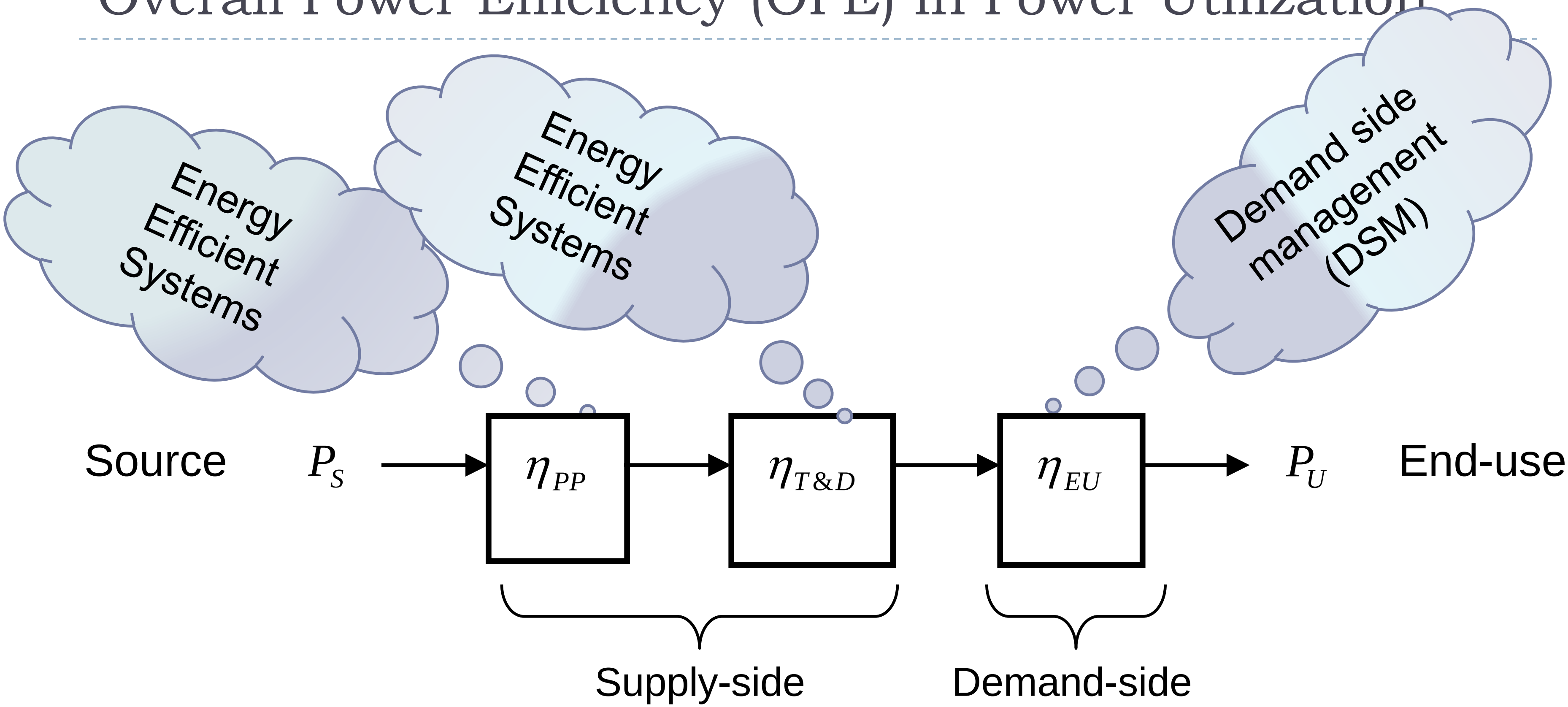
Energy Management & Utilization

Chapter 6:

Energy Efficiency and Renewable Energy Systems: Developing Countries

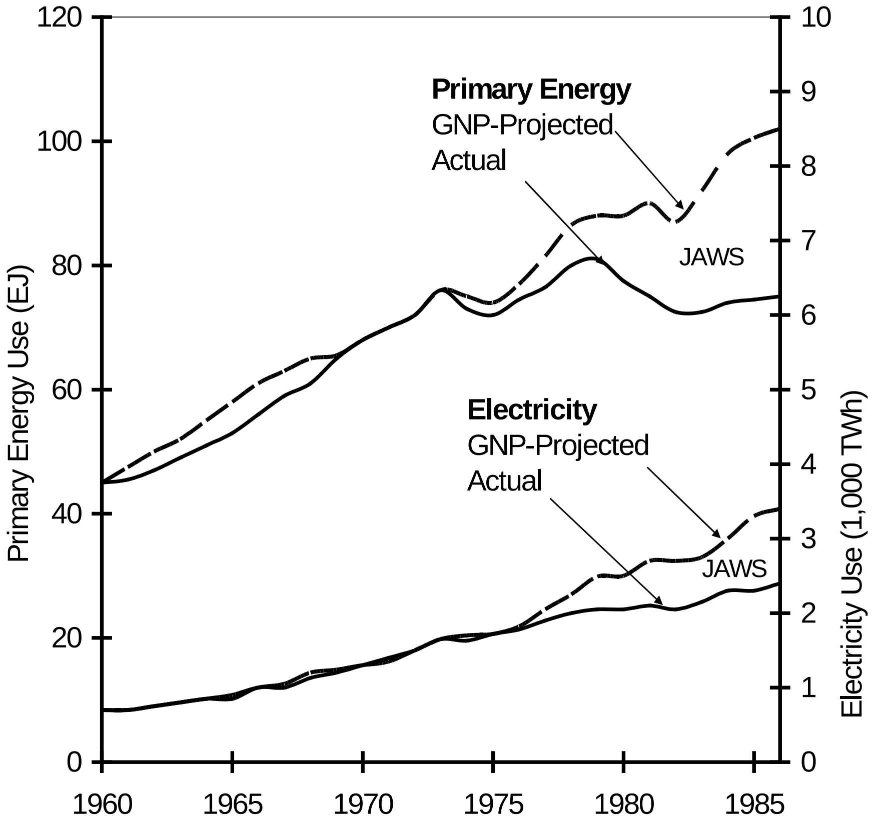
Prof. Dr. Uğur Atikol

Overall Power Efficiency (OPE) in Power Utilization



$$P_U = \underbrace{\eta_{PP} \times \eta_{T\&D} \times \eta_{EU}}_{\text{Overall Power Efficiency (OPE)}} \times P_S$$

