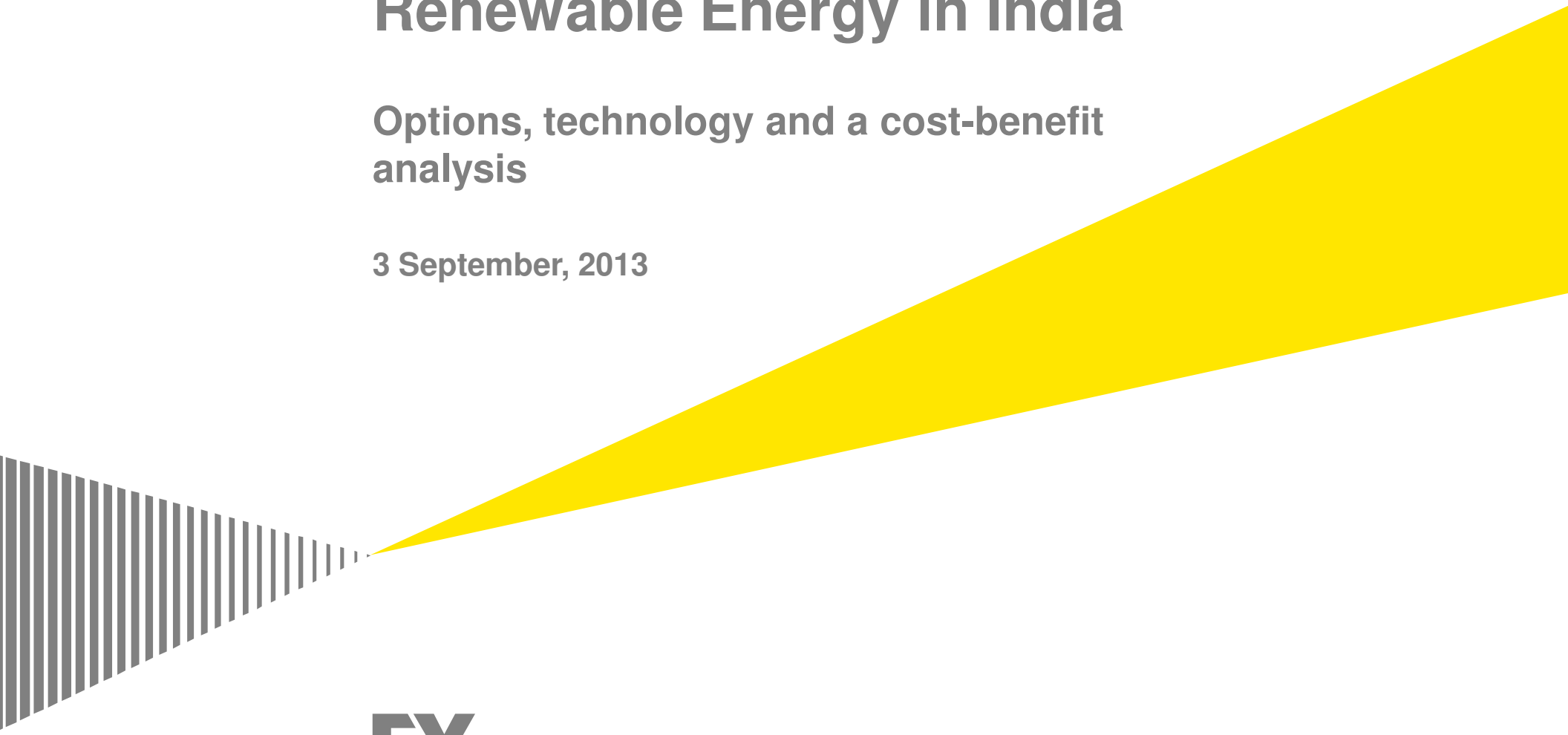
Renewable Energy in India

Options, technology and a cost-benefit analysis

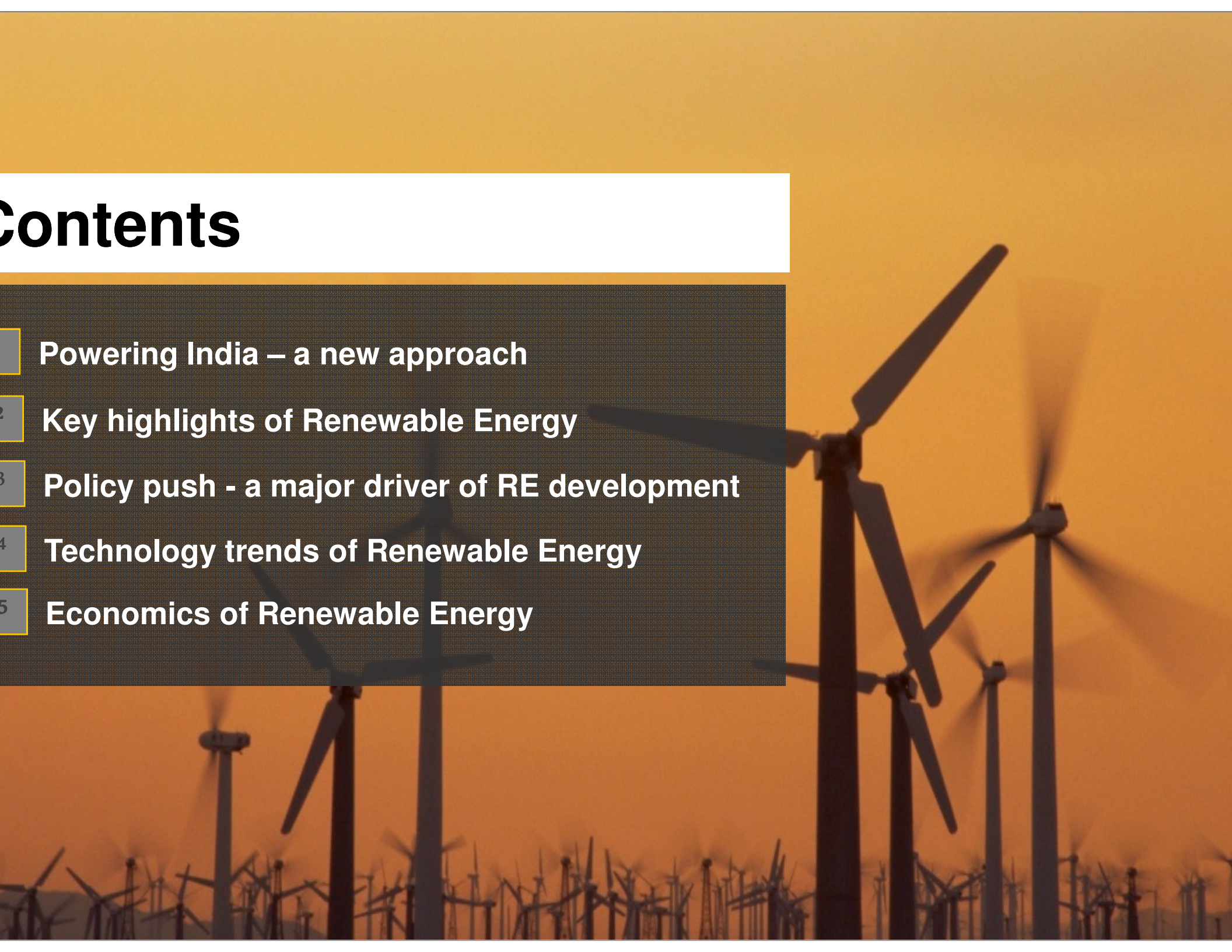
3 September, 2013



EY

Building a better working world

Contents

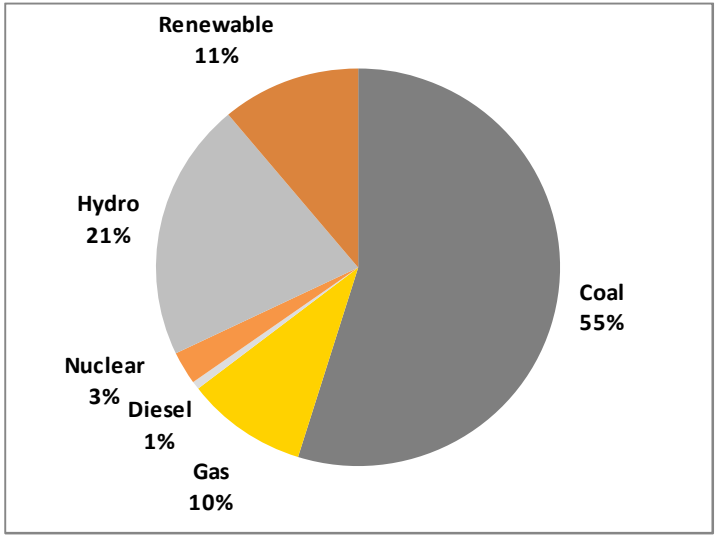


Power scenario in India

- Renewable energy accounts for ~11% of a total of 170 GW of power generation capacity installed in India. Coal accounts for nearly 55% of power generation capacity
- Demand for power in India has been increasing due to growth in economy, rising population and changing lifestyles
- Though over the years there has been appreciable increase in the overall power generation capacity, it is still lower than the overall power demand
- Challenges with conventional power generation:
  - Coal linkages
  - Import of coal (availability and port capacity)
  - Equipment supply
  - Long gestation period
- The demand-supply gap and the disadvantages of conventional power generation are some of the drivers promoting renewable energy in India

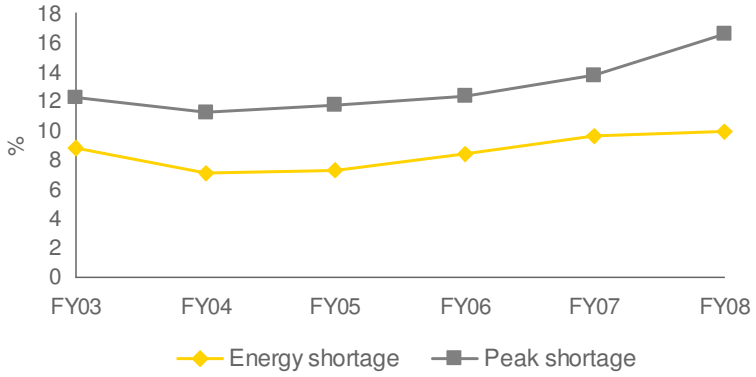
Coal is likely to remain the mainstay of power generation but issues like energy security and environmental concerns are leading India to focus on renewable energy and energy efficiency..

