Power generation in India

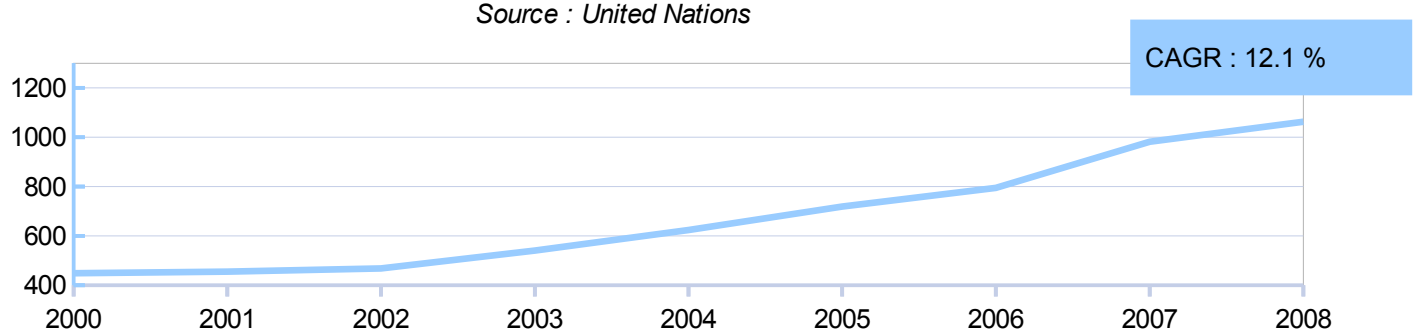
6th December 2010

1. Macro-economics
2. Primary power sources
3. Fossil fuels
4. Nuclear energy
5. Green power
6. Conclusions

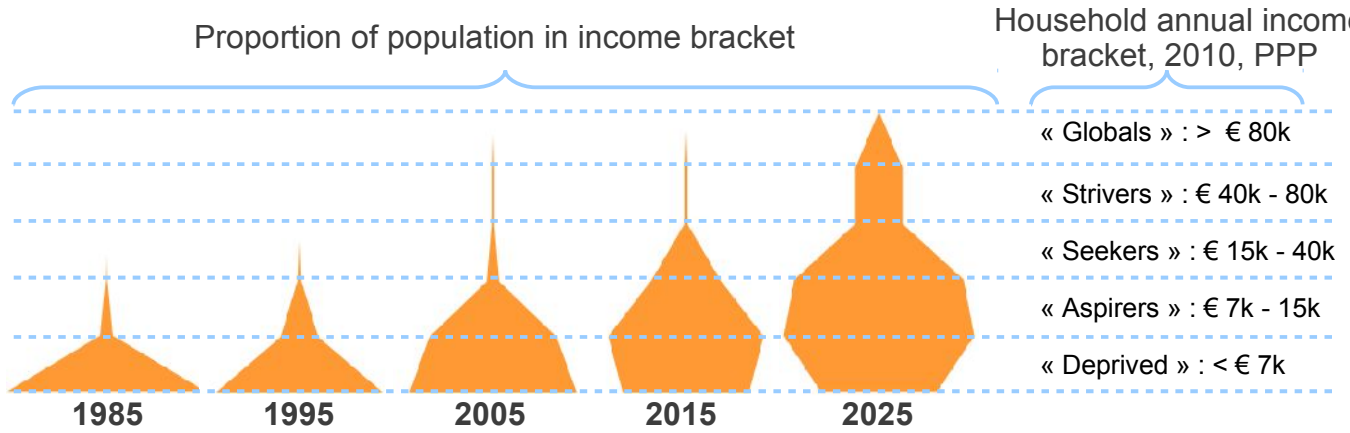
Foreword on India's socio-economic environment

GDP (US$), India, 1990-2008

Source : United Nations



- 83000 millionaires (in USD) in India in 2009, up 20% from 2008
- India's growth expected to overtake China's before 2015
- Per capita income expected to overtake UK, US, by 2040



Recent statistics as well as projections demonstrate that the middle class (« seekers » and « strivers ») is growing both in population and purchasing power.

This fast growth requires electricity to fuel its industry, shopping malls and household equipment. One of the challenges of India for the next two decades will be to supply its population and industry with adequate power ressources.

Electricity : Constraints, demand

- Limited fossil fuel reserves
- 30% of power is lost in transmission
- 12% deficit in eletricity generation
- Demand to grow by 50% by 2025
- Heavy dependence on foreign supplies
- Nuclear power stations are said to run at 50% of capacity only due to sanctions on fuel imports.
- Difficult terrain at its borders, plus « unfriendly » neighbours make it difficult to safeguard imports of primary fuels

-> self-sufficiency is a national priority

- Fast growing economy (5-8% per year, 15% estimate for industry alone)
- Growth depends heavily on industry
- Eastwards shift of power- and labour-intensive industrial processes
- High demand for domestic appliances (A/C, W/M, etc...)

