

## Overview

- Recap intermittent resources
  - \*\* How to characterize the resource \*\*
- Understanding electric load patterns
  - Aggregating loads
- Load duration curve
  - Coincident peak
  - A 'cumulative distribution function'
- Load management

2

## Intermittent Resources

- Solar insolation & Wind energy
  - How can we characterize these resources?
  - Model with equations (text)
  - Model with measured (hourly) data
  - Model by adjusting measured data according to known statistics and equations
- Hydro
  - See text chapters 4 and 6 for equations and flow chart

3

## Solar Power Equations

$$\rho = \rho_o \cos \xi (\alpha_{dt} - \beta_{wa}) \alpha_p$$

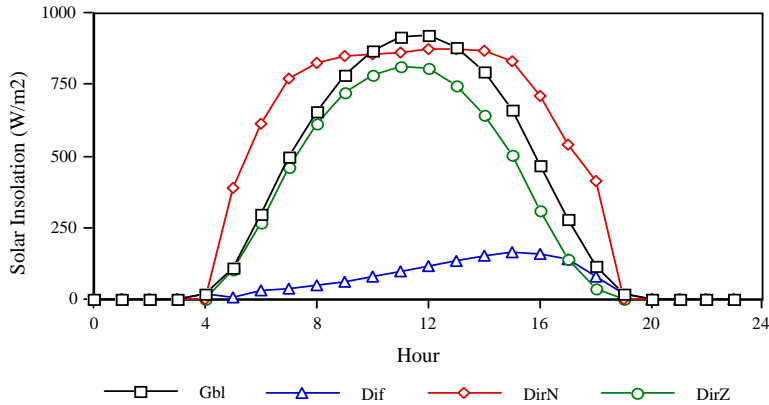
$$\eta_s = \frac{\rho}{\rho_o}$$

$$\eta_s = \cos \xi (\alpha_{dt} - \beta_{wa}) \alpha_p = 5 - 70\%$$

- Ranges of values for solar efficiency??
- Where/when is solar efficiency maximum?

4

## Solar Hourly Data



5

## Wind Power Equations

$$KE = \frac{1}{2} m v^2 = \frac{1}{2} A \delta t v^3$$

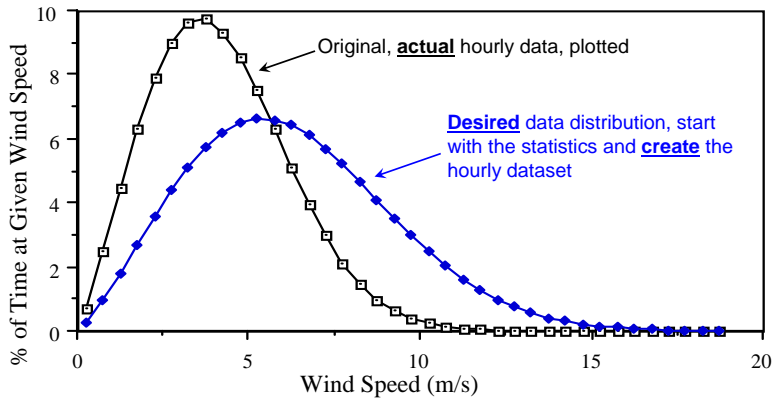
$$P = \frac{KE}{t} = \frac{1}{2} A \delta v^3$$

