# 3. ECONOMICS AND COSTING

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# 3. ECONOMICS AND COSTING

## 3.1. INTRODUCTION

The multi-institutional Starlite Project [1] is the initial phase of a conceptual design of a demonstration (Demo) power plant, based on the tokamak approach to magnetic fusion and strongly coupled to commercial considerations. Together with public acceptance and regulatory simplicity, both deriving from favorable safety and environmental performance, satisfactorily competitive economics addresses a key Starlite requirement [1, 2] and provides an organizing nexus and object function for tokamak improvements. Key economic goals and requirements, as viewed by the power-producer community, are updated [3] in a broadened context of the fission industry [4,5], as well as fusion-specific recommendations of a Utility Advisory Committee [1]. Anticipation of future load growth, coupled with timely and optimal capacity addition, is the classic problem [6] of traditional utilities or other evolving power-producer entities, with societal penalties for both underbuilding or overbuilding [7].

Projections of future power plant costs are used in energy forecasting models [8] and, therefore, can influence public policy planning, which can affect the allocation and priorities within the portfolio of energy R&D funds. The R&D phase represents the investment of time and resources to develop information and expertise anticipated to facilitate the implementation of the optimal Demo at reduced uncertainty (*i.e.,* risk). While an integrated global economic/environmental modeling effort is beyond the scope of the Starlite Study, cooperation with such efforts [8] can better characterize the market penetration of fusion [9, 10], relative to its suitably characterized competitors [11]. All identified externalized adverse impacts of these technologies, as a matter of public policy, should be explicitly internalized as mitigating operating costs or tax disincentives [12,13]. In so doing, the case for projecting the successful Economics Demonstration element of the Starlite Mission [1] is established.

The timing of the introduction of fusion, subject to adjustment by the funding pace and technical successes/failures of the R&D effort [10], is calibrated here, but not conceptually restricted by, the most recent U.S. comprehensive planning document [14]. Following a ten-year construction lead-time, initial operation of the Demo was targeted for ∼2025, with the first commercial power plant (contingent upon a successful Demo) targeted for initial operation ∼2040.

While it may be possible to characterize energy options in terms of energetics and materials requirements [15] without explicit reference to the corresponding economics, a cost based framework is useful and consistent with systems engineering practice [16–18]. Cost optimization focuses the physics and engineering choices and trades made in the course of the Starlite study. Key cost drivers continue to be plant size, system power density, recirculating power fraction, use of expensive/exotic materials [19, 20], with increased attention to operational availability, as driven by unplanned and planned outages. In contrast to Cost of Electricity (COE) projections made historically for 10th-of-a-kind commercial power plants, specific considerations for a first-of-a-kind (FOAK) Demo include a possible longer construction lead time, the absence of learning-curve credits [21], higher contingency costs [22], and special arrangements consistent with a Demo-specific utility-government financial partnership to spread risk. As these Demo-specific considerations are worked out, a Demo cost summary can be derived from the corresponding commercial summary as needed.

The remainder of this section describes certain aspects of the expression defining the projected levelized Cost of Electricity in Sec. 3.2. The role of the projected plant capacity factor is discussed in Sec. 3.3. A preliminary target space for future fusion market penetration is established in Sec. 3.4. Conclusions of this reassessment of the Starlite costing methodology and context are summarized in Sec. 3.5.

## 3.2. COST MODEL

The present commercial power plant costing model [23] provides a point of departure for the Starlite study, as well as a opportunity to revisit and re-calibrate all features, as found to be appropriate. Development of the power plant cost summary of Table 3.2-I begins with the assessment of the direct costs, organized by a comprehensive Cost Breakdown Structure (CBS) [22, 23], resolved into sufficient levels of detail to adequately characterize the conceptual design. Each Direct Cost entry may be resolved into factory fabrication, site material, and site labor cost components. A suitable distinction between lower conventional unit costs and higher so-called nuclear-safety-grade ("N-stamped") unit costs, consistent with U.S. Code of Federal Regulations 10CFR50, Appendix B, and updating the application of Level of Safety Analysis (LSA) credits [23] is made.

Cost components are distinguished as "fixed" or "variable" w.r.t. the plant capacity factor, $p_f$ (see next section). At the retail level, fixed costs are associated with so-called demand charges and variable costs are associated with energy charges. At this

**Table 3.2-I.**
**Taxonomy of Fusion Demo Life-Cycle Costs**

| Cost Component | Type[a] |
|---|---|
| R&D Costs[b] | f |
| Capital Costs: | |
| Direct Costs[c] | f |
| Land and land rights | |
| Structures and improvements | |
| Reactor Plant Equipment (RPE) | |
| Reactor Equipment[d] | |
| Main heat transfer system | |
| Turbine Plant Equipment (TPE) | |
| Electric Plant Equipment (EPE) | |
| Miscellaneous Plant Equipment | |
| Heat rejection system | |
| Indirect Costs: | |
| Construction Services | f |
| Home Office Eng. & Serv. | f |
| Field Office Eng. & Serv. | f |
| Owner's Costs[e] | f |
| Project Contingency[f] | f |
| AFUDC[g] | f |
| Production Costs: | |
| Fuel (Deuterium) | v |
| Scheduled Component Replacement | v |
| O&M: | |
| Staff | f,v |
| Coolant makeup | v |
| Breeder makeup | v |
| Other consumables | f,v |
| Waste disposal | v |
| Decommissioning Costs | f |

