



Wind Generation Trends

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Project Goal

- **Establish a methodology for evaluating time variable wind turbine performance**
- **Assess power generation according to time of day and season of year**
- **Compare wind power generation against electrical demand**
- **Incorporate the time value of energy into economic calculations**



Project Background

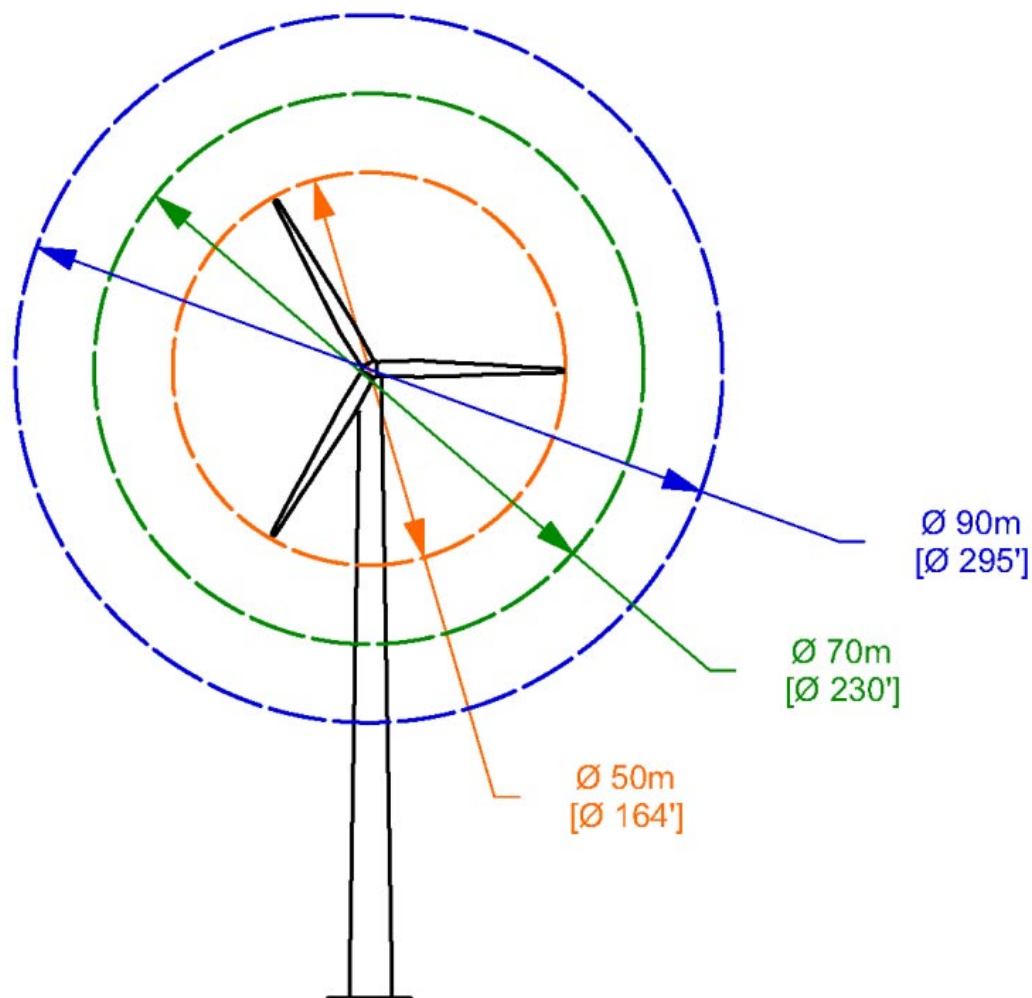
- **Hourly data for year 2001**
- **Tehachapi Mountain wind data normalized to sea level density and 6, 7, 8 m/s average**
- **California ISO demand data normalized against peak demand value**
- **Turbine rated power set to 1 MW (unity)**
- **50 m, 70 m, 90 m rotor diameter**
- **Time dependent valuation of energy normalized using annual average**



Turbine Model

- **1 MW Rating**
- **50 / 70 / 90 m Rotor Diameter**
- **Varying specific power**

