CLIMATE CHANGE AND THE ENERGY SECTOR

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What is Climate

* To a geologist or geomorphologist, it is an external agent which forces many geological phenomena
* For an archaeologist, 'climate' of an earlier period could have had a crucial influence on the people being studied, or might have been of little socio-economic significance; it could still be an environmental feature so strong that it has left a 'signature' that can be interpreted.
* An agriculturalist probably sees the 'climate' as the background 'norm' upon which year-to-year and day-to-day weather is imposed
* The average person speaks of moving to a location with a 'better climate'
* To many of us, 'climate' often first suggests temperature, although rainfall and humidity may also come to mind
* Earlier, when we think of climatic change it used to be in the time frame of glacial periods
* Recently, however, most of us have become aware of the shorter-term impact of anthropogenic activities, resulting in increasing atmospheric carbon dioxide and other trace greenhouse gases, upon the climate

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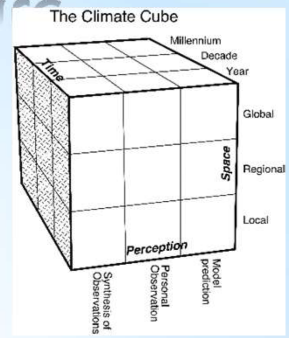
What is Climate

* A single satisfactory definition of climate is probably unobtainable because the climate system encompasses so many variables and so many time- and space-scales.
* One definition might be 'all of the statistics describing the atmosphere and ocean determined over an agreed time interval (seasons, decades or longer), computed for the globe or possibly for a selected region'



Climate can be viewed as existing in at least three domains - time, space and human perception.

Higher-order statistics, such as variance may be more useful in characterizing a climatic state than just the mean

This definition also permits further description of a climatic change as the difference between two climatic states, and a climatic anomaly as the difference between a climatic state and the mean state

Variations of the system arise from interactions between different parts of the climate system and from external forcings

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Climate Change

* Recognized to be one of the most serious challenges facing mankind today
* Driven by anthropogenic activities, it is known to be a direct threat to our food, water, and energy supplies, and an indirect threat to world security
* Increase in the concentration of carbon dioxide and other greenhouse gases (GHGs) in the atmosphere – Global warming
* Climate change refers to a change in the state of the climate that can be identified by changes in the mean or the variability of its properties persisting for an extended period, typically decades or longer - could be due to natural causes or human activities (IPCC, 2007)

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The Challenge

Climate change presents a two way challenge today

* how to cut emissions of gases responsible for global warming – mitigation
* how to adapt to current and future climate change in order to reduce adverse impacts on human beings - adaptation

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Global Warming

* It is a long-term rise in the average temperature of the Earth's climate system, an aspect of climate change shown by temperature measurements and by multiple effects of the warming
* The term commonly refers to the mainly human-caused observed warming since pre-industrial times and its projected continuation, though there were also much earlier periods of global warming
* *Global warming* more specifically relates to worldwide surface temperature increases; while *climate change* is any regional or global statistically identifiable persistent change in the state of climate which lasts for decades or longer, including warming or cooling

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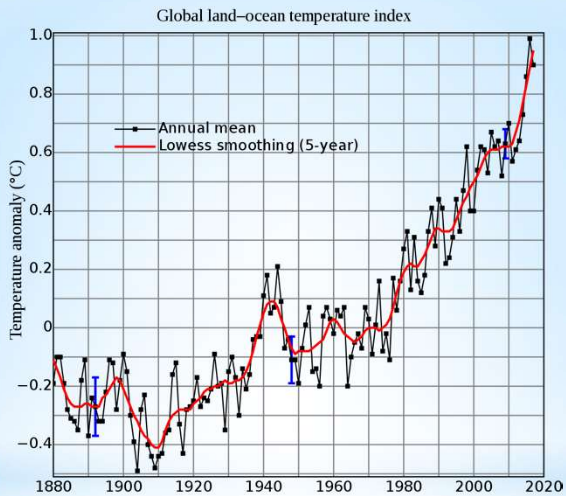

Global mean surface-temperature change from 1880 to 2017, relative to the 1951–1980 mean. The 1951–1980 mean is 14.19°C (57.54 °F). The black line is the global annual mean, and the red line is the five-year local regression line. The blue uncertainty bars show a 95% confidence interval.

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IPCC

* The Intergovernmental Panel on Climate Change (IPCC) - a scientific, intergovernmental body under the auspices of the UN, set up at the request of member governments in 1988 by two United Nations organizations, the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) and later endorsed by the UN General Assembly
* Membership of the IPCC is open to all members of the WMO and UNEP
* IPCC is dedicated to the task of providing the world with an objective, scientific view of climate change and its political and economic impacts
* The objectives of the IPCC are to assess scientific information relevant to
    * human-induced climate change
    * impacts of human-induced climate change
    * options for adaptation and mitigation

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IPCC

* The IPCC produces reports that support the United Nations Framework Convention on Climate Change (UNFCCC), which is the main international treaty on climate change. The ultimate objective of the UNFCCC is to "stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic [i.e., human-induced] interference with the climate system".
* IPCC reports cover "the scientific, technical and socio-economic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts and options for adaptation and mitigation."
* The IPCC does not carry out its own original research, nor does it do the work of monitoring climate or related phenomena itself. The IPCC bases its assessments on published literature, which includes peer-reviewed and non-peer-reviewed sources.

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Global Warming

* In 2013, the IPCC, in its Vth AR concluded, "It is *extremely likely* that human influence has been the dominant cause of the observed warming since the mid-20th century." The largest human influence has been the emission of GHGs such as carbon dioxide, methane, nitrous oxide etc. In view of the dominant role of human activity in causing it, the phenomenon is sometimes called "*anthropogenic* global warming" or "*anthropogenic* climate change".

* Climate model projections summarized in the report indicated that during the 21st century, the global surface temperature is likely to rise a further 0.3 to 1.7°C (0.5 to 3.1 °F) to 2.6 to 4.8°C (4.7 to 8.6 °F) depending on the rate of greenhouse gas emissions. These findings have been recognized by the national science academies of the major industrialized nations and have not been disputed by any scientific body of national and international standing.

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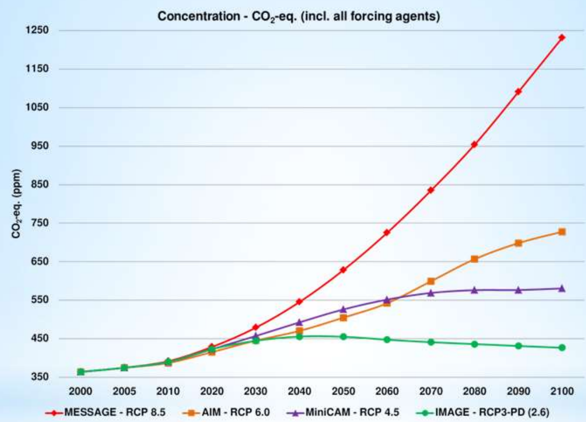

Future CO_2 projections, including all forcing agents' atmospheric CO_2-equivalent concentrations (in parts per million-by-volume (ppmv)) according to four RCPs (Representative Concentration Pathways)

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Likely Impacts of Global Warming

* Future climate change and associated impacts will differ from region to region. Ongoing and anticipated effects include rising sea levels, changing precipitation, and expansion of deserts in the sub- tropics.
* Future warming is expected to be greater over land than over the oceans and greatest in the Arctic, with the continuing retreat of glaciers, permafrost, and sea ice. Other likely changes include more frequent extreme weather events such as heat waves, droughts, wild fires, heavy rainfall with floods, and heavy snowfall, ocean acidification, and massive extinction of species due to shifting temperature regimes.
* Effects significant to humans include the threat to water, food, and energy security from decreasing crop yields and availability the abandonment of populated araes due to rising sea levels.
* Because the climate system has a large "inertia" and greenhouse gases will remain in the atmosphere for a long time, many of these effects are likely to persist for not just decades or centuries, but for tens of thousands of years.

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Response to Global Warming

* Societal response to global warming - mitigation by emissions reduction, adaptation to its effects and impacts, building systems resilient to its effects, and possible future climate engineering.
* Parties to the UNFCCC have agreed that deep cuts in emissions are required and that global warming should be limited to well below 2.0°C (3.6°F) compared to pre-industrial levels, with efforts made to limit warming to 1.5°C (2.7°F).
* Public reactions to global warming and concern about its effects are also increasing. A global 2015 Pre Research Centre report showed that a median of 54% of all respondents asked consider it "a very serious problem". Significant regional differences exist, with Americans and Chinese among the least concerned.

It is Global Heating

* Richard Betts, who leads the climate research arm of Britain's meteorological monitoring organization, commented recently at the U.N. climate summit in Katowice, Poland, that "global heating" is a more accurate term than "global warming" to describe the changes taking place to the world's climate, amid growing evidence that rising temperatures have passed the comfort zone and are now bringing increased threats to humanity. He further added "We should be talking about risk rather than uncertainty".
* Early December 2018, the U K Met Office produced a new report that showed the searing heatwave that hit the U.K. this summer — along with other parts of the northern hemisphere — was made 30 times more likely by human induced climate change.

Hothouse Earth

* Hans Joachim Schellnhuber, a professor of theoretical physics and founder of the Potsdam Institute for Climate Impact Research in Germany echoed similar views in his recent Hothouse Earth report, one of the most widely quoted and downloaded studies of this year. He said “Global warming doesn’t capture the scale of destruction. Speaking of hothouse Earth is legitimate”.
* A domino-like cascade of melting ice, warming seas, shifting currents, and dying forests could tilt the Earth into a “hothouse” state beyond which human efforts to reduce emissions will be increasingly futile
* This grim prospect is sketched out in the work that considers the combined consequences of 10 climate change processes, including the release of methane trapped in Siberian permafrost and the impact of melting ice in Greenland on the Antarctic.

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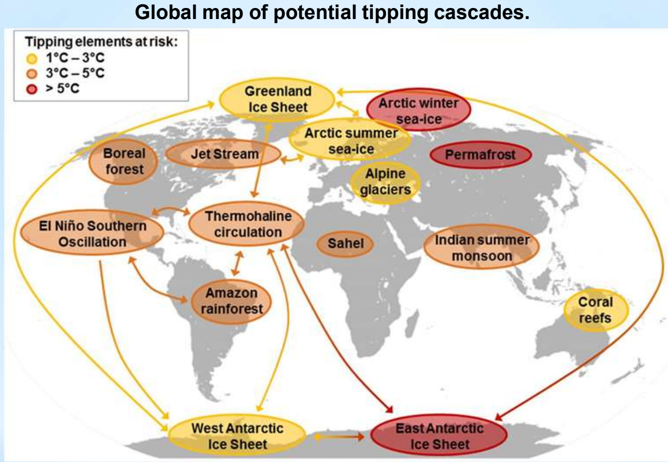
Global map of potential tipping cascades.



Will Steffen et al. PNAS 2018;115:33:8252-8259

The individual tipping elements are color-coded according to estimated thresholds in global average surface temperature (tipping points). Arrows show the potential interactions among the tipping elements based on expert elicitation that could generate cascades. Although the risk for tipping (loss of) the East Antarctic Ice Sheet is proposed at >5 °C, some marine-based sectors in East Antarctica may be vulnerable at lower temperatures.

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PNAS

Hothouse Earth

* The scientists involved in the study warned that the Paris commitment to keep warming at 2^0C above pre-industrial levels may not be enough to "park" the planet's climate at a stable temperature.
* They warn that the hothouse trajectory "would almost certainly flood deltaic environments, increase the risk of damage from coastal storms, and eliminate coral reefs (and all of the benefits that they provide for societies) by the end of this century or earlier."
* Another study published in the PNAS reveals that increased rainfall – a symptom of climate change in some regions - is making it harder for forest soils to trap greenhouse gases such as methane.

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Hothouse Earth

* These scientists expressed frustration at the slow pace of action by political leaders. In signing the 2015 Paris agreement, governments around the world aimed to keep global warming to within 1.5^0 to 2^0 C above pre-industrial levels. But current commitments are far off track.
* The U K Met Office upgraded its forecasts this week to show the planet is on track to warm by between 2.5^0C and 4.5^0 C. In the U.K., Betts said the trend was toward wetter winters with more floods, hotter summers with more droughts interspersed with increasingly intense rain.
* At 3^0C change, Schellnhuber said southern Spain would become part of the Sahara. Even 2^0 C could not be guaranteed as safe. The Paris pact was a firewall. "It's not helping us to keep the world as it is now. We've lost this opportunity already. It's a firewall against climate chaos."

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Hothouse Earth

* Betts said: "As a scientist, it's frustrating to see we're still at the point when temperatures are going up and emissions are going up. I've been in this for 25 years. I hoped we'd be beyond here by now."
* Schellnhuber concurred saying "I've worked on this for 30 years and I've never been as worried as I am today."

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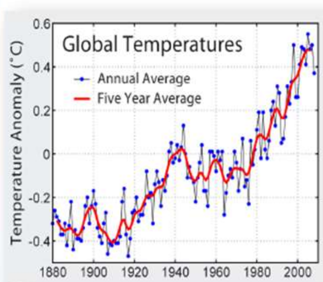
Where we are…



So we know that the climate of the world and of our region and country has changed under global warming.

We also have been convinced that it will continue to change.

What we want to know is what will that future change look like?

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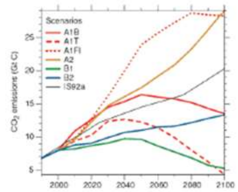
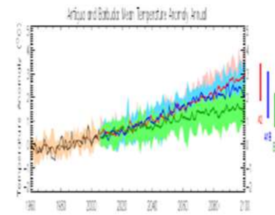
To answer the question…





Models + **Scenarios** = **Future Climate**

Temperature
Rainfall
Sea Level Rise

India - Political Map

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STATE LEVEL CLIMATE CHANGE TRENDS IN INDIA
Meteorological Monograph No. ESSO/IMD/EMRC/02/2013

Number of stations whose data are used for preparing state time series of temperature and rainfall for 1951-2010.

