Lecture – 24A

Energy Resources, Economics and Environment

Energy Policy Examples

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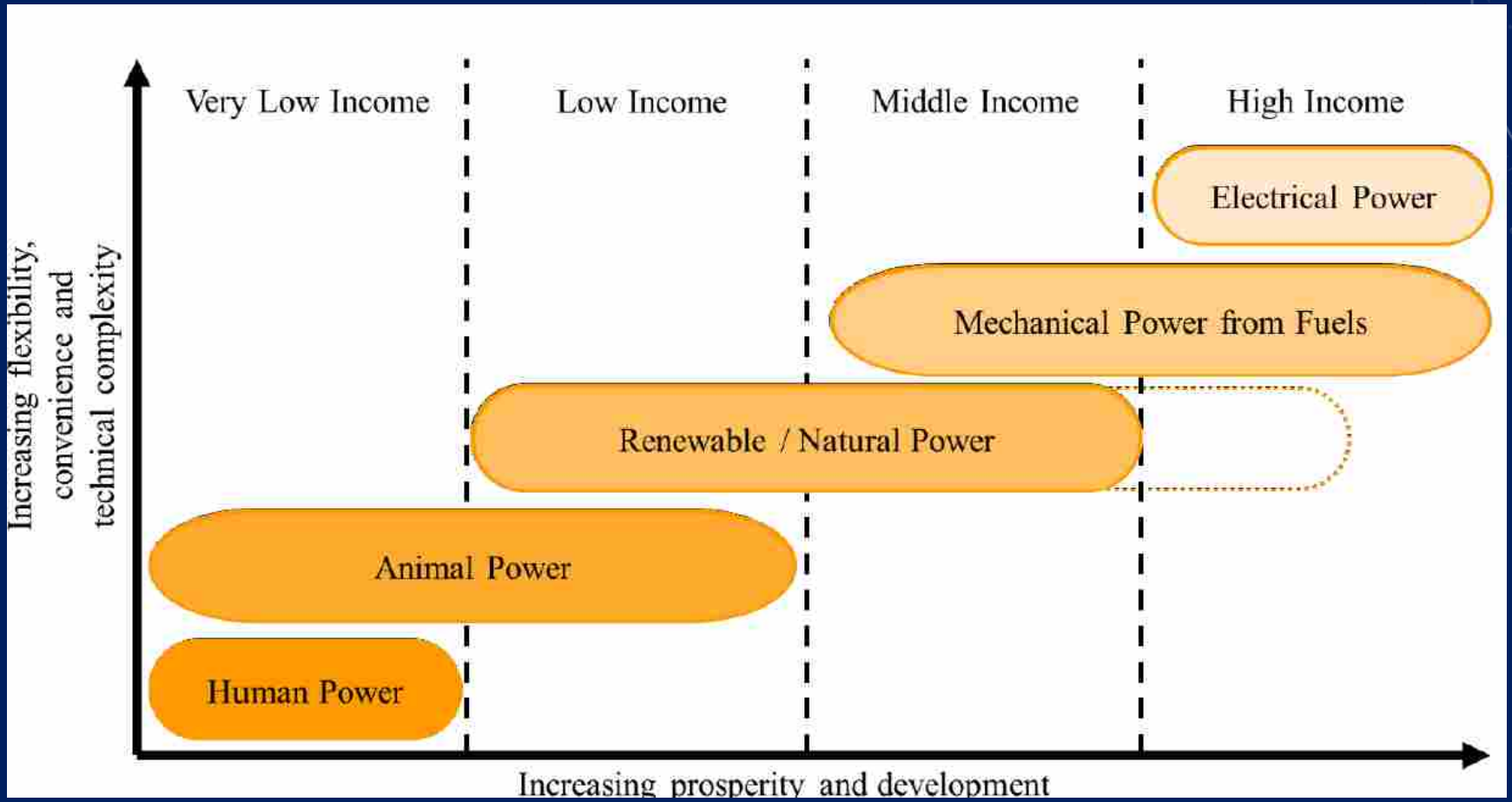
Access

- Cooking
- Rural Electrification

Mechanical Power Ladder



GEA, Chapter 19

Energy Access - definition

"a household having reliable and affordable access to both clean cooking facilities and to electricity, which is enough to supply a basic bundle of energy services initially, and then an increasing level of electricity over time to reach the regional average"

IEA definition (WEO 2017 special report)

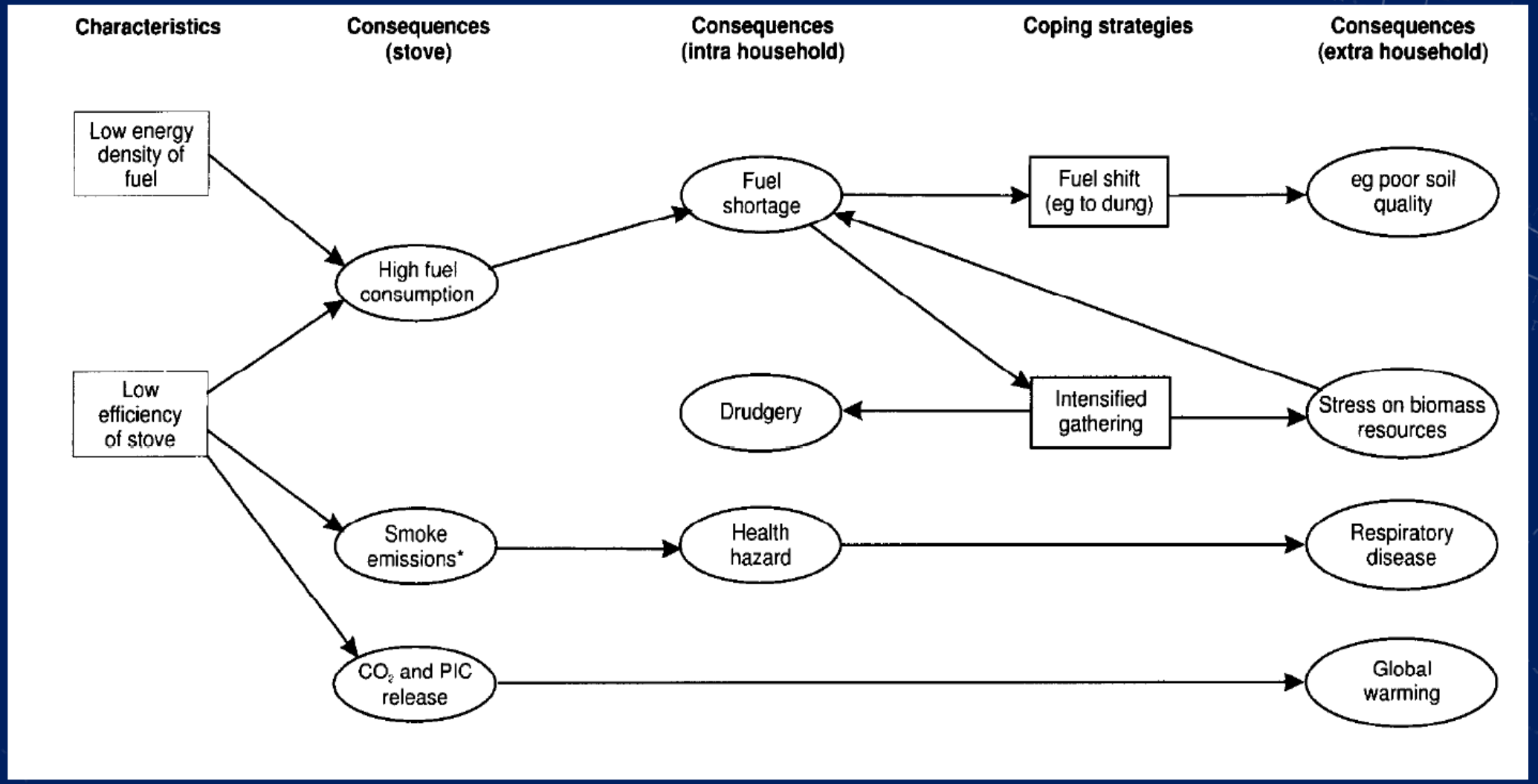
Fuel use by Quintile (2010)

Nation	Energy Carrier	RQ1	RQ2	RQ3	RQ4	RQ5	UQ1	UQ2	UQ3	UQ4	UQ5
		%	%	%	%	%	%	%	%	%	%
Indonesia	Electricity	64	73	79	82	88	93	96	98	99	99
	Kerosene	90	91	91	93	93	93	94	93	86	62
	LPG	1	1	1	2	8	1	5	12	24	48
India	Electricity	31	44	53	63	79	75	90	94	97	98
	Kerosene	97	96	94	90	79	85	72	55	41	21
	LPG	1	2	6	12	38	19	46	68	83	90
Brazil	Electricity	50	57	63	69	78	84	91	93	95	96
	Kerosene	21	15	12	9	5	2	1	1	0	0
	LPG	42	61	75	85	90	91	98	98	96	85
Ghana	Electricity	2	5	7	9	19	28	27	34	43	61
	Kerosene	29	27	25	27	27	13	10	6	6	4
	LPG	0	0	0	0	2	0	2	4	8	10

Energy Access Policies

- BPL schemes- Electricity connection- Kutir Jyoti- wiring, meter, one connection (tribal, Annual income < 27000 Rs/ year)
- Bhagya Jyoti Scheme
- Pradhan Mantri Har Ghar Sahaj yojana

Health, Environmental impacts of traditional fuels



Ravindranath and Ramakrishna, 1997

Chulha Designs

Sampoorna - Phillips

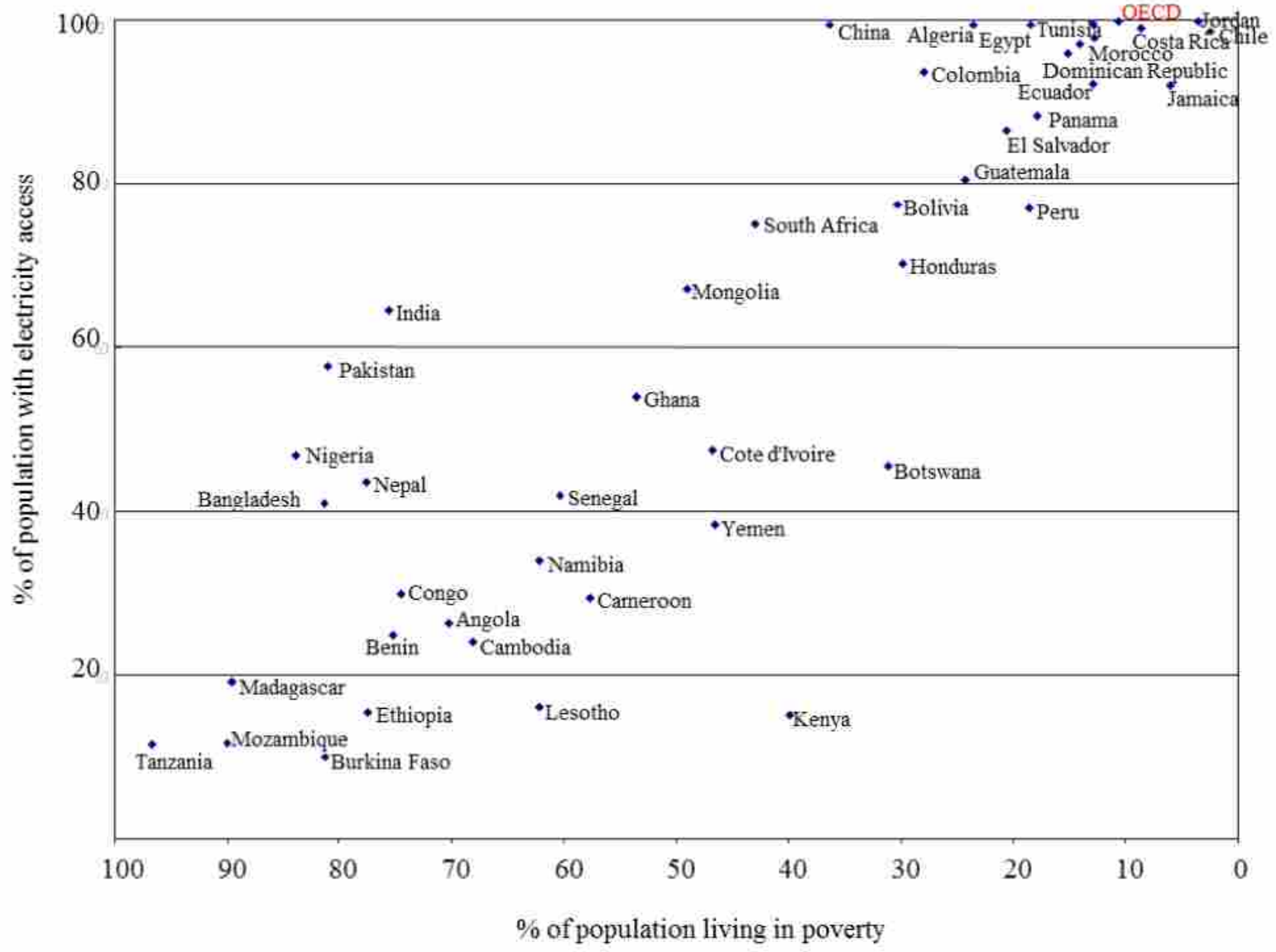
Kerosene/ LPG/ Electricity

Chulha Costing (Sample-2011)

	Costing for Saral Chulha fabrication and installation as on 23 October 2011 Prepared by Junglescapes Charitable Trust, Lokkere, Karnataka, India			
	Cost Item	**Quantity**	**Rate**	**Amount per chulha**
1	Cement - Basic Quality (kgs)	22	6.2	136
2	Stone grit 6 mm (Bandlis)	2	25	50
3	Stone powder (Bandlis)	1	10	10
4	Chicken mesh (3 ft by 1-1/4 ft)	1	40	40
5	Steel bars (4-6mm)	in kgs		50
	2 feet bars (nos)	2		
	10 inch bars (nos)	7		
6	Wastage on above raw materials at 5%			14
7	Red cement paint for finishing			10
8	Chimney Pipe (3 inch)	1	100	100
9	Chimney Cap (3 inch)	1	40	40
10	Clamp for chimney pipe	1	10	10
11	Grate	1	180	180
12	Raw material transportation (batch of 10)			50
13	Labour for fabrication and finishing (4 hours)			75
14	Transportation of chulha to installation site (batch of 6)			50
15	Bricks for installation (nos)	15	5	75
16	Labour for installtion (3 hours)			50
17	Profit margin for entrepreneur			75
	Total cost			**1016**
18	Add: Mould amortisation			80
	Total cost including mould amortisation			**1096**
	Rounded off			**1100**
	Notes			
a	All rates are bsed on current market prices of raw materials at Gundulpet			
b	Landed cost of mould of Rs 24000 assumed to be amortised over 300 chulhas (life as indicated by Fomo)			
c	These rates are based on wholesale market prices of raw materials under ideal conditions. The prices in the retail hardware stores (or when there is a shortage) can be higher by 5-10% than what is indicated above.			

http://www.lowsmokechulha.com/index.php?title=File:Chulha_costing_2011.ppt

Access to electricity versus poverty levels



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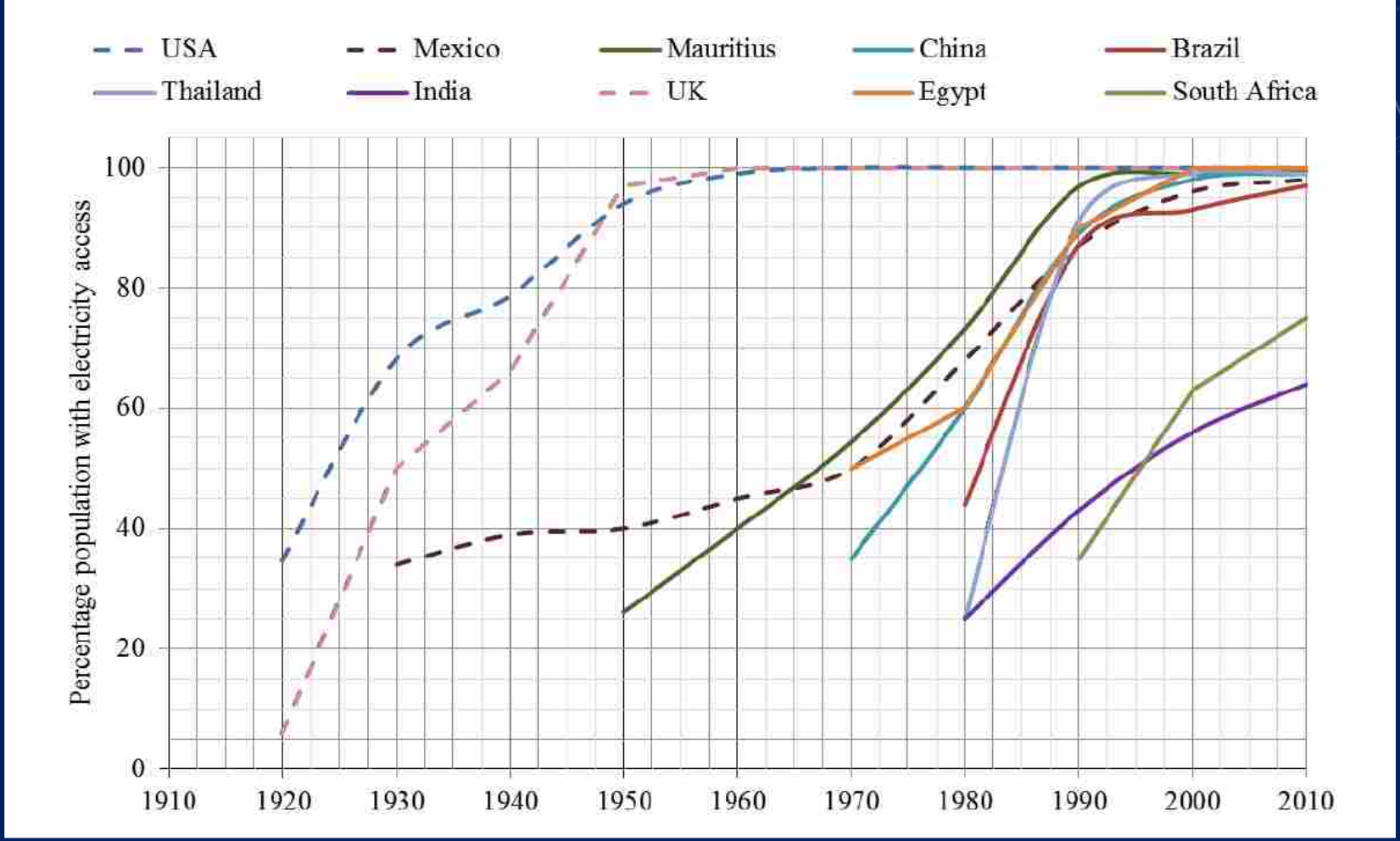
Historical Household Electrification Rates



