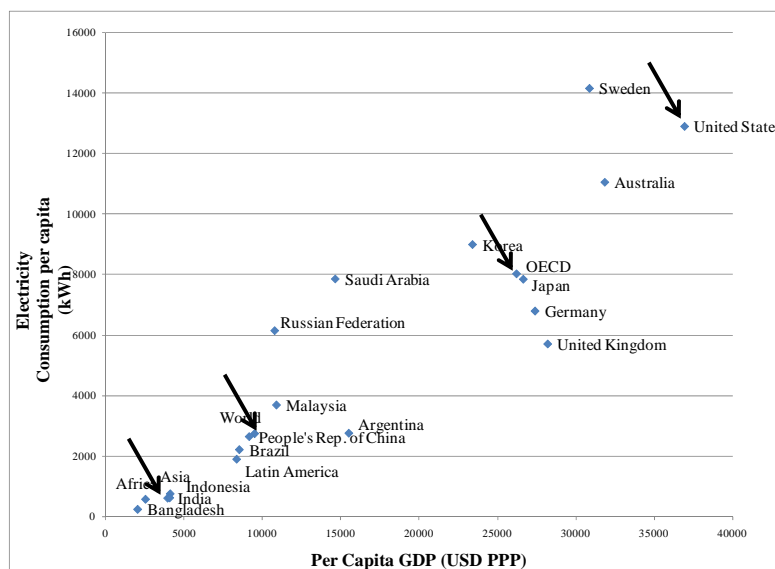


5th Capacity Building Programme for
Officers of Electricity Regulatory Commissions
18 – 19 Oct., 2012, IIT Kanpur &
21 – 23 Oct., 2012, Bangkok

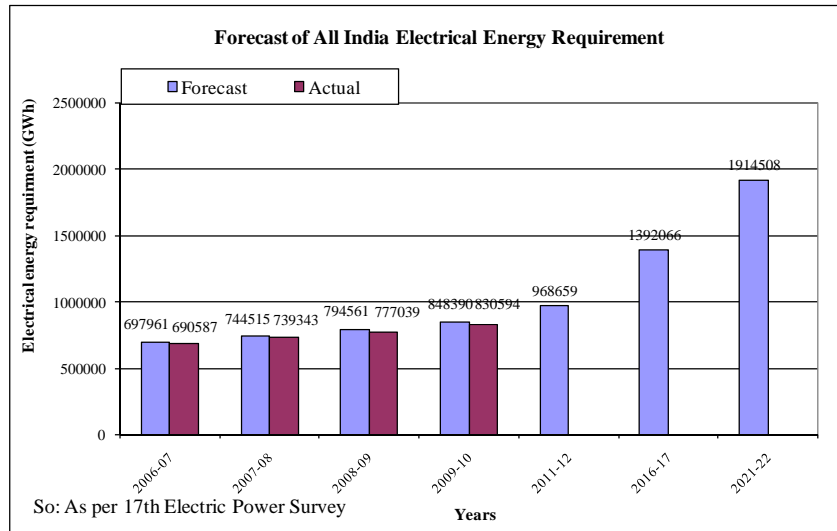
Renewable Energy: Resources, Technology, Economics and Policies

Anoop Singh
Associate Prof.
Dept of Industrial and Management Engg.
IIT Kanpur

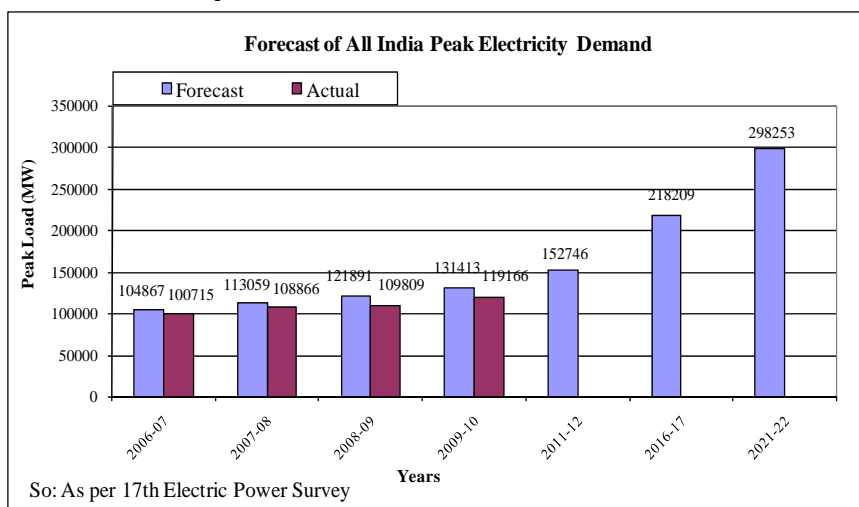
Electricity Consumption and Economic Growth



Shortage and Growing Need for Electricity



Shortage and Growing Need for Electricity (Contd.)



