KRISHNA BHARADWAJ MEMORIAL LECTURE

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CRISIS

a situation that does not permit continuation of old patterns of behaviour

ENERGY SYSTEM IS TRAPPED IN CRISES

- capital crisis
- performance crisis
- access or equity (= distribution) crisis
- environment crisis

ANNUAL INVESTMENT REQUIRED FOR CAPACITY EXPANSION

I = E (0) . g(CAP) . UCOP

= E(0) . a . g(GDP) . UCOP

E(0) =Capacity (In MW) in Base Year

g(CAP) = Growth Rate of Capacity

g(GDP) = Growth Rate of GDP

a = Ratio of growth rates of capacity & GDP

UCOP = Unit Cost of Capacity(Rs/kW)

OPTION #2: BELT-TIGHTENING

- Take (a . UCOP) as given/unchangeable
- E(t-1) is also given
- Accept I(t) = I(G) + I(ES) + I(NPS) + I(ML)

And live with g(GDP) = I/(t) / Constant

But this g(GDP) may be less than g(POP)

If so, crisis!

OPTION#1 : ENSURE MINIMUM INVESTMENT

- Take (a . UCOP) as given/unchangeable
- E(t-1) is also given

ˆ I(t) = constant x g(GDP)

If there is a g(GDP) target, then ensure a minimum investment I(t)

SOURCES OF INVESTMENT

I(t) = I(G) +I(ES) + I(NPS) + I(ML)
+ I(FPS)

But I(G) » 0, I(ES) » 0,
I(NPS) » 0, I(ML) » 0

ˆ I(t) must come from I(FPS)

ˆ Go abroad with begging bowl

ENVIRONMENTAL CRISIS

Conventional energy production is associated with local and global impacts that degrade the environment

ENVIRONMENTAL CRISIS

- Hydroelectric projects $\Rightarrow$ displace people and submerge forests
- Thermal power projects $\Rightarrow$ produce acid rain and other forms of atmospheric & surface pollution
- Nuclear power plants $\Rightarrow$ safety and radiation hazards.

EQUITY CRISIS

- Electricity systems expanded in the name of development
- But, they bypass the poor
- Less than half the HH benefit directly from its electricity
- Village electrification =/= HH electrification

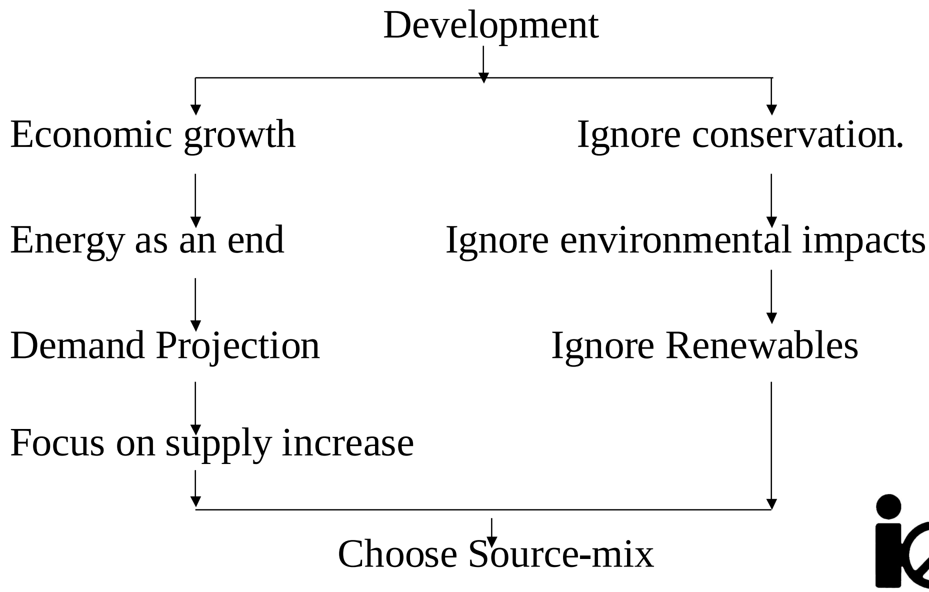
ORIGIN OF THE CRISES

Conventional energy paradigm or mind-set that determines the thinking of virtually all energy decision-makers and planners

CONVENTIONAL PARADIGM FOR ELECTRICITY PLANNING

Development = Growth = Energy = Electricity = Centralized Generation = Grid Transmission & Distribution

