The Abdus Salam
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National Energy Planning

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Energy Planning and Contemporary Challenges

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Why energy planning?

- Energy is strategic in the key dimensions of sustainable development: Economic, Social and Environment
- Energy is integrated: One part of the system affects other parts
- Energy is intra-grated: Energy policies affect and are affected by a myriad of other decisions/developments
- Energy systems are dynamic and moving targets
- Hence, energy planning is about choices and dealing with uncertainty
  - Technology
  - Fuels and prices
  - Policy
  - Demand

Planning addresses the energy tri-lemma

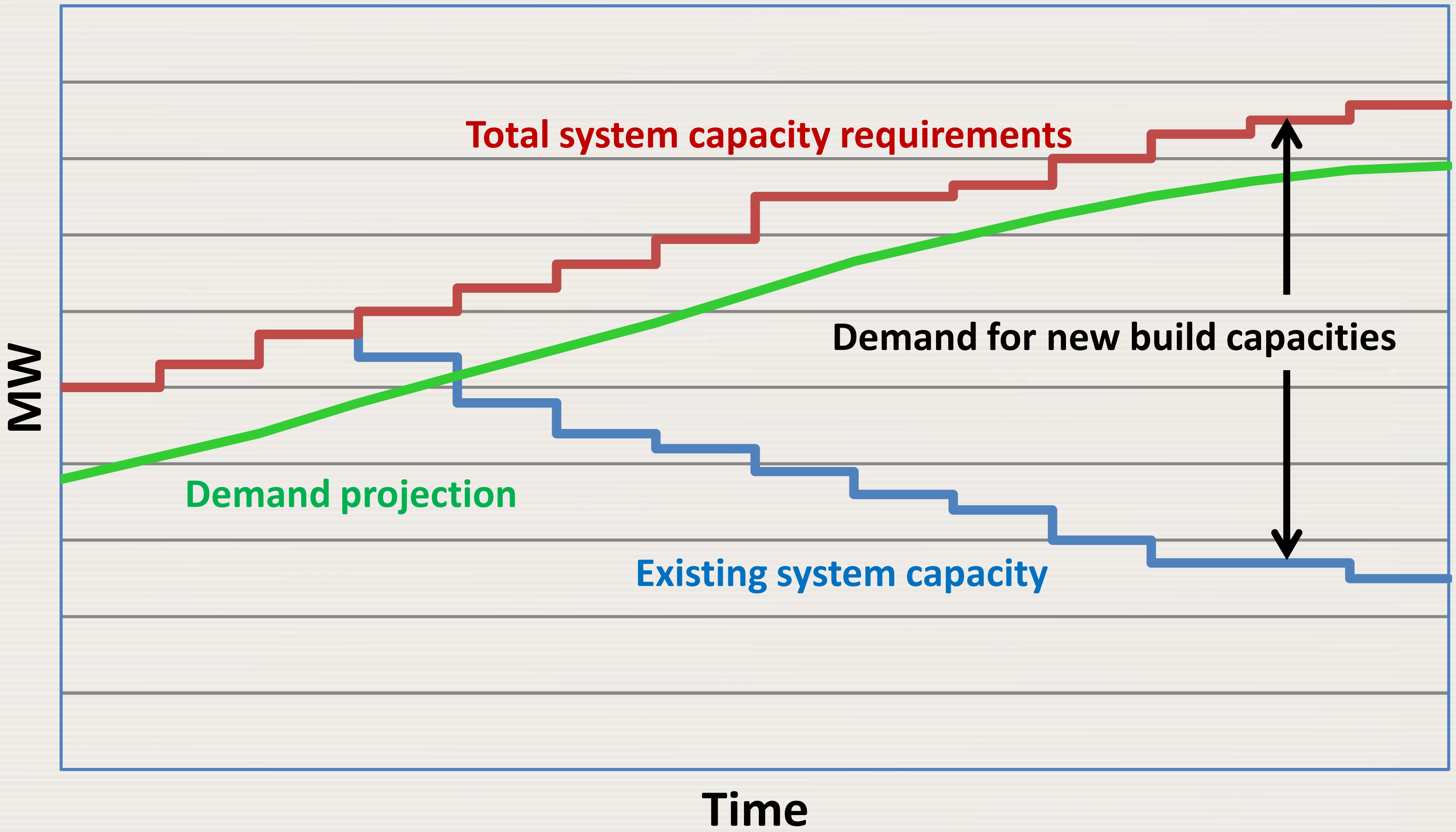
- Energy security
  - Supply security
  - Reliability
- Economic competiveness
  - Affordability
  - Access
- Environmental considerations
  - Climate change
  - Local and regional pollution

What is Energy Planning?

- Preparing for an uncertain future in a comprehensive, organized and transparent manner
- Anticipating needs and risks, identifying options and reviewing different ways to meet those needs - Identifying robust trajectories
- Affordability, competitiveness and finance
- Compliance wit environmental constraints
- Stakeholder involvement

One objective of energy planning

Type and schedule of new capacity additions for an uncertain future



Energy modelling – a panacea?

- Energy modeling is an art
- Energy modeling provides insights NOT answers
- Different actors require different answers and thus different approaches (no one size fits all)
- Answers for and thus information to decision and policy makers and markets are not trivial – analysis and planning tools (with their deficiencies are inevitable prerequisites)
- Energy planning never ends…

Why energy planning?

- Comprehensive energy planning essential for sustainable (energy) development
  - Optimal domestic resource allocation
  - Energy security
  - Access and affordability
  - Health and environment protection
- Shift from sequential stop-gap measures to integrated energy system planning
- Testing of effectiveness of policy measures
- Investment requirements
- Re-occurring or rolling activity

Why energy planning – or do not confuse me with facts, I already made up my mind

- A prerequisite for informed decision making
- Financial viability and capability
- Social/public/political commitment & acceptance
- Economic development & environmental protection
- Regional approaches & infrastructure sharing
- Without in-depth domestic energy planning capacity, the poorest member states will always be at the mercy of big industry and relying on the goodwill of the international and donor community

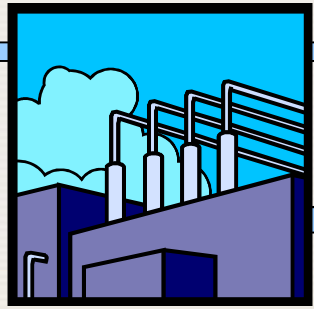
An Energy "Chain"

