The Abdus Salam International Centre for Theoretical Physics

United Nations Educational, Scientific and Cultural Organization

IAEA International Atomic Energy Agency

2257-16

Joint ICTP-IAEA School of Nuclear Energy Management

8 - 26 August 2011

Strategic Energy Investments

A.I. Jalal

IAEA, Vienna
Austria

M.I. Howells

Royal Institute of Technology, Stockholm
Sweden

Strada Costiera 11, 34151 Trieste, Italy - Tel.+39 040 2240 111; Fax +39 040 224 163 - sci_info@ictp.it

Strategic Energy Investments

Mark Howells
*mark.howells@energy.kth.se
Professor and head of division: **Energy Systems Analysis**
Royal Institute of Technology, Sweden

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Outline

- Introduction
- What is a levelised cost?
- Why levelise?
- Basic engineering economics:
  - Time value of money
  - Discount rate
  - Generation costs (Capital and production)
  - Levelised costs
- Case studies
  - Setting up a screening curve
  - Comparing options
  - Questions
- Conclusions

Introduction: Strategic energy investments

- Different actors have different objectives
  - Energy supply security
  - Maximizing profits
  - Increasing market share
  - Environmental compatibility
  - Etc..
- There are complex systems models which can represent various aspects of the energy system
- There are various complex financing models to figure how to manage risks
- Key to all, and the focus of our limited time today: How much does it cost?
- The focus is comparing discrete single investments over their life time using a single indicator, namely the “Levelised cost” of production

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What is a levelised cost?

- The concepts and methodologies of cost levelization assume that the life-cycle present worth value of all **revenues** produced by the electricity generated (per kW.h) **equals** the present worth value of all **expenditures** incurred in the implementation and operation of the plant
- Levelised cost calculations can be made with **increasing sophistication** to meet additional operating constraints and to simulate reality more closely. Nevertheless they can never replace detailed systems plus financial analysis or be used as stand-alone basis for business plans.
- The levelised cost employs techniques, methodologies and conventions applicable for the purpose of comparative evaluation of future plant (supply-side) and demand response (demand-side) alternatives. The results of such analyses are intended for **economic indications only**. The resultant levelised costs do not reflect the “embedded” costs of the system and are not intended for use in terms of absolute values, for setting tariff
- Methods for simplified comparisons between alternative generating units using lifetime levelized cost are presented as derived from basic concepts of **engineering economics**. In this it is important to differentiate between concepts considered strictly financial and basic engineering economics (For example, financial considerations such as, special discounts, tax, etc. are not addressed unless explicitly stated. If these were to be considered it could very well change the ranking of the options analyzed in an economic evaluation)

What is a levelised cost?

- The **“levelised” capital investment** cost is that portion of per-unit-of-electricity cost incurred over the life of the plant, when discounted and summed, yields the total PV cost of the capital invested.
  - It is **calculated** by dividing the discounted capital cost by the discounted production of electricity over the life of the plant.
  - Note that this is a function of the **load factor** of the power plant.
  - It is often the case that the capital investment cost applies not to a single generating unit but to **a number of units** built collectively to form a power station. The capital is phased over a time period consistent with a phased increase in capacity until all the units are brought into commercial service. When calculating a phased capital expense it is necessary to apply some convention in order to “lock down” a reference point. Phased capex on either side of this reference is either escalated or discounted to this point and summed to obtain a PV cost of capex at the reference point. Thereafter this PV cost is levelised i.e. annualized by dividing the total discounted capex flows expended by the total discounted capacity flows.

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What is a levelised cost?

- Simply put the levelised **production costs** are the annual fixed and variable costs of production of the plant
  - However, when coupled with different annual costs and production levels taken over the future life of the plant it is calculated as the total discounted annual production cost flows divided by the total discounted annual production flows and separated into the respective fixed and variable cost portions
  - It is important to note that this methodology is not intended to be used to reflect isolated years taken out of context of the life-cycle continuum.

Why levelise?

- Electric generation **production costs typically vary** from year to year often in a highly irregular fashion depending on prevailing economic conditions and the specific characteristics of the operating utility
- In addition to the changing production costs over time, the **kilowatt-hours of electricity generated also vary** from year to year owing to factors such as hydrological conditions, scheduled & unscheduled maintenance and varying load patterns
- These year-to-year variations in costs and electrical generation cause the power generation cost (expressed in mills per kilowatt-hour of net electricity produced) to vary from year to year, making cost **comparisons between generation alternatives difficult**
- Performance parameters are projected values. They only become known as fact once they are actually incurred. They are therefore subject to extreme **uncertainty** and irregularity

