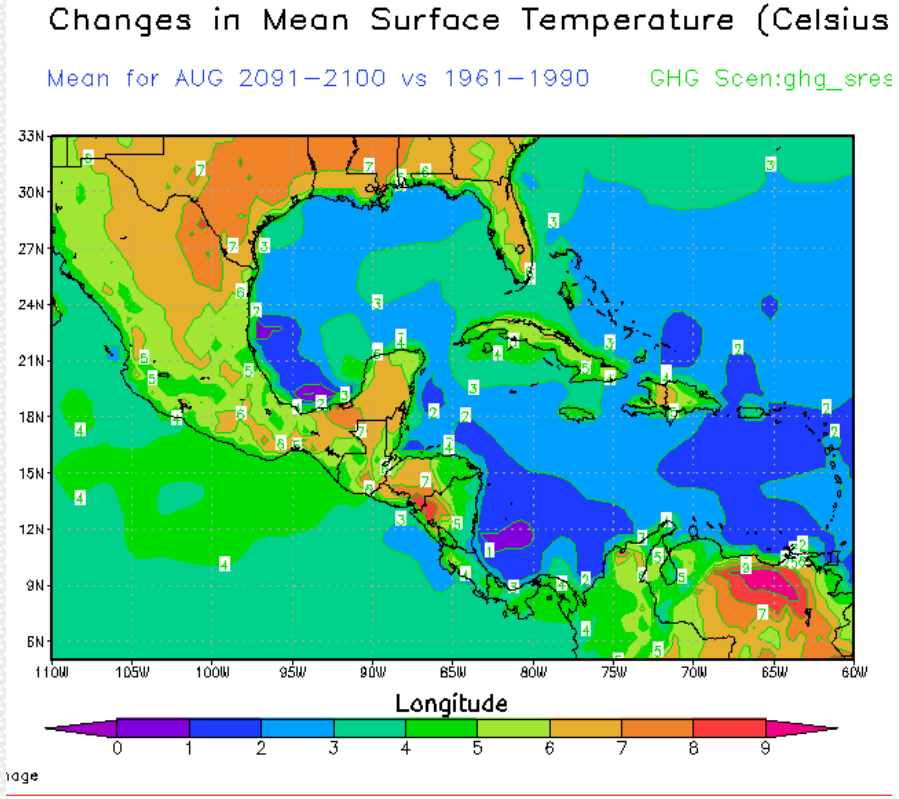


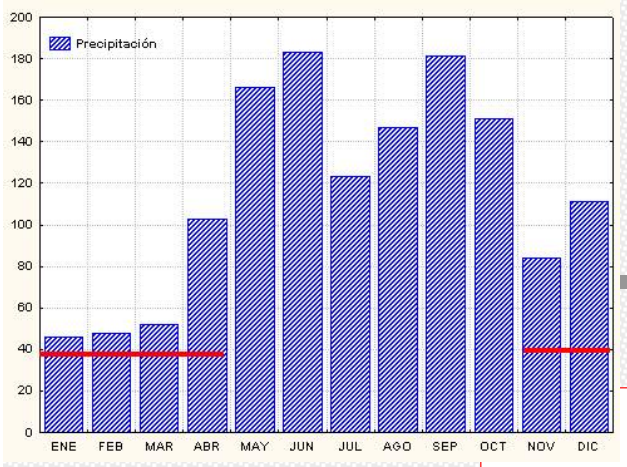
http://precis.insmet.cu

Temperature

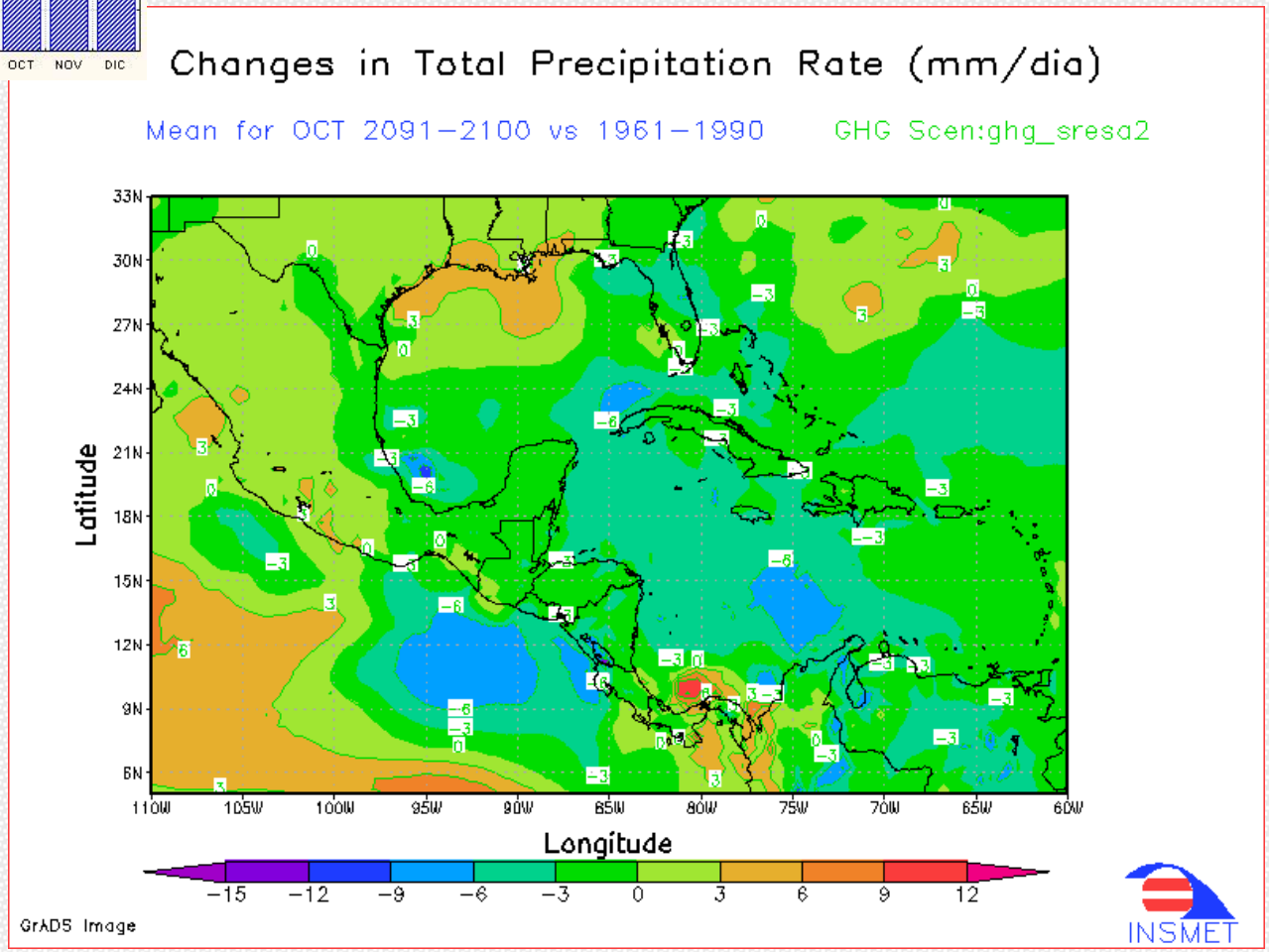




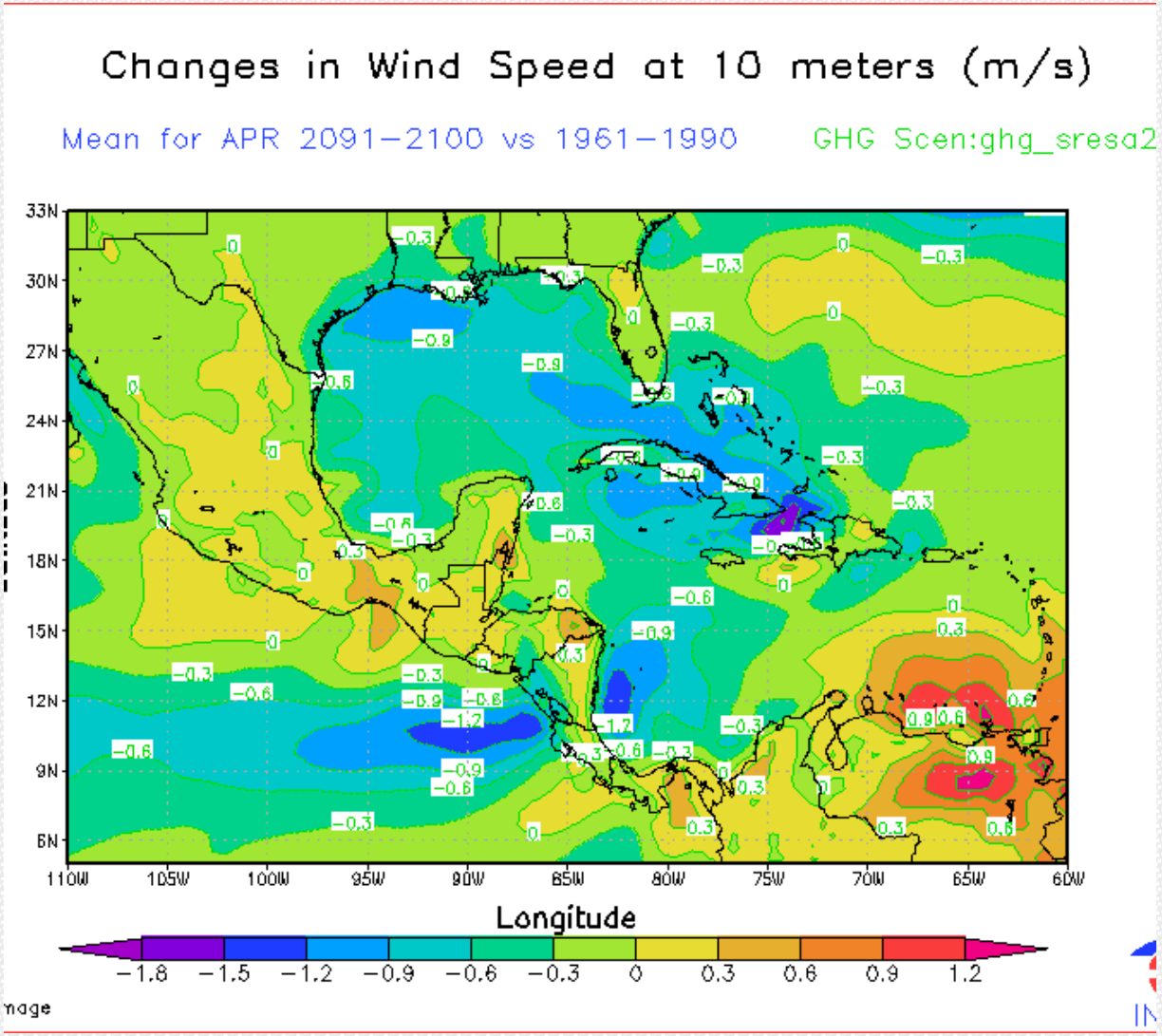




Precipitation



Winds



- A little decrement in the wind speed

Tropical Storms & Hurricanes

- 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.
- The first decade of the century have been the most active in Cuba since 1800.

PERIOD/CATEGORY (Saffir – Simpson scale)	1800-2012	2003-2012
Total	**115**	**12**
SS1 (118-153 km/h)	56	3
SS2 (154-177 km/h)	27	-
SS3 (178-209 km/h)	17	1
SS4 (210-250 km/h)	12	5
SS5 (≥251 km/h)	3	3

Year	Hurricane	Total Lost, Millions USD
2004	Charley (August), SS4	2 145,8
	Ivan (September), SS5	
2005	Dennis (July), SS4	3 036,0
	Rita (September), SS5	
	Wilma (October), SS5	
2006	Ernesto (September), SS1	95.1
2007	Heavy rains and tropical storm Noel (October), SS1	1 155,4
2008	Fay (August), tropical storm	9 759
	Gustav (September), SS4	
	Ike (September), SS4	
	Paloma (November), SS4	
2012	Isacc (August), SS1	No official report yet
	Sandy (October), SS3	

115 in 213 years, 0.54/year
12 in last 10 years, 1.2/year

Sources: Tropical Hurricane/Summary season, Cuban Meteorological Institute, www.insmet.cu
National Hurricane Center, www.nhc.noaa.gov /
Environmental panorama, Cuba 2011, Office for National Statistics