S. No.	State Name	No. of Stations Used: Temperature	No. of Stations Used: Rainfall
1	Andaman & Nicobar	6	6
2	Andhra Pradesh	21	94
3	Arunachal Pradesh	1	1
4	Assam	6	12
5	Bihar	7	18
6	Chhattisgarh	7	5
7	Delhi	2	3
8	Goa	3	7
9	Gujarat	18	27
10	Haryana	3	22
11	Himachal Pradesh	5	36
12	Jammu & Kashmir	4	9
13	Jharkhand	6	17
14	Karnataka	20	222
15	Kerala	7	18
16	Lakshadweep	2	2
17	Madhya Pradesh	25	120
18	Maharashtra	33	142
19	Manipur	1	1
20	Meghalaya	2	4
21	Mizoram	1	6
22	Nagaland	0	1
23	Orissa	14	18
24	Punjab	2	20
25	Rajasthan	21	241
26	Sikkim	2	1
27	Tamil Nadu	22	207
28	Tripura	2	12
29	Uttarakhand	4	3
30	Uttar Pradesh	16	162
31	West Bengal	19	14
	Total	282	1451

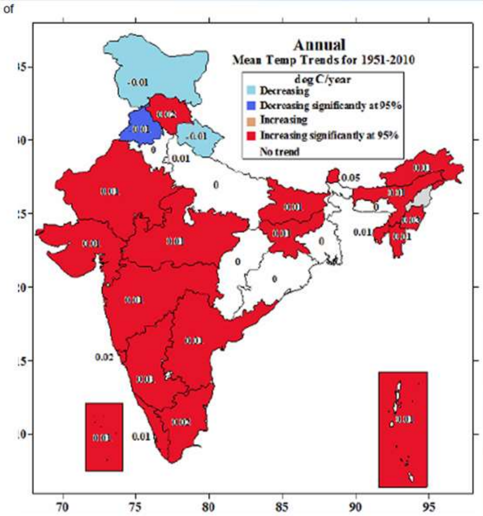

Figure State level annual mean temperature trends.

STATE LEVEL CLIMATE CHANGE TRENDS IN INDIA
Meteorological Monograph No. ESSO/IMD/EMRC/02/2013

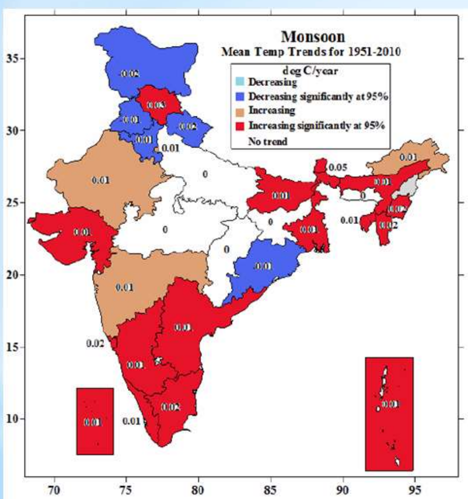

Figure State level mean temperature trends for monsoon season.

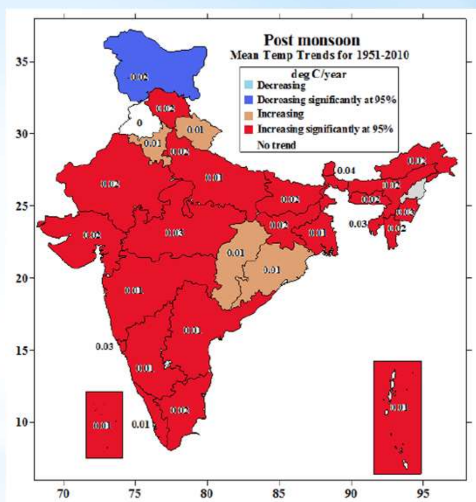

Figure State level mean temperature trends for post monsoon season.

STATE LEVEL CLIMATE CHANGE TRENDS IN INDIA
Meteorological Monograph No. ESSO/IMD/EMRC/02/2013

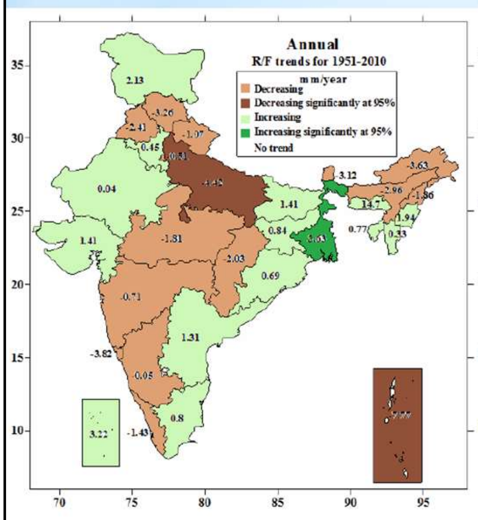

Figure State level annual rainfall trends.

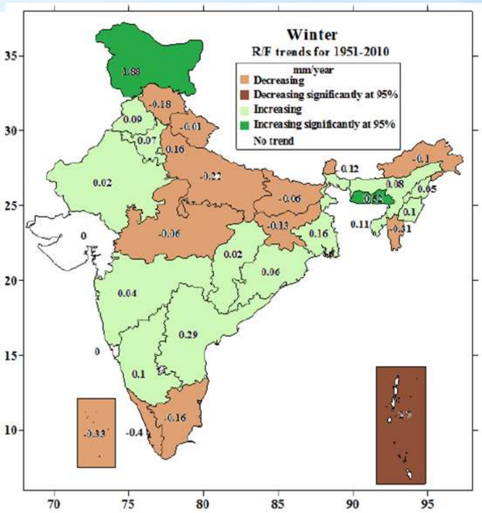

Figure State level rainfall trends for winter season.

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STATE LEVEL CLIMATE CHANGE TRENDS IN INDIA
Meteorological Monograph No. ESSO/IMD/EMRC/02/2013

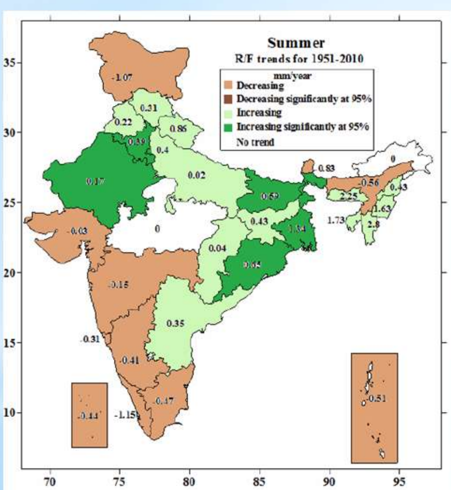

Figure State level rainfall trends for summer season.

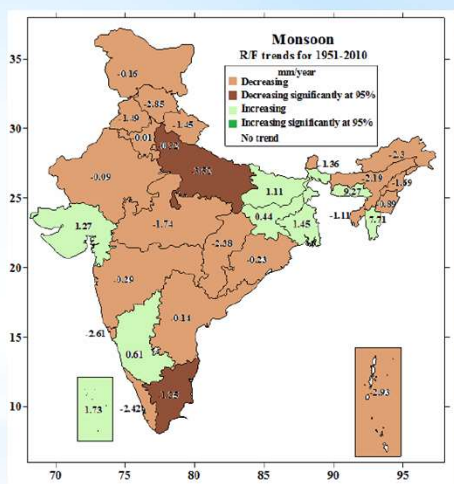

Figure State level rainfall trends for monsoon season.

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Energy and Climate

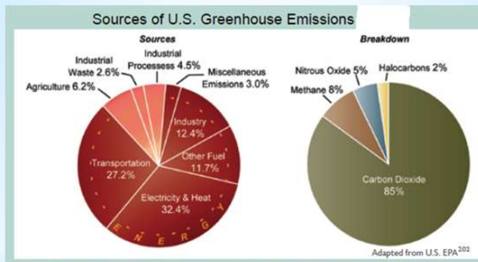
* Energy is at the heart of the global warming challenge
* Production and use of energy is the primary cause of global warming; climate change will eventually affect our production and use of energy
* The energy sector will be affected by climate change and these effects can have dire consequences on the economy depending on the area and intensity of the impact
* To date, insufficient attention has been paid to energy sector vulnerability in relation to projected climate change
* Several characteristics of the energy sector make it vulnerable to climate change and in need of sustainable transformation

Energy and Climate

* The energy sector consists of a large network of physical infrastructure which is vulnerable to damage caused by extreme climate events
* Energy is an input to many sectors; the energy sector also depends on other sectors in its functioning. The water and agricultural sectors are examples of indispensable inputs for energy production and use; these are themselves at risk of climate change impacts
* Changes in temperature, precipitation, and sea level, and the frequency and severity of extreme events will affect how much energy is produced, delivered, and consumed

Energy and Climate

* The vast majority of greenhouse gas emissions in developed countries, e.g. about 87 percent in the USA, come from energy production and use



About 87 percent of U.S. greenhouse gas emissions come from energy production and use, as shown in the left pie chart. The right pie chart breaks down these emissions by greenhouse gas.

Some trends in the US increasing energy use

- Population shifts to the South, especially the Southwest, where air conditioning use is high
- an increase in the square footage built per person
- increased electrification of the residential and commercial sectors
- increased market penetration of air conditioning

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Energy and Climate

Overview of Greenhouse Gases

* Carbon dioxide (CO_2): Carbon dioxide enters the atmosphere through burning fossil fuels (coal, natural gas, and oil), solid waste, trees and wood products, and also as a result of certain chemical reactions (e.g., manufacture of cement). Carbon dioxide is removed from the atmosphere (or "sequestered") when it is absorbed by plants as part of the biological carbon cycle.
* Methane (CH_4): Methane is emitted during the production and transport of coal, natural gas, and oil. Methane emissions also result from livestock and other agricultural practices and by the decay of organic waste in municipal solid waste landfills.
* Nitrous oxide (N_2O): Nitrous oxide is emitted during agricultural and industrial activities, as well as during combustion of fossil fuels and solid waste.
* Fluorinated gases: Hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride, and nitrogen trifluoride are synthetic, powerful greenhouse gases that are emitted from a variety of industrial processes. Fluorinated gases are sometimes used as substitutes for stratospheric ozone-depleting substances (e.g., chlorofluorocarbons, hydrochlorofluorocarbons, and halons). These gases are typically emitted in smaller quantities, but because they are potent greenhouse gases, they are sometimes referred to as High Global Warming Potential gases ("High GWP gases").

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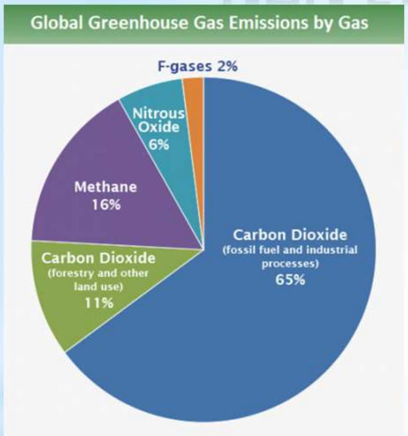
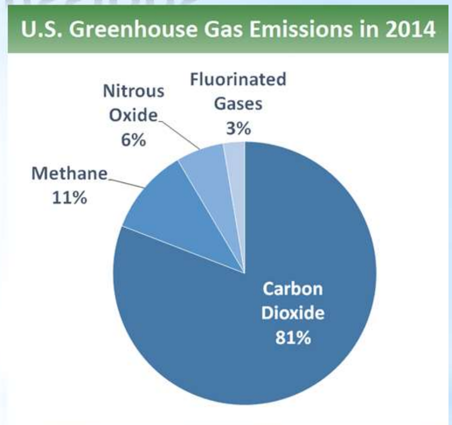
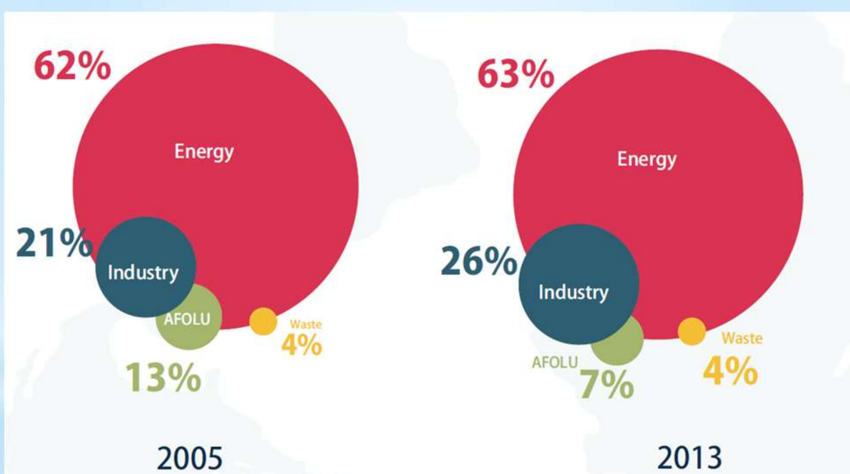
GHG Emissions