India's Energy Resources

India's Hydrocarbon Reserves

Resources	Unit	Proved	Inferred	Indicated	Production in 2004-05	Net Imports in 2004-05	Reserve/Production Ratio	
		(P)	(I)		(Q)	(M)	P/Q	(P+I)/Q
Coal (as on 1.1.2005)	Mtoe	38114	48007	15497				
Extractable Coal ^{oo}	Mtoe	13489	9600-15650		157	16	86	147-186
Lignite (as on 1.1.2005)	Mtoe	1220	3652	5772				
Extractable Lignite	Mtoe	1220			9	-	136	136
Oil (2005)	Mt	786 ^o	-	-	34	87	23	23
Gas (2005)	Mtoe	1101 ^o	-	-	29	3 (LNG)	38	38
Coal Bed Methane	Mtoe	765	-	1260-2340				
In-situ Coal Gasification ^{ooo}		?	?					

India's Energy Resources

Reserves/Production of Crude Oil & Natural Gas

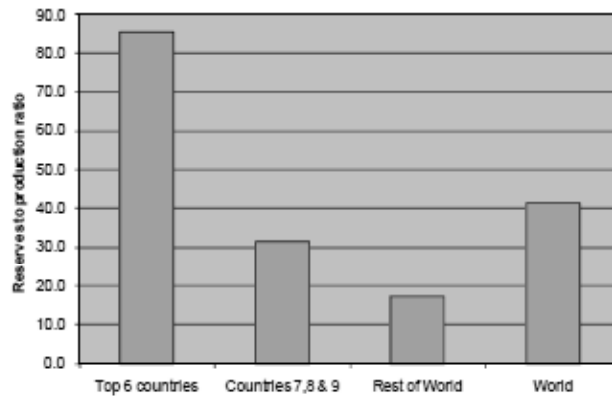
Year	Crude Oil (Mt)		Natural Gas (BCM)	
	Reserves ^o	Production	Reserves ^o	Production
1970-71	128	6.9	62	1.4
1980-81	366	10.5	351	2.4
1990-91	739	32.2	686	18.0
2000-01	703	32.4	760	29.5
2001-02	732	32.0	763	29.7
2002-03	741	33.0	751	31.4
2003-04	761	33.4	853	32.0
2004-05	739	33.9	923	31.8
2005-06(p)	786	33.2	1101	32.2

(p) Provisional

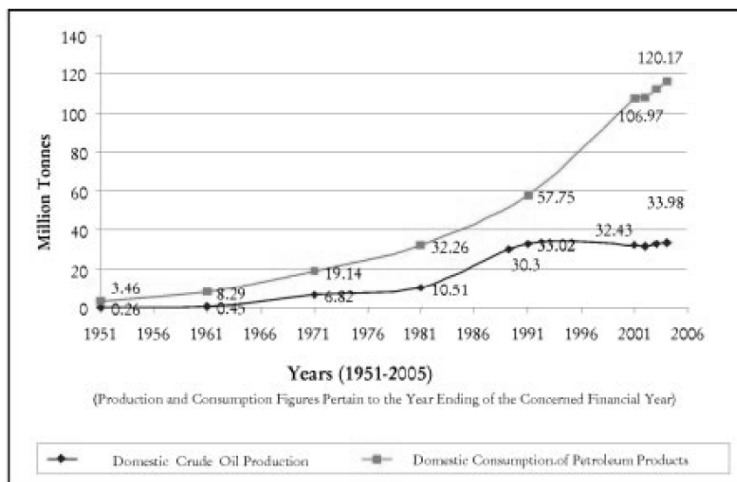
* Reserves position as on 1st April of commencing year

Source: Ministry of Petroleum & Natural Gas

Oil - Reserves to production ratios in 2008 (Source: WEC SER)



Domestic Consumption and Production of Crude Oil



Top ten hard coal producers and importers – 2008 (So: IEA)

	million tonnes	million tonnes	Steam	Coking	Total
China	2 716	Japan	128	58	186
USA	993	Korea (Republic)	76	24	100
India	484	Taiwan, China	60	6	66
Australia	332	India	31	29	60
South Africa	251	Germany	37	9	46
Russian Federation	246	China	35	11	46
Indonesia	229	UK	37	7	44
Kazakhstan	100				
Poland	84				
Colombia	74				

Projections for Total Primary Commercial Energy Requirements

Year	Population in millions	GDP (Rs. in Billion @1993-94 prices)		TPCES (Mtoe) 1 GDP Growth Rate		TPCES (Mtoe) 2 GDP Growth Rate	
		8%	9%	8%	9%	8%	9%
		2006-07	1114	17839	18171	389	397
2011-12	1197	26211	27958	521	551	537	570
2016-17	1275	38513	43017	684	748	732	807
2021-22	1347	56588	66187	898	1015	998	1142
2026-27	1411	83145	101837	1166	1360	1361	1617
2031-32	1468	122170	156689	1514	1823	1856	2289

Almost four times growth!