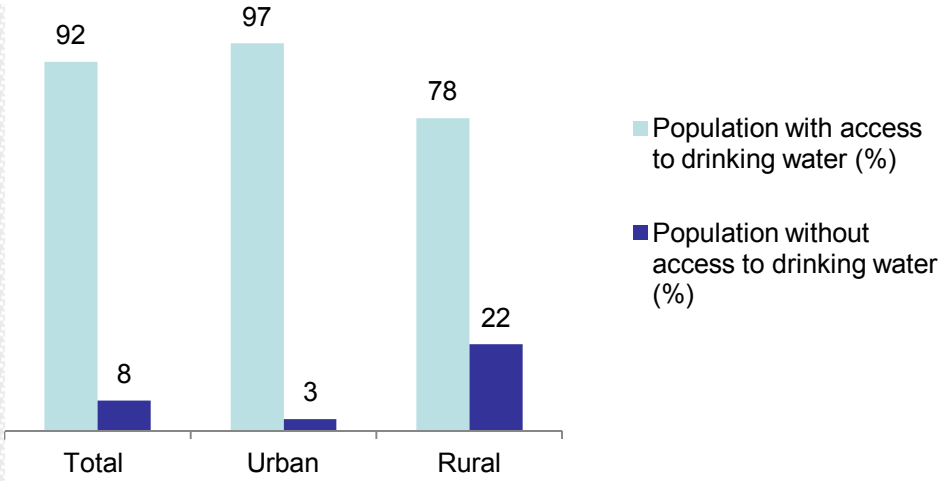
Water

Availability of water

Specific water availability index: 1.4

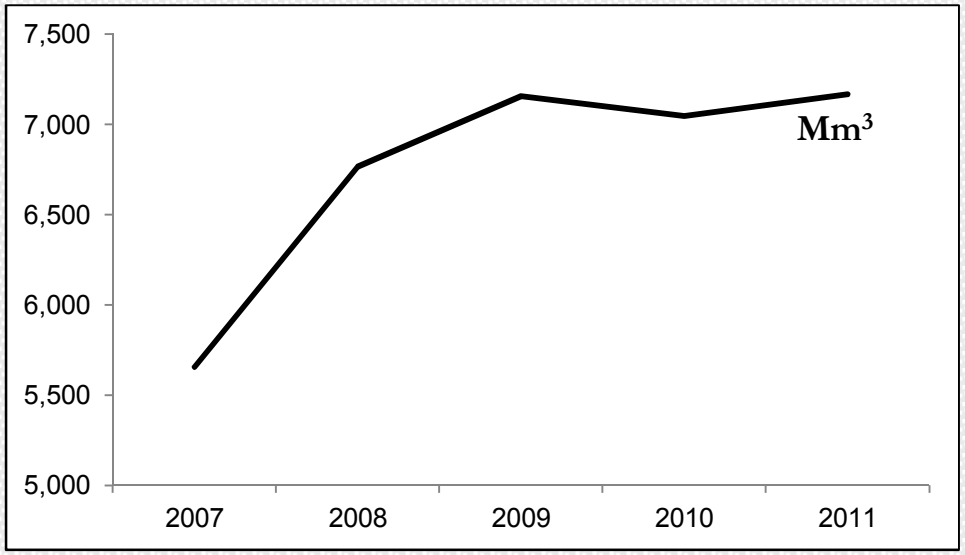
(very low availability)

Source: Shiklomanov (1998)

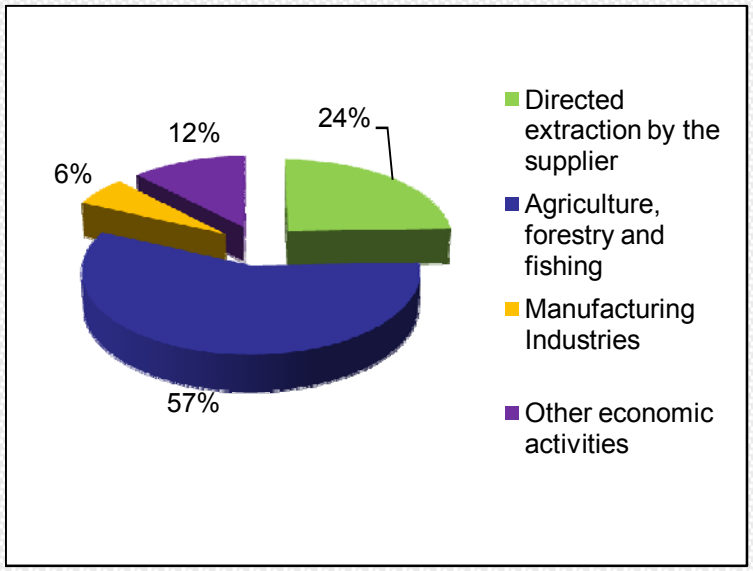


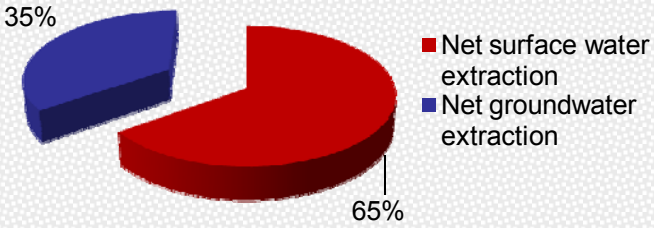
Water withdrawals

Net water withdrawals



According to its use





Source: ONE,2011

Water projections

Its expected an increment in the water demand. However in short term it is expect a reduction in the water withdrawals, policies are focuses to reduce the currently losses, around the **50%**.

Water and Climate Change

- Expected impacts:
  - Changes in the precipitation regimen.
  - Impact on water bodies by sea level rise.
  - Relative reduction in original flows and declining natural self-purification capabilities.