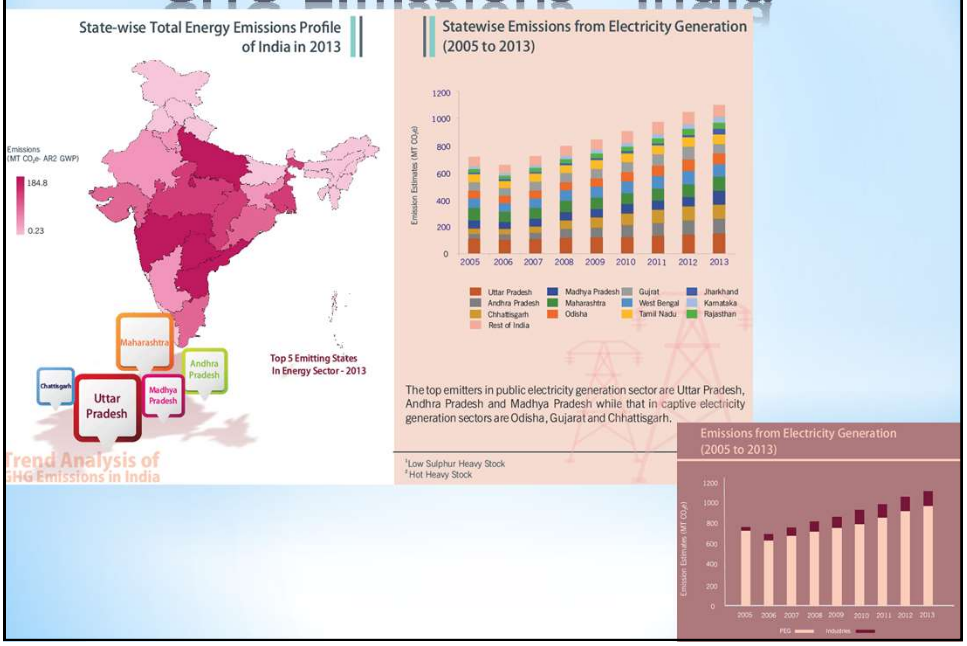


Kerala emits only 0.94 % of the total carbon emission in the country. In 2000, it is reported that the state emitted 30314.19 metric tons of carbon dioxide. Emission of other green-house gases (GHGs) is also reported to be comparatively low

GHG Emissions - India



GHG Emissions - India



Energy and Climate

Likely Impacts - General

* Warming will be accompanied by decrease in demand for heating energy and increase in demand for cooling energy. This will result in significant increases in electricity use and higher peak demand in most regions
* Energy production is likely to be constrained by rising temperatures and limited water supplies in many regions
* Energy production and delivery systems are exposed to sea-level rise and extreme weather events in vulnerable regions
* Climate change is likely to affect some renewable energy sources, such as hydropower production in regions subject to changing patterns of precipitation or snowmelt
* Concerns about climate change impacts could change perceptions and valuations of energy technology alternatives

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Energy and Climate

Likely Impacts - General

* Warming may reduce energy used directly in certain processes such as residential, commercial, and industrial water heating, and increases energy used for residential and commercial refrigeration and industrial process cooling (e.g., in thermal power plants or steel mills)
* It may cause an increase in the energy used to supply other resources for climate-sensitive processes, such as pumping water for irrigated agriculture and municipal uses
* It can change the balance of energy use among delivery forms and fuel types, as between electricity used for air conditioning and natural gas used for heating
* It changes energy consumption in key climate-sensitive sectors of the economy, such as transportation, construction, agriculture, and others

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Energy and Climate

Temperature, Energy Demand, and Energy Supply

* Increases in temperature will likely increase our energy demand, as well as change our ability to produce electricity and deliver it reliably
* In a warmer climate, more electricity will be used for air conditioning and less natural gas, oil, and wood for heating. Since demand for electricity for cooling is expected to increase as a result of temperature increase and extreme heat events, the balance in energy delivery is likely to shift from natural gas and fuel oil used for heating to electricity used for air conditioning
* Changes in energy demand will likely affect greenhouse gas emissions, but the net effect depends on which energy sources, including alternative energy, are used for electricity and heating
* Warming is likely to increase summer peak electricity demand in most regions. Meeting increases in this peak demand could require investments in new energy generation and distribution infrastructure, and new mechanisms will need to manage system reliability and peak demand, which can be more expensive than average demand levels. This would require large additional investment.
* A warmer climate may reduce the efficiency of power production for many existing fossil fuel and nuclear power plants because these plants use water for cooling. The colder the water, the more efficient the generator. Higher air and water temperatures could reduce the efficiency with which these plants convert fuel into electricity.

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Energy and Climate

Water Availability and Energy

* Energy and water systems are connected. Energy is needed to pump, transport, and treat drinking water and wastewater. Cooling water is needed to run many of today's power plants. Hydroelectricity) is itself an important source of power. Changes in precipitation, increased risk of drought, reduced snowpack, and changes in the timing of snowmelt in spring will influence our patterns of energy and water use. For e.g., power plants can require large amounts of water for cooling. On average, a kilowatt-hour of electricity (enough power to run 400 typical compact-fluorescent light bulbs for an hour) requires 25 gallons of water to be withdrawn from rivers or lakes.
* More frequent and severe heat waves will likely increase the demand for electricity. At the same time, these areas are likely to experience reduced water supplies due to increased temperature and evaporation, as well as possible decreased rainfall. Since water is necessary for electricity production, these combined effects could stress water resources.
* Hydroelectric power plants are sensitive to the volume and timing of stream flows. In some regions, especially during times of increased rainfall, dam operators may have to allow some water to bypass the electric turbines to prevent downstream flooding. Maintaining stream flow for hydroelectric dams could present conflicts with other activities.

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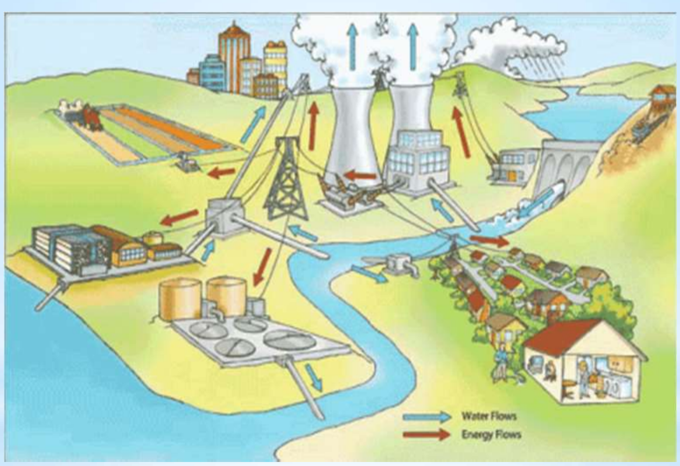

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Energy and Climate

Water Availability and Energy

* Growing crops for biomass and biofuel energy could stress water resources in certain regions, depending on the type of crop, where it is grown, agricultural production in the region, and current water and nutrient management practices. Given the many factors involved, more research is needed to understand how climate change may affect these resources.
* Rising temperatures, increased evaporation, and drought may increase the need for energy-intensive methods of providing drinking and irrigation water. For example, desalinization plants can convert salt water into freshwater, but consume a lot of energy. Climate change may also require irrigation water to be pumped over longer distances, particularly in dry regions.

Energy and Climate

Sea Level Rise, Storm Surge, and Extreme Events

* At many locations, energy infrastructure including power plants are located in coastal areas and therefore sensitive to sea level rise and storm surge (a substantial portion of U.S. energy facilities are located on the Gulf Coast or offshore in the Gulf of Mexico). Fuel ports and the generation and transmission lines that bring electricity to major urban coastal centers are at risk. Several thousand oil drilling platforms offshore of the Gulf Coast in the US and elsewhere are vulnerable to extreme weather events. For e.g., hurricanes Katrina and Rita damaged more than 100 platforms and damaged 558 pipelines in 2005. Sea level rise and changes in the frequency and severity of storms and other extreme events may also damage energy infrastructure, resulting in energy shortages that harm the economy and disrupt peoples' daily lives.
* Flooding and intense storms can damage power lines and electricity distribution equipment. These events may also delay repair and maintenance work. Electricity outages can have serious impacts on other energy systems as well. For example, oil and gas pipeline disruptions following extreme weather events are often caused by power outages rather than physical damage to the infrastructure.
* Railways and marine transportation that move large amounts of oil and coal are also vulnerable to climate change. More intense rainfall and storms can threaten railways by washing out railway lines. Changes in precipitation could affect marine transportation by reducing the navigability of rivers.

Energy and Climate

Wind Speed, Cloud Cover, and Renewable Energy

* The impacts of climate change on wind and solar power is still a developing area of research due to the challenges involved in modeling wind and cloud cover changes at the necessary spatial scales

Energy and Climate

* **Generation**
* Most modes of energy generation, such as thermal power, hydropower etc depend on climatic conditions
* Some examples
  * The power output of a gas turbine decreases proportional to rise in temperature
  * During the 2003 and 2007 heat waves in Europe, 17 thermal power plants had to be shut down or had to cut production in Germany, France, Spain, Romania, the Czech Republic and Slovakia, as there was insufficient cooling water and the plants' wastewater exceeded temperature limits
  * In countries threatened by scarcity of water/ drastic reduction in water resources due to projected reduced precipitation as a result of climate change, the consequent economic loss due to reduction in hydropower potential/ production is estimated to be of the tune of millions of dollars

The main impacts of climate change on energy generation sources by climate stressor

Climate stressor	Warming trend	Precipitation	Cyclone	Sea level
Hydro power	High temperatures may induce glacier melting, increasing water quantities in hydro basins. Extreme temperatures may affect energy generation due to increased reservoir evaporation.	Changes in precipitation may increase run-off variability. Droughts may affect run-off and energy output.	Equipment damage may decrease output.	*No significant impact*
Wind power	Increased temperatures may decrease air density decreasing energy output.	*No significant impact*	Alteration in wind speed may increase output variability. Damage from cyclones may decrease plant lifetime and output.	Sea-level rise may damage off-shore infrastructure.
Biomass	Increased temperatures may impact crop yield and irrigation needs. Extreme temperatures may induce fires and threaten crops.	Precipitation fluctuations may cause variable irrigation needs. Droughts may impact crop yield.	Storms may threaten crop yield.	Erosion and salinisation may threaten crop productivity.

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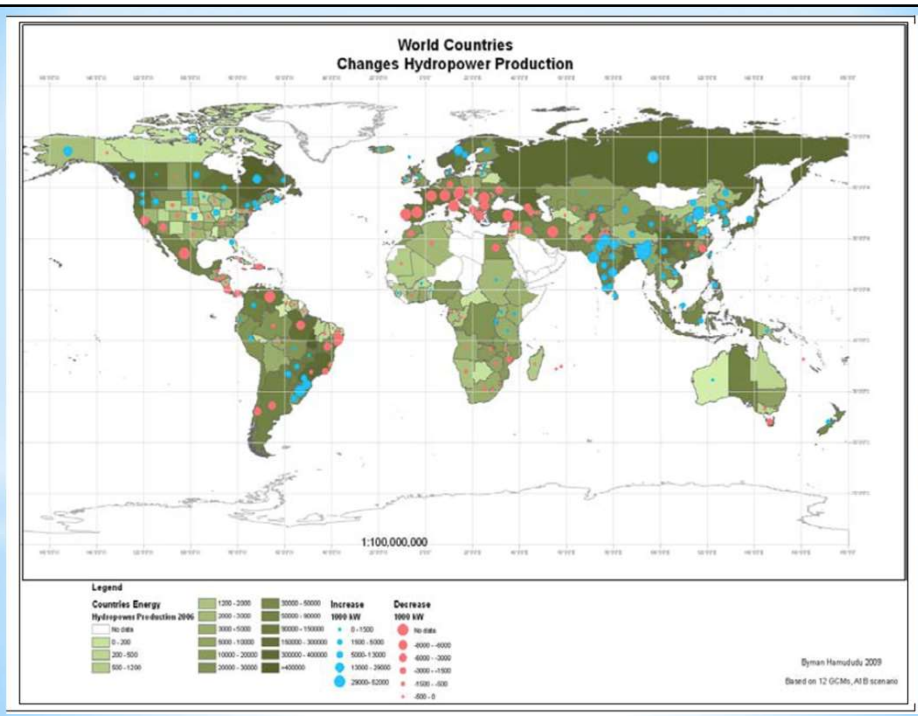

The hydropower sector will be particularly affected by changes in run-off due to snow and glacier melt, rainfall variability, heat waves, droughts, floods as well as extreme storms. The projected changes in hydropower generation in 2050 are presented based on the IPCC A1B emissions scenario from 12 General Circulation Models (GCM) w.r.t. the hydropower production in 2006

Climate stressor	Warming trend	Precipitation	Cyclone	Sea level
Solar power[17]	High temperatures may reduce solar PV cell efficiency. High temperatures may alter Concentrated Solar Power (CSP) efficiency (see Thermal power).	Increased cloud cover may decrease solar PV generation output. Droughts may affect Concentrated Solar Power (CSP) generation (see Thermal power).	Extreme events may damage structures and decrease plant lifetime.	*No significant impact*
Thermal power[18, 19]	Higher temperature of cooling water may decrease plant efficiency.	Increased water content may affect fossil fuel quality. Droughts may affect water availability for cooling.	Cyclones may damage plant infrastructure.	Sea-level rise may increase risk of damage to off-shore infrastructure and coastal stations.

17) Solar power includes: photovoltaic (PV) and Concentrated Solar Power (CSP).
18) Thermal power includes: fossil fuel powered plant and nuclear plants.
19) Ocean energy is not being considered as it is still at the research phase. Geothermal is not being considered as it will not be significantly impacted by climate change.

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Energy and Climate

*Transmission and Distribution

- Impacts of climate variability and change on energy generation are most obvious; however energy transport, transmission and distribution infrastructure will also be indirectly and directly affected
- For e.g. In the electricity sector, resistance of copper lines increases by 0.4% and transformer capacity decreases by 1% for each degree Celsius increase in temperature

The main impacts of climate change on energy transmission and distribution by climate stressor

Climate stressor	Warming trend	Precipitation	Cyclone	Sea level
Transmission and distribution	Higher temperatures may increase electrical resistance for transmission lines, decreasing transmission efficiency. Higher temperatures may increase fire risk, damaging infrastructure including electricity lines.	Precipitation variations may block or delay road transport, affecting transport of oil or gas.	Storms and strong winds may damage infrastructure and electricity lines, reducing system reliability.	Sea-level rise may damage infrastructure through salt-water corrosion.

)18

Energy and Climate

*Energy Consumption

* Energy demand will considerably increase due to development and population growth, prompting changes in usage of energy. Global warming will induce increased energy needs for cooling in summer seasons and decreased heating needs in winter seasons. Overall, additional energy reserves and emergency energy capacity will be needed for extreme events, such as heat waves.
* For e.g. In Thailand, a global temperature rise of 1.7 to 3.4^{0} C could induce an increase in peak electricity demand by 6.6% to 15.3% by 2080.