Economic Growth and Energy



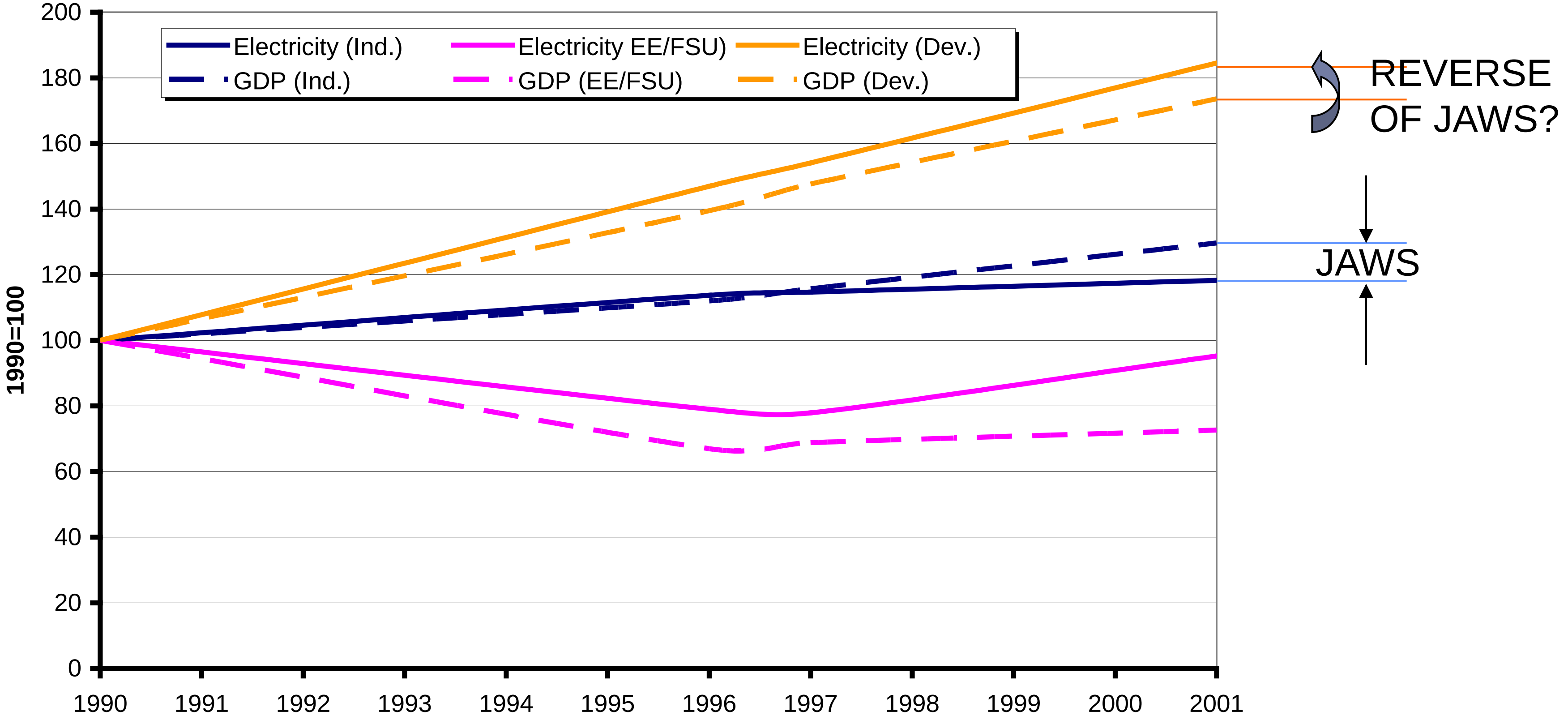
The oil crises of the 1970s led to higher energy efficiency in the industrialized world and especially in USA

The main objective was to reduce energy consumption while maintaining the economic growth

The savings-gap between the two trends was referred to as "JAWS" in USA, coined by Rosenfeld.

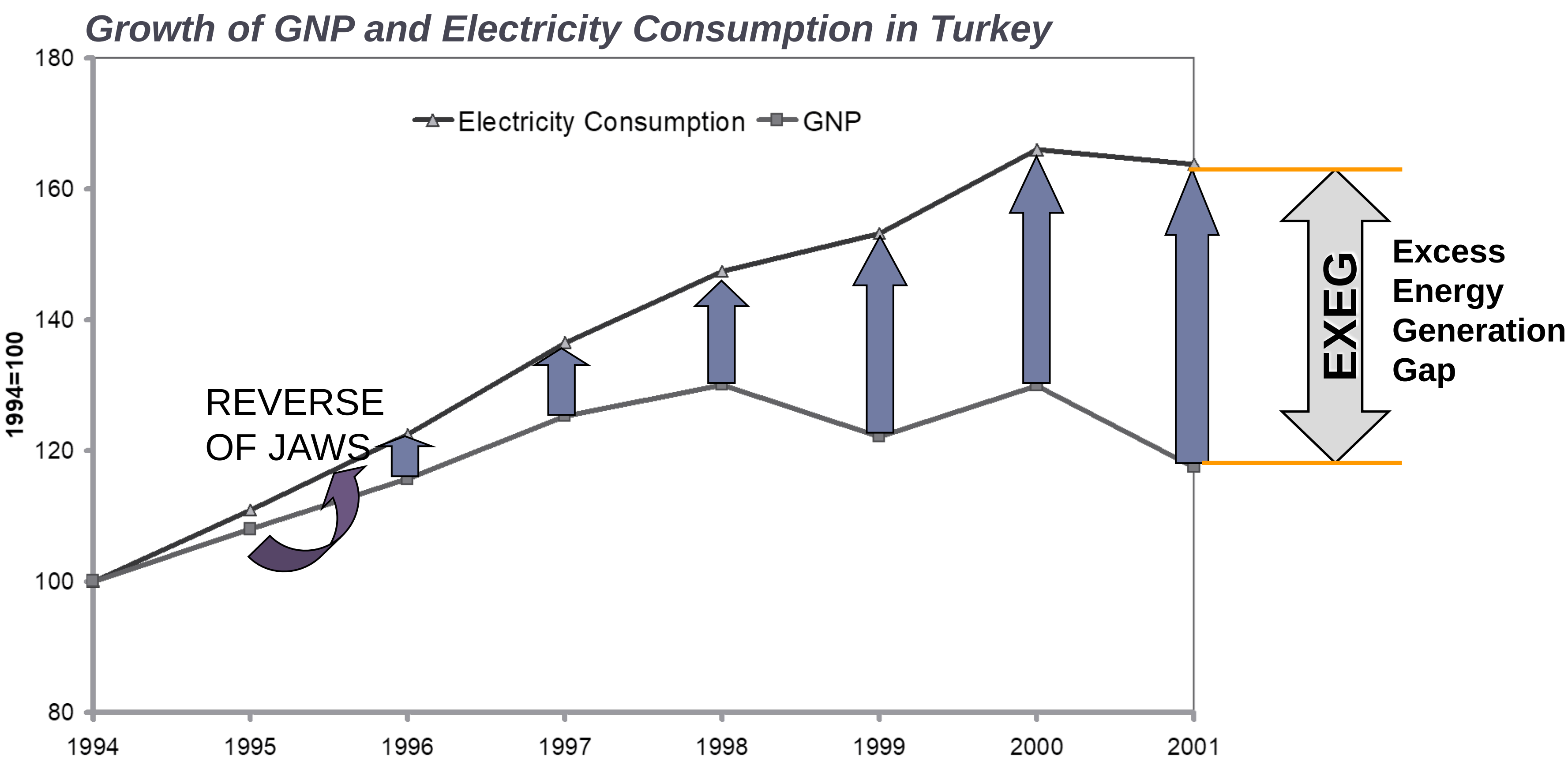
U.S. total primary energy and electricity use: actual and GNP projected (Rosenfeld et al, 1992).

Economic Growth and Energy



World electricity consumption and GDP by region (Energy Information Administration, 2003).