-> fast increasing electrical power demand

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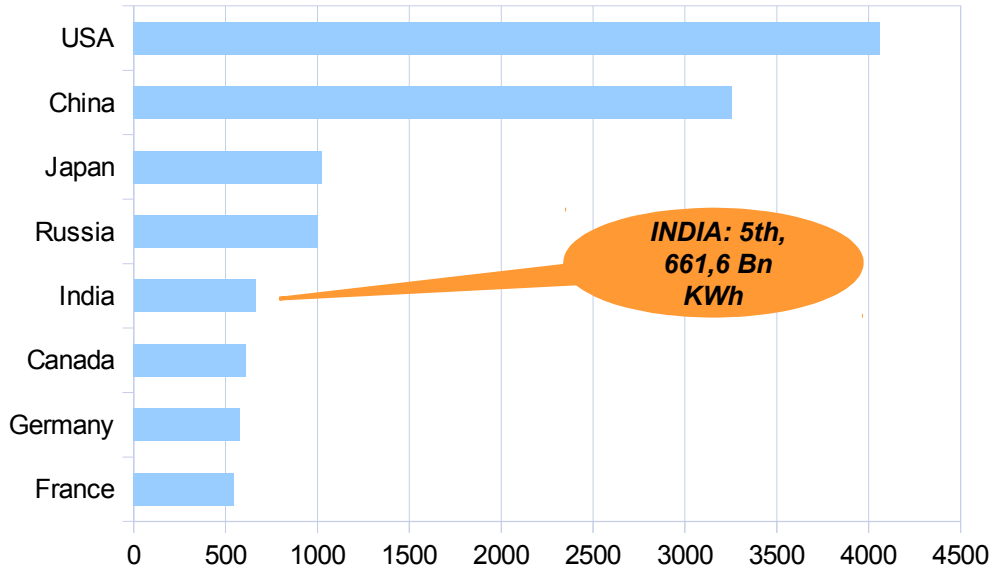
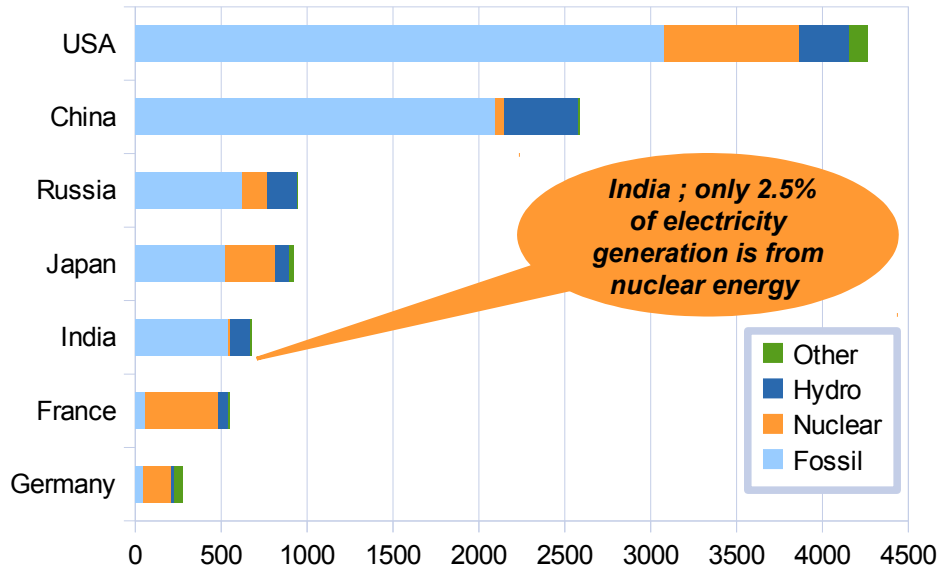
India's electricity generation in the global context