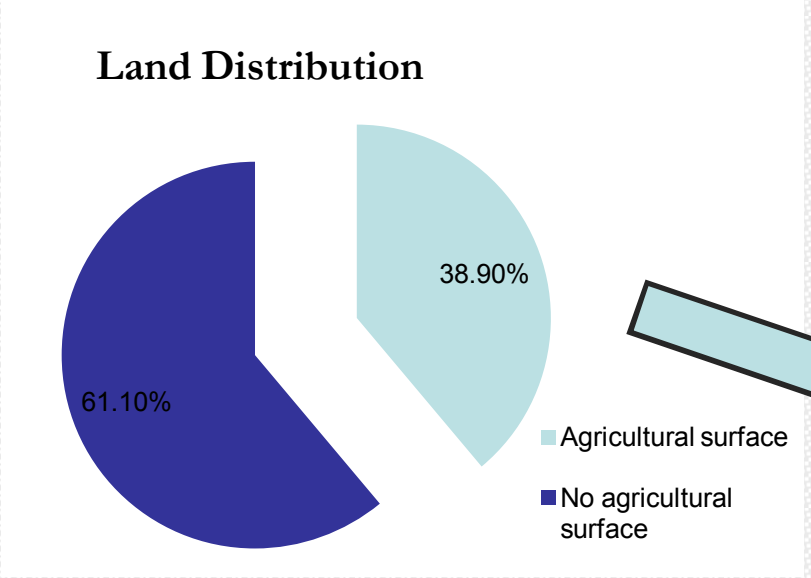
Land Use

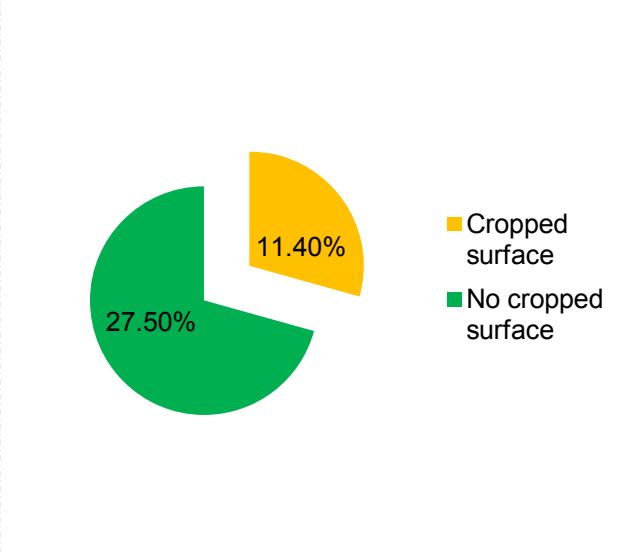
Land-use

Global Land Cover Characteristics Data Base

- Urban or built-up land
- Crops and pastures
- Grassland
- Savannah
- Forest land
- Water body
- Forested wetland

Land distribution and its use





Total Land (10^3ha)	**6,088.9**
Agricultural surface	**2,371.2**
No Agricultural surface	**3,717.7**

Source: ONE, 2011

Unused land: 627.2 10^3ha (10.3%)

Land-use projections

- Its expected an increment in the food production to reduce importations.
- To increase the lands for rice and potatoes production (short term).
  - **176.6*10^3ha +40*10^3ha**
- To restore the sugar sector.
  - **506.1*10^3ha until level of 1984/1985 1347.8 10^3ha ?**
- To reduce the water consumption in agriculture (short term).

Source: UN RISO, 2012

Agriculture and Climate Change

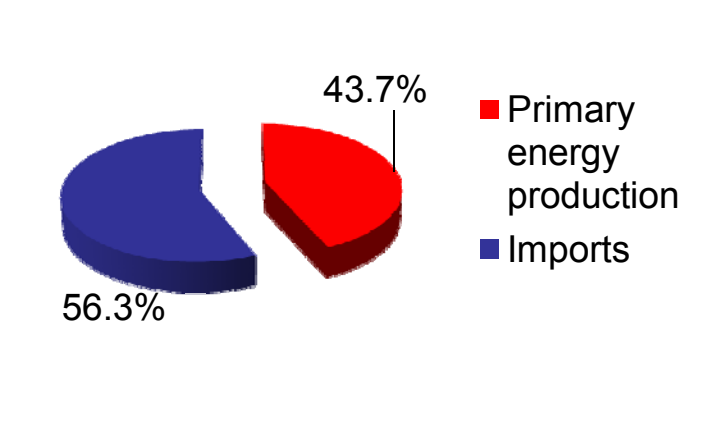
- Progressive reduction in agricultural yields due to reduced water availability for irrigated crops.
- Its expected an increment in agricultural pests and a reduction in potato yield as a result of temperature rise.

