Amirkabir Univ. of Technology
(Tehran Polytechnic)
Graduate School

A Course on

Energy Planning

(Section-9)

M.S. Program
Power and Energy Management Division
Department of Electrical Engineering

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Least-Cost Planning Criteria

- **In an IRP process, resource options are evaluated based on the following fundamental criterion: to provide energy services at the least total cost, in which the total cost includes the costs of electricity generation, transmission, distribution, environmental emissions, and other societal costs.**

- **Each alternative combination of resources should be evaluated using the same IRP criteria, and each should provide at least the same level of energy services, including end-use convenience and supply reliability, as the baseline case.**

Least-Cost Planning Criteria

- The resource planning goal can be formalized as an optimization problem which can be tackled either through formal optimization models or using a range of simpler techniques.

- The following equations summarize the IRP optimization process:

Least-Cost Planning Criteria

- **Minimize Total Costs:**
  Cs (E, R) + CD (D) + Cp (E, D, R) **Eq. (1)**
- **Subject to:**
  E + D = ES **Eq. (2)**
- **E: Electricity sold to consumers**
- **D: DSM electricity savings**
- **R: Required emission reduction**
- **Cs (E,R): Cost of electricity supply (includes capital and O&M costs and is a function of electricity sales E; also includes the cost of pollution control equipment to meet legal environmental standards and is thus also a function of R)**

Least-Cost Planning Criteria

- **CD (D): Cost of DSM programs (is a function of the size of DSM programs D)**
- **Cp (E,D,R): Cost of pollutant emissions, i.e., the value of the environmental damage to society caused by electric power production (is a function of the amount of electricity sales E, the level of DSM programs D, and the required level of emission controls R)**
- **ES: Level of energy services demanded by electric customers.**

Least-Cost Planning Criteria

- **Note that the cost of electricity supply includes the cost of pollution control equipment required to meet environmental regulations.**

- **For example, if the cost of generating, transmitting, and distributing electricity is $5O/MWh, but pollution control equipment costs another $10/MWh, then the total cost of electricity supply would be $60/MWh.**

- **The cost of the pollution control equipment is then said to be internalized into the electricity price.**

Least-Cost Planning Criteria

- **However, even after installing the pollution control equipment, there would still be some residual pollution which is released into the environment and causes damage to society.**
- **This cost, which is not borne by the power plant but rather by society as a whole, is known as an externality.**
- **The value of this externality, typically ignored in conventional planning, is captured in the IRP equation above by the Cp term.**

Least-Cost Planning Criteria

- **The constraint on this cost-minimization problem is simply that the same total quantity of energy services must be met, whether by producing electric energy or by saving energy via DSM or other efficiency programs.**
- **This criterion does not mean that energy services are constant over time; indeed they can be expected to increase.**
- **Nor does it mean that the baseline level of demand for energy services is a fixed trend that is known with certainty; rather, there may be a range of different baseline scenarios, for example reflecting different rates of future economic growth.**

Least-Cost Planning Criteria

- **The IRP criterion simply requires that, for each baseline scenario of expected energy service demand, the defined level of energy services should be met by all alternatives to that baseline scenario.**
- **Using this criterion, we can describe and evaluate electricity supply and demand-side alternatives.**
- **Having already analyzed the energy efficiency and DSM options, the next task is to evaluate the costs of supply-side options, including unconventional sources.**

Least-Cost Planning Criteria

- We can then estimate the environmental impacts of different options and, if possible, their effect on supply costs.
- Finally, we rank the options according to cost and construct integrated resource scenarios.
- These scenarios combine supply and demand-side options, together with implementation programs and operating plans, to arrive at an integrated least-cost plan, or a set of plans based on a sensitivity analysis of important assumptions.

Electricity Production Costs

- **The basic goal of electricity supply economics is to estimate the production costs of electric power, based on the least-cost mix of available generating options.**

- **IRP is not unique in trying to minimize costs, but it does introduce new criteria and new options, such as DSM and non-utility supply, that are not part of the traditional utility planning process.**

Electricity Production Costs: Utility Revenue Requirements

- The standard procedure for capital budgeting and cost analysis for electric utilities is the net revenue requirements method.
- Revenue requirements are the expected revenues that would provide a minimum acceptable return to investors.
- Revenue requirements include all of a utility's cost of service including fuel, operating and maintenance (O&M) expenses, capital depreciation, taxes, interest, and additionally costs of DSM, non-utility energy purchases, etc.

Electricity Production Costs: Utility Revenue Requirements

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- In Eq. 1, revenue requirements would be defined as Cs + CD.
- These costs are projected over the planning period, which should be at least as long as the longest-lived investment option, and discounted to obtain a present worth that can be compared across different investment scenarios.
- The basic planning criterion is to minimize this present worth of utility revenue requirements.

Electricity Production Costs: Utility Revenue Requirements

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- **Conventional planning applies this criterion to supply options only, while IRP includes DSM options into revenue requirements and also includes environmental costs if possible.**

- **In other words, in a conventional planning process, Eq. 1 minimizes just Cs, while in IRP, Eq. 1 tries to minimize Cs + CD + Cp**

Electricity Production Costs: Utility Revenue Requirements

- **Note that we have defined revenue requirements in the IRP context as Cs + CD in the above paragraphs, but the total costs which we are trying to minimize are defined by Cs + CD + Cp.**

- **The reason Cp has not been included in utility revenue requirements is that the cost of the environmental damage caused by pollution from power production has traditionally been borne by the society in general and not by the utility.**

Electricity Production Costs: Utility Revenue Requirements

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- **However, if it were the case that the utility had to pay for the societal cost of pollution (through a pollution tax, for example), then Cp would become part of the utility's revenue requirements.**

- **In that case, revenue requirements could be redefined as Cs + CD + Cp**

Electricity Production Costs: Utility Revenue Requirements

- [Explanation Note: The revenue requirements method is slightly different from the present worth rule that is typically used for corporate budgeting, in which the net present worth of projected revenues minus projected costs must be positive, after discounting at a threshold rate that reflects the risk-adjusted cost-of-capital.