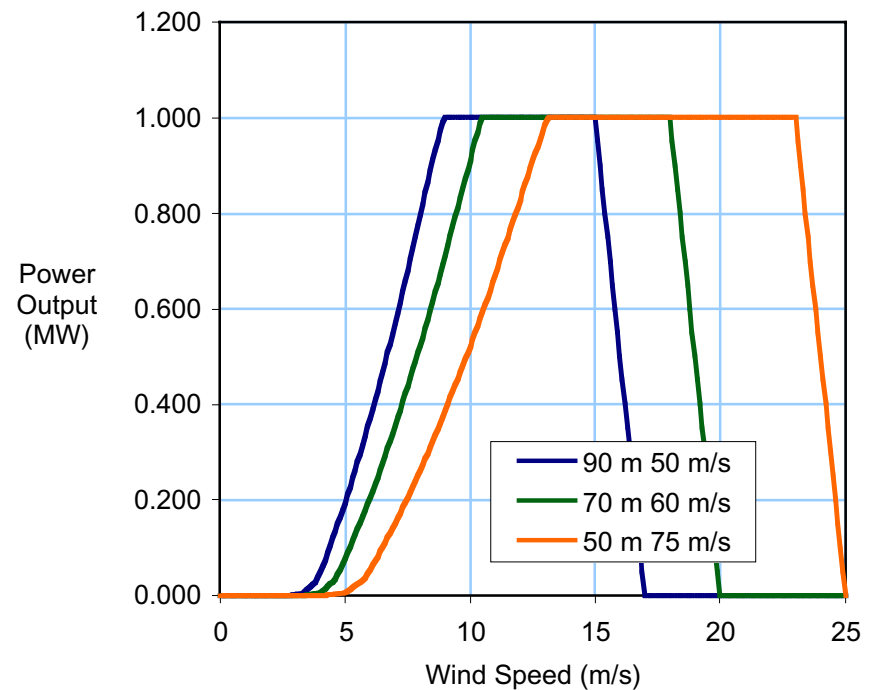
Rated Power (MW)	Rotor Diameter (m)	Specific Power (W/m ²)
1.000	50.0	509
1.000	70.0	260
1.000	90.0	157





Performance Model

- Rotor diameter
90, 70, 50 m
- Blade tip speed
50, 60, 75 m/s
- Cut-out speed
17, 20, 25 m/s
- Performance
includes drive
train losses