Energy and Climate

The main impacts of climate change on energy consumption by climate stressor

Climate stressor	Warming trend	Precipitation	Cyclone	Sea level
End-User	Higher temperatures may increase energy demand for cooling, and reduce energy demand for heating.	Variable precipitation may increase power outages and cause disruptions. Floods and droughts may require additional emergency energy capacity.	Extreme weather events may damage end-user infrastructure and cause power outages.	Sea-level rise may increase the need for energy for desalinisation plants (as fresh water sources are threatened) and for water efficient irrigation techniques (as crops are threatened).

Summarising

- Energy generation will be particularly vulnerable to temperature increases and precipitation fluctuations
- Transmission and distribution networks will suffer from extreme storms and tropical cyclones
- Energy consumption will be highly sensitive to heat waves for cooling energy demand

The energy sector will therefore be increasingly affected by climate change impacts. Moreover, the climate-vulnerability of the developing countries adds to the severity and urgency of these consequences.

Key Areas of Action to Build a Resilient Energy Sector

MEASURES TO ADAPT THE ENERGY SECTOR TO CLIMATE CHANGE

* Climate proofing refers to the "consideration and internalisation of the risks and opportunities that climate change scenarios are likely to imply for the design, operation, and maintenance of infrastructure"
* Climate proofing also includes prevention of maladaptation, which is "adaptation that does not succeed in reducing vulnerability but increases it instead". For e.g., simply providing a community with access to energy can lead to over-extraction of natural resources. Often water is the targeted resource
* In general, energy generation also requires immense quantities of water, making the challenge of balancing water availability with energy demand and supply an issue of increasing urgency and importance. Whilst energy will predominantly contribute positively to climate change adaptation, awareness of maladaptation must exist during energy project planning and implementation.
* Projects must be implemented using a holistic approach considering all the natural, human, social and financial resources specific to the socioecological system where the project is based

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Key Areas of Action to Build a Resilient Energy Sector

MEASURES TO ADAPT THE ENERGY SECTOR TO CLIMATE CHANGE

* As there will always be uncertainties concerning the nature and intensity of future climate change as well as the vulnerability of systems, climate adaptation will remain an ongoing process
* Adaptation measures for the energy sector include
* Proactive measures - reduce exposure to future risks, such as by planning the location of future power systems in less exposed areas
* Reactive measures – reduce the impacts on already installed systems, such as by fortifying a dam on an installed hydropower plant

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Key Areas of Action to Build a Resilient Energy Sector

GENERAL ADAPTATION SOLUTIONS TO PROTECT MARKET SEGMENTS OF THE ENERGY SECTOR

* **Ensure enough adaptive capacity to address climate change uncertainty -** Adaptive capacity refers to the "ability or potential of a system to respond successfully to climate variability and change". This can be facilitated through the control and access to social, human, natural and financial resources.
* **Access to energy, in particular in rural areas, in developing countries to reduce climate vulnerability -** As extending an electricity network to rural regions is often costly, an effective means to increase energy access in rural areas is through off-grid decentralised renewable energy systems.
* **Energy diversification to eliminate reliance on one single generation source to enhance security of supply**

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Key Areas of Action to Build a Resilient Energy Sector

GENERAL ADAPTATION SOLUTIONS TO PROTECT MARKET SEGMENTS OF THE ENERGY SECTOR

* Energy efficiency, water efficiency and demand—side management to alleviate supply constraints
* Reducing and shifting energy demand away from peak hours and thus smoothing the demand curve for energy over the day and the year, thereby lowering overall required energy capacity
* Distributed as opposed to centralised energy systems can increase resilience

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ADAPTATION MEASURES BY ENERGY SOURCE AND CLIMATE STRESSOR

Adaptation measures cannot be generalised, as specific geographic and socio-economic conditions require a differentiated local approach

The main impacts of climate change on energy transmission and distribution by climate stressor

Climate stressor	Warming trend	Precipitation	Cyclone	Sea level
Hydro power	Glacier melt may increase the water capacity requirements of a hydro plant, thus inducing the requirement for enlarged and strengthened dams and hydropower station fortification.	Precipitation increases may increase mountain erosion and the quantity of silt and grit in the water being transported to the hydro plants. This effect would require improved de-siltation[31] gates and improved hydrological forecasting. Floods may require enlarged hydro flood gates and increased dam height. Based on flow regime (e.g. in case of precipitation decrease), relocation of upstream river tributaries or dams can be considered.	Increased storm and cyclone intensity and/or frequency may require resilient hydropower infrastructure.	*No significant adaptation measure*

ADAPTATION MEASURES BY ENERGY SOURCE AND CLIMATE STRESSOR

Wind power	*No significant adaptation measure*	Flood risks may require plant relocation.	Increased storms and cyclones may require turbine designs to withstand high wind speeds. Increased wind speeds will be maximal at higher altitudes and in order to capture the strongest winds higher towers could be used. Variation in wind speed may require the consideration of vertical axis turbines as the latter are less sensitive to rapid changes in wind direction.	Sea-level rise may require plant relocation.
Biomass	Higher temperatures may require crop species that can tolerate these high temperatures.	Precipitation uncertainties may require enhanced irrigation systems. Increased precipitation may require crop selections for biomass that can tolerate higher water stresses. Floods may require building of dykes and drainage.	Storms may require early warning systems for emergency harvesting.	Sea-level and risk of salinisation may require building of dykes and drainage systems.

ADAPTATION MEASURES BY ENERGY SOURCE AND CLIMATE STRESSOR

Solar power	Increased temperatures may require increased airflow beneath mounting structure to cool.	Decreased precipitation risks for CSP plants may require air cooling systems instead of water cooling systems. Water re-use can also be considered.	Increased storms and cyclones may require panels designed to withstand strong winds.	Sea-level rise may require plant relocation.
Thermal power	Increased temperatures may require more efficient cooling systems (wastewater usage, water reuse, water recovery from heat exchangers, reduction of evaporative losses) and decentralised generation.	Droughts and floods may require improvements in robustness of plant stations. Flood risks may require relocation of storage reservoirs. Decreased precipitation may require air cooling systems instead of water cooling systems. Water re-use can also be considered.	Storm risks may require improvements in robustness of plant stations. Extreme events may require additional storage capacity. Extreme events may require emergency planning procedures. Increased storms may require wind proof standards.	Sea-level rise may require plant relocation, flood control systems (embankments, dykes, ponds, barriers).

The adaptation measures presented can only be adopted after a site-specific climate risk assessment has been performed

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ADAPTATION MEASURES BY ENERGY SOURCE AND CLIMATE STRESSOR

Transmission and distribution	Increased temperatures may require additional powerline protection. Underground transport and transfer structures could be used. Cooling for substations and transformers & ICT components that are resistant to high temperatures could be considered.	*No significant adaptation measure*	Extreme events may require enhanced powerline robustness. Extreme events may require emergency planning procedures and regular infrastructure assessments and monitoring. Extreme events may require concrete-sided buildings instead of metal (structure is more resistant to wind and corrosion).	Sea-level rise may require relocation and robustness increases to avoid salt-water corrosion.
End-User	Increased temperatures may require energy efficient appliances/fuel substitutes for heating/ cooling and transport.	Variable precipitation may require water efficient appliances.	Extreme storms may increase power outages and require investment in decentralised power at the household level for energy supply stability.	Sea-level rise may require relocation.

- Before implementing all infrastructure projects, especially those with long lifetimes, both an environmental impact assessment and a climate risk assessment, or the two assessments in combination shall be carried out to identify where extra fortification and adaptation needs lie in the present and future

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CARBON FOOTPRINT

* Total emission caused by an individual event, organization or product expressed as carbon dioxide equivalent
* CO_2e (Carbon dioxide equivalent) is the measure of describing how much global warming a given type and amount of greenhouse gas (GHG) may cause, using the functionally equivalent amount or concentration of CO_2 as the reference
* The total amount of CO_2 and other greenhouse gases emitted over the full life cycle of a product or process, from extraction of raw materials through to decommissioning
* Expressed as gCO_2eq/kWh – accounts for the GWP of other GHGs

GLOBAL WARMING POTENTIAL(GWP)

Global warming potential (GWP) is a relative measure of how much heat a greenhouse gas traps in the atmosphere. It compares the amount of heat trapped by a certain mass of the gas in question to the amount of heat trapped by a similar mass of carbon dioxide. GWP is calculated over a specific time interval, commonly 20, 100, or 500 years and is expressed as a factor of carbon dioxide

GLOBAL WARMING POTENTIAL(GWP)

* Two key ways in which these gases differ from each other are their ability to absorb energy (their "radiative efficiency"), and how long they stay in the atmosphere (also known as their "lifetime").
* Global Warming Potential (GWP) was developed to allow comparisons of the global warming impacts of different gases. Specifically, it is a measure of how much energy the emissions of 1 ton of a gas will absorb over a given period of time, relative to the emissions of 1 ton of carbon dioxide (CO_2). The larger the GWP, the more that a given gas warms the Earth compared to CO_2 over that time period. The time period usually used for GWPs is 100 years.
* CO_2, by definition, has a GWP of 1 regardless of the time period used, because it is the gas being used as the reference. CO_2 remains in the climate system for a very long time: CO_2 emissions cause increases in atmospheric concentrations of CO_2 that will last thousands of years.

GLOBAL WARMING POTENTIAL(GWP)

* Methane (CH_4) is estimated to have a GWP of 28-36 over 100 years. CH_4 emitted today lasts about a decade on average, which is much less time than CO_2. But CH_4 also absorbs much more energy than CO_2. The net effect of the shorter lifetime and higher energy absorption is reflected in the GWP. The CH_4 GWP also accounts for some indirect effects, such as the fact that CH_4 is a precursor to ozone, and ozone is itself a GHG.
* Nitrous Oxide (N_2O) has a GWP 265-298 times that of CO_2 for a 100-year timescale. N_2O emitted today remains in the atmosphere for more than 100 years, on average.
* Chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs), hydrochlorofluorocarbons (HCFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6) are sometimes called high-GWP gases because, for a given amount of mass, they trap substantially more heat than CO_2. (The GWPs for these gases can be in the thousands or tens of thousands.)

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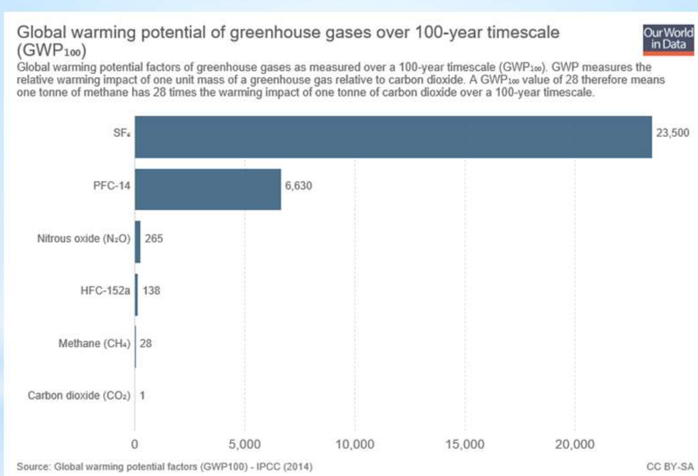
GWP of GHGs



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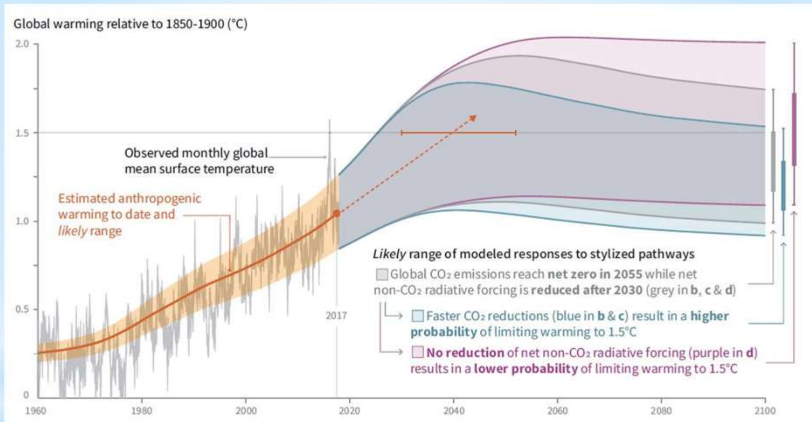
NET ZERO CARBON FOOTPRINT

* Carbon neutrality, or having a net zero carbon footprint, refers to achieving net zero carbon emissions by balancing a measured amount of carbon released with an equivalent amount sequestered or offset, or buying enough carbon credits to make up the difference. It is used in the context of carbon dioxide releasing processes associated with transportation, energy production, and industrial processes such as production of carbon neutral fuel
* Net zero carbon dioxide (CO_2) emissions are achieved when anthropogenic CO_2 emissions are balanced globally by anthropogenic CO_2 removals over a specified period

GLOBAL WARMING OF 1.5°C

* Human activities are estimated to have caused approximately 1.0°C of global warming above pre-industrial levels, with a likely range of 0.8°C to 1.2°C. Global warming is likely to reach 1.5°C between 2030 and 2052 if it continues to increase at the current rate
* Reflecting the long-term warming trend since pre-industrial times, observed global mean surface temperature (GMST) for the decade 2006–2015 was 0.87°C (likely between 0.75°C and 0.99°C) higher than the average over the 1850–1900
* Warming greater than the global annual average is being experienced in many land regions and seasons, including two to three times higher in the Arctic. Warming is generally higher over land than over the ocean