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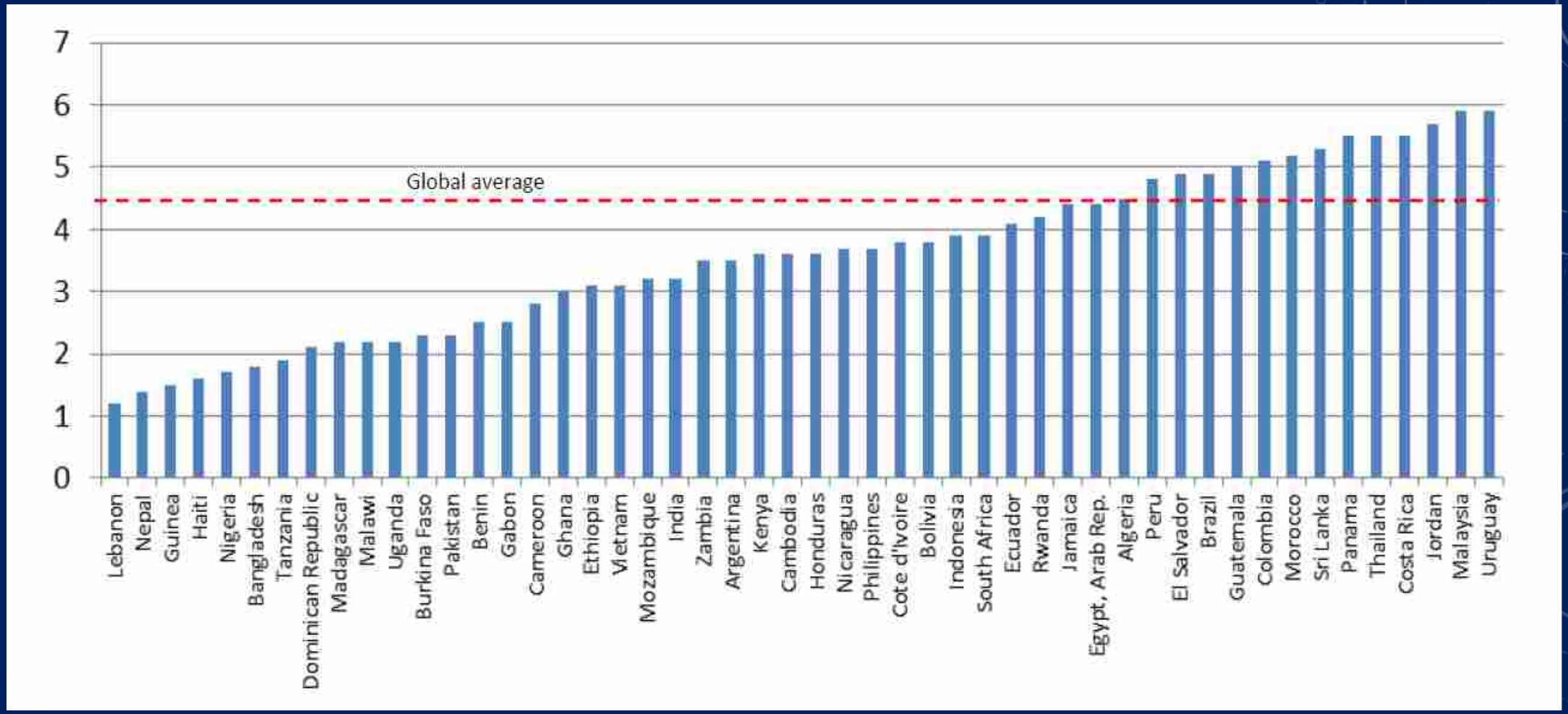
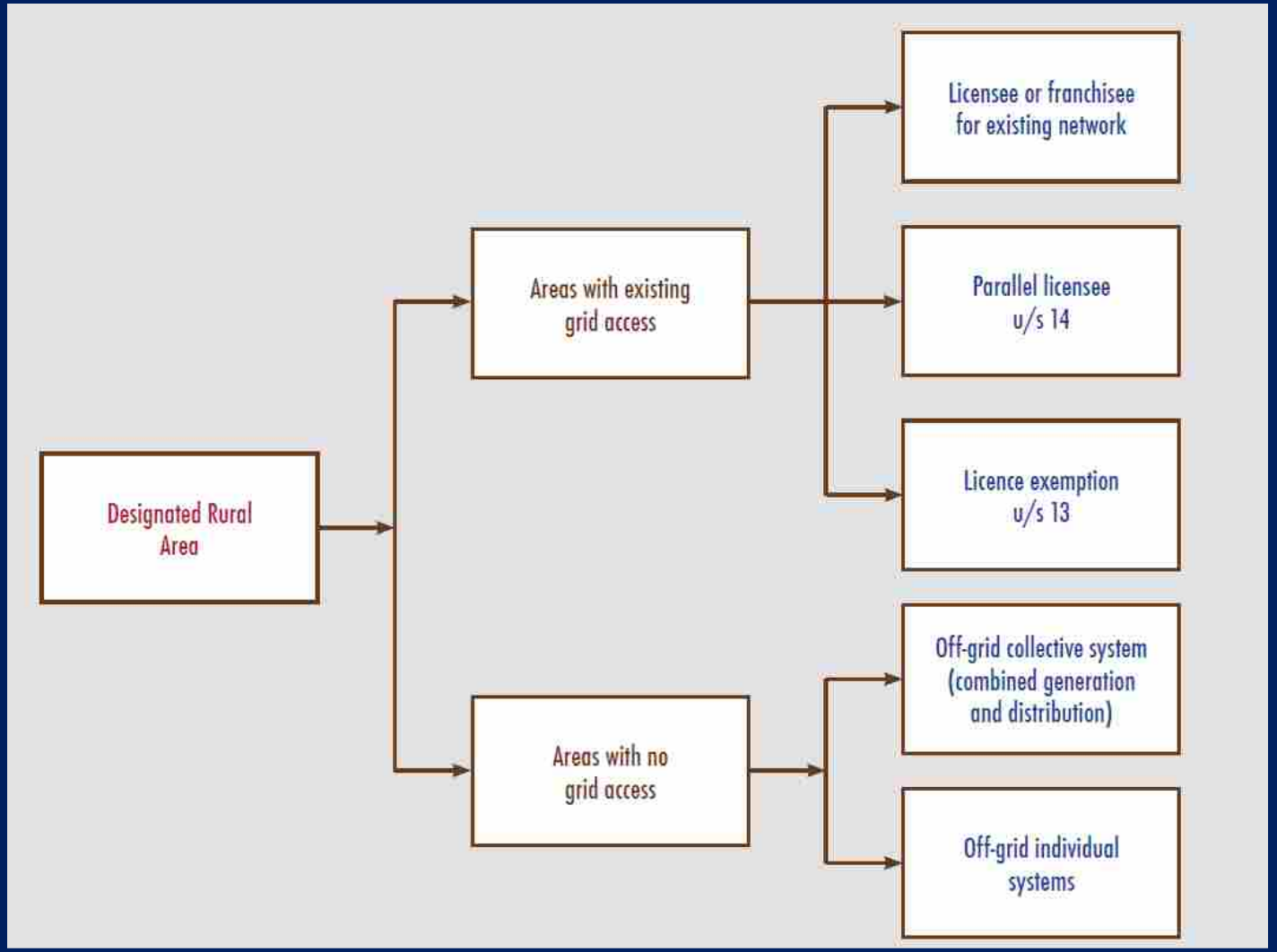
Quality of Electricity Index



Possible Supply Models



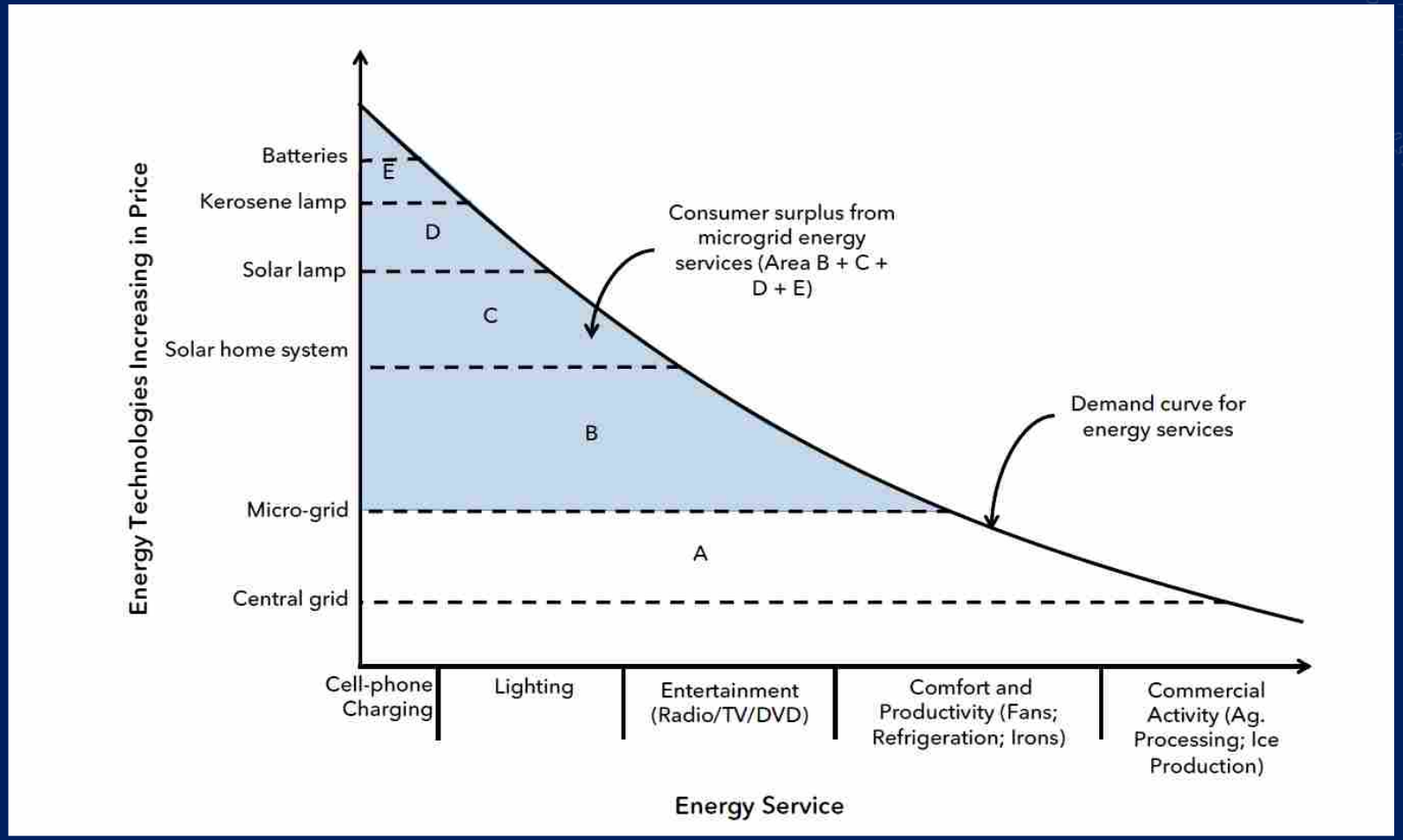
Source: GNESD, 2014

Capital Subsidy

Scheme	Time frame	Target under the scheme	Ownership	Finance	
				Subsidy vehicle	Central Financial Assistance
RVEP	2001 onwards	Electrification of census villages and hamlets near electrified villages that are not likely to receive grid connectivity	VEC/Community	Capital Subsidy subject to upper limits	90% of the costs of various renewable energy devices/systems subject to pre-specified maximum subsidy *Maximum CFA per household is US$300*[4]
VESP	2004-09	1,000 villages to be electrified within the current 5-year plan	VEC/Community	Capital subsidy Operational subsidy for first 2 years	90% of the total project cost *Maximum CFA per household is US$333* 10% of the total project cost
DDG under RGGVY	2009 onwards	N/A	State Government	Capital subsidy Operational subsidy for 5 years	90% of the total project cost 10% of the total project cost
JNNSM (Off-grid component)	2010 -2022	20 million decentralised solar PV systems	Local bodies/State Government/	Capital subsidy	US$1.5/$W_p$ (with battery storage) US$1.17/$W_p$ (without battery storage)

Source: GNESD, 2014

Electricity Service and Price



Source : UN Foundation, 2014

Tariff Comparison

Developer (Business Model)	Tariff Price (Local Currency)	Tariff Price (USD, January 2014 exchange rate)	Operating Expenses	Major Maintenance	Capital Costs[3]	Profit (for Developer)
CREDA (FS)	5-10 Rs/mo.	0.08 – 0.16/mo.	Partial	No	No	No
DESI Power (PS)	5 – 8 Rs/kWh	0.08 – 0.13/kWh	Yes	Yes	Partial	No
Green Empowerment/ Tonibung/PACOS (PS)	3 – 20 Ringgit/mo.	0.91 – 6.09/mo.	Yes	Partial	No	No
Haiti (PS)	~200 HTG/mo.	4.55/mo.	Yes	No	No	No
Husk Power Systems (FP)	~150 Rs/mo. (average)	2.41/mo.	Yes	Yes	Yes	Yes
OREDA (FS)	10 – 30 Rs/mo.	0.16 – 0.48/mo.	Partial	No	No	No
WBREDA (PS)	80 – 270 Rs/mo.	1.28 – 4.32/mo.	Yes	Partial	No	No

Source : UN Foundation, 2014

Community Involvement

Categories (of Voluntary/ Paid Village Participation)	DESI Power	GE/T/P	EDH	HPS (BM Model)	OREDA	CREDA	WBREDA
Daily Operations	✓	✓	✓	✓	✓ ✓	✓	✓
Major Maintenance							
Collect Tariffs	✓	✓	✓ ✓	✓	✓	✓	
Enforce Penalties			✓ ✓				✓
Initiation/ Planning Strategy Help		✓		✓		✓	✓
Construction Labor		✓				✓	
Village Energy Committee Existence	✓	✓	✓ ✓		✓	✓	✓
VEC Bank Account Existence		✓	✓		✓	✓	
Contribute Land	✓	✓		✓	✓	✓	✓
Initial Community Ownership		✓					
Community Eventually Owns					✓		

