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The potential effect of climate change and extreme events on energy systems in the African region

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Joint ICTP/IAEA Workshop on Vulnerability of Energy Systems to Climate change and Extreme Events

The Potential Impact of Climate Change and Extreme Events on the Energy Systems in the African Region

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Presentation Outline

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- The Vulnerability of African Countries to Climate Change

II. Energy Situation in African Countries
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- Energy Systems and Adaptation to Climate Change

IV. Conclusions and Recommendations

Observed and Projected Climate Change in Africa

➢ Climate change is a major threat to sustainable growth and development in Africa, and the achievement of the Millennium Development Goals.
➢ ***The African Union is raising climate change adaptation as a key priority*** and seeks more support for adaptation and better integration of climate in development programmes.

- **Observed Climatic Changes (Hulme et al., 2001; IPCC, 2001)**

➢Warming of 0.7°C over the 20th century for Africa
➢ 0.05°C warming per decade through the 20th century
➢ Increased precipitation for East Africa

- **Projected Climate Change (Hulme et al., 2001; IPCC, 2001)**

➢ Projected warming for Africa ranges from 0.2°C per decade (low scenario) to more than 0.5°C per decade (high scenario)
➢ 5-20% increase in precipitation from December-February (wet months)
➢ 5-10% decreased in precipitation from June-August (dry months) by 2050

- **Climate Change Impacts: - *Extreme Weather Events***

➢ Warming temperatures are projected to cause more frequent and more intense extreme weather events, such as heavy rain storms, flooding, fires, hurricanes, tropical storms and El Niño events (IPCC, 2001) ⇒ Extreme weather events damage buildings and urban infrastructure
➢Extreme weather events pose a significant risk for communities in all parts of Africa.

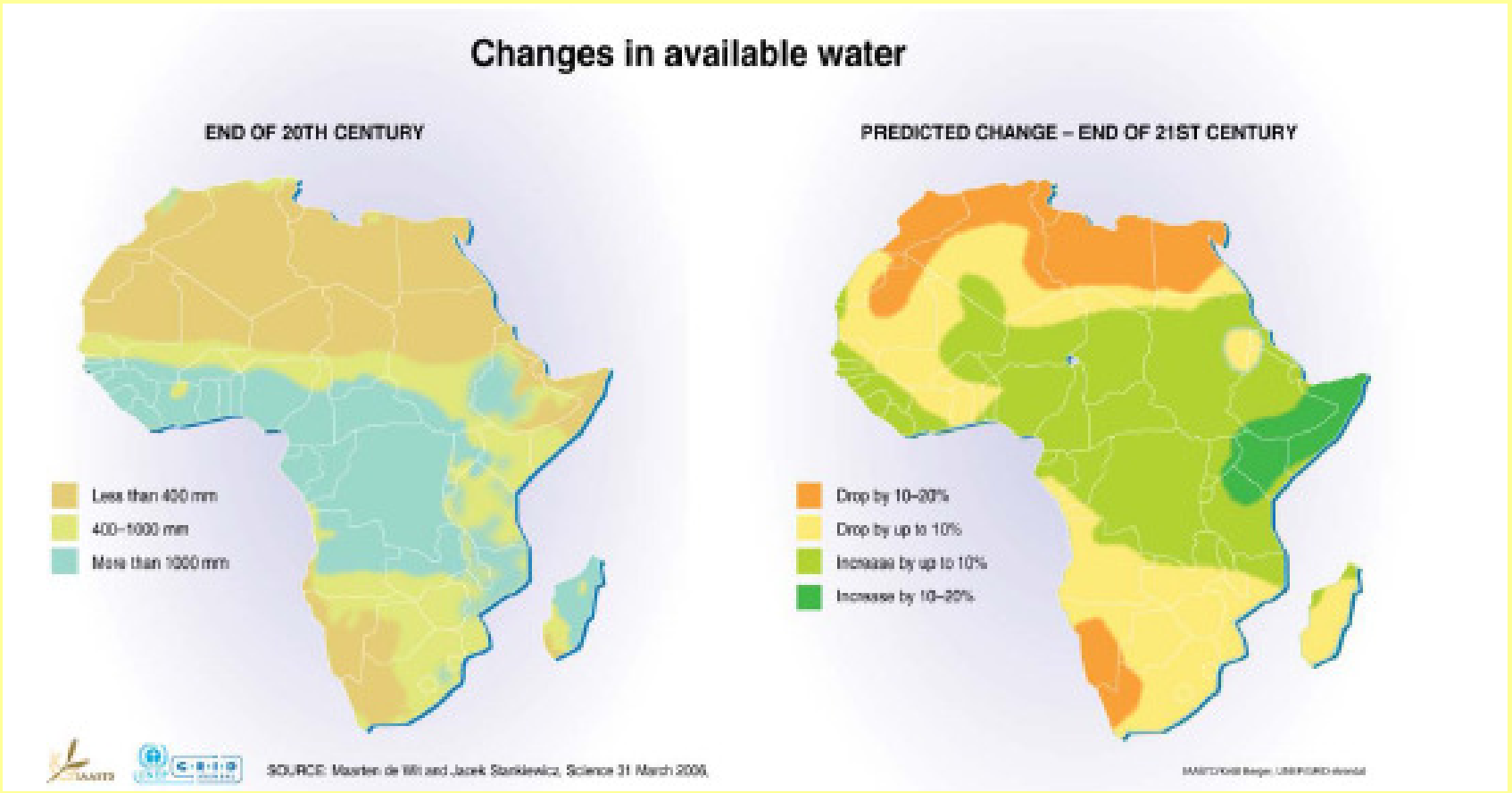
Observed and Projected Climate Change in Africa