CONVENTIONAL SUPPLY-BIASED PARADIGM



ENERGY-GDP “CORRELATION”

- Every economy consists of a number of energy-utilizing activities
- Each activity involves an energy intensity, I_j, and a fraction/contribution, $c_j = f_j(GDP)$, to the GDP

TOTAL ENERGY DEMAND

E = Sum of energy demands of various activities

$E = \text{Sum } E_j = \text{Sum } [C_j \times I_j]$

$= \text{Sum } [f_j(\text{GDP}) \times I_j]$

ˆ **$E = [\text{Sum } f_j \times I_j] \times \text{GDP}$**

ENERGY DEMAND IS PROPORTIONAL TO GDP

if and only if

the term $[\text{Sum } (f_j \times i_j)]$

is a constant

ENERGY-GDP CORRELATION

is valid only during periods when there is no change in the economy's

(1) energy efficiency

(2) structure

E-GDP PROPORTIONALITY BREAKS DOWN UNDER CHANGES

- of **energy intensity** due to efficiency improvements, process changes or product changes and/or
- of the **economy's structure**, i.e., the contributions of different activities to the GDP (e.g., the share of less-energy intensive activities increases)

Changes in Energy Demand

can arise from

Changes in Energy Intensity (I_i)

Changes in contribution to GDP (C_i), i.e.,Changes in α_I

Technical Changes

(1) Efficiency improvements

(2) Process Changes

(3) Product Changes

Structural Changes

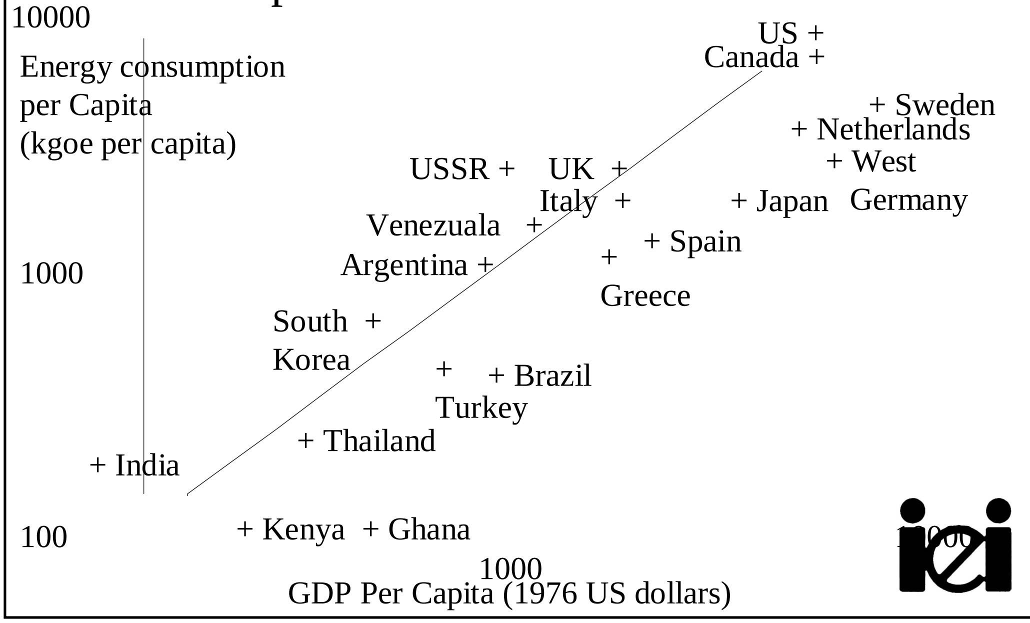
(1) New composition of Product Services, i.e., New a_i's