Basic concepts of Engineering Economics

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- The relationship between time and money is affected in the main by:
  - **Inflation** (or deflation) which changes the buying power of money, where the term inflation is defined as the increase in prices for a basket of goods and services usually expressed on an annual basis.
  - The value given to possession of money now rather than later, since the former allows the money to be invested for an interval of time to earn a **real return**
- The mathematical process by which different monetary amounts are moved either forward or backward to a common point in time is called **present value or present worth analysis**
- Common terms used in present worth analysis include:
  - **Interest**, which generally refers to the return earned by the productive investment of capital. The interest rate is defined as the ratio between interest chargeable (or payable) at the end of a period of time to the money owed (or invested) at the beginning of the period;
  - **Compounding**, which corresponds to the process of moving money forward in time;
  - **Discounting**, which corresponds to the process of moving money backward in time.
  - A study that includes the effects of inflation, such that monetary values are expressed in terms of actual prices of each year, is defined in terms of **current (or nominal)** monetary amounts, while a study that excludes the effects of inflation such that monetary values are expressed in terms of general purchasing power in a base year is defined in terms of **constant (or real)** monetary amounts.

Basic concepts of Engineering Economics

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- **Discount Rate** - Annual factor that accounts for the time value of money independently of inflation. The discount rate selected is important, sensitive, difficult and uncertain
  - Important because it has to be known in order to **compare sums of money** spent at different times.
  - Sensitive because the **economics of a project** will depend very much on the selected value.
  - Difficult if one finds that selecting the average cost of capital as the discount rate does not perfectly reflect the reality faced and especially in view of the **long lead-times** of the options under review for selection.
  - **Uncertain** - Because of the time factor it is likely that the discount rate will be changed many times throughout the product life-cycle. E.g. at the point of decision the discount rate may be a certain value but when actually built and earning revenue it may be a completely different value, so much so that were this known by the utility at the time of the decision another option may very well have been selected.

Basic concepts of Engineering Economics

- **Discount Rate** - notes
  - In the case of a publicly owned tax-exempt utility that meets its investment needs by borrowing on a capital market where funds are available without limitation at a constant interest rate, the discount rate is equal to the interest rate prevailing on the market. This situation rarely occurs in the real world. From a more realistic viewpoint, state-owned utilities use a discount rate suggested or imposed by the economic planning authorities that (ideally) should reflect the **cost of capital in the national economy**
  - Different but no less complex problems arise in the determination of a suitable discount rate for a **privately owned tax-paying electric utility** whose capital needs are met by a combination of bond and stock financing in a proportion fixed by regulation or custom. In such cases, the rate at which expenditures and revenues must be discounted through time must be determined on a **case-by-case basis** and will involve the proportion of bond to stock financing as well as the income tax rate on gross profits
  - Some entities use the weighted cost of capital (**WACC**) as reflective of the discount rate. The WACC is also often calculated using Capital Asset Pricing Models (**CAPM**). CAPM's are subjective and open to interpretation. There are also several factors used in CAPM models which individually may have a low band of uncertainty but when used together can have high impact on the outcome of the calculation of the WACC

Basic concepts of Engineering Economics

- The **capital cost** to build the facility including plant refurbishment costs and the back-end or de-commissioning cost at the end of its life (including spent fuel storage, waste management, transport, fuel reprocessing, environmental policy requirements etc.). These costs are not defined as annual costs but are invariably incurred over a phased period of time before, during or after the operational period of the plant.
- **"Overnight" construction costs** refer to the instantaneous cost of construction & exclude interest incurred during construction (IDC) and cost price adjustments (CPA)
  - IDC reflects the accumulated money disbursed by a utility to pay off interest on the capital invested in the plant during construction.
  - CPA or economic price adjustment (EPA) implies a provision in a contract document for upward or downward revision of specified prices, if and when certain conditions (such as inflation or deflation) occur.
- Note, that the values you get from the literature are often '**back calculated**'
  - Normally financial and accounting practice, include IDC and CPA. Therefore calculations are needed to derive (estimate) an "overnight" value often from nominal values of projects already completed or visa versa for new projects.