2007 productions, in Bn Kwh



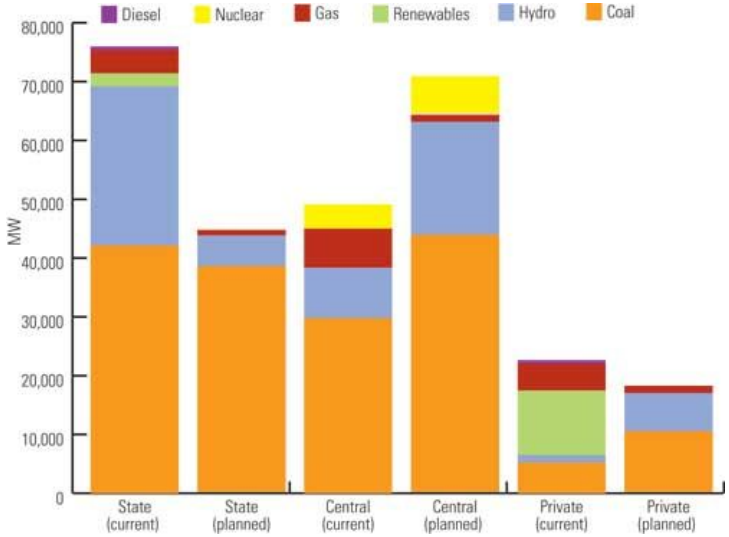
2006, Bn Kwh, by type of fuel



- Total installed capacity in India (2007): 110 Gwe
- Over 75% of electricity is produced from fossil fuels, 15% from hydro,
- Only 3 % of electricity is produced from nuclear energy
- aims to supply 25% of electricity from nuclear power by 2050

Territorial competences, main players

- 100GW additional coal or gas powered electricity generation planned by 2017
- Operators: central, states, private, PPP
- New plants will mostly be under 800MW each
- Main local players : NTPC, BHEL, L&T-MHI, Tata Power, Rel, Torrent...
- BHEL manufactures turbines from 100 to 1000MW, sells in India but also abroad



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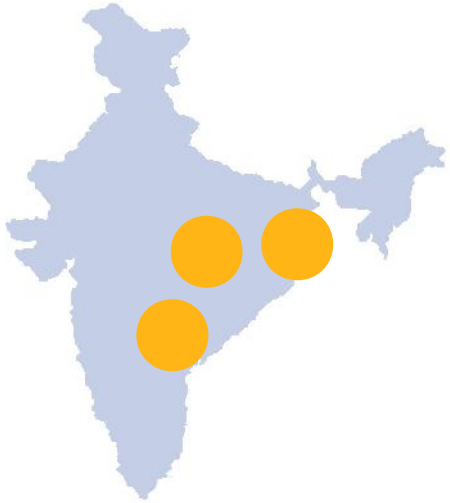
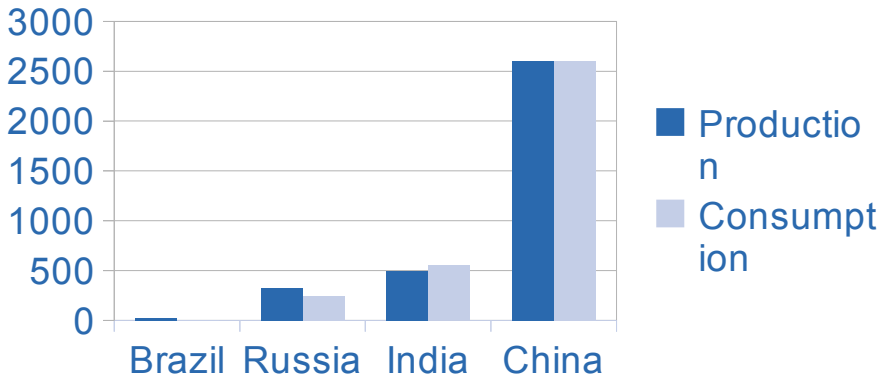
Primary energies : Fossil energy resources

- Oil: a large (and growing) net importer :
  - 880k brls/day production (1% of world production)
  - 3M brls/day consumption (3% of world consumption)
  - Only 0.5% of world's proven reserves
- Gas: a balanced production and consumption
  - 33Bn m3/year production & consumption (1% of the world's total)
  - 2.5% of world's proved reserves
- Coal: large reserves & production, but relatively low quality
  - 3rd producer of coal in the world (530MT/yr, 8% of world's total)
  - Growing imports (10% of consumption)
  - 5Bn T reserves (10% of world's reserves ?), but largely of 30% lower calorific content than average

Coal extraction

- 3rd largest producer of coal in the world
- 7% of world reserves
- Major players:
  - SCCL: 13 opencast, 42 underground mines
  - CIL: 163 opencast, 279 underground mines
- CIL plans to open 34 new underground mines in the next 2-5 years
- Smaller players follow the same trend, some also buy mines in Australia, Indonesia and South Africa