- In a public utility, the revenue requirements are assumed to only balance the costs, giving a net present worth of zero, when discounted at the utility's cost-of-capital, which is generally set by government regulation to be sufficient to attract investors.

Electricity Production Costs: Utility Revenue Requirements

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- Similarly, if we imagine electricity production in a perfectly competitive market, the competition should drive the producers' returns down to the point where revenues only balance costs, based on the market-based cost-of-capital.

- In either case, the revenue requirements method will indicate the least-cost strategy for providing electricity services.]

Electricity Production Costs: Utility Revenue Requirements

- The present worth of revenue requirements is a criterion for choosing among alternatives that provide an equivalent level of service.
- Traditionally, the level of service has been defined by the quantity and reliability of electric energy.
- In the IRP framework, the definition of services is expanded to include energy services at the end-use level, which allows the consideration of DSM options.

Electricity Production Costs: Utility Revenue Requirements

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- **The value to minimize is thus:**

$$PW(RR) = RR_0 + \sum_{i=1}^{t=n} \frac{RR_t}{(1+r)^t} \qquad \textbf{Eq. 3}$$

Where

PW(RR) =present worth of revenue requirements
RR_0 = revenue requirements from expenditures until year 0
RR_t = revenue requirements from expenditures in the year t
r = discount rate = weighted-average cost-of-capital (WACC)
n = number of years in the planning period

Electricity Production Costs: Utility Revenue Requirements

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- **The value for RR_o represents the current revenue requirements remaining (sunk costs) due to investments in previous years; they reflect the capital costs of existing generation, transmission, and distribution facilities which have not yet been fully depreciated.**

- **The revenue requirements from a future given year RR, are the sum of investments, expenses and taxes:**

$$R_t = I_t + Ex_t + T_t \qquad \textbf{Eq. 4}$$

Where

I_t=capital investment expenditures in the year t
Ex_t=operating expenses in the year t
T_t =taxes in the year t

Electricity Production Costs: Utility Revenue Requirements

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- **Investments I, Include the capital costs of generation, transmission and distribution facilities:**

$$I_t = Cg_t + Ct_t + Cd_t \qquad \textbf{Eq. 5}$$

Where
Cg_t=capital investment in generation in the year t
Ct_t=capital investment in transmission in the year t
Cd_t=capital investment in distribution in the year t

Electricity Production Costs: Utility Revenue Requirements

- **Expenses Ex, include fuel costs and both fixed and variable operation and maintenance costs.**
- **Variable costs, such as fuel costs, depend on the amount of energy generated from a given plant.**
- **Fixed costs, on the other hand, are usually expressed as constant annual values, independent of the amount of energy generated. Therefore:**

$$Ex_t = Cfuel_t + C\,\mathrm{var}_t + Cfix_t \qquad \textbf{Eq. 6}$$

Where

C*fuel*$_t$=capital investment in generation in the year t
C*var*$_t$=capital investment in transmission in the year t
C*fix*$_t$=capital investment in distribution in the year t

Electricity Production Costs: Utility Revenue Requirements

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- **Regarding taxes T_t , they will be ignored for the remainder of this course for the sake of simplicity.**

- **We can assume that taxes vary proportionally with investments, and that taxes and investments can therefore be combined into one term**

- **Therefore, the explicit tax term can be removed from Eq. 4, which can be rewritten as:**

$$I_t = I^*_t \quad \text{Eq. 7}$$

and

$$R_t = I^*_t + Ex_t \quad \text{Eq. 8}$$

- **in which I^*_t incorporates taxes as a given fraction of investment expenditures**

Electricity Production Costs: Utility Revenue Requirements

- **The following example provides a simplified illustration of the calculation of utility revenue requirements.**

- **Example:**

- **An electric utility expansion plan for the period 1995-2005 includes investments in supply capacity (generation, transmission, and distribution) of $7 million in 1997, $2 million in 1999, and $1 million in 2001. The annual operating costs (fuel, fixed O&M, and variable O&M) remain constant at $1 million per year during the entire period.**

- **What is the present worth (at the beginning of 1995) of the revenue requirements for this plan? Use an annual discount rate of 6%/year.Assume no RRO, and assume that taxes are included in the investment figures.**

Electricity Production Costs: Utility Revenue Requirements

- **First, we sum the cost components to determine the annual revenue requirements. Then we take the present worth (at 6%) of each annual value. The sum of the present worth series is the total present worth of the revenue requirements, $15.92 million.**

Year	Capital Investment	Operating Expenses	Annual Revenue Requirement	Present Worth of Annual Revenue Requirements
1995	0	1	1	0.94
1996	0	1	1	0.89
1997	7	1	8	6.72
1998	0	1	1	0.79
1999	2	1	3	2.24
2000	0	1	1	0.70
2001	1	1	2	1.33
2002	0	1	1	0.63
2003	0	1	1	0.59
2004	0	1	1	0.56
2005	0	1	1	0.53
Total Present Worth of RR in Beginning of 1995:				15.92