Basic concepts of Engineering Economics

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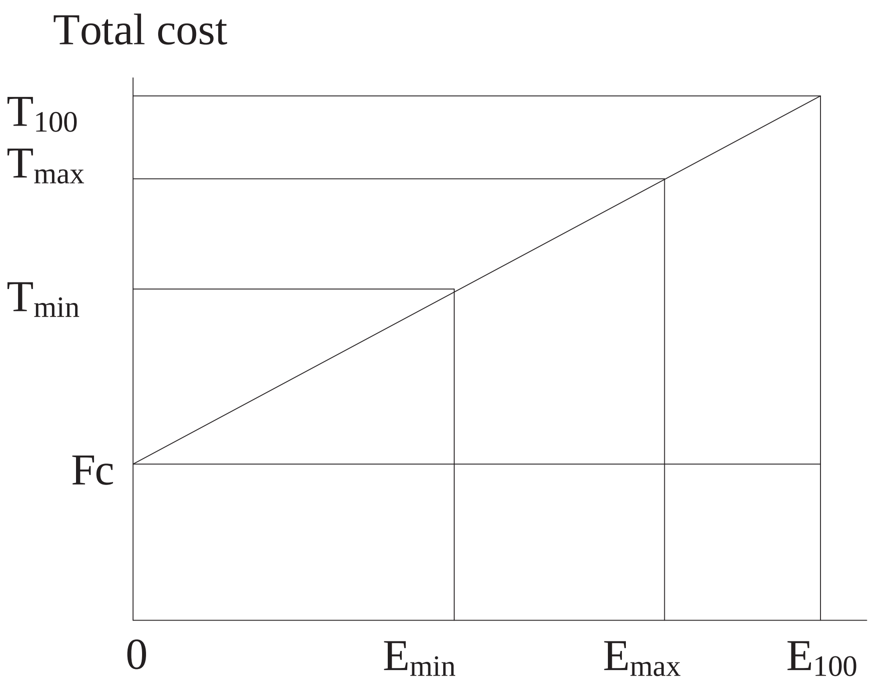
- **Phasing** of capital investment cost:
  - The overnight capital cost must be phased in an expenditure pattern;
  - A challenge arises when using an overnight cost to reference similar new build plant options but with different phasing of expenditure patterns and different values for inflation to the IDC and CPA indices used in the original determination;
  - This is exacerbated when dealing with plant with long construction lead times;
  - It is also expedient to define the capital investment cost in terms of a “station” related cost and a “unit” related cost in a multi-unit station.
- **Gross versus net** capacity:
  - In electrical terms, what is measured and sold is the net (bus bar) electrical power sent out to the transmission grid. As such a distinction is made between “installed” power plant capacity, this being the gross capacity of the plant and the net “sent-out” capacity which is the installed capacity reduced by the “house load” or “own auxiliary” requirement.
  - Electric power costs reported in literature often refer to the unit output capacity as a function of cost such as in $/kW. For comparative or analysis purposes, it is necessary to know whether the electric power capacity is calculated in terms of the gross or net output. We'll use net.
- The inclusion or otherwise of **transmission and distribution** cost and performance parameters

Basic concepts of Engineering Economics

- **Production costs** to operate the facility. These costs are normally given annually and comprise the annual cost to operate & maintain (O&M) the power plant and the annual fuel costs. Capital can also be expended in terms of these costs. This capital can either be annualized and added to the annual production costs or be included separately under the capital costs together with an explicit phasing of expenditure. Where applicable, special savings schemes can be designed "upfront" towards addressing some of the **back-end requirements**. These savings can be made either in terms of a phased capital expense or calculated on an annual basis and added to the annual production.
- The total cost of production is the sum of the variable & fixed cost-components incurred during production.
  - The **fixed costs** of production are independent of variations in output for the system under consideration. They include aspects of the costs of *labour, material, maintenance, technical, services & laboratory expenses, taxes and insurance, plant overheads and administration* which are independent of the volume of the production and stay the same over the defined period (planning horizon) of activity under review.
  - The **variable costs** of production are those processing costs which vary with plant output whether considered in the short-, medium- or long-term. These can include aspects of *the costs of labour, material, maintenance, technical, services & laboratory expenses, taxes and insurance, various plant overheads and administration* that change according to the change in the volume of the production unit.

Basic concepts of Engineering Economics



- *Convention - Linear representation of the costs of production*
- *The costs reflected are only valid in the range Minimum to Maximum i.e. Emin to EMax:*
- *Variable cost:*

Vc={Tmax –Tmin}/{Emax – Emin}

- *Fixed cost*

Fc={Tmin*Emax –Tmax*Emin}/{Emax – Emin}

- *Total cost of production at the (theoretically maximum output)*

T100 = Vc*E100 +Fc

Basic concepts of Engineering Economics

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Some notes on levelised cost use and derivation

- The methodology employs a **linear distribution** of costs between two (or more) levels of production. To obtain more accurate results smaller increments between the levels of production would need to be selected.
- Selecting different **operating conditions** may result in very different cost parameterisation. Consider for example a peaking plant operating as baseload versus, servicing the reserve only.
- The **net discount rate** can have an impact on the outcome of the fixed and variable component costs of production. The extent of the impact of changes to the net discount rate is a function of the extent of the differences in the levels of production and costs in each of the years over the economic life.
- Using present worth analysis techniques it is possible to develop values for production costs which can be used in optimization and **model analyses** to compare future cash outflows of competing options (including existing options) which would result in the optimal operation of these plant in the near-term taking into account the future anticipated operating expenses incurred in the long-term.