Oil extraction
Coal import

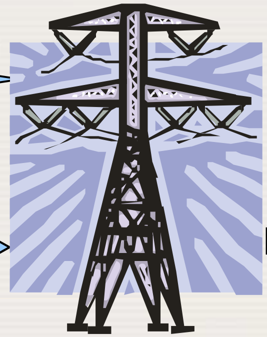
Power plant
Refinery

T&D Network

End user



Conversion



Transmission &
Distribution

Conversion

PRIMARY

- oil -
gas -
coal -
water

SECONDARY

-diesel
- kerosene
- gas
- electricity
- coal

FINAL

- diesel
- kerosene
- gas
- electricity
- coal

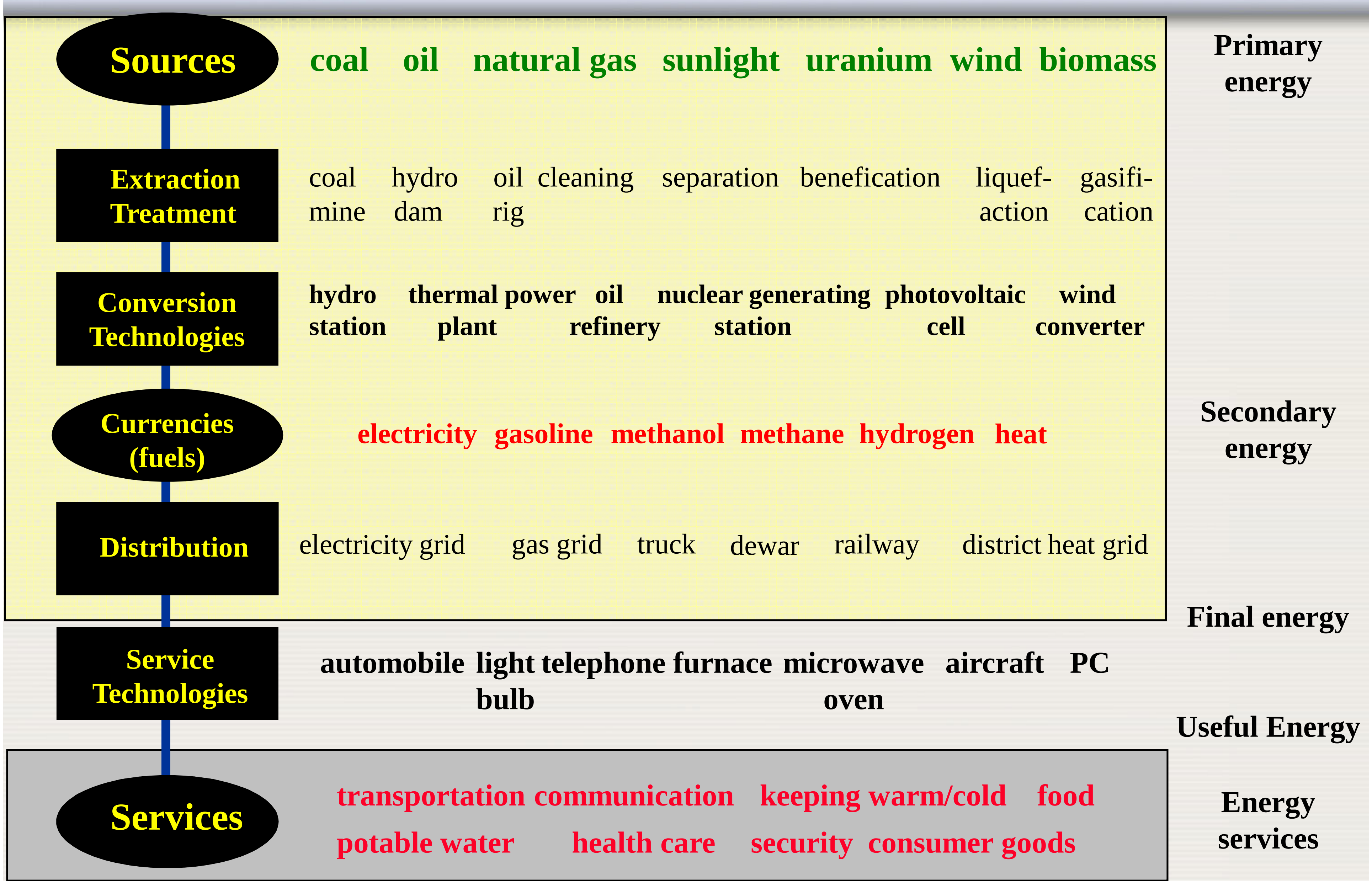
USEFUL

- heat
- light
- mechanical energy

Architecture of the Energy System

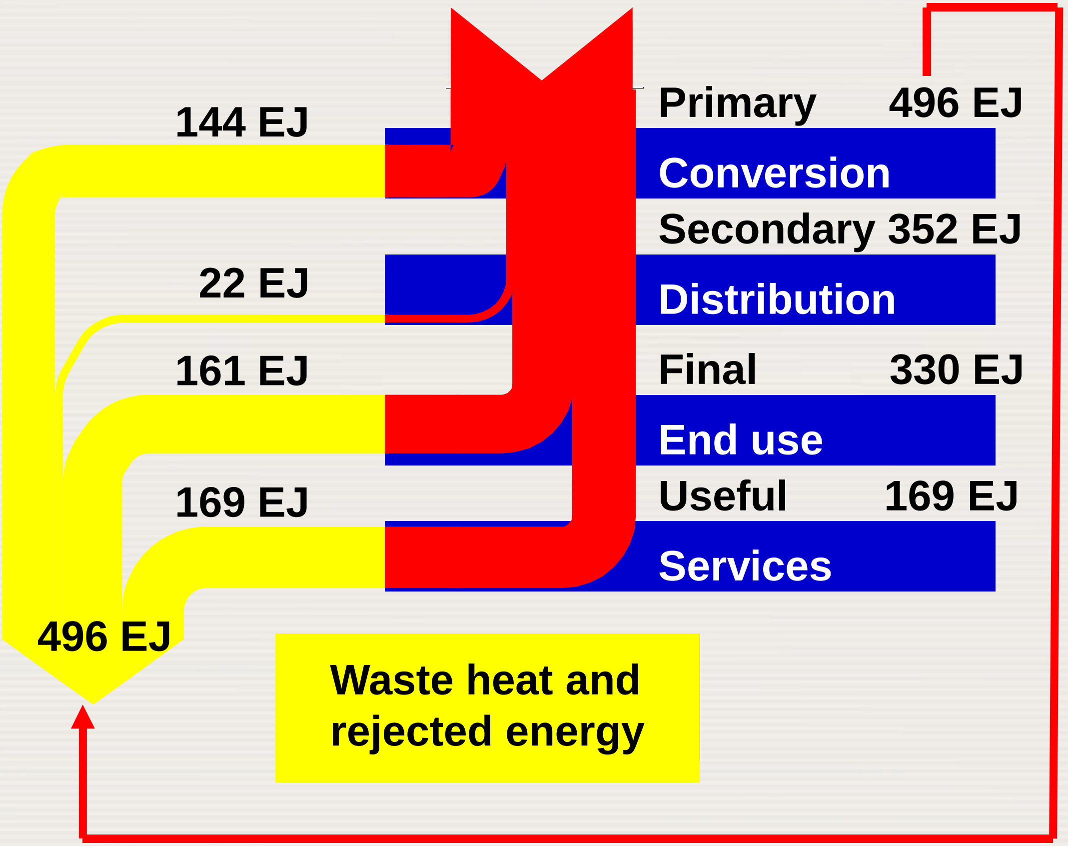
Sources	coal oil natural gas sunlight uranium wind biomass	What nature Provides
Extraction Treatment	coal mine, hydro dam, oil rig, cleaning, separation, benefication, liquef-action, gasifi-cation	
Conversion Technologies	hydro station, thermal power plant, oil refinery, nuclear generating station, photovoltaic cell, wind converter	Energy Sector
Currencies (fuels)	electricity gasoline methanol methane hydrogen heat	
Distribution	electricity grid, gas grid, truck, dewar, railway, district heat grid	
Service Technologies	automobile, light bulb, telephone, furnace, microwave oven, aircraft, PC	*Efficiency & Infrastructure*
Services	transportation, communication, keeping warm/cold, food, potable water, health care, security, consumer goods	What people want