Break up of installed power generation capacity
(as on 31st Aug 2011)



Note: Hydro is also a form of renewable energy, however it is accounted separately. Small hydro power (<=25MW) is classified under Renewable

Energy and Peak Demand Shortage



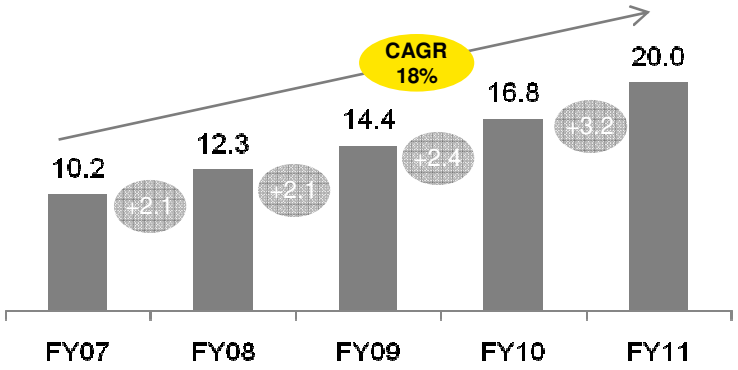
Renewable Energy in India
Untapped potential

- Renewable energy accounts for ~11% of a total of 170 GW of power generation capacity installed in India
- However, renewable energy contributes about 4% (as of January 2011) to the overall electricity generation.
- Wind energy with ~14 GW installed capacity accounts for a significant majority of installed renewable energy capacity in India
- Untapped potential in areas like off-shore wind, tidal, and geothermal energy

Resource	Estimated potential (GW)	Installed capacity (GW)	Untapped potential (GW)
Wind	48.5	14.2	34.3
Small hydro	15.4	3.0	12.4
Biomass	23.0	2.7	20.3
Solar	20-30 MW/sq. km	0.04	-

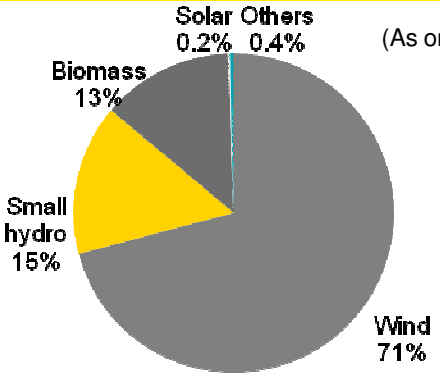
As of 31 Mar 2011 Source: MNRE, EY analysis

Growth of renewable energy installed capacity in India (GW)



Includes wind, solar, biomass (incl. bagasse), and small hydro. Excludes large hydro.
Source: MNRE

Renewable energy installed capacity split in India



(As on 31 March 2011)

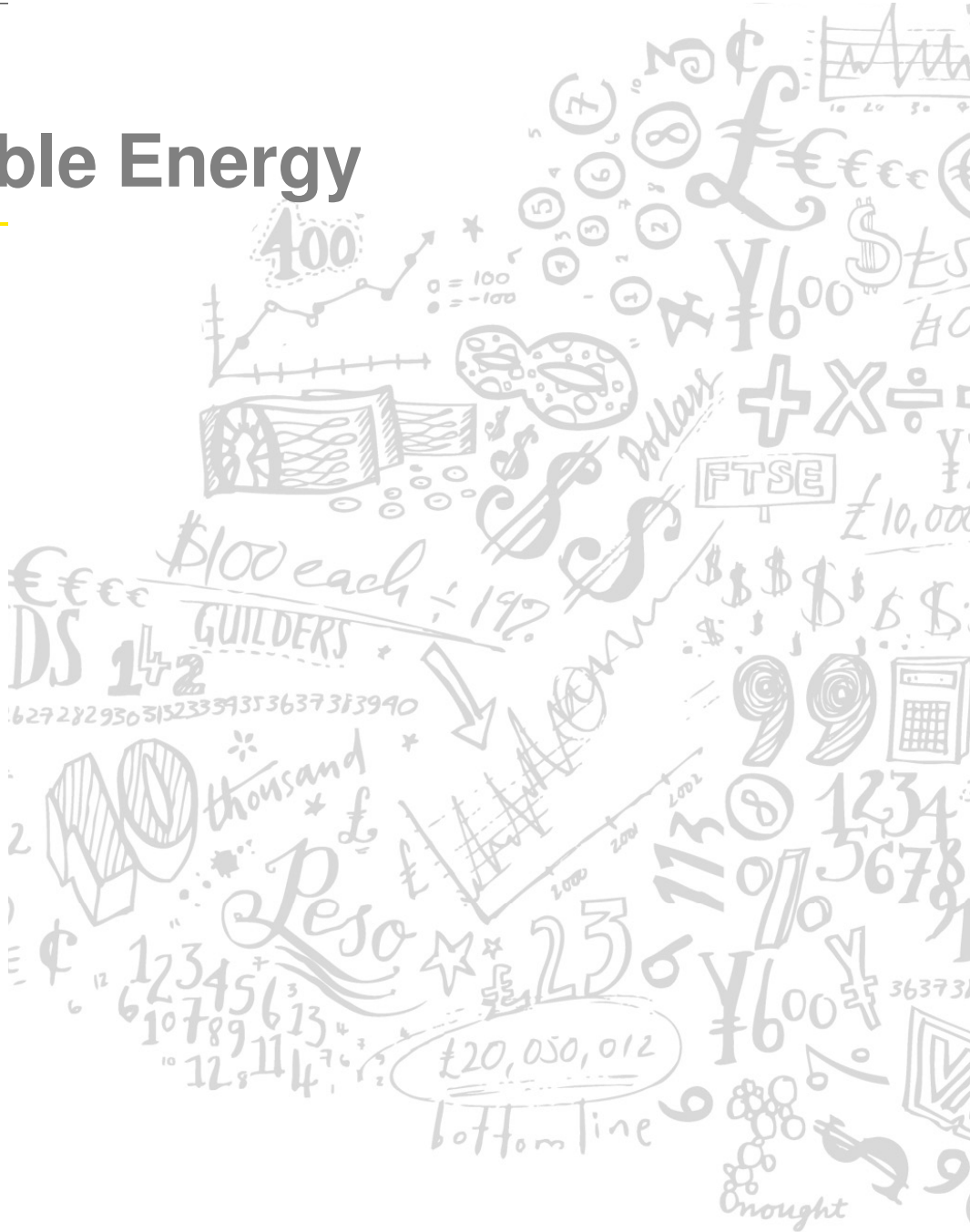
Source: MNRE
Biomass includes bagasse cogeneration; Others includes Waste to power

6 key trends shaping the context of Energy Security issues that would be critically analysed...

1. **Resource security** – (A) Energy security – availability, price volatility, affordability, quality (B) Raw material security – Reserve depletion, Environmental constraint on supply, Commodity price, Resource nationalism
2. **Global economic slowdown** – (A) Declining market (B) Re-distribution of demand
3. **Resource productivity** - (A) Operational efficiency of Indian consumers (B) Cost reduction (C) CAPEX freedom
4. **Government intervention** - (A) Economic competitiveness and growth (B) Domestic CC regulations (C) Disclosure and regulatory transparency (D) Regulations to drive innovation
5. **Emergence of green/ low carbon business model** (A) Convergence of technology (cleantech, ICT, biotech, nanotech) (B) Policy push (C) Increased funding for green solutions
6. **Increase in consumers' preference for low carbon products-** Demand for 'green' goods/services

Key highlights of Renewable Energy

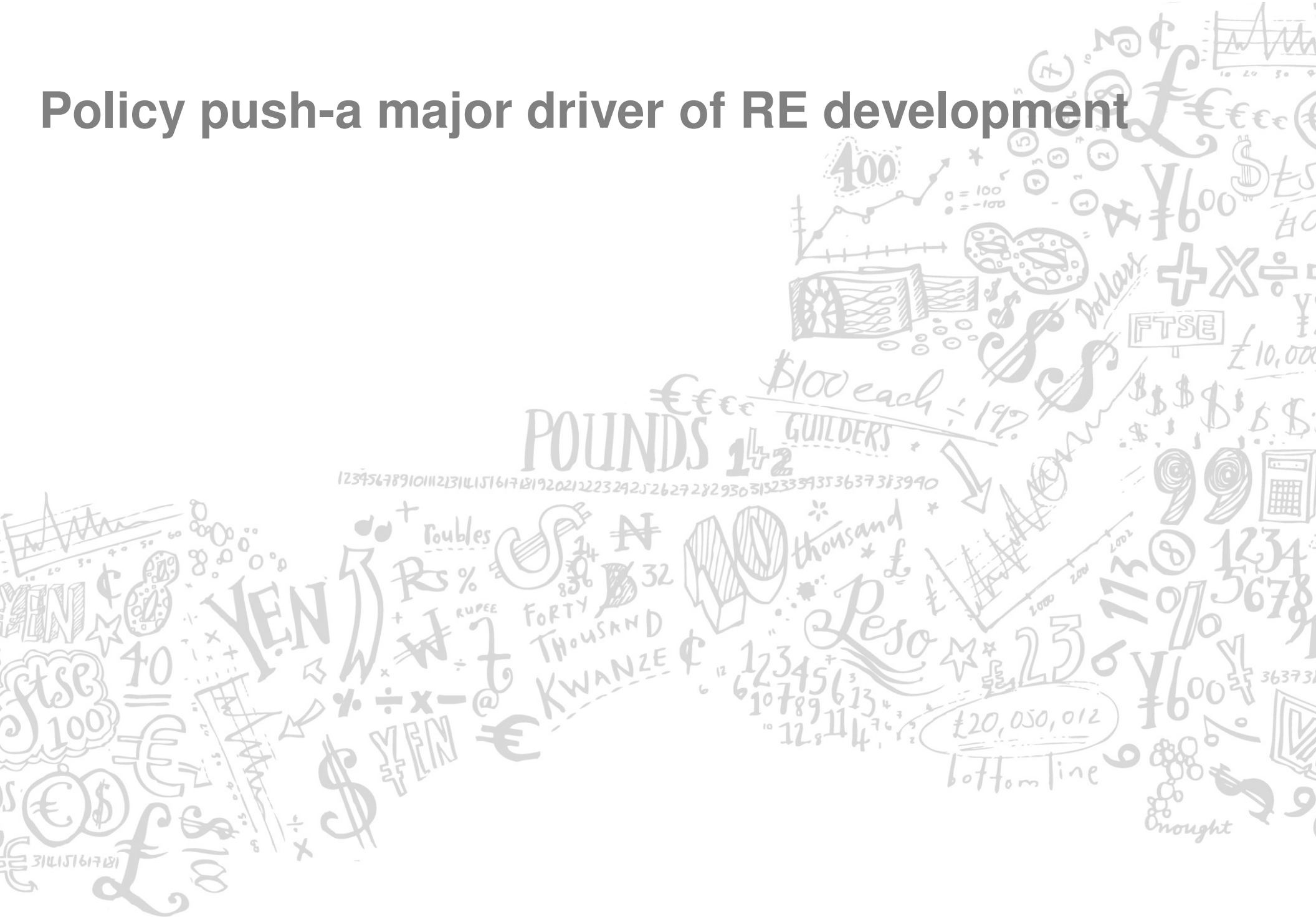
- India is the most developed renewable energy market in South Asia, with annual revenues of about USD 185 billion.
- India has been attracting over USD 3 billion investment every year in renewable sector
- Captive, RPO & REC Market, Accelerated Depreciation Market has 2.5 GW Potential



How is Renewable Energy perceived across the world ?