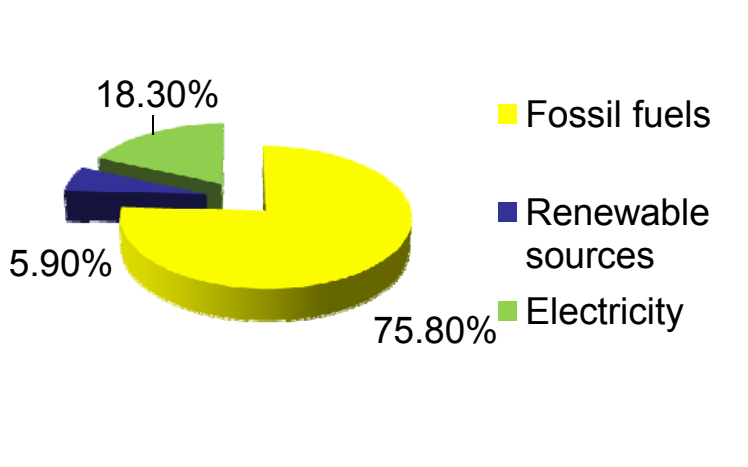


Energy

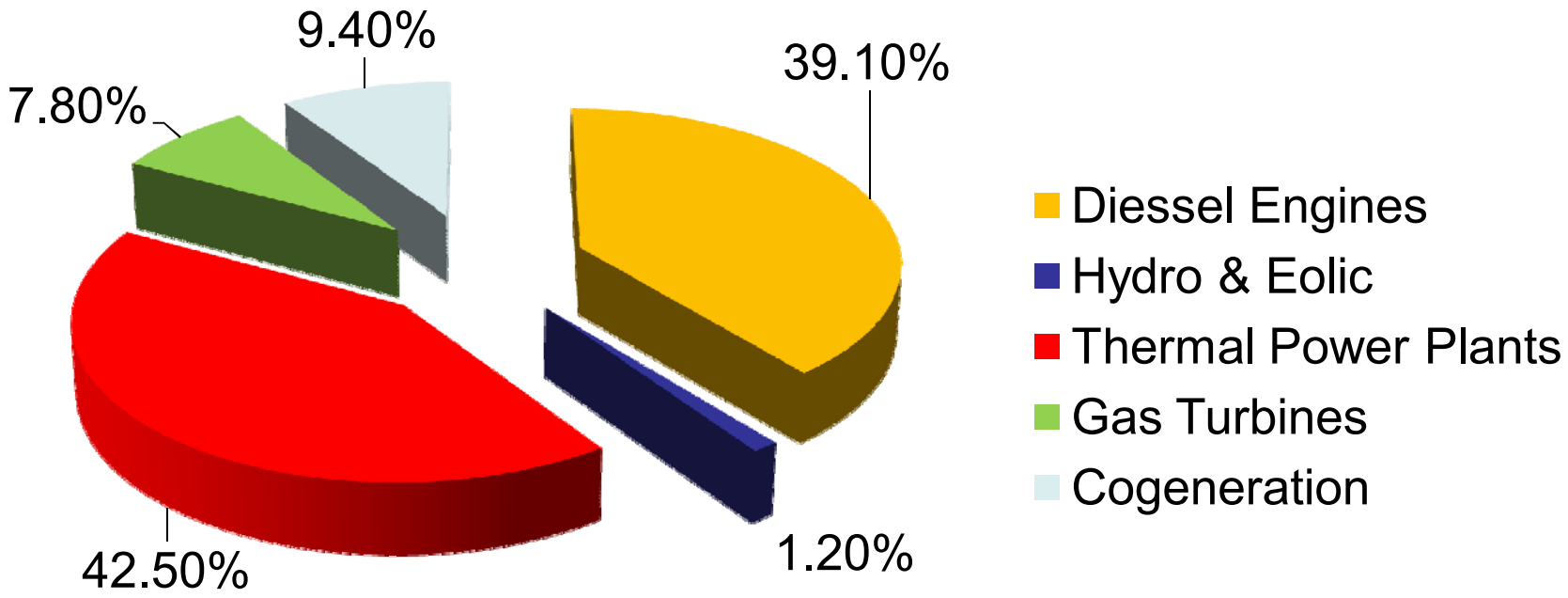
Total primary energy (TPES) supply and final energy use

TPES (Mtoe)	**11.8**
Primary energy production	5.1
Imports	6.6
Final energy use (Mtoe)	**6.5**
Fossil fuels	4.9
Renewable sources	0.4
Electricity	1.2





Total electricity installed capacity 2010: 5852.6 MW



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 (reduce the energy vulnerability).**

Major Energy Transformation: aspects of this strategy

- To accelerate the introduction of renewable energy technologies **(16%, 2020?)**.
- 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.

Generation sets impact

In spite of the positive impacts for Distributed Generation of the Diesel and Fuel Oil generation sets, its operation has bring a negative impact on the population due the emissions of local air pollutant (SO_2 and NOx). Currently its use have limited to the hours of high electricity demand, mainly for those located closer to human settlements.

Lasted studies

- IAEA RESEARCH CO-ORDINATE PROGRAM: "Greenhouse Gas Mitigation Strategies and Energy Options"
- UN RISO "Carbon 2012"
- UN RISO "Technology needs assessments"

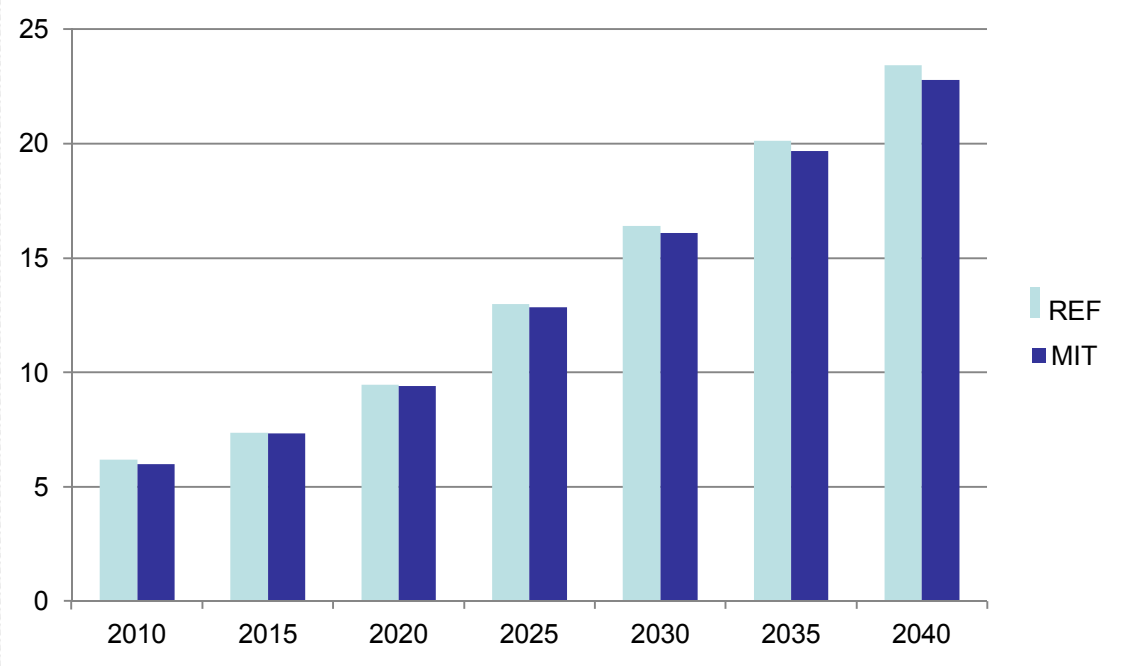
Using the IAEA tools, MAED and MESSAGE, a set of demands and supplies scenarios were developed. These scenarios take into account the country's energy policy.

Assumptions in energy demand scenarios

- Penetration solar energy for heating purposes,
- Use of biogas for cooking,
- Reducing energy intensity,
- Replacing diesel by CNG in transport,
- Introduction of electric passenger transport,
- Increase the transportation by rail,
- Increase in the use of biomass (bagasse and forestry),
- Use of ethanol and biodiesel.