- TPCES 1 - Falling Energy-GDP elasticities
- TPCES 2 – Constant Energy-GDP elasticities

Projections for Electricity Demand

Year	Billion kWh			
	8%	9%	8%	9%
2006-07	700	700	140	140
2011-12	1029	1077	206	215
2016-17	1511	1657	303	331
2021-22	2221	2550	445	510
2026-27	3263	3923	655	785
2031-32	4793	6036	962	1207

Policy and Regulatory Regime to attract investment

Demand Scenario for Petroleum Products

Year	Projections by the Various Agencies										
	EIA (2004)			IEA (2004)	IHV-2025 (2000)	India Vision-2020 (2002)		Working Group Report of 10th Plan (2001-02)	Power & Energy Division's (Planning Commission) Projections (2003-04)	IRADe & PWC* (2005)	
	Reference Case	High Case	Low Case			BAU	BCS			BAU	HOG
Base Year	2001 (105 Mt)	2001 (105 Mt)	2001 (105 Mt)	2000 (102 Mt)	1998-99 (91 Mt)	1997 (83 Mt)		2001-02 (108 Mt)	2001-02 (108 Mt)	2003-04 (109.7 Mt)	
2004-05	119	122	115	122	132	121	112	119	124	125	127
2009-10	139	149	129	145	175	153	135	139	147	162	176
2014-15	157	194	154	171	226	193	162	164	174	191	212
2019-20	219	254	189	201	288	245	195	195	207	212	259
2024-25	264	324	204	230	368	309	235	232	240	260	347
2029-30				271				276	281	320	465

Demand Projection of Coal (in Mt)

Source	Sectors/Period	Base year	06-07	2011-12	2016-17	2021-22	2024-25
X Plan working group	Power		322	469	617		
	Captive Power		28	32	37		
	Steel		43	40	40		
	Cement		25	24	25		
	Fertiliser		4	5	5		
	Others		51	50	56		
	Total	2001-02	473	620	780	981	1126
Coal Vision 2025* 7% GDP	Power		322	413	517	635	719
	Captive Power		28	43	60	84	102
	Fertiliser		4				
	Steel		43	53	67	84	97
	Cement		25	38	58	88	113
	Others		51	64	80	101	117
	Total	2006-07	473	611	782	992	1147
Coal Vision 2025* 8% GDP	Power		322	427	553	699	804
	Captive Power		28	44	63	90	112
	Fertiliser		4				
	Steel		43	54	69	90	105
	Cement		25	39	61	95	123
	Others		51	65	82	106	123
	Total	2006-07	473	630	828	1079	1267

Projected Primary Commercial Energy Requirements – A Scenario (Mtoe)

Year	Hydro	Nuclear	Coal		Oil		Natural Gas		TPCES	
			8%	9%	8%	9%	8%	9%	8%	9%
2011-12	12	17	257	283	166	186	44	48	496	546
2016-17	18	31	338	375	214	241	64	74	665	739
2021-22	23	45	464	521	278	311	97	111	907	1011
2026-27	29	71	622	706	365	410	135	162	1222	1378
2031-32	35	98	835	937	486	548	197	240	1651	1858
CAGR -% (Compounded Annual Growth Rates)	5.9	11.2	5.9	6.3	5.1	5.6	7.2	8	6	6.4
Per capita consumption In 2032 (Kgoe)	24	67	Clean Coal technologies SC, USC, IGCC		Efficient Engines, bio-fuels, fuel cells, veh. emissions				1124	1266
In 2004 (Kgoe)	6.5	4.6	157	171	111	111	27	27	306	306
Ratio 2032/2004	3.7	14.6	3.6	4.1	2.9	3.4	5.2	6.3	3.7	4.1

Demand of Various Energy Items for Household Consumption (Mtoe)