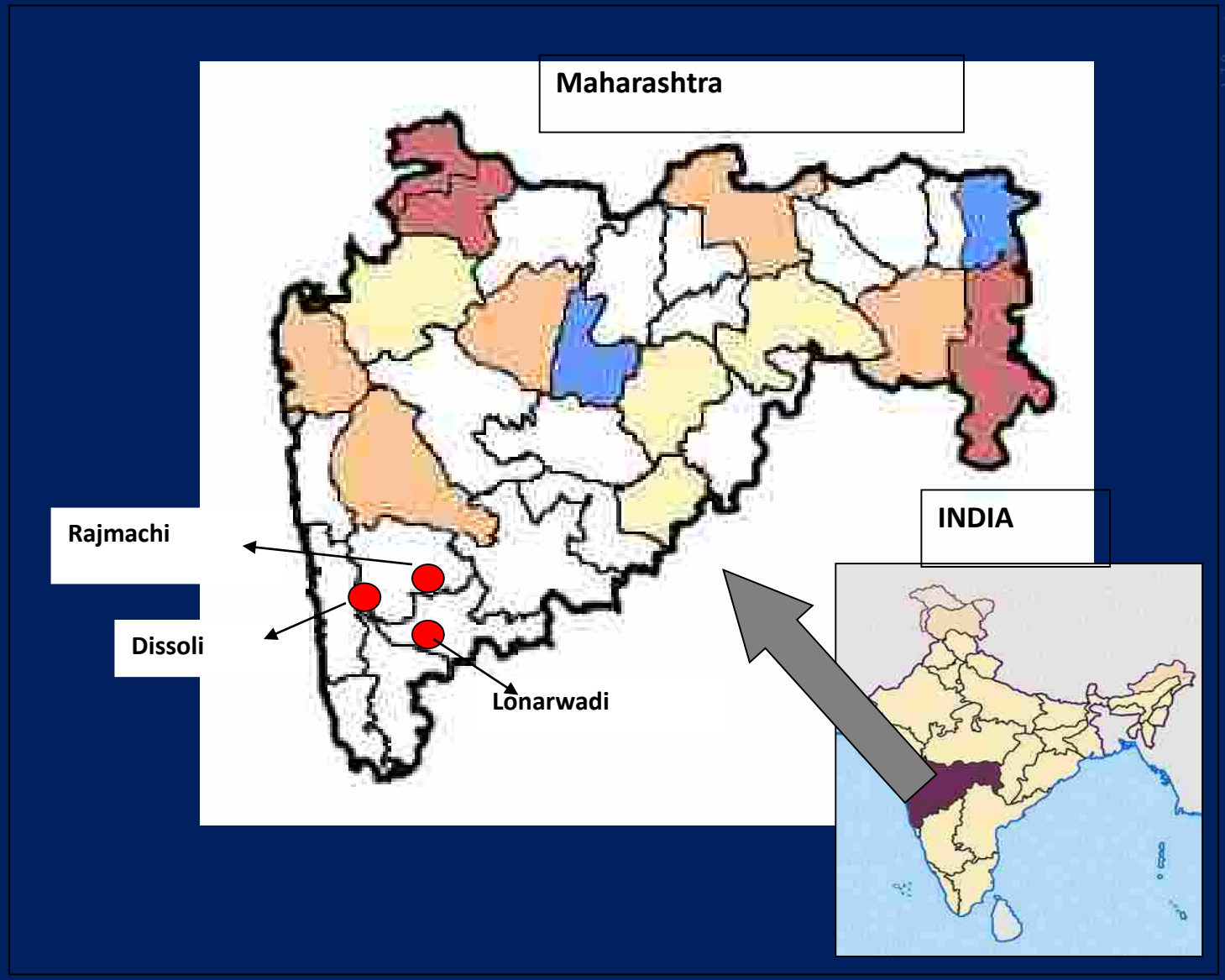
Source : UN Foundation, 2014

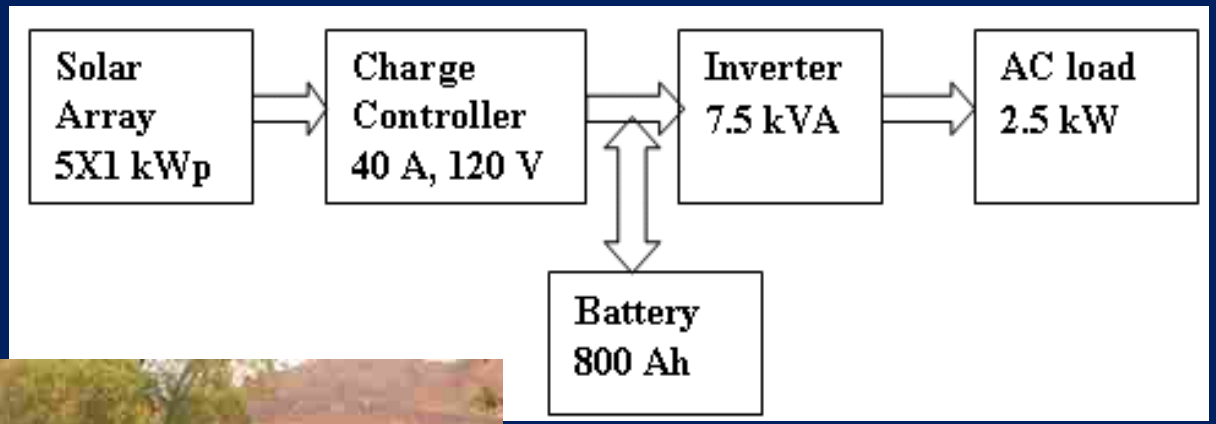
DSM Measures used

Developer	Efficient Appliances	Limiting Business Hours	Restricting Residential Use			
			Customer Agreements	Home-Wiring Restrictions	Over-Use Penalties	Load Limiters
CREDA	✔		✔	✔		✔
DESI				✔	✔	✔
GE/T/P			✔		✔	✔
Haiti						
HPS	✔		✔	✔	✔	✔
OREDA	✔		✔	✔		✔
WBREDA	✔		✔	✔	✔	✔

Source : UN Foundation, 2014

Affordable Access

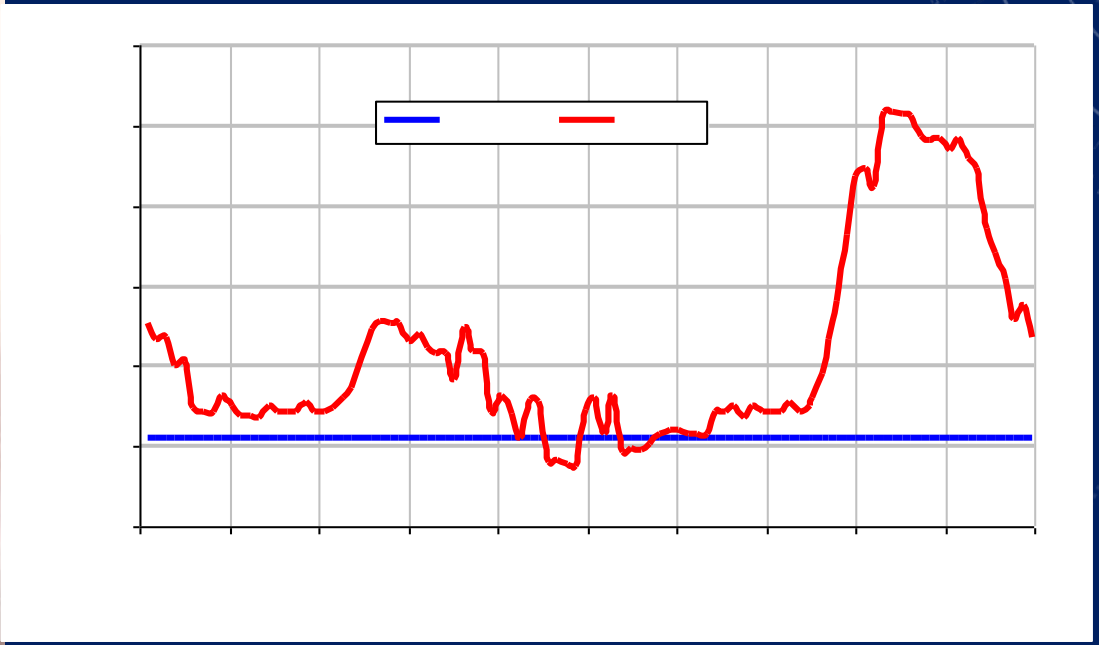




No. of house holds: 29
Connected load : 1.4 kW

5 kWp Solar PV power plant at Rajmachi Village, Maharashtra

Measurements

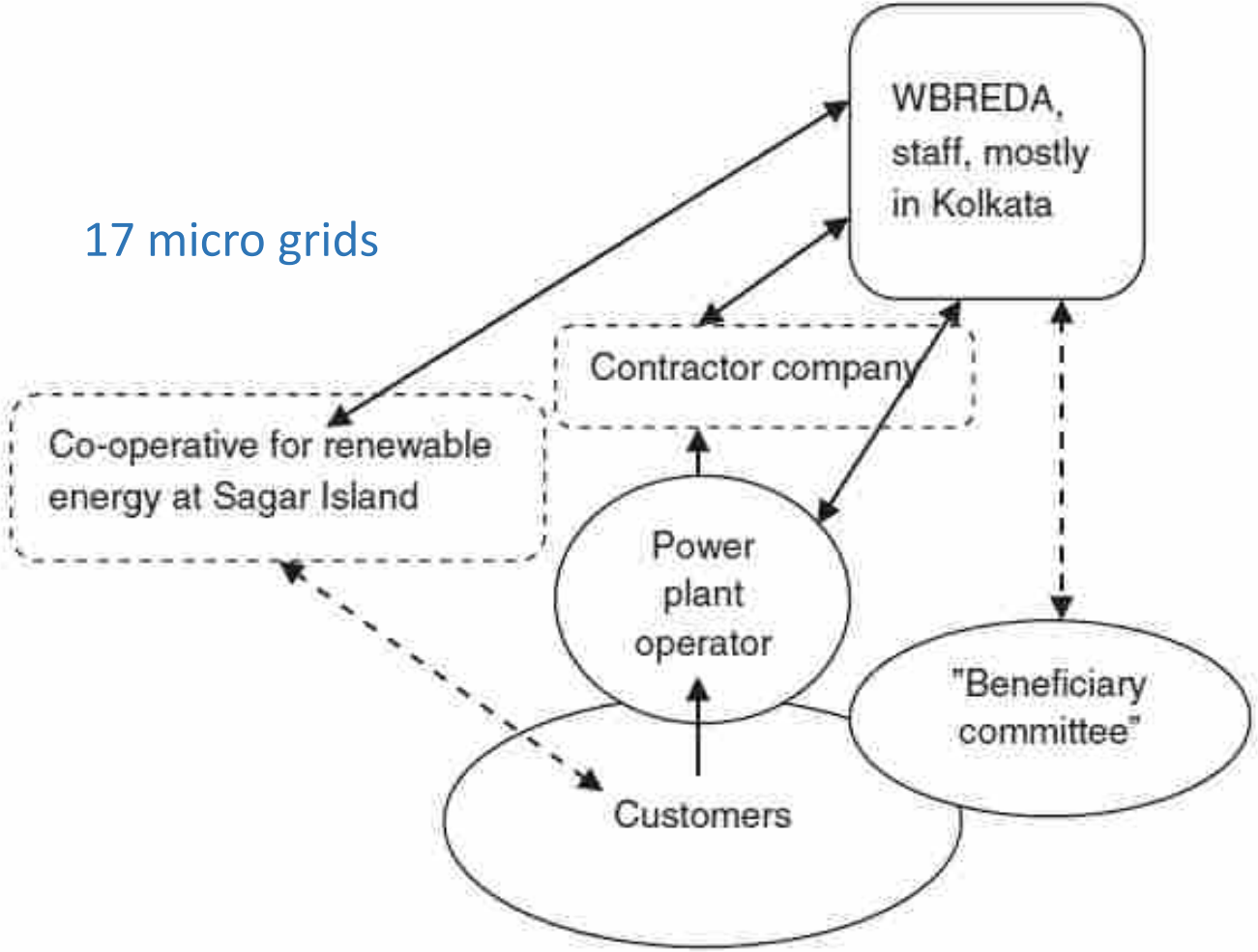


Integrated design-Summary

Name of the plant	Connected Load (kW)	Plant Capacity		Distribution loss (%)		Plant capacity factor (%)		Energy cost Rs / kWh	
		Existing	Designed	Existing	Designed	Existing	Designed	Existing	Designed
Solar PV, Rajmachi	1.4	5 kWp	4 kWp	4.6	0.5	8.3	11.5	32	25
Biomass gasifier, Dissoli	6.9	10 kW	10 kW	12.3	2.0	8.8	12	29-37	21-25
Biomass gasifier, Lonarwadi	10.7	20 kW	10 kW	14.6	2.7	5.6	14	43-54	16-25

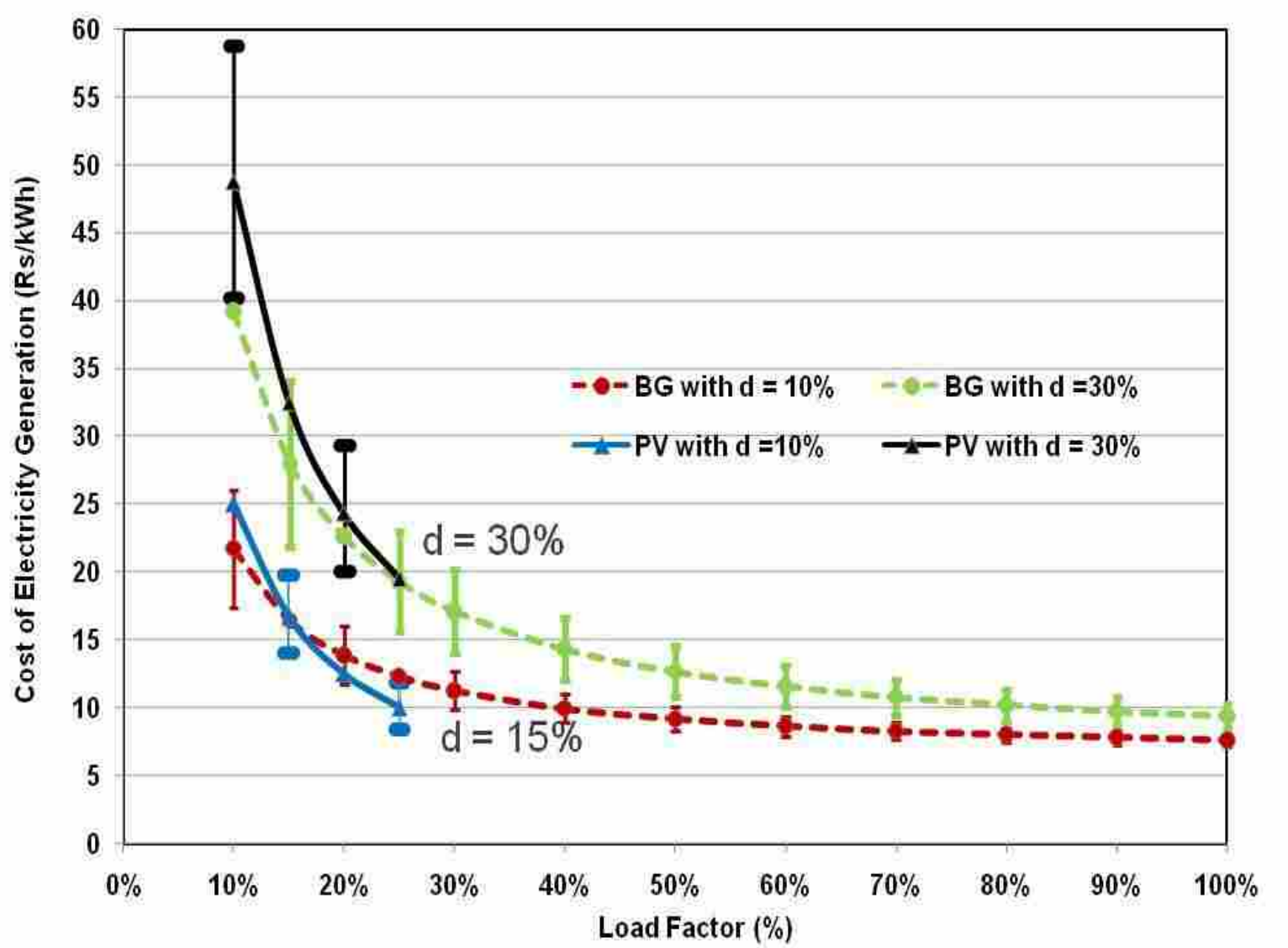
Sunderbans Microgrids - Organisation

17 micro grids



Source: Ulsrud et al (2011)

Cost of Electricity Generation



Capital cost Rs/kW

Biomass Gasifier	Solar PV + Battery
65,000	1,25,000
90,000	1,55,000
1,15,000	1,90,000

Selco Case study

- For profit company – Solar Home systems – started 1996 – sold about 100,000 SHS
- 90% of products – credit schemes
- Partnership with 9 banks – interest rates between 12-17%
- Financing Institutions pay 85% of the amount- monthly payments of Rs 300- 400 over a period of 5 years
- Financing/ repayment options – tailormade to end users – paddy farmers – repayment schedule based on crop cycle, street vendors – daily payments – Rs 10
- Funding from REEP – meet margin amount for poor customers, reduce interest rate

Source: SELCO, 2011

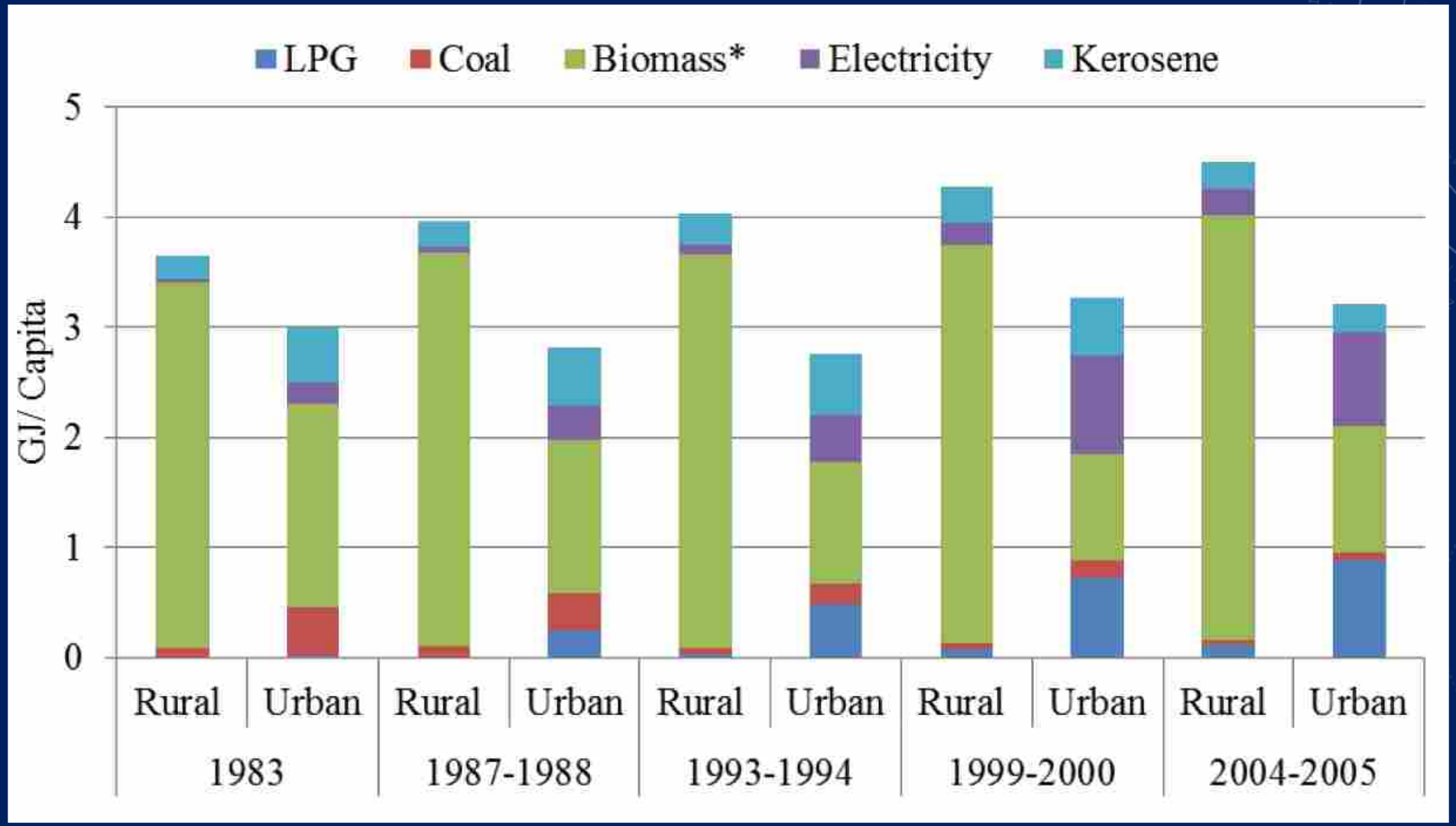
DESI Power

- Biomass based power solutions – Bihar- 25 kW to 100 kW
- Local distributors – decide pricing
- Registered under CDM and sold CERs to Swiss buyer
- MNRE funds, Promoters Equity, ICICI Loan
- Monthly rate based on no of bulbs / loads, Circuit breaker to limit consumption
- Irrigation pump users Rs 50/ hour, Household Rs 120- 150 per month
- Underground trunk wiring-distribution
- Enabling micro-enterprises –battery charging station, flour mill, workshop etc
- Tie up with Telecom towers – increasing capacity factor