Summary of the Impacts of Climate Change in Africa by 2099

By 2099	Low warming scenario	Mid warming scenario	High warming scenario
CO_2 concentrations	600ppm	850ppm	1,550ppm
Global temperature	1.8°C	2.8°C	4.0°C
Global sea-level rise	0.18–0.38m	0.21–0.48m	0.26–0.59m
Water	- 20–30% decrease in water availability in vulnerable areas	- Precipitation in sub-tropical areas falls by up to 20% - Annual mean rainfall increases by 7% in East Africa - Precipitation decrease of 20% along Mediterranean coast	- 30–50% decline in water availability in southern Africa
Agriculture and food	- 5–10% decline in African crop yields	- 550 million additional people at risk of hunger	- Decrease of 15–35% in agricultural yields across continent
Extreme events	- Up to 10 million more people affected by coastal flooding globally	- Coastal flooding affects between 11 and 170 million additional people per year globally - 10–20% increase in cyclone activity, southern Indian Ocean	- 420 million people exposed to flooding globally - Tens of millions displaced by extreme weather events and climate processes

Source: IPCC, 2007

Observed and Projected Climate Change in Africa



➢ There is evidence that the global climate is changing. The main impacts of climate change on humans and the environment occur through water.

➢ Climate change is a fundamental driver of changes in water resources and an additional stressor through its effects on other external drivers ⇒ Nile could see up to an 80% fall in flow towards the end of this century

The Vulnerability of African Countries to Climate Change

➢**Africa**:- one of the most vulnerable continents to climate variability and change because of multiple stresses and low adaptive capacity

• **Impacts**:-

➢ include desertification, sea-level rise, reduced fresh water availability, cyclones, costal erosion, deforestation, loss of forest quality, woodland degradation, coral bleaching, spread of malaria and impacts on food security

➢ Energy systems:- installation, production, supply, usage

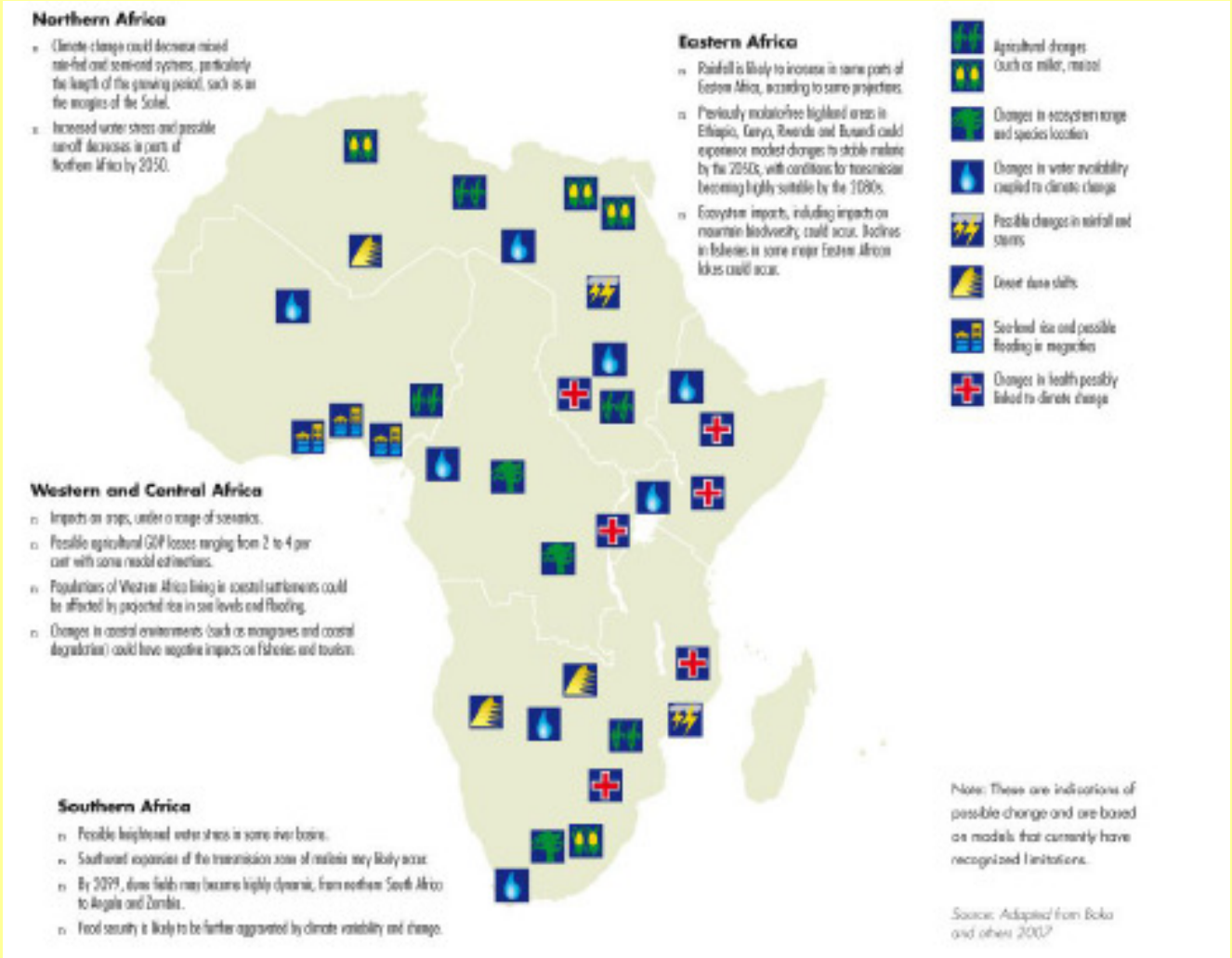
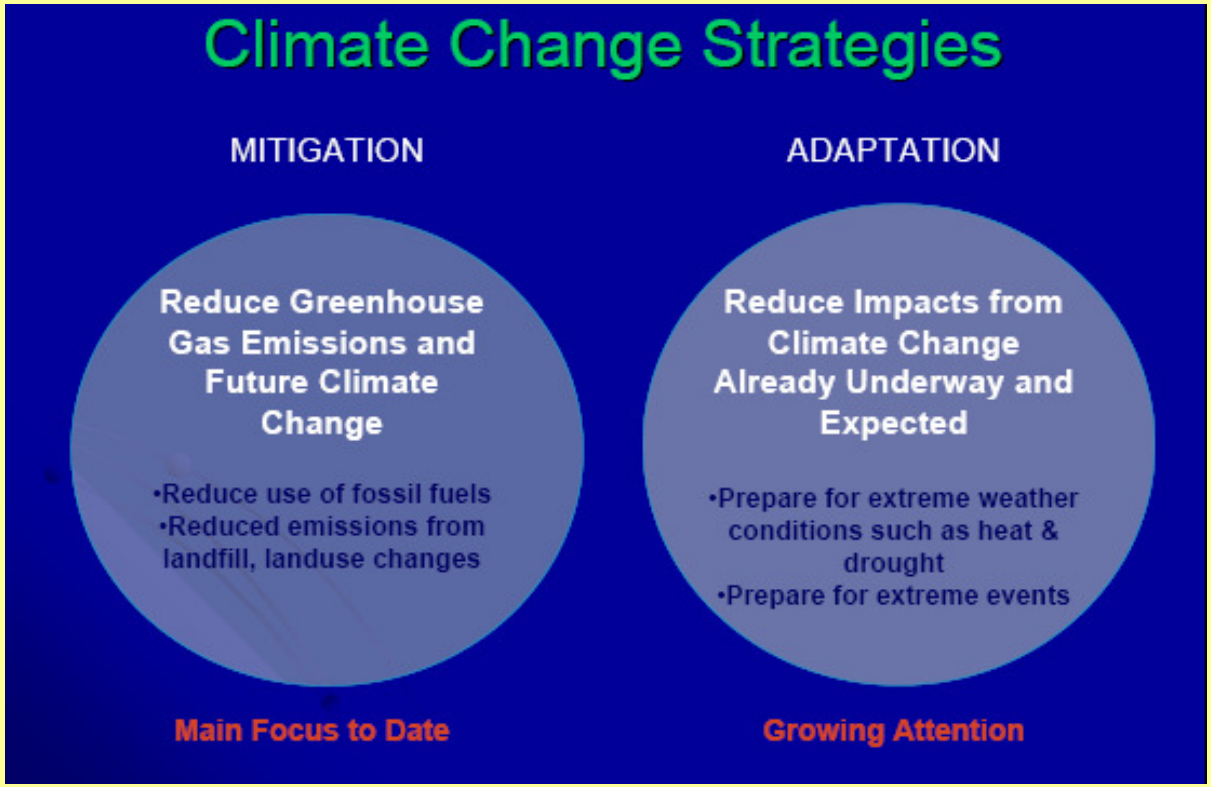