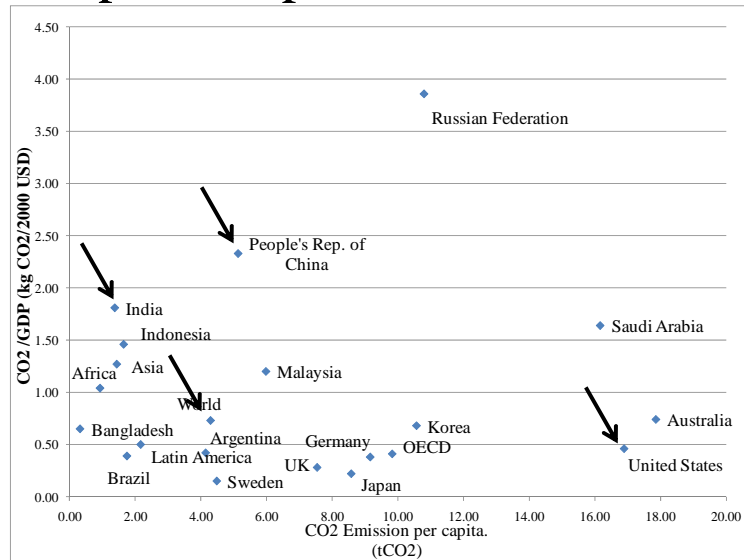
Year	Fire Wood & Chips		Efficient Appliances (star rating)		Baking Cake		Kerosene		L.P.G.	
	8%	9%	8%	9%	8%	9%	8%	9%	8%	9%
2000	79.62	79.62	8.43	8.43	29.61	29.61	10.07	10.07	6.42	6.42
2006	88.64	88.78	18.17	19.26	36.97	37.33	12.68	12.77	15.85	16.87
2011	94.11	94.05	27.17	29.68	40.42	40.48	14.01	14.02	23.94	26.07
2016	98.44	98.50	38.38	42.28	41.93	41.35	14.84	14.70	33.11	35.93
2021	102.06	102.46	50.39	54.78	41.79	40.87	15.16	14.93	41.63	44.16
2026	104.64	105.07	61.37	64.95	40.95	40.28	15.17	14.93	48.11	49.63
2031	106.39	106.59	69.72	71.80	40.47	40.21	15.12	14.96	52.27	52.89

Per Capita Energy Requirements in Selected Countries

India's Commitment at UNFCCC

	TPES (kgoe)	Electricity Consumption (kWh)	Oil (kgoe)	Gas (Cu.m.)	Coal (Kg)	Nuclear (kWh)	Hydro (kWh)
India 2003-04	439	553	111	30	257* (375)	16	69
India 2031-32 (projected @ 8% GDP growth)**	1250	2471	331	149	925* (1388)	256	273
World Average (2003)	1688	2429	635	538	740	403	423
OECD (2003)	4668	8044	2099	1144	1651	1924	1076
U.S.A. (2003)	7840	13066	3426	2176	3410	2624	948
China (2003)	1090	1379	213	32	1073	32	215
South Korea (2003)	4272	7007	2264	627	1541	2570	101
Japan (2003)	4056	7816	2146	845	1247	1859	816

CO2 Emissions – Per Capita and per GDP



Sustainable Energy Path

- Domestic Drivers
 - Increasing energy demand
 - Lack of fossil resources
 - Increasing energy import (energy security)
 - Low clean energy access
- International Drivers
 - Global warming & Kyoto Protocol
 - Competitiveness

Sustainable Energy Policy Options

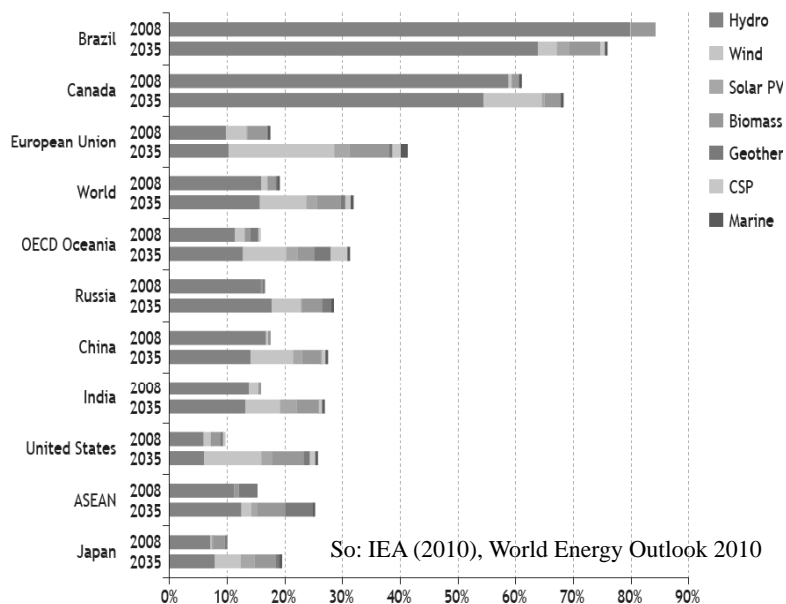
- **Stimulate Green Investment**
 - FiT, RPO, REC
- **Address Distortions in Energy Pricing**
 - Encourage energy conservation
- **Address Environmental Externalities**
 - Chimney height, fly ash use, SC technology
- **Enhance Energy Efficiency**
 - Star Labeling, PAT Scheme