Architecture of the Energy System



First Law of Thermodynamics: Energy conservation

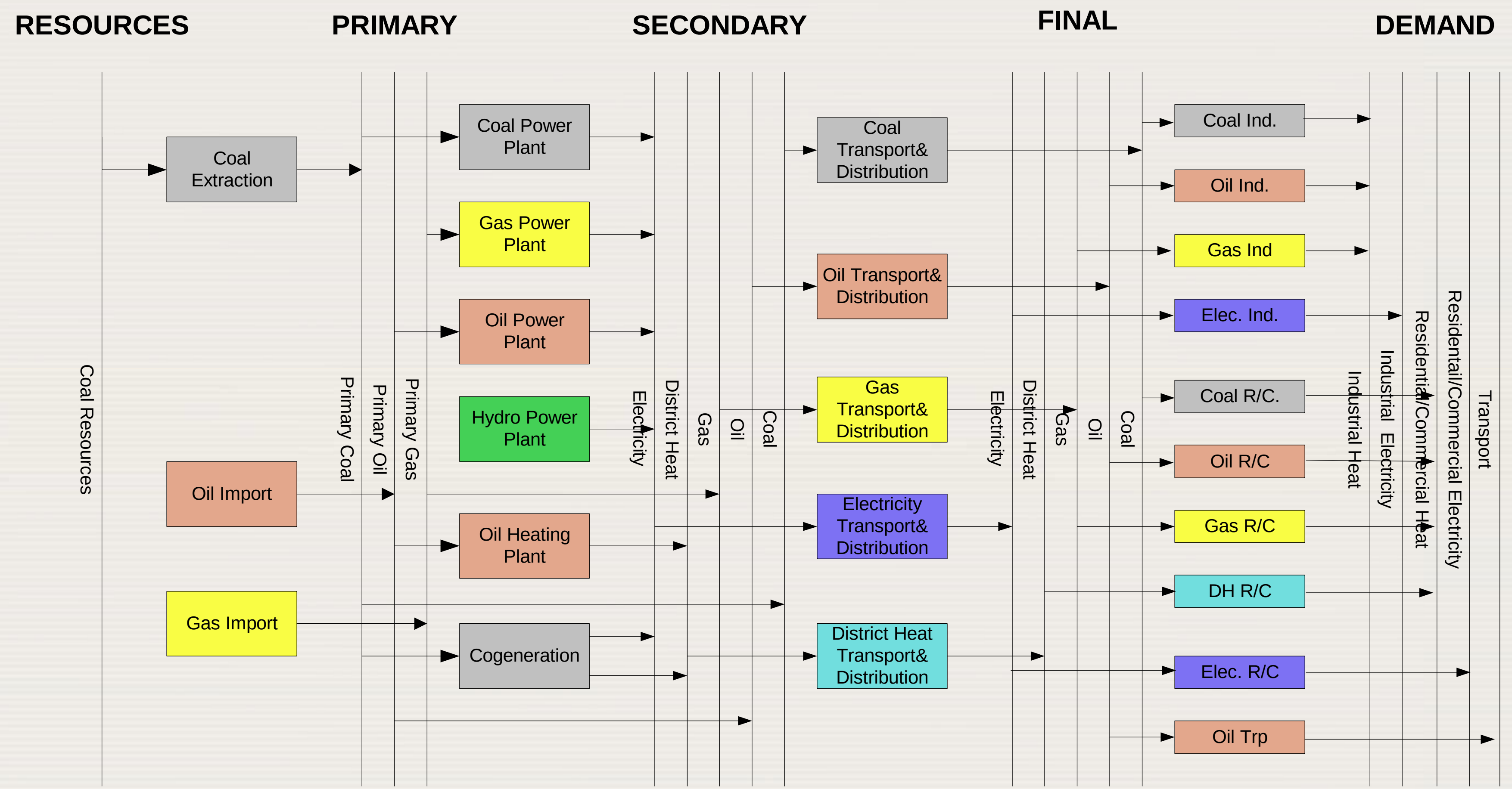
Energy



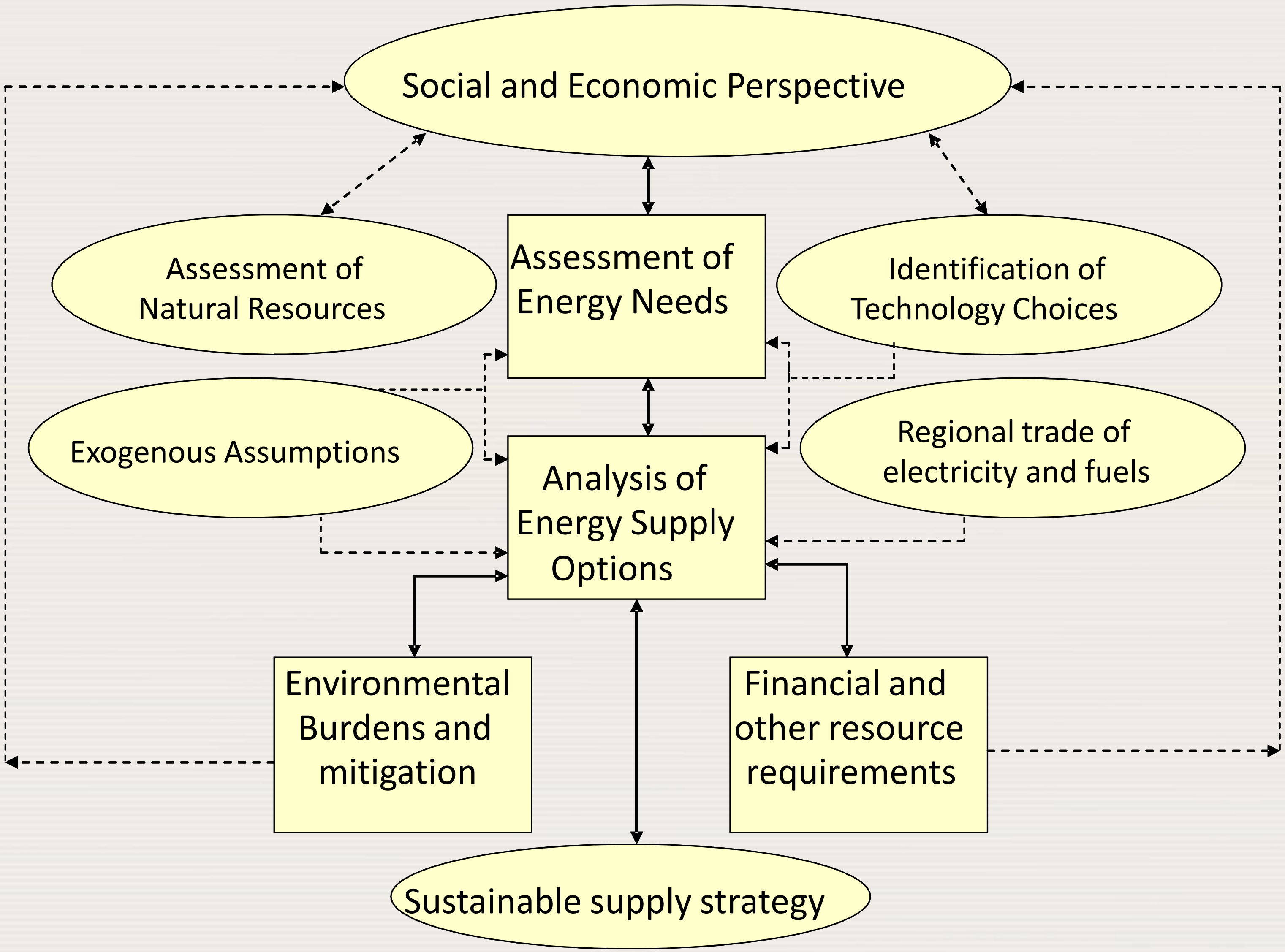
Examples

Crude Oil	Coal
Refinery	**Power Plant**
Gasoline	Electricity
Truck	**Grid**
Gasoline	Electricity
Car	**Light Bulb**
Kinetic	Radiant
Passenger-km	**Light**

A reference energy system



Framework for comprehensive energy assessment



Trade-offs

- Trade-offs between environmental, economic and social sustainability components are inevitable
- They are predominantly influenced by value judgments
- Emphasis on economic development harms the environment
- Emphasis on environmental protection adversely affects the economy
  - Poverty is the largest polluter
- Emphasis on economy penalizes renewables (current accounting systems)
- Emphasis on environment penalizes fossil chains
- Emphasis on social aspects penalizes nuclear

Comparative assessment of options

How to combine these criteria?

How to compare these alternatives?

Criteria / Alternatives	stments	Fuel costs	Waste/ decom	Reliability	Secutiy	Environment	Material	Acceptance
Wind	,200	0	15	low	high	very good	very high	high
Coal (domestic fuel)	,800	[illegible]	[illegible]	base load / [illegible]	very [illegible]	[illegible]	igh	low - high
Nuclear	,500	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	igh	low
Gas turbine (imp fuel)	400	5	12	peak	low	medium	low	high
Hydro	,500	0	50	seasonal	high	good	high	medium
End-use efficiency	225	0	1	-	very high	excellent	low	mixed

How to interpret the results?

Multi-criteria decision making

Criteria selection

↓

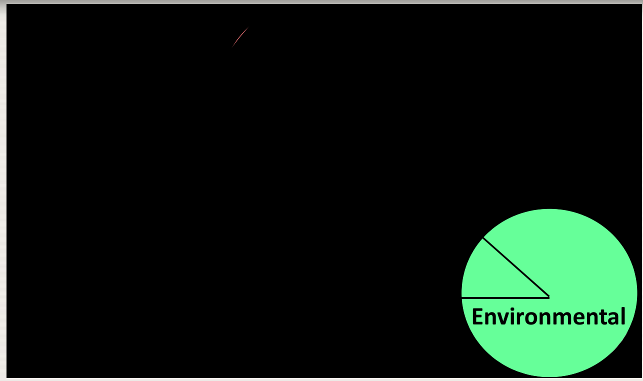
Alternatives selection

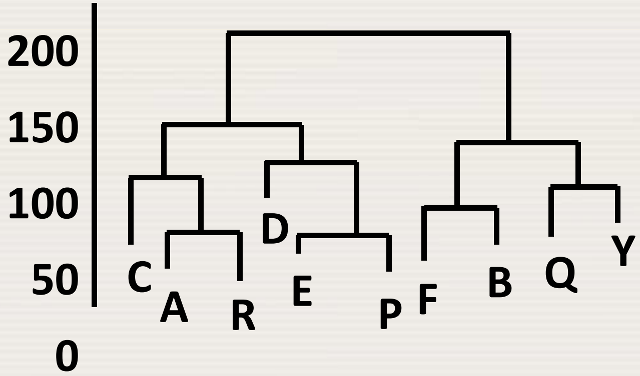
↓

Criteria weights

↓

Groupings



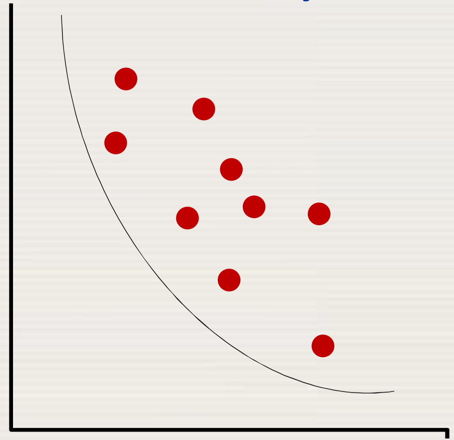


Scenario ranking
1
2
....

Scenario results

↓

Multi scenario
Tradeoff analysis



Performance matrix

Grouping	C1	C2	C3	C4	C5	C6	C7	C8
A								
B								
C								
D								
E								
Z								

Collateral benefits of energy planning

- **Comprehensive and transparent energy planning with stakeholder involvement paramount for**
  - **Public & political acceptance**
  - **Engaging foreign vendors and finance – confidence building**
  - **Mitigating environmental pollution, deforestation and climate change**
  - **Analyzing and responding "what if…" questions**
  - **Allows planners to extend analyses beyond national borders**
  - **Development of robust/resilient energy strategies**

Introduction to energy planning tools – the role of mathematical models

- **With a model we make an abstraction of the real world and simulate / plan … something**
- **A typical "energy systems model" will relate techno-physical aspects of the energy system *such as:***

type of energy technology(e.g. CCGT vs wind), the extent of that installation (MWs) required, when the installation operates, its level of activity etc.

- **to attributes *such as:***

  ***cost,* environmental or economic impact, flexibility, robustness, security, etc.**

  - **Includes some level of feedback between the two.**
  - **Objectives subject to various constraints**
  - **Analysis of different scenarios of the future**
  - **Policy formulation, testing, implementation and monitoring**

Approach to energy planning

- Minimize the economic cost of meeting demand while accounting for important technical physical constraints for energy system development over a 20-50 year period
- Start with as simple a representation as possible to account for constraints that may effect general conclusions
- Broadly: what technologies or policies help meet the development objective in a techno-economic manner?
- This includes
  - What kind of investments need to take place
  - When
  - How much
  - Operational aspects
- This is then iterated in more detail as more information/detail is required for the informed decision making

Challenge: Determining the system boundary

- Function of the question at hand
- Data availability
- Full energy system (energy services to trade & resource extraction) or subsystem?
- Technology representation: Detail and diversity?
  - Production & use of fuel in 15 min intervals or 10 year periods? Multiple fuels and products (CHP, refineries); individual technologies (large power plants) or groups of millions (e.g. lightbulbs, vehicles), technology learning etc.
- Level of interaction with other systems
  - Economy
  - Environment
  - Water, Land
  - Materials
  - Human resources
  - Etc.

Challenges: System boundary

- Level of regional integration and trade
  - Explicit imports and exports, indications of trading partners, number of regions, etc.
- Energy demand “endogenisation” and feedback
  - Demand in terms of final energy or energy service
  - Demand as a function of prices, income, etc.
- Dealing with uncertainty
  - Parametric sensitivities
  - Scenario sensitivities
  - Hedging strategies
  - Etc.

Energy planning

- **Objectives**
  - Least system costs
  - Energy security
  - Environment protection
  - Reliability
  - Employment
  - Income maximization
  - Multiple objectives