Fig. : Examples of current and possible future impacts and vulnerabilities associated with climate variability and change in Africa

The Vulnerability of African Countries to Climate Change



- A portfolio of adaptation and mitigation measures can diminish the risks associated with climate change
- Adaptation will be necessary to address impacts resulting from the warming which is already unavoidable due to past emissions ⇒ allow us to manage the unavoidable
- Many impacts can be avoided, reduced or delayed by mitigation ⇒ avoid the unmanageable

Energy Situation in African Countries

The Challenge

- One billion people, one sixth of the world population, live in Africa
- Only 4% of electricity generated worldwide is produced in Africa
- Sub-Saharan Africa has the world's lowest electrification rate at 25.9%
- Rural electrification rates in Sub-Saharan Africa are only 8%
- 70% of household income in Africa is spent on energy (diesel, kerosene, charcoal)
- 80% of Africans rely on biomass for energy (wood or charcoal fuel)
- Exposure to indoor air pollution is globally responsible for over 1.6 million premature deaths a year
- 4 million hectares of forest are felled each year in Africa, twice the world average

Energy Sector and Climate Information Needs

- Climate services necessary to support an effective energy transformation and to secure a sustainable energy future
- Why a transformation of the energy sector?
  - ➢ Increasing energy access,
  - ➢ Increasing energy consumption,
  - ➢ Shifting to low-carbon and environmentally sound technologies,
  - ➢ **Final objective**:
    - Energy for sustainable development, energy security, adaptation and mitigation
    - Climate Information is critical for designing new or retrofitting existing energy infrastructures

Energy Situation in African Countries - Fossil fuels

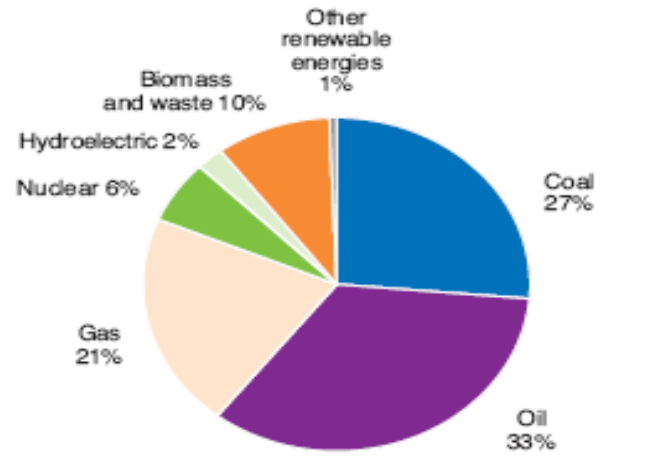
Opportunities ⇒ **Vast and diverse energy potential**