(*a*) "f" denotes fixed cost, "v" denotes variable cost.
(*b*) Typically amortized or excluded as "sunk" from commercial power plant cost estimates.
(*c*) See Ref. [23] for CBS details.
(*d*) May contribute more than 50% of the direct cost.
(*e*) The sum of Direct Costs and Indirect Costs to this point yields the Base Cost.
(*f*) Added to the Base Cost yields the Overnight Cost.
(*g*) Allowance for Funds Used During Construction, *i.e.,* interest paid on borrowed capital. Added to the Overnight Cost yields the Total Capital Cost (TCC), which dominates the Production and Decommissioning Costs.

phase of the Starlite study, cost items are represented by parametric cost estimates and analogous cost estimates, rather than direct engineering and vendor quotes, consistent with Fig. 17.8 of Ref. [16]. To the extent that certain Balance of Plant (BOP) systems (*e.g.,* turbogenerators) are selected in common with existing plants, firmer costs are available [24, 25]. Costing of the tokamak Fusion Power Core (FPC) benefits from recent ITER work [26]. Historical costs have been brought up to a given reference year using the overall U.S. Gross National Product implicit price deflator [27], but will henceforth be adjusted using more specific indices (*cf.* Table 84 of Ref. [28]). Figure 3.2-1 summarizes the various price deflators of interest. The reported indices are here normalized to a 1980 base year with price deflator (PD) equal to unity. Historic information and cost projections dating back to 1965 can be brought forward to the reference year for purposes of comparison. The various indices show the period of relatively high price inflation in the late 1970s in contrast with the more moderate recent trend. The Handy Whitman Index of Public Utility Construction Costs [27] suggests a somewhat higher sector rate of recent price increase than the general rate, although the North Atlantic (NA) and the Pacific regions tend to outpace the nationally averaged index [28]. Absent recent, detailed, fusion-specific, vendor-provided, cost information, estimates kept current using such PD factors are appropriate to the conceptual level of the Starlite project.

All costs are summed to yield the Total Direct Cost (TDC). Indirect costs are estimated using percentage factors [23].

The Cost of Electricity (COE) estimate at the busbar (neglecting transmission and distribution cost components of the retail price) combines the total cost estimate with reference economic ground-rules to yield

$$COE \;=\; \frac{C_{AC} + (C_{O\&M} + C_{SCR} + C_F)\,(1+y)^Y}{(8.760E-3)\,P_E\,p_f} \;+\; C_D \;+\; C_{R\&D}\,, \qquad (3.2\text{-}1)$$

where $C_{AC}(M\$) = TCC \times FCR$ is the annual capital cost and $P_E$ (MWe) is the net electrical output power, *i.e.,* the Design Electrical Rating (DER). While each term in the definition of COE may be considered strictly to vary over the life of the plant, a convenient approximation is that each term represents a time average. The fixed values of decommissioning cost, $C_D$, and R&D cost, $C_{R\&D}$, are cast into (mill/kWeh) units. The general inflation rate is $y$ (*i.e.,* 0%/yr for constant-dollar evaluations and $5\%/yr$ for nominal-dollar evaluations). For a reference construction spending profile [29], interest during construction charges are calculated for the construction lead time, $\tau_c = Y$. Projections of life-cycle costs as a figure of merit allow characterization of the pre-Demo R&D phase [30, 31], construction phase, operational life, and end-of-life decommissioning