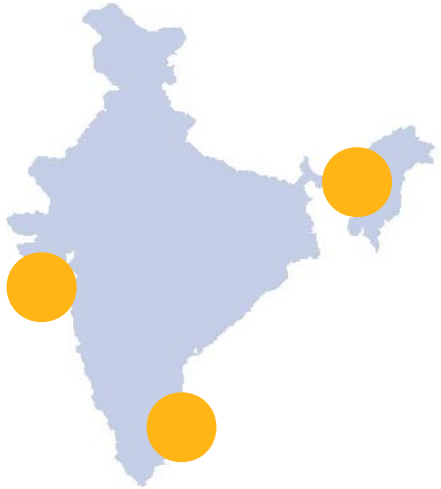


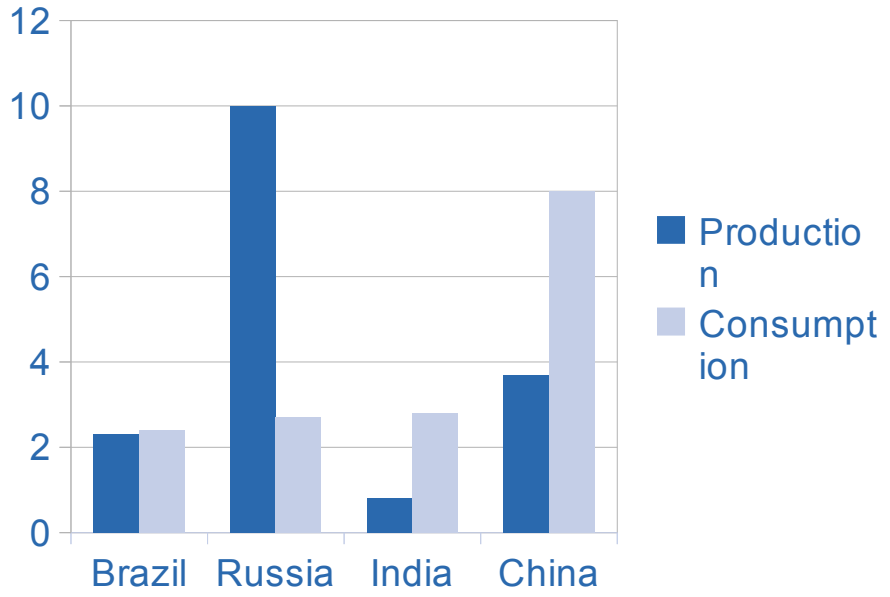


Unit: Million bbl/day
Figures : IndexMundi, 2009

Oil extraction

- India consumes 2.8M bbl/d
- ... produces 0.8M bbl/d
- 3600 oil wells in total
- Largest fields are offshore
- Largest field: Bombay High, off the west coast
- India is home to several engineering and EPC companies involved in designing, building, maintenance of on- and off-shore rigs

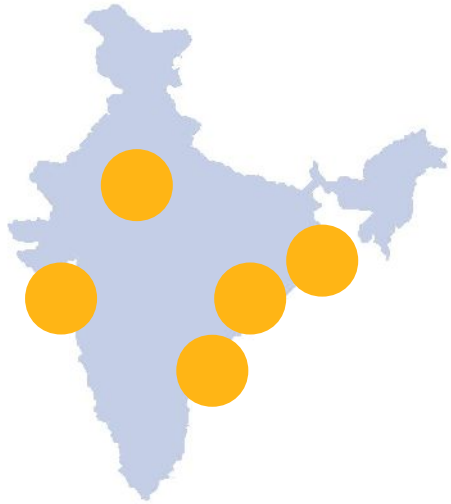


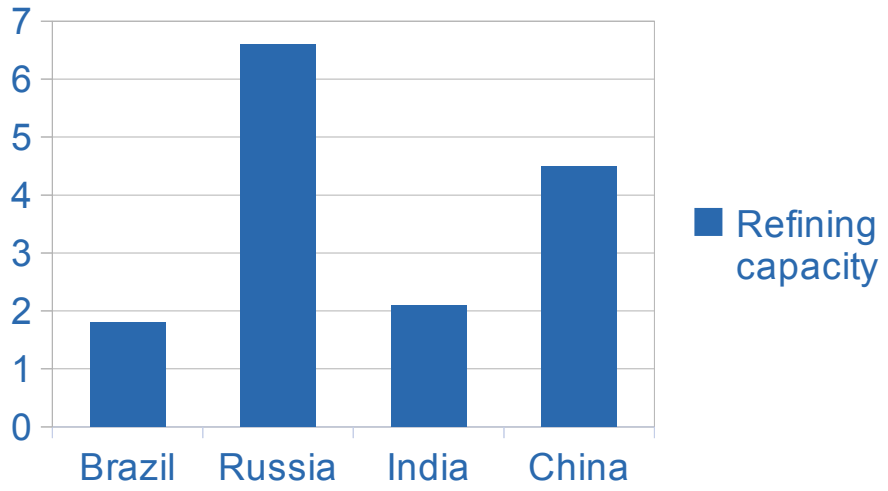


Unit: million Short Tons / year
Figures : IndexMundi, 2009

Oil refining

- 5th refining capacity in the world
- 160 MTPA in 2009, 242 expected by 2012 (80 MTPA addition)
- 20 or so refineries today, 5 to 10 more planned in next 5 years
- Main players : Indian Oil (40%), Reliance, Essar, Bharat Petroleum, Hindustan Petroleum...
- Capacity being expanded at 20% per year or so to meet domestic demand, but also feed Europe and the US as refineries are not welcome there anymore
- Some players (Essar, Reliance) even dedicate some of their refineries solely to exports