Fossil fuels:-

• dominant resources of primary energy worldwide in the Reference Scenario

(projected to increase 1.5% per year between 2007 and 2030 ~ 1200 Mtoe to 16 800 Mtoe ~ overall increase of 40%)

• accounting for more than three-quarters of the overall increase in energy use between 2007 and 2030

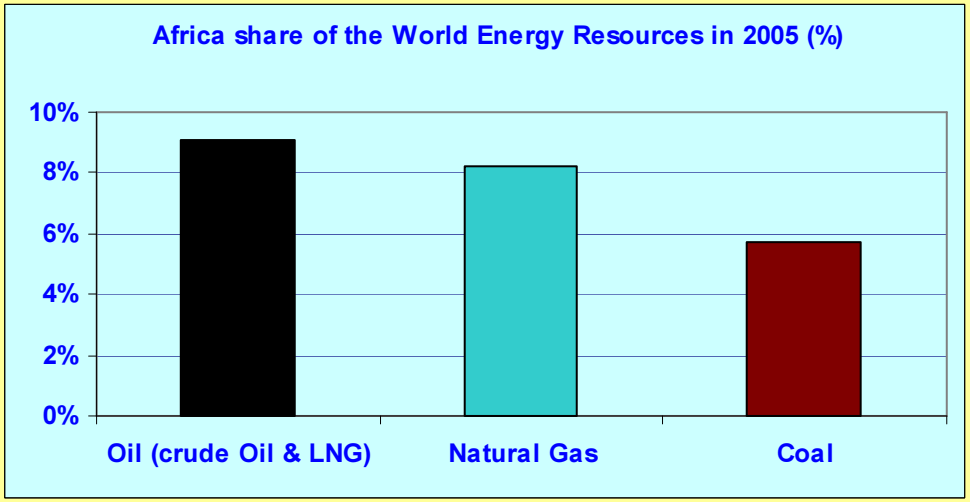


- World primary energy demand, in 2007 (12 Gtoe)

➢ **Africa is well endowed in fossil energy resources**

➢ Crude oil & liquids resources are huge in Africa but exploiting them will be challenging

- 9% to the world oil reserves



Energy Situation in African Countries - Fossil fuels

• World electricity demand is projected to grow at annual rate of to 2.5% to 2030

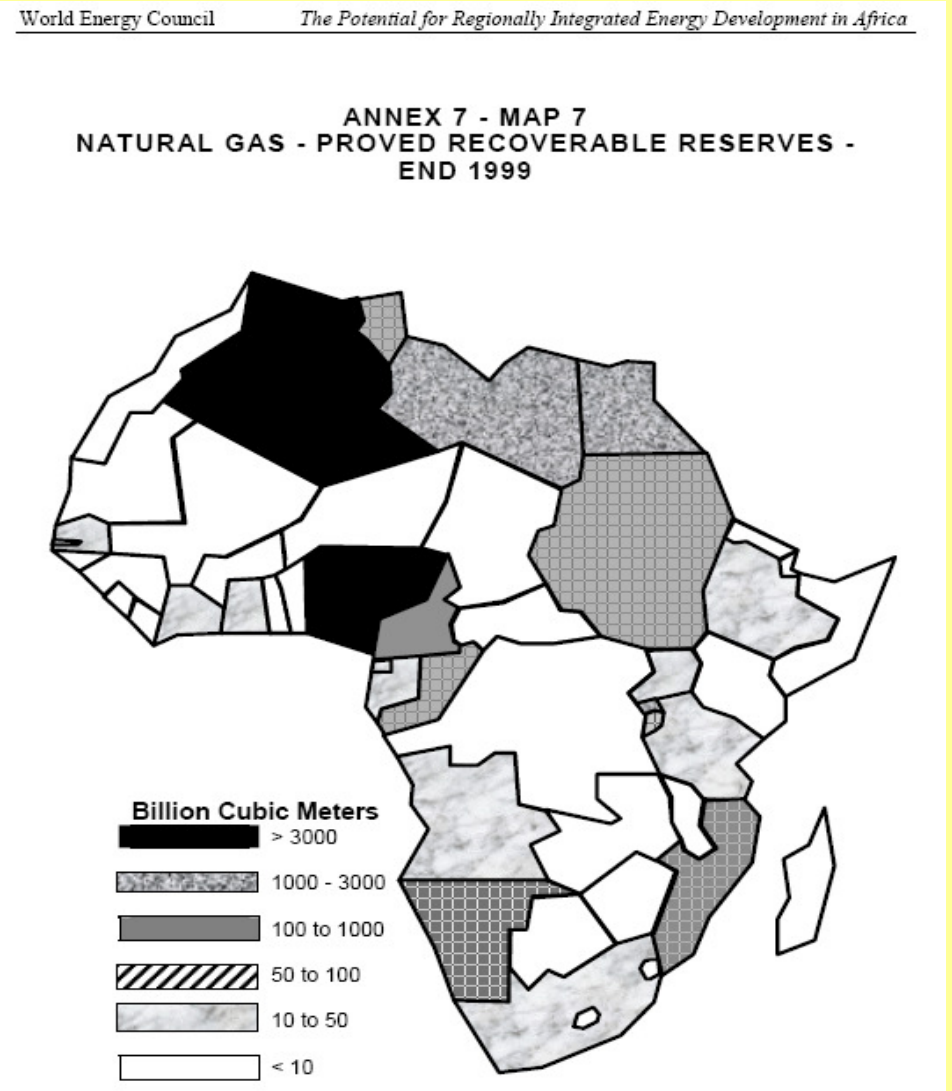
➢ gas and coal – major contributor for the power generation

➢ Gas resources are huge in Africa but exploiting them will be challenging due to high operational cost of gas technology

• Africa is endowed with substantial gas resources for electricity generation (such as Angola, Nigeria, Gabon and Côte d'Ivoire, etc.)