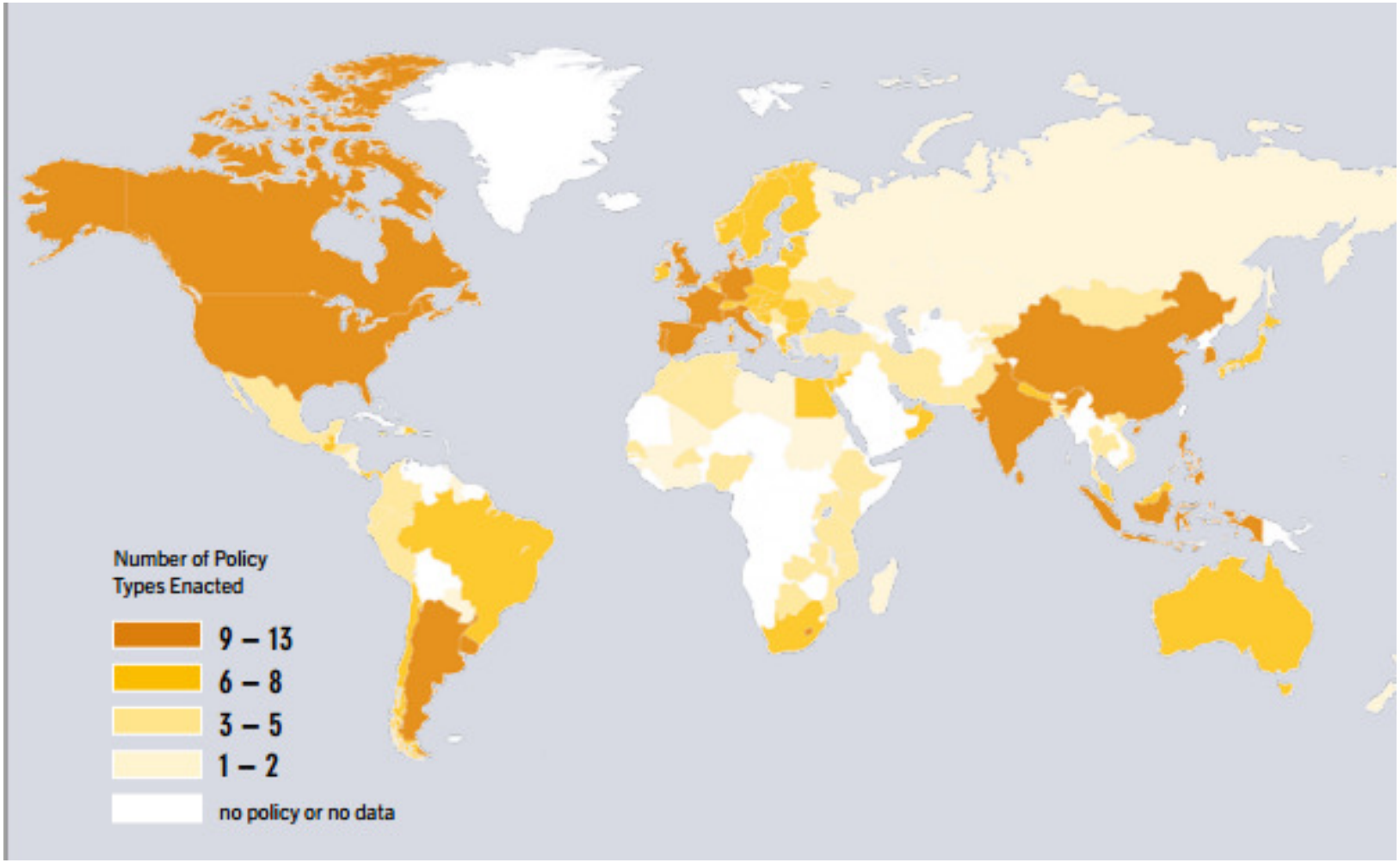
- In 2010, global investment in renewable energy increased by 32% to a record USD 211 billion.
- Worldwide, venture capital investment increased by 59% to USD 2.4 billion and public market investment gained 23% to USD 15.4 billion.
- Global R&D expenses on renewable energy rose to USD 9 billion in 2010, with most R&D going into solar (USD3.6 billion) followed by biofuels (USD2.3 billion).
- Top 5 countries for total investments in renewable energy in 2010 were China, Germany, the United States, Italy and Brazil.
- India ranked eighth in the world for renewable energy investment.
- Investment rose by 25% to USD 3.8 billion, dominated by wind power projects (USD2.3 billion), followed by USD400 million each for solar and biomass power including waste-to- energy.

Policy push-a major driver of RE development



Policy Maps - Countries with renewable energy policies, early 2013

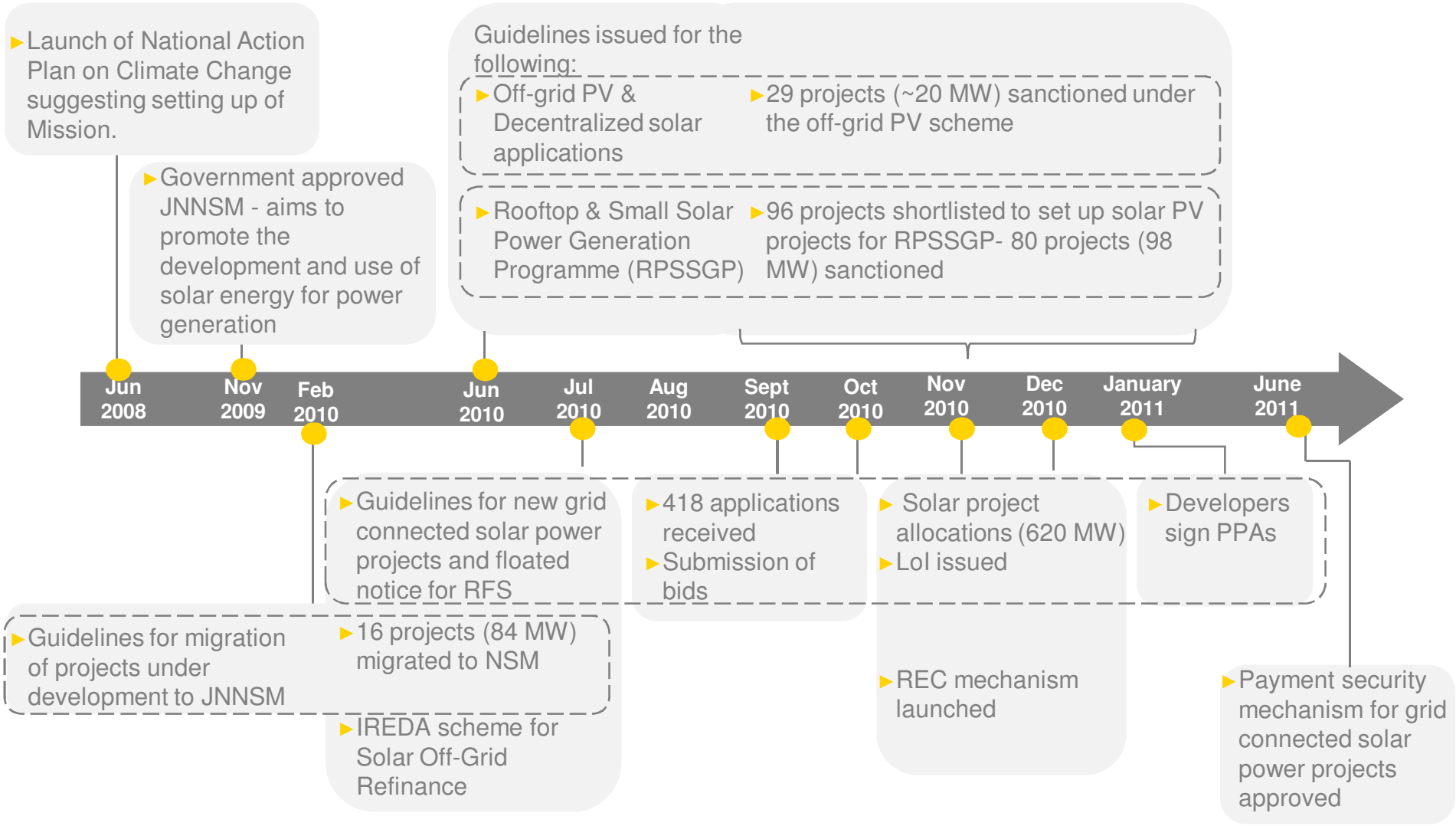
138 countries have defined RE targets



Where India stands in the global market?

	REGULATORY POLICIES						FISCAL INCENTIVES				PUBLIC FINANCING	
	Feed-in tariff (incl. premium payments)	Electric utility quota obligation/ RPS	Net metering	Biofuels obligation/ mandate	Heat obligation/ mandate	Tradable REC	Capital subsidy, grant, or rebate	Investment or production tax credits	Reductions in sales, energy, CO2, VAT, or other taxes	Energy production payment	Public investment, loans, or grants	Public competitive bidding
Argentina	●			●			●	●	●	●	●	●
Brazil				●					●		●	●
Canada	●	●	●	●			●	●	●		●	●
China	●	●		●	●		●			●	●	●
France	●	●		●		●	●	●	●		●	●
Germany	●			●	●		●	●	●		●	
India	●	●		●		●	●	●	●		●	●
South Korea		●		●		●	●	●	●		●	
United Kingdom	●	●		●		●			●	●	●	

Solar Policy roadmap



Source: MNRE Press Releases; IREDA; EY analysis

How has these policies and regulations helped India?