Resources	Unit	Present	Potential	Basis of Accessing Potential
Hydro-power	MW	32,326	1,50,000	Total potential assessed is 84,000 MW** at 60% load factor or 1,50,000 MW at lower load factors
Biomass				
Wood	Mtoe/year	140	620*	Using 60 million Ha wasteland yielding (20) MT/Ha/year
Biogas	Mtoe/year	0.6**	4	In 12 million family sized plants
		0.1	15	In community based plants if most of the dung is put through them.
Bio-Fuels				
Bio-diesel	Mtoe/year	-	20*	Through plantation of 20* million hectares of wasteland or 7* million hectares of intensive cultivation
Ethanol	Mtoe/year	< 1	10	From 1.2 million hectares of intensive cultivation with required inputs.
Solar				
Photovoltaic	Mtoe/year	-	1,200	Expected by utilising 5 million hectares wasteland at an efficiency level of 15 percent for Solar Photovoltaic Cells
Thermal	Mtoe/year		1,200	MWe scale power plants using 5 million hectares
Wind Energy	Mtoe/year	< 1	10	Onshore potential of 65,000 MWe at 20 percent load factor
Small Hydro-power	Mtoe/year	< 1	5	

Renewable Energy Resources – Technological Challenges

- Increasing PV efficiency
- Cost effective power electronics
- Energy Storage – Fuel Cells
- High capacity offshore wind
- Grid Integration
- Generation Forecasting
- (New Business Models – Replicability, Scalability Challenges)

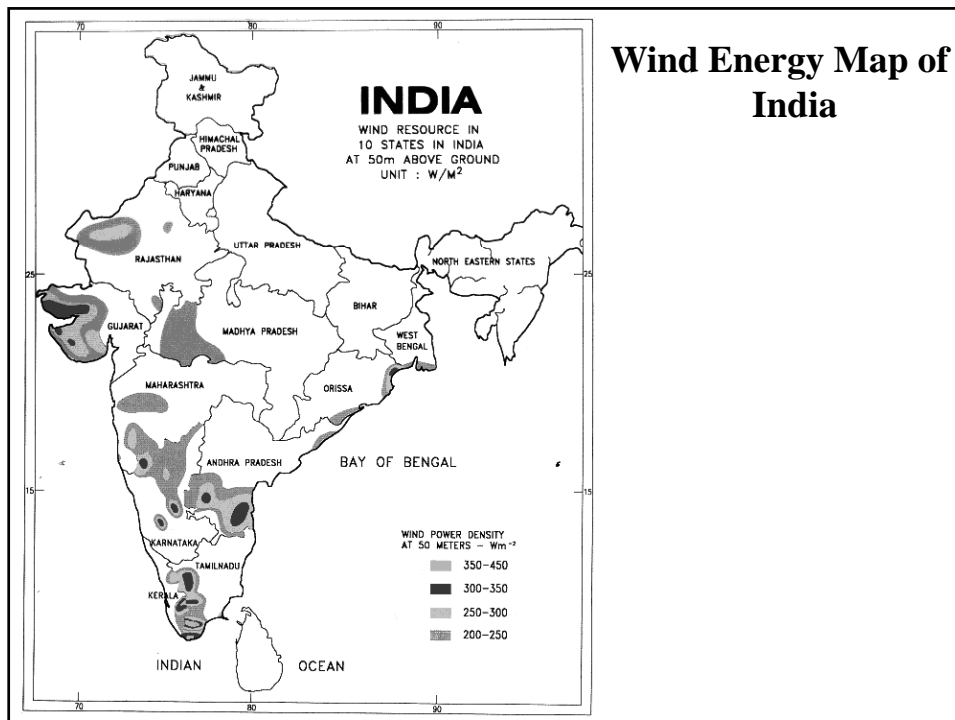
Share of Renewables in Electricity Gen.