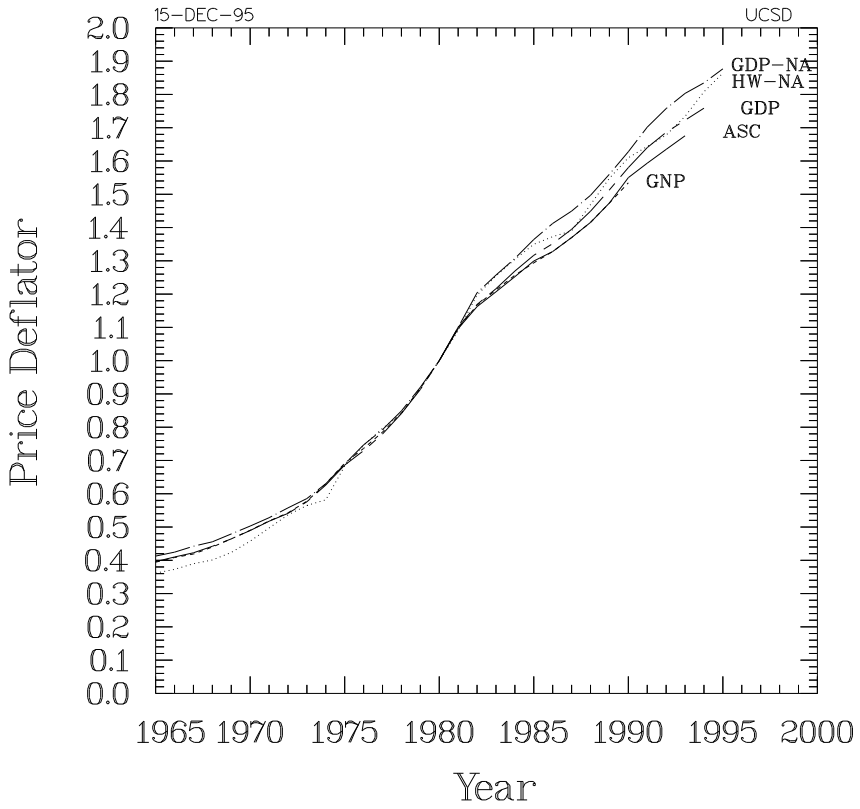


**Figure 3.2-1.** Comparison of U.S. historic price deflator (PD) factors. The ARIES Systems Code (ASC) [23] uses an index linked to the Gross National Product (GNP), until its discontinuance in 1990 and replacement by the Gross Domestic Product (GDP). The North Atlantic (NA) regional index tends to be larger than the national average for both the GDP and the Handy Whitman (HW) sector Index of Public Utility Construction Costs [27].

phase [32, 33] of such a project as a discriminator between candidate Demo designs [34] and various subsystem options.

Standard financial assumptions are invoked to facilitate comparisons with competitive electrical generating technologies, although special financial arrangements for a federal-government/power-producer partnership appropriate for a fusion Demo are being identified. Under one possible funding scenario, The U.S. fusion Demo is envisioned as a joint venture between the Federal government and a consortium of private interests [35, 36], with a power purchase contract. The Federal real discount rate under OMB Circular A-94 is 10%, close to that calculated for U.S. investor-owned utilities, such that no pro-

portional weighting is necessary [23,37]. High discount rates tend to minimize long-term benefits and discourage capital intensive projects. The discount rate is an important issue in discussions of intergenerational equity bearing on energy policy and resource depletion, as well as in international differences in the evaluation of cost-benefit ratios. Considerations relating to the Demo as a first of a kind (FOAK) device with appropriately higher-than-commercial contingency cost [22] and the narrow scaling step [1] between the Demo and subsequent commercial fusion power plants are monitored. The tokamak Demo could well be built to the same physical specifications as the anticipated commercial power plant and operated at lower power by operating the coils at a slightly derated field strength.

Considerations of the spinning reserve requirement of the grid tend to inhibit very large single plants, with the contemporary "rule of thumb" limiting the addition to ∼7% of the grid; future load growth and greater interconnectivity may be anticipated to relax this constraint. Economies of scale, it is argued [38,39], suggest the choice of very large fusion power plants to reduce the COE. Projections that have been used to support this view have tended to assume a fixed plant capacity factor, resulting in $COE \propto P_E^{-0.6}$, but neglecting the increasingly adverse impact of higher neutron wall load with fixed fluence lifetime on operation time.

The unit will tend to be limited by the largest single turbogenerator unit (with gross electrical power output presently ∼1,350 MWe in the U.S. (60 Hz at 1,800 rpm) and ∼1,500 MWe in France (50 Hz at 1,500 rpm). Because of the generally larger recirculating power requirements for tokamak fusion (because of plasma current drive) relative to fission, the net power output of the fusion unit would be correspondingly lower. A false counterexample to this view is the recent British Sizewell-B PWR, which has two 650-MWe class turbogenerators, representing the largest conveniently available domestic component while not linking the introduction of first British PWR to a new BOP technology. The corresponding use of two turbines in a fusion plant could allow a single ∼2,400 MWe(net) plant (U.S.) or ∼2,800 MWe(net) plant (France) at a modest additional cost counteracting the economy of scale. It is rather recommended to consider multiple units of the largest single-turbogenerator size at suitable sites, consistent with fission and coal experience. Some savings due to shared staff and support facilities can be realized.

Once a COE for a given plant size is determined, it is not recommended to re-scale the COE to a different output for comparison purposes (*e.g.,* as done in Ref. [40]), particularly if the scaling exponent is set arbitrarily (rather than consistent with the design study itself) and the scaled design violates some constraint applied in the original design.

## 3.3. PLANT CAPACITY FACTOR

The plant capacity factor, $p_f$, is the ratio of the energy actually generated in a reference time period to the energy that would have been generated in that time period had the plant been operating full time at its Design Electrical Rating (DER). As a figure of merit, $p_f$, captures the plant operational availability, $A$, in terms of scheduled (planned) and unscheduled (forced) outages, as corrected for startup and shutdown transients and any load-following operation. A projection of $A$ for a future power-plant technology is necessarily very uncertain, but an allocation of target outage times, as summarized in Table 3.3-I, sets goals and requirements for the Reliability, Availability, and Maintenance (RAM) activity of the conceptual Demo design. Itemized $A_i$ values for each system reflect Mean Time to Failure (MTTF) and Mean Time to Repair/Replace (MTTR) estimates.

**Table 3.3-I.**
**Preliminary Availability Allocation**

| | |
|---|---|
| Scheduled down-time, $T_S(day/yr)$ | $22.5^{(a)}$ |
| Unscheduled down-time, $T_U(day/yr)$ | 25.0 |
| Operation time, $T_O(day/yr)$ | 317.5 |
| Forced outage rate, $FOR^{(b)}$ | 0.075 |
| Operational Availability, $A^{(c)}$: | |
| Early operation | $\geq$0.30 |
| Mature operation | 0.87 |
| Plant capacity factor, $p_f \propto A$: | |
| Early operation | $\geq$0.25 |
| Mature operation$^{(d)}$ | 0.75-0.80 |

($a$) Consistent with 30 days/outage at routine 18-month intervals and an extended 45 day outage each decade for turbine overhaul, *etc.*.