Husk Power

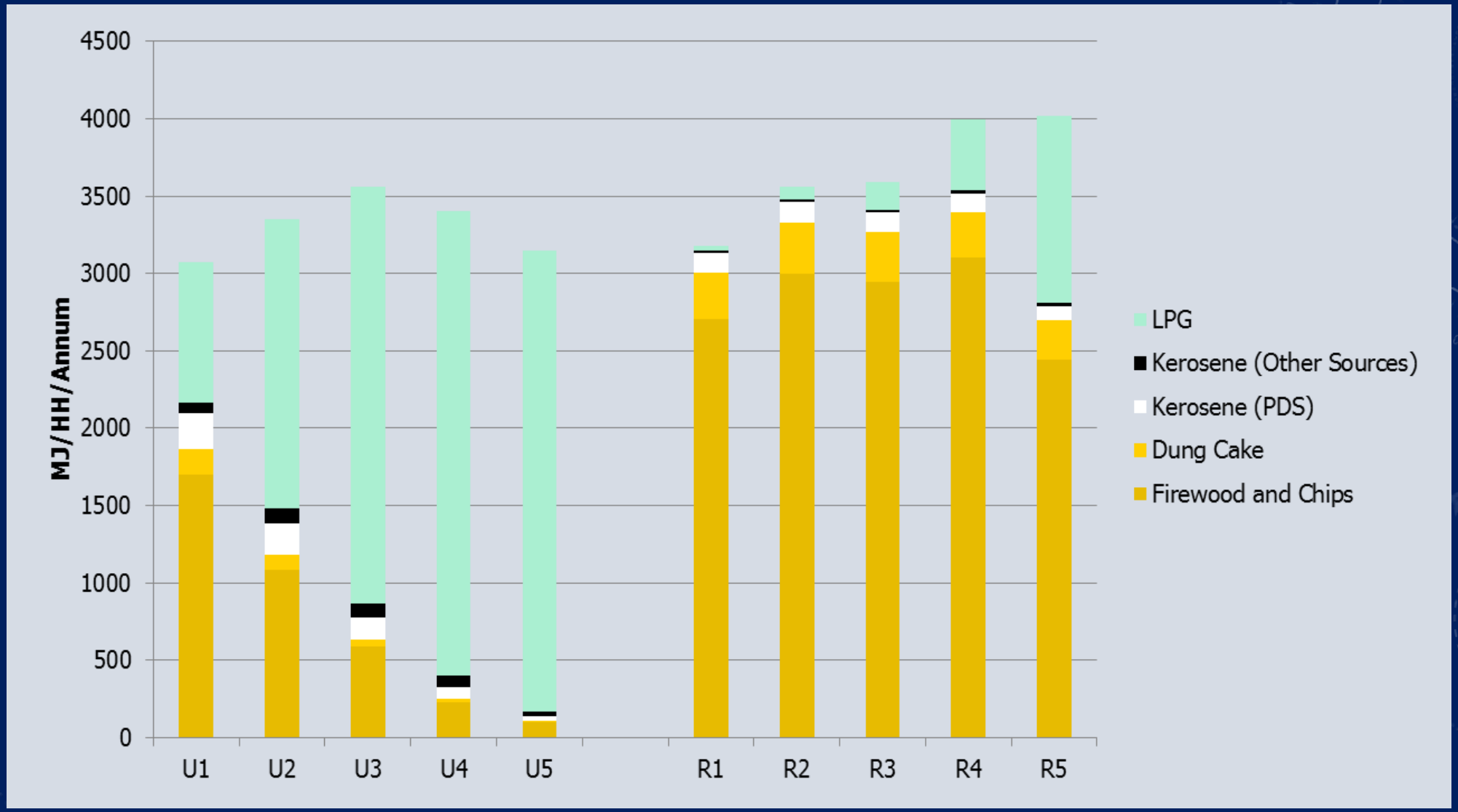
- Initial funding – prize money
- 30-100 kW – biomass gasifiers- based on rice husk
- Energy audit of households
- Focus on household demand for lighting
- Lower production, operating costs – use of bamboo, asbestos
- Overhead pole wiring
- Directly reach end user

Average Household Energy Use - India



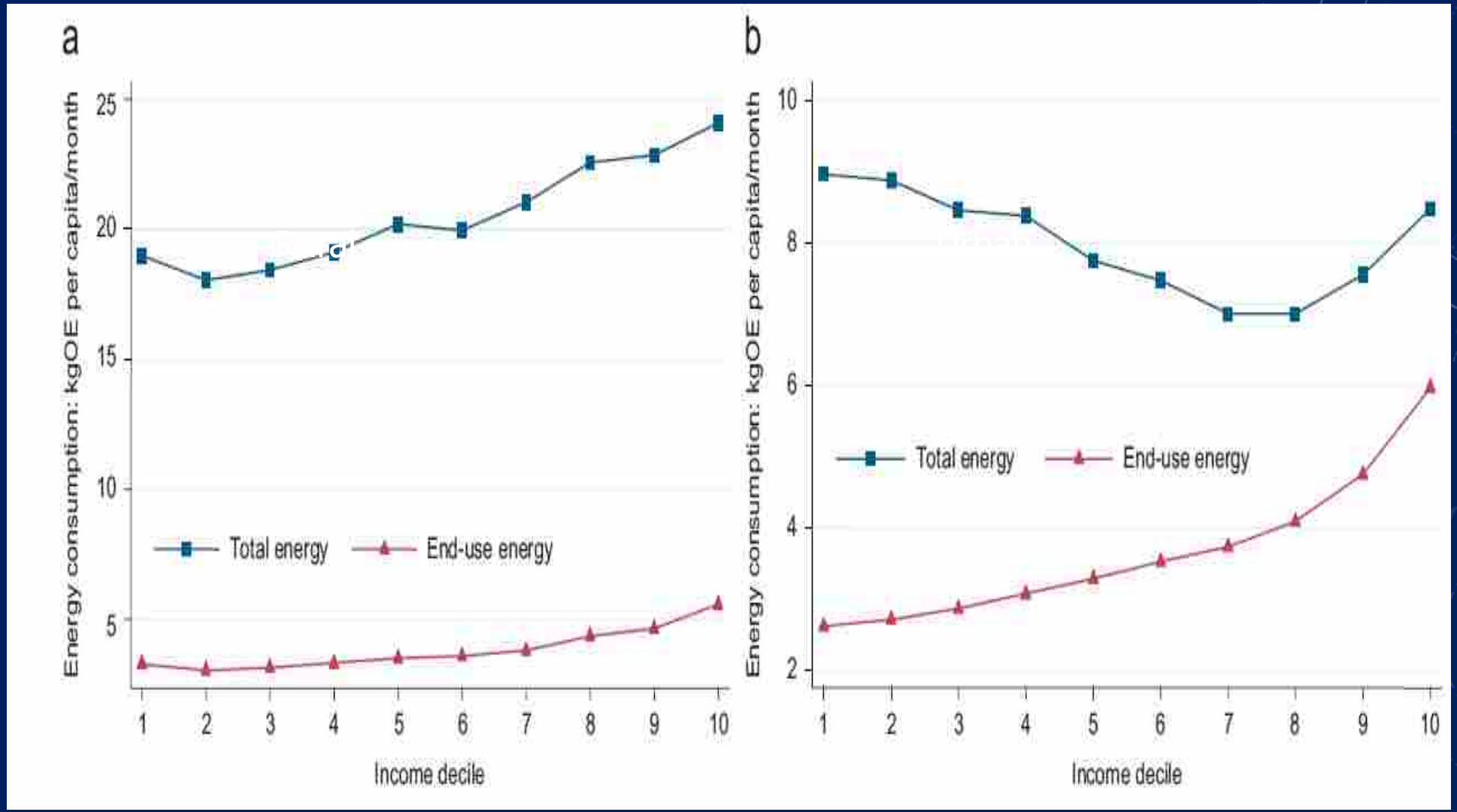
GEA, Chapter 19

Cooking Energy Use (2010)



Source: 2010 NSSO

Energy Use Household (2005)



Khandker et al, 2012

Comparison Cooking fuels

Fuel	Avg Price/Useful Energy	Heat Rate (MJ/Std. Unit)	Thermal Efficiency %	Emission Factor PM (gm/kg)
Fuelwood	0.777	16	15	3.2
Dungcake	1.379	15	15	3
Kerosene PDS	2.557	35	35	1.54
Kerosene Other	5.773	35	35	1.54
LPG	0.871	45	60	0.32

Gasifier Cook stove Designs

Source: Anderson, 2012

Rice Husk gasifier Cookstoves

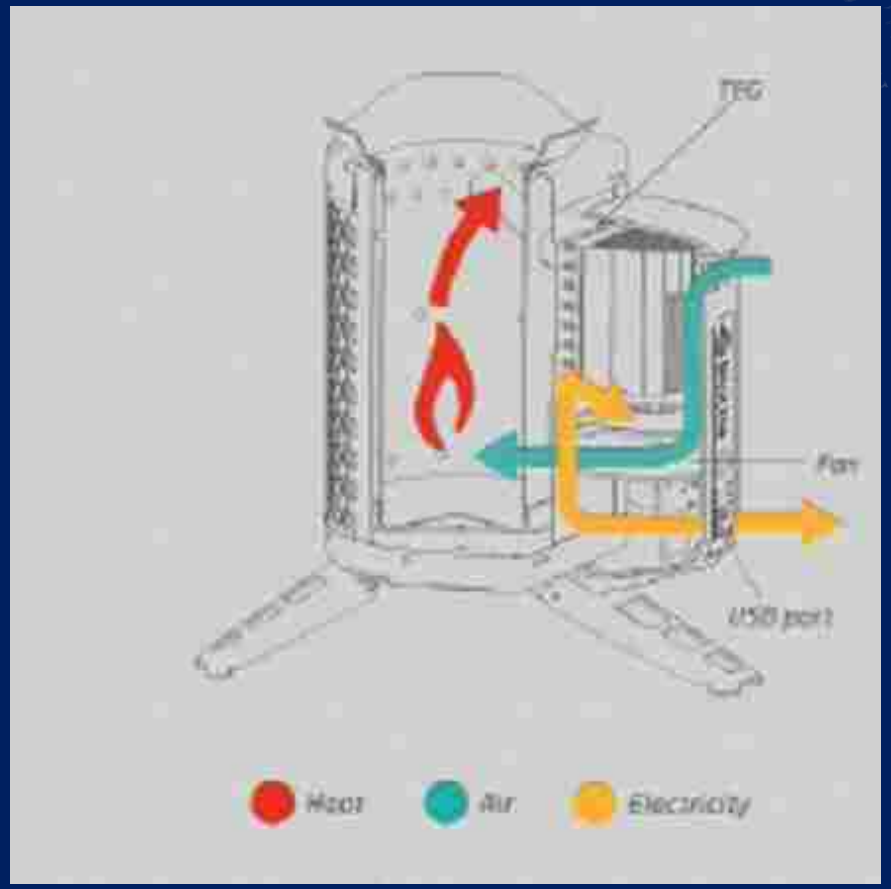
Source: Anderson, 2012

Oorja stove

Mukunda et al, 2010

http://www.firstenergy.in

Biolite Stove



Source: GEA Chapter 10

http://www.biolitestove.com

Sampada Biomass Gasifier Stove

Source: www.arti-india.org/

Compact Biomass Gasifier

Source: www.arti-india.org/

1 m^3 – digestor – 2 kg kitchen waste

0.5 m^3 – digestor –1 kg kitchen waste

Subsidy Mechanism

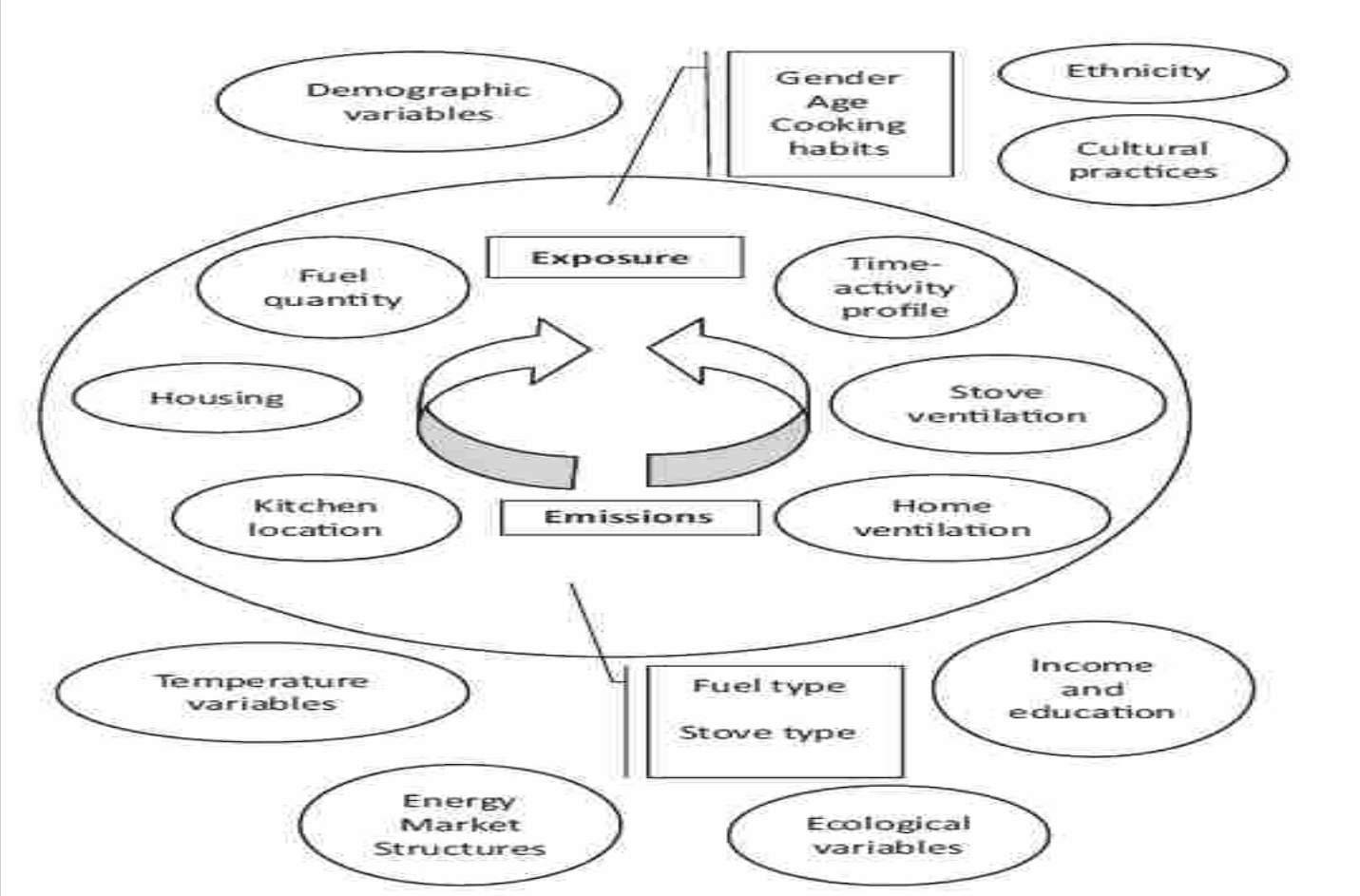
Government intervention	Example	Lowers cost of production	Raises cost of producer	Lowers price to consumer
Direct financial transfer	Grants to producers /service providers: Subsidy for bulk power supply Direct operating subsidy Capital subsidy	✓		
	Grants to consumers: Direct connection subsidy Connection subsidy through service provider Direct consumption subsidy to low power users (lifeline rate)			✓
	Low-interest or preferential loans: Financing subsidy for producers Consumer credit for new connections	✓		
Preferential tax treatment	Rebates or exemptions on royalties, sales taxes, producer levies and tariffs	✓		
	Tax credit	✓		✓
	Accelerated depreciation allowances on energy-supply equipment	✓		
Trade restrictions	Quotas, technical restrictions and trade embargoes		✓	
Energy-related services provided directly by government at less than full cost	Direct investment in energy infrastructure	✓		
	Public research and development	✓		
	Liability insurance and facility decommissioning costs	✓		
Regulation of the energy sector	Demand guarantees and mandated deployment rates: Cross-subsidy to low power users (lifeline rate)	✓	✓	
	Price controls		✓	✓
	Market-access restrictions		✓	

Disability Adjusted Life Years

- One DALY can be thought of as one lost year of "healthy" life. The sum of these DALYs across the population, or the burden of disease, can be thought of as a measurement of the gap between current health status and an ideal health situation where the entire population lives to an advanced age, free of disease and disability. (Source: WHO)
- DALY = YLL +YLD

https://www.who.int/healthinfo/global_burden_disease/metrics_daly/en/

Indoor Air Pollution



GEA Chap 4

Consider a poor rural household that uses three kerosene lanterns with the following data:

a) cost of lamp Rs 100

Life 5 years

Annual O& M cost Rs 20/year

Usage: 4 hours/ day (20ml/hour)

Price of kerosene: Rs 35/ litre (market price)

82% Carbon by weight (specific gravity 0.8)

Replace by solar PV lantern:

Capital cost: Rs 550(life 10 years)

Rs 150 (battery -2 years)

a) Consider a household that uses kerosene. Calculate the annual cost and the CO_2 emissions for each kerosene lantern and the viability of replacement with solar. (Use a residential discount rate of 60 %)

b) Consider the impact of having a subsidy on kerosene (Rs 18/l). Does this affect the viability?

c) Compute the cost of lighting for each solar lamp. If the model was to have a lease model, calculate the effective monthly payment. Use a government discount rate of 10%.

d) If the effective household subsidy is to remain constant, suggest a model for capital subsidy for reductions in lease payments.