Source: Perez. D, et al 2012

Final Energy Demand, Mtoe



- Demand grows at 3.6% annual
- Decrease in the MIT scenario of 1.6 Mtoe, avoiding 15.1 million tones CO_2

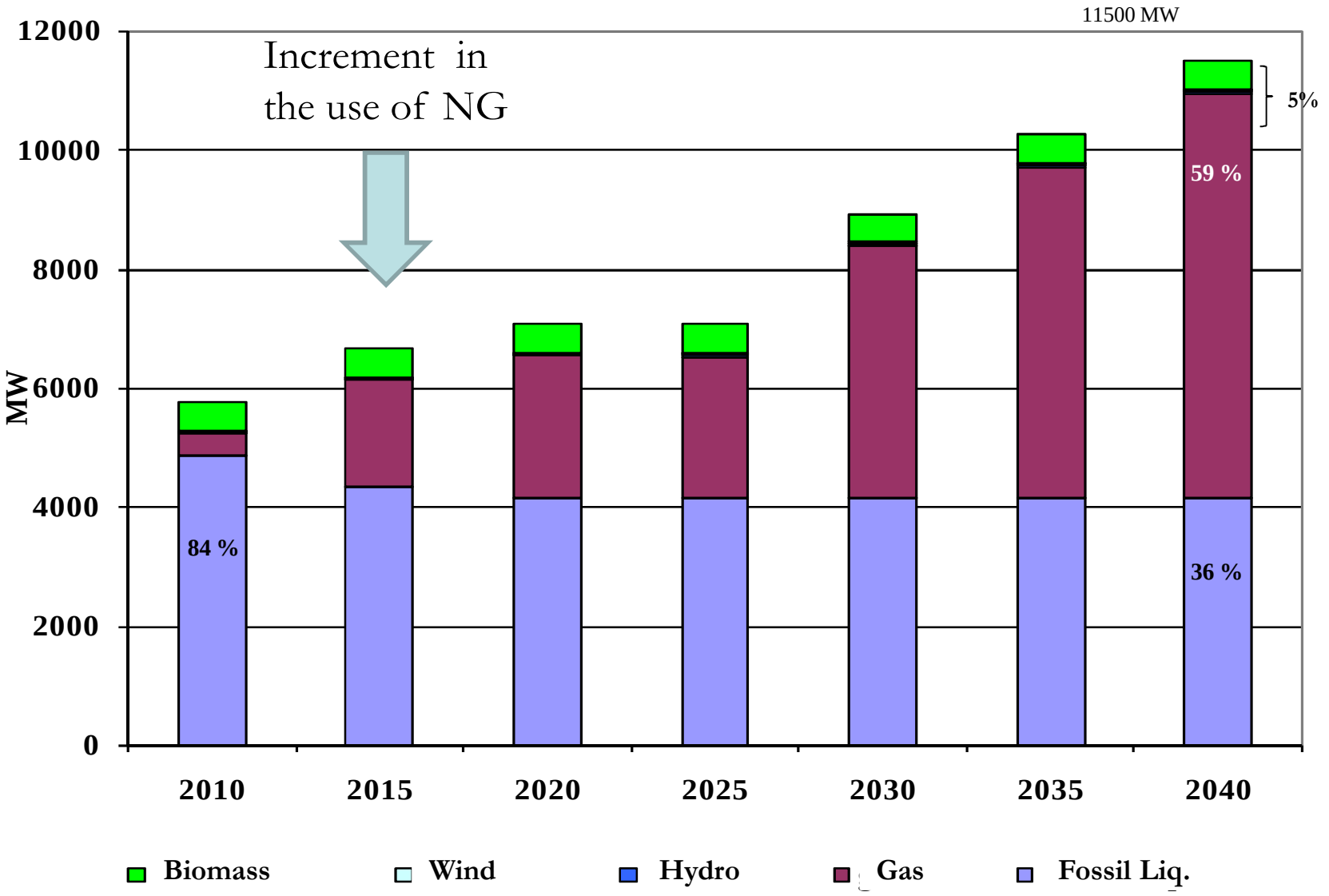
Source: Perez. D, et al 2012

Assumptions in energy supply scenarios

- Using NG in the existing PP (2015),
- Increase of NG in combined cycle,
- Installed more efficiently Steam Turbine in sugar mill,
- Integrated gasification combined cycle using forest biomass,
- Increased hydropower,
- Increased wind power,
- Solar photovoltaic grid connected,
- Using biogas in gas turbines.