($b$) $FOR \equiv T_U/(T_O + T_U)$

($c$) $A \equiv (1 - FOR)(365 - T_S)/365$

($d$) Used in COE projections.

## 3.4. MARKET CONTEXT

The results of Ref. [40] are generalized in Fig. 3.4-1 to set the market context for electrical production in the ∼2025 time frame for Demo and the ∼2040 time frame for early commercial fusion power plants. Included are constant-dollar busbar Cost of Electricity [COE (mill/kWeh)] projections for fission, including an evolutionary light water reactor (ELWR) and a passively-safe advanced light water reactor (ALWR), an advanced pulverized-coal (PC) plant, and a combined cycle combustion turbine (CCCT) burning natural gas. The fission cost projections assume a favorable regulatory and licensing climate and a solution to the radioactive waste disposal issue, absent which, no additional fission capacity is likely [41–43]. The coal and natural gas projections, neglecting regional variations, are shown for a range of fuel-cost escalation rates over and above the general inflation rate (5%/yr), consistent with eventual depletion. The near-term picture favors the use of natural gas, particularly in small units as the lowest cost option for incremental capacity, although displacement by coal is projected [42] after $\sim$ 2010. Near term natural gas costs were thought to be growing at a rate nearer to the 2%/yr curve [41,42], but the most recent [43] data and extrapolations suggest less growth and even a decline in price. The situation for coal is similar if less dramatic, as shown in Fig. 3.4-2. Of course, these long range projections are uncertain and must be used cautiously.

Resolution of the COE into its fixed and variable cost components allows comparison of the fusion estimate with those of potential competitors *calculated on the same basis* in the context of the Load Duration Curve, a standard electrical planning device, as illustrated in Fig. 3.4-3. The horizontal axis of the LDC frame denotes the number of hours per year that the given load, normalized by a typical 15–20 GWe, would be exceeded. Selected non-fusion cases from Table 6 of Ref. [40] are compared with the preliminary reverse-shear Starlite Demo candidate of Ref. [34]. Capital intensive plants, ranked by the $p_f = 0$ vertical-axis intercepts, with high plant capacity factors provide base-load operation. Plants with high production costs (proportional to the slope of the screening curves) are used to address peak loads. The early operational behavior of the fusion Demo, characterized by intermittent operation in a reliability growth phase, may lend itself to dispatching for peak loads and will depress its lifetime-average $p_f$. Mature Demo performance would be $p_f \simeq 0.80$, consistent with the availability goal of $A \simeq 0.87$ [1].

The cost-based design window for the Demo and subsequent commercial fusion power plants is illustrated in Fig. 3.4-4. The unit overnight cost includes direct costs plus