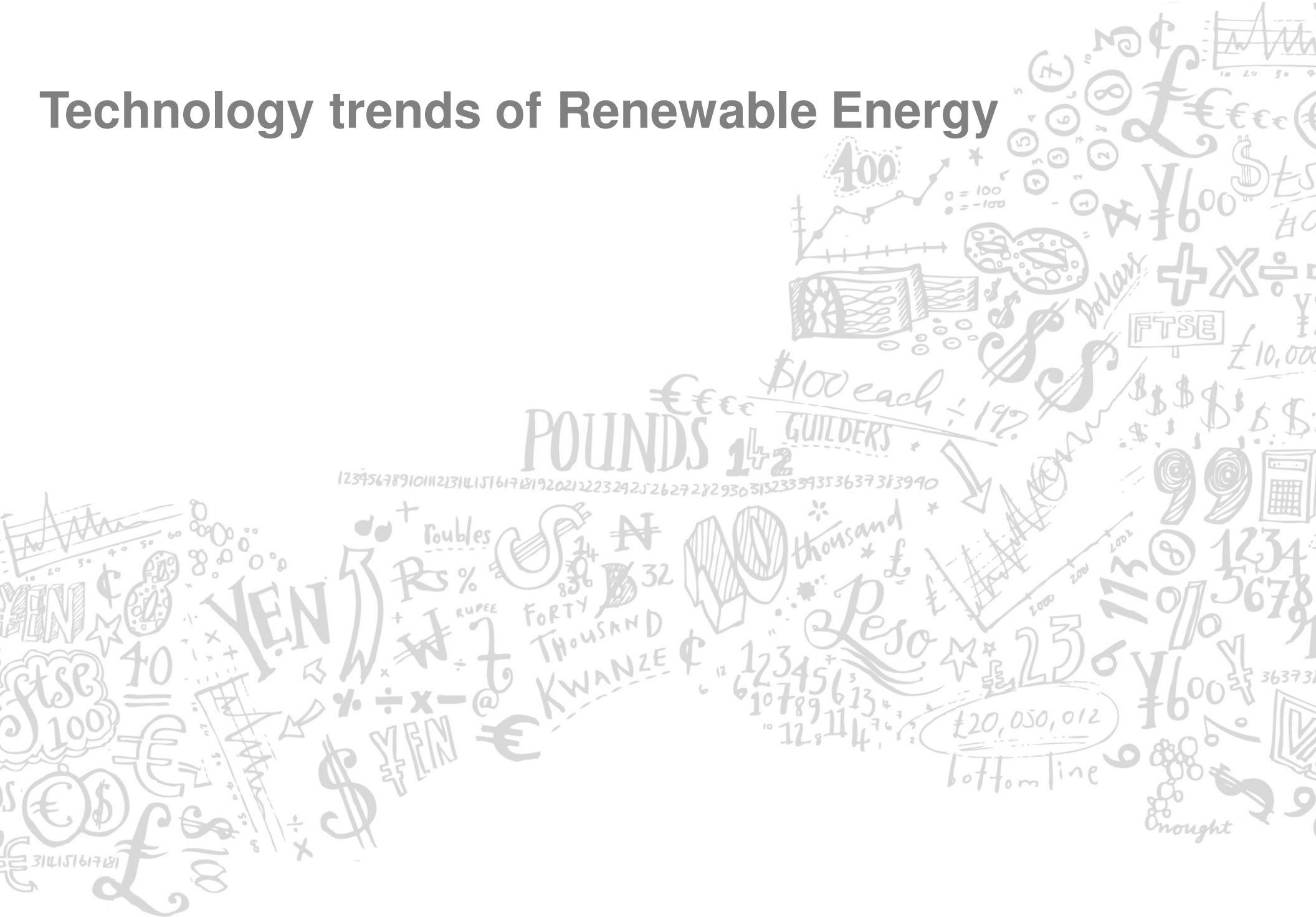
TOP FIVE COUNTRIES – Annual additions in 2010

	New capacity investment	Wind power	Solar PV	Solar hot water/heat[2]	Ethanol production	Biodiesel production
1	China	China	Germany	China	United States	Germany
2	Germany	United States	Italy	Germany	Brazil	Brazil
3	United States	India	Czech Republic	Turkey	China	Argentina
4	Italy	Spain	Japan	India	Canada	France
5	Brazil	Germany	United States	Australia	France	United States

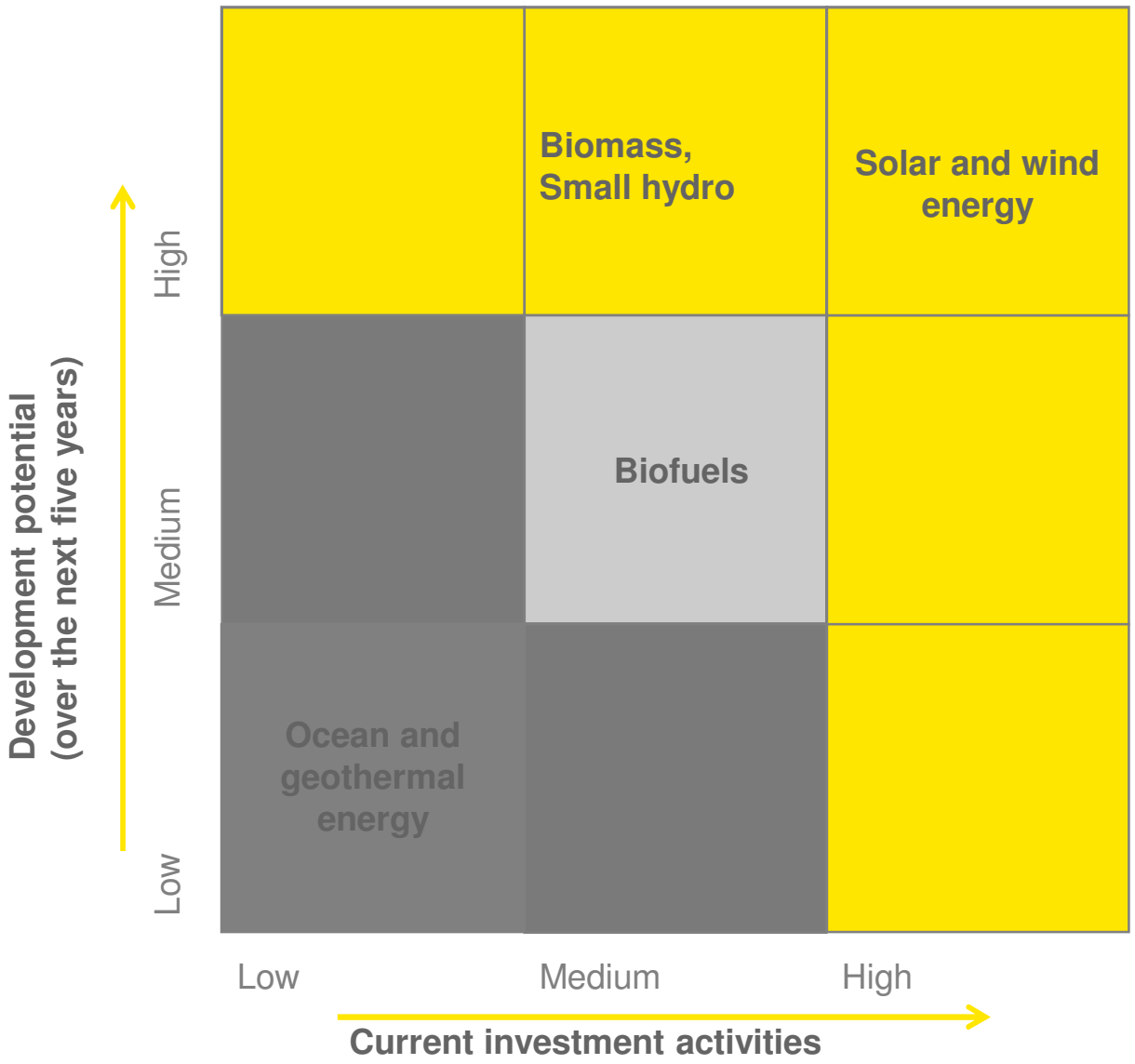
TOP FIVE COUNTRIES – Existing capacity as of end-2010

	Renewables power capacity (not including hydro)	Renewables power capacity (including hydro)	Wind power	Biomass power	Geothermal power	Solar PV	Solar hot water/heat[2]
1	United States	China	China	United States	United States	Germany	China
2	China	United States	United States	Brazil	Philippines	Spain	Turkey
3	Germany	Canada	Germany	Germany	Indonesia	Japan	Germany
4	Spain	Brazil	Spain	China	Mexico	Italy	Japan
5	India	Germany/ India	India	Sweden	Italy	United States	Greece

Technology trends of Renewable Energy



Attractiveness of renewable energy technology sectors in India



EY perspective

Ernst & Young regularly tracks the attractiveness of investment options in renewable energy.

- The **solar** and wind energy sectors have elicited the greatest investor interest and present the highest growth potential over the coming years.
- **Biomass**, **small hydro** are also key areas to watch for.
- Investor interest and current investment activities are lowest for **ocean and geothermal energy** as of now.

.

Key drivers of renewable energy in India

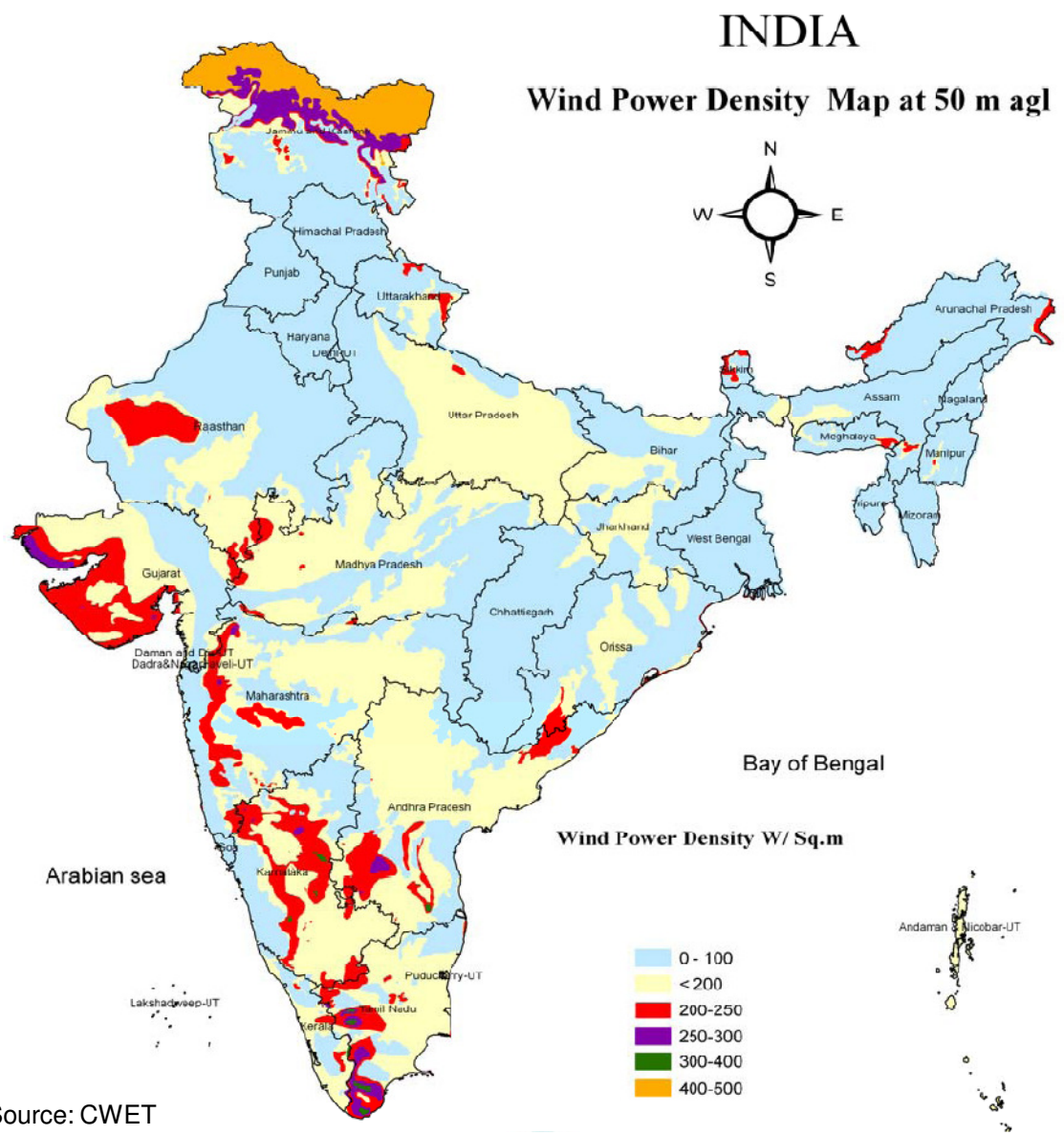
Internal drivers

- Energy demand-supply gap and waste management challenges due to rapid industrial growth and urbanization
- Energy security and water scarcity
- Abundance of untapped renewable energy resources such as solar, wind, biomass and water
- Benefits under the Clean Development Mechanism (CDM)
- Opportunities for Indian companies to develop a global cleantech business on the backing of high-skilled professionals and low-cost manufacturing