References

- GEA, 2012 Chapter 2,4, 10 & 19 : Global Energy Assessment - Toward a Sustainable Future, Cambridge University Press, Cambridge, UK and New York, NY, USA and the International Institute for Applied Systems Analysis, Laxenburg, Austria.
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- http://www.firstenergy.in
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Lecture – 24B

Energy Resources, Economics and Environment

Energy Policy Examples – Part 2

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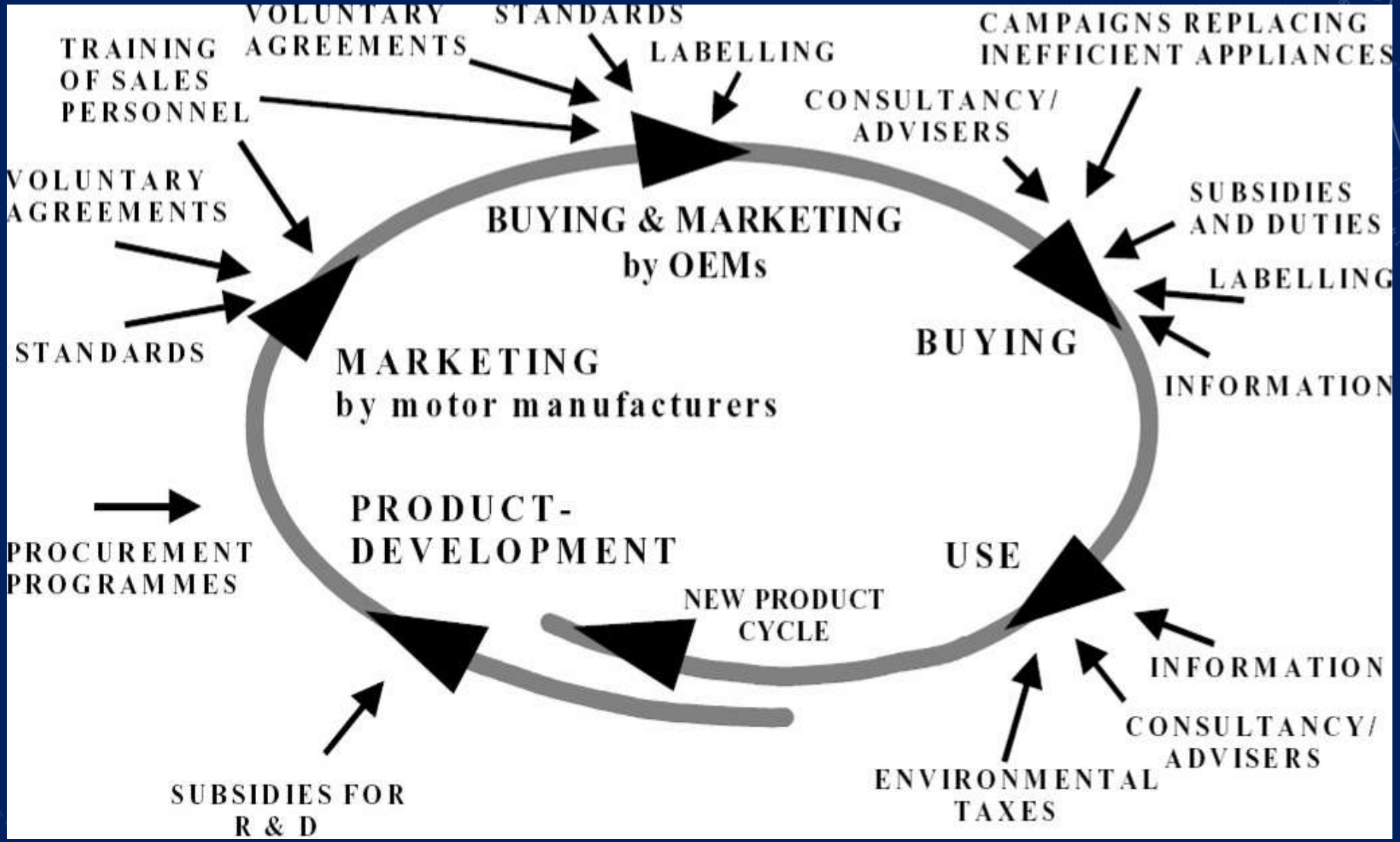
S. No.	Equipment	Rating	Initial cost (Rs)	Annual Electricity Cost (Rs)	ALCC (Rs)	Cost of electricity as % of ALCC
1	Motor	20 hp	45,000	600,000	605,720	99.0
2	EE Motor	20 hp	60,000	502,600	512,700	98.0
3	Incandescent Lamp	100 W	10	1168	1198	97.5
4	CFL	11 W	350	128	240	53.6

EE- Energy Efficient, CFL- Compact fluorescent lamp, ALCC- Annualised life cycle cost

Obstacles Removal for Motors



GEA, 2012

Nuclear Power

- Public Acceptance
- Safety Risks – Fuel cycle/ Power Plant
- Nuclear Waste Disposal (High Level Waste)
- Proliferation (Weapons, Fissile Materials)
- Climate Change
- Costs

Table 1: Minimum annual energy consumption and estimated number of Designated Consumers (DCs) in select sectors

Sector	Minimum annual energy consumption for the DC (tonnes of oil equivalent)	No. of probable DCs
Aluminium	7500	11
Cement	30000	83
Chlor-alkali	12000	20
Fertilizer	30000	23
Iron and steel	30000	101
Pulp and paper	30000	51
Railways (diesel loco sheds and workshops)		8
Textiles	3000	128
Thermal power plants	30000	146

Source: PAT Consultation Document 2011

PAT CONSULTATION DOCUMENT

Cement	Cement	Tonnes
Fertilizer	Urea	Tonnes
Iron & Steel (Integrated)	Crude Steel	Tonnes
Iron & Steel (Sponge Iron)	Sponge Iron	Tonnes
Aluminium (Refinery)	Alumina	Tonnes
Aluminium (Smelter)	Molten Aluminium	Tonnes
Aluminium (Integrated)	Molten Aluminium	Tonnes
Paper (Pulping)	Pulp	Tonnes
Paper (Paper Making)	Paper	Tonnes
Paper (Pulp & Paper)	Paper	Tonnes
Textile (Spinning)	Fabric	Kg
Textile (Composite)	Yarn	Kg
	Fabric	Kg
Textile (Processing)	Fabric	kg
Chlor-Alakli	Caustic Soda	Tonnes
Power Plant	Electricity	Million kWh

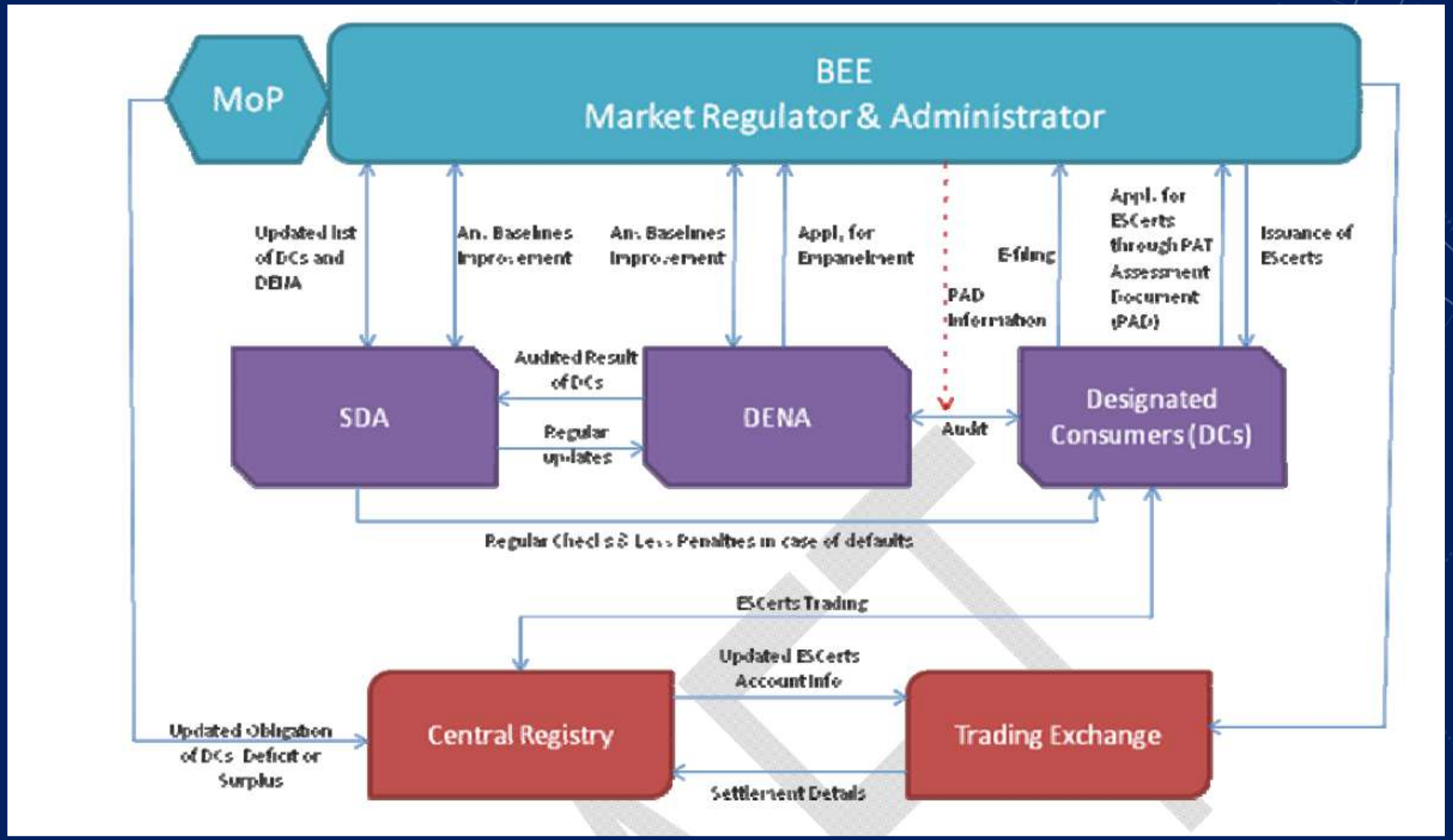
Source: PAT Consultation Document 2011

Target Setting for Aluminium Smelters

Statistical analysis for Smelter

Plant Name	Production (in Tonnes)				Estimated SEC (in MTOE/ ton)				Relative SEC	Total Energy consumption (in MTOE)	% Target	To be Energy Saving
	2007-08	2008-09	2009-10	Average production (MT)	2007-08	2008-09	2009-10	Average SEC				
Plant#1	3,62,793	3,68,867	3,78,157	3,69,939	1.275	1.272	1.277	1.274	1.000	4,71,455	X	4714.55x
Plant#2	3,58,954	3,58,734	3,59,213	3,58,967	1.364	1.365	1.362	1.364	1.070	4,89,546	1.07X	5238.14x
Plant#3	76,867	2,07,741	2,50,981	1,78,530	1.569	1.355	1.276	1.400	1.098	2,49,920	1.10X	2749.12x
Plant#4	66,347	73,008	99,406	79,587	1.425	1.452	1.408	1.428	1.121	1,13,679	1.12X	1273.2x
Plant#5	NA	NA	37,635	37,635	NA	NA	1.780	1.780	1.397	66,995	1.40X	937.93x
Total										13,91,594		14912.94X

Source: PAT consultation Document, 2011



Source: PAT consultation Document, 2011

Perform, Achieve & Trade (PAT) Mechanism

- The market based mechanism to enhance the cost effectiveness in improving the Energy Efficiency in Energy Intensive industries through certification of energy saving which can be traded

Stakeholders

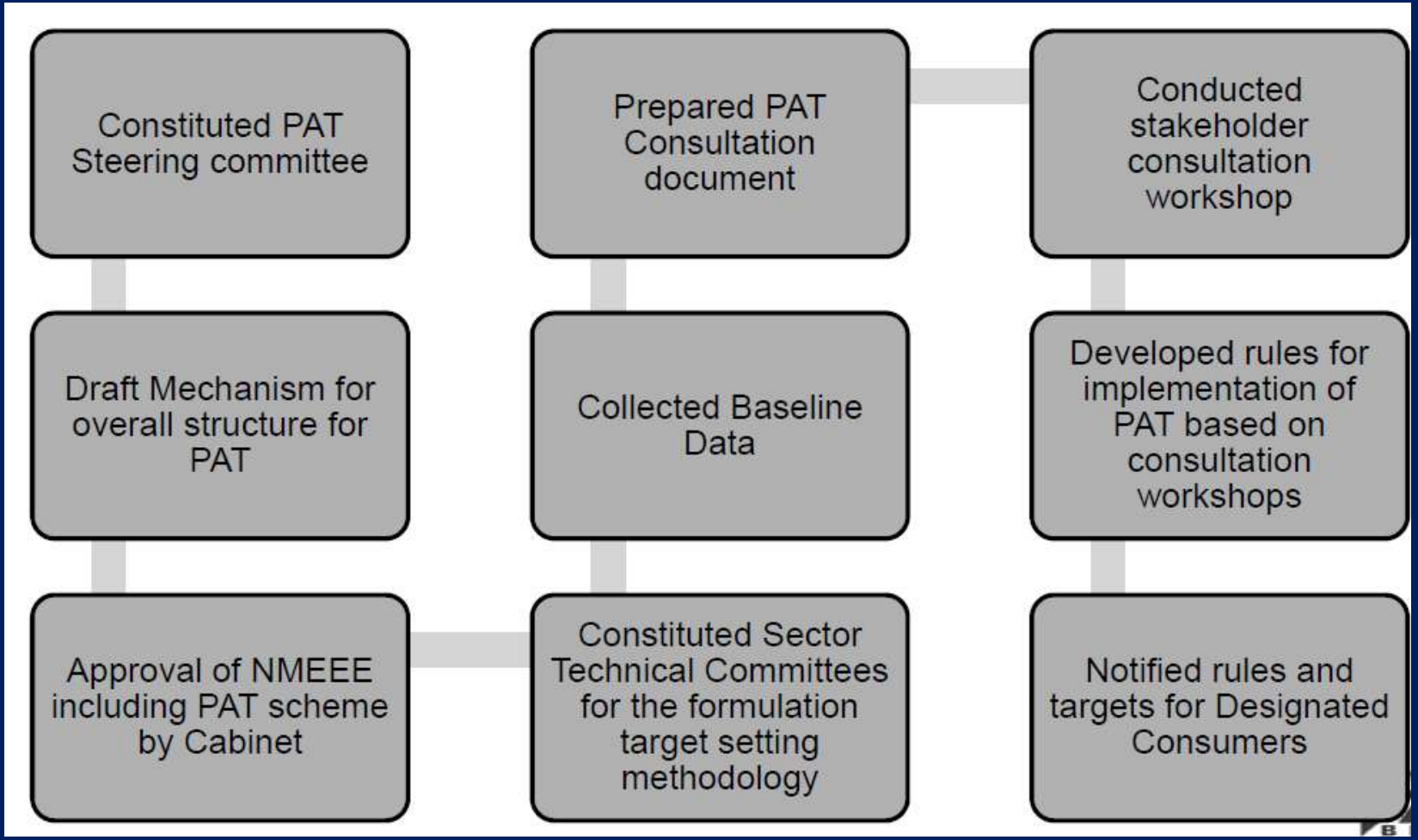
Administrator	Designated Consumers	Auditing Agencies	Market Place
• Set target and compliance period	• 8 sectors Thermal Power Plant, Steel, Cement, Fertilizer, Pulp & Paper, Textile, Aluminium, Chlor-alkali	• Independent • Monitor, verify and certify	• Transaction of energy efficiency instrument