$$\rho = \frac{P}{A} = \frac{1}{2} \delta v^3$$

$$\rho \sim v^3$$

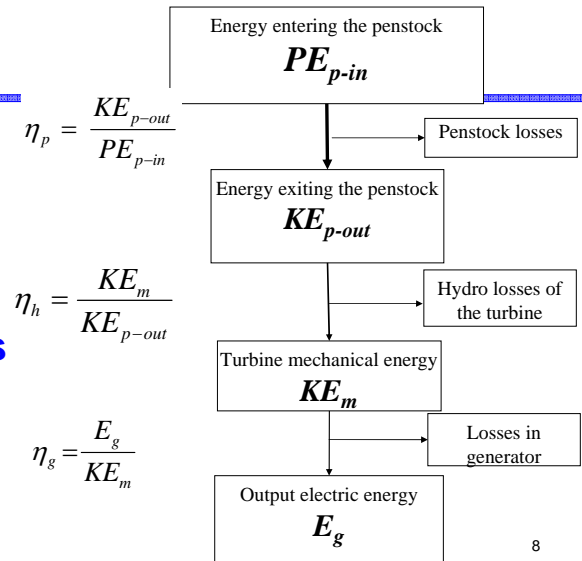
6

## Adjusting Wind Hourly Data



7

## Hydro Modeling via Equations

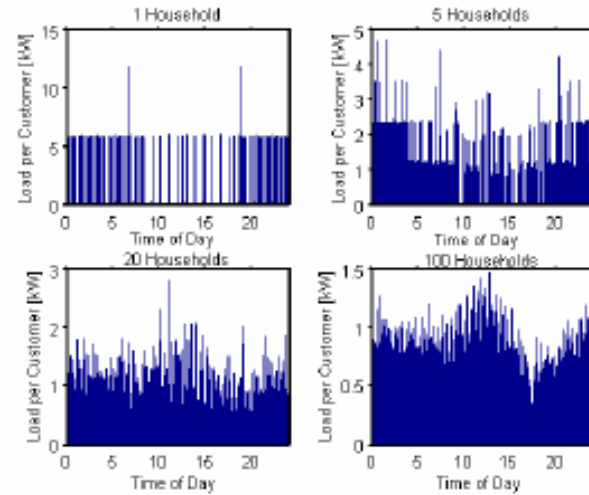


8

On to Load Modeling...

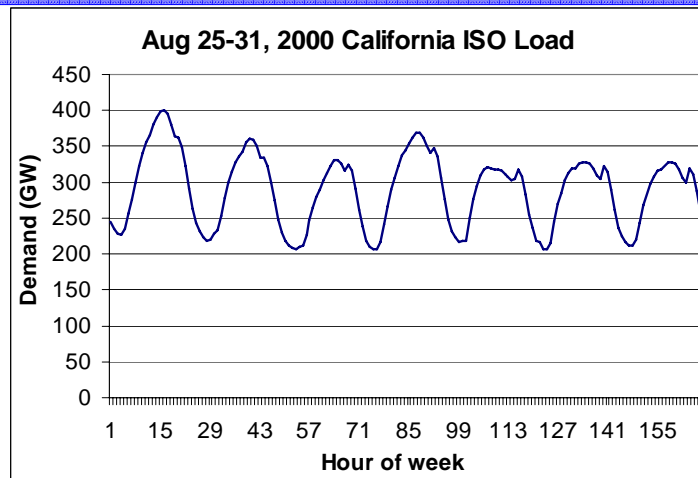
9

## Aggregating Load



10

## Weekly Load Pattern



## Annual Load Pattern

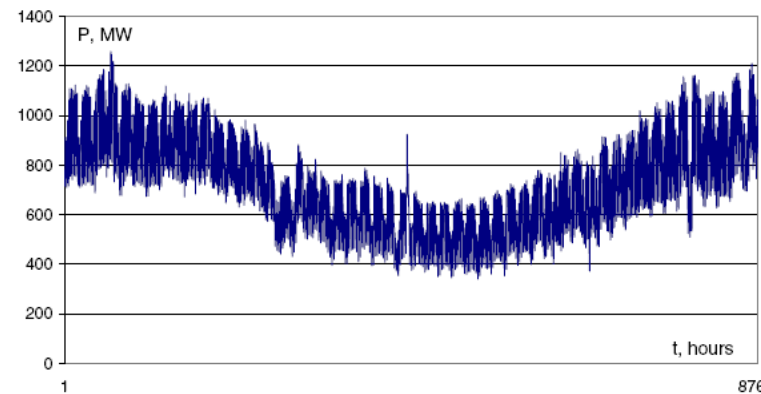
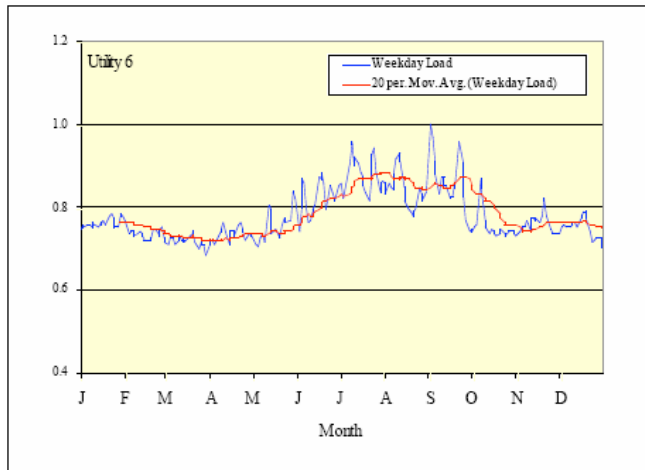