Unit: Million bbl/day
Figures : UN, 2009

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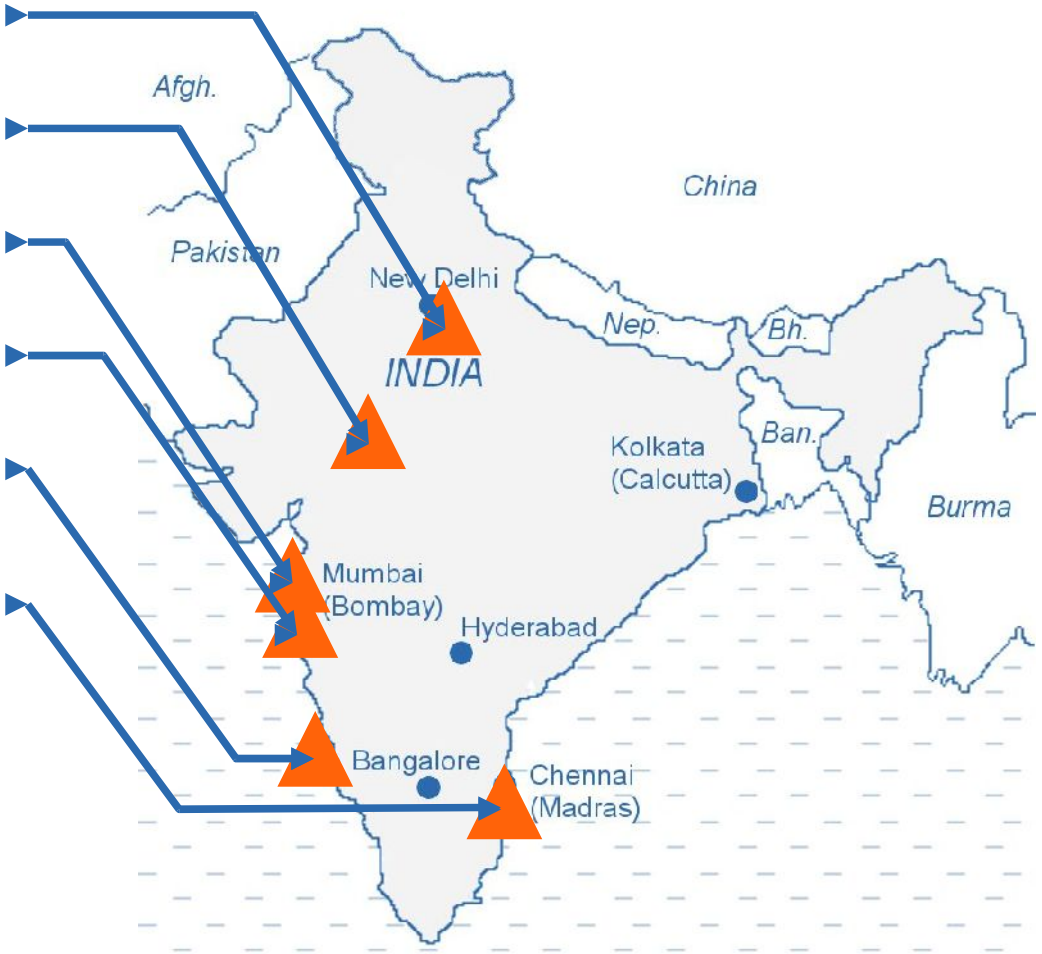
Nuclear power : Policy, expected trends

- 2007 IAEA report : « India's nuclear production will be multiplied by 8 by 2030 »
- Indian Government: « Nuclear energy to reach 26% of total production by 2050. »
- 2007 KPMG report : « India needs to spend US$ 120-150 billion on power infrastructure over the next five years » (including transmission and distribution)
- Analysts: « 6.3% average annual growth in electricity consumption in India until 2020. »

Nuclear reactors currently operating (as of April 2009)

- Narora 1-2 : 404 MWe
- Rawatbatha 1-4 : 681 Mwe
- Kakrapar 1-2 : 404 MWe
- Tarapur 1-4 : 1280 Mwe
- Kalpakkam 1-2, 404MWe
- Kaiga 1-3 : 606 Mwe