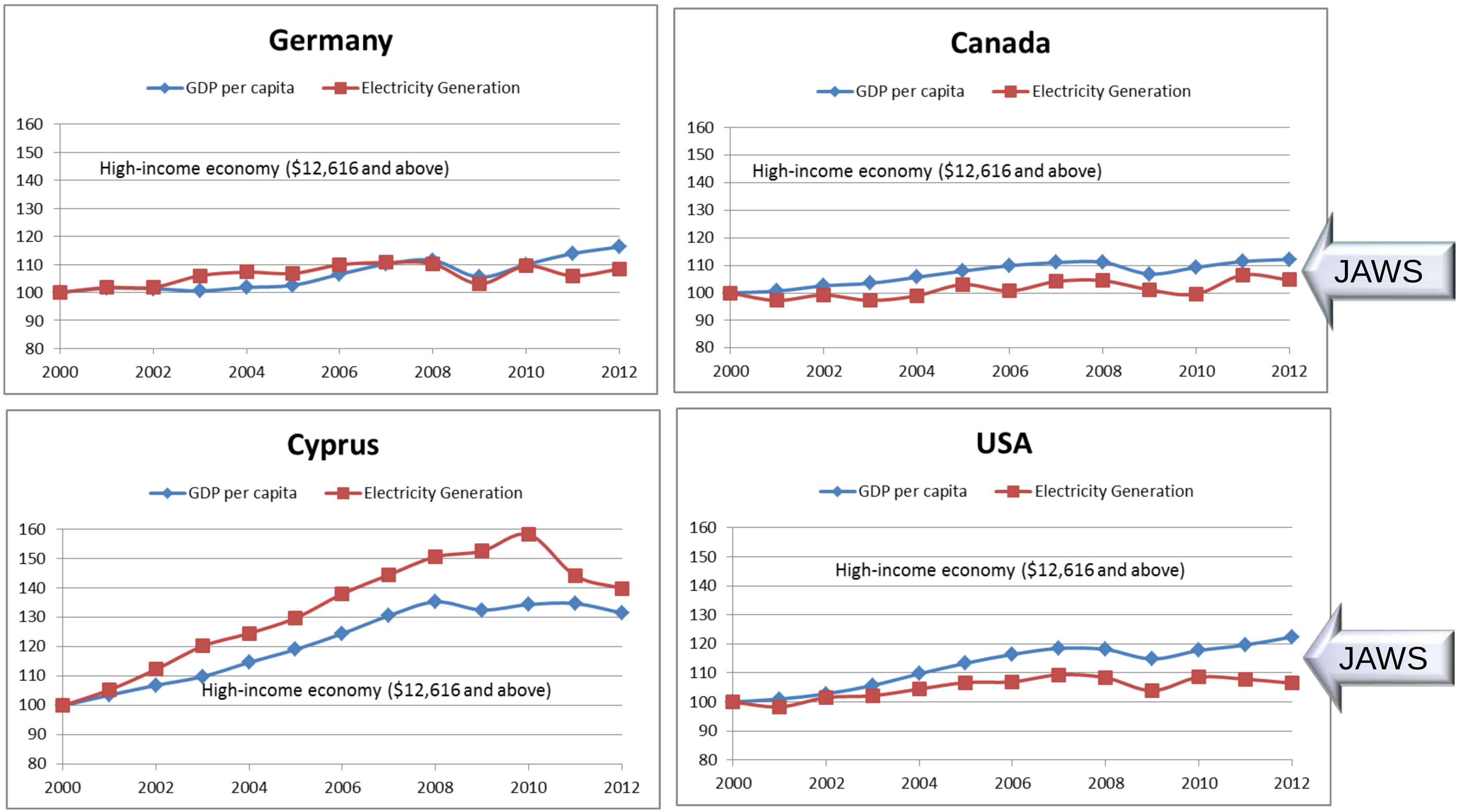
Economic Growth and Energy: *Definition of EXEG*



Source: ***Turkish State Institute of Statistics (SIS)***

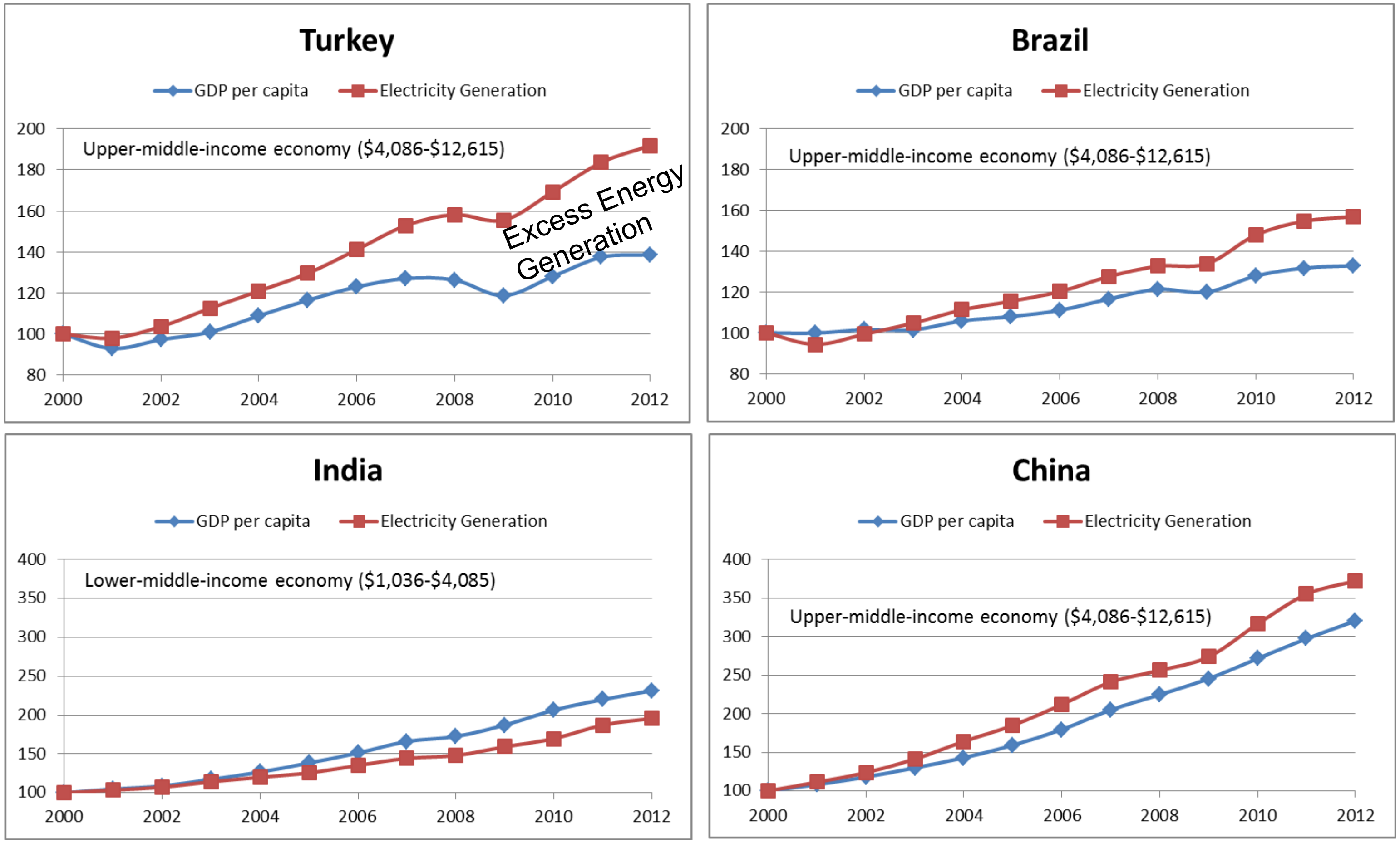
High-income Economies

(Source: US Energy Information Administration, 2013)