Basic concepts of Engineering Economics

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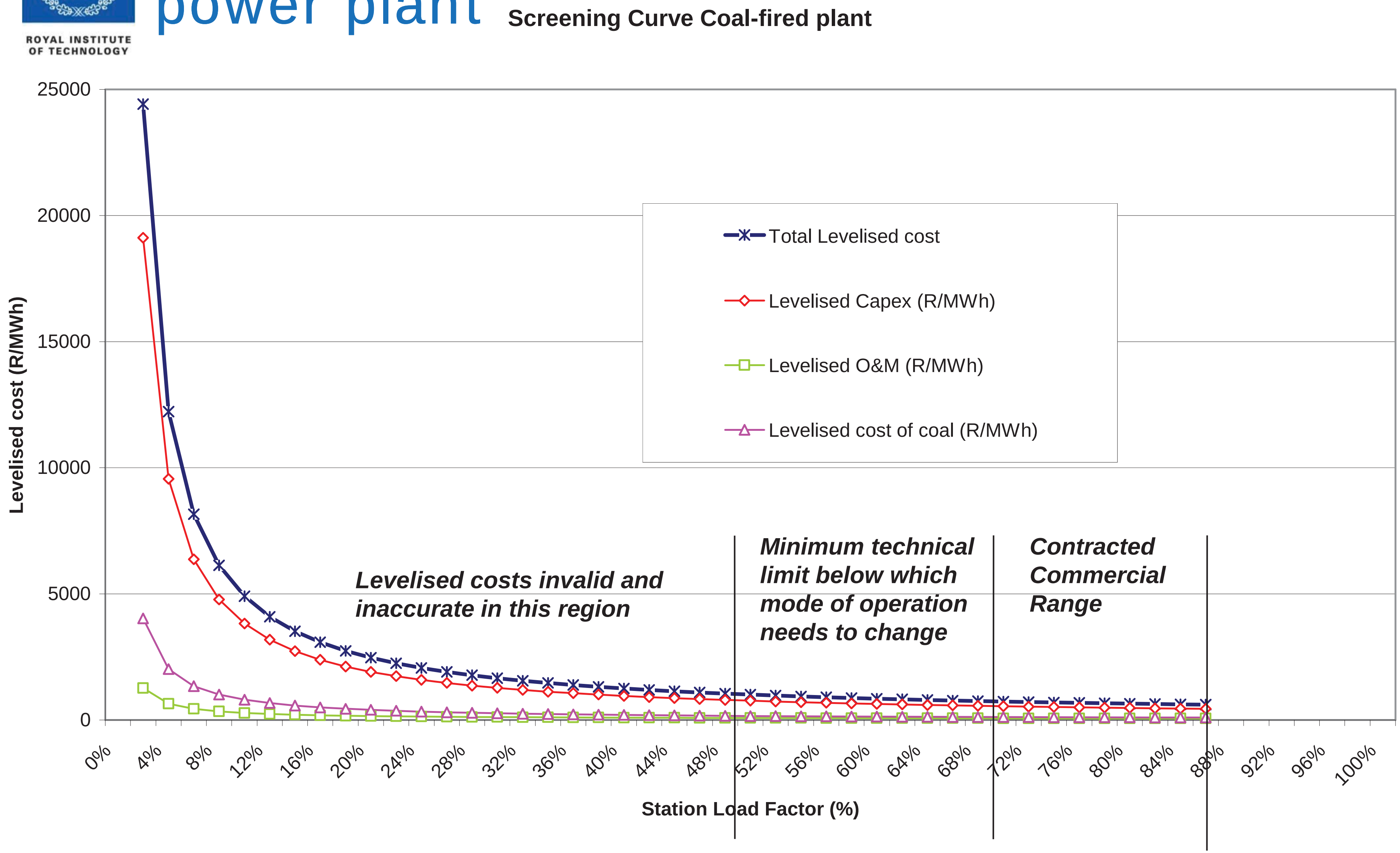
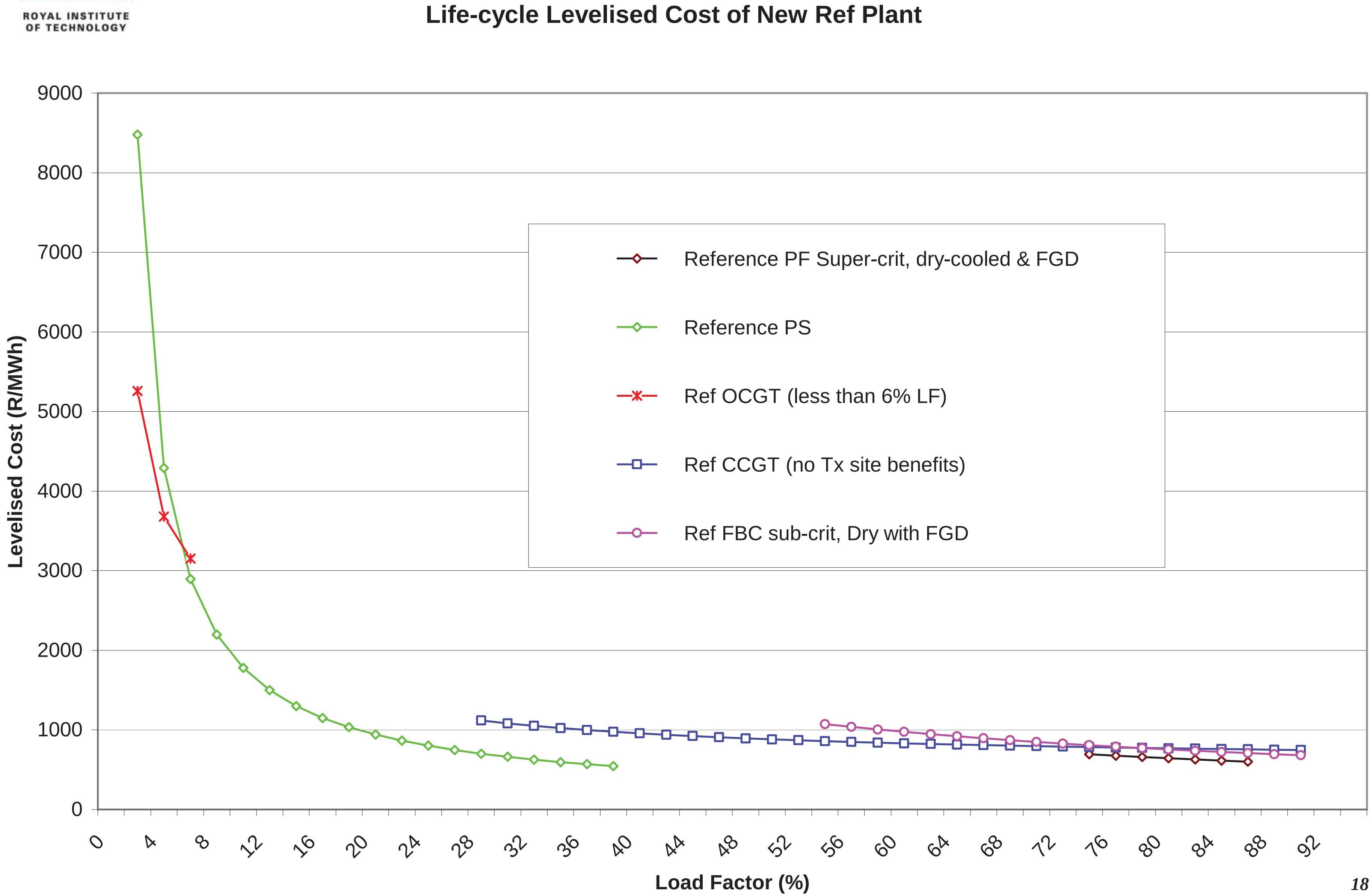
- The life cycle levelised cost to build and operate plant when operating at a different load factors can be calculated (assuming the plant operates at these specified production levels over its entire life). An aggregation of such levelised costs across a range of production levels constitutes a "**screening curve**"
- Screening curves provide a simplistic methodology for **eliminating** from further consideration those new supply-side and demand-side alternatives which are significantly less economic for selection into a generating system. A screening curve methodology only provides rough approximations and is not appropriate for evaluations requiring reasonable accuracy. In the main they are used to:
  - Screen out options with obvious high economic cost.
  - Distinguish possible dispatch order in the modeling problem
  - Test the validity of the model outputs at certain stages of expansion
- They are not intended for use in setting **electricity tariffs**. They cannot determine the level of production of any specific plant during system production
- They indicate a **minimum hurdle rate** (price of generating electricity from the specific plant over the defined operating range) which requires to be met were this plant to be operated at this level over its entire life
- A screening curve only takes into consideration the individual generation cost of the specific technology option under review. **Other system costs** including other generation options making up the system as well as transmission and overheads are not considered