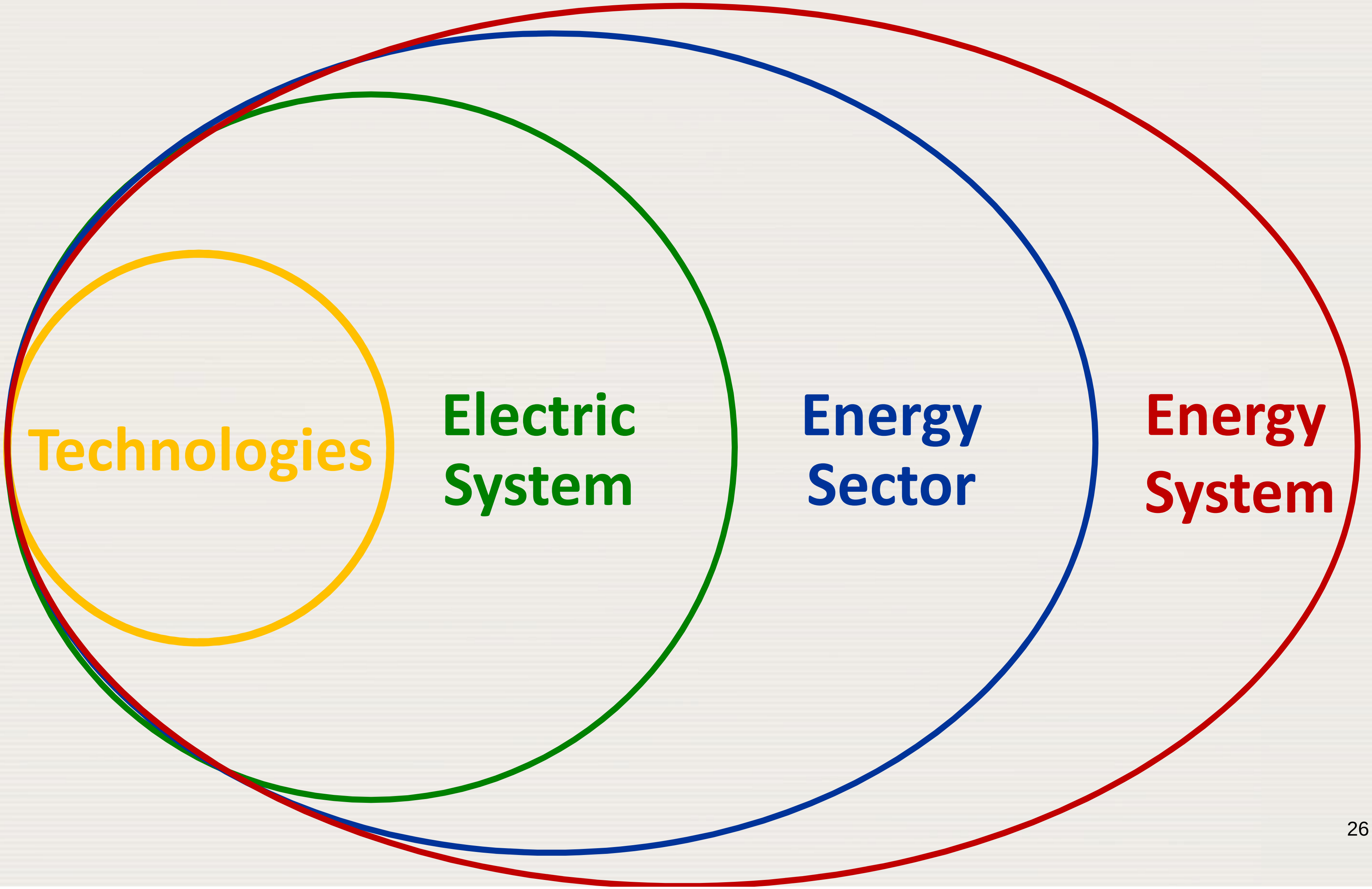
Challenges – the devil is in the detail

- **Energy carriers/currencies**
  - Electricity only
  - Multi-fuel
- **Technology representation**
  - Detail and diversity
  - Load characteristics and intervals - 15 min or 10 year periods
  - Multiple fuels – multiple outputs (CHP, refineries)
  - Individual technologies (large power plants) or groups of similar smaller technologies (e.g. small CHP, appliances),
  - Technology learning & innovation
- **Energy policy and associated subsidies, e.g.,**
  - Renewable portfolios
  - Smart grids

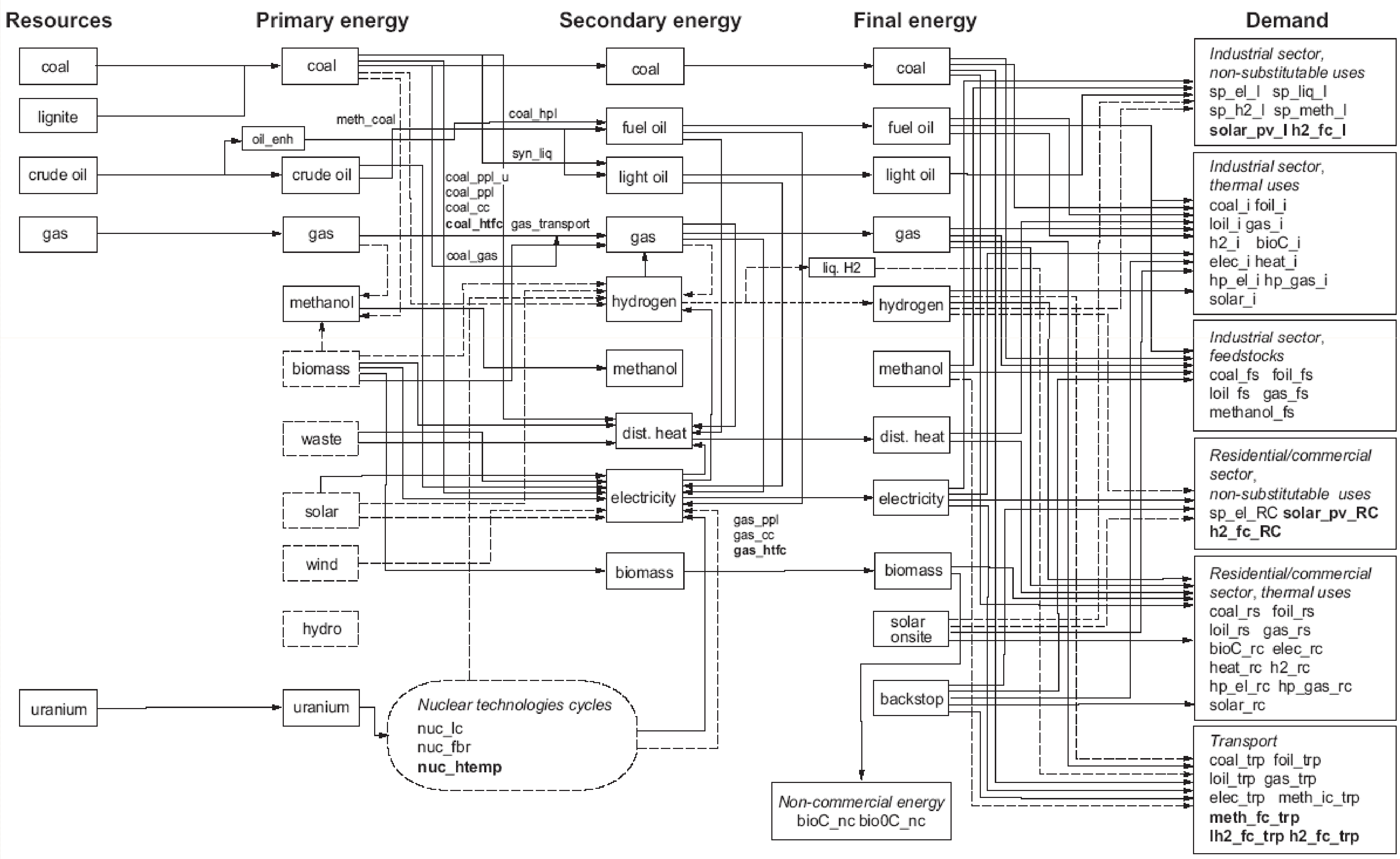
Collateral benefits of energy planning

- **Comprehensive and transparent energy planning with stakeholder involvement paramount for**
  - Public & political acceptance
  - Engaging foreign vendors and finance – confidence building
  - Mitigating environmental pollution, deforestation and climate change
  - Analyzing and responding "what if…" questions
  - Allows planners to extend analyses beyond national borders
  - Development of robust/resilient energy strategies