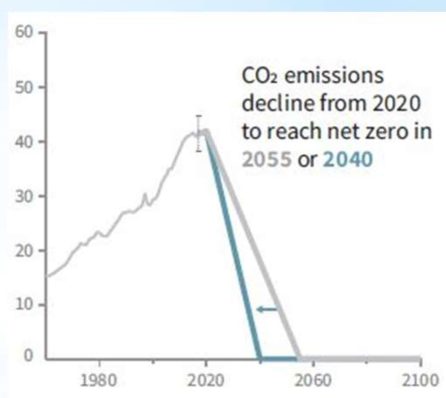
GLOBAL WARMING OF 1.5˚C



Observed global temperature change and modeled responses to stylized anthropogenic emission and forcing pathways

GLOBAL WARMING OF 1.5˚C

* Warming from anthropogenic emissions from the pre-industrial period to the present will persist for centuries to millennia and will continue to cause further long-term changes in the climate system, such as sea level rise, with associated impacts (high confidence), but these emissions alone are unlikely to cause global warming of 1.5˚C (medium confidence)

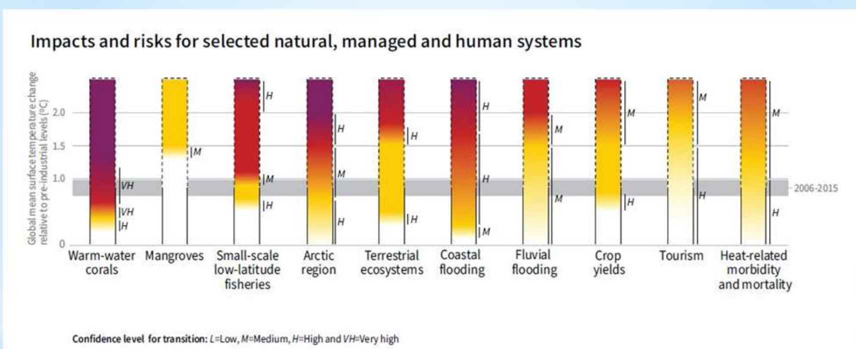


Stylized net global CO_2 emission pathways

PROJECTED CLIMATE CHANGE, POTENTIAL IMPACTS AND ASSOCIATED RISKS

* Climate models project robust differences in regional climate characteristics between present-day and global warming of 1.5˚C, and between 1.5˚C and 2˚C. These differences include increases in: mean temperature in most land and ocean regions (high confidence), hot extremes in most inhabited regions (high confidence), heavy precipitation in several regions (medium confidence), and the probability of drought and precipitation deficits in some regions (medium confidence)
* By 2100, global mean sea level rise is projected to be around 0.1 meter lower with global warming of 1.5˚C compared to 2˚C (medium confidence). Sea level will continue to rise well beyond 2100 (high confidence), and the magnitude and rate of this rise depend on future emission pathways. A slower rate of sea level rise enables greater opportunities for adaptation in the human and ecological systems of small islands, low-lying coastal areas and deltas (medium confidence)
* On land, impacts on biodiversity and ecosystems, including species loss and extinction, are projected to be lower at 1.5˚C of global warming compared to 2˚C. Limiting global warming to 1.5˚C compared to 2˚C is projected to lower the impacts on terrestrial, freshwater and coastal ecosystems and to retain more of their services to humans (high confidence).

PROJECTED CLIMATE CHANGE, POTENTIAL IMPACTS AND ASSOCIATED RISKS



Recent data confirm that emissions continue to grow and CO_2 concentrations have increased to over 390 ppm, or 39% above preindustrial levels, by the end of 2010

RENEWABLE ENERGY SOURCES AND TECHNOLOGIES

* **Bioenergy** can be produced from a variety of biomass feed stocks, including forest, agricultural and livestock residues; short-rotation forest plantations; energy crops; the organic component of municipal solid waste; and other organic waste streams. Through a variety of processes, these feed stocks can be directly used to produce electricity or heat, or can be used to create gaseous, liquid, or solid fuels
* **Direct solar energy** technologies harness the energy of solar irradiance to produce electricity using photovoltaics (PV) and concentrating solar power (CSP), to produce thermal energy (heating or cooling, either through passive or active means), to meet direct lighting needs and, potentially, to produce fuels that might be used for transport and other purposes

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RENEWABLE ENERGY SOURCES AND TECHNOLOGIES

* **Geothermal energy** utilizes the accessible thermal energy from the Earth's interior. Heat is extracted from geothermal reservoirs using wells or other means. Reservoirs that are naturally sufficiently hot and permeable are called hydrothermal reservoirs, whereas reservoirs that are sufficiently hot but are improved with hydraulic stimulation are called enhanced geothermal systems (EGS)
* **Hydropower** harnesses the energy of water moving from higher to lower elevations, primarily to generate electricity. Hydropower projects encompass dam projects with reservoirs, run-of-river and in-stream projects and cover a continuum in project scale. This variety gives hydropower the ability to meet large centralized urban needs as well as decentralized rural needs

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RENEWABLE ENERGY SOURCES AND TECHNOLOGIES

* **Ocean energy** derives from the potential, kinetic, thermal and chemical energy of seawater, which can be transformed to provide electricity, thermal energy, or potable water. A wide range of technologies are possible, such as barrages for tidal range, submarine turbines for tidal and ocean currents, heat exchangers for ocean thermal energy conversion, and a variety of devices to harness the energy of waves and salinity gradients
* **Wind energy** harnesses the kinetic energy of moving air. The primary application of relevance to climate change mitigation is to produce electricity from large wind turbines located on land (onshore) or in sea- or freshwater (offshore). Onshore wind energy technologies are already being manufactured and deployed on a large scale

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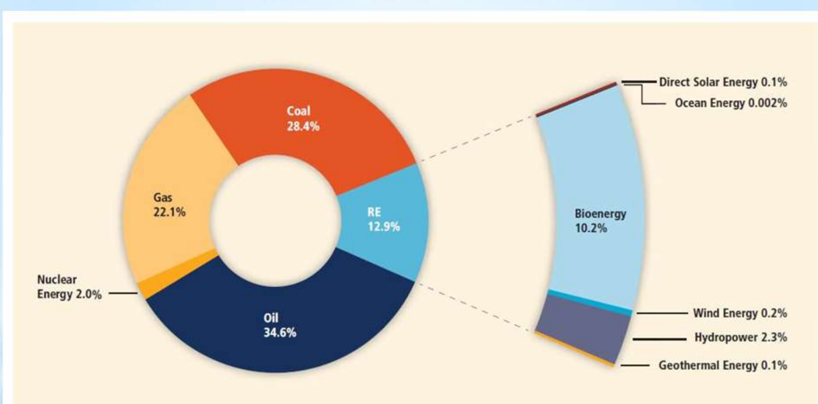
RENEWABLE ENERGY SOURCES AND TECHNOLOGIES



Share of different energy sources in total global primary energy supply in 2008

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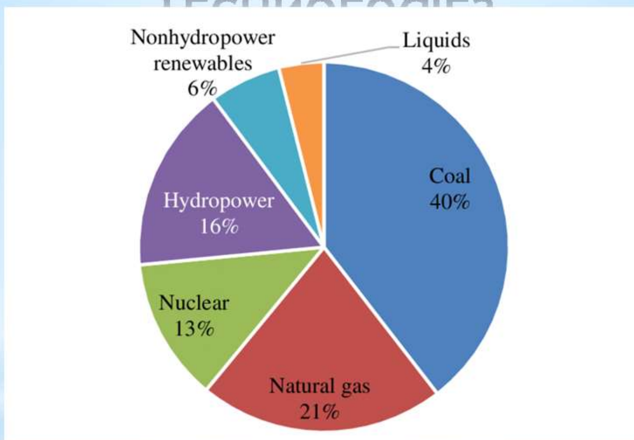
RENEWABLE ENERGY SOURCES AND TECHNOLOGIES



World-electricity-generation-percentage-by-energy-source-2015-trillion-kilowatt-hours

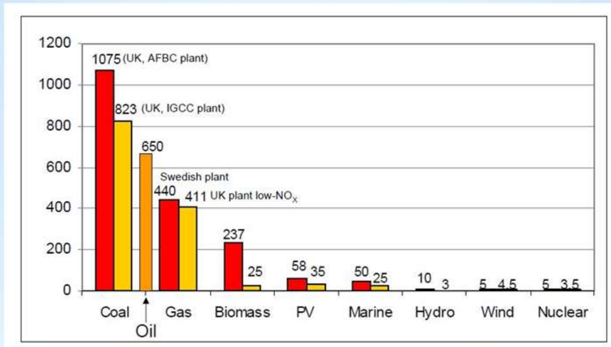
CARBON FOOTPRINT OF ELECTRICITY GENERATION

* No electricity generation technology is 'carbon free'
* All electricity generation technologies have a carbon footprint
* Carbon footprints are calculated using Life Cycle Assessment (LCA)

Questions

* Current carbon footprint ?
* Future carbon footprint ?
* Comparison ?

Carbon Footprints of Electricity Generation Technologies



UK & EUROPEAN DATA 2004-2006

Ranges in each electricity generation technology are due to

- Differences between individual plants – some older and/or less efficient
- Different technologies – e.g. run-of-river vs. reservoir storage

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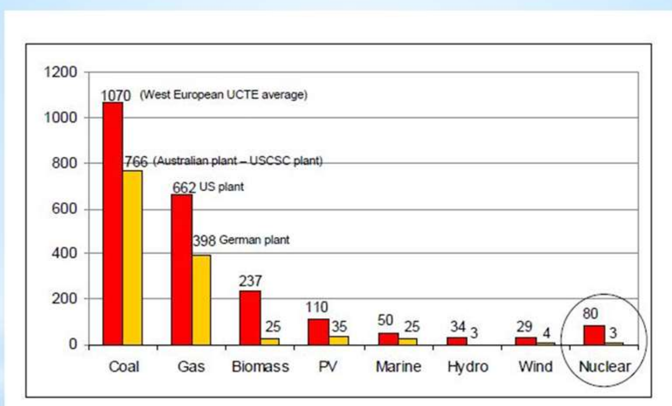
Carbon Footprints of Electricity Generation Technologies



Global Data 2004-2006

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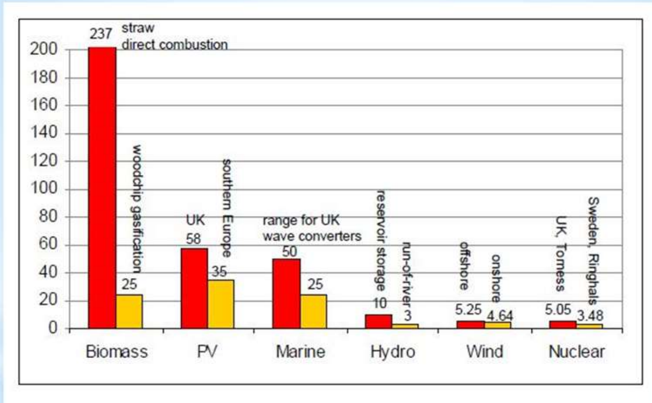
Carbon footprint of low carbon electricity generation technologies (UK & Europe)



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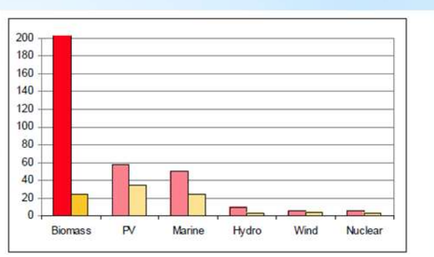
Carbon Foot Print - Biomass

Carbon footprint range:

* Highest: 237 g CO_2 eq/kWh (direct combustion of straw)
* Lowest: 25 g CO_2 eq/kWh (gasification of wood chip)



Issues:

* Biomass is 'carbon neutral' → CO_2 absorbed (growth) = CO_2 released (burning)
* Transport contributes the largest amount of life cycle CO_2 , also fertilizers, harvesting

Large range of carbon footprints → related to differences in energy and density

Co-firing biomass + fossil fuels can reduce the carbon footprint of fossil fuelled power

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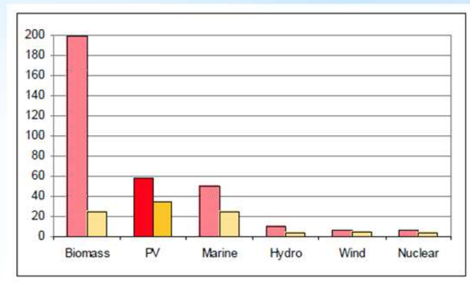
Carbon Foot Print – Photovoltaics (Solar)

Carbon footprint range:

* Highest: 58 gCO_2eq/kWh (UK)
* Lowest: 35 gCO_2eq/kWh (southern Europe)

Issues:

* PV cells predominantly made of high grade silicon
* Silicon extraction and **purification** is most energy intensive phase (60% of CO_2)



- Future reductions in silicon use (e.g. thin film) will lower carbon footprint
- Carbon footprint lower in southern Europe because greater operating hours

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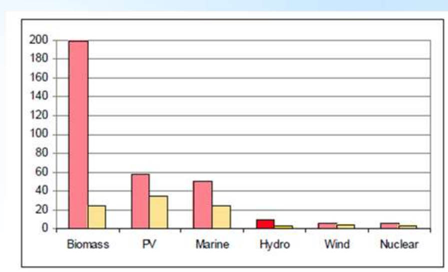
Carbon Foot Print - Hydro

Carbon footprint range:

* Highest: 10 gCO_2eq/kWh (non-alpine reservoir storage)
* Lowest: 3 gCO_2eq/kWh (non-alpine run-of-river)
* Issues:
* Two main schemes: reservoir storage (large scale), run-of-river (small scale)
* Storage schemes have higher carbon footprint since a dam is constructed



- Run-of-river schemes have the smallest carbon footprint of all technologies
- Hydro has small CO_2 emissions, but some methane (CH_4) is also emitted

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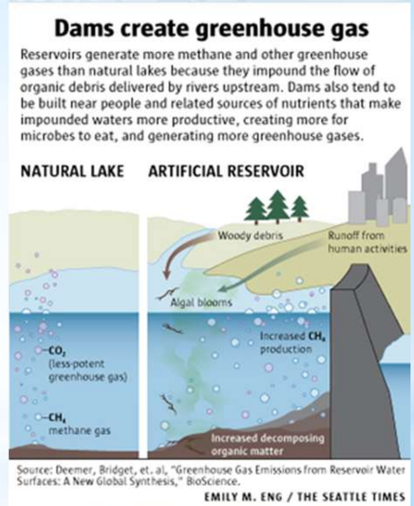
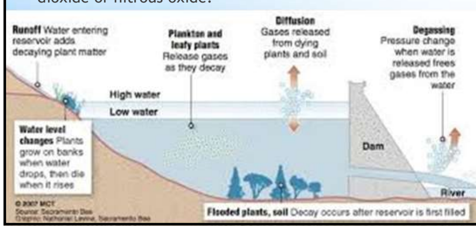
Hydropower and GHGs

* Reservoirs are a classic instance of how major human alteration's to the Earth's landscape can have unexpected effects. Flooding large areas of Earth can set off new chemical processes as tiny microorganisms break down organic matter in the water, sometimes doing so in the absence of oxygen — a process that leads to methane as a byproduct. One reason this happens is that the flooded areas initially contain lots of organic life in the form of trees and grasses. Meanwhile, as nutrients like nitrogen and phosphorus flow into reservoirs from rivers — being poured in by human agriculture and waste streams — these can further drive algal growth in reservoirs, giving microorganisms even more material to break down. Methane accounted for 79 percent of carbon dioxide equivalent emissions from reservoirs, while the other two greenhouse gases, carbon dioxide and nitrous oxide, accounted for 17 percent and 4 percent. The study finds that for these reasons, reservoirs emit more methane than "natural lakes, ponds, rivers, or wetlands." "If oxygen is around, then methane gets converted back to CO_2," said John Harrison, another of the study's authors, and also a researcher at Washington State. A similar process occurs in rice paddies, which are also a major source of methane emissions. Some reservoirs are indeed "sinks" for carbon dioxide or nitrous oxide.