➢ 490- trillion cubic feet of gas to world natural gas reserves

➢ Nigeria - 186-trillion cubic feet of gas resources, which is enough to power the whole of West Africa for the next 20 years



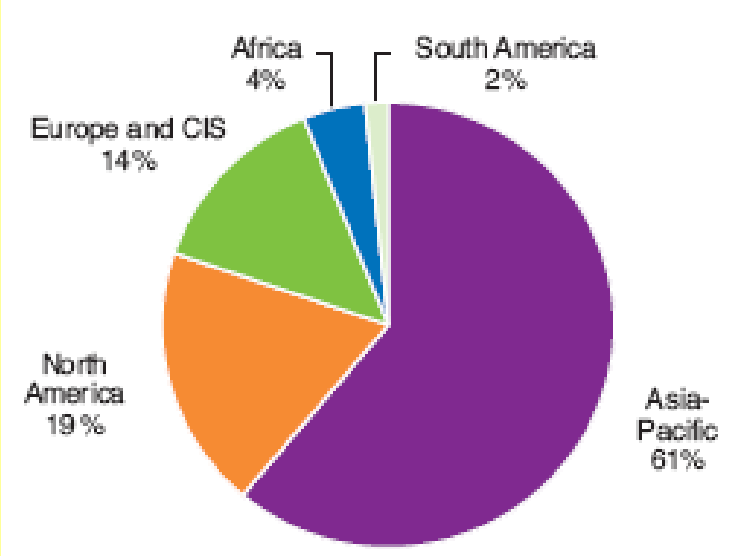
Africa Natural Gas Reserves Map: Source – *World Energy Council*

Energy Situation in African Countries - Fossil fuels

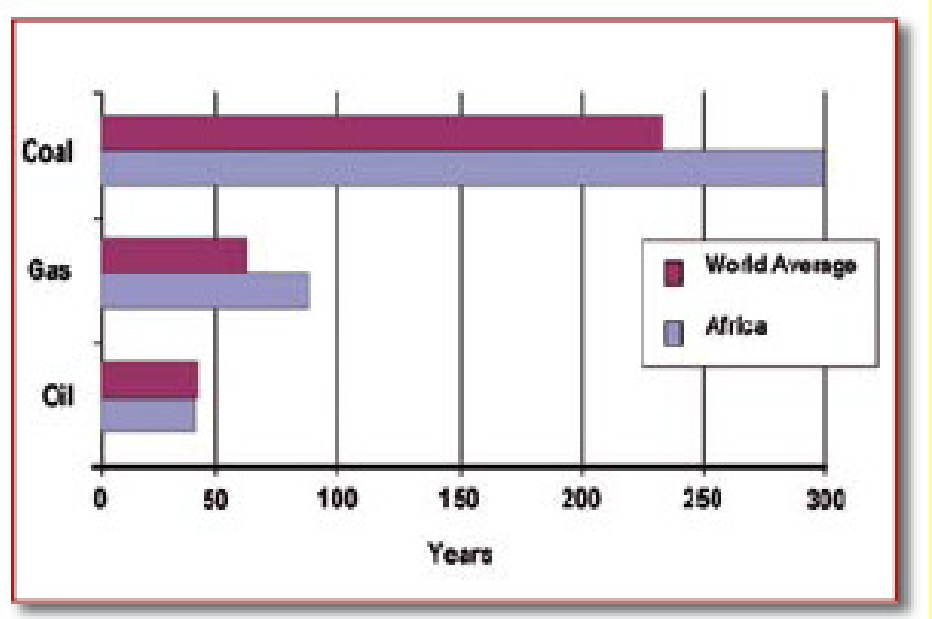
• Africa must exploit abundant coal reserves

➢ South Africa's coal reserves ~ estimated to be between 60 billion and 100 billion tons

- World coal production, in 2008 (6.8 Gt)



Source: BP Statistical Review 2009



Source: Davidson, 2004

Figure : Reserves-to-production ratio for fossil sources (Africa and the world)