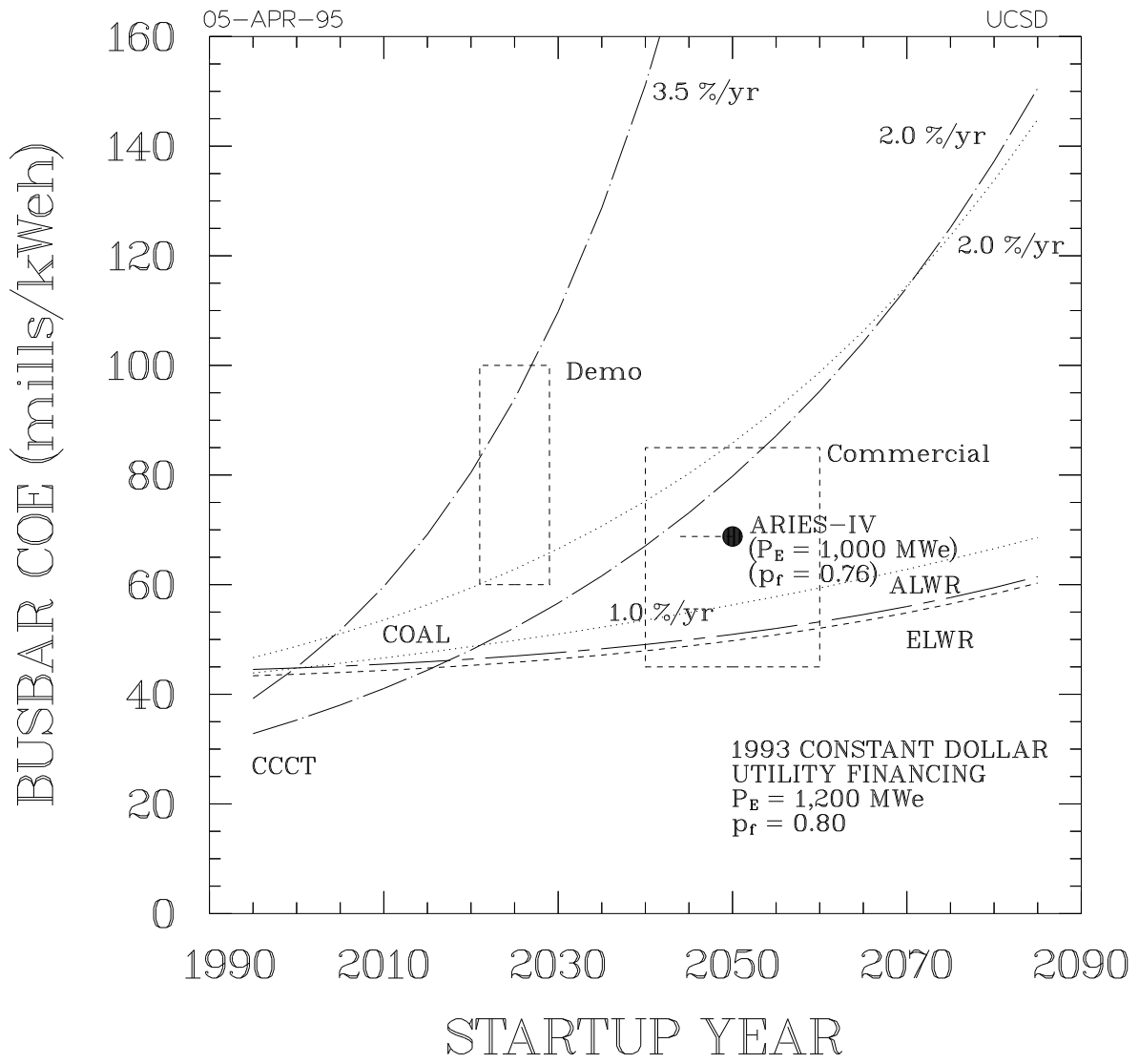


**Figure 3.4-1.** Busbar Cost of Electricity [COE (mill/kWeh)] projections for future competitive technologies to fusion, setting the market penetration context, based on Ref. [40]. The fission projections are for an evolutionary light water reactor (ELWR) and a passively-safe advanced light water reactor (ALWR) [4, 40]. The coal and natural gas [combined cycle combustion turbine (CCCT)] projections are shown for a range of fuel cost escalations. The assumed plant capacity factor, $p_f$, is also an aggressive target for fusion power plants. Target windows for the Starlite Demo and subsequent commercial power plants (*e.g.,* tenth-of-a-kind ARIES-IV tokamak [23] with indicated six-year construction lead time) are indicated by the dashed boxes.

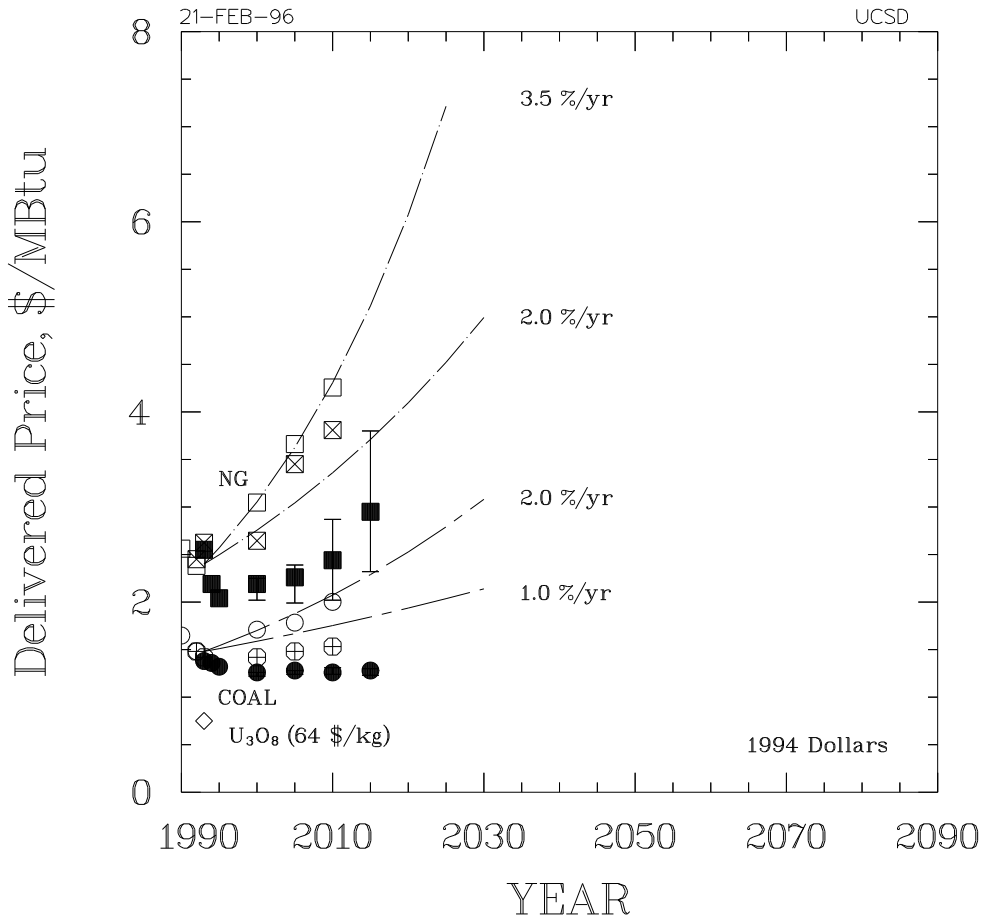


**Figure 3.4-2.** Fuel cost projections for natural gas (NG) and coal from a series of recent U.S. Energy Information Agency (EIA) estimates for 1994 [41] (open circles), 1995 [42] (partially filled circles), and 1996 [43] (filled circles) indicating the softening of these fossil-fuel prices. The extrapolation curves [40] for the indicated assumed escalation rates are more consistent with then-available projections. A fission fuel point [25] is included for comparison.

