

## Overview

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- Complex system analysis
- Information used in long term planning
  - System planning criteria
  - Characterizing generating units
- Practice with PowerPlan
  - Multiyear plan
  - Varying planning, or expansion, criteria

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## Complex System Analysis

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- Divide the full system into sub-systems
- In power systems we can analyze...
  - By system sector: generation, transmission, distribution, customer...
  - By geographic region
  - By time scale
    - Time scale separation of events
  - By analysis question
    - Cost, environmental impacts...

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## Power System Expansion Planning

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- System planning objectives
- Reliability criteria
- Characterize generating units
- Production cost model
- Analysis with production cost model PowerPlan

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## System Planning Objective

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- Determine the technology mix
    - Types of generating units to build
    - Capacity of each generating type
- ... in order to meet our planning criteria

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## System Planning Criteria

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- Meet system demand into the future
- Low cost
- **High reliability**
- Low environmental impacts (emissions)
- Fuel diversity
- Sustainability (inter-generational issues)
- Every variable will have a time series

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## Reliability

- How is reliability defined?
- How do we measure reliability?

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## \*\* Reliability \*\*

- Unit Reliability / Availability
  - Forced outage rate – reliability
  - Maintenance (planned outage) – availability
  - Also for NDTs: availability of resource
- System Reliability
  - Reserve margin
  - Loss of load probability
  - Cost of unmet energy

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## Characterizing Generating Units

- Relevant unit characteristics
  - Costs – fixed and variable
  - Fuel → emissions
  - Forced outage rate → Reliability
  - Maintenance (planned outage) → Availability
  - Expected lifetime

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## Characterizing Generating Units

- Which units are best for:
  - Baseload – operate continuously
  - Intermediate – operate much but not all of the time
  - Peaking – operate a small number of hours during the year (perhaps up to 500 hours)

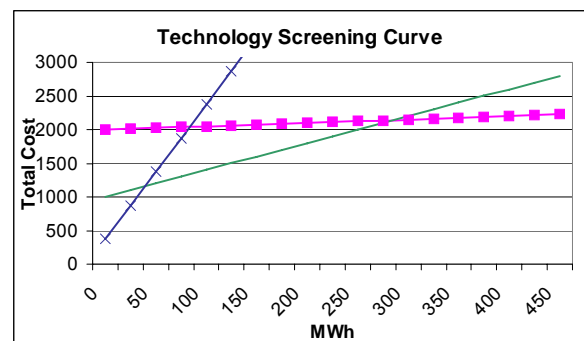
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## Characterizing Generating Units

- Matching generator types to operating decisions
  - Nuclear
  - Steam turbine: coal, oil, gas
  - Combustion turbine
  - Combined cycle
  - Cogeneration
  - Hydroelectric
  - NDTs: wind, photovoltaics
  - Demand side programs

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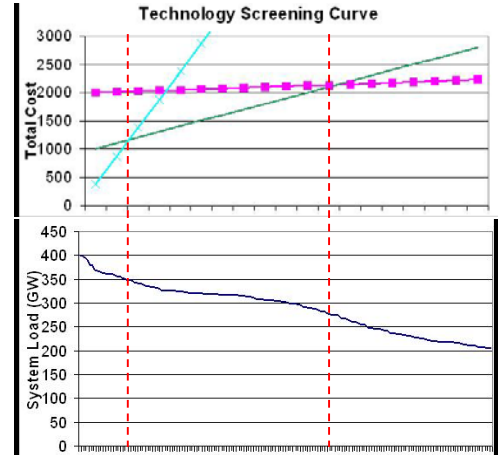
## Simple Technology Mix Tool: Using a Screening Curve...



## ...With a Load Duration Curve

- The power system load is typically divided into 3 categories:
  - Baseload (duration time 8760 hours)
  - Intermediate load (duration time from ~2000 to 8760 hours)
  - Peak-load (perhaps up to 500 hours)
- Each of these three categories represents a different type of generating technology

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## Match Technology to Operations

- Which technology characteristics represent a baseload, an intermediate and a peaking plant?

Techn.	Cap. Cost	Var. Cost	Emissions	Reliability
1	high	high	high	high
2	low	high	low	high
3	low	low	low	high
4	high	low	high	medium
5	medium	medium	high	low

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## Loading Order

- Once the generating units are built
- The order in which they are used is called
- The "loading order"
  - And the "merit order," and the "dispatch order"
- The bottom of the loading order
  - The units that run for the most time
    - The baseload units
- The top of the loading order
  - The units that run rarely – the peaking units

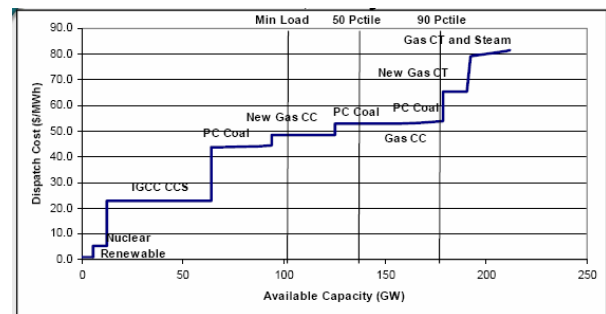
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## Production Cost Models

- A computer model to perform the task of the LDC + Screening curve
  - More complex input and output than the hand calculation

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## Example: ECAR Electric Supply Curve / Loading Order



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## Additional Analysis with Production Cost Models

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- Include demand side management
- Include NDTs
- Allow for uncertainty in
  - Load growth forecasts
  - Fuel cost forecasts

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## Summary of Terminology

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- Reliability terms
  - Unit
    - Forced outage and planned maintenance
  - System
    - Reserve margin
    - LOLP
    - Cost of unmet energy
- Loading order
  - aka dispatch order and merit order

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## Summary

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- Analysis of complex systems
- Experience with production cost computer model – PowerPlan
  - Developing a long term plan

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