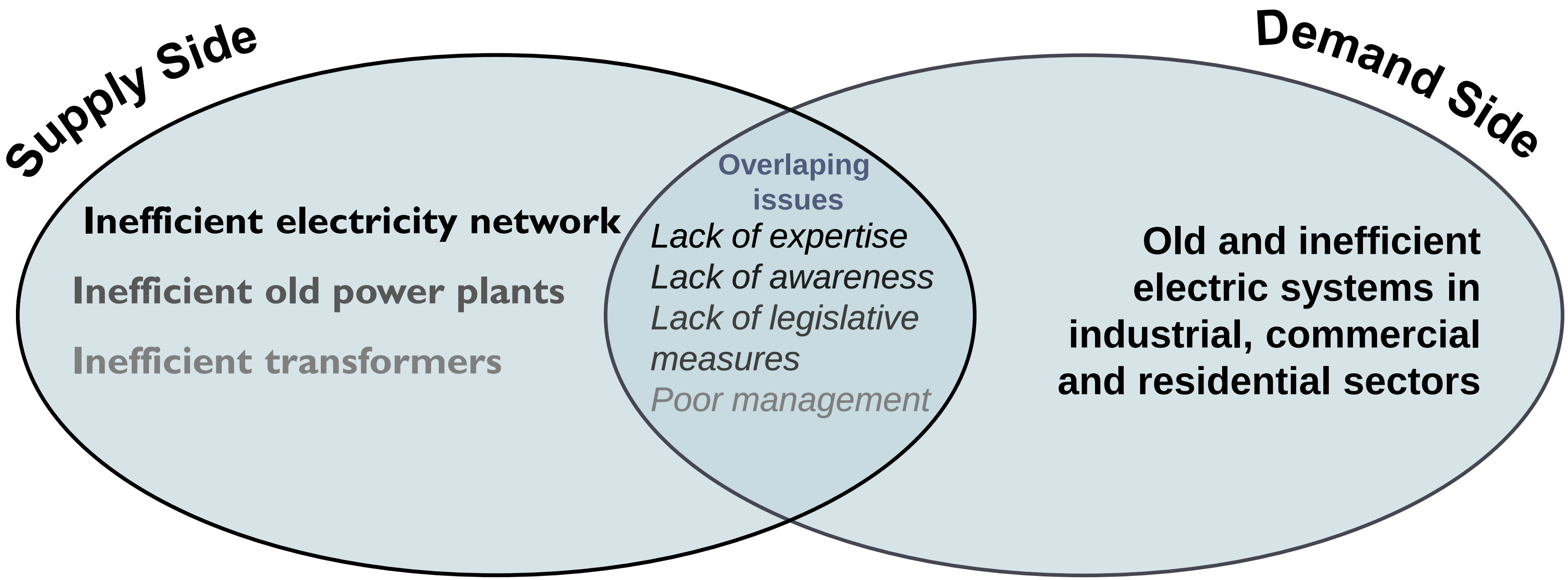


Developing Economies

(Source: US Energy Information Administration, 2013)



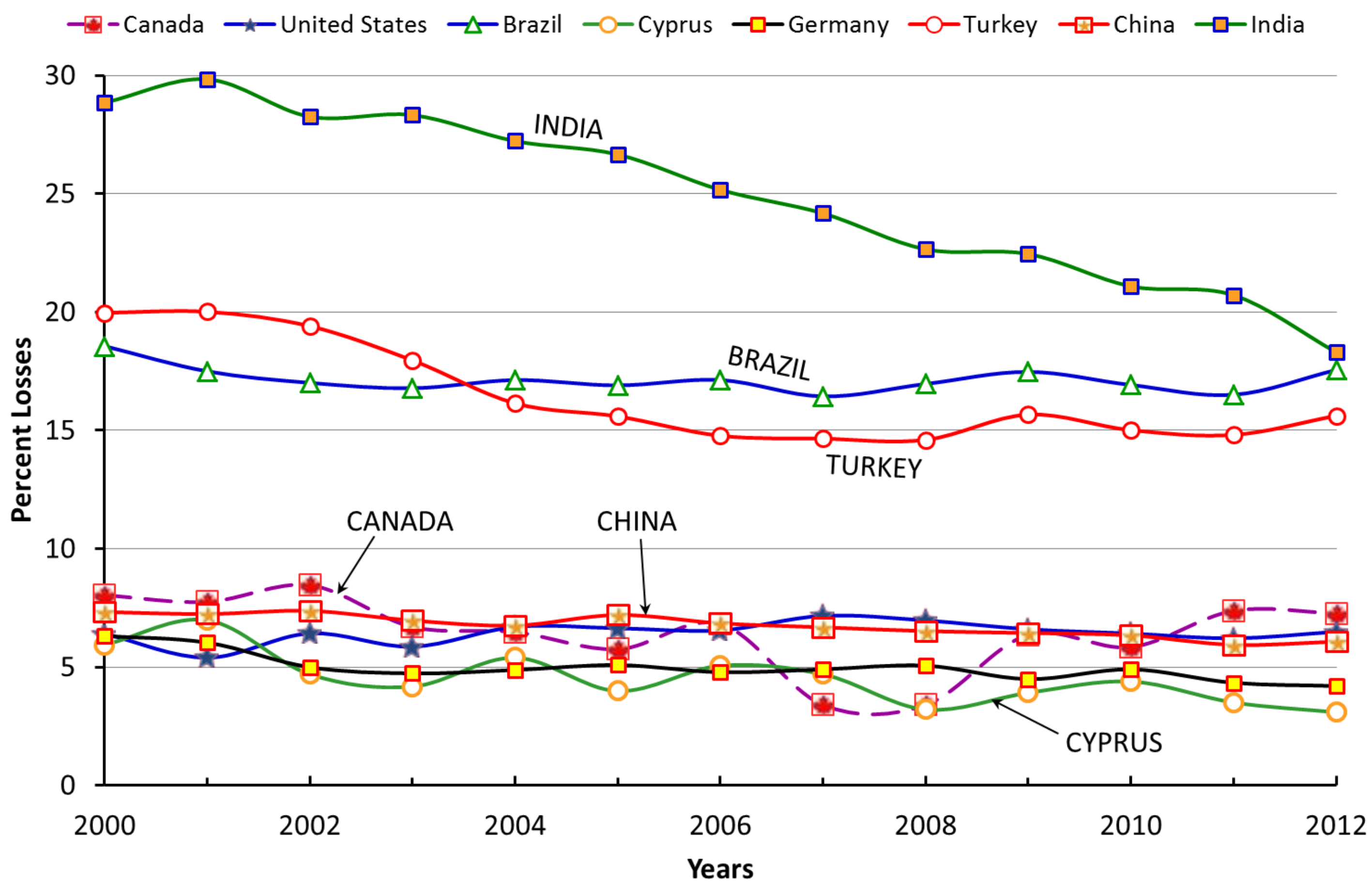
Reasons for Excess Energy Generation



Source: U. Atikol, *6th IAEE European Conference 2004*, 2-3 September, 2004, Zurich.

Electricity Distribution Losses

(Source: US Energy Information Administration, 2013)



The Reasons for Excess Distribution Losses in India

- Inadequate Investments
- Theft of power
- Haphazard growth of distribution system
- Large scale rural electrification through low-tension lines
- Too many stages of transformation
- Improper load management
- Inadequate reactive compensation

Sources: [1] Mahmood et al. *IJAREEIE* Vol.3 No.2 (2014) [2] Navani et al. *IJECSE* Vol.1 No.2

The Reasons for Reduced Distribution Losses in China

- Deploying long distance ultra-high-voltage AC (referring to 1000kV) transmission
- Deploying long distance ultra-high-voltage DC (referring to ±800kV) transmission
- Installing high-efficiency amorphous metal transformers