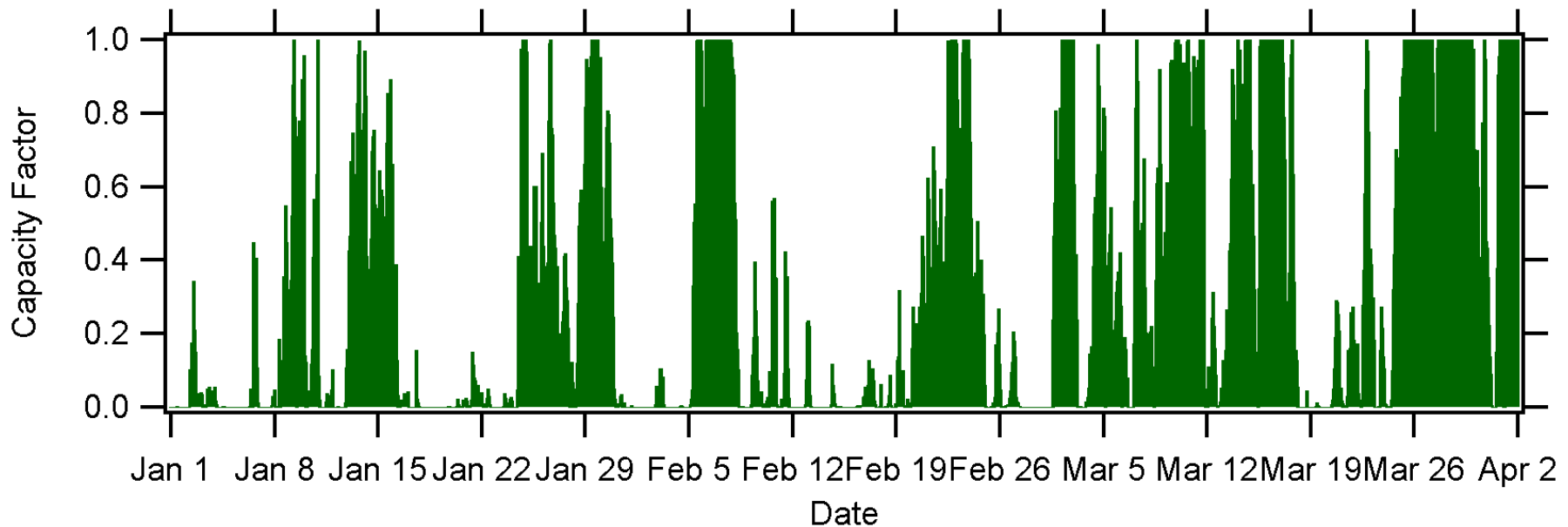




Wind Energy Generation

1st Quarter 2001

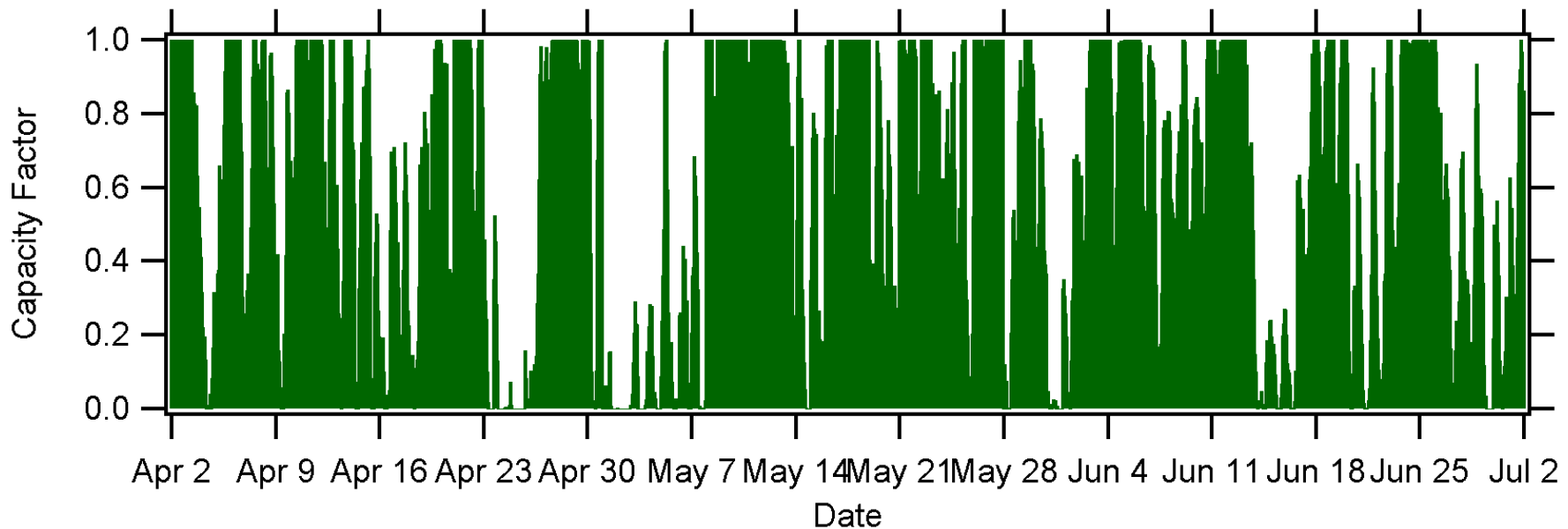
- Hourly generation (MW) and capacity factor as a function of time and day of the year
- 70 m Rotor at 7 m/s average wind site
- January through March