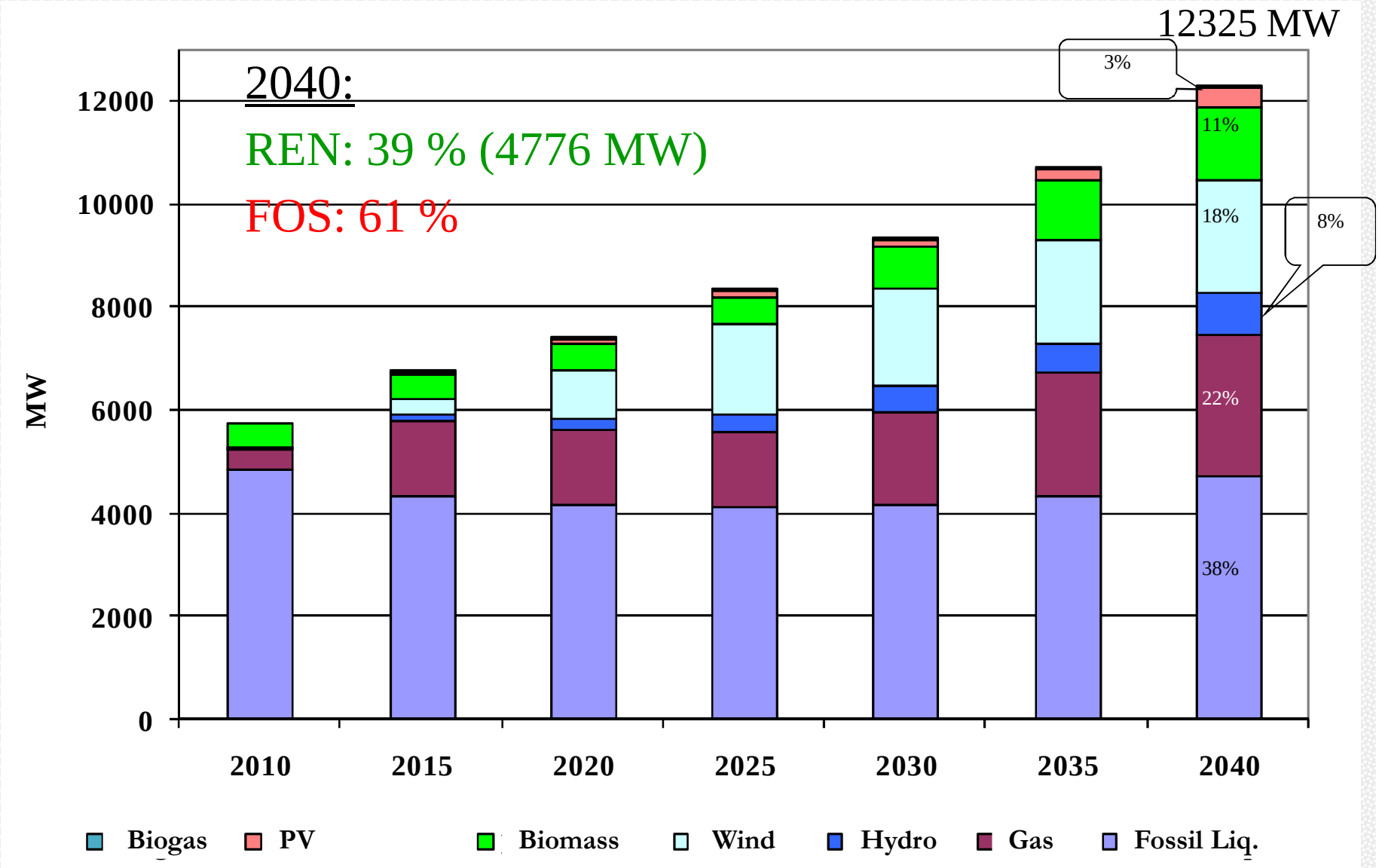
Source: Perez. D, et al 2012

Electricity Installed Capacity REF scenario



Source: Perez. D, et al 2012

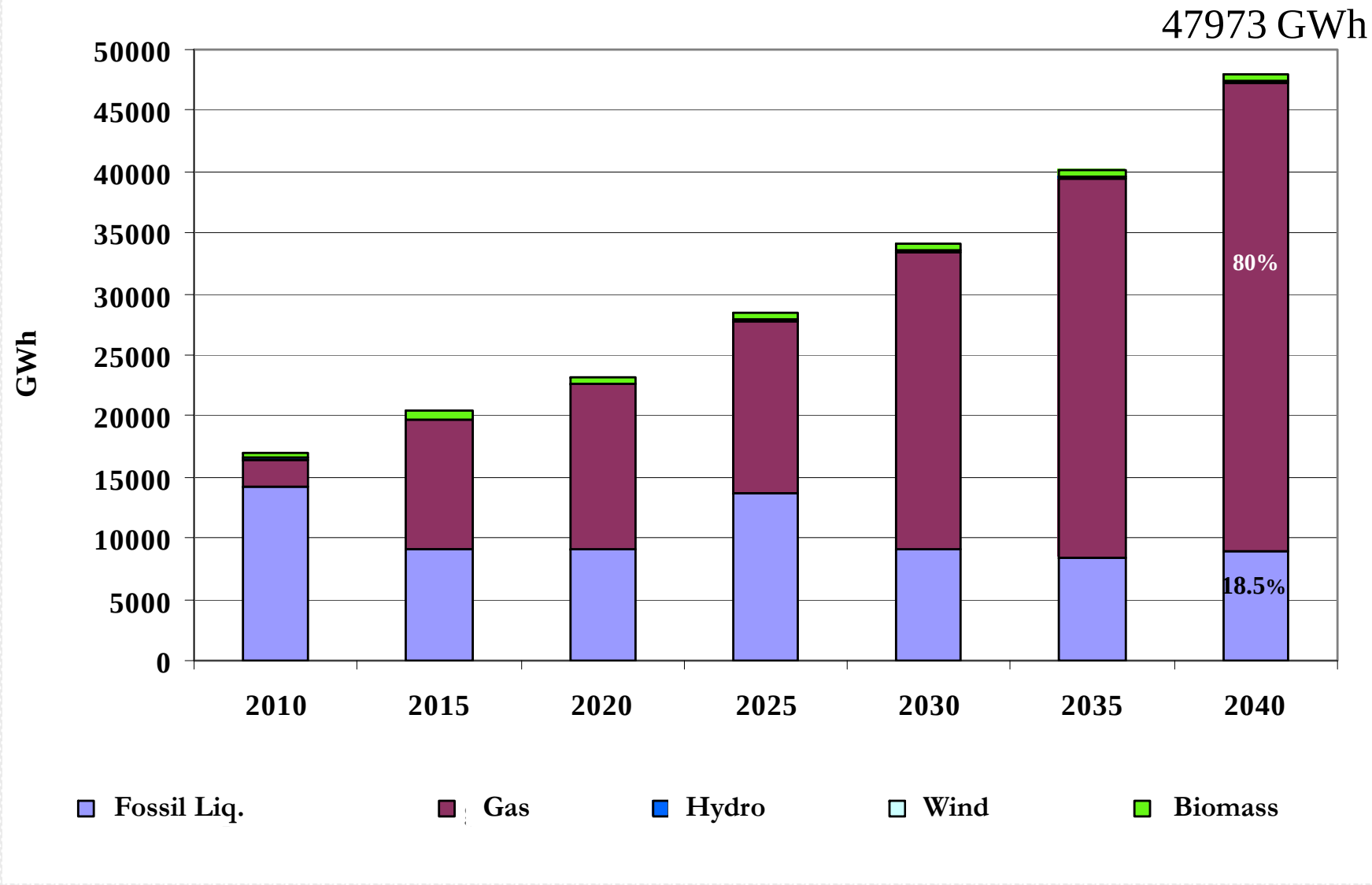
Electricity Installed Capacity MIT scenario