Result: (a I_I) & å ($a_i I_I$) can decrease and Decouple energy from GDP

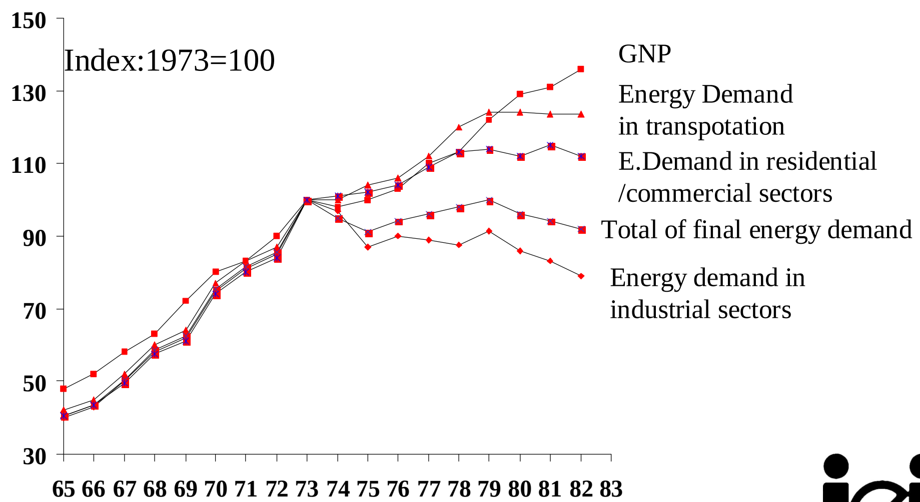
DECREASE OF [SUM (f_j x I_j)]

- can offset an increase in GDP
- reduce the coupling between GDP and energy
- there can even be decoupling (decrease in energy consumption associated with an increase in GDP)

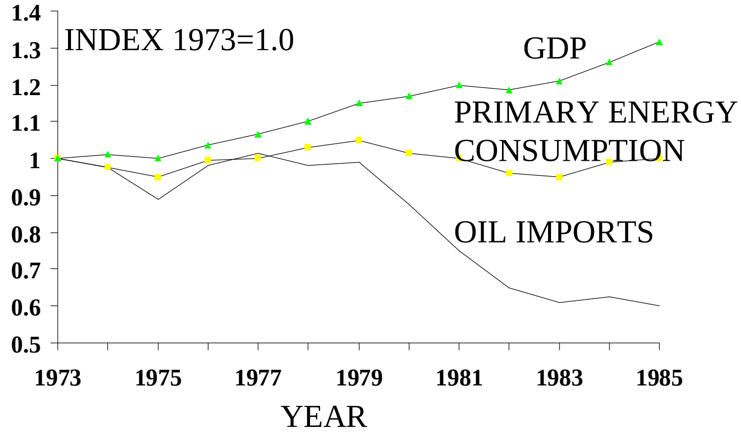
GDP per Capita Vs Energy Consumption per capita for Selected Countries



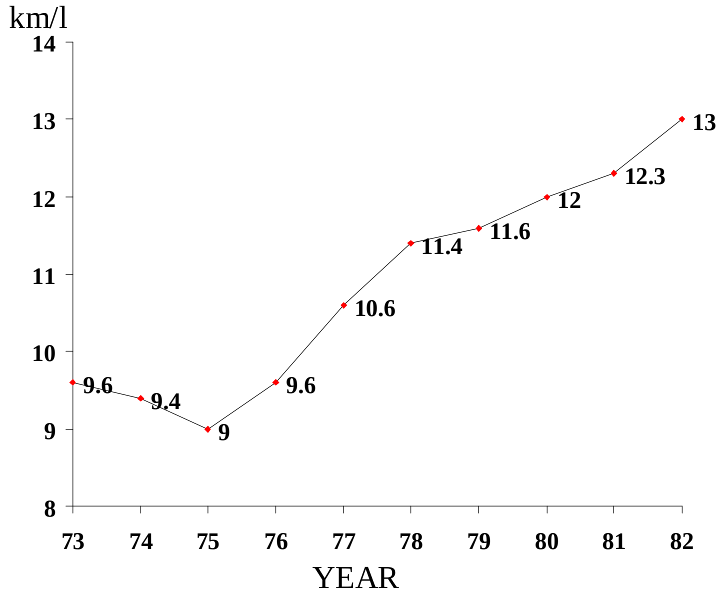
Trends in Japan's Energy Demand by sector and GNP