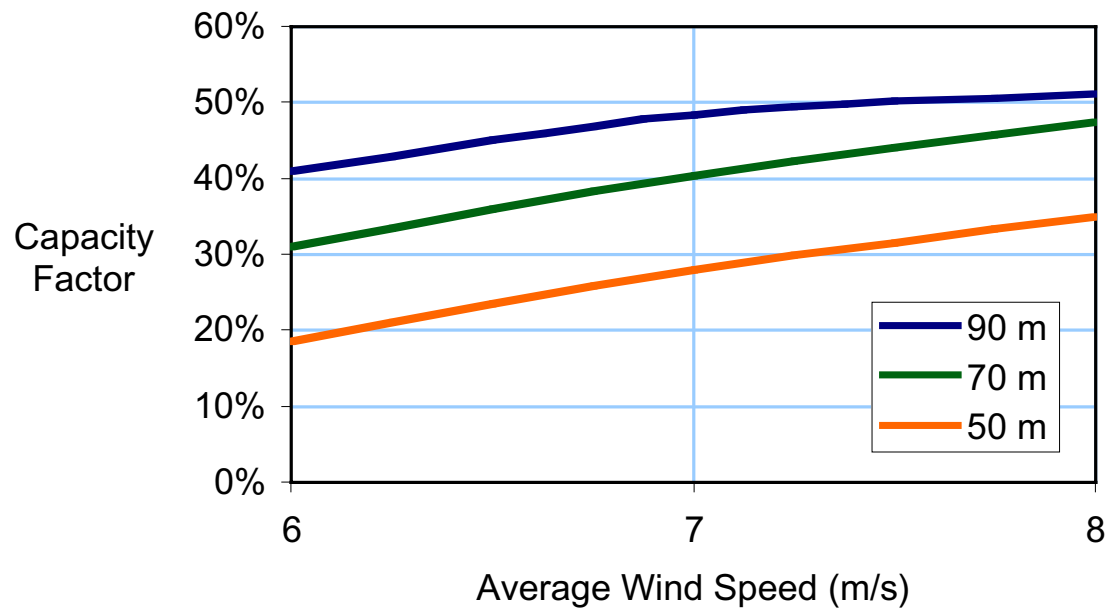
Wind Energy Generation 2nd Quarter 2001

- 70 m Rotor at 7 m/s average wind site
- April through July





Annual Capacity Factor

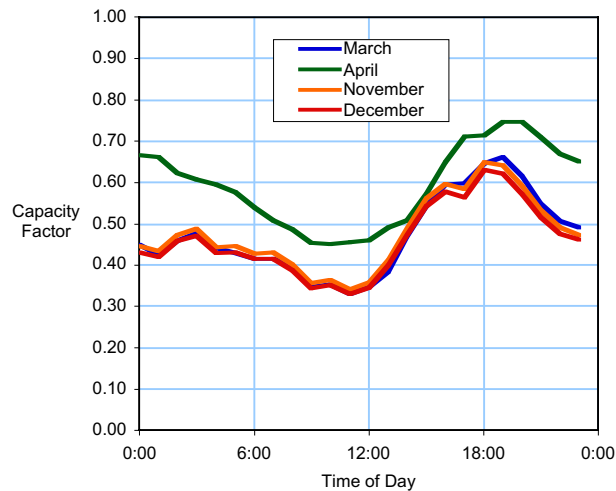


Wind Speed (m/s)	Annual Capacity Factor		
	Rotor Diameter (m)		
	50 m	70 m	90 m
6	18.6%	31.0%	41.0%
7	27.0%	40.4%	48.5%
8	35.0%	47.4%	51.2%

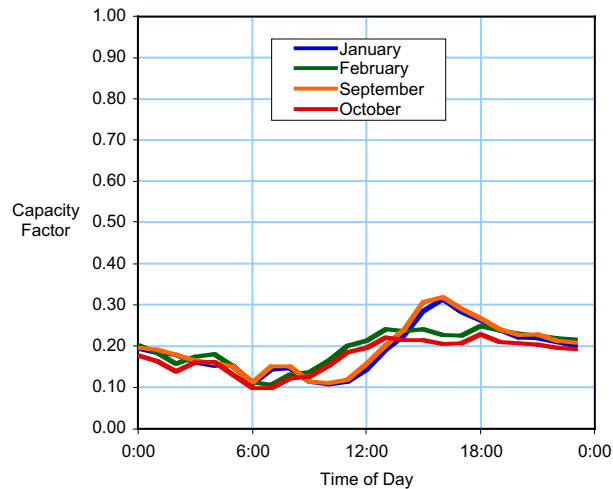


Diurnal Generation Trends

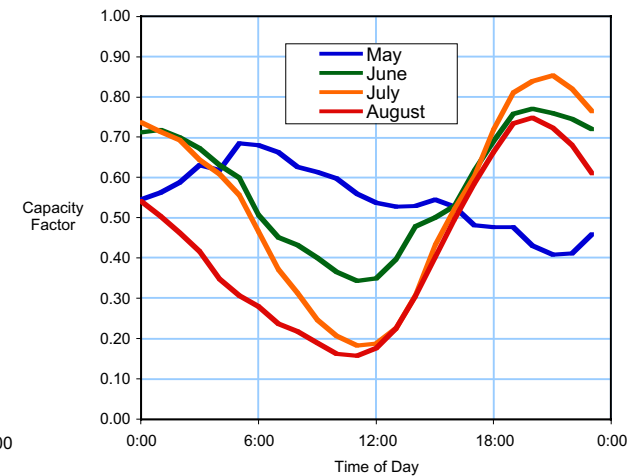
- Observed patterns are the result of local and regional meteorological conditions
- Results should not be viewed as representative for the state as a whole
- Results show that wind generation is not random and can be characterized by time of day and time of year