Example: Screening curves data for a coal power plant



Example: Screening curves data several power plants



Case Studies: comparing options

		Oil	Gas	Nuclear	Coal	CSP	Wind
Lifetime	yrs	25	25	50	35	25	25
Overnight cost	$/kW	400	750	4500	2000	3785	1200
Station size	MW	250	750	1200	1000	500	200
Build profile	-10			10%			
	-9			10%			
	-8			10%			
	-7			10%			
	-6			10%			
	-5			10%	20%	20%	
	-4			10%	20%	20%	
	-3		33%	10%	20%	20%	
	-2		33%	10%	20%	20%	50%
	-1	100%	33%	10%	20%	20%	50%
Fixed cost	$/kW	7	3	2	5	10	10
Variable cost	$/kW-yr	100	75	40	140	140	40
Efficiency	%	35%	45%	35%	40%	100%	100%
Fuel cost	$/kW	250	200	5	126	0	0
Emission factor	ton/kW	6	6	0	9	0	0
Discount rate	%	8%					
Emissions penalty	($/ton)	10					

Setting up a screening curve

- **Consider the period of the analysis**
  - -10 to +50 years
  - Electricity production is to start at the beginning of year 0
  - Determine the 'discount factor' for each year
    - $1/(1+DR)^{Yr}$ for money withdrawn at the start of the year
    - $1/(1+DR)^{Yr+0.5}$ for money withdrawn throughout the year
- **Capital cost**
  - Multiply the capital cost by the station size
  - Distribute the overnight cost during the years -10 to 0
  - Multiply the overnight cost by the appropriate discount factor to get the present worth of the capital cost (and sum this)
- **Fixed cost**
  - For plant life determine the annual fixed cost (Capacity * fixed cost)
  - Multiply the expenditure by the appropriate discount factor to get the present worth of the fixed O&M cost (and sum this)