Role of Policy and Regulation

Policy – Low Carbon Growth

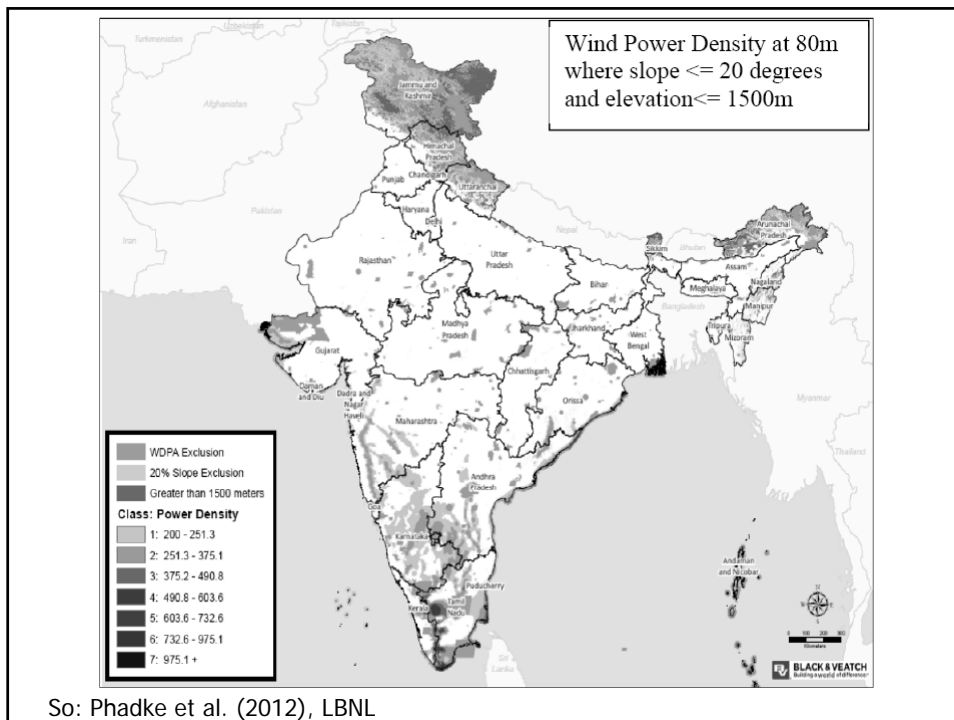
- Renewable Energy
 - Electricity Act – Renewable Purchase Obligation
 - Renewable Energy Certificates (REC)
- Energy Efficiency
 - Energy Efficiency Standards
 - Appliance Rating
- National Action Plan for Climate Change
 - JN National Solar Mission



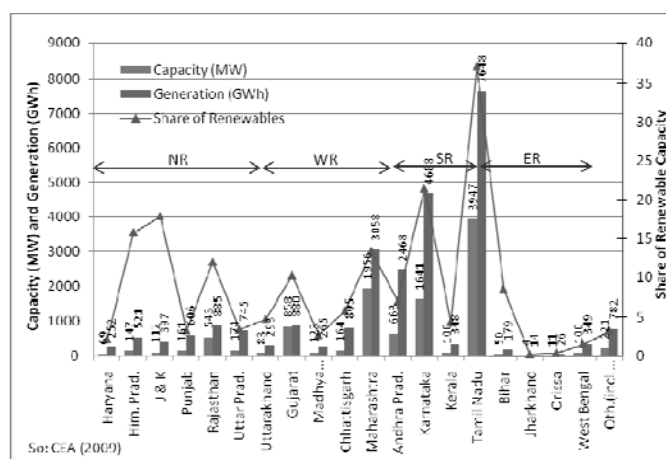
Untapped Wind Potential!

- Hub Height
- Off-share
- Vertical Axis

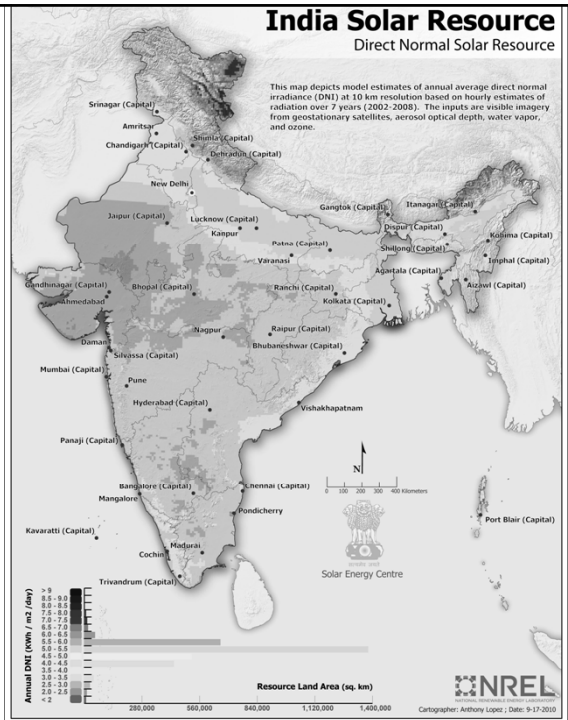
- LBNL Study projects India's onshore wind potential to be 2,006,000 MW (3,121,000 MW) at 80 m (120 m) hub height!!!