Processes Involved

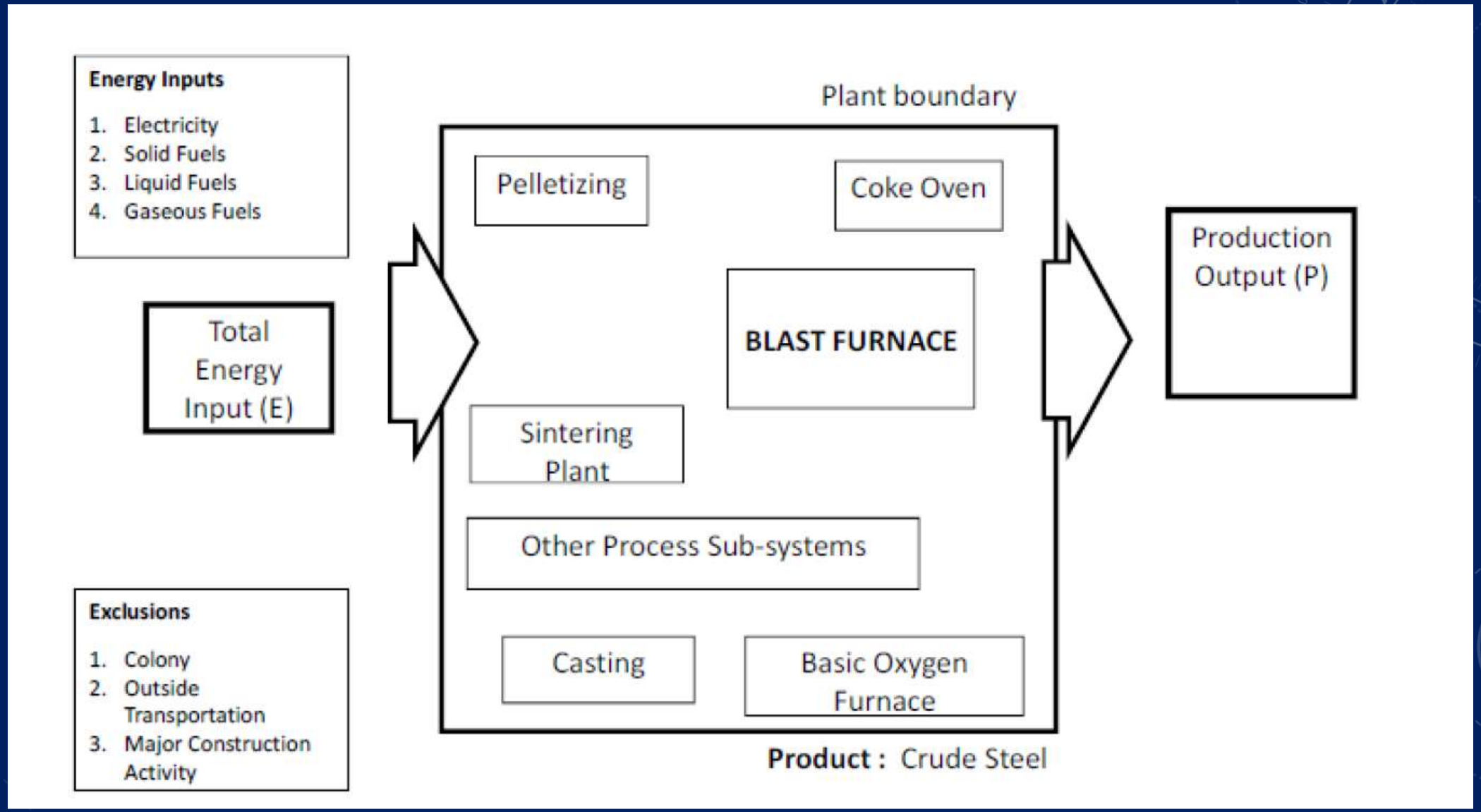
Set Targets	Monitoring & verification of targets by Designated Energy Auditors (DENA)	Trading of ESCerts
•Setting targets on the basis of current specific energy consumption •Set compliance period •May take into account Location, Vintage, Technology, raw materials, product mix etc.	•Check if designated consumer has achieved targets •Underachievement: Obligations to buy ESCerts or pay penalty •Overachievement: Issuance of ESCerts for banking for later use or trade	•Participation by Designated consumers on platform provided by Power Exchanges •Symmetrical flow of information

Source: BEE - Dr Ashok Kumar presentation

PAT Steps



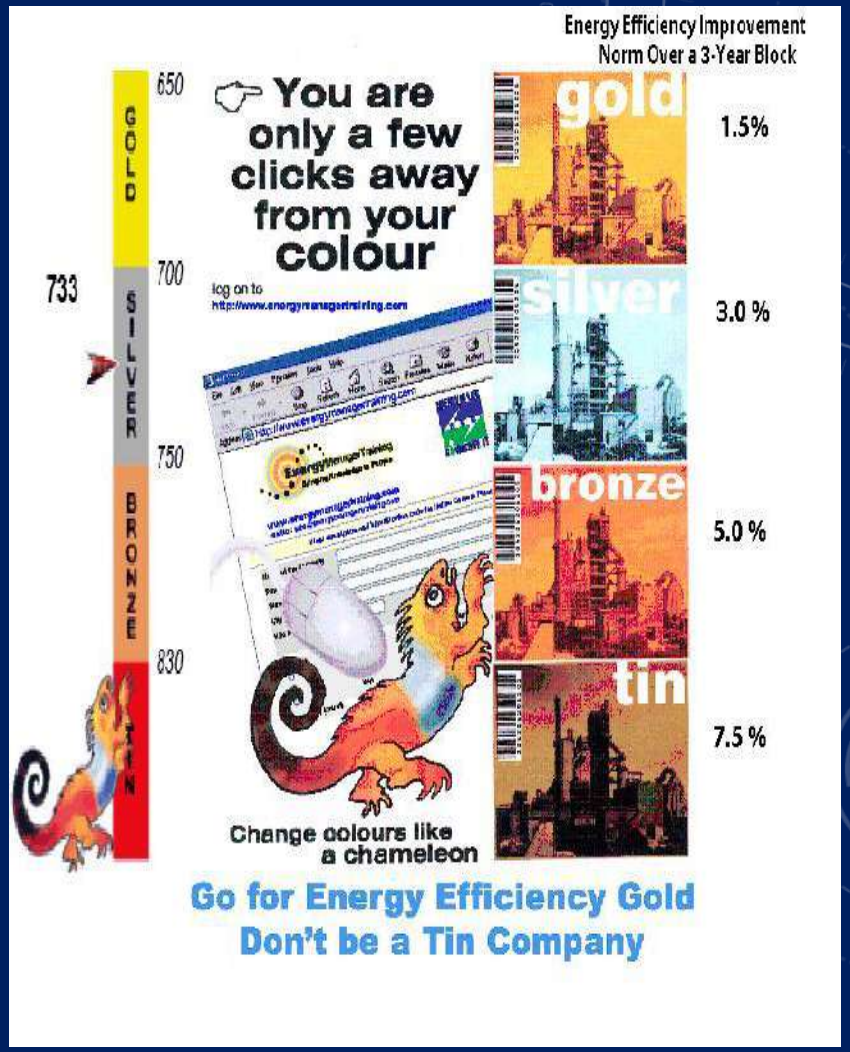
Source: BEE - Dr Ashok Kumar presentation



Source: PAT Consultation Document 2011

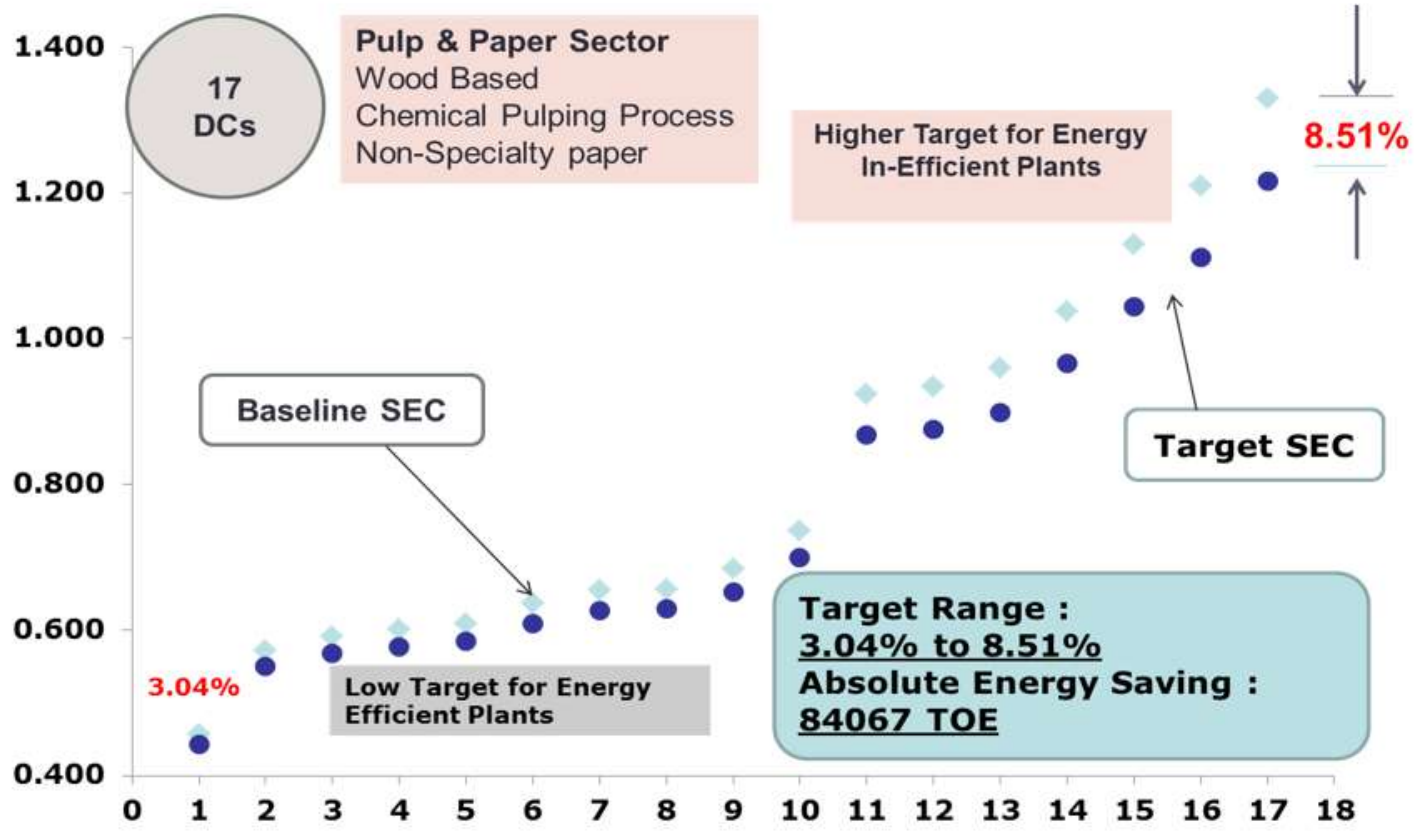
Setting Energy Consumption Norms

- Not feasible to define a single norm/standard unless there is significant homogeneity amongst units in a sector
- Energy efficiency improvement targets would have to be *almost* "unit specific"
- Bands of differential targets to be created within sectors
- Each DC mandated to reduce its SEC by a fixed percentage, based on its current SEC within the sectoral bandwidth



Source: DG BEE presentation

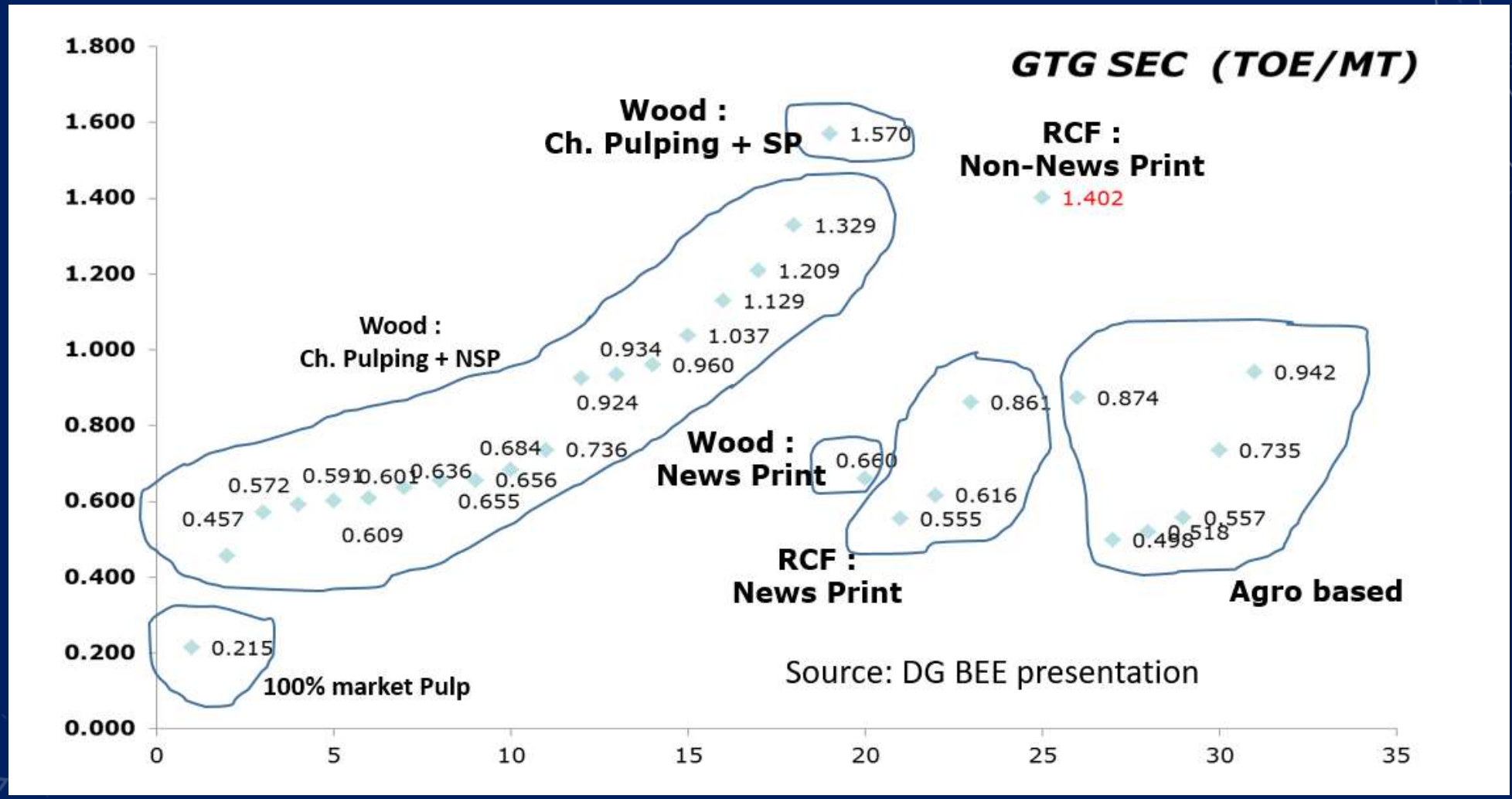
SEC Spread in Pulp & Paper Sector



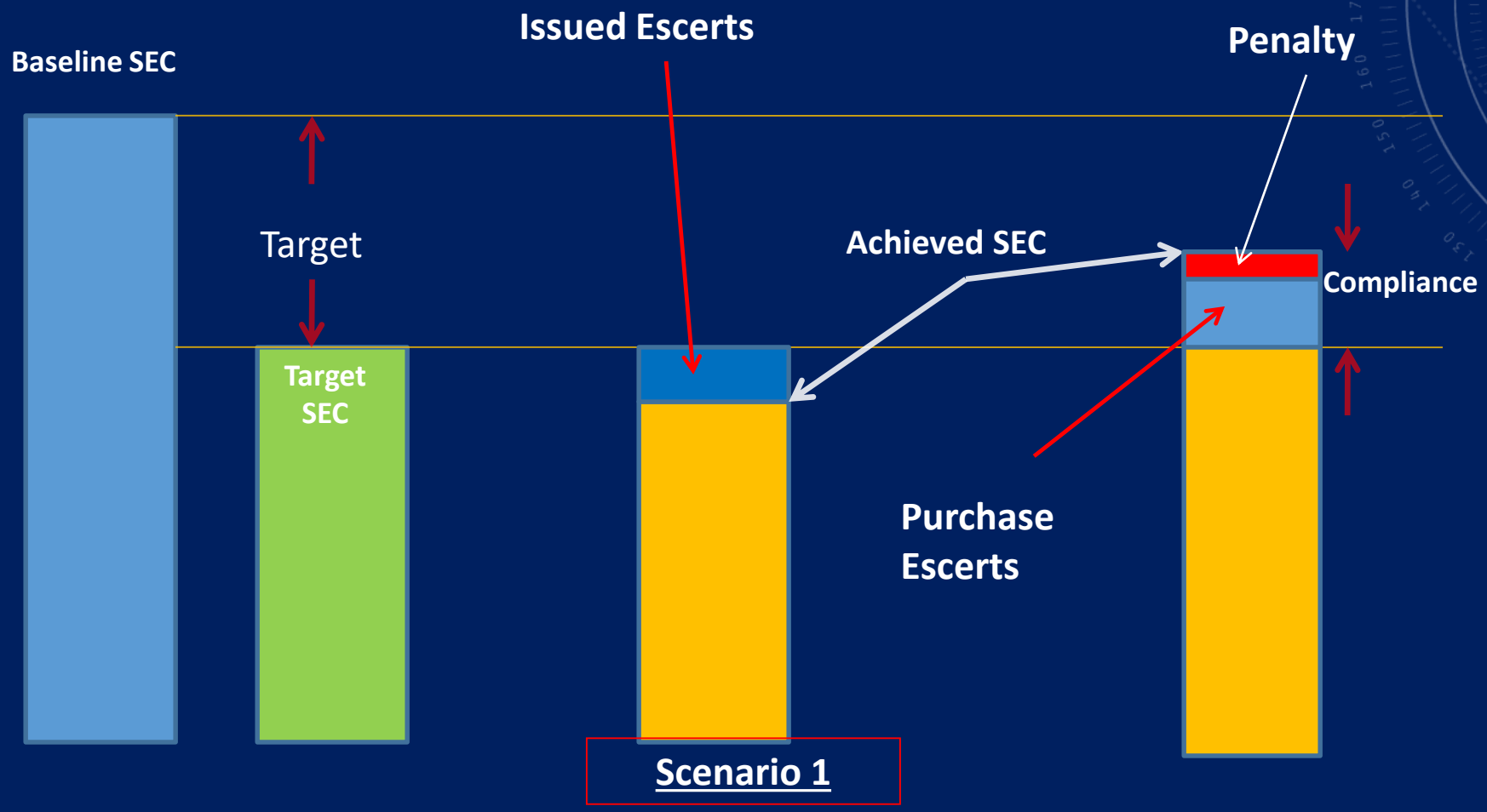
Target is Plant Specific ..... Less for Energy Efficient and more for Inefficient Plants