Setting up a screening curve

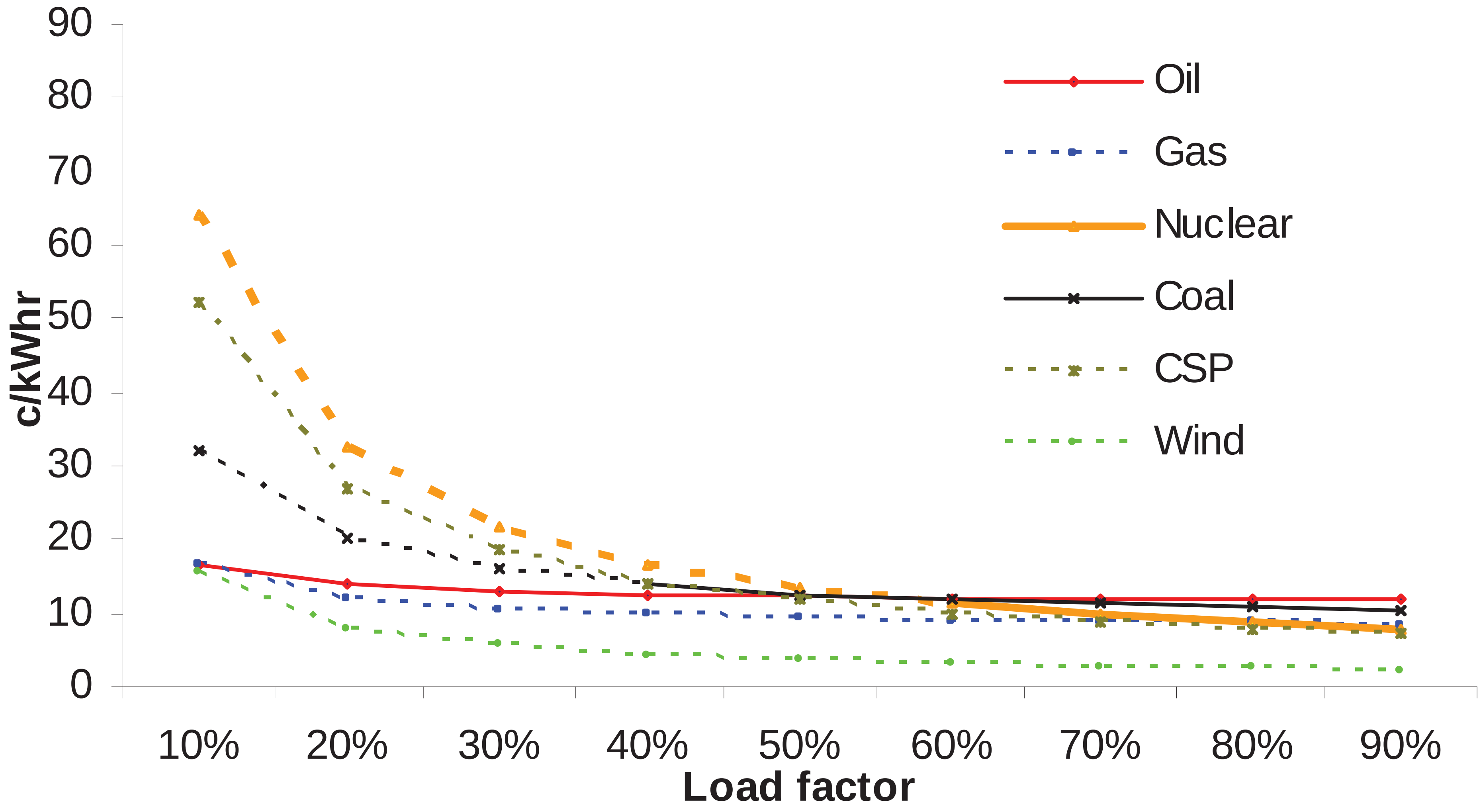
- **Determine production**
  - Choose a **load factor (LF)**
  - Determine the power output
  - Electricity production is to start at the beginning of year 0 for the life of the plant
  - Determine the ‘discount factor’ for each year
  - Multiply the production by the appropriate discount factor to get the ‘present worth’ (and sum this)
- **Variable cost**
  - Multiply the production by the variable cost
  - Determine the ‘discount factor’ for each year
  - Multiply the variable cost by the appropriate discount factor to get the present worth (and sum this)
- **Fuel cost**
  - Divide the production by the efficiency to obtain the fuel use for each year
  - Multiply the fuel use by the fuel cost to determine the annual fuel cost
  - Multiply the expenditure by the appropriate discount factor to get the present worth of the fuel payment (and sum this)