Capacity and Electricity Generation from Renewable Energy Sources (2008-09)



Solar Resources in India



Challenge for Harnessing Renewable Energy

- Resources
- Technology
- Financing
- Policy & Regulation

Need some Carrots (and small sticks)

Carrots

- Subsidies
- Feed-in Tariffs
- Tax Breaks

Sticks!

- Obligation to buy electricity generated from renewable energy resources, Renewable Portfolio Obligation (RPO)

Electricity Act 2003 and Policy Framework for Renewable Energy

- State Electricity Regulatory Commissions (SERCs) to specify a percentage of the total consumption of electricity in the area of a distribution licensee, for purchase of electricity from co-generation and renewable energy sources (renewable portfolio obligation) (Sec. 81 (1) (e)).
- SERCs to promote co-generation and generation of electricity through renewable sources of energy by providing suitable measures for connectivity with the grid and sale of electricity to any persons (Sec. 81 (1) (e)).
- Terms and conditions for the determination of tariff to be prescribed by the SERCs to promote co-generation and generation of electricity from renewable sources of energy. (Sec. 61 (h))

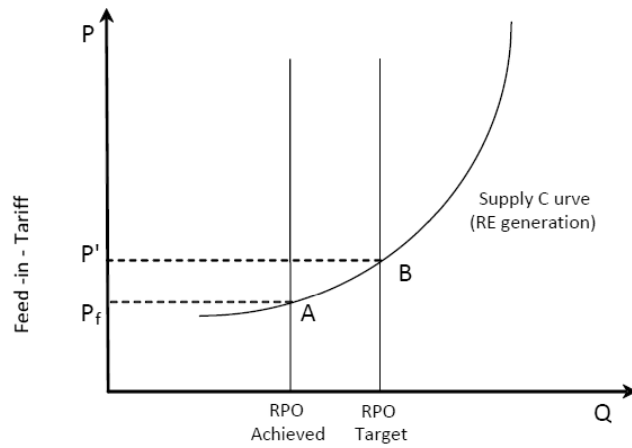
Electricity Act 2003 and Policy Framework for Renewable Energy (Contd.)

- National Electricity Policy to be formulated by the central government, in consultation with the state governments for development of the power system based on optimal utilization of resources including renewable sources of energy. (Sec. 3 (1))
- Central Government to prepare a national policy, in consultation with the State Governments, permitting stand alone systems (including those based on renewable sources of energy and other non-conventional sources of energy) for rural areas. (Sec. 4)

RPO and its Compliance Across States (in %)

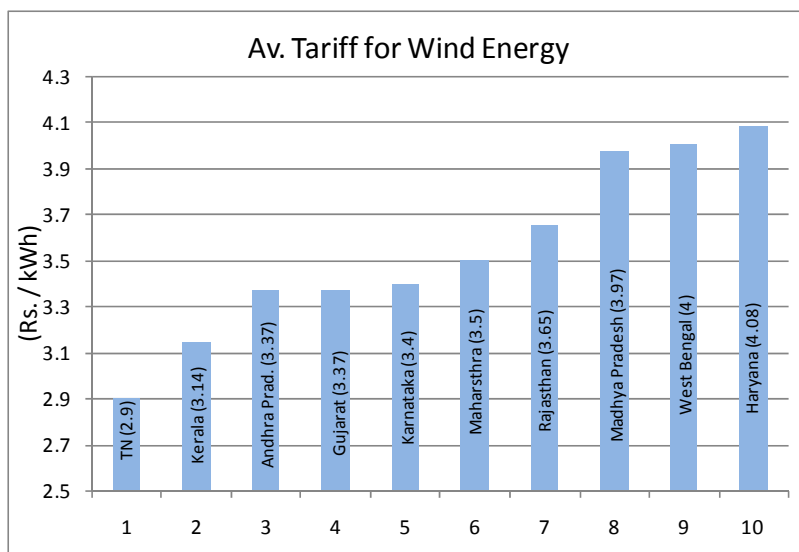
States	RPO Targets					RPO Performance		
	2007-08	2008-09	2009-10	2010-11	2011-12	2007-08	2008-09	2009-10
Andhra Pradesh#\$	5	5	5	5	5	4.41	3.95	4.06
Bihar@			4	5	6			NA
Delhi	1	1	1	1		---	---	---
Gujarat	1	2	2			2.07	NA	2.55
Haryana	3	5	10	10	10	NA	0.01	5.7
Karnataka	7-10	7-10	7-10			9.83	10.80	11.04
Madhya Prad.		10	10	10	10	0.08	0.07	0.06
Maharashtra\$	4	5	6			3.35	3.36	4.25
Orissa	3	3	4			0	0	1.26
Punjab	1	1	2	3	4	0.69	0.74	1.49
Rajasthan\$	4.88	6.25	7.45	8.50	9.75	2.57	4.90	3.23
Tamil Nadu	10	10				11.65	12.08	13.79
Uttaranchal	5	5	8	9	10	1.4	1.7	2.18
Uttar Pradesh	7.5	7.5	7.5			1.26	2.98	2.97
West Bengal	0.95-3.8	2-4.8	4-6.8	7-8.3	10	NA	0-0.37	0-0.34