Energy Efficient technology usage

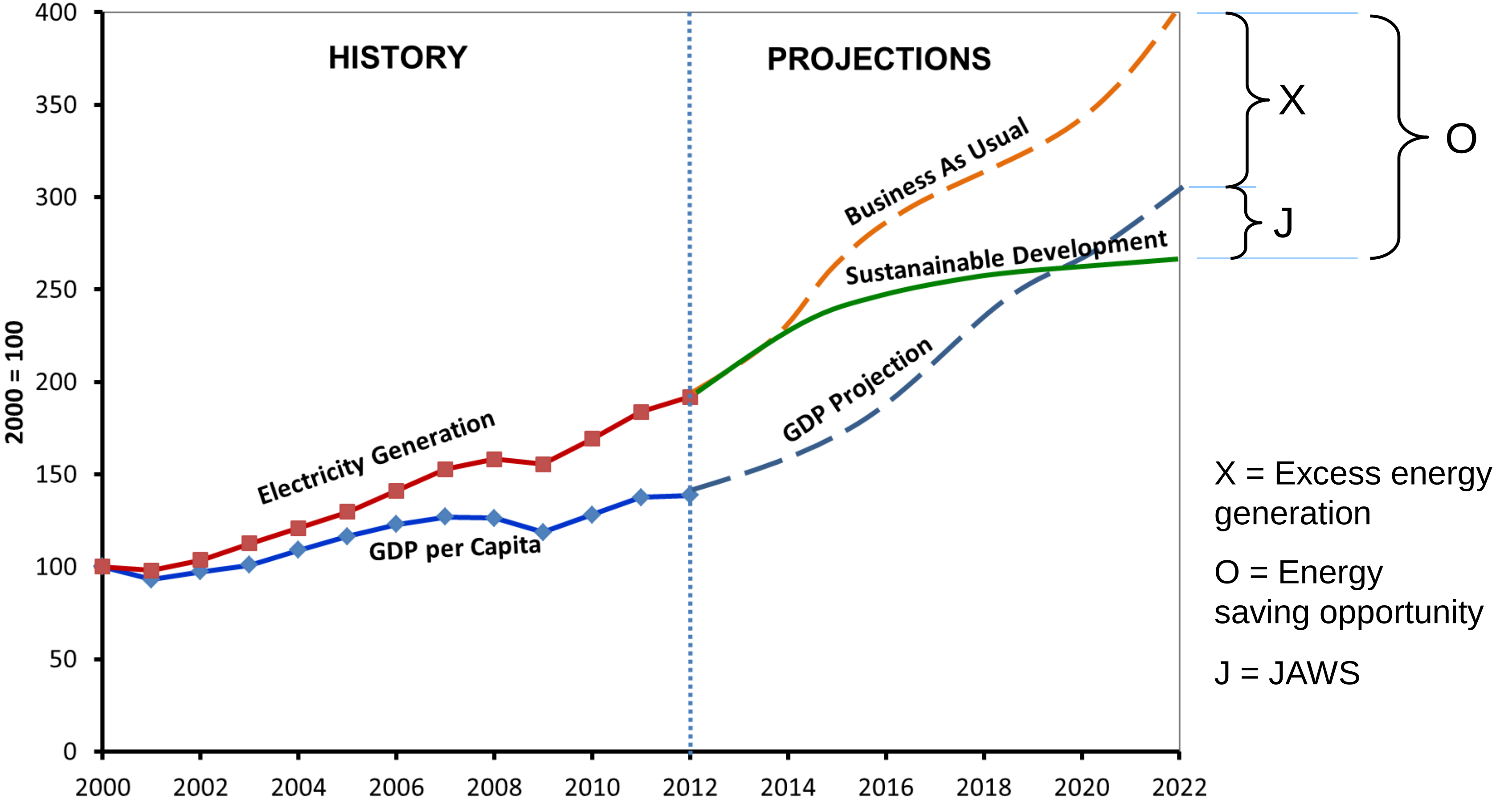
Source: https://en.wikipedia.org/wiki/Ultra-high-voltage_electricity_transmission_in_China

Electricity Distribution Losses in North Cyprus (2003 – Present)

Infrastructure Development	Improvement
Replacement of old transmission lines	300-km out of 550-km renewed
High-tension power lines	From 66-kV to 132-kV
Medium-tension power lines	From 11-kV to 22-kV
Transformer Capacity	From 280-MW to 560-MW

T & D Losses reduced from 24% to 11%

Energy Saving Opportunity by Sustainable Development



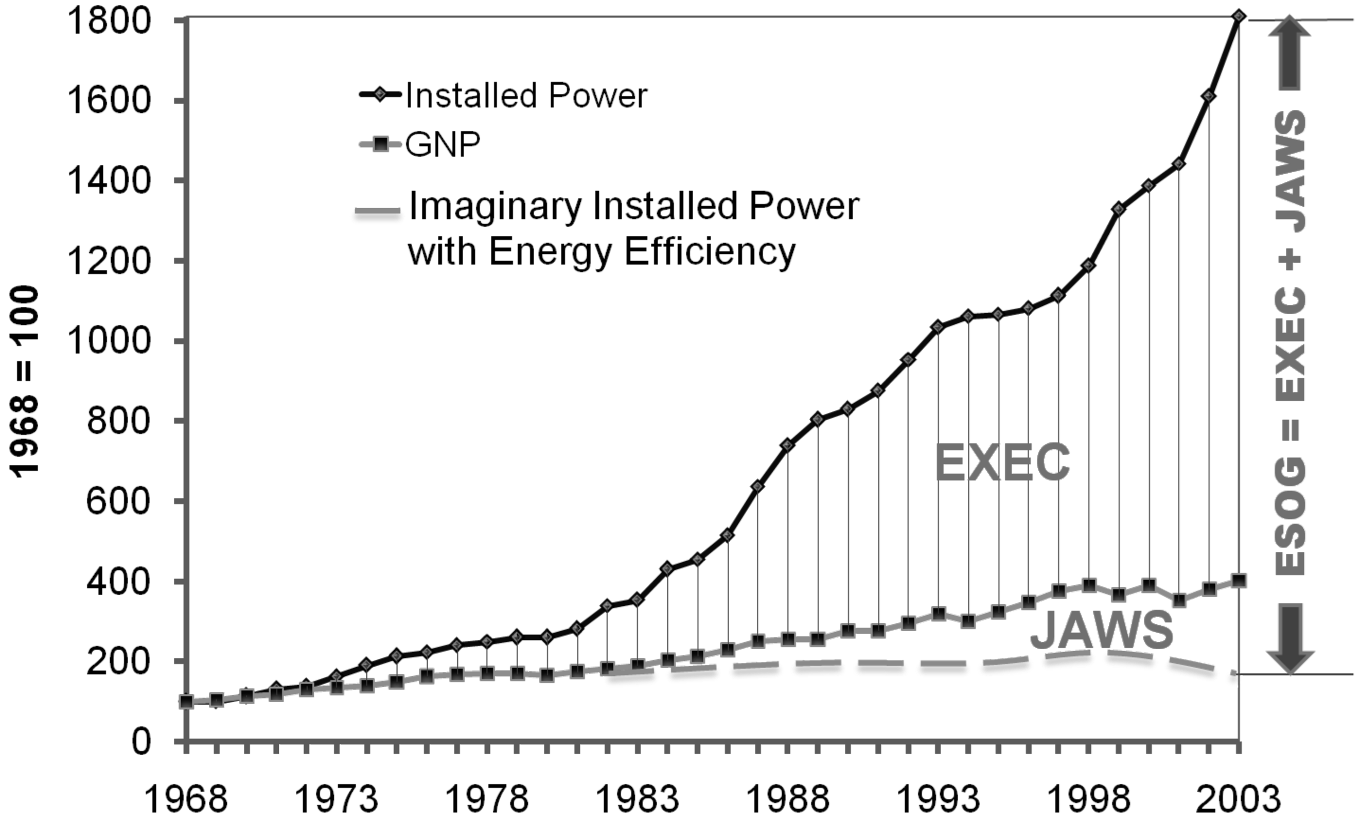
X = Excess energy generation

O = Energy saving opportunity

J = JAWS

Energy Saving Opportunity Gap (ESOG) in Turkey

Economic and power capacity developments of Turkey between 1968 and 1997

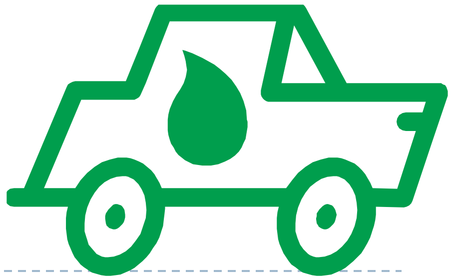


Sources: *Turkish Electricity Generation – Transmission Corporation, 1998; State Institute of Statistics, 2003*

Difficulties in technology transfer to developing countries

Common barriers for Energy Efficiency (EE) are:

- Lack of finance
- Inadequate incentives
- Inappropriate institutional structure
- Lack of policy framework
- Habits, traditions and cultural issues
- Poor public awareness
- Lack of technical expertise and know-how