Setting up a screening curve

- **Environmental costs**
  - Multiply the fuel use by the emission factor to get annual emissions
  - Multiply the emissions by the emissions penalty to determine its annual cost
  - Multiply the environmental penalty by the appropriate discount factor to get the present worth (and sum this)
- **Levelised costs**
  - Sum the present value of the : Capital, Fixed, Variable, Environmental costs
  - Divide this by the discounted production
  - You now have a “levelised cost” as a function of the load factor
- **Screening curve**
  - Determine the “levelised cost” for different load factors
  - Plot this and you have a ‘screening curve’

Case Studies: comparing options

8% Discount rate



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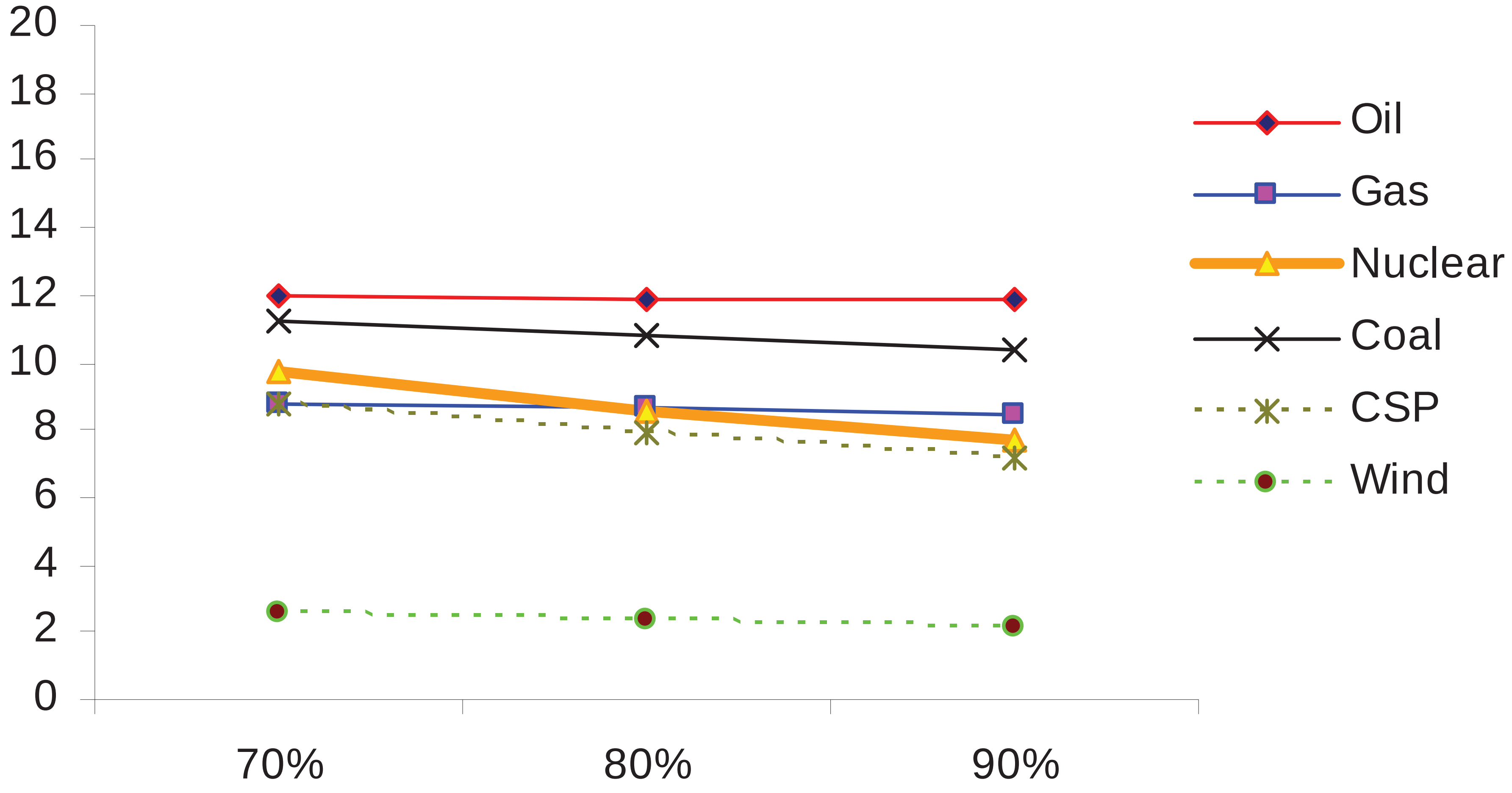
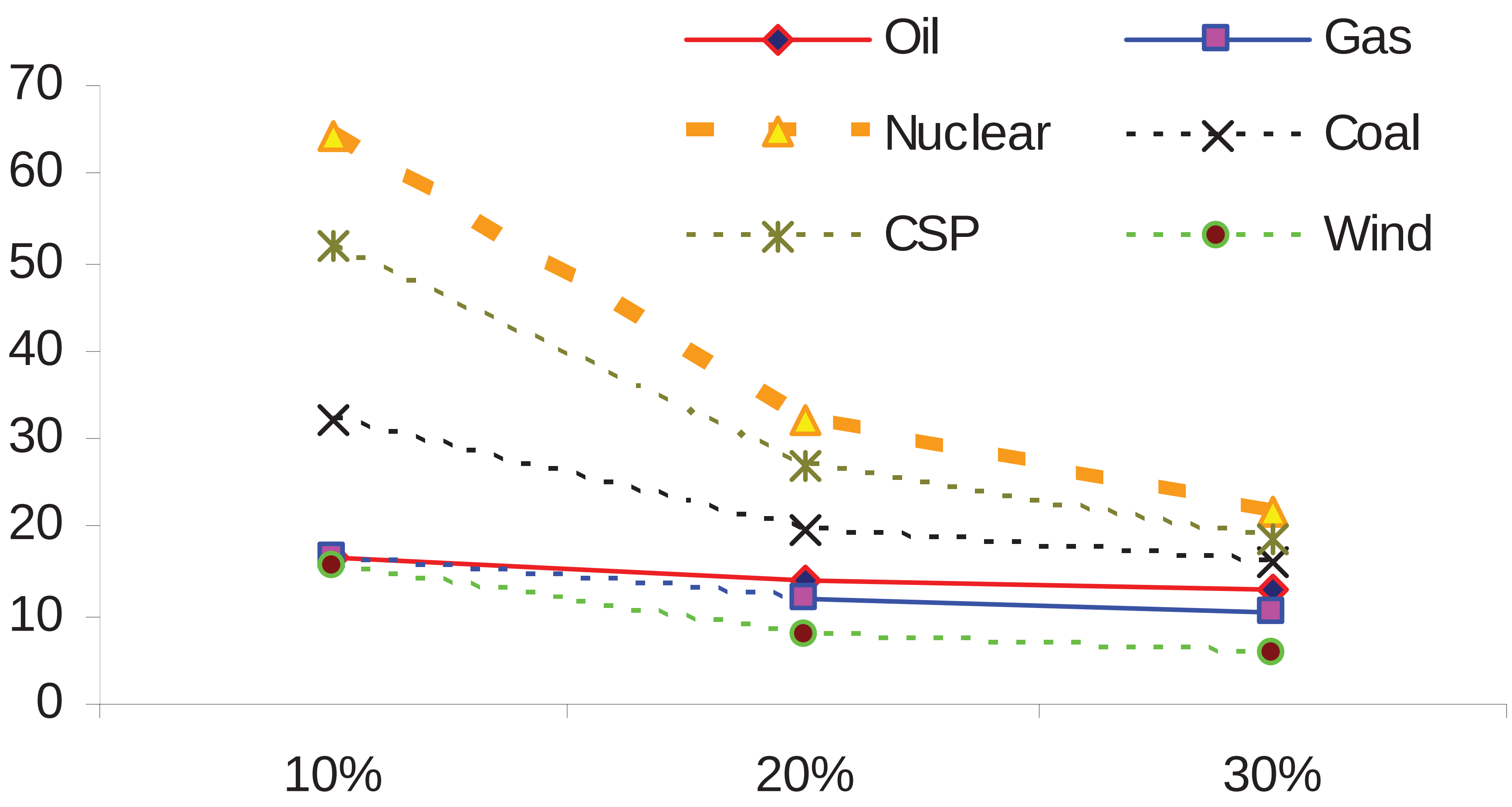
Case Studies: comparing options