indirect costs plus contingency costs. The Total Capital Cost is then the sum of the Overnight Cost and the interest cost during construction. The portion of the total COE allocated for Production Costs [*i.e.,* fuel (negligible for fusion), non-fuel O&M, and scheduled component replacement (SCR)] plus decommissioning is taken to be a typical COE* $\simeq$ 13 mill/kWeh. In this context that the Starlite [1] Goals [80 mill/kWeh (Demo), 65 mill/kWeh (Commercial)] and Requirements [90 mill/kWeh (Demo), 80 mill/kWeh (Commercial)] can be resolved into major components.

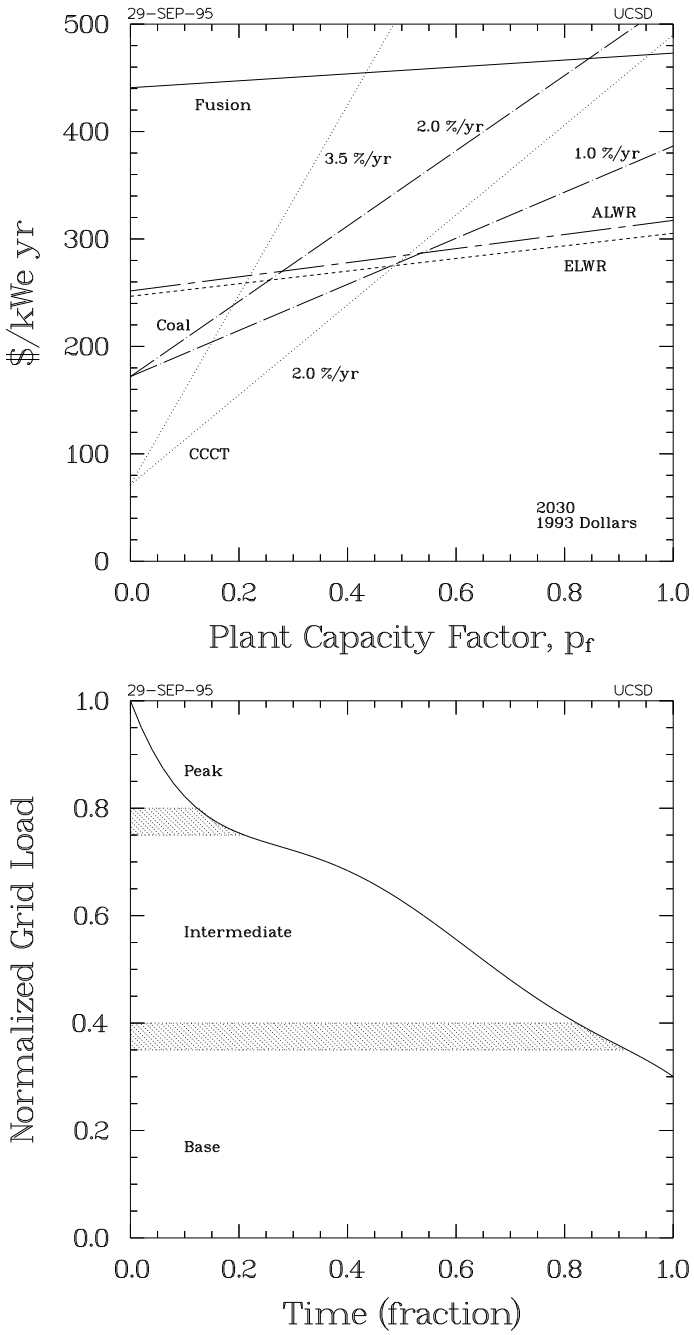


**Figure 3.4-3.** Screening curve representation of COE values (upper frame), resolved into fixed ($\propto$ vertical-axis intercept) and variable ($\propto$ slope) components, linked to a representative annual (8760 hour) Load Duration Curve (lower frame) [7]. Crossings of the screening curves suggest the allocation of the various plant types on the grid in response to the diurnal and seasonal variations of load to minimize system costs.