Discontinuity in prices in the demand function



Feed-in-Tariff and Shortfall in RPO Compliance

Wind Energy Tariff Across States



Challenges

- Economic Efficiency of existing policies
- States have different resource endowments and some have very limited ones (e.g. Delhi)
- How to incentivise renewable resources in remote areas not connected with grid?

Jawaharlal Nehru National Solar Mission (JNNSM)

- One of the 8 national missions under the National Action Plan on Climate Change (NAPCC), which was launched on June 30, 2008.
- About 5,000 trillion kWh per year solar energy is incident over India's land area. In most parts, solar incidence ranges 4-7 kWh per sq.m per day.
- NAPCC - National level target for RE Purchase may be set at 5% of total grid purchase for FY 2010. This could be increased by 1% each year for the next 10 years.

JNNSM Roadmap

S. No.	Application segment	Target for Phase I (2010-13)	Target for Phase II (2013-17)	Target for Phase III (2017-22)
1	Solar collectors (million sq. meters)	7	15	20
2	Off grid solar applications (MW)	200	1000	2000
3	Utility grid power, incl. roof top (MW)	1,000-2000	4000-10,000	20000

National Mission on Enhanced Energy Efficiency (NMEEE)

Mission Goals – (by 2014-15)

- Annual fuel savings in excess of 23 million toe
- Cumulative avoided electricity capacity addition of 19,000 MW
- CO2 emission mitigation of 98 million tons per year

Market-based approaches to unlock energy efficiency opportunities, estimated to be about Rs. 74,000 crores.

NMEEEE - Mandate

- Perform Achieve and Trade (PAT) - A market based mechanism to enhance cost effectiveness of improvements in energy efficiency in energy-intensive large industries and facilities, Tradable certificates of energy savings.
- Market Transformation for Energy Efficiency - Energy efficient appliances in designated sectors
- Energy Efficiency Financing Platform - Creation of mechanisms to help finance demand side management programmes in all sectors.
- Framework for Energy Efficient Economic Development - Developing fiscal instruments to promote energy efficiency.

What influences economics of Renewable Energy Sources

- High capital cost
- Low capacity utilisation
- Weather risk (instead of fuel risk)
- Evolving technology
- Grid integration

- Increasing land prices and land squatting

Road Ahead

- Energy Efficiency – Low hanging fruit and no regret option
- Renewable Energy – Road to Energy security but some technical challenges
- Policy and Regulatory Environment need to provide incentive for adoption of clean and efficient technology in the energy sector.

Thank You

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Courses, Workshops and Conferences

- Short Term Course “Challenges and Implementation Issues post Electricity Act 2003: Regulatory, Policy & Technical Solutions”, 10-14 April, 2004
- International Conference on “Power Market Development in India: Reflections from International Experience”, 19-21 April, 2005
- National Workshop on “Project Financing for Energy and Infrastructure Sector”, April 19-22, 2007

Courses, Workshops and Conferences (contd.)

- 2nd National Workshop on “Project Financing for Energy and Infrastructure Sector”, April 24-27, 2008
- Capacity Building Programme for Officers of Electricity Regulatory Commissions, 30th June - 5th July, 2008
- 2nd Capacity Building Programme for Officers of Electricity Regulatory Commissions, 3-8 August, 2009
- 3rd Capacity Building Programme for Officers of Electricity Regulatory Commissions, 23-28 August, 2010
- 4th Capacity Building Programme for Officers of Electricity Regulatory Commissions, 18-23 July, 2011
- Energy Conclave 2010, 8-15 Jan. 2010