Energy & nuclear power planning

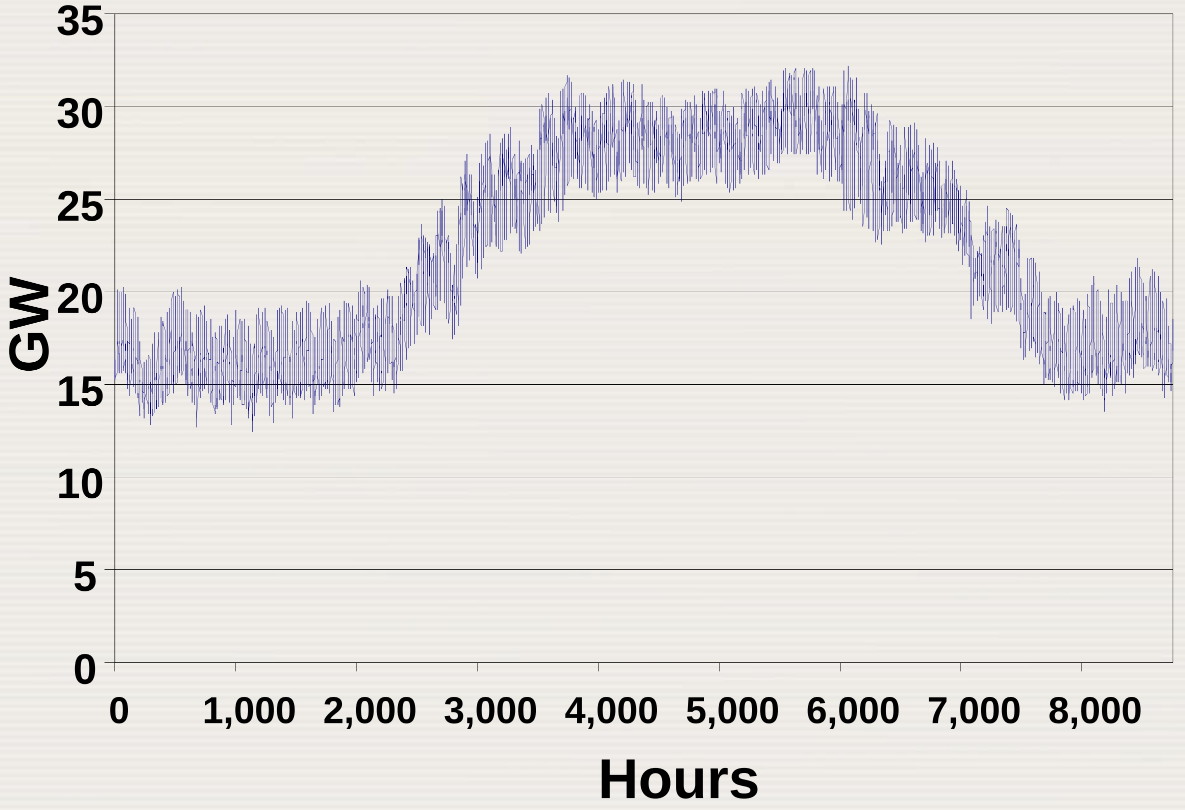


Energy planning and nuclear power



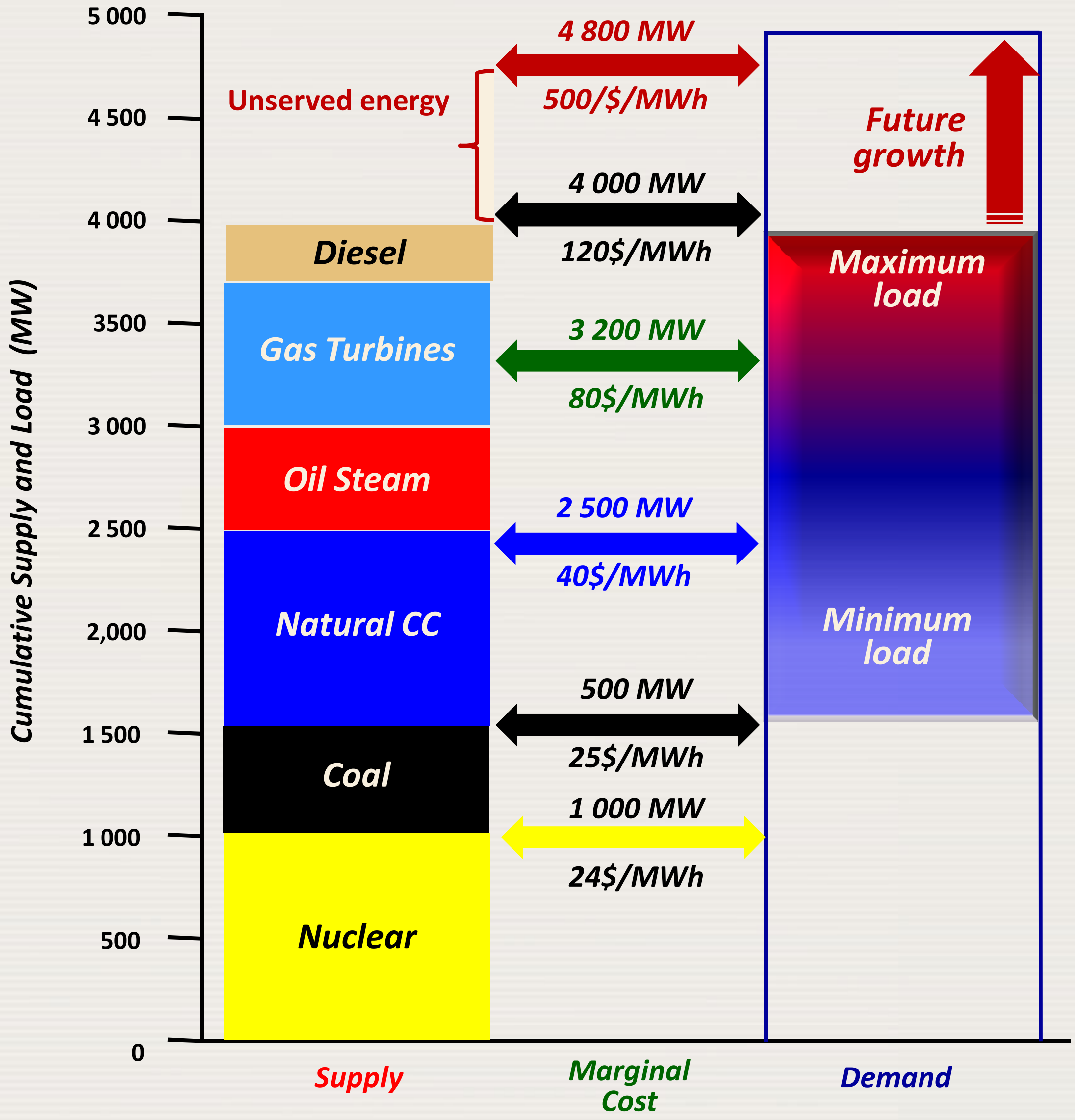
Load curves

- **For each *load region* already specified:**
  - **Variation of demand for certain fuels within a year**
  - **e.g. Electricity, heat, natural gas**

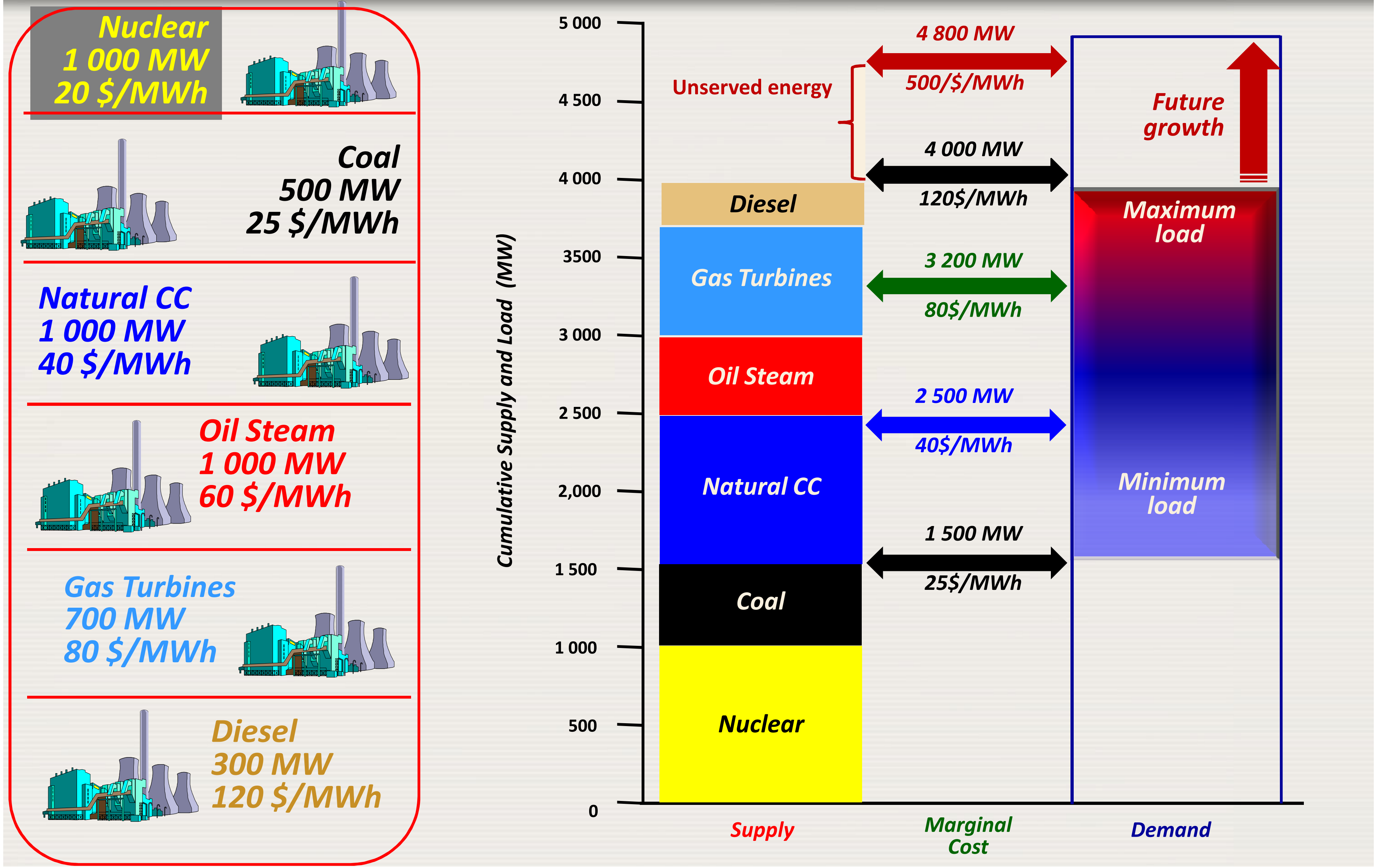


Dispatchable sources must respond to changes in load and variable output from intermittent technologies

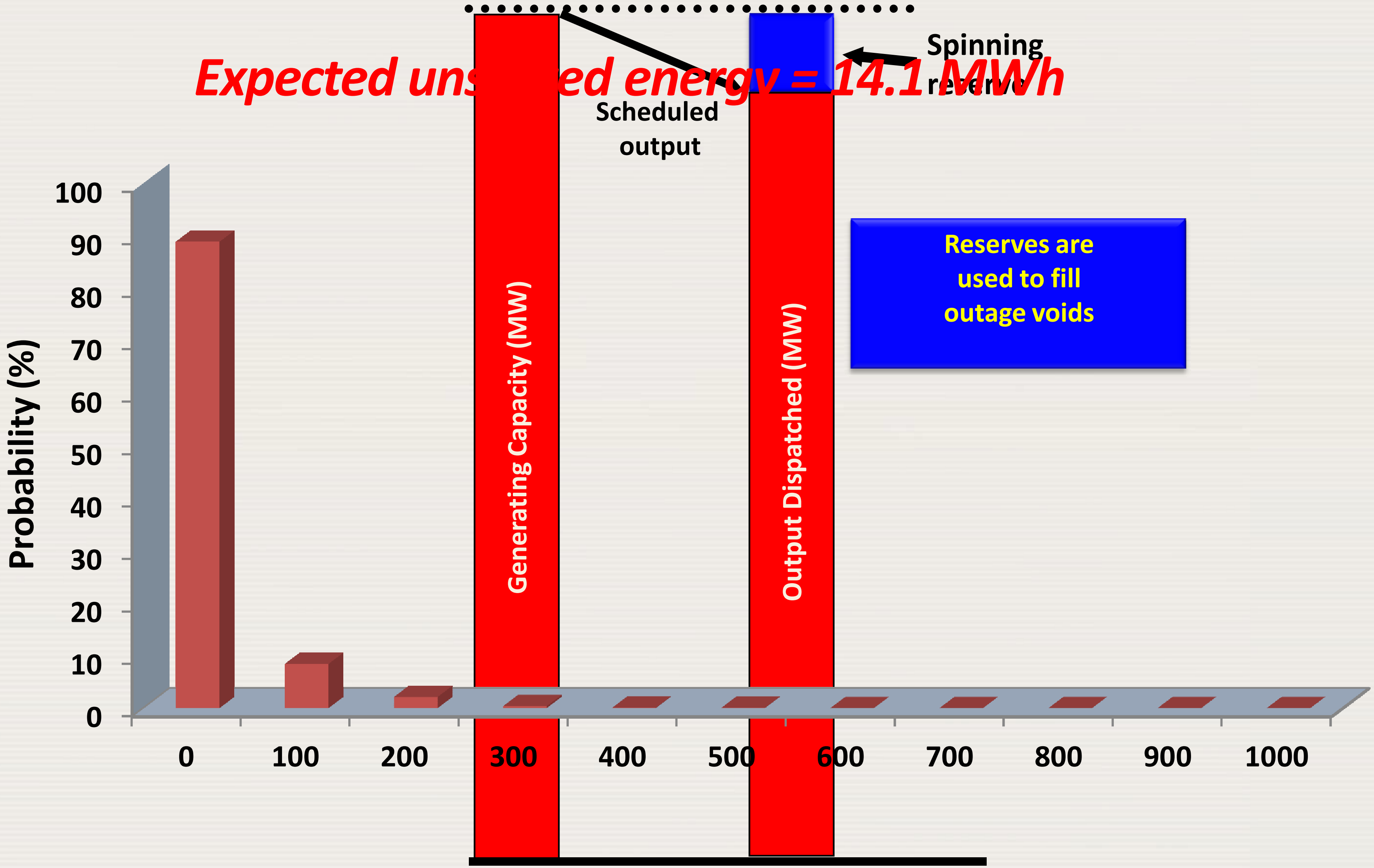
- Merit order dispatch
- Outages
  - Scheduled maintenance
  - Random events
- Reliability measures
  - Loss of load probability
  - Expected unserved energy
- Production and marginal costs
  - Probability distributions
- Ancillary services
  - Spinning reserves
- Cost of reliability