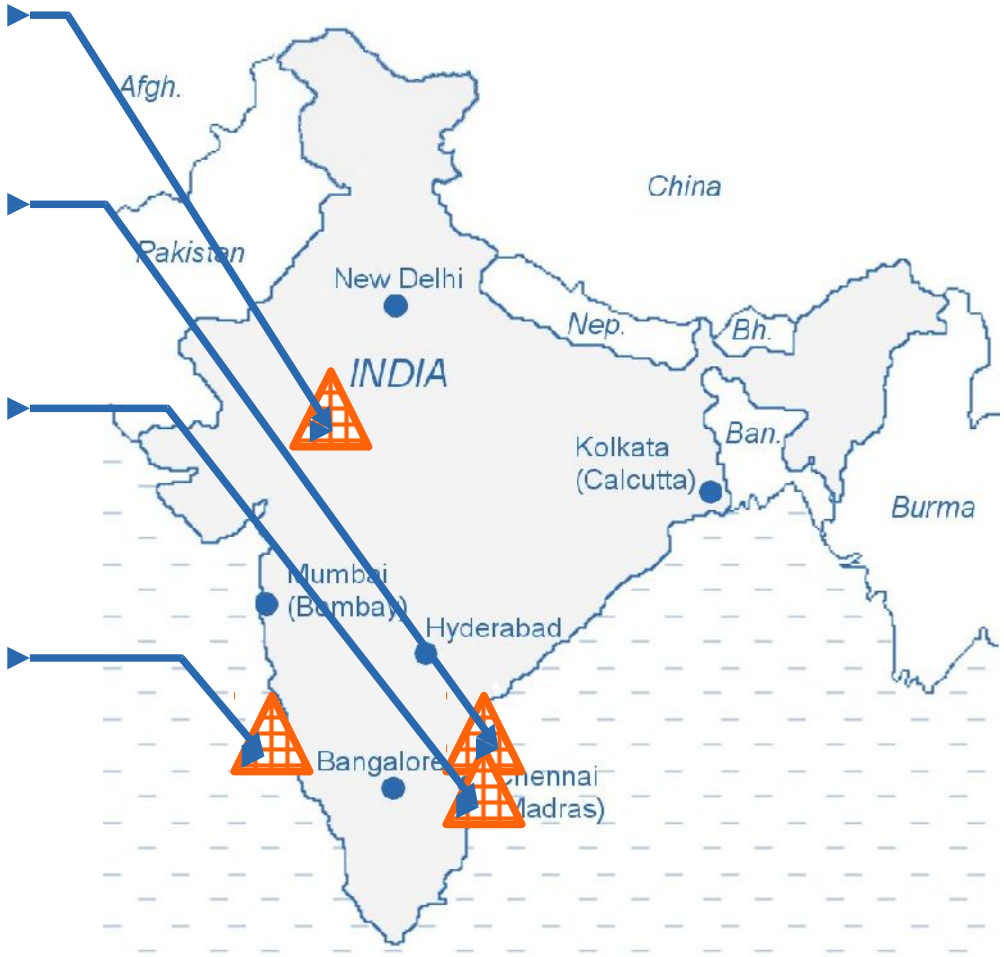
TOTAL: 3779 MWe



Nuclear reactors under construction (as of April 2009)

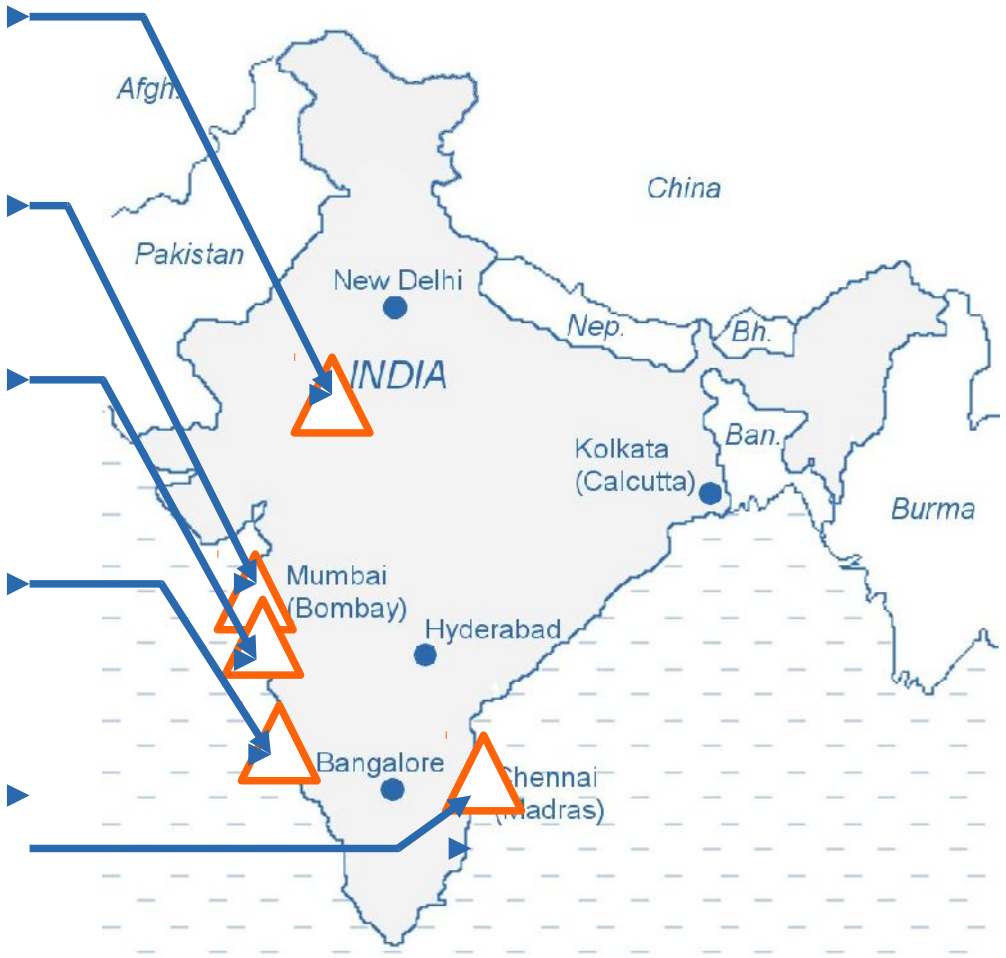
- Rawatbatha 5-6 : 404 MWe (completion: end 2009 ?)
- Kalpakkam « 3 » : 470 MWe (completion: 2011?)
- Kudankulam 1-2 : 950 Mwe (completion: mid-2010 ?)
- Kaiga 4 : 202 MWe (completion: end 2009 ?)