**March, April,
November, December**



**January, February,
September, October**

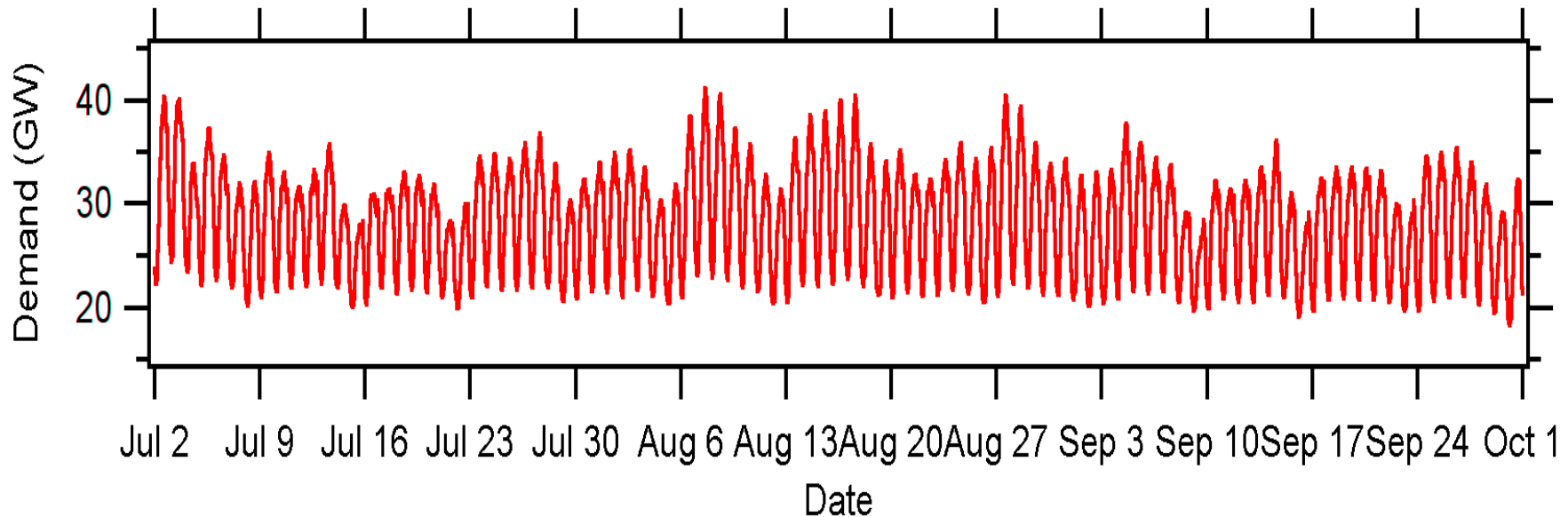


**May, June,
July, August**



California Demand 3rd Quarter 2001

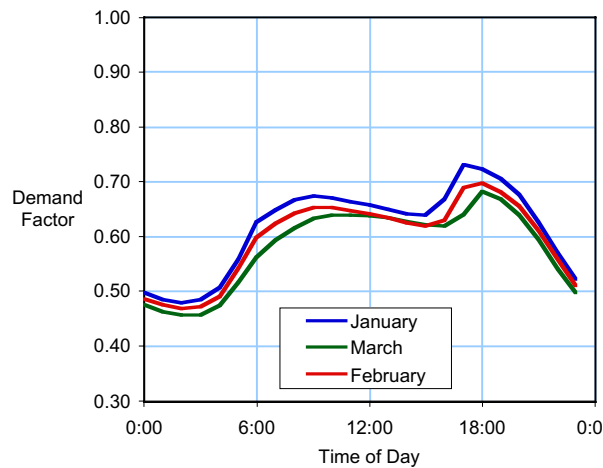
- **Peak demand in 2001 was 41.2 GW**
- **Statewide average may not be representative of local conditions within California**