OECD COUNTRIES 1973-1985



CHANGES OF FUEL EFFICINCY OF JAPANESE PASSENGER CARS



EFFICIENCY IMPROVEMENTS & ENERGY DEMAND

Implicit incorporation of EI via energy prices

$ED = f(GDP, P) = A \, . \, GDP^{a} \, . \, P^{-b}$

$\ln ED = \ln A + a \ln GDP - b \ln P$

$a = (\delta \ln ED / \delta \ln GDP)_{P}$

= GDP elasticity of ED

$-b = (\delta \ln ED / \delta \ln P)_{GDP}$

= Price elasticity of ED

RELATION BETWEEN GROWTH RATES

ED, GDP and P are functions of time

ˆ $\ln [ED(t)/ED(0)] = a \ln [GDP(t)/GDP(0)] - b \ln [P(t)/P(0)]$

But $ED(t)=ED(0) [1+g_{ED}]^{t}$ or

$ED(t)/ED(0)= (1+g_{ED})^{t}$ and $\ln(1+g_{ED})$ » g_{ED}

ˆ $g_{ED} = a \, g_{GDP} - b \, Gp$

SINGLE ELASTICITY EXPRESSION FOR ENERGY DEMAND

If P(t) = P(0), i.e., ED= Constant A . GDP^a

a = [d ln ED]/[d ln GDP]

gED = a. gGDP or a = g_{ED}/g_{GDP} =

GDP elasticity of ED = Ratio of growth rates of ED and GDP

WB ESTIMATE OF ANNUAL CAPITAL REQUIREMENTS

Δ ED/yr = ED(1) - ED(0) = ED(0). g_{ED}

= ED(0) . a . g_{GDP}

$\hat{}$ Δ I/yr = ED(0) . g_{GDP} . a . UCOP

= 600 GW x 4% x 1.5 x $2777/kW

= $100 billion/year

PROBLEMS WITH ELASTICITIES

Price elasticities cannot cope with following questions:

- How will future price increases affect ED and carrier substitution?
- What is the role of non-price-related measures?
- How will economy (e.g.recession) will affect ED?

PROBLEMS WITH ELASTICITIES

- Elasticities are difficult to measure and vary a great deal
- Price elasticities overemphasize role of prices
- Any change not explained by GDP (including non-price-related measures) is ascribed to price

PROBLEMS WITH ELASTICITIES

- Elasticities are black boxes that do not explain how prices affect ED
- e.g. Price elasticity of household demand will integrate effect of prices on
  - level of ED
  - changes in existing EU equipment
  - choice of new equipment

DOUBLE ELASTICITY MODEL

with Explicit Incorporation of EI

$$\mathbf{ED = A.\ GDP^{a}\ P^{-b} / (1+c)^{n}}$$

P^{-b} = Price-induced efficiency improvement

$(1+c)^{n}$ = Non-price-induced efficiency improvement

SUBSIDIES TO THE POWER SECTOR

- Subsidies promote waste and discourage efficiency
- There should be no net subsidies to power sector
- Cross-subsidies (from one consumer category to another) permissible with consumer consent up to a limit

DISCOURAGING CONSUMERS FROM WASTING ELECTRICITY

- Two options: tariff increases versus efficient equipment
- If consumers' demand is ***inelastic*** (i.e., does not decrease even after price increases), tariff increase may not reduce electricity demand
- Improving equipment efficiency is better than mere tariff increases

BETTER TO SUBSIDIZE EFFICIENT EQUIPMENT THAN SUBSIDIZE ELECTRICITY

- Some consumers may be unable to pay first cost of efficient equipment
- Financing schemes to lower/defer first costs for promotion of improved equipment and reduction in energy demand
- Subsidy (with sunset clause) should be restricted to emerging technologies

TECHNO-ECONOMIC MODELS

Σ End-uses → ΣUE → Σ FE → ED

End-use data → not always available

So, work with activities

Economy = Σ Sectors

= Σ Sectoral activity

Each sectoral activity

↓ Activity level per capita

↓ Specific energy (GJ/unit level)