TOTAL: 2976 MWe



Nuclear reactors « seriously planned » (as of April 2009)

•Rawatbatha 7-8: 1280 MWe (completion: end 2012 ?)
•Kakrapar 3-4 : 1280 MWe (completion: end 2012 ?)
•Jaitapur 1-6: 9600 MWe (completion ?)
•Kaiga 5-6 : 2000MWe (completion: 2014 ?)
•Kudankulam 3-6 : 4800 Mwe (completion ?)
TOTAL: ~ 20 GWe



Nuclear fuel resources

- India has limited ressources of Uranium, mainly in the north of the country (extraction: under 500T/year, estimated reserves: 50 000 T)
- Plans to triple extraction by 2012, but this will still be insufficient to fuel the reactors in existence and under construction
- It has however large resources of Thorium (300 000T)
- This has an incidence on the civil nuclear policy of India:
  - Short term: import more Uranium as soon as sanctions lifting allows it in order to save national resources
  - Mid-term: strike « technology for Uranium » deals with Uranium-rich nations (such as Kazakhstan)
  - Long term: give preference to fuel cycles making use of thorium

Civil nuclear industry : India's history

- Bhaba Atomic Research Center (BARC) opened in 1957 to develop civilian nuclear technology. First PHWR reactor was developed and built in collaboration with Canada and commissioned in 1972.
- India is a de facto nuclear power, but is not recognised as such by the 1970 Non-Proliferation Treaty.
- As a result, India was barred from importing fuel and technology for civilian use and had to rely almost exclusively on its indigenous ressources and industry for over 30 years.
- From the embargo of the early 2000s, the situation gradually evolved into less stringent sanctions, and, since late 2008, lifting of those sanctions.

Civil nuclear industry : Focus on Thorium cycle

- India invested in the development of a Thorium cycle due to lack of Uranium (see previous slides)
- In 1985, it became the sixth country to operate a Fast Breeder Test Reactor India's first foray in the Thorium cycle led to t has an active development programme featuring both fast and thermal breeder reactors.
- A « commercial », 500MWe version is currently being built in Kalpakkam (south of India) by Bhavini (state company), under direction of the Indira Gandhi Centre for Atomic Research (IGCAR)
- There are concerns over the cost of the construction compared to the standard PHWR type, but some in te West believe that India may in the future take a lead over other nations in this particular field.

Civil nuclear industry : Public sector : R&D, BOO

- State-owned Bhaba Atomic Research Center (« BARC », located near Mumbai, under the Department of Atomic Energy), is the Indian research center on nuclear fission related technologies
- State-owned Institute for Plasma Research (« IPR », Ahmedabad) is the nuclear fusion nodal research center
- State-owned Nuclear Power Corporation of India Ltd (« NPCIL ») is responsible for design, construction and operation of the existing PHWR nuclear power plants.
- State utility NTPC may operate its own NPP in the future.
- A new state-owned company (« Bhavini ») has been set-up specifically to build and operate FBRs (fast breeder reactors).

Civil nuclear industry : assemblies and components

- 5 to 6 very large conglomerates are active in the supplies of large, complex assemblies to NPCIL, including nuclear-grade pressure vessels.
- Some of those major players are well-known abroad (Tata, L&T, BHEL, etc...), some are not for various reasons.
- After many years of keeping technology and know-how in-house exclusively, DAE (atomic energy), CSIR (civil science) and DRDO (defence R&D) started a decade or so ago to encourage SMEs to apply their findings to the industry.
- This has created a pool of SMEs with interesting processes in-house, often with personnel from those R&D labs. However, they usually lack the reach, export experience and international qualifications of their European counterparts.