Fig. 1. Annual electric load curve

## Annual Load Pattern



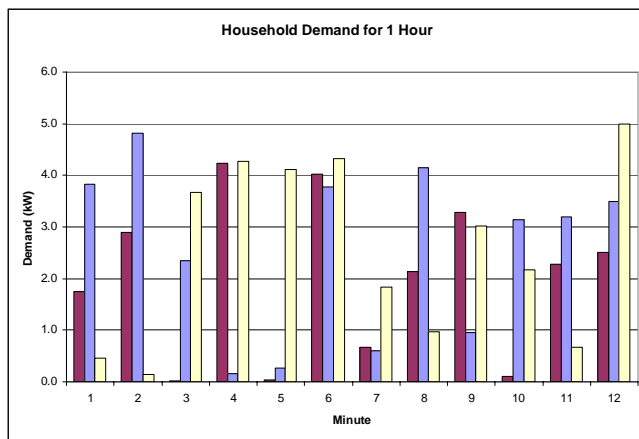
13

## Coincident Peak

- Given the following 5 minute electrical demands, for three homes
  - When does the coincident peak occur?
  - What is the significance of the coincident peak?

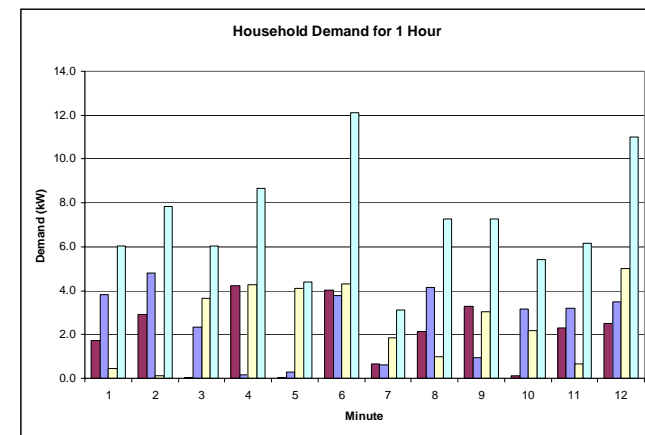
14

## Coincident Peak



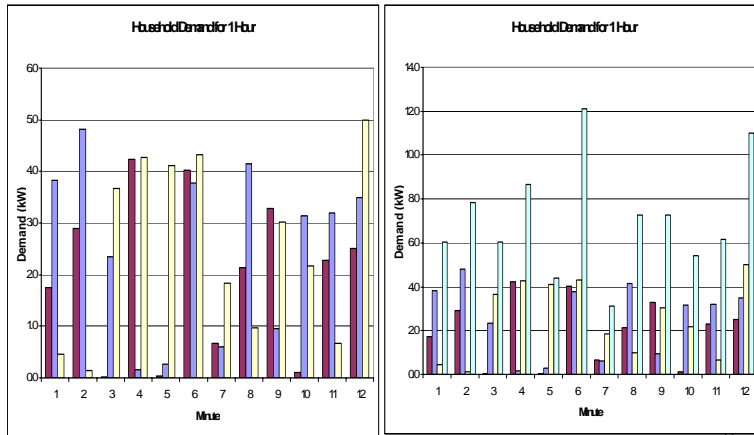
15

## Coincident Peak



16

## Coincident Peak



## Load Level Definitions

- Daily, Weekly and Seasonally
- Three typical “load level” identifications
  - These are *relative* values, not absolute
  - Peak : Off-peak : Shoulder
- Where are these levels on the previous slides?