$ED = \Sigma[(\text{Activity level})_i \times (\text{Specific energy})_i]$

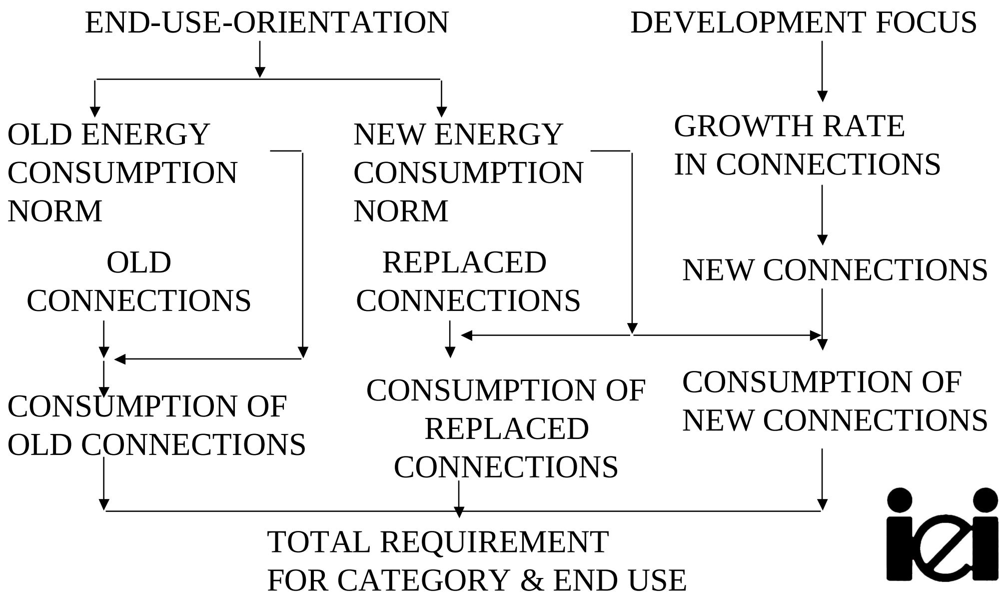
A THOUGHT EXPERIMENT

E(total) = Σ**[(Activity level)$_i$*(Specific Energy)$_i$)]**

Assuming Activity levels = Activity levels of Western Europe in 1970's

Result $\Rightarrow$ 1 kW/capita Final Energy versus 0.9 kW/capita Final Energy in 1980 including 0.45 kW/capita NCE

DEFENDUS ENERGY REQUIREMENT SCENARIO FOR YEAR B+J FOR EACH END-USE OF EACH CONSUMER CATEGORY



CONVENTIONAL PARADIGM FOR ENERGY

- **GR**owth-oriented **S**upply-**S**ided **CON**sumption-biased (GROSSCON) Paradigm
- Magnitude of energy consumption is deemed to be the indicator of development

A NEW PARADIGM FOR ENERGY

- What human beings and their activities require is not energy *per se* but the work that energy performs and the services that energy provides (heat for cooking, warmth, process heat, illumination, mobility, etc.)
- Development requires increases in energy services

INCREASING ENERGY SERVICES

- Not only by increasing the supply of energy to the devices (lamps, heaters, motors vehicles, etc)
- But also by increasing the efficiency of these devices and/or by shifting to more efficient energy carriers

SWITCH FROM KEROSENE WICK LAMPS TO 20 W FLUORESCENT TUBELIGHTS

- Illumination increases about 19 times but utilization of input energy decreases to only one-ninth initial value (with kerosene)
- because of 420 times greater efficiency of 20 W fluorescent tubelights compared to kerosene wick lamps

BEFORE SWITCH TO FLUORESCENT TUBELIGHTS

Households consumed far more energy but enjoyed far less lighting energy service

IMPROVEMENT IN THE LEVEL OF ENERGY SERVICES

- by increasing energy consumption through an increase of energy supplies (CENTs or DECENTs) and/or
- by increasing the efficiency with which end-use devices utilize energy, i.e., by end-use efficiency improvements (EUEIs)

THIS ADVANCE IN DEVELOPMENT HAS BEEN ACHIEVED ALONG WITH A DECREASE IN THE CONSUMPTION OF ENERGY

GENERAL PARADOX OF ENERGY IN DEVELOPING COUNTRIES

High levels of energy consumption with low levels of energy services

IT IS THE <u>LEVEL OF ENERGY SERVICES</u> -- AND NOT THE MAGNITUDE OF ENERGY CONSUMPTION -- THAT MUST BE TAKEN AS THE <u>INDICATOR OF DEVELOPMENT</u>

REDUCTION OF INVESTMENT

[with E(0) and g(GDP) as given]

- Decrease a, the coupling factor, through efficiency improvements and/or
- Decrease UCOP, the unit cost of capacity in Rs/kW (by avoiding T&D losses through decentralized generation and/or cogenerating electricity

LEAST-COST MIX

- Include **saving** options
- Don’t restrict generation options to centralized options and fossil-fuel/ non-renewable options
- Include **decentralized** options as well as **renewables**

OPTION #3--> IRP APPROACH

- E(t-1) given
- Minimum growth rate of GDP given
- Scrutinize (a.UCOP) in order to decrease a and/or decrease UCOP