The study does not represent a full "life cycle analysis" of reservoirs, taking into account how much carbon was stored (or emitted from) lands prior to their being flooded, and also what happens after reservoirs are decommissioned.

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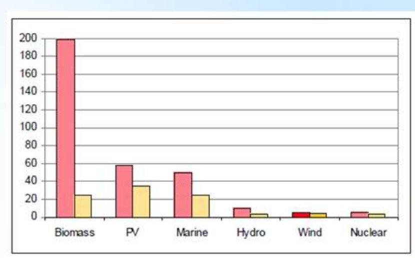
Carbon Foot Print – Wind

Carbon footprint range:

* Highest: 5.25 gCO_2eq/kWh (UK offshore)
* Lowest: 4.64 gCO_2eq/kWh (UK onshore)

Issues:

* Wind has one of the lowest carbon footprints
* 98% of emissions arise during manufacturing & construction (steel, concrete)
* Remaining emissions arise during maintenance phase of life cycle
* Footprint of offshore turbine is greater due to larger foundations



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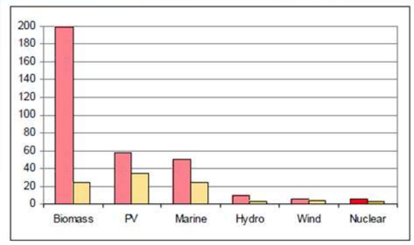
Carbon Foot Print – Nuclear

Carbon footprint range:

* Highest: 5.05 gCO_2eq/kWh (UK, Torness plant)
* Lowest: 3.48 gCO_2eq/kWh (Sweden, Ringhals plant)

Issues:

* Nuclear also has a very small carbon footprint
* Most CO_2 emitted during uranium mining (40% of life cycle CO_2)
* Global uranium reserves – lower grades may cause footprint to rise in future
* 3 studies: AEA (6.8g), Öko (30-60g), Storm van Leeuwin (60 to 120g)



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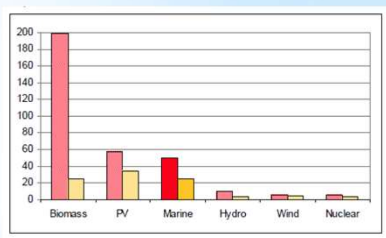
Carbon Foot Print -Marine (Wave and Tidal)

Carbon footprint range:

* Highest: 50 gCO_2eq/kWh (range for UK wave converters)
* Lowest: 25 gCO_2eq/kWh

Issues:

* Two main types of devices: wave energy converters & tidal stream/barrage devices
* Marine electricity generation still an emerging technology – most still prototypes
* No commercial marine powered electricity generation in the UK yet
* Marine carbon footprint currently equivalent to PV, but may reduce to level of wind



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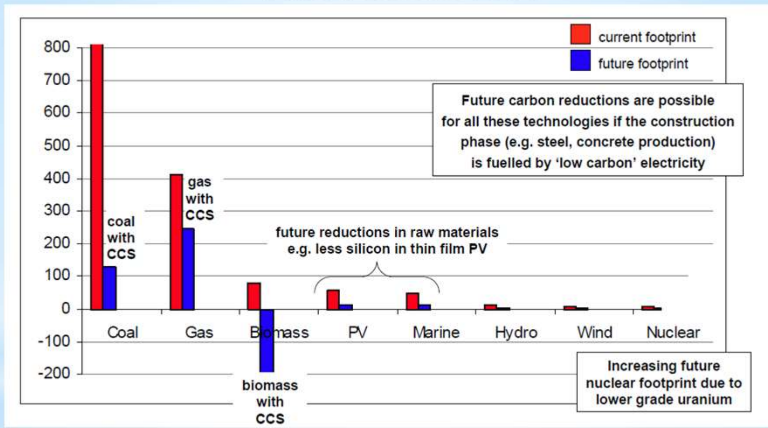
Future carbon footprint reductions (increases???)



Future carbon footprints can be reduced for all electricity generation technologies if the high CO_2 emission phases are fuelled by low carbon energy sources

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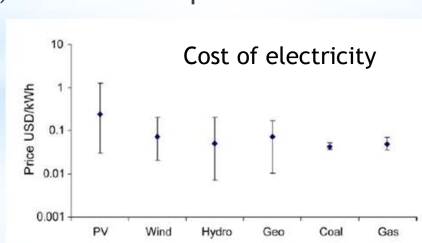
SUSTAINABILITY INDICATORS FOR RENEWABLE ENERGY TECHNOLOGIES

* Non-combustion based renewable electricity generation technologies were assessed in a study against a range of sustainability indicators
* The indicators used to assess each technology were price of generated electricity, greenhouse gas emissions during full life cycle of the technology, availability of renewable sources, efficiency of energy conversion, land requirement, water consumption, and social impacts



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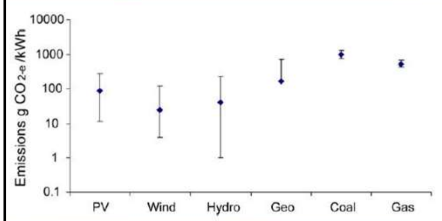
SUSTAINABILITY INDICATORS FOR RENEWABLE ENERGY TECHNOLOGIES



Carbon dioxide equivalent emissions during electricity generation

Water consumption in kg per kW h of electricity generation

Photovoltaic	10
Wind	1
Hydro	36
Geothermal	12–300
Coal	78
Gas	78

Qualitative social impact assessment

Technology	Impact	Magnitude
Photovoltaic	Toxins	Minor–major
	Visual	Minor
Wind	Bird strike	Minor
	Noise	Minor
	Visual	Minor
Hydro	Displacement	Minor–major
	Agricultural	Minor–major
	River Damage	Minor–major
Geothermal	Seismic activity	Minor
	Odour	Minor
	Pollution	Minor–major
	Noise	Minor

Efficiency of electricity generation

Photovoltaic	4–22%
Wind	24–54%
Hydro	>90%
Geothermal	10–20%
Coal	32–45%
Gas	45–53%

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SUSTAINABILITY INDICATORS FOR RENEWABLE ENERGY TECHNOLOGIES

Sustainability rankings

	Photovoltaics	Wind	Hydro	Geothermal
Price	4	3	1	2
CO_{2-e} Emissions	3	1	2	4
Availability and limitations	4	2	1	3
Efficiency	4	2	1	3
Land use	1	3	4	2
Water consumption	2	1	3	4
Social impacts	2	1	4	3
Total	20	13	16	21

The ranking revealed that wind power is the most sustainable, followed by hydropower, photovoltaics and geothermal

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10 nations that produce highest amount of electricity

* China - 6,495,100 GWh
* United States - 4,281,800 GWh
* India - 1,387,000 GWh
* Russia - 1,091,200 GWh
* Japan - 1,020,000 GWh
* Canada - 693,400 GWh
* Germany - 654,200 GWh
* Brazil - 590,900 GWh
* South Korea - 571,700 GWh
* France - 554,100 GWh

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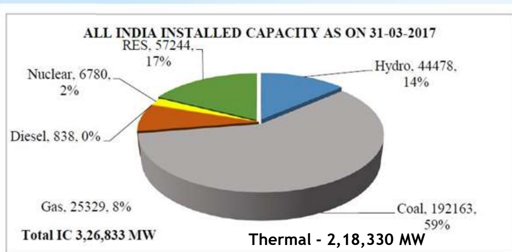
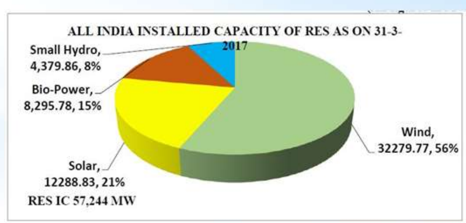
Energy Scenario - India



The country has significant potential of generation from renewable energy sources
India ranks fourth in the world in terms of installed capacity of wind power plants



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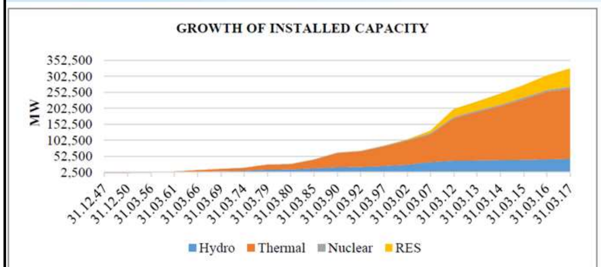
Energy Scenario - India



Per Capita Electricity Consumption

YEAR	PER CAPITA CONSUMPTION (kWh)
2012-13	914.41
2013-14	956.64
2014-15	1010.00
2015-16	1075.00
2016-17	1122.00

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Energy Scenario - India

Some Policy Initiatives of the GoI

* **Development of Power Projects On Tariff Based Bidding**
* **Hydro Policy - 2008**
* **Renewable Energy Sources**

The Government of India has presently set an installed capacity target of 1,75,000 MW from renewable energy sources by 2022. This includes 1,00,000 MW from solar, 60,000 MW from wind, 10,000 MW from biomass and 5000 MW from small hydro power. Within the target of 1,00,000 MW for solar energy, 40,000 MW would be from solar roof tops and the balance 60,000 MW would be from off the ground large and medium scale projects involving both the State Governments and also other institutes like Central Public Sector Undertakings (CPSUs), Independent Power Producers (IPPs), Solar Energy Corporation of India (SECI) etc.

* **Nuclear Power**

The Government has recently taken several initiatives to facilitate expansion of nuclear power in the country like creation of the Indian Nuclear Insurance Pool (INIP), and an amendment to the Atomic Energy Act to enable Joint Venture companies of Public Sector Enterprises to set up nuclear power plants.

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Energy Scenario - India

Some Policy Initiatives of the GoI

* Integrated Power Development Scheme (IPDS)
* Deen Dayal Upadhyaya Gram Jyoti Yojna" (DDUGJY)
* National Smart Grid Mission (NSGM)
* Creation of National Electricity Fund (NEF) for Distribution Scheme
* Improving Energy Efficiency
* The National Mission on Enhanced Energy Efficiency
* Domestic Efficient Lighting Programme
* Scheme for Utilisation of Gas Based Capacity

Recent Renewable Energy Initiatives

* Solar Parks
* Solar Cities
* National Offshore Wind Energy Policy 2015
* National Solar Mission
* Solar Pumps

Integration of RE Sources in the Grid

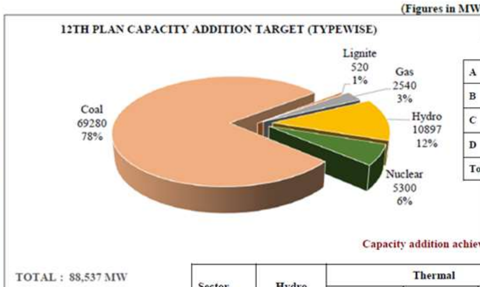
Energy Scenario - India

12th Plan Capacity Addition Target

(Figures in MW)

Source	Central	State	Private	Total
Hydro	6,004	1,608	3,285	10,897
Thermal	14,878	13,922	43,540	72,340
Nuclear	5,300	0	0	5,300
Total	26,182	15,530	46,825	88,537

(Figures in MW)



Summary of capacity addition achieved during 12th Plan

(Figures in MW)

A	12th Plan Capacity Addition Target	88,537
B	Capacity addition as per target (88,537 MW) of 12th Plan as on 31.03.2017	63,912.9
C	Capacity slipped from the capacity addition target of 12th Plan	24,613.8
D	Additional Capacity commissioned during 12th Plan as on 31.03.2017 outside the capacity addition target	35,296.6
Total Capacity addition achieved during 12th Plan (B+D)		99,209.5

Capacity addition achieved during 12th Plan

(Figures in MW)

Sector	Hydro	Thermal			Nuclear	Total
		Coal+Lignite	Gas	Total		
State	1076	20130	2071.4	22201.4	0	23,277.4
Private	1819	49730	3930.5	53660.5	0	55,479.5
Central	2584	14990	878.6	15868.6	2000	20,452.6
Total	5,479	84,850	6,880.5	91,730.5	2000	99,209.5

Energy Scenario - India

The installed capacity of renewable energy sources in the country at the end of 11th Plan (2007-12) was 24,503 MW. During 11th Plan, a capacity addition of 16,744 MW was achieved from renewable energy sources.