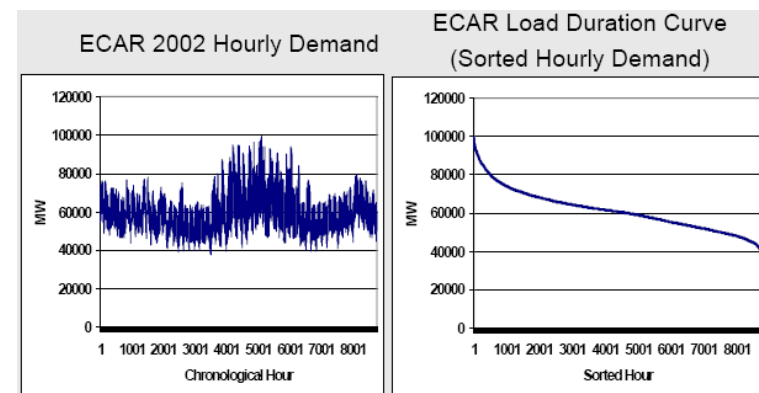
18

## Load Duration Curve

- Load duration curves are profiles of system demand for specified periods of time (e.g., annual)
  - Graphed as a histogram, a CDF
  - Not graphed chronologically
- System load is plotted
  - In descending order of magnitude per time intervals
  - The curve indicates the period of time load was above certain magnitude.

19

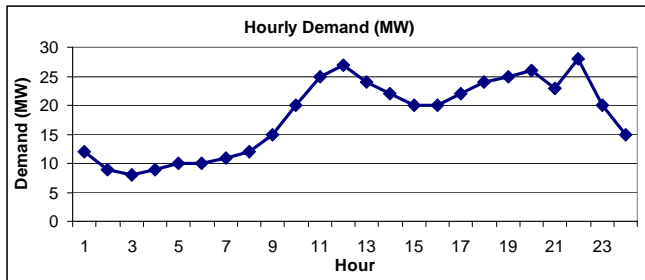
## Creating an LDC from Hourly Data



20

## Load Duration Curve

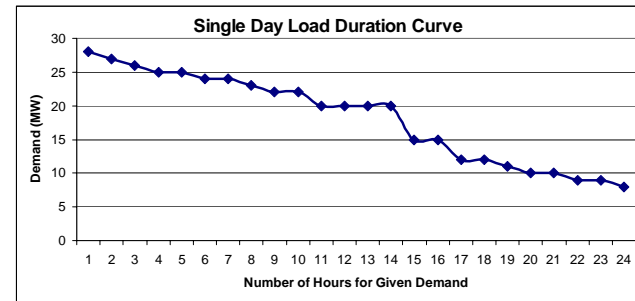
- What is the load duration for one day with the following hourly load levels (in MW)?
- 12, 9, 8, 9, 10, 10, 11, 12, 15, 20, 25, 27, 24, 22, 20, 20, 22, 24, 25, 26, 23, 28, 20, 15



Hr	MW
1	12
2	9
3	8
4	9
5	10
6	10
7	11
8	12
9	15
10	20
11	25
12	27
13	24
14	22
15	20
16	20
17	22
18	24
19	25
20	26
21	23
22	28
23	20
24	15