OPTION #3--> IRP APPROACH

1. EUEI Ý, a ß (greater GDP "bang" for lower energy "buck")
2. Cost of CENTs ß through EI in generation (PLF Ý Þ availability Ý) through reduction of T & D losses (technical and non-technical)
3. DECENT Þ grid-connected (cogeneration) or stand-alone (at construction sites)

OPTION #3--> IRP APPROACH

a ß and/or UCOP ß ∴ I(t) ß

Thus Capital crisis eased

Also, Performance crisis eased

Environment crisis eased

Access crisis eased

THREE RESOURCES

- CENTS (Conventional)
- DECENTS (Non-conventional)
- EUEIs

COSTS OF ELECTRICITY FROM SOURCES SUCH AS BIOMASS, WIND, SMALL HYDEL, PHOTOVOLTAICS, ETC., ARE FALLING RAPIDLY

THREE ENERGY OPTIONS FOR INDIA

- "**Copying the worst**" (early industrializers with the highest maxima)
- "**Copying the best**" (latest industrializers (e.g., Japan) showing the lowest maxima)
- "**Beating the best**" through technological leap-frogging

THE NEW CHALLENGE

- **Reducing the coupling** between GDP growth and energy consumption
- **Identifying & implementing a least-cost mix** of generation & saving options for increasing energy services.

POWER SECTOR MUST

- acquire a human face
- become an instrument of Sudevelopment
- ask: electricity for whom? what? how (efficiently)?
- emphasize energy services for the poor

POWER SECTOR MUST

acquire a development focus

and

an end-use orientation

directed towards energy services.

WHAT IS REQUIRED

- A new paradigm for energy
- A **DE**velopment-**F**ocussed **END-U**se-oriented **S**ervice-directed or **DEFENDUS** paradigm to rescue us from the crises

BENEFICIARIES OF IRP
Government/Energy Ministry

- To avoid gross excess capacity of Cents
- To maximize funds for other development activities by implementing least-cost mix
- To overcome funds constraint on capacity expansion
- To guide public sector investment in capacity expansion

BENEFICIARIES OF IRP
Government/Energy Ministry

- To define niche for Decents
- Least environmental impact mix
- To arrive at PURPA-like basis for PPAs
- To provide rational basis for formulating enabling policies for energy technologies
- To provide rational basis for funding R & D for energy technologies

BENEFICIARIES OF IRP: ELECTRICITY UTILITY

- To define niche for Decents
- To identify cost-effective DSM/EI measures

BENEFICIARIES OF IRP: ELECTRICITY REGULATORY COMMISSION

- To define lowest Marginal Cost Price of electricity
- To define corresponding rational tariff
- To evaluate PPAs on PURPA-like avoided cost basis

BENEFICIARIES OF IRP: CONNECTED CONSUMERS

- To know lowest Marginal Cost Tariffs
- To be protected against tariff distortions by high-cost PPAs

BARRIERS TO IRP

Dominance of old paradigm

- Decision making based on supply-biased paradigm
- Any-power-is-better-than-no-power syndrome

Costing of Energy/Power

- Stand-alone rather than Marginal Costing

INSTITUTIONAL BARRIERS

- Decision-maker only responsible for supply side management but not for DSM
- Decision-maker profits from consumption increase
- Vested interests (in private/public sector) that benefit from business-as-usual approaches and practices and, therefore, resist change
- Institutional obstacles (including monopoly position of utilities and lack of appropriate fora and rules for interaction between relevant organizations).

MARKET BARRIERS TO IRP

- Subsidies (open/hidden) to conventional energy particularly fossil fuels
- Electricity prices do not reflect costs
- Market prices do not reflect environmental costs and damage
- Market prices mask environmental advantages of the new and cleaner energy options

MARKET BARRIERS TO IRP

- Limited access to information
- First cost sensitivity (where decisions are based on initial, rather than life-cycle, costs)
- Indifference to energy costs leading to limited attention to alternative energy options.

SUCCESSFUL IRP: NECESSARY AND SUFFICIENT CONDITIONS

- National Policy Commitment
- Agency that can control generation & influence demand
- IRP capacity backed by IRP exercises
- Constraints (e.g., capital, environmental) on supply expansion
- Marginal Cost Pricing as basis for arriving at PPAs
- Marginal Cost Pricing as basis for tariffs