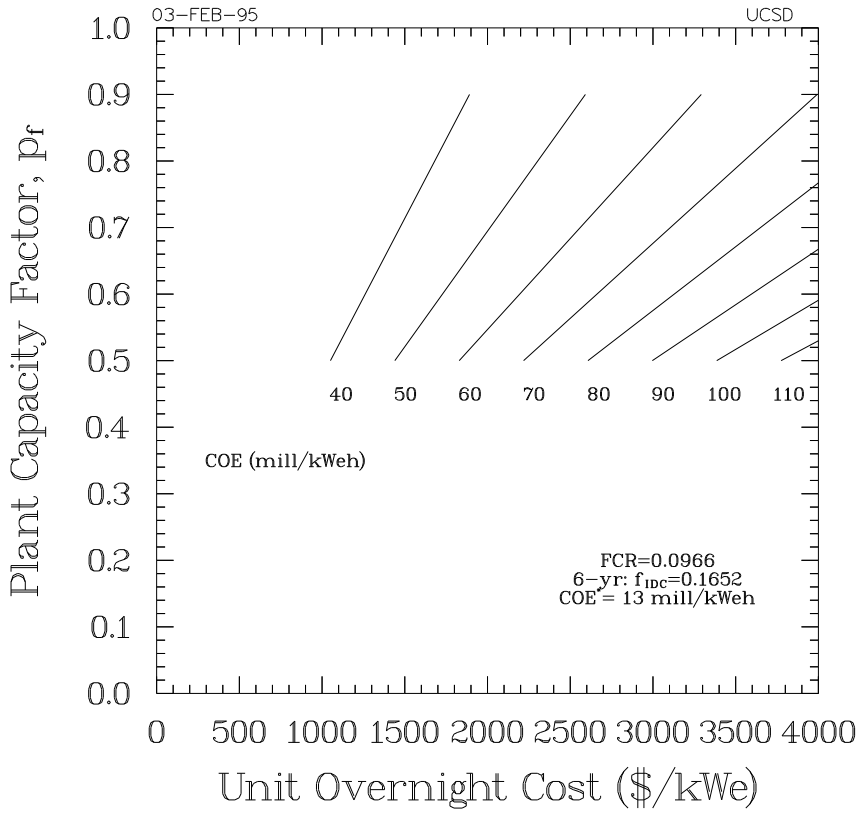


**Figure 3.4-4.** Fusion power plant design window in terms of unit overnight cost, UOC ($\$/kWe$), and plant capacity factor, $p_f$, leading to projected constant-dollar busbar Cost of Electricity, COE (mill/kWeh).

## 3.5. SUMMARY AND CONCLUSIONS

The economic methodology to be used in the Starlite tokamak fusion Demo study has been determined in advance of the integration of the physics and engineering into a detailed reference design. Cost considerations are used within the project in an iterative manner to guide the design process toward an optimal tokamak Demo as reported results interface with the external world of energy forecasting and policy determination, with implications for the planning of the magnetic fusion R&D program. A coherent linkage between the Demo and the subsequent commercial tokamak power plant is established in response to the present perception of future energy market requirements and goals. As the Starlite Project progresses, exposition of cost information anticipates the concerns of future Demo participants and addresses formal documentation and traceability considerations [44].

# REFERENCES

[1] L. Waganer, F. Najmabadi, M. S. Tillack, and the ARIES Team, "What Must Demo Do?" *Proc. IEEE 16th Symp. on Fusion Eng.,* Champaign, IL (Oct. 1995) IEEE No. 95CH35852, IEEE, Piscataway, NJ (1995) 1157.

[2] J. Kaslow, *et al.*, "Criteria for Practical Fusion Power Systems - Report from the EPRI Fusion Panel," Electric Power Research Institute report BR-104469 (1994).

[3] D. A. DeFreece, "Fusion Energy: Utility Requirements and Economics," *Fusion Reactor Design Concepts,* International Atomic Agency, IAEA-TC-145/48 (1978).

[4] "Advanced Light Water Reactor - Utility Requirements Document," Electric Power Research Institute report NP-6780 (March 1990).

[5] L. S. Tong, "Adoption of New Design Features for the Next Generation Nuclear Power Reactors," *Nuclear Safety,* **35** (1994) 98.

[6] R. Fischl, "Optimal System Expansion: A Critical Review," *Systems Engineering for Power: Status and Prospects*, in Proc. an Engineering Foundation Conf. sponsored by the U.S. Energy Research & Development Administration and Electric Power Research Institute, CONF-750867 (August 1975) 233.

[7] "Expansion Planning for Electrical Generating Systems," International Atomic Energy Agency Technical Reports Series No. 241 (1984).

[8] J. Clarke, "Environmental Issues and Global Energy Economy Project," *Proc. IEEE 16th Symp. on Fusion Eng.,* Champaign, IL (Oct. 1995) IEEE No. 95CH35852, IEEE, Piscataway, NJ (1995).

[9] R. W. Conn *et al.*, "Economic, Safety and Environmental Prospects of Fusion Reactors," *Nucl. Fusion,* **30** (1990) 1919.

[10] P. K. Kaw, "Fusion Power: Who Needs It?" *Proc. 14th Int. Conf. on Plasma Phys. and Controlled Nucl. Fusion Research,* Würzburg, Germany (Oct. 1992), International Atomic Energy Agency, Vienna (1993) (1993) 3.

[11] C. Starr, M. F. Searl, and S. Alpert, "Energy Sources: A Realistic Outlook," *Science,* **256** (15 May 1992) 981.

[12] P. M. S. Jones, "Social Costs of Energy," *Atom,* **403** (1990) 23.

[13] B. F. Hobbs and P. Centolella, "Environmental Policies and Their Effects on Utility Planning and Operations," *Energy,* **20** (1995) 255.

[14] *National Energy Strategy - Powerful Ideas for America*, First Edition 1991/1992, U.S. Department of Energy report (Feb. 1991).