Civil nuclear industry : Private sector trends

- Many investment funds have put SMEs active in the nuclear industry high in their priority investments list.
- Indian large public and private utility, design and building companies, along with their contractors / suppliers plan to invest over US$ 50 billion in the next five years to expand their manufacturing base in the nuclear energy sector.
- BHEL alone plans to spend $7.5 billion in two years building plants to supply components for the EPR.
- It also plans to set up a joint venture with NPCIL that will supply components for other nuclear plants (Russian and US origin probably), and to bring overseas partners to bring technology to their equation.

International cooperation : ITER programme

- India is one of the participants to ITER (international nuclear fusion reactor to be built in Cadarache, France)
- India's scope of supply is the design, construction, erection and commissioning of 9 systems revolving around cooling, initial power supply and diagnostics (Cryostat & VVPSS, in-wall shield, cooling water system, diagnostic neutral beam, ICRH source, start-up EC source, cryolines and distribution, power supplies, various diagnostics systems).
- The Institute for Plasma Research (IPR) is the « ITER-India » nodal agency.
- Private companies in India are currently being consulted by IPR in order to map the possible contractors. Packages are said to be worth EUR 500M in total and a tender is already out for some heat exchangers.

Hot topic : EPRs in India

- Lifting of sanctions has opened the door to AREVA selling EPRs to India.
- French and Indian governments signed a framework agreement to this effect in Sept. 2008.
- A MOU was signed in Feb. 2009 between AREVA and NPCIL, covering an initial requirement of 2 reactors and option for 4 more, plus fuel supply for 20 to 60 years.
- It is however likely that India will apply the « multipolar » approach it has applied to defence supplies to nuclear reactors too, i.e. not allowing one of the players (France, Russia, Canada, USA/Japan) to have more than 25 to 50% of the business.

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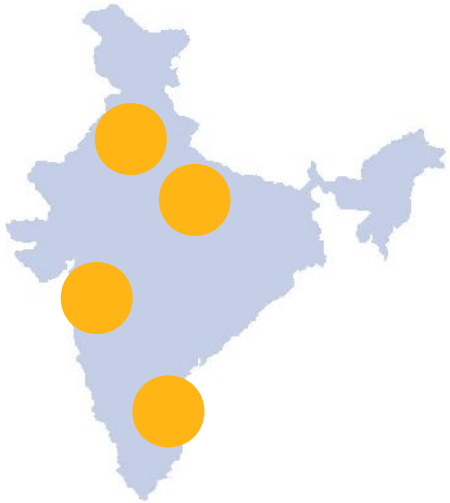
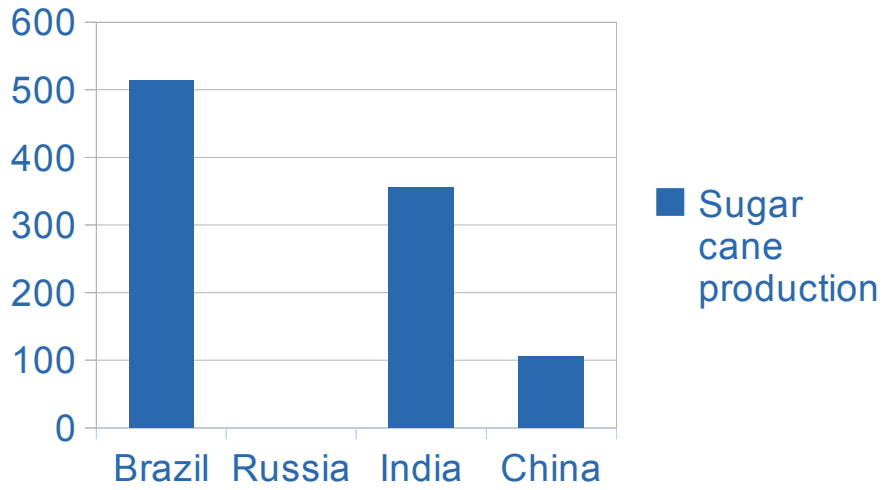
- India is the 2nd largest producer of sugar cane in the world, and the 4th largest of ethanol
- Anaerobic digestion is widely used in distilleries in India. 60% of biogas produced is methane
- Indian Government gives incentives for methane recovery in general, including in sugar processing plants / distilleries
- Most of the processing technologies, engineering, plant design, plant erection are 100% indigenous
- Many of those EPCs sell their plants outside India too





Unit: Million metric ton/year
Figures : Gvt of India, 2008

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