Difficulties in technology transfer to developing countries

Demand Side Management (DSM) Technologies

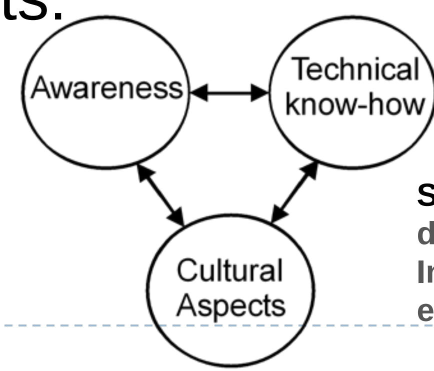
- Common barriers for EE also apply in this case however they may differ for each developing country
- World Bank Atlas method can be used to determine the per capita income group of countries for determining the correct options
- Examination of other macro and micro level indicators

Source: U. Atikol and H. Guven, Feasibility of DSM-technology transfer to developing countries, *Applied Energy*, 76(2003), pp.197-210

Difficulties in technology transfer to developing countries

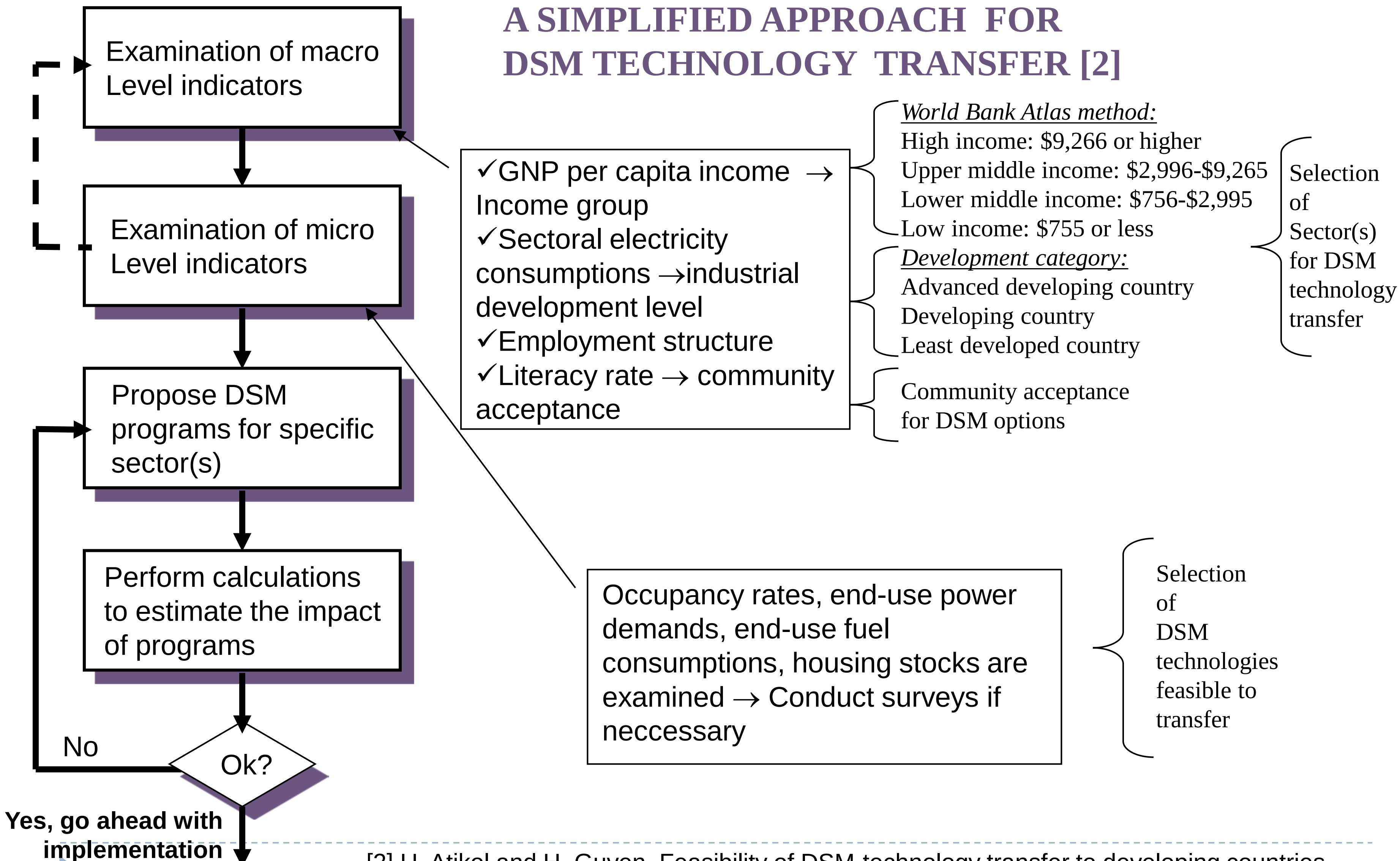
Renewable Energy (RE) Technologies

- Common barriers for EE and DSM also apply here
- The larger the *ESOG* the less chance there is for large RE projects to succeed
- Application of incentives need to be supported by awareness campaigns and technical training
- Issues delaying the RE technologies in developing countries are awareness, know-how and cultural aspects:



Source: U. Atikol, Application of green energy technologies in developing countries, Plenary Speech, The 7th ASME/WSEAS International Conference on heat transfer, thermal engineering and environment (HTE'09), 20-22 August, 2009, Moscow

Application of Green Energy Technologies in Developing Countries

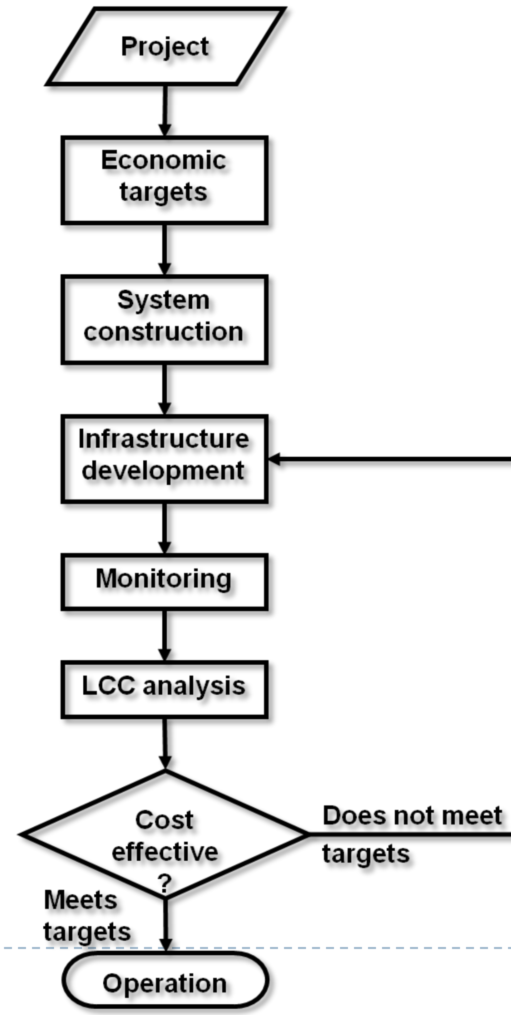


[2] U. Atikol and H. Guven, Feasibility of DSM-technology transfer to developing countries, *Applied Energy*, 76(2003), pp.197-210

Application of Green Energy Technologies in Developing Countries

PROPOSED APPROACHES FOR GREEN ENERGY APPLICATIONS: *SUPPLY -SIDE*

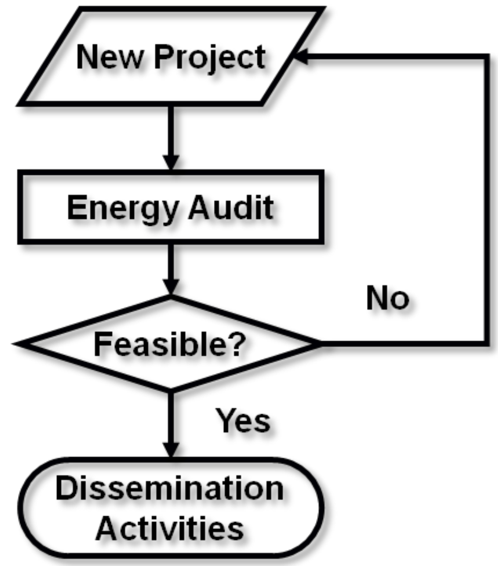
- Consider a green energy technology for the supply-side
- Simultaneously consider upgrading the infrastructure
- Monitoring, metering and data recording
- Perform economic feasibility estimates
- Keep upgrading the infrastructure untill economic targets are met.