Capacity addition target for Renewable Energy Sources during 12th Plan

(Figures in MW)

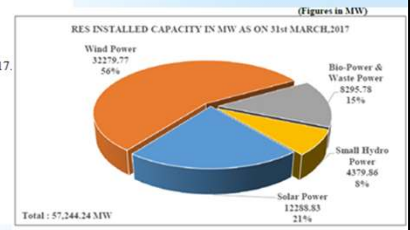
Source	Capacity
Solar	10,000
Wind	15,000
Other RES	5,000
Total	**30,000**

However, the target of installed capacity of RES by 2021-22 has been revised to 1,75,000 MW.
The installed capacity from renewable energy sources in the country is 57,244.23 MW as on 31.03.2017.

Installed capacity of Renewable energy sources as on 31st March,2017

(Figures in MW)

Source	Capacity
Solar	12,288.83
Wind	32,279.77
Bio-Power and waste power	8,295.78
Small Hydro	4,379.86
Total	**57,244.24**



Capacity addition achieved from Renewable Energy Sources during 12th Plan as on 31st March,2017

(Figures in MW)

Source	Capacity*
Solar	11,347.53
Wind	15,383.17
Bio-Power and waste power	5,040.78
Small Hydro	969.36
Total	**32,740.84**

Note: As reported by MNRE

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Energy Scenario - India

Energy Efficiency Initiatives by BEE

Regulatory	Market Transformation
• Mandatory Standards and Labelling (S&L) for selective appliances and equipment • Energy Conservation Building Code (ECBC) • Energy usage norms for large industries through Perform-Achieve-Trade (PAT) scheme • Certification of Energy Efficiency professionals (Energy Auditors and Energy Managers) • Fuel efficiency norms for passenger cars • Mandatory Energy Audit of large industries • State level regulations (appliances, buildings & industry sector)	• Promotion of energy efficiency in Agriculture and Municipality sectors to reduce peak demand: Identification of options in AgDSM, MuDSM and SME programs • Formulate and Promote EE and new technologies: CFL, LED, Waste Heat Recovery, Tri-generation etc. • Promote and facilitate usage of energy efficient appliances: Public Procurement • Market transformation of large industries in adopting EE technologies: Energy Saving certificates in PAT scheme • Capacity Building of DISCOMs for implementation of DSM measures • Create awareness and disseminate information on energy efficiency and conservation: Consumer awareness program • Promote use of CFLs through innovative financing i.e. Bachat Lamp Yojana through CDM route • Promote use of LEDs through innovative financing i.e. Domestic Efficient Lighting Program • Promote Super-Efficient Appliance Deployment (SEAD) in colour TVs by international recognition: SEAD program under Clean Energy Ministerial • International co-operation
Fiscal Measures	**Financial Incentives**
• Creation of Partial Risk Guarantee Fund (PRGF) and Venture Capital Fund (VCF) • Creation of State Energy Conservation Funds (SECF)	• Formulate and facilitate implementation of pilot projects and demonstration projects: AgDSM, WHR projects in States, LED street lighting, LED village campaign • Enhancement of laboratory facilities for testing of energy efficient appliances: Laboratory capacity building program • Provision of incentives to manufactures in Super-Efficient Equipment Program (SEEP)

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Energy Scenario - India

Electrical energy consumption, T&D losses, electrical energy requirement and peak electricity demand for the years 2016-17, 2021-22 & 2026-27 on all-India basis as per 19th EPS Report

	Year			CAGR (%)	
	2016-17	2021-22	2026-27	2016-17 to 2021-22	2021-22 to 2026-27
Electrical energy consumption (MU)	920,837	1,300,486	1743,086	7.15	6.03
T&D losses (MU)	239,592	265,537	304,348		
T&D losses (%)	20.65	16.96	14.87		
Electrical energy requirement (MU)	1160,429	1566,023	2047,434	6.18	5.51
Peak Electricity Demand (MW)	161,834	225,751	298,774	6.88	5.77
Derived Load factor (%)	81.85	79.19	78.23		

Expected RES Capacity addition from 2017-22

(All figures in MW)

RES Category	Target RES IC as on 31.03.2022	RES Installed Capacity as on 31.03.2017	Expected RES Capacity addition from 2017-22
Solar	1,00,000	12,289	87,711
Wind	60,000	32,280	27,720
Biomass	10,000	8295	1,705
Small Hydro	5,000	4380	620
Total	**1,75,000**	**57244**	**1,17,756**

Anticipated capacity addition from renewable energy sources during 2022-27 is considered to be of **1,00,000 MW** (**50,000 MW** – Solar, **40,000 MW** Wind, **7,000 MW** Biomass and **3,000 MW** Small Hydro)

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Energy Scenario - India

Committed Units

(All Figures in MW)

Year	Hydro(MW)	Gas(MW)	Nuclear(MW)	Hydro Import(MW)
2017-22	6,823	406	3,300	4,356
2022-27	12,000	0	6,800	17,244

- **Coal based Plants**

The balance capacity (after considering the committed capacity addition from hydro, nuclear, gas and RES) to meet the projected demand is proposed to be met from coal based power plants.

Committed Capacity Addition during 2017-22 and 2022-27

Years	Committed Capacity Addition (MW)			Committed RES Installed Capacity(MW)	Retirement (MW)
	Hydro	Nuclear	Gas		
2017-22	6,823	3,300	406	1,75,000 (By Mar'22)	22,716
2022-27	12,000	6,800	0	2,75,000(By Mar'27)	25,572

With this committed capacity addition, retirements, etc., the additional coal based capacity required by 2021-22 and 2026-27 to meet the peak demand and energy demand would be as follows:

Capacity Addition Required During 2017-22 and 2022-27

Year	Additional coal based Capacity required(MW)	Remarks
2017-22	6,445	Since 47,855 MW are under different stages of construction and are likely to materialise during 2017-22, so no additional capacity is required.
2022-27	46,420	This is in addition to 47,855 MW of coal based capacity which is in different stages of construction and is likely to materialise during 2017-22.

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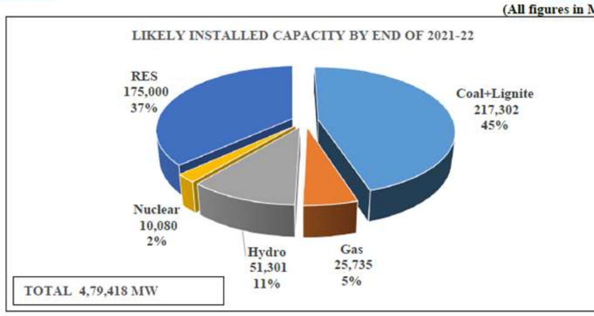
Energy Scenario - India

Projected Installed capacity by the end of 2021-22

Fuel Type	Capacity (MW)	%
Hydro	51,301	10.7
Coal + Lignite	2,17,302	45.3
Gas	25,735	5.4
Nuclear	10,080	2.1
Total Conventional Capacity *	**3,04,419**	**63.5**
Total Renewable Capacity	**1,75,000**	**36.5**
Total Capacity by 2021-22	**4,79,418**	**100.0**

*This includes 47,855 MW of Coal based capacity addition currently under construction and likely to yield benefits during 2017-22.
* This IC does not include Imports from Neighbouring countries during 2017-22

(All figures in MW)



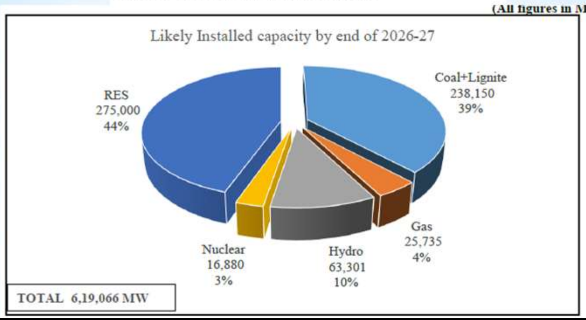
Energy Scenario - India

Projected Installed capacity by the end of 2026-27

Fuel Type	Capacity (MW)	%
Hydro	63,301	10.2
Coal + Lignite	2,38,150	38.5
Gas	25,735	4.2
Nuclear	16,880	2.7
Total Conventional Capacity *	**3,44,066**	**55.6**
Total Renewable Capacity	**2,75,000**	**44.4**
Total Capacity by 2026-27	**6,19,066**	**100.0**

*Including 47,855 MW of Coal based capacity addition currently under construction and likely to yield benefits in 2017-22 and an additional 46,420 MW coal based capacity addition required during 2022-27(**Table 5.13**).
* This IC does not include Imports from Neighbouring countries during 2022-27
Note: The actual IC will change to the extent of thermal capacity materialising and actual retirement taking place between 2022-27.

(All figures in MW)



Energy Scenario - India

Renewable Energy Generation Potential in India

In order to arrest the climate change and in view of the depleting conventional energy sources, India is taking firm steps towards the development of renewable energy. India has significant potential of electricity generation from Renewable Energy Sources (RES). The Renewable Energy (RE) potential in India is estimated at 8,96,602 MW comprising of 7,48,991 MW of Solar Power, 1,02,772 MW of Wind Power, 19,749 MW of Small Hydro Power and 25,090 MW of Bio-Energy.

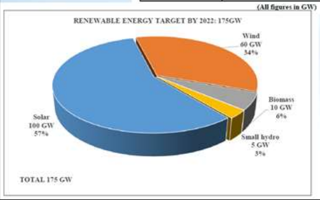
The Government of India, in pursuit of energy security and for minimizing impact on environment, has been prioritizing the development of RE sector through its policies and programmes. Wind, Solar and Small Hydro are three emerging renewable energy sources.

Targeted contribution of the major Renewable Energy Sources

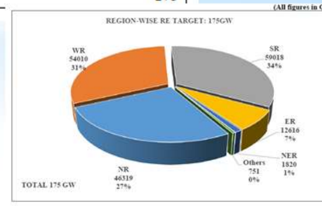
(All figures in GW)

Sl. No.	Renewable Energy Source	Targeted Installed Capacity by 2022
1.	Solar	100
2.	Wind	60
3.	Biomass	10
4.	Small Hydro	5
	Total	**175**

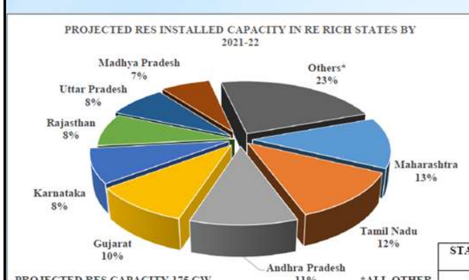
(All figures in GW)



(All figures in GW)



Energy Scenario - India



Estimated Electricity Generation from RES in years 2021-22 and 2026-27

Year	Installed capacity of RES (GW)	Expected Generation in (BU)					Contribution of RES to Total Energy Demand(%)
		Solar	Wind	Biomass	SHP	Total	
2021-22	175	162	112	37	15	326	**20.1%**
2026-27	275	243	188	63	24	518	**24.4%**

STATE-WISE DETAILS OF ESTIMATED POTENTIAL FOR RENEWABLE POWER IN INDIA (ALL FIGURES IN MW)

Sl. No.	States / UTs	Wind Power	Small Hydro Power	Bio-Energy		Solar Power	Total Estimated Potential
				Biomass Power/ Bagasse Cogen.	Waste to Energy		
1	Andhra Pradesh	14,497	978	578	423	38,440	54,916
2	Arunachal Pradesh	236	1,341	8	0	8,650	10,236
3	Assam	112	239	212	8	13,760	14,330
4	Bihar	144	223	619	373	11,200	12,559
5	Chhattisgarh	314	1,107	236	24	18,270	19,951
6	Goa	0	7	26	0	880	912
7	Gujarat	35,071	202	1,221	462	35,770	72,726
8	Haryana	93	110	1,333	374	4,560	6,470
9	Himachal Pradesh	64	2,398	142	2	33,840	36,446
10	Jammu & Kashmir	5,685	1,431	43	0	1,11,050	1,18,208
11	Jharkhand	91	209	90	10	18,180	18,580
12	Karnataka	13,593	4141	1,131	450	24,700	44,015
13	Kerala	837	704	1,044	36	6,110	8,732

Energy Scenario - India

Hydro Power – A Flexible Solution

The power system operation stability requires the system to minimise fluctuations between demand and supply. This encompasses, for example, short term reserves (generation, storage, demand response) to cover potential incidents, which decrease power supply to the system, or to respond to short-term variations in demand and generation. Hydropower therefore provides an ideal solution for the challenges of a transitioning power system.

Conventional reservoir-type hydropower plants and pumped storage power plants can provide the full range of grid-stabilising services in view of their ability to follow demand or generation fluctuations within only a few minutes. There are several different ancillary services or grid stabilising services of hydropower, thus facilitating the integration of variable RES into the power system and providing a key tool to maintain a stable and balanced grid:

*Pumped Storage Plants – The Best Friend of an Electricity Grid

While many forms of energy storage systems have been installed globally, Pumped Storage Plants (PSP) are playing an increasingly important role in providing peaking power and maintaining system stability in the power system of many countries. Pumped storage technology is the long term technically proven, cost effective, highly efficient and operationally flexible way of energy storage on a large scale to store intermittent and variant energy generated by solar and wind.

Out of 96,524 MW of pumped storage potential identified in India by CEA at 63 sites, at present 9 pumped storage schemes with aggregate installed capacity of 4,786 MW are in operation out of which only 5 Nos. plants with aggregate installed capacity of 2,600 MW are being operated in pumping mode. The remaining 4 Nos. plants with an installed capacity of about 2,200 MW are not operating in pumping mode mainly because the 2nd reservoir is either under construction or the same has not been constructed. Efforts should be made to complete and operationalize the pump storage projects not running in PSP mode by resolving the issues.