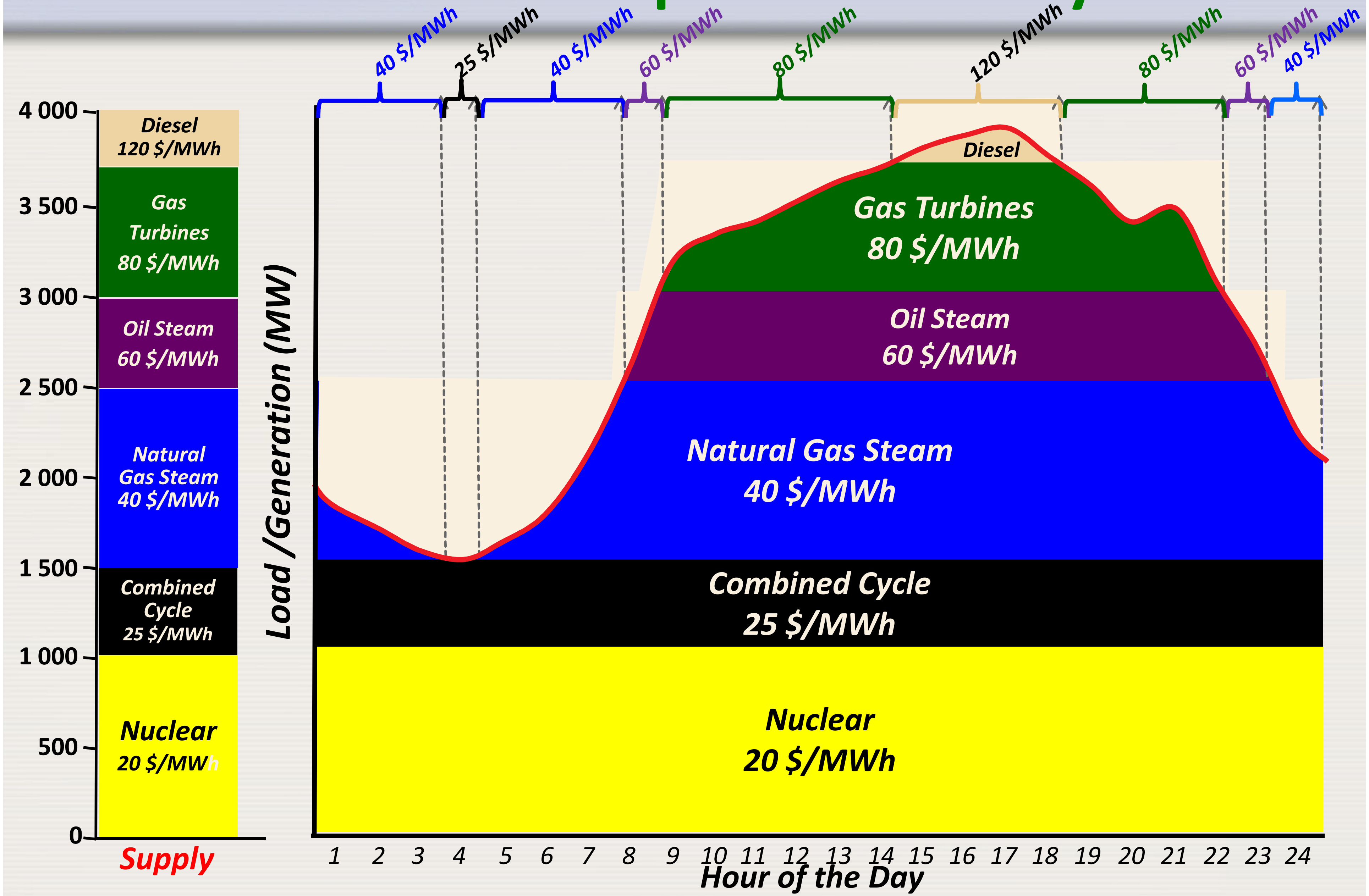
Power system operations and pricing: resource stack and least cost dispatch *Units are loaded into the grid based on generation costs (1 hour)*



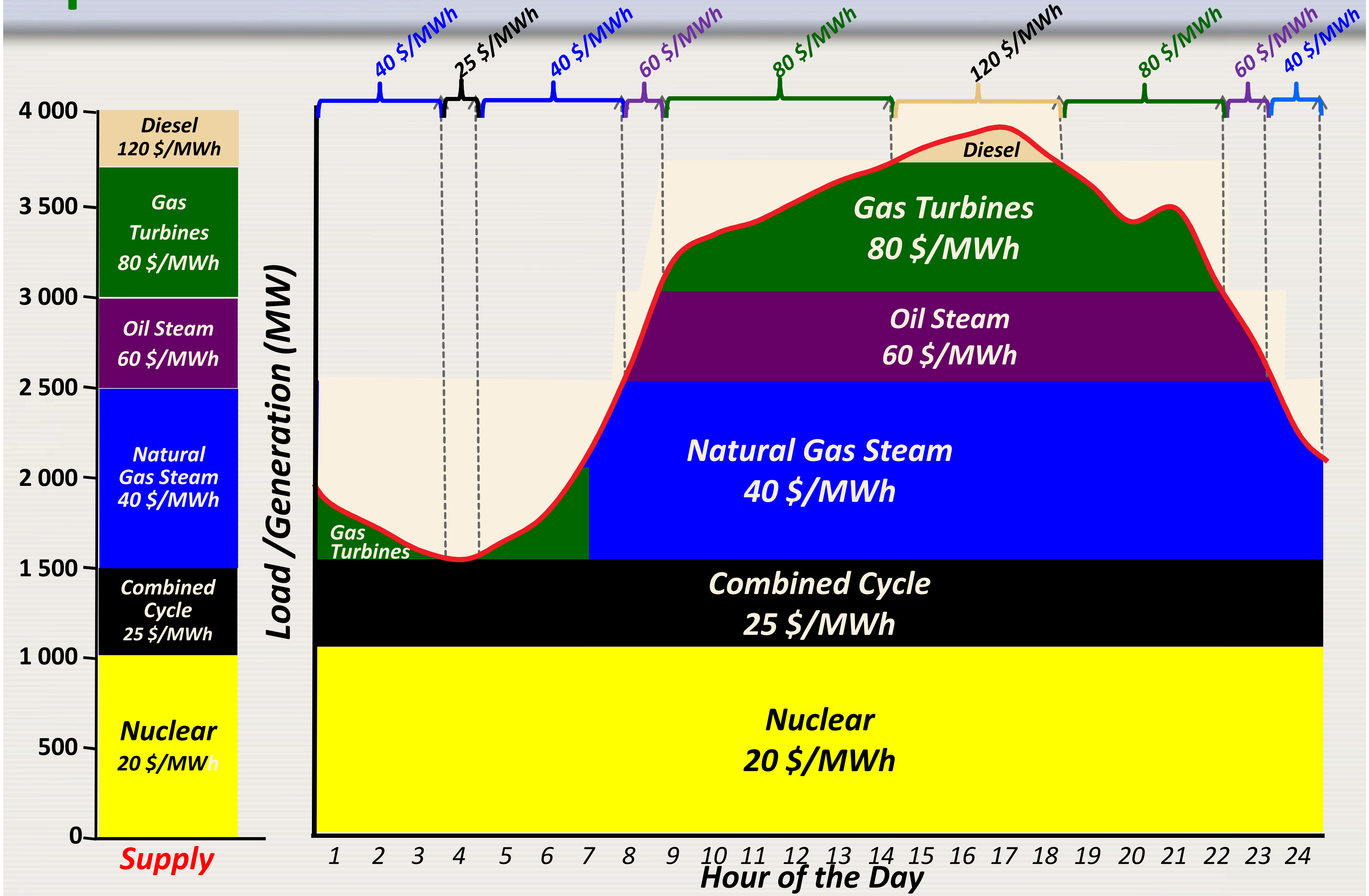
Spinning reserve & unserved energy



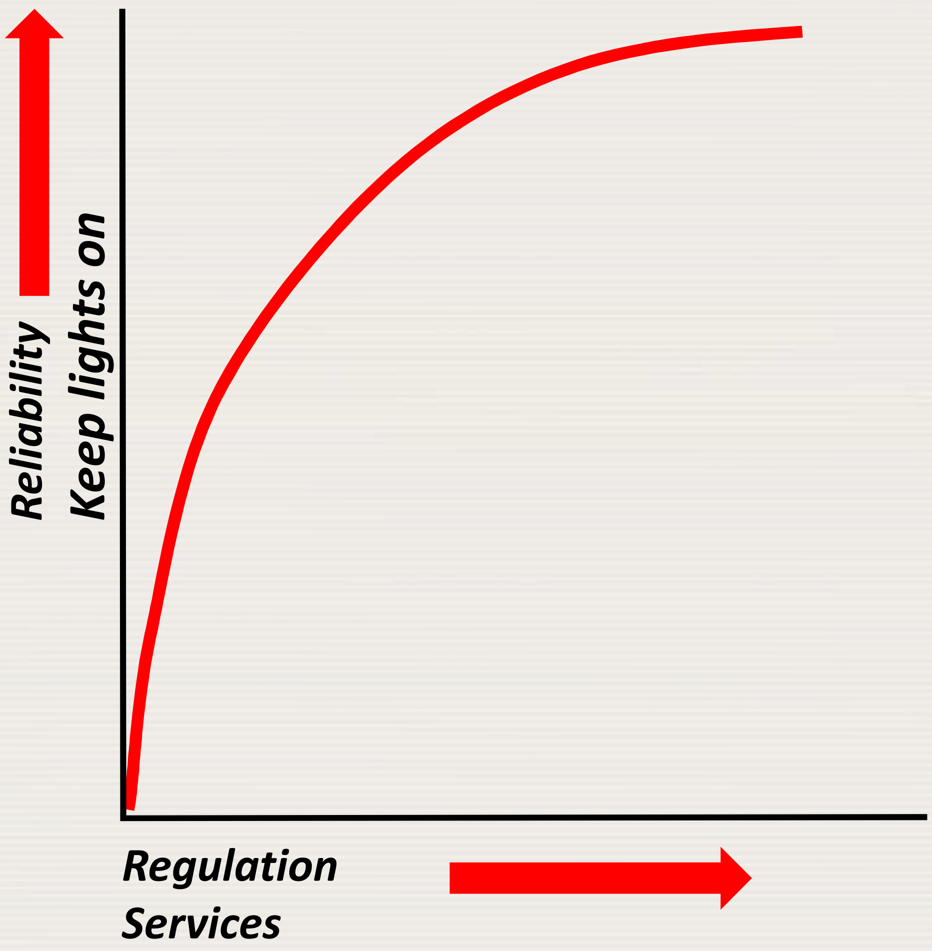
Electricity system operations and pricing: resource stack and dispatch – Full day