PROPOSED APPROACHES FOR GREEN ENERGY APPLICATIONS: *DEMAND-SIDE*

The traditional way for end-users:

- Make a LCC analysis for the proposed project (i.e., energy audit)
- If it is feasible proceed with the implementation
- If not feasible try testing another green energy option

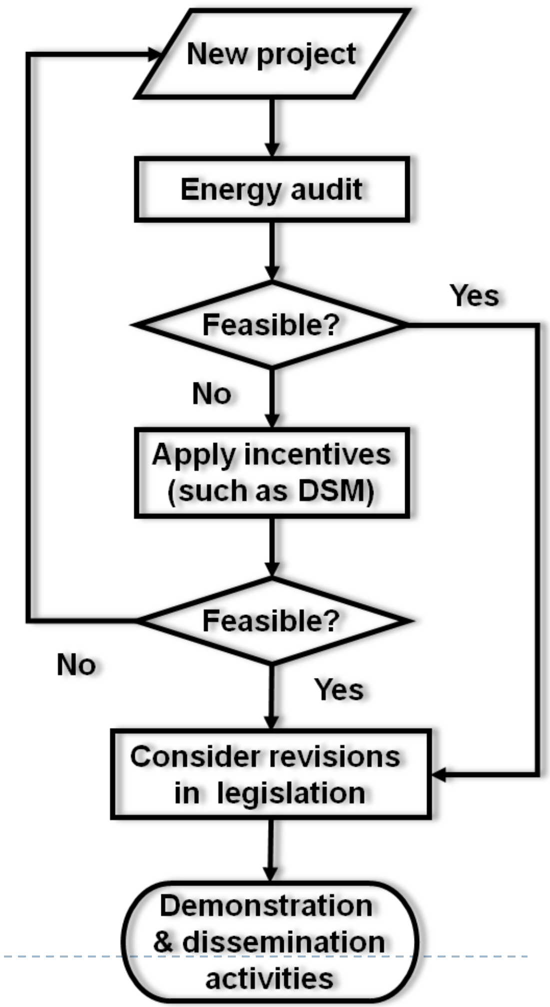


Application of Green Energy Technologies in Developing Countries

PROPOSED APPROACHES FOR GREEN ENERGY APPLICATIONS:
DEMAND- SIDE

Proposed Approach:

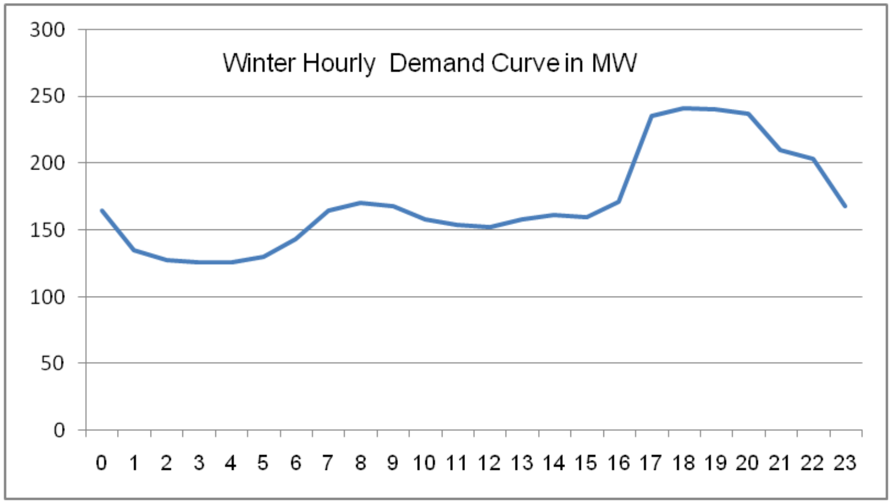
- Perform LCC analysis
- If not feasible apply incentives and check the feasibility again
- The feasible projects may need to be supported by new legal frameworks
- Awareness and know-how activities

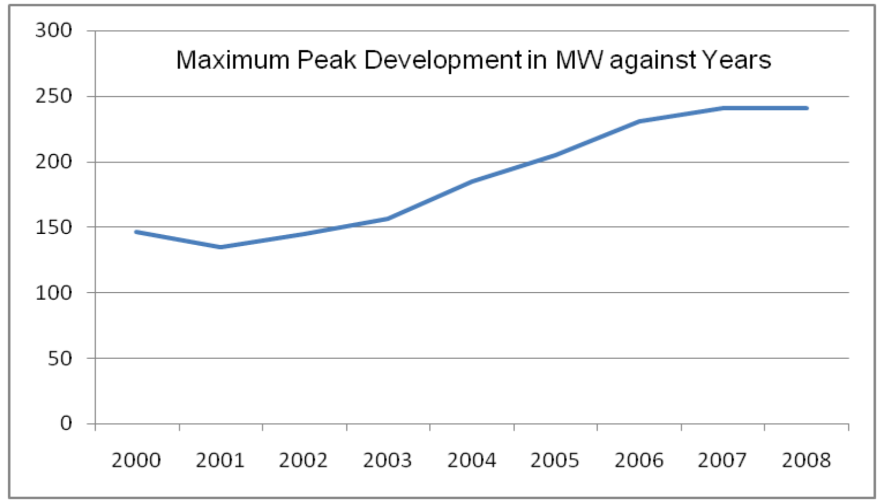


Application of Green Energy Technologies in Developing Countries

CASES FROM N. CYPRUS: ENERGY BRIEF

Fuel used for electricity production: Fuel-oil # 6





Total installed power	307 MW
Maximum peak load	240 MW
Transmission & Distribution (T & D) losses	24 % (2003) 11 % (at present)

OPE Improvement of 13%

Application of Green Energy Technologies in Developing Countries

CASES FROM N. CYPRUS: INFRASTRUCTURE DEVELOPMENT

Electricity infrastructure development in N. Cyprus between 2003 and present

Infrastructure Development	Improvement
Replacement of old transmission lines	300-km out of 550-km renewed
High-tension power lines	From 66-kV to 132-kV
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Application of Green Energy Technologies in Developing Countries

CASES FROM N. CYPRUS: INFRASTRUCTURE DEVELOPMENT

A Pilot project: 1-MW solar (PV) power plant

Features	
Cost	4 million Euros
Capacity	1-MW
Annual Electricity production	1.5 million kWh

Application of Green Energy Technologies in Developing Countries

CASES FROM N. CYPRUS: INFRASTRUCTURE DEVELOPMENT

Returns of a 1-MW solar power plant with different T & D losses in N. Cyprus

	T & D Losses	Tariff: 0.14 €/kWh
2003	24%	• Sales: 1.14 million kWh/yr • Return: 159,600 Eur/yr
Present	11%	• Sales: 1.335 million kWh/yr • Return: 186,500 Eur/yr
Target	7%	• Sales: 1.395 million kWh/yr • Return: 195,300 Eur/yr