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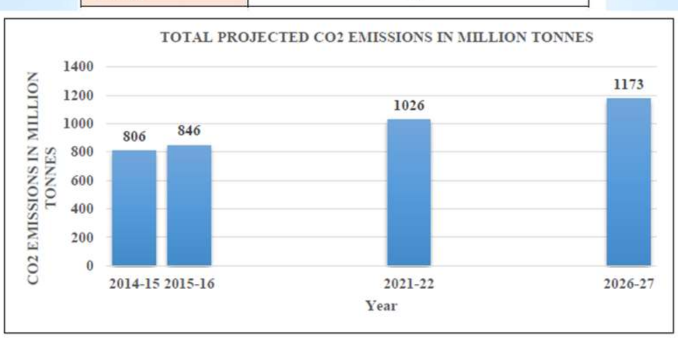
Energy Scenario - India

Per capita emission of CO_2 of different countries

Country	Per capita CO_2 emission in the 2011 (tonnes of CO_2)
India	1.7
USA	17.0
Australia	16.5
U.K	7.1
Japan	9.3
China	6.7
World	4.5



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Energy Scenario - India

COUNTRY'S STAND ON CLIMATE CHANGE- INDCs

Under the Copenhagen Accord, India had pledged to reduce its CO_2 intensity (emissions per GDP) by 20 to 25 percent by 2020 compared to 2005 levels. Also in October,2015, India had submitted its Intended Nationally Determined Contribution (INDC) to UNFCCC. The key elements are:

- To reduce the emissions intensity of its GDP by 33% to 35 % by 2030 from 2005 level.
- To achieve about 40 percent cumulative electric power installed capacity from non-fossil fuel based energy resources by 2030, with the help of transfer of technology and low cost international finance including from Green Climate Fund (GCF).
- To create an additional carbon sink of 2.5 to 3 billion tonnes of CO_2 equivalent through additional forest and tree cover by 2030.

The studies show that the proposed trajectory of capacity addition programme for 2017-22 and 2022-27 is in line with India's submissions under INDCs.

As on 31st March,2017, share of non-fossil fuel based capacity (Hydro + Nuclear + RES) in the total installed capacity of the country is around 33 %. It is expected that the share of non-fossil based capacity will increase to 49.3% by the end of 2021-22 and will further increase to 57.4 % by the end of 2026-27.

Installed capacity and share of non-fossil fuel

Year	Installed Capacity (MW)	Installed Capacity of Fossil fuel (MW)	Installed Capacity of Non-Fossil** fuel (MW)	%of Non-fossil fuel in Installed Capacity
March,2016	3,26,833	2,18,330	1,08,503	33.20%
March,2022	4,79,419	2,43,038	2,36,381	49.31%
March,2027	6,19,066	2,63,885	3,55,181	57.37%

** Non Fossil Fuel – Hydro, Nuclear and Renewable Energy Sources

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Energy Scenario - India

CO_2 emissions Intensity from Power Sector

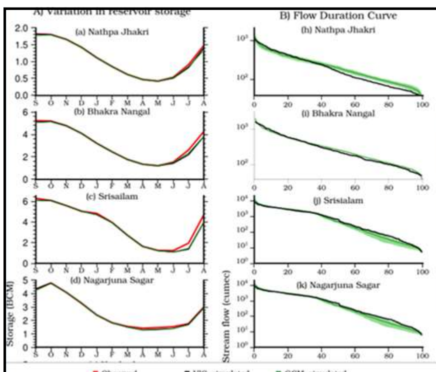
	Years		
	2005	2022	2027
Emission intensity kg/₹ GDP	0.015548	0.009249	0.007207
% Reduction in emission intensity base 2005		40.51	53.65

- Government of India has taken various measures to reduce environmental emissions from thermal power stations. This includes improving efficiency of power generation, notification of stricter environment norms and retiring old and inefficient plants, Perform Achieve and Trade scheme etc.
- The average CO_2 emission rate from coal based stations in the country has been on declining trend indicating improvement in efficiency of power generation from coal based power plants.
- About 20.69 Million tonnes of CO_2 emissions have been saved due to commissioning of Supercritical technology based units.
- It is estimated that about 268 Million tonnes of CO_2 will be avoided annually by the end of 2021-22 due to renewable energy sources.

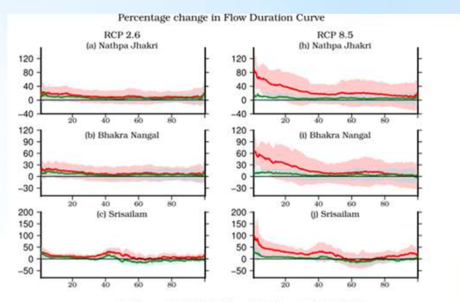
12/20/2018

Hydropower Production under Projected Climate Change – A Study

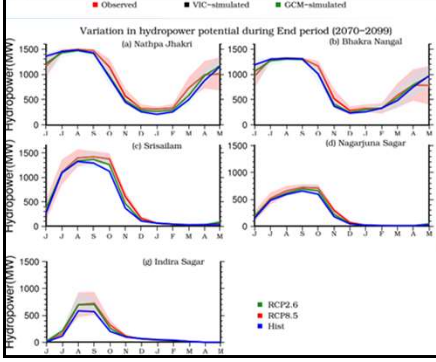
* In this study, using observations and model simulations, the authors showed that seven large hydropower projects that experienced significant warming and a decline in precipitation and streamflow during the observed period of 1951–2007, are all projected to experience a warmer and wetter climate in the future. Multimodel ensemble mean annual average temperature (precipitation) is projected to rise up to 6.3 ± 1.6 °C (18 ± 14.6%) in the catchments upstream of the other reservoirs by the end of the 21st century under RCP8.5. Due to the projected increase in precipitation, mean annual streamflow (up to +45%) and hydropower (up to +25%) production are projected to rise under the future climate. However, significant warming (6.25 ± 1.62 °C) is projected to result in a decline in streamflow and hydropower production in May- June for snow-dominated Nathpa Jhakri and Bhakra Nangal hydropower projects.



(A) Comparison of observed storage reservoir storage (red) (BCM) with the VIC model simulated reservoir storage (black) with the observed meteorological forcing and multimodel ensemble mean storage (green) simulated using the VIC model using downscaled and bias-corrected forcing for 10 CMIP5-GCMs for the period of 2002–2014. (B) Comparison of flow duration curves obtained using the VIC model simulated streamflow with observed data (black) and downscaled and bias-corrected data from the GCM models (green) for the historic period (1971–2000). Shaded regions show intermodel variability for the historic (green) period. The figure was developed using the Generic Mapping Tools (GMT) version 5.4.2 (http://gmt.soest.hawaii.edu).



Multimodel ensemble mean change in flow duration curves for the near (2010–2039, green) and end (2070–2099, red) period for the RCP 2.6 and RCP 8.5. Changes were estimated for each CMIP5-GCM with respect to the historic reference (1971–2000) period and then ensemble mean was estimated. The shaded region shows intermodel variation estimated using one standard deviation for the near (cyan) and end (pink) period. The figure was developed using the Generic Mapping Tools (GMT) version 5.4.2 (http://gmt.soest.hawaii.edu).



Seasonal cycle of multimodel ensemble mean developed hydropower potential (DHP, MW)for the historic (1971–2000, blue) and end period (2070–2099) periods under RCP 2.6 (green) and RCP 8.5 (red) for (a) Nathpa Jhakri, (b) Bhakra Nangal, (c) Srisailam, (d) Nagarjuna Sagar, (e) Hirakud, (f) Sardar Sarovar, and (g) Indira Sagar. Shaded regions show intermodel variation for 10CMIP5-GCMs under RCP 2.6 (cyan) and RCP 8.5 (pink). The figure was developed using the Generic Mapping Tools (GMT) version 5.4.2 (http://gmt.soest.hawaii.edu).

Energy Scenario - Kerala

KERALA POWER SYSTEM AT A GLANCE (AS ON 31.10.2017)						
Transmission & Distribution Lines						
400KV	**220KV**	**110KV**	**66KV**	**33KV**	**11KV**	**LT**
571.96 km	**2801.88 km**	**4484.05 km**	**2154.973 km**	**1929.03 km**	**59946 km**	**285506**

Total connected load	**: 22,040.62MW**
Total internal generation (2016-‘17)	**: 4,369.54 MU**
Total power purchased at Kerala (2016-‘17)	**: 19,050.17 MU**
Energy sales to other state (2016-‘17)	**: 49.3 MU**
Energy input to Kerala/ Total sale within state (2016-‘17)	**: 23,325.95/ 20,038.25 MU**
Per capita consumption (2016)as per above	**: 582 KWh**
Transmission & Distribution losses(2016-2017)	**: 3287.70 MU**
Maximum daily consumption 2016-2017)	**: 80.44MU (29.04.2016)**
Average daily consumption(2016-2017)	**: 65.26 MU**

Energy Scenario - Kerala

GENERATING STATIONS KERALA - OVERVIEW

Sl. No.	Name of Station	Installed Capacity (MW)	Annual Generation Capacity (MU)
	Ia. Hydro Electric Projects (KSEB)		
1	Idukki	780	2398
2	Sabarigiri	340	1338
3	Kuttiyadi HEP, Extension & KAES (75 + 50 + 100)	225	566
4	Lower Periyar	180	493
5	Neriamangalam & Extension (52.65 + 25)	77.65	295.27
6	Idamalayar	75	380
7	Sholayar	54	233
8	Kakkad	50	262
9	Poringalkuth & PLBE (36 + 16)	52	244
10	Sengulam	51.2	182
11	Pallivasal	37.5	284
12	Panniyar	32.4	158
	Sub total	**1954.75**	**6833.37**
	Ib. Small Hydro Electric Projects (KSEB)		
1	Kallada	15	65
2	Malankara	10.5	65
3	Poozhithodu	4.8	10.97
4	Ranni-Perunad	4	16.73
5	Kuttiyadi Tailrace	3.75	17
6	Chembukadavu Stage 1	2.7	6.59
7	Chembukadavu Stage 11	3.75	9.03
8	Urumi-1	3.75	9.72
9	Urumi 11	2.4	6.28
10	Lower Meenmutty	3.5	7.63
11	Peppara	3	11.5
12	Malampuzha	2.5	5.6
13	Mattuppetty	2	6.4
14	Peechi	1.25	3.315
15	Vilangad	7.5	22.63
16	Chimmony	2.5	6.7
17	Andavanpara	3.5	9.01
18	Barapole	15	36
19	Vettathooval	3.6	12.17
20	Perunthenaruvi	6	25.77
	Sub Total	**101**	**353.05**

GENERATING STATIONS KERALA - OVERVIEW

Sl. No.	Name of Station	Installed Capacity (MW)	Annual Generation Capacity (MU)
	Ic. Other Hydro Electric Projects (Pvt.)		
1	Kuthunkal (CPP)	21	79
2	Maniyar (CPP)	12	36
3	Ullunkal (IPP)	7	32
4	Iruttukanam (IPP)	4.5	15.86
5	Karikkayam	10.5	43.69
6	Meenvallam (Dist. Palakkad)	3	8.37
7	Pampumkeyam	0.11	.029
8	Kallar	0.05	0.13
	Sub Total	**58.16**	**215.34**
	Total (Ia + Ib + Ic)	**2113.91**	**7401.66**
	II. THERMAL		
1	Kayamkulam (NTPC) (CENTRAL SECTOR)	359.58	2158
2	BSES Kerala Power Ltd. (BKPL) (Pvt. IPP)	157	1099
3	Kozhikode Diesel Power Plant (KSEB)	96	597
4	Brahmapuram Diesel Power Plant (KSEB)	63.96	364
5	Kasargode Power Corporation Pvt. Ltd. IPP	21.90	140
6	MPS Steel Co-Generation Plant Pvt. IPP	10	67.63
7	Philips Carbon Black India – Co Generation Plant	10	70.08
	Total	**718.44**	**4495.71**
	III.WIND		
1	Kanjikkode (9 x 0.225MW) (KSEB)	2.025	4
2	Ramakkalmedu (9 x 0.75MW) (Pvt. IPP))	14.25	32.46
3	Agali (31 x 0.6MW) (Pvt. IPP)	18.6	37.47
4	Ahalia, Kanjikode (4 x 2.1 MW)	8.40	16.19
	Total	**43.275**	**90.12**
	IV. SOLAR		
	KSEB (8.546MW), CIAL (IPP - 20.5273 MW), Solar Park Ambalathara	**82.0733**	**131.93**
	(IPP-50MW), ANERT Kuzhalmandam (IPP - 2MW), HINDALCO (IPP - 1MW)		
	Total Installed Capacity	**2957.7**	**12119.42**

Energy and Climate

Some mitigation measures – Kerala

* Promote low carbon foot print options for energy generation – solar, wind, small hydro etc as well as hydro including pumped storage
* Chalk out an implement a plan of action in line with the National Action Plan on Climate Change and its component National Missions such as those pertaining to Solar, Energy Efficiency, Water, Sustainable Habitat, Green India etc
* Improve the operational efficiency of existing power projects
* Reduce losses in transmission and distribution
* Distributed generation and commissioning of smart grids
* Incorporate and implement energy conservation measures through appropriate measures including enforcement through building codes and rules
* Promote energy efficient buildings – future proofing of buildings by appropriate measures such as adding additional insulation, increasing use of daylighting, window shading and natural ventilation, energy audits and recommissioning to ensure building performance, blending traditional wisdom into modern architecture and building construction

12/20/2018

Energy and Climate

Some mitigation measures – Kerala

* Reduce wasteful usage of all resources including water
* Develop and promote energy efficient but environment friendly appliances and gadgets
* Demand response programs and efficiency programs aimed at peak loads can help counteract the increase in peak demand due to increased use of air conditioning and address the uncertainties in generation and consumption due to extreme weather, and thus help avoid the need for additional power plants
* Make existing enforcement mechanisms for ensuring compliance of pollution norms and standards meaningful by establishing augmenting and strengthening existing mechanisms through appropriate interventions

12/20/2018