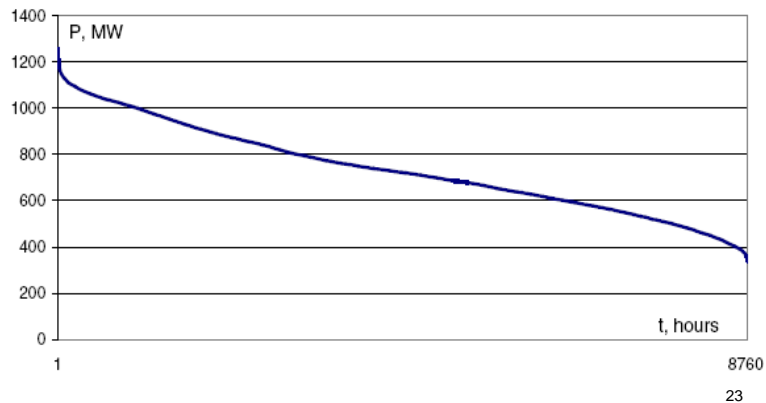
## Load Duration Curve

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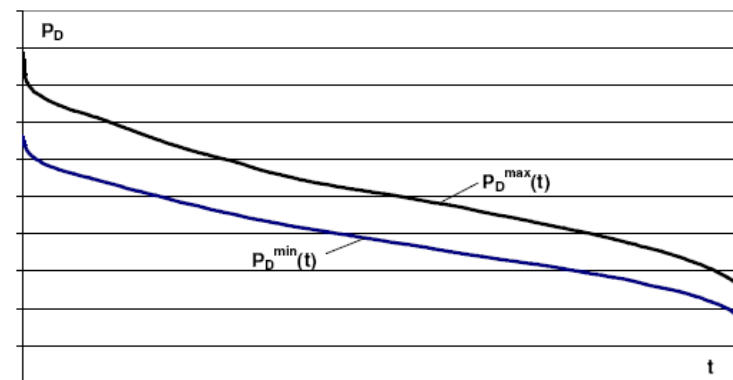
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15	20
16	20
17	22
18	24
19	25
20	26
21	23
22	28
23	20
24	15

## Load Duration Curve



23

## LDC with Uncertainty



24

## Load Duration Curve

- Question 1 ...
- Two pieces of information are... ?
  - System peak load level
    - A *CAPACITY* value, e.g., power
  - Total system energy demand
    - An energy value
- Where are these pieces of data displayed on the LDC?

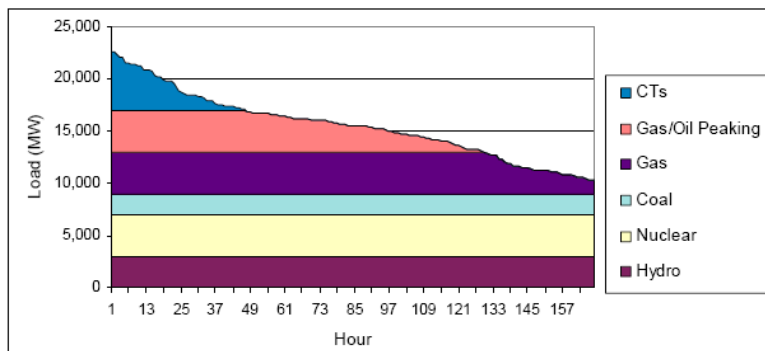
25

## Load Duration Curve

- The power system load is typically divided into 3 categories:
  1. Base-load (duration time 8760 hours)
  2. Intermediate load (duration time from 2000 to 8760 hours)
  3. Peak-load (duration time up to 2000 hours)
- Each of these three categories represents a different type of generating technology
  - Which characteristics are desirable for each type of technology?

26

## Load Duration Curve



Synapse Energy

27

## Load Management

- Question 2 ...
- Two types of load management are “peak shaving” and “energy conservation.”
- What are these programs? What are their benefits?
- How would these be represented on the LDC?

28

## More LDC Questions

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- Sketch an LDC and then sketch changes to the LDC if:
  - Baseload generation is decreased by 10%
  - Intermediate generation is decreased by 10%
  - Peaking generation is decreased by 10%
  - The top 20MW of peak is shifted to the intermediate load hours
  - Wind displaces 5% of baseload and 5% of intermediate generation, but does not generate at all during system peak load hours

29

## More LDC Questions

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- For the same options on the previous slide
  - What is the change to total system energy demand
  - What is the change to system fossil fuel usage
  - What is the change to system capacity needs

30

## Summary

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- Recap of modeling intermittent energy resources
  - *How* are they modeled?
  - Equations, hourly data, statistics...
- Understanding electrical load
  - Aggregating load
  - Load duration curve
    - Peak, intermediate and baseload categories
    - Energy and capacity information

31