Source: DG BEE presentation

SEC Spread and Grouping of DCs in Pulp & Paper Sector



PAT - Energy Savings Certificates - incentivize actions



Source: DG BEE presentation

Data Requirements and Verification

- Verification to be carried out by independent BEE-designated energy auditors (DENAs)
- SEC for a plant is based on the records of quantum of energy going into the plant and quantity of products shipped out of plant
- Cross check with records such as invoices, payment receipts, and excise paid
- Inplant renewable energy production would not be added to quantum of energy used
- Normalization factors for large changes (during the 3-year period) in:
  - Share of captive electricity generation
  - Capacity utilization
  - Raw material quality/Product Mix

Source: DG BEE presentation

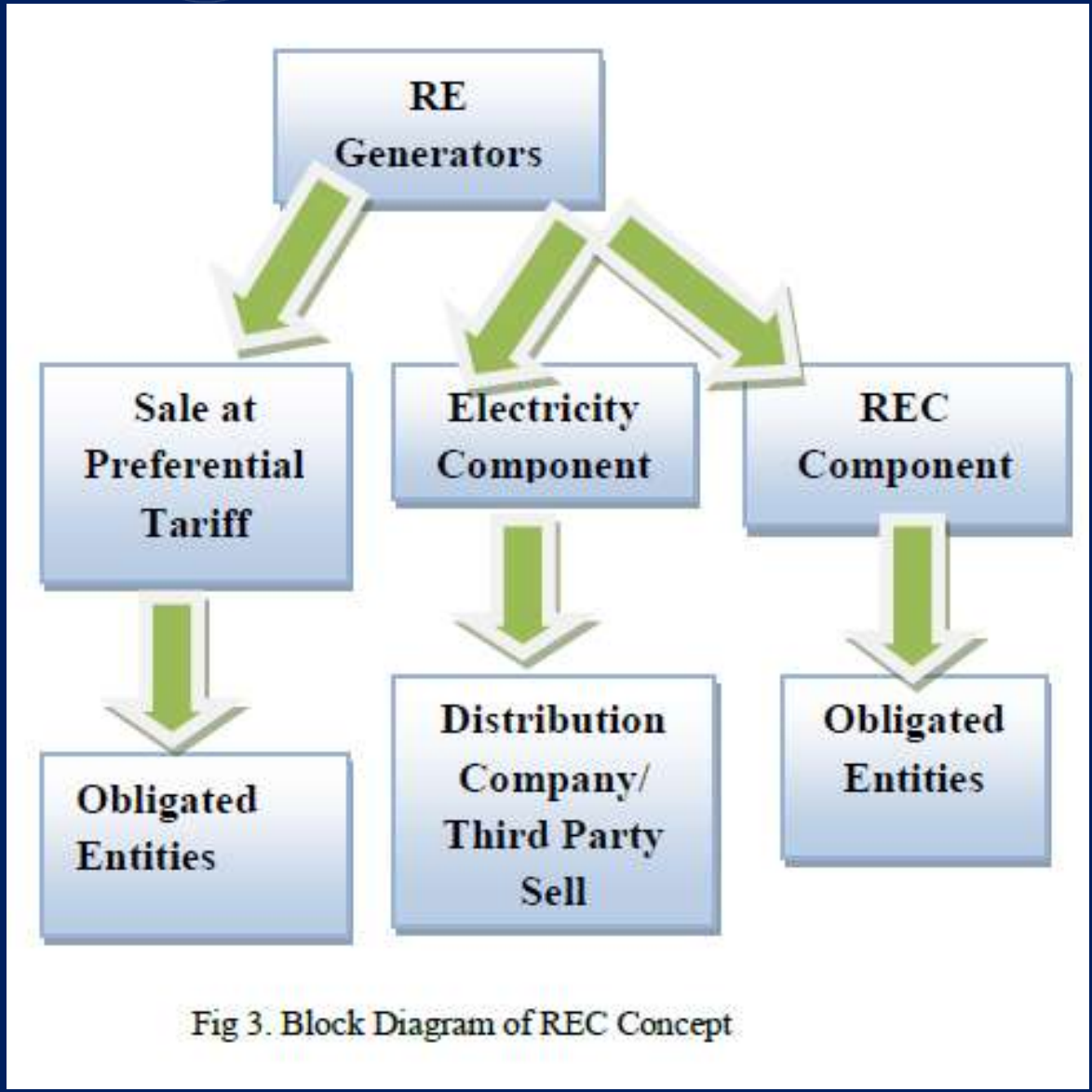
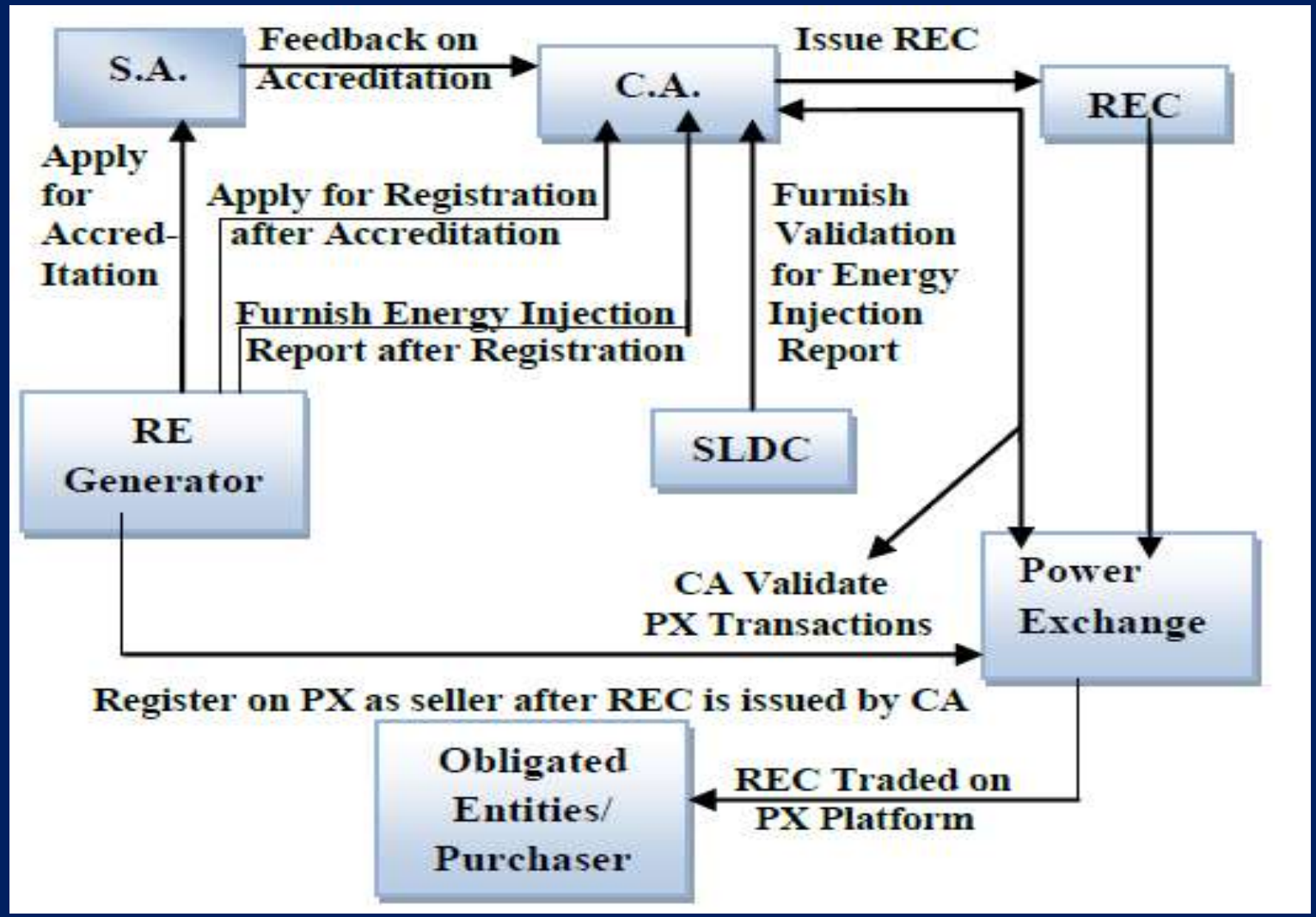