External drivers

- Escalating costs of conventional energy sources with depleting fossil fuel reserves
- Global growth in the demand for energy
- Concerns about global warming and climate change
- Technological improvements, resulting in the gradual cost reduction of systems/ equipment
- Increased investments by global corporations to reduce climate change risks and pursue new products/service opportunities

Renewable energy potential in India – Wind Sector overview



Source: CWET

Wind potential and installed capacity (MW)

(as of 31 Mar 2011)

S. No.	State	Estimated potential *	Installed capacity
1	Tamil Nadu	5,530	5,904
2	Maharashtra	4,584	2,317
3	Gujarat	10,645	2,176
4	Karnataka	11,531	1,727
5	Rajasthan	4,858	1,525
6	Madhya Pradesh	1,019	276
7	Andhra Pradesh	8,968	192
8	Kerala	1,171	35
9	Others	255	4
	All India	**48,561**	**14,156**

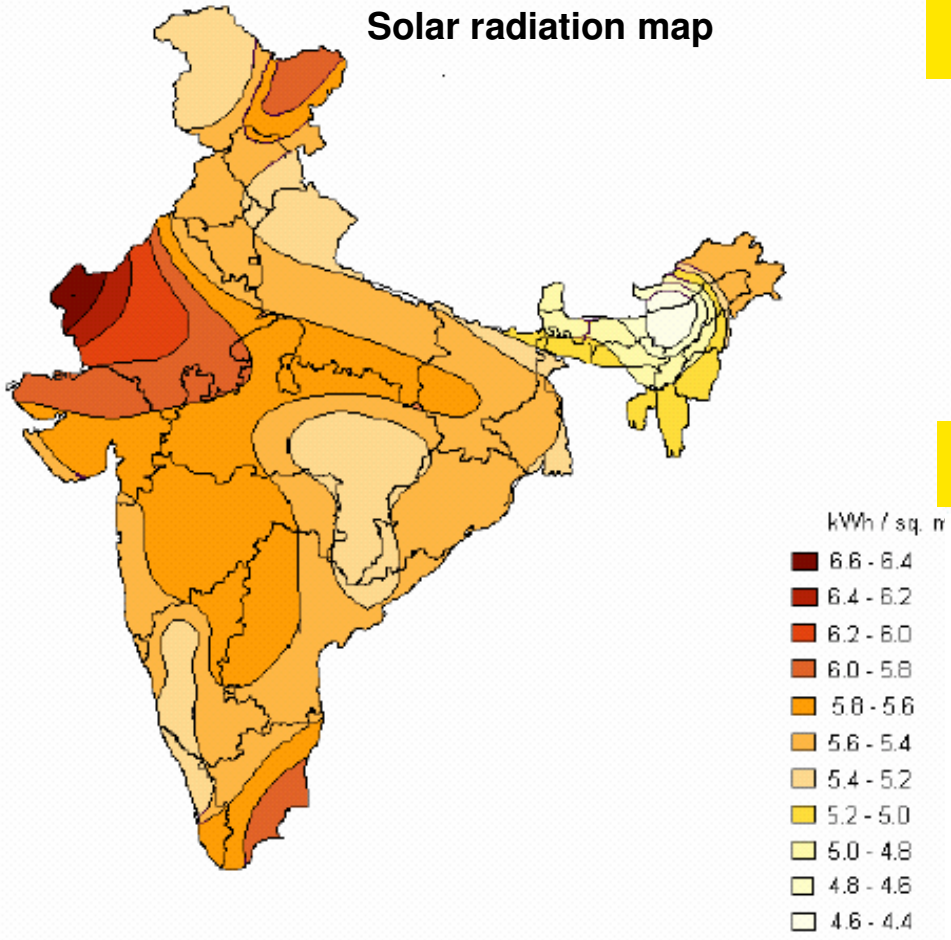
- CAGR of ~27% from 2002-11.
- About 1500+ MW/yr during last 5 yrs

Source: MNRE, Wind Power India

*Taking sites having wind power density greater than 200/W sq. m at 50 m hub-heigh with 1% land availability in potential areas for setting up wind farms @12 ha/MW. Actu potential could be different.

Renewable energy potential in India - Solar

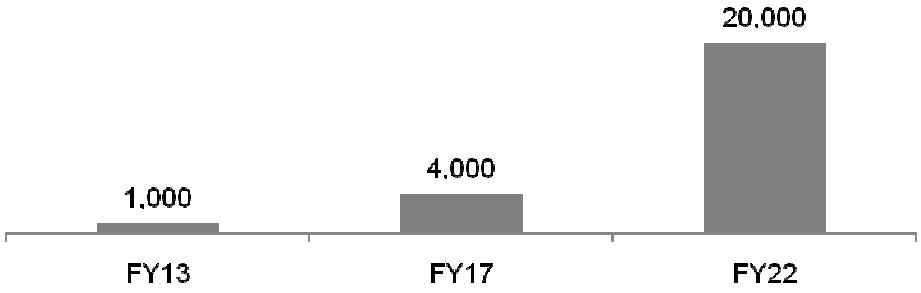
Solar radiation map



- Total solar installed capacity: 38 MW (as on 31st March 2011)
- High sunshine days, abundance of sites make solar energy an enticing prospect
- Daily solar radiation 4 - 7 kWh per sq. m. translates into a potential >100 GW

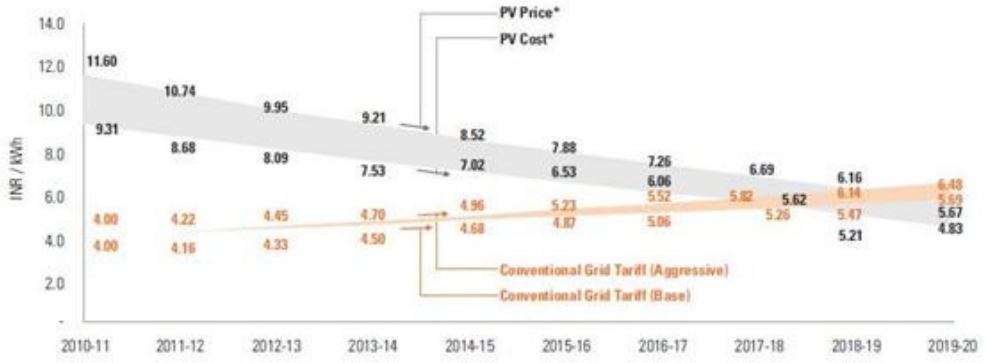
Source: TERI

Solar capacity addition plan under the Jawaharlal Nehru National Solar Mission (GW)



Source: MNRE, JNNSM policy document

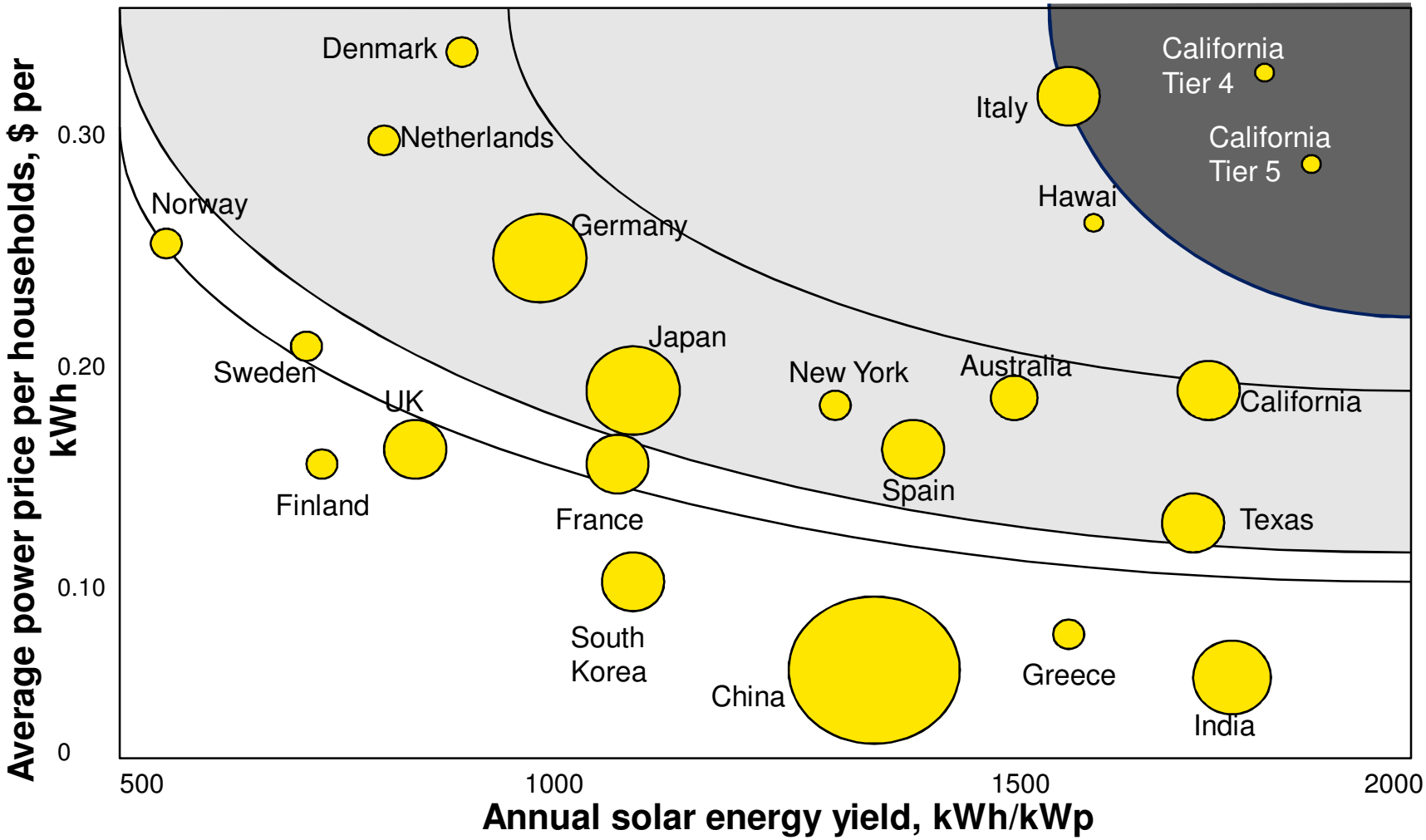
Grid Parity Scenario



Grid Parity Year	Aggressive Case	Base-Case
Utility PV Price	2017-18	2019-20

Source: KPMG's Solar Grid Parity Model
*Note that the CDM benefit of INR 0.60 / KWH has been factored in the Solar Costs

Multiple Solar Markets Are Now Approaching Grid Parity - Would Hugely Impact Indian Power Sector.