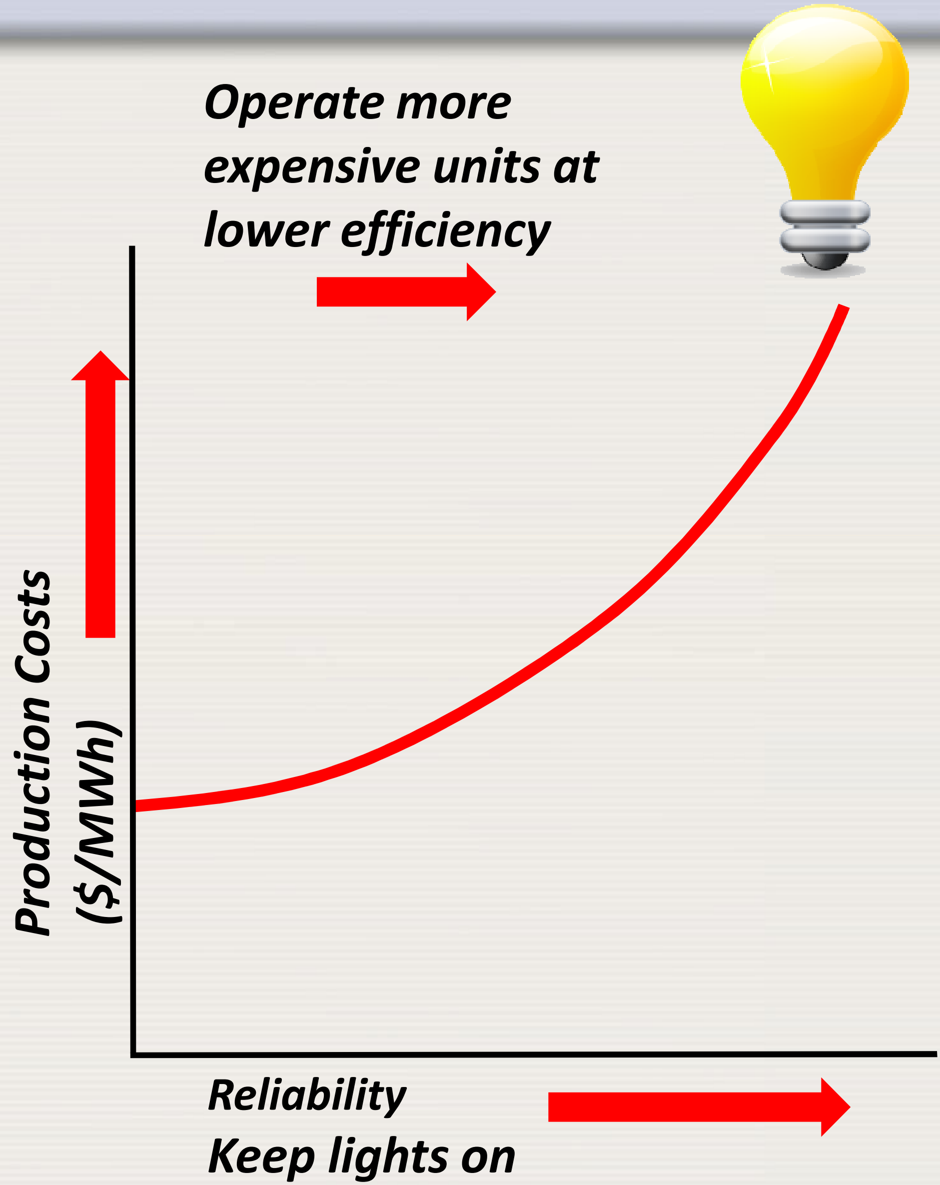


A steam plant may not have the flexibility to operate at a low level

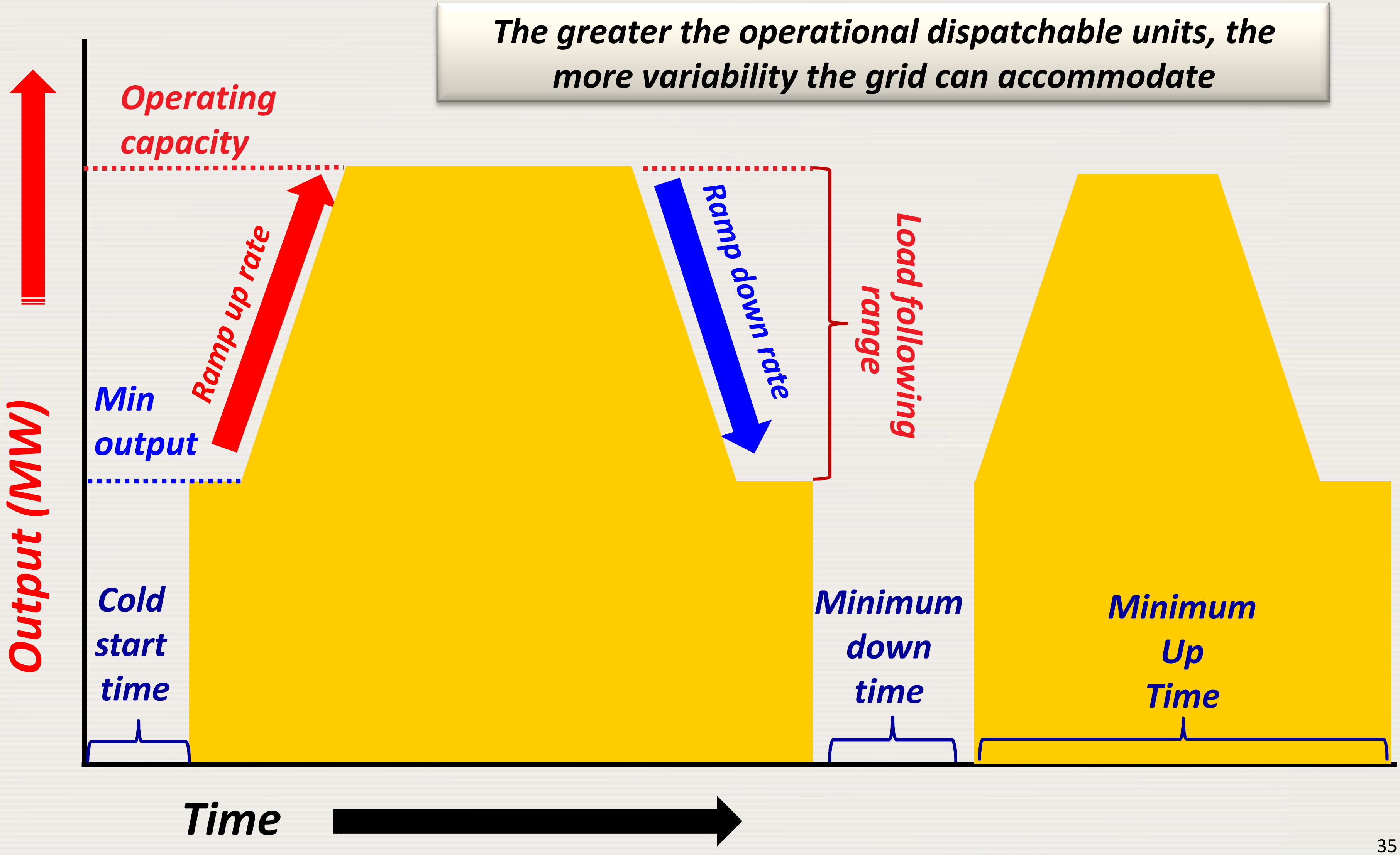


Reliability increases as more regulation services are added but higher reliability is increasingly more expensive