Fig 3. Block Diagram of REC Concept

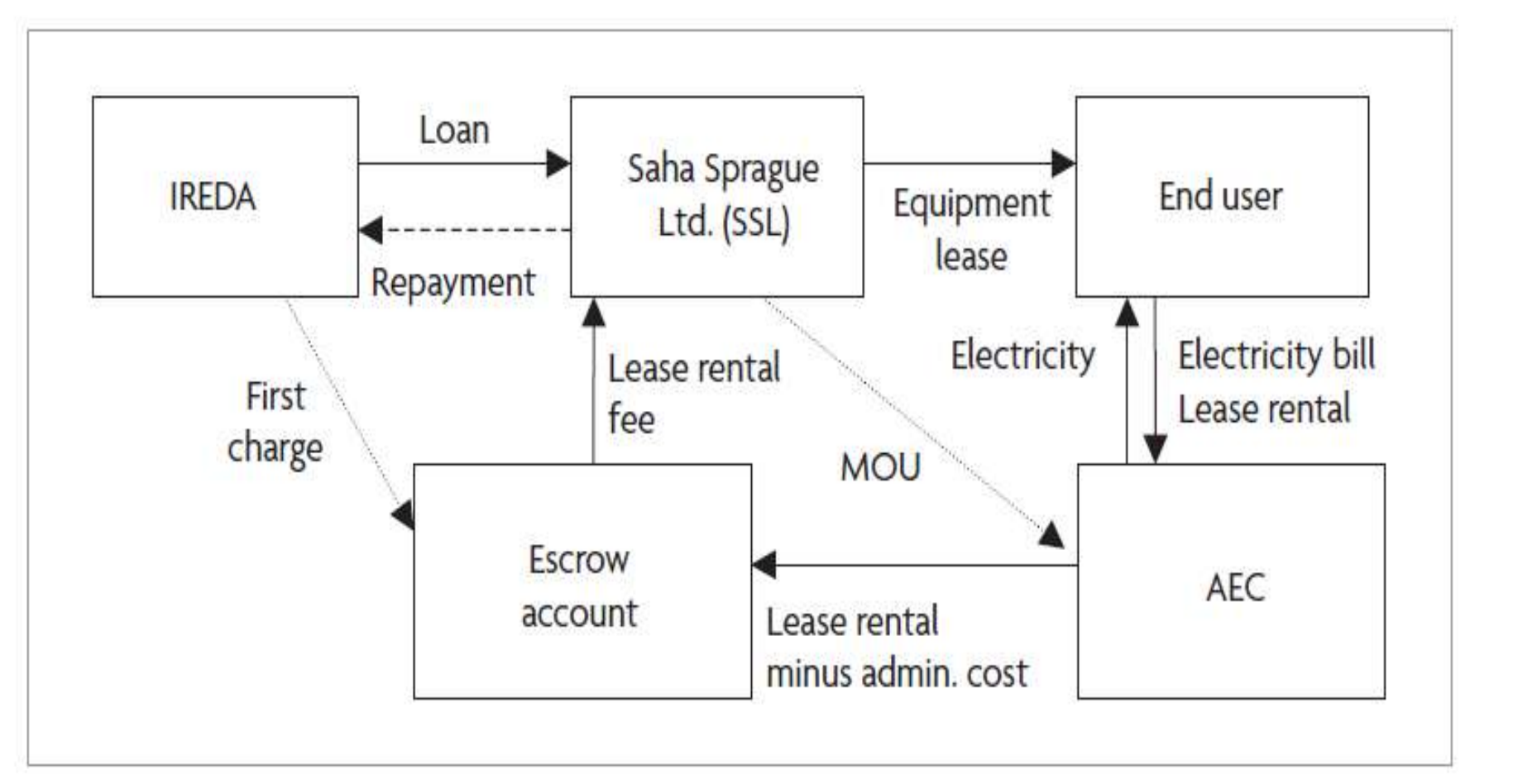
Soonee et al, 2010

REC Mechanism

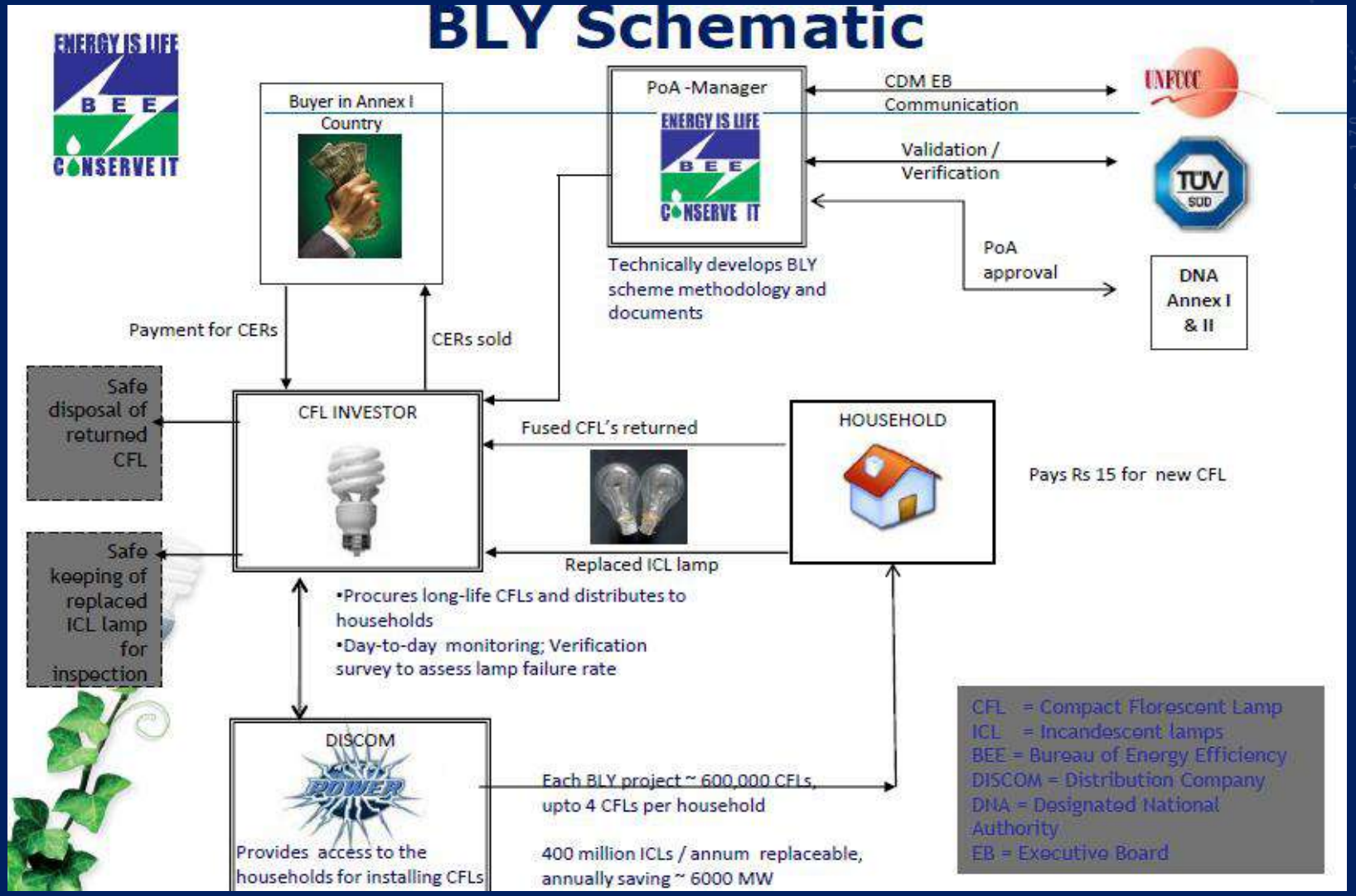


Soonee et al, 2010

Case Study : Capacitor Leasing



Source: Taylor et, al, 2008

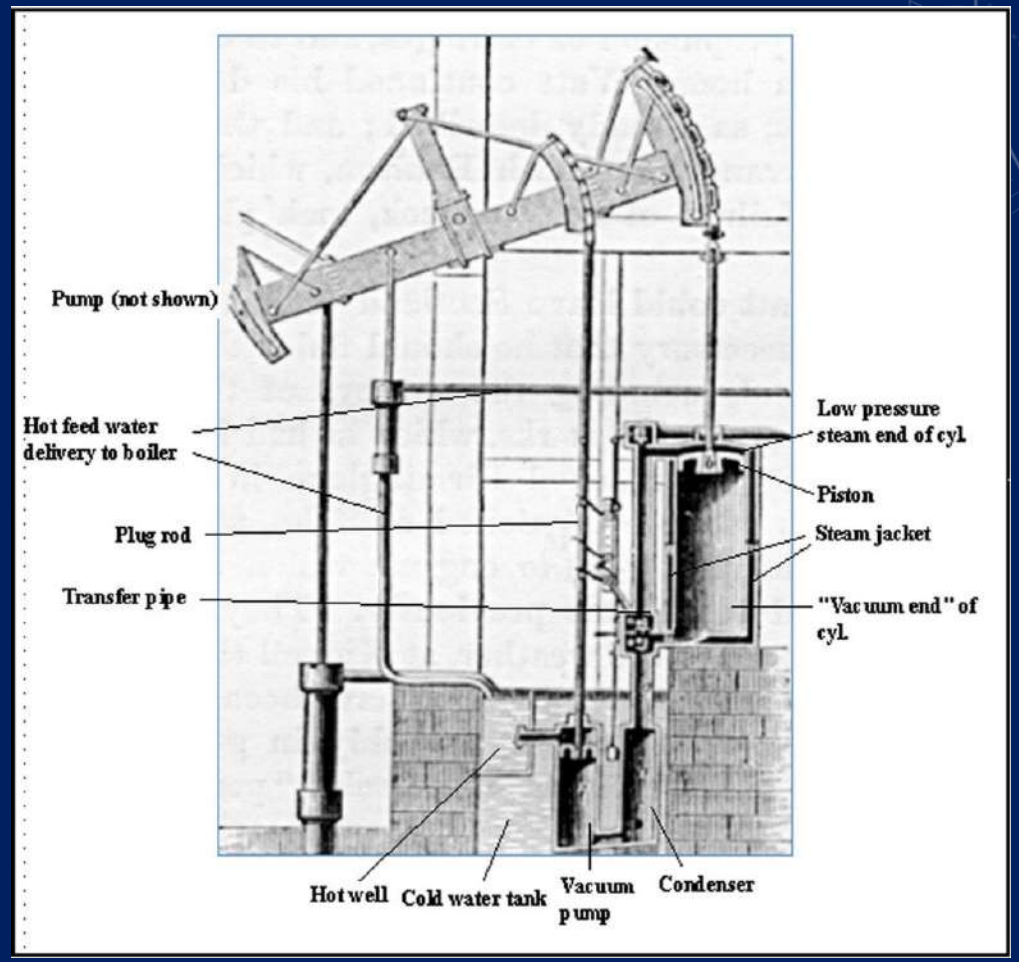


Source: BEE web site

Early ESCO concept

"We will leave a steam engine free of charge to you. We will install these and will take over for five years the customer service. We guarantee you that the coal for the machine costs less, than you must spend at present at fodder (energy) on the horses, which do the same work. And everything that we require of you, is that you give us a third of the money, which you save."

[James Watt, 1736-1819]



http://upload.wikimedia.org/wikipedia/en/5/5c/Watt_steam_pumping_engine.JPG

Nuclear Power

- Public Acceptance
- Safety Risks – Fuel cycle/ Power Plant
- Nuclear Waste Disposal (High Level Waste)
- Proliferation (Weapons, Fissile Materials)
- Climate Change
- Costs

(2013)

Estimated costs from damages to persons, goods and environment

- **Fukushima: €187 billion**
- **Chernobyl: €450 billion**

Operator's liability according to national laws in EU member states (in Euro)

Country	Operators liability	Limit fin. security
Belgium	1.2 billion	1.2 billion
Finland	Unlimited	700 million
France	700 million	700 million
Germany	Unlimited	2.5 billion
Netherlands	1.2 billion	1.2 billion
Sweden	Unlimited	1.2 billion
UK	156.7 million	156.7 million

Source: European Commission, 2013
See: http://ec.europa.eu/energy/nuclear/consultations/20130718_powerplants_en.htm

Source: Turkenburg, 2014

Levelized costs in 2030 of different electricity generation technologies

(in US$2005/MWh, using a 5% discount rate)

	Capital ($/kWe)	O&M ($/kWe)	Fuel ($/GJ)	Waste ($/MWh)	Generating costs ($/MWh)
Solar PV	900-2800	6-18	0	0	27-151
Wind (onshore)	900-1300	9-30	0	0	21-131
Nuclear	4000-6200 [a]	118-180	0.7-0.9	1-2	53-100
Advanced Coal	1100-1600	46-65	1.3-2.8	0	27-46
Adv. Coal with CCS	1700-2400	69-96	1.3-2.8	6	44-69
Gas CC	400-500	16-20	2.6-6.5	0	24-49

a) In East Asia at present 1800-2500 $/kWe; the GEA pathways assume these costs will increase with rising affluence

Source: Thomas B. Johansson et al., *Global Energy Assessment* (CUP, 2012)

Source: Turkenburg, 2014

Nuclear Liability

- Civil Liability for Nuclear Damage Act – Operator Liability Limit Rs 1500 crores
- “The operator shall have a right of recourse where-the nuclear incident has resulted is a consequence of an act of supplier or his employee, which includes supply of equipment or material with patent or latent defects or sub-standard services.”

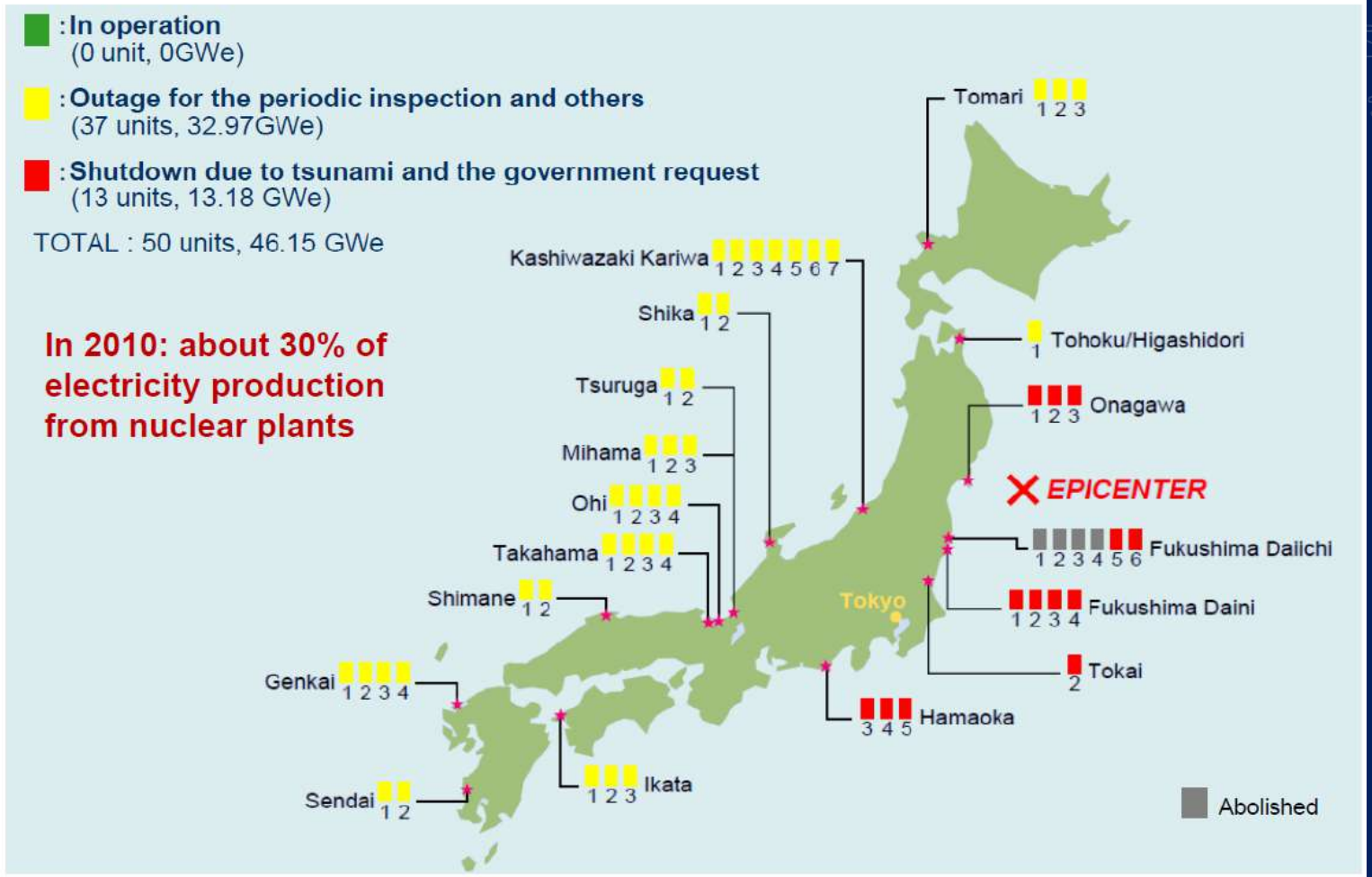
Indo-US Deal (Jan 2015)

- Nuclear Liability Fund – Insurance cover of Rs 1500 crores
- Insurance premium from electricity supply price

New Nuclear Power Plants

- Kudankulam, Tamil Nadu – VVERs – Russia – 2X1000 MW- Rs 17320 crores
- Jaitapur 9900 MW (6*1600 MW) – Ratnagiri district – French – AREVA 9.3 Billion US $

Status of the Nuclear Power Plants in Japan
as of June 18, 2012 (and also March 8, 2014)



Source: JAIF website, 18 June 2012

Source: Turkenburg, 2014

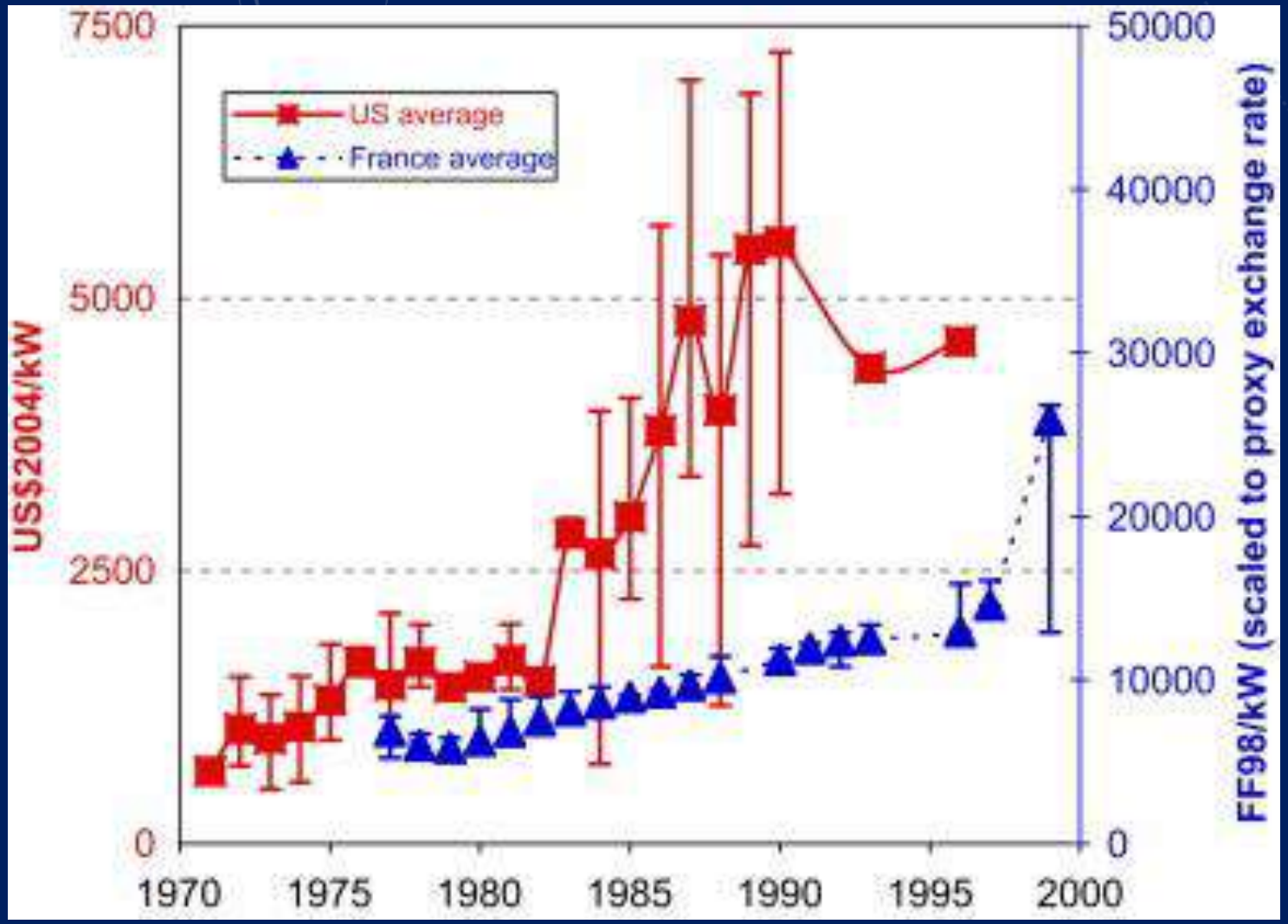
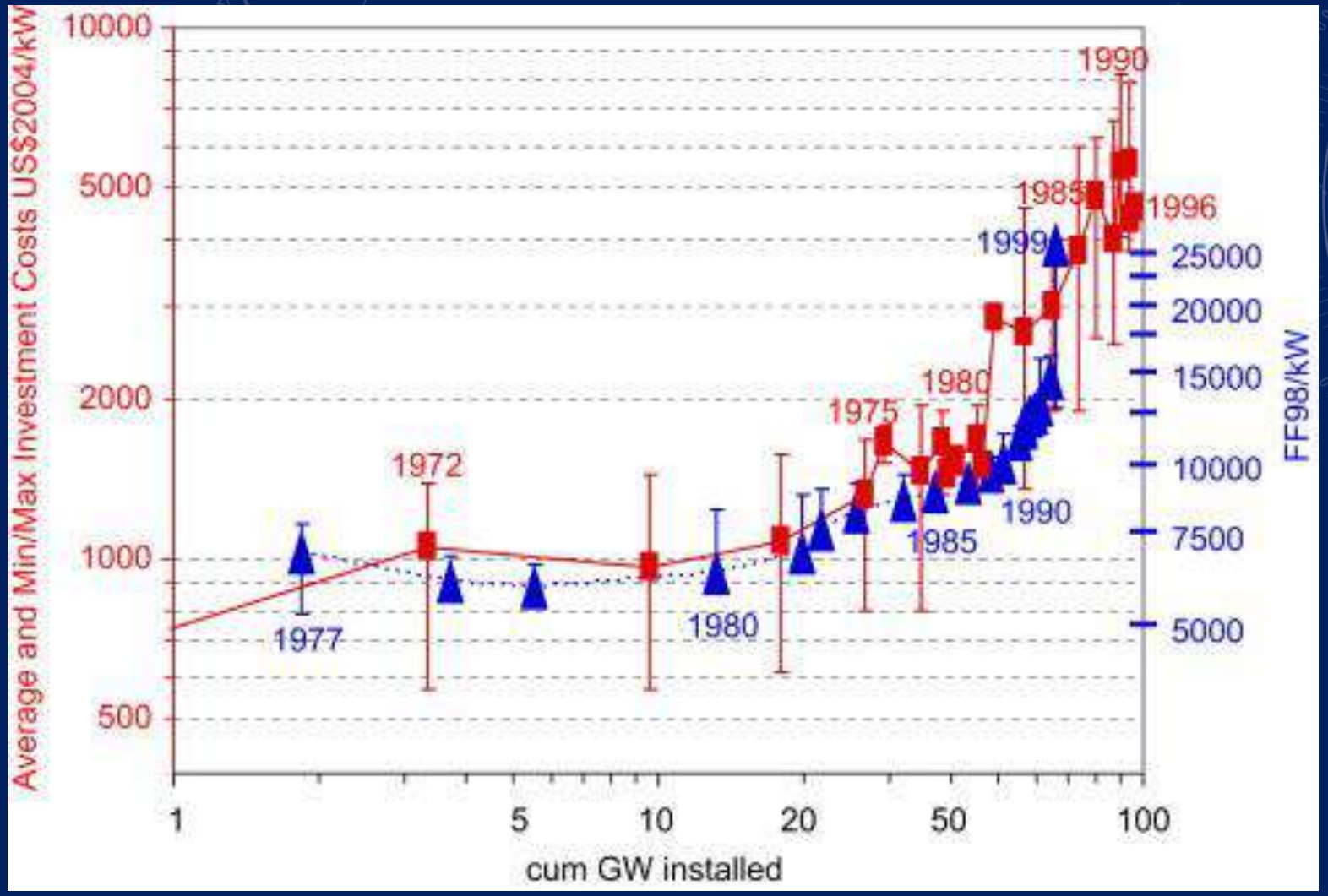


Fig. 1 Rhythm of the French nuclear PWR program (grid connections of MWgross by major size type). *Source* : IAEA PRIS data base (2009).

Arnulf Grubler, **The costs of the French nuclear scale-up: A case of negative learning by doing**

Energy Policy, Volume 38, Issue 9, 2010, 5174 – 5188. DOI: http://dx.doi.org/10.1016/j.enpol.2010.05.003



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