Energy Situation in African Countries - Renewable Energy

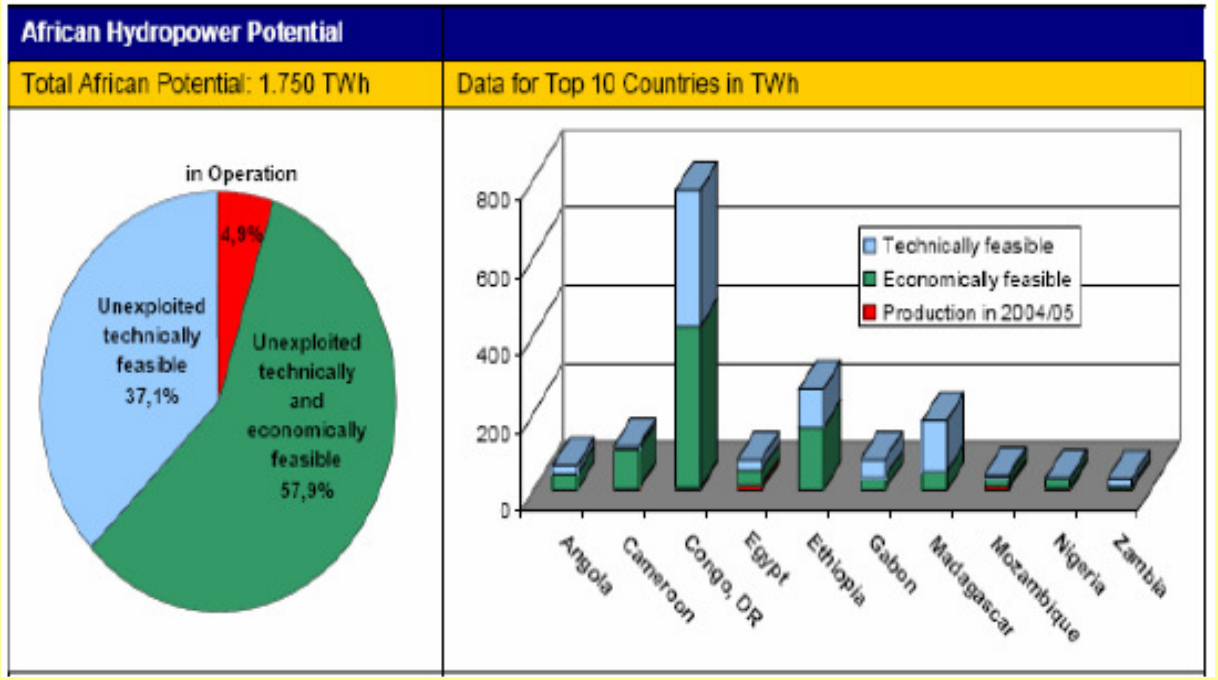
• **Hydropower :-**

potential for ten top countries in Africa

➢**Total installed capacity**

21 000 MW, 90% of which are concentrated in eight countries

➢ Current Africa hydropower development ~ 2 403 MW



• The gross theoretical potential hydropower potential ~ 3892 TWh/year,

• The technically exploitable ~ 1917 TWh/year,

❖ Ethiopia: 30 - 45 GW of hydropower potential

• The economically exploitable ~ 1096 TWh/year,

• The percentage of technical and economic hydropower potential currently exploited is about 7% ,

➢ the lowest in the World's Regions (Western Europe 75%, North America 69%, Australia 69%,

Energy Situation in African Countries - Renewable Energy

- **Geothermal (hot water)**
  - Potential estimated at 2.5-6 GW
  - Exist along the Rift Valley
  - Only Kenya that has exploited up to 129 MW

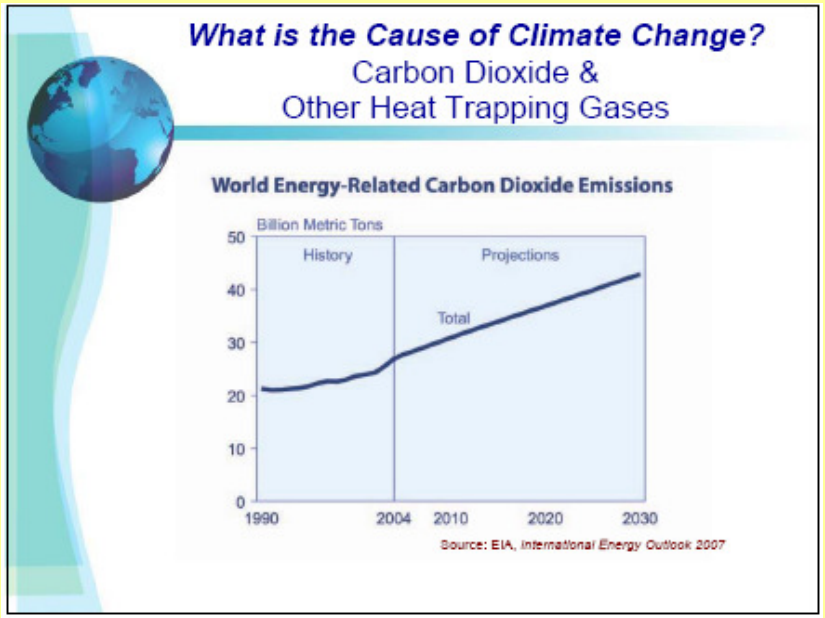
The **geothermal potential** for selected African countries:
Kenya ~ 3 GW; Ethiopia ~ 5 GW, Djibouti ~ 850 MW, Uganda ~ 450 MW and Tanzania ~ 150 MW.

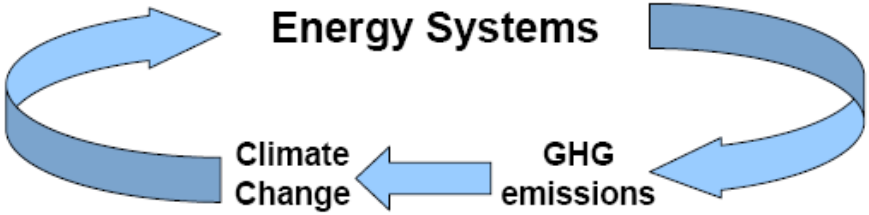
- **Solar**
  - Most countries in tropics and good sunshine hours ~ 5 - 6 KWh/m^2/day of solar insolation
  - Used extensively as PVs, solar water heaters, etc
  - Ethiopia: exploitable resource ~ 10^6 GW with average insolation of 5 kwh/m^2/day

- **Modern Biomass**
  - Agricultural and forestry residues in West Africa are a large and under-exploited potential energy resource
  - 4 billion litres of ethanol can be obtained from converting all sugarcane available in the continent

- **Wind**
  - Most countries have resource 3 - 5 m/s
  - North and South coastal areas (higher)
  - Ethiopia: exploitable reserve ~ 10,000 MW with average speed of 3.5 – 5.5 m/s, 6 hours/day

Energy Sector and Climate Change





Energy sector major source of global GHG emissions:

- 85% of CO_2 emissions are energy related;
- 68% of overall GHG emissions are energy related;
- 26% of GHG emissions are from energy supply sector

➢ **Climate changes may impact energy systems:**

❖ Many existing infrastructures may be affected,

❖ New infrastructures may need to be redesigned,

❖ New investments in energy infrastructures need to consider potential climate change impacts

Bases on a Scenario of Average Emission:

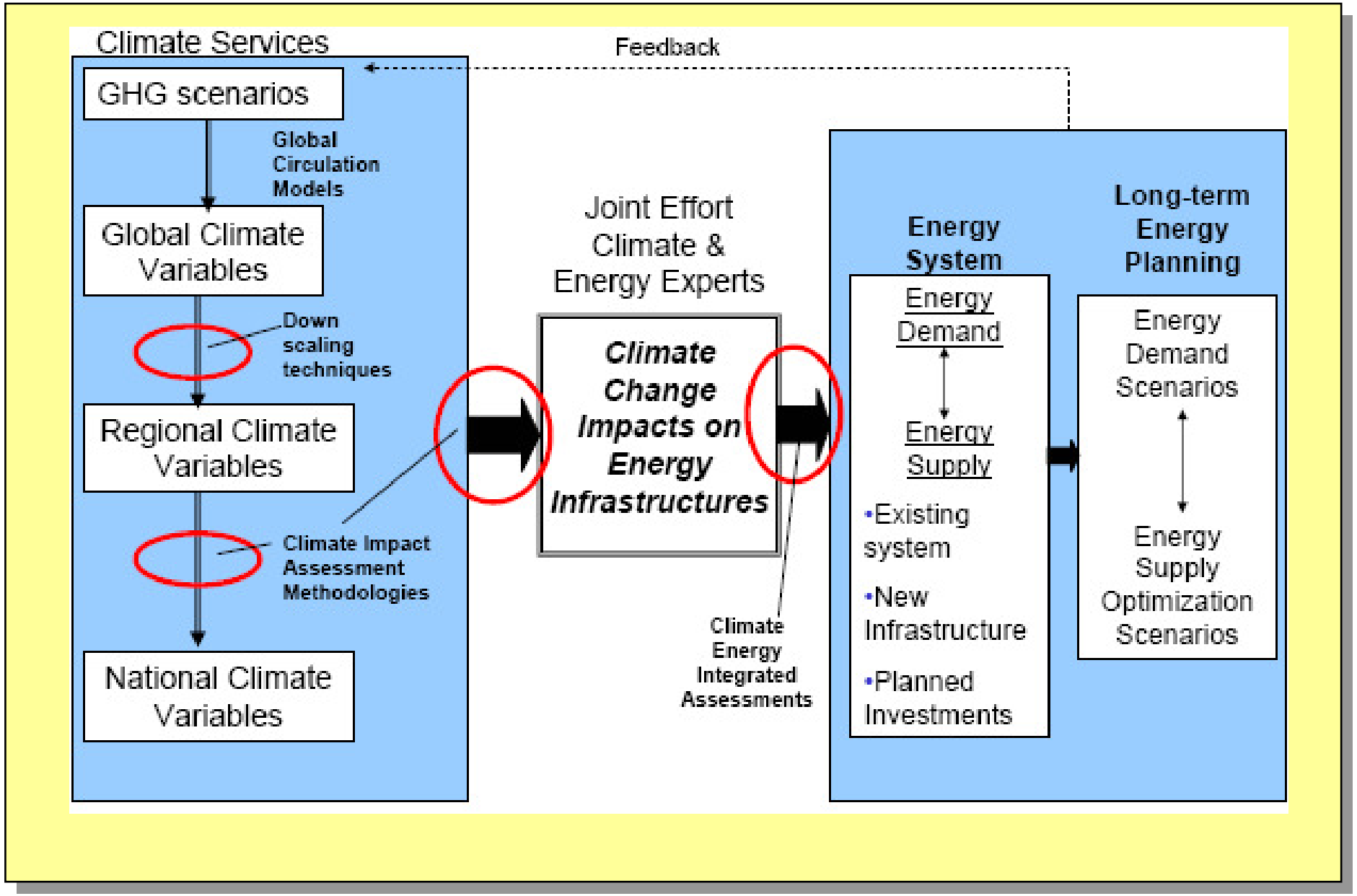
➢ A rise in global average surface temperatures of 3 or 4 degrees Celsius expected by the period 2080-2099 compared to the last two decades, 1980-1999

Vulnerability of Energy Systems:

➢ Many oil and gas facilities are located in areas vulnerable to climate change. Their operation and physical structures may be affected.

➢ hydropower plants in many locations are expected to be affected. Glaciers are retreating. Hydrological cycles and precipitation patterns are more variable.

Information Gaps in Integrated Energy System



Climate Change Impacts on Africa's Energy Systems

❖ **Direct Impacts of Climate Change on the Energy Systems**

- Reduced water availability for hydropower generators;
- Decreased availability of cooling water resources for electricity generation at thermal power plants;
- Impacts of increased temperatures and humidity on thermal power generating efficiency:
- Impacts on fossil fuel production and distribution activities;
- Impacts on electricity transmission and distribution;
- Seasonal and daily temperatures and precipitation changes affect the timing of peak electricity demands and the size of these peaks; and
- Increased intensity and frequency of severe weather events impacts on energy infrastructure.

❖ **Indirect Impacts of Climate Change on the Energy Systems**

- Agriculture Sector,
- Commercial and Residential Sectors,
- Industrial Sector,
- Transportation Sector

Climate Change Impacts on Africa's Energy Systems

Fossil Fuels:- Many oil and gas facilities are located in areas vulnerable to climate change. Their operation and physical structures may be affected.

- **Coal → Climate Impact Mechanisms**

Cooling water quantity and quality (T), cooling efficiency (T, W, H), erosion in surface mining

- **Natural Gas → Climate Impact Mechanisms**

Cooling water quantity and quality (T), cooling efficiency (T, W, H), disruptions of off-shore extraction (E)

- **Petroleum → Climate Impact Mechanisms**

Cooling water quantity and quality, cooling efficiency (T, W, H), disruptions of off-shore extraction and transport (E)

- **Liquified Natural Gas → Climate Impact Mechanisms**

Disruptions of import operations (E)

(T = water/air temperature, W = wind, H = humidity, P = precipitation, and E = extreme weather events)

Climate Change Impacts on Renewable Energy Systems

❖ **Renewable Energy Technologies (RETs):-**dependant on meteorological and climatic variables and patterns

- hydrological resources (hydropower, thermal power plants) ,
- biofuel production plants.
- wind patterns and intensity, and solar radiation
- they therefore tend to be very vulnerable to climate change and variability.