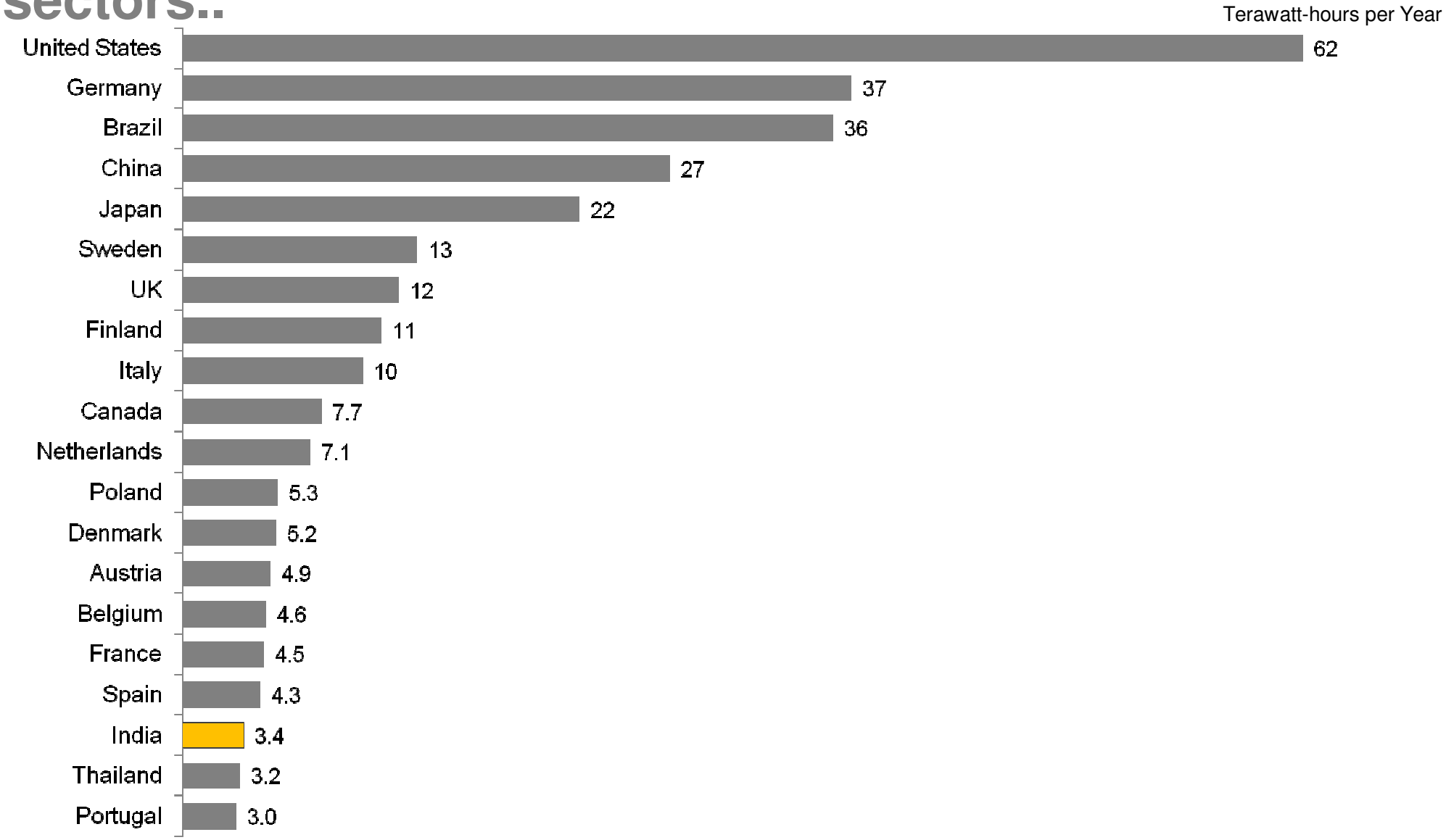
Annual solar yield is amount of electricity generated by a south facing 1 kW peak rated module in 1 year or equivalent number of hours that the module operates at peak rating

Tiers 4 & 5 are names of regulated forms of electricity generation and usage

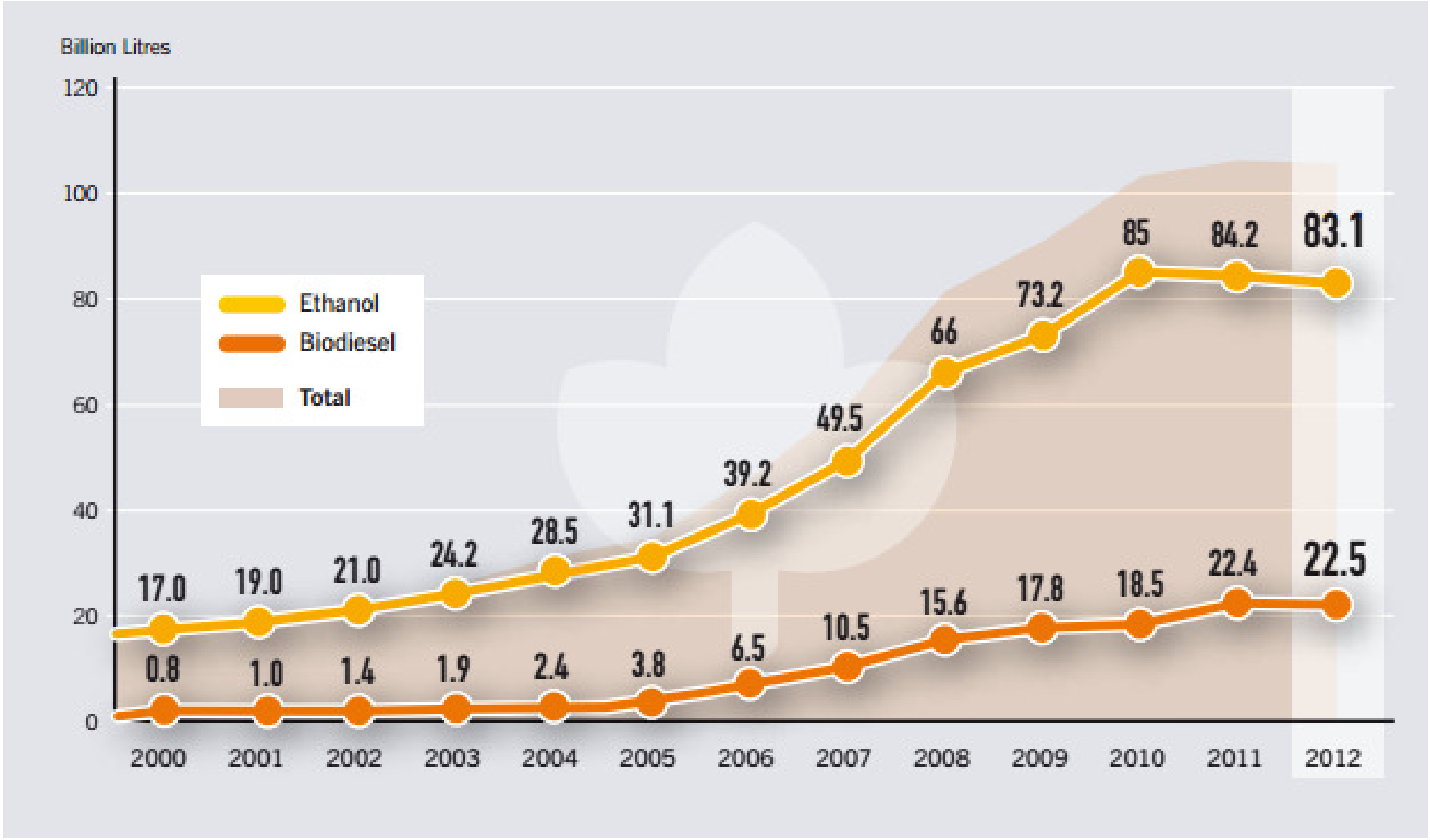
Size of bubble denotes size of electricity market

Source: CIA Country files, European PV Group, Eurostat, Pacific Gas & Electric, Public Policy Institute of New York State

Bioenergy - the use of biomass to provide modern energy services has continued to increase in end-use sectors..



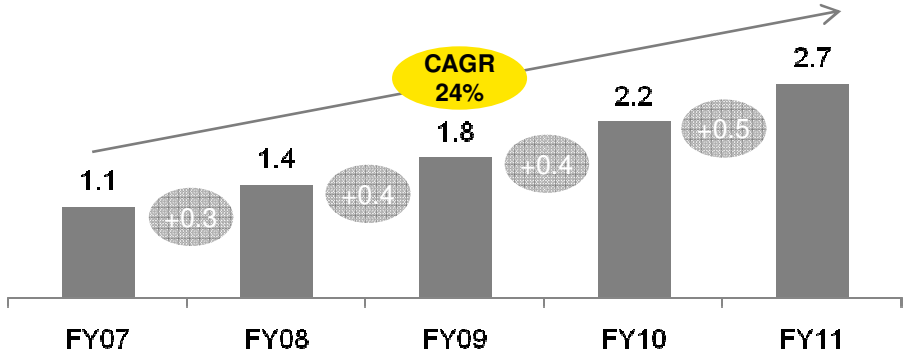
The biodiesel production has increased 32.06 % within the last decade…



Renewable energy potential in India – Biomass Power

- At present around 500 million metric tonnes of biomass available per year
  - Rice husk, rice straw, bagasse, sugar cane trash, groundnut shells, cotton stalks, mustard stalks, etc.
- It is estimated that 70-75% of biomass is used as fodder, fuel and for other purposes
- 120 – 150 million tonnes of usable biomass is available per year for power generation
- The total potential in India is estimated to be 18,000 MW of biomass and around 5,000 MW for bagasse-based cogeneration plants
- The total grid interactive installed biomass capacity in India was about 2.7 GW (as of March 2011):
  - Biomass based projects: 997 MW
  - Bagasse cogeneration projects:1,668 MW
- The states of Uttar Pradesh, Tamil Nadu and Maharashtra lead installations

Growth of biomass power installed capacity in India (GW)



Source: MNRE

State-wise biomass power installed capacity (MW)

as of 31 Mar 2011

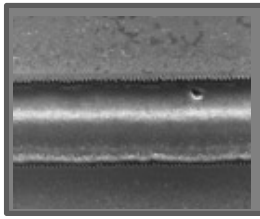
S. No.	State	Installed capacity
1	Uttar Pradesh	593
2	Tamil Nadu	488
3	Maharashtra	403
4	Karnataka	365
5	Andhra Pradesh	363
6	Others	453
	All India	**2,665**

Source: MNRE

New technologies making way in the Renewable Energy area…

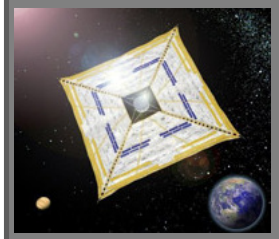
Common Algea for Biofuel Butanol Production: There have been various methods tried for reducing fossil fuel dependency and containing carbon footprints for a healthier and more eco-friendly future. Corn-produced ethanol has been used for mixing with gasoline but there have been side effects like corrosion from ethanol. Also huge tracts of precious farmlands need to be diverted for corn production. But now new research has thrown up results that show common algae can be used for biofuel production

The New Role of Microbes in Bio-Fuel Production: Currently biofuel is produced from plants as well as microbes. The oils, carbohydrates or fats generated by the microbes or plants are refined to produce biofuel. This is a green and renewable energy that helps in conserving fossil-fuel usage. But a new research has led to a new discovery of getting the microbes to produce fuel from the proteins instead of utilizing the protein for its own growth.