In 2040 3817 MW additional would be needed to meet the total demand

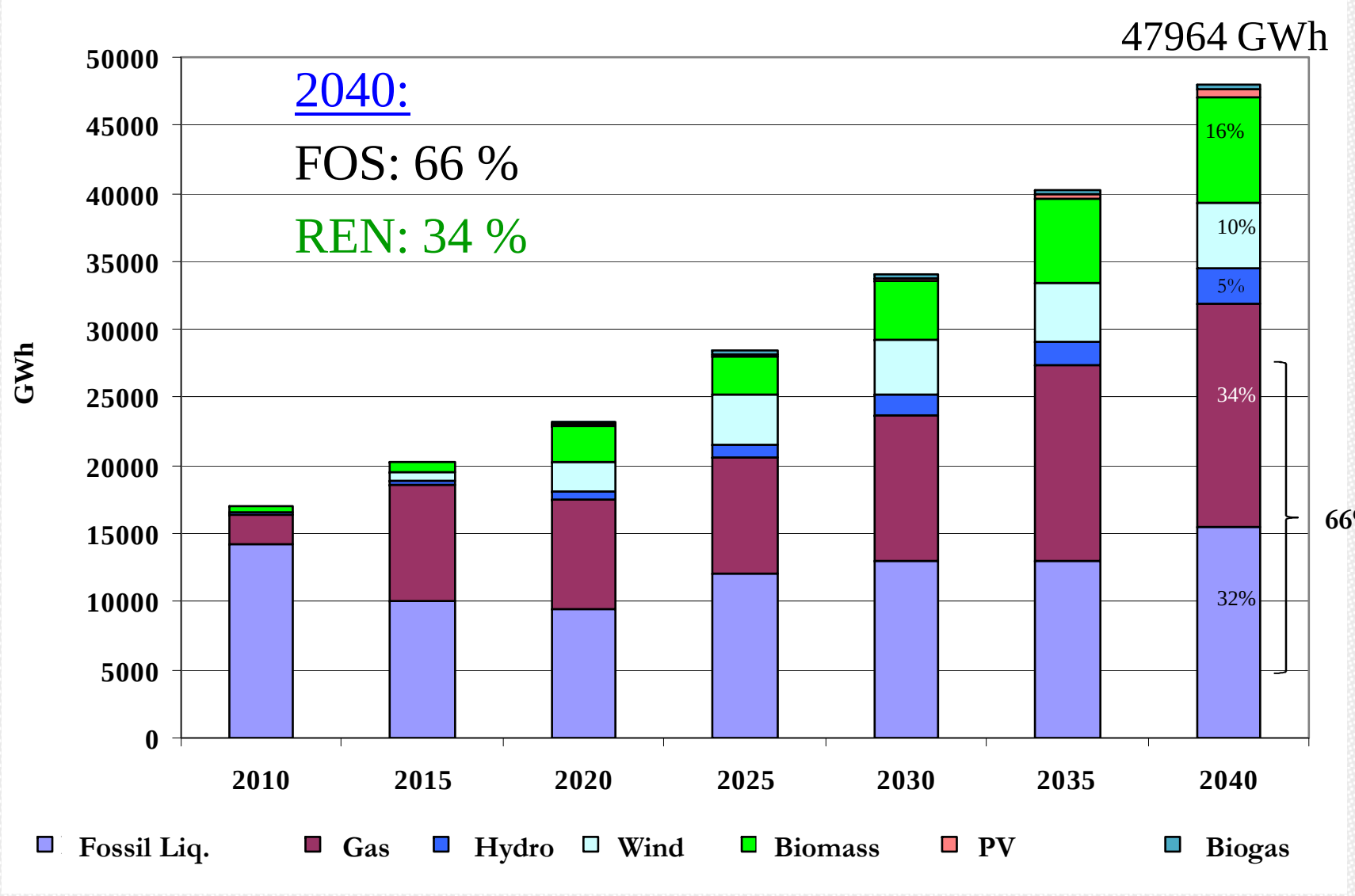
Source: Perez. D, et al 2012

Electricity Generation REF scenario



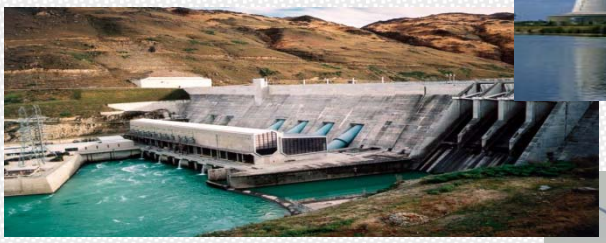
Source: Perez. D, et al 2012

Electricity Generation MIT scenario



Source: Perez. D, et al 2012

Energy & Climate



- Damages in the energy facilities due tropical hurricanes.
- Reduction of hydropower generation potentials and biomass production due the droughts,
- Reduction of the power production efficiency due the temperature increment,
- Damages on the oil production facilities by the increment of the sea level, etc.

MIT scenario	Biogas	PV	Hydro	Biomass	Wind	Gas	Liquid fossil
Installed Capacity (MW)	45	410	843	1378	2100	2748	4721

CLEW (climate, land, energy and water) interaction approach

Overall CRP Objectives

To test and implement prototype methodologies that allow us to national scale to demonstrate and quantify tradeoffs associated with interventions to meet development goals (specifically food, energy and water supply).

National framework

National counterpart project started last January 2013 (same objectives + analysis of energy technologies vulnerability).

III National communications to UNFCCC

Involved institutions

- ✓ Meteorological Institute, INSMET: Center of Atmospheric Physics.
  - ✓ Regional Climate Models (PRECIS model).
  - ✓ Climate Projections.
- ✓ National Institute of Hydraulic Resources.
  - ✓ Water: current status, polices, projections and data. Water Planning model
- ✓ National Institute of Land Use Research.
  - ✓ Land use: current status, polices, projections and data.

Others institutions

- ✓Havana University: Faculty of Economics.
  - ✓GDP projections.
- ✓Sugar Enterprise Group, AZCUBA: Cuban Research Institute of sugarcane derivatives, ICIDCA.
  - ✓Sugar industry: current status, polices, projections and data
- ✓Ministry of Mining and Energy (new ministry).
  - ✓Energy: current status, polices, projections and data.

Others institutions

- Ministry of Agriculture: Forest Research Institute, IIF.
  - Sugar industry: current status, polices, projections and data
- Ministry of Mining and Energy: Engineering Company for Electricity, INEL.
  - Energy: current status, polices, projections and data.

CLEW interactions

	Energy	Water	Land
Energy		Demand of energy for water pumping *Water pumping is the fifth power consumer in Cuba	Demand of energy for agriculture Fertilizer production, Irrigation and Transport
Water	Demand of water for energy production ➢ Crops for energy: Sugar cane, energetic Cane (420MW Bioelectric), Jatropha, crops and forestry wastes. ➢ Water consumption in energy facilities (No Hydro).		Water for irrigation
Land	Demand of land for energy Crops for energy production: Sugar cane, energetic cane, Jatropha.		

CLEW scenarios

- BAU: Using previous studies assumptions.
- MIT: Higher penetration of renewable energy sources.
- BAU+CC/MIT+CC: Taking into account the impact of the climate change in agriculture, water resources and energy (e.g. increase of energy demand for cooling, lost of Power Plant efficiency due to the temperature increments, lost of productivity in biomass production (bagasse and rice crop wastes, etc.).

Analytical Tools

PRECIS	Regional Climate projections
MAED - MESSAGE/ LEAP	Energy system analysis
MAWD-WEAP	Water system planning
ACROPWAT	Simulates yield response to water
IECM	Loss of efficiency by increasing the temperature of cooling water.

Project challenges

- To coordinate and integrate the work of different institutions.
- To obtain specific data models.
- Although there are strategies and policies related to energy, climate, water and land use systems, there are no data to quantify the projections.

Thank you