➢ Renewable energy resources are therefore linked to climate change in a very complex manner.

Climate change impact on hydro power systems → Climate Impact Mechanisms

Water availability and quality, temperature-related stresses, operational modification from extreme weather (floods/droughts), (T, E) ⇒ changing levels of precipitation (rainfall)

➢ hydroelectric generation around the African region as highly vulnerable to climate change (e.g: Gibe, Inga,)

- increased runoff and siltation from land degradation on hydro-generation;
- losses or fluctuations in hydropower production due to increased stresses on water supply systems and changing rainfall patterns
- high risks (technical, economic, commercial, environmental and social)

Climate Change Impacts on Renewable Energy Systems

- **Climate change impacts on biofuels production systems→ Climate Impact Mechanisms**

➢ promising types of biomass energy systems to replace oil imports by using indigenous resources

• Classic energy-crops for fuel production: grain, oilseed crops, grasses and ast-growing tree
➢ affected by climate change because their yield is mainly dependant on climatological and agronomical conditions

➢ Biofuels production in Central Africa – the world's second largest forested area – will deplete forest cover, reduce food production and result in greater import dependence

➢ Biofuels and the implications for climate change

- **Climate change impacts on wind energy generation → Climate Impact Mechanisms**

➢ expected to mean greater variability in wind resources ⇒ changing levels of wind speeds

➢if temperature gradients changes it can be argued that wind patterns may also changes

➢ Changes in diurnal wind patterns can also lead to significant challenges in matching wind power production

➢ Changes in cloud cover changes wind resources availability or productivity

➢ Wind resource changes (intensity and duration), damage from extreme weather

Climate Change Impacts on Renewable Energy Systems

- **Climate change impact on solar energy production systems → Climate Impact Mechanisms**

➢Expected to mean greater variability in direct solar radiation (Solar Variability) due to cloud cover

➢ The amount of energy that reaches Earth's outer atmosphere is called the total solar irradiance. Total solar irradiance is variable over many different timescales, ranging from seconds to centuries due to changes in solar activity $\Longrightarrow$ changing levels of solar radiation (sunshine)

➢ Insolation changes (clouds), damage from extreme weather

- **Climate change impacts on geothermal energy production systems → Climate Impact Mechanisms**

➢ The generation of electric power in thermal power plants often relies on a large volumes of water for cooling

➢ Changes in temperature and precipitation affect water availability for thermal power generators

➢ Cooling efficiency for air-cooled geothermal (T)

Energy Systems and Adaptation to Climate Change

• Energy assets can be protected from these impacts both by protecting the facility or relocating it to safer areas.

• Generate a better understanding of successful adaptive strategies occurring at the international, regional & local level, share strategies for 'best practice' adaptation and integrate the impact of climate change into national development strategies and existing policies including security risk assessments

➢ Research on and assessments of implications of extreme weather events for energy system resiliency, including strategies for both reducing and recovering from impacts.

• Research on and assessments of potentials, costs, and limits of adaptation to risks of adverse effects, for both supply and use infrastructures.

• Attention to linkages and feedbacks among climate change effects, adaptation, and mitigation; to linkages between effects at different geographic scales; and relationships between possible energy effects and other possible economic, environmental, and institutional changes.

• Potential climate change and localized variability on energy production from wind and solar technologies.

• Pursuing strategies and improved technology potentials for adding resilience to energy supply systems that may be subject to stress under possible scenarios for climate change

Conclusions & Recommendations

- Climate change may cause significant shifts in current weather patterns and increase the severity and possibly the frequency of major storms
- Climate impact assessment methodologies are needed to develop national projections and to identify specific climate impacts on energy infrastructures
- Energy resource planning, installation, production , transmission and distribution systems are mainly vulnerable to effects of sea level rise and extreme weather events.
- Africa is currently using ~ 20 - 30% of its hydropower potential with non-uniform regional distribution and the energy imbalance needs to be addressed through regional integration.
- Africa is characterized by low level of technology on hydropower, in particular SHP development. Hydropower technology is widely available elsewhere worldwide and technology transfer is the immediate option to enhance development.
- Incorporating possible climate change impacts into planning processes could strengthen energy production and distribution system infrastructures
- Hydropower production is expected to be directly and significantly affected by climate change, in most regions of Africa (very likely).
- Climate change impact assessments of current and future energy infrastructures are necessary.
- Climate change projections and information at national level are necessary to support substantial future energy investment.

Conclusions & Recommendations

• Climate change is expected to mean greater variability in wind resources and direct solar radiation, substantially impacting the planning, implementing, and financing of these technologies (likely).

• Increased temperatures and other climate change effects will affect energy transmission and distribution requirements, but these effects are not well-understood.

• Possible impacts of climate change policy interventions on technology choice and emissions can be offered with relatively high confidence based on published research

➢ Develop regional and sub-regional climate models at a scale meaningful to decision makers

• Climate change concerns are very likely to affect perceptions and practices related to risk management behavior in investment by energy institutions (very likely).

• Research on and assessments of implications of changing regional patterns of energy use for regional energy supply institutions and consumers.

• Improvements in the understanding of effects of changing conditions for renewable energy and fossil energy development and market penetration on regional energy balances and their relationships with regional economies.

• Alternative **long-term energy demand and optimal supply scenarios** need to be developed that reflect potential climate change impacts.

Aknowledgements

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