(at a high load factor)



Case Studies: comparing options

(at a low load factor)



Case Studies

1) At a load factor of 70%, what NPP life time is required to make:

- More competitive than coal with a DR of 8%?
- More competitive than coal with a DR of 15%?

2) At a 70% load factor and assuming an equal annual capital expenditure - how much must the construction time for nuclear be reduced to compete with coal for a:

- DR of 10%...?

3) At a 70% load factor, and discount rate of 12% what carbon tax is required in order to make:

- Nuclear cheaper than coal?
- Nuclear cheaper than gas?

4) At a 90% load factor, 8% DR, what % gas price decrease is needed to make gas competitive with nuclear?

Case Studies

5) At a 90% load factor what discount rate does nuclear become more expensive than

- Coal?
- Gas?

6) Under what circumstances (discount rate and load factor) do the RE technologies compete with nuclear and why? What do RE and nuclear have in common?

7) What technologies are the best options to meet demand for electricity at peak times (i.e. low load factor) for a:

- 2% DR?
- 5% DR?
- 10% DR?

8) At what efficiency (Coal PP) change is required for coal to compete with nuclear at a 90% load factor?

9) At what % nuclear fuel price increase must occur before it is more expensive than gas or coal at a 90% load factor?

Selected shortcomings of a screening curve approach

- Intermittency is not handled
- Determining plant load factors to meet a given demand cannot be done
- There is no representation of the quantity of electricity to be produced
- Data used is normally for specific ranges, those are not always clear
- Data and circumstance change over time