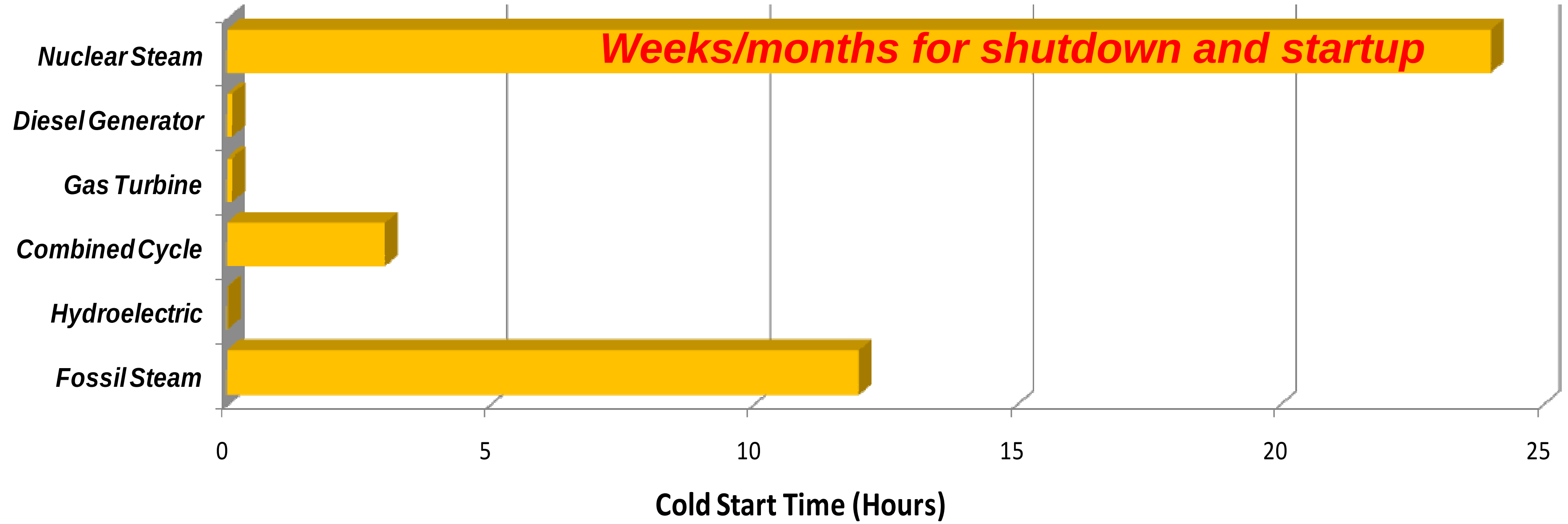


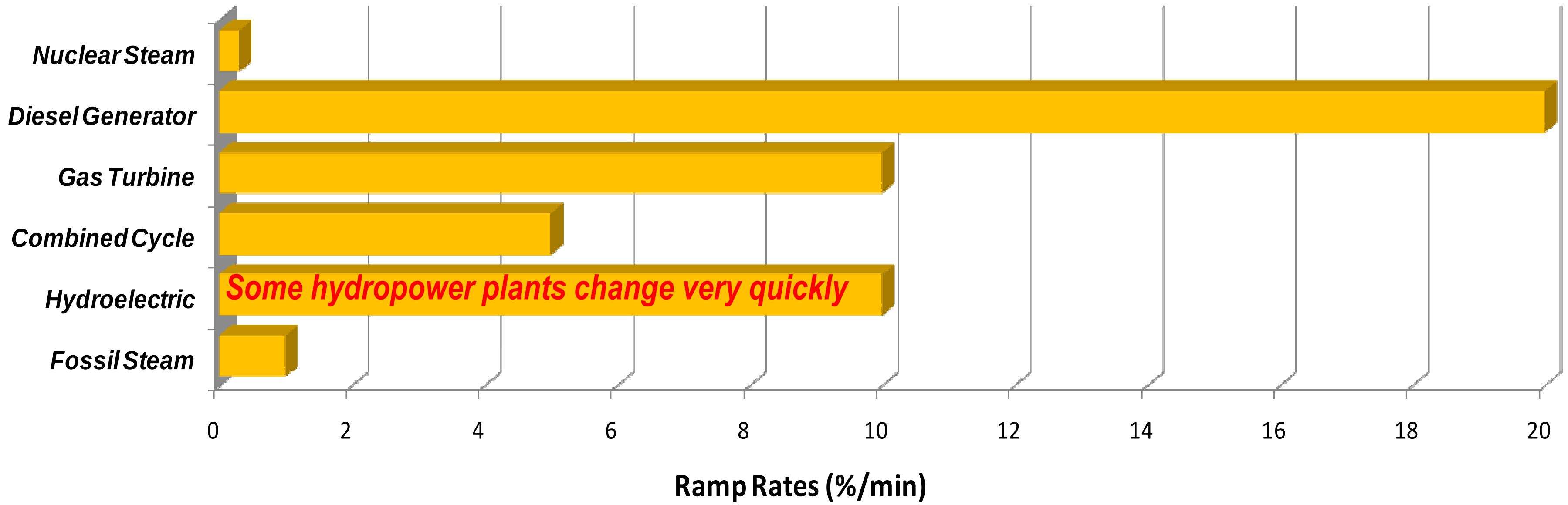


Electricity system operation and pricing: Changing thermal unit production levels

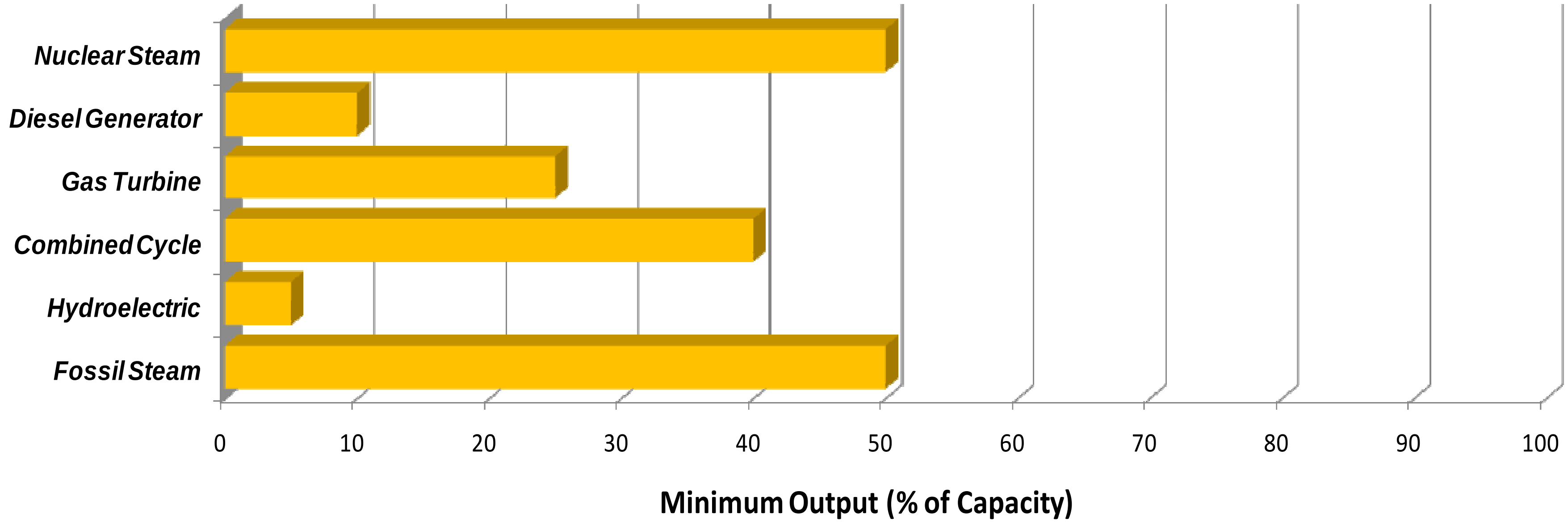


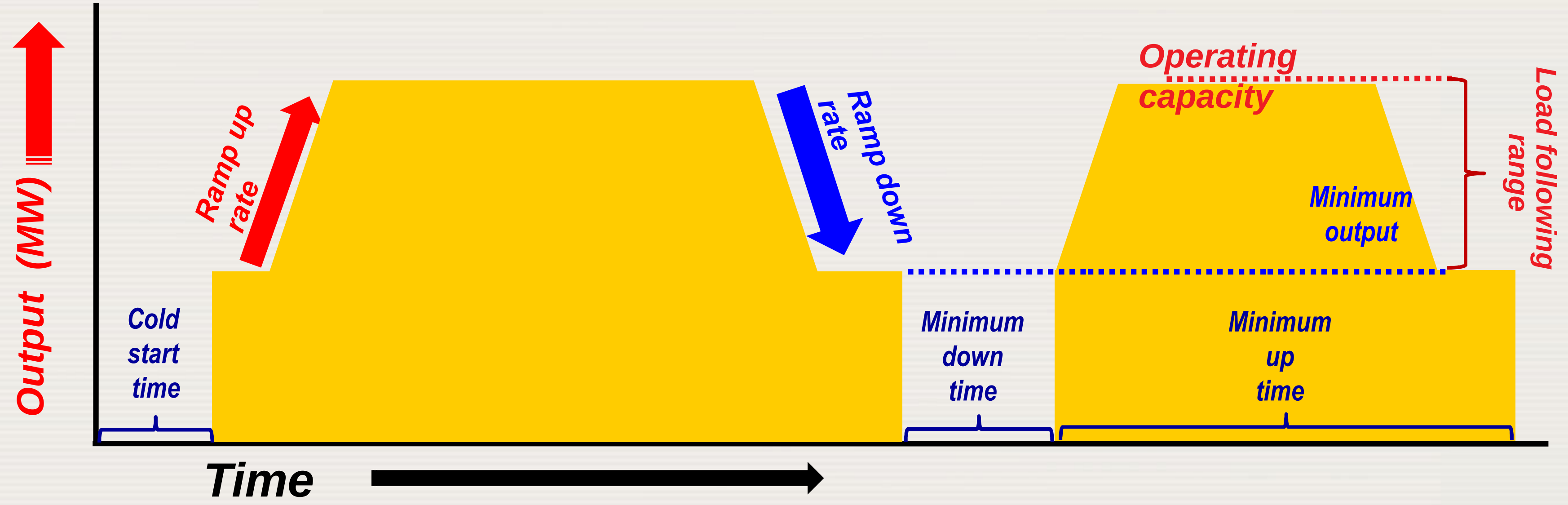
Some technologies are able to come on-line quickly to respond to rapid load changes while others are less flexible





The load following range is restricted by the output minimum and generation capacity





Energy planning

The IAEA analysis & planning tools

Why is IAEA involved in system energy planning?

- **Many developing countries lack the capability and/or capacity for integrated resource planning**
- **Sequential stop-gap measures instead of long-term development planning**
- **Only UN organization which is promoting energy planning and assists Member States since the mid-1970s**

The objective is to build planning capacity, especially in developing countries

Energy analysis and planning tools – the models

- **An model is an abstraction of the real world a system**
- **A typical "energy systems model" will relate techno-physical aspects of the energy system *such as:***
  - ***type of energy technology (e.g. gas CCGT, wind, nuclear power, coal with CCS, demand side efficiency, etc.)***
  - ***extent of that installation (MWs) timelines as of when the installation operates***
  - ***level of activity,***
  - ***etc***

to attributes *such as:*

- ***levelized costs & system costs***
- ***investment requirements and finance***
- ***environmental compatibility***
- ***cconomic impacts***
- ***system reliability (flexibility, robustness)***