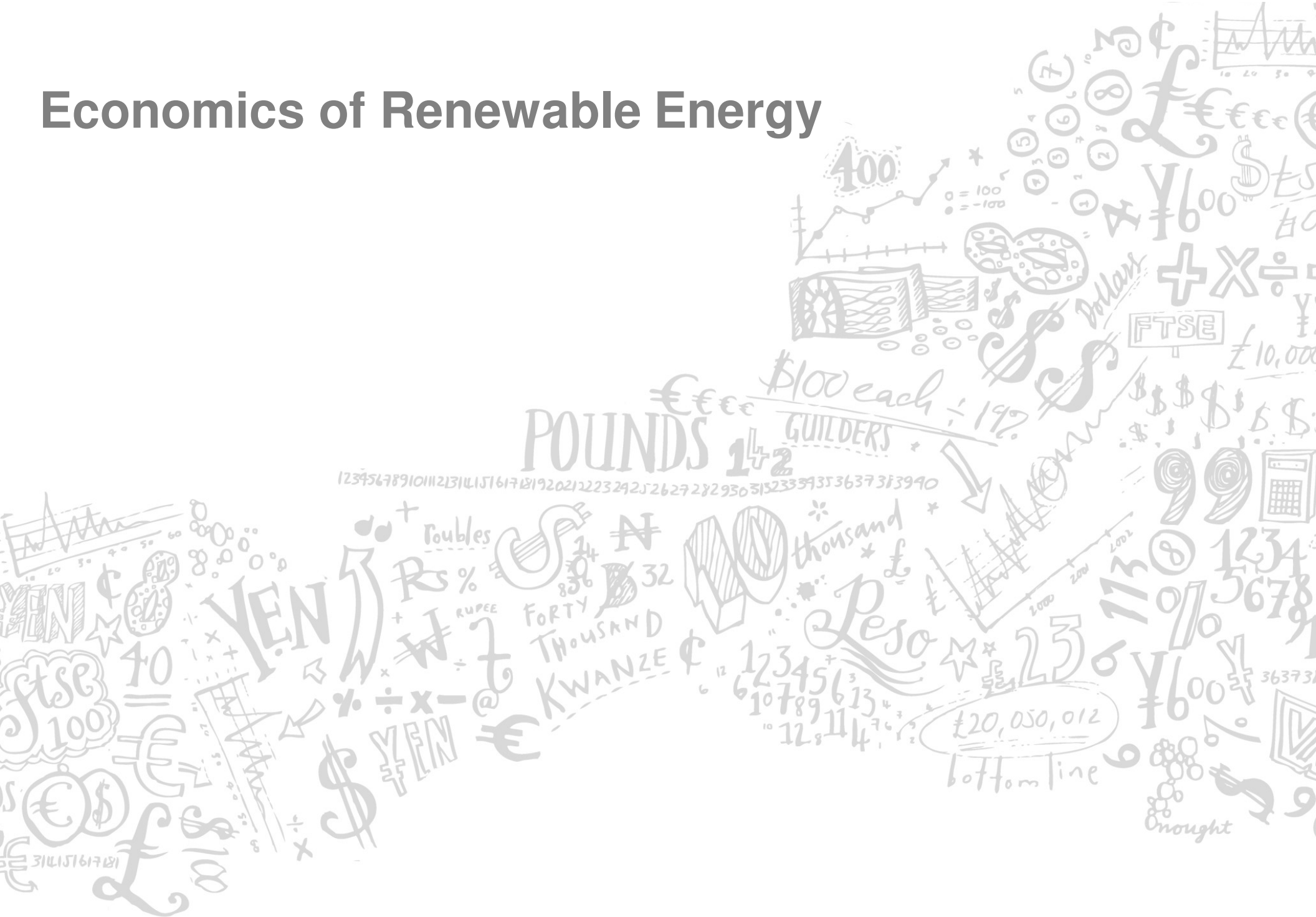
Laser 'Scribing' to Increase Solar Cell Efficiency: Over the years, thanks to the devoted research work going on for increasing the efficiency of solar cells, today solar cells are no longer flat shaped or unyielding. Ultra thin film-type solar cells have now been manufactured which are quite flexible and adaptable for use in corners, curvilinear and other structures. Today almost 20% of global solar power generation is done by these thin-film solar cells and expected to grow more in near future.

Making the Best Use of Polymer Solar Cells: A report recently published in an online journal points out that a process has been developed by the researchers that can produce thin and constant light absorbing layers on textured substrates. This increases light absorption by polymer solar cells, thereby increasing their efficiency and enabling its best use.

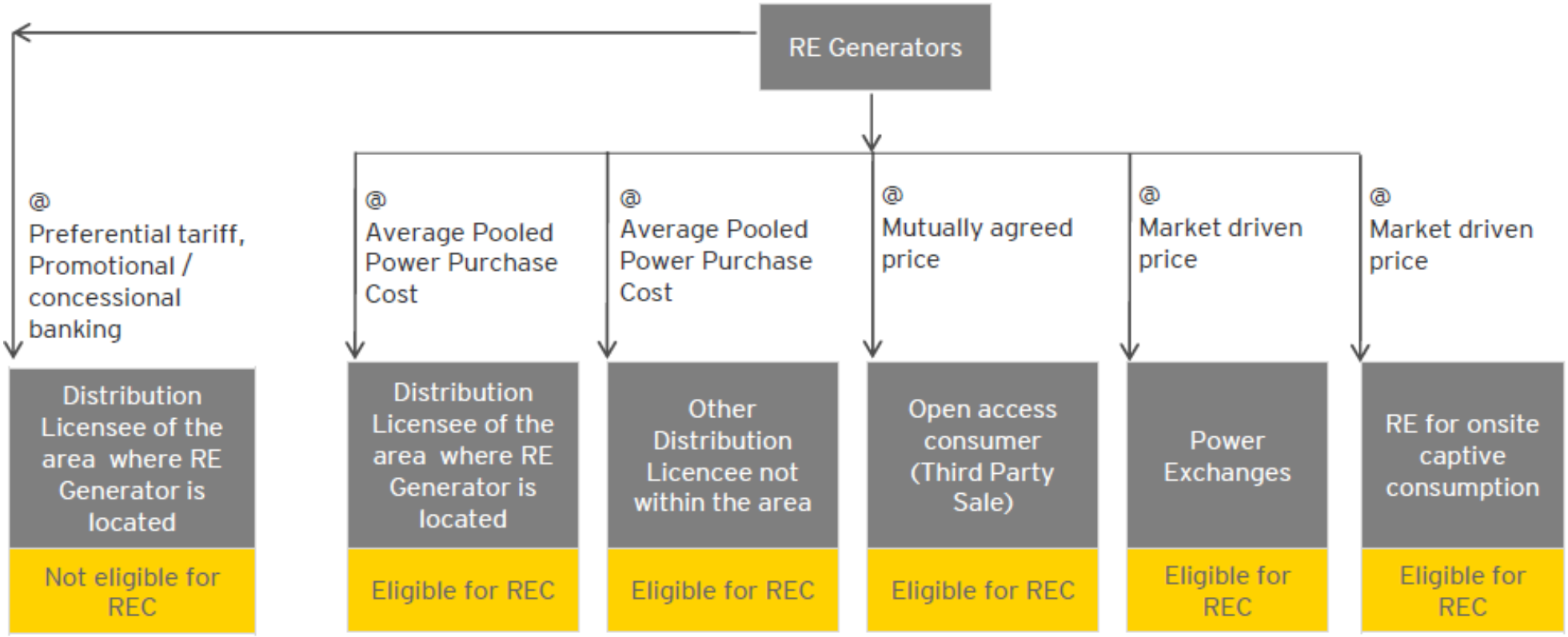


Solar Wind Power: Generating Power In The Future: As the world discovers new ways to meet its growing energy needs, energy generated from Sun, which is better known as solar power and energy generated from wind called the wind power are being considered as a means of generating power. Though these two sources of energy have attracted the scientists for a very long time, they are not able to decide, which of the two is a better source to generate power. Now scientists are looking at a third option as well. Scientists have now combined solar power and wind power to produce enormous energy called the solar wind power, which will satisfy all energy requirements of human kind.

Economics of Renewable Energy



Opportunities lies for RE Generators in India…



- Average Pooled Power Purchase Cost (State specific): means the weighted average pooled price at which the distribution licensee has purchased the electricity including cost of self generation in the previous year from all the long-term energy suppliers, but excluding those based on liquid fuel, purchase from traders, short-term purchases and RES
- Power Exchange: means that power exchange which operates with the approval of the Central Commission
- Preferential Tariff: means the tariff fixed by the Commission for sale of energy from a generating station based on RES to a distribution licensee;
- Note: Eligibility criteria for onsite captive consumption in state & project specific. Relevant SERC orders need to be looked for evaluation

Cost economics of Renewable Energy in India and beyond…

Technology	Typical Characteristics	Capital Costs (USD/kW)	Typical Energy Costs (LCOE – U.S. cents/kWh)
Solar PV: Rooftop	Peak capacity: 3–5 kW (residential); 100 kW (commercial); 500 kW (industrial) Capacity factor: 10–25% (fixed tilt)	2,275 (Germany; average residential) 4,300–5,000 (USA) 3,700–4,300 (Japan) 1,500–2,600 (Industrial)	20–46 (OECD) 28–55 (non-OECD) 16–38 (Europe)
Solar PV: Ground-mounted utility-scale	Peak capacity: 2.5–250 MW Capacity factor: 10–25% (fixed tilt) Conversion efficiency: 10–30% (high end is CPV)	1,300–1,950 (Typical global) Averages: 2,270 (USA); 2,760 (Japan); 2,200 (China); 1,700 (India)	12–38 (OECD) 9–40 (non-OECD) 14–34 (Europe)
Concentrating solar thermal power (CSP)	Types: parabolic trough, Fresnel, tower, dish Plant size: 50–250 MW (trough); 20–250 MW (tower); 10–100 MW (Fresnel) Capacity factor: 20–40% (no storage); 35–75% (with storage)	Trough, no storage: 4,000–7,300 (OECD); 3,100–4,050 (non-OECD) Trough, 6 hours storage: 7,100–9,800 Tower, 6–15 hours storage: 6,300–10,500	Trough and Fresnel: 19–38 (no storage); 17–37 (6 h. storage) Tower: 20–29 (6–7 hours storage); 12–15 (12–15 hours storage)
Wind: Onshore	Turbine size: 1.5–3.5 MW Capacity factor: 25–40%	1,750–1,770 925–1,470 (China and India)	5–16 (OECD) 4–16 (non-OECD)
Wind: Offshore	Turbine size: 1.5–7.5 MW Capacity factor: 35–45%	3,000–4,500	15–23
Wind: Small-scale	Turbine size: up to 100 kW	3,000–6,000 (USA); 1,580 (China)	15–20 (USA)