[15] B. Hannon, "Energy Discounting," *Technology Forecasting & Social Change,* **21** (1982) 281.

[16] B. S. Blanchard and W. J. Fabrycky, *Systems Engineering and Analysis,* Prentice Hall (1990).

[17] R. de Neufville, *Applied Systems Analysis,* McGraw-Hill, Inc. (1990).

[18] *Department of Energy Project Management System*, U.S. Department of Energy Draft Order DOE 4700.1A (10 Mar. 1995).

[19] R. A. Krakowski, "Simplified Fusion Power Plant Costing: A General Prognosis and Call for 'New Think'," *Fusion Technol.,* **27** (1995) 135.

[20] R. A. Krakowski, "Magnetic Fusion Reactor Economics," *Proc. IEEE 16th Symp. on Fusion Eng.,* Champaign, IL (Oct. 1995) IEEE No. 95CH35852, IEEE, Piscataway, NJ (1995) 1549.

[21] L. Argote and D. Epple, "Learning Curves in Manufacturing," *Science,* **247** (23 Feb. 1990) 920.

[22] J. G. Delene and C. R. Hudson II, "Cost Estimate Guidelines for Advanced Nuclear Power Technologies," Oak Ridge National Laboratory report ORNL/TM-10071/R3 (May 1993).

[23] F. Najmabadi, R. W. Conn, *et al.*, "The ARIES-II and -IV Second-Stability Tokamak Fusion Power Plant Study—The Final Report," UCLA report UCLA-PPG-1461 (to be published); also, F. Najmabadi, R. W. Conn, *et al.*, "Directions for Attractive Tokamak Reactors: The ARIES-II and ARIES-IV Second-Stability Designs," *Proc. 14th Int. Conf. on Plasma Phys. and Controlled Nucl. Fusion Research,* Würzburg, Germany (Oct. 1992), International Atomic Energy Agency, Vienna (1993) 295.

[24] J. H. Crowley *et al.*, "Technical Reference Book for the Energy Economic Data Base Program EEDB Phase IX (1987)," U.S. Department of Energy report DOE/NE-0092 (July 1988).

[25] J. G. Delene, K. A. Williams, and B. H. Shapiro, "Nuclear Energy Cost Data Base," U.S. Department of Energy report DOE/NE-0095 (Sept. 1988).

[26] *ITER Interim Design Report* (12 July 1995).

[27] J. G. Delene, Oak Ridge National Laboratory, personal communication (24 Oct. 1995).

[28] Edison Electric Institute, "Statistical Yearbook of the Electric Power Industry 1993," (1994) p. 96.

[29] J. Sheffield *et al.*, "Cost Assessment of a Generic Magnetic Fusion Reactor," *Fusion Technol.,* **9** (1986) 199.

[30] M. J. M. Posner and D. Zuckerman, "A Note on Socially Optimal R&D Programs and Their Inducement," *Oper. Res.,* **40**, Suppl. No. 2 (1992) S335.

[31] B. E. Johnson, "Modeling Energy Technology Choices," *Energy Policy,* **22** (1994) 877.

[32] T. S. LaGuardia, "Guidelines for Producing Commercial Nuclear Power Plant Decommissioning Cost Estimates," *Proc. American Power Conference,* **48** (1986) 964.

[33] "Yankee Rowe - Decommissioning Will Cost an Extra $94 Million," *Nuclear News,* **37** (Dec. 1994) 23.

[34] C. G. Bathke and the ARIES Team, "A Preliminary Systems Assessment of the Starlite Demo Candidates," *Proc. IEEE 16th Symp. on Fusion Eng.,* Champaign, IL (Oct. 1995) IEEE No. 95CH35852, IEEE, Piscataway, NJ (1995) 1139.

[35] "Alternative Financing Plan for the Clinch River Breeder Reactor Project," Hearing before the Subcommittee on Energy Research and Production of the Committee on Science and Technology, U.S. House of Representatives (15 Sept. 1983).

[36] The System 80+ Team, "Program Plan for Deployment of a System 80+ Multi-Purpose Nuclear Facility at Savannah River Site," (31 Mar. 1994).

[37] J. Quirk and K. Terasawa, "Choosing a Government Discount Rate: An Alternative Approach," *J. Environmental Economics and Management,* **20** (1991) 16.

[38] B. G. Logan, "On the Utility of Tokamaks for Energy," *Fusion Eng. & Des.,* **22** (1993) 145.

[39] T. J. Dolan, "Fusion Power Economy of Scale," *Fusion Technol.,* **24** (1993) 97.

[40] J. G. Delene, "Advanced Fission and Fossil Plant Economics - Implications for Fusion," *Fusion Technol.,* **26** (1994) 1105.

[41] Energy Information Administration, "Annual Energy Outlook 1994," U.S. Department of Energy report DOE/EIA-0383(94) (Jan. 1994).

[42] Energy Information Administration, "Annual Energy Outlook 1995," U.S. Department of Energy report DOE/EIA-0383(95) (Jan. 1995).

[43] Energy Information Administration, "Annual Energy Outlook 1996," U.S. Department of Energy report DOE/EIA-0383(96) (Jan. 1996).

[44] *Cost Estimating, Analysis, and Standardization*, U.S. Department of Energy Order DOE 5700.2D (12 June 1992).