INVESTMENT APPRAISAL FOR RE POWER PLANTS

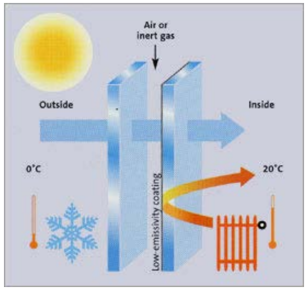
- It is anticipated that in N. Cyprus it is possible to have RE systems of up to 25-MW
- The feasibility of RE systems depend on
  - Their capital costs
  - Rates of return
  - Fuel, personnel, operation and maintenance costs of both old systems and RE systems
  - Cost of infrastructure development
  - Cost of incentives

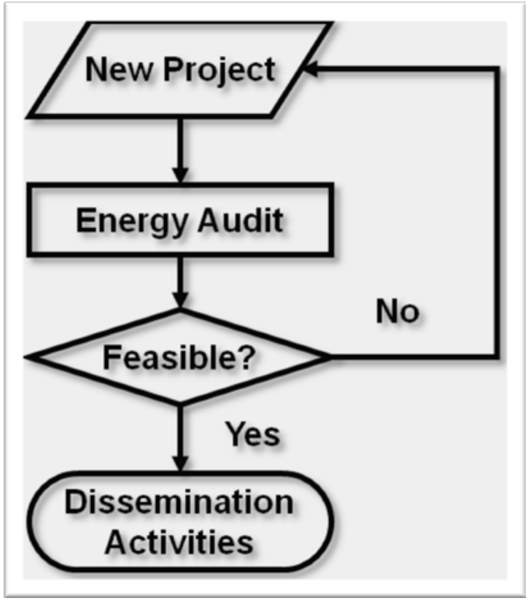
Application of Green Energy Technologies in Developing Countries

CASES FROM N. CYPRUS: FEASIBLTY OF HPWs IN N. CYPRUS

Life cycle cost indicators for different HPWs. (Discount rate was taken to be 16% with an economic life time of 15 years.) [3]

	Single Glazing	Simple double glazing	Double glazing with Low-e	Double glazing with Argon gas	Double glazing with Krypton gas	Triple glazing
Price (YTL)	153	170	204	255	306	425
U value	5.6	2.6	1.8	1.6	0.7	0.6
U value difference	0	3	3.8	4	4.9	5
Total annual energy saving (kWh)	-	109.2	138.32	145.6	178.36	182
Total annual cost saving (YTL)	-	10.08	12.77	13.44	16.47	16.8
NPV(YTL)	-	25	11.76	-22	-40	-149
SIR	-	1.4	1.2	0.9	0.8	0.5
IRR	-	22%	19%	14%	13%	7%
Simple payback(years)	-	4.7	5.3	7.2	7.7	11.7

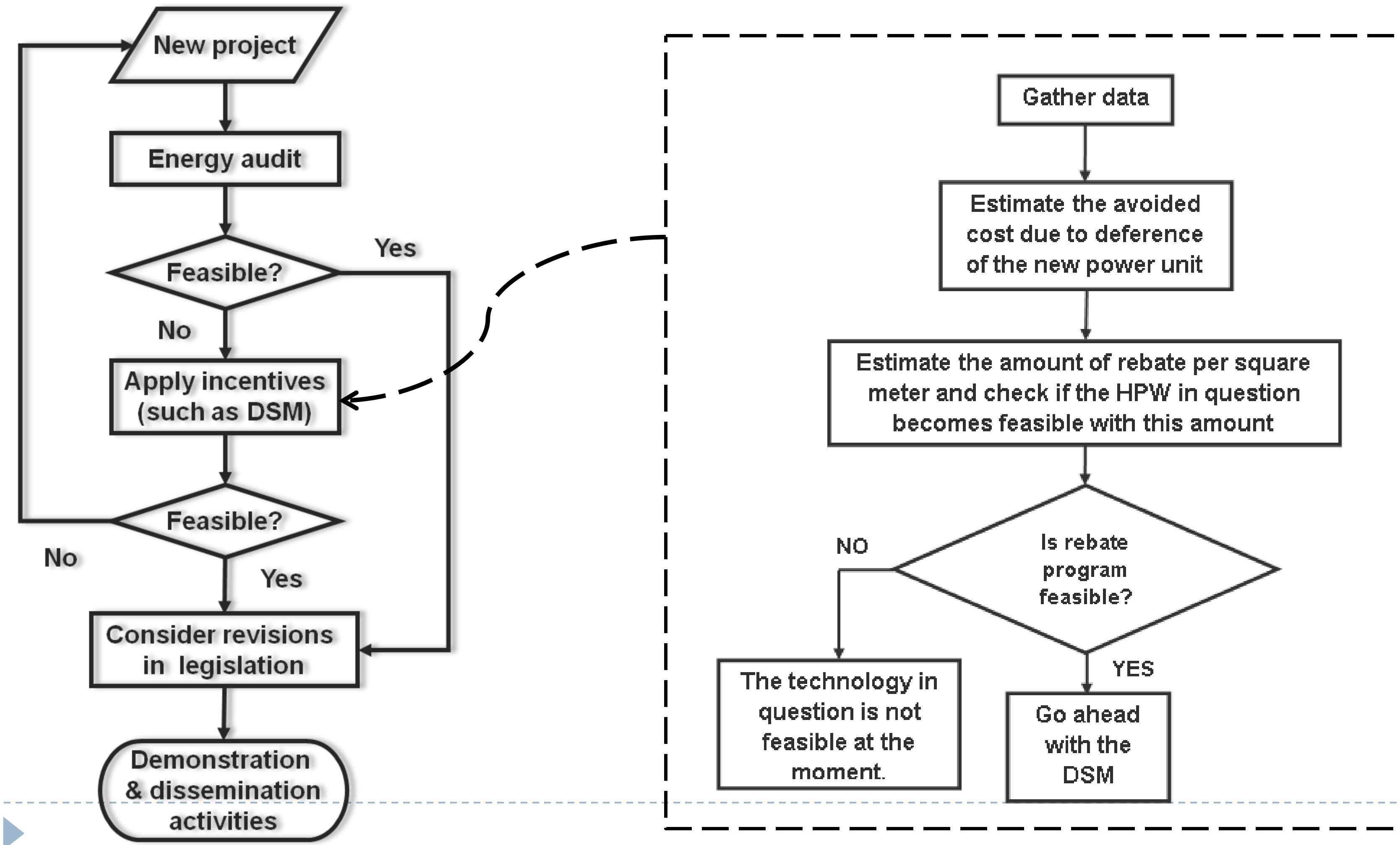




[3] U. Atikol et al., Effect of DSM on the feasibility of HPWs, Proceedings Of The 3rd IASME/WSEAS International Conference On Energy & Environment - Energy And Environment III, (2008), pp.84-89

Application of Green Energy Technologies in Developing Countries

CASES FROM N. CYPRUS: FEASIBLTY OF HPWs IN N. CYPRUS



Application of Green Energy Technologies in Developing Countries

CASES FROM N. CYPRUS: FEASIBLTY OF HPWs IN N. CYPRUS

Demand-side management cost parameters, deferred power capacities and the corresponding deference periods.

	High Performance Windows (HPWs)				
	Simple double glazing	Double glazing with Low-e	Double glazing with Argon gas	Double glazing with Krypton gas	Triple glazing
Power reduction at 15th year (MW)	21.6	28.8	30.6	38.7	39.6
The price of needed Power plants (MYTL)	21.6	28.8	30.6	38.7	39.6
needed rebate	-	-	-40.5	-75.5	-223
Accumulated cost saving due to energy saving (MYTL)	64	81	85.4	105	107
Total saving by Utility (MYTL)	85.6	109.84	75.5	68.2	-76.4
Deferring period (years)	13.3	21.8	24.8	58.8	-

CONCLUSIONS

- In this presentation, problems of applying green energy technologies in developing countries were discussed.
- It was acknowledged that in order to achieve EE and increase the feasibility of RE power systems it is required to deal with the infrastructure, create incentives and raise awareness.
- Economic feasibility of green energy projects needs to be accomplished in order to facilitate their successful application.