Cost economics of Renewable Energy in India and beyond…

Technology	Typical Characteristics	Capital Costs (USD/kW)	Typical Energy Costs (LCOE – U.S. cents/kWh)
Power Generation			
Bioenergy combustion: Boiler/steam turbine Co-fire; Organic MSW	Plant size: 25–200 MW Conversion efficiency: 25–35% Capacity factor: 50–90%	800–4,500 Co-fire: 200–800	5.5–20 Co-fire: 4–12
Bioenergy gasification	Plant size: 1–10 MW Conversion efficiency: 30–40% Capacity factor: 40–80%	2,050–5,500	6–24
Bioenergy anaerobic digestion	Plant size: 1–20 MW Conversion efficiency: 25–40% Capacity factor: 50–90%	Biogas: 500–6,500 Landfill gas: 1,900–2,200	Biogas: 6–19 Landfill gas: 4–6.5
Geothermal power	Plant size: 1–100 MW Capacity factor: 60–90%	Condensing flash: 2,100–4,200 Binary: 2,470–6,100	Condensing flash: 6–13 Binary: 7–14
Hydropower: Grid-based	Plant size: 1 MW–18,000+ MW Plant type: reservoir, run-of-river Capacity factor: 30–60%	Projects >300 MW: <2,000 Projects <300 MW: 2,000–4,000	2–12
Hydropower: Off-grid/rural	Plant capacity: 0.1–1,000 kW Plant type: run-of-river, hydrokinetic, diurnal storage	1,175–3,500	5–40
Ocean power: Tidal range	Plant size: <1 to >250 MW Capacity factor: 23–29%	5,290–5,870	21–28

Cost economics of Renewable Energy in India and beyond…

INDICATIVE

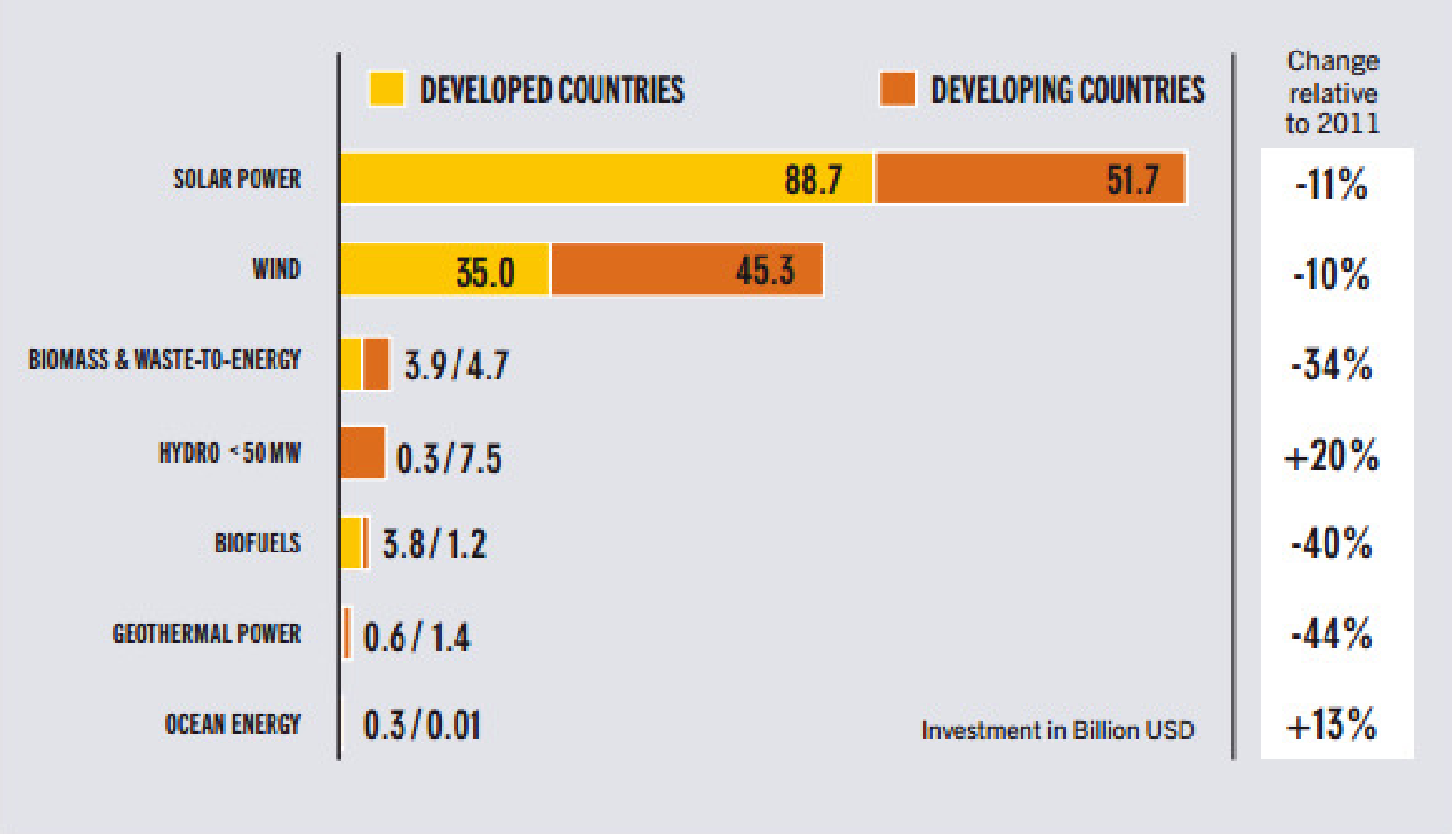
Technology	Technology Characteristics	Cost of Installation	Tariff Range	IRR
Solar PV	Highest Capacity - ~ 220 MW Capacity Factor – 10-15%	9.35 - 10 Crore / MW	~6.5 INR/kWh to 9 INR/kWh	~10% to 11%
Wind	Turbine Size – 1.5 to 2 MW Capacity Factor – 20%	5.5 Crore/MW to ~8.5 Crore/ MW	~5.5 INR/kWh to 6.0 INR/kWh	~15% to 18%
Small Hydro	Turbine Capacity - <25 MW Capacity factor – 35% to 45%	5.5 Crore/MW to 6.0 Crore/ MW	~4.5 INR/kWh	~12% - 17%
Biomass	Capacity factor – 70%	4.5 Crore/MW to 5.5 Crore/MW	~4.5 INR/kWh	~14% to 17%

Renewable Energy has a huge potential of creating jobs…

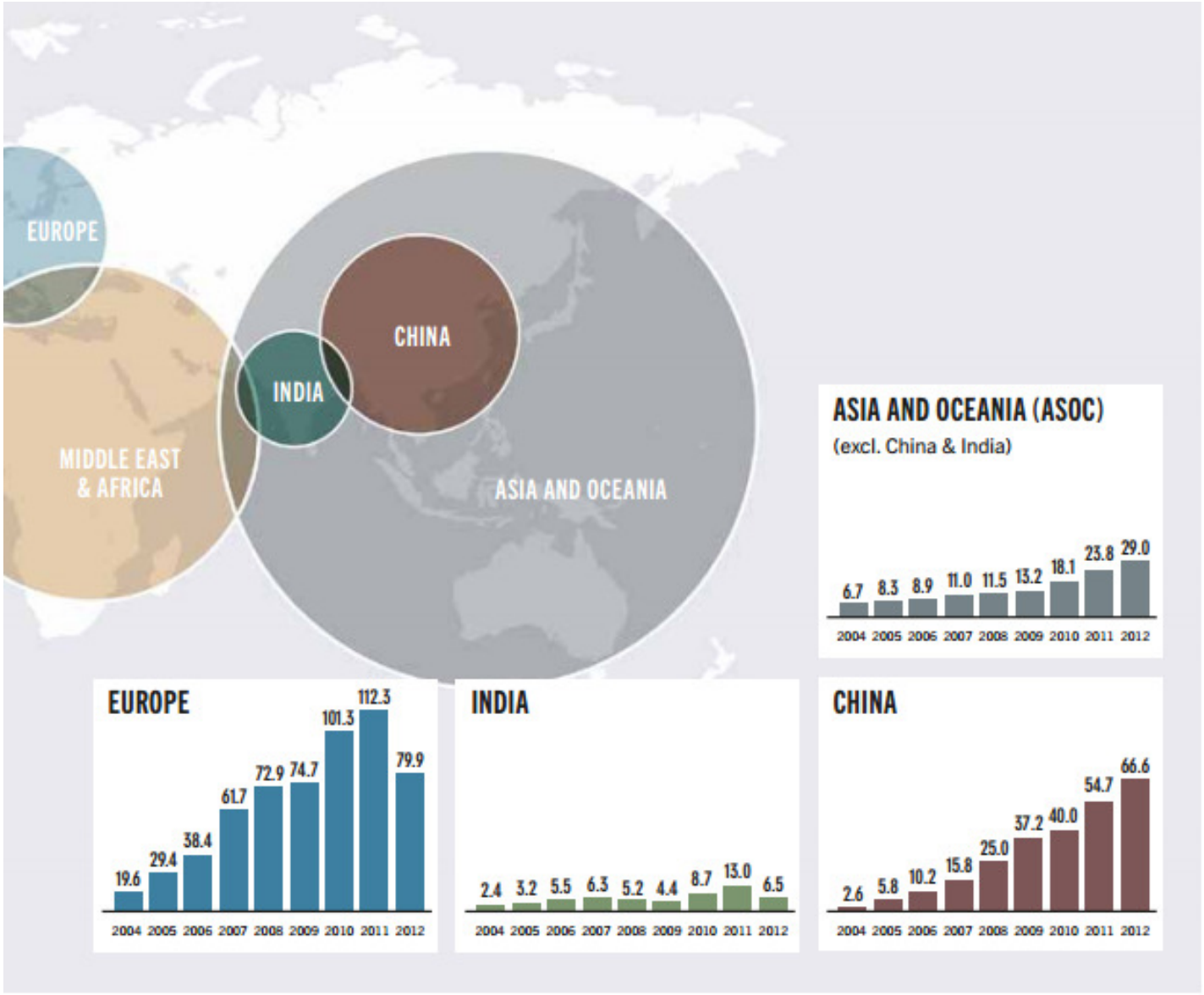
Technologies	Global	China	EU	Brazil	United States	India	Germany	Spain
	Thousand Jobs							
Biomass[a]	753	266	274		152[f]	58	57	39
Biofuels	1,379	24	109	804[e]	217[g]	35	23	4
Biogas	266	90	71			85	50	1
Geothermal[a]	180		51		35		14	0.3
Hydropower (small)[b]	109		24		8	12	7	2
Solar PV	1,360	300[d]	312		90	112	88	12
CSP	53		36		17		2	34[j]
Solar heating/ cooling	892	800	32		12	41	11	1
Wind power	753	267	270	29	81	48	118	28
Total[c]	**5,745**	**1,747**	**1,179**	**833**	**611**	**391**	**378[h]**	**120**

Investment flows in Renewable Energy…

Global new investment in renewable energy by Technology - Developed and Developing Countries, 2012



Global new investment in renewable energy by region, 2004–2012



Thank you…