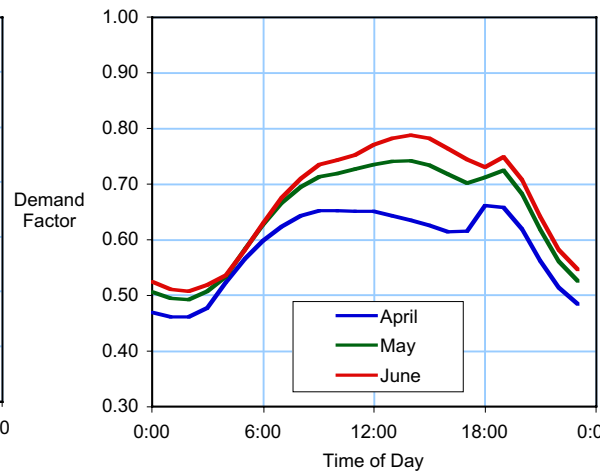


Diurnal Demand Trends

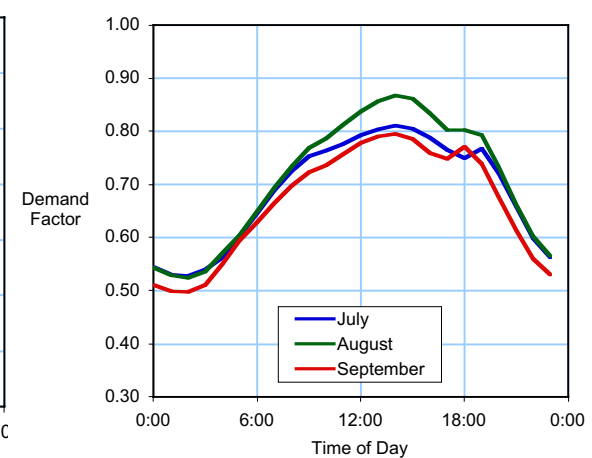
- Demand factor normalized using peak value of 41.2 GW
- Seasonally variable patterns



**January, February
March**



**April, May,
June**

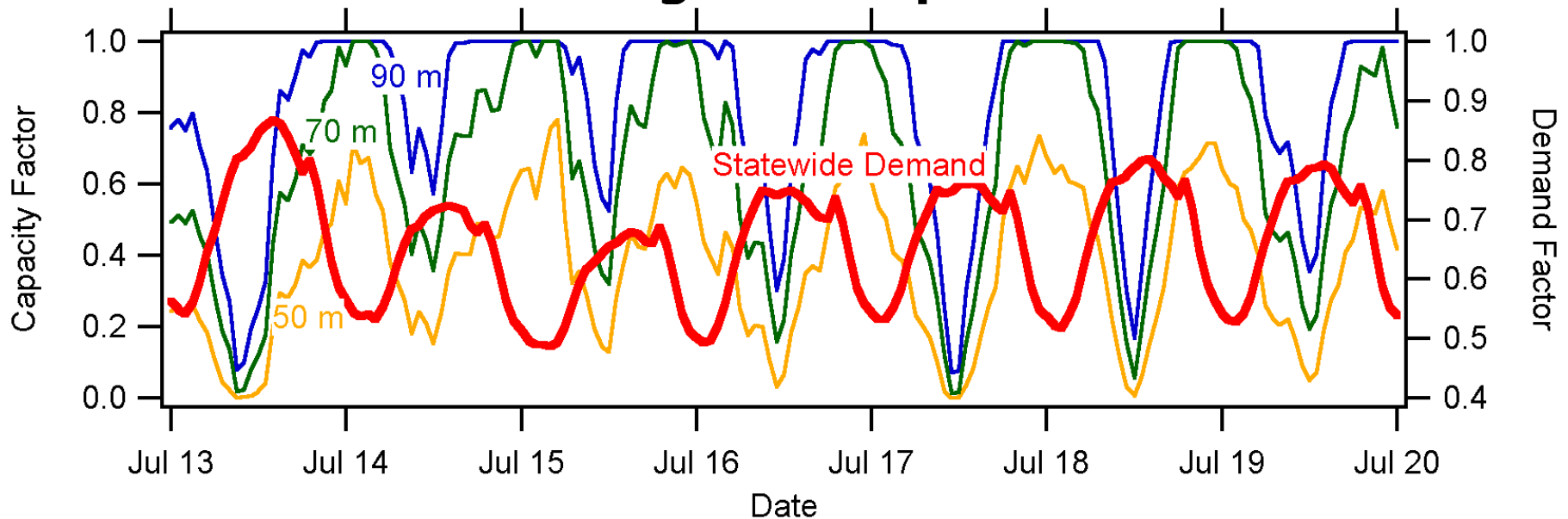


**July, August,
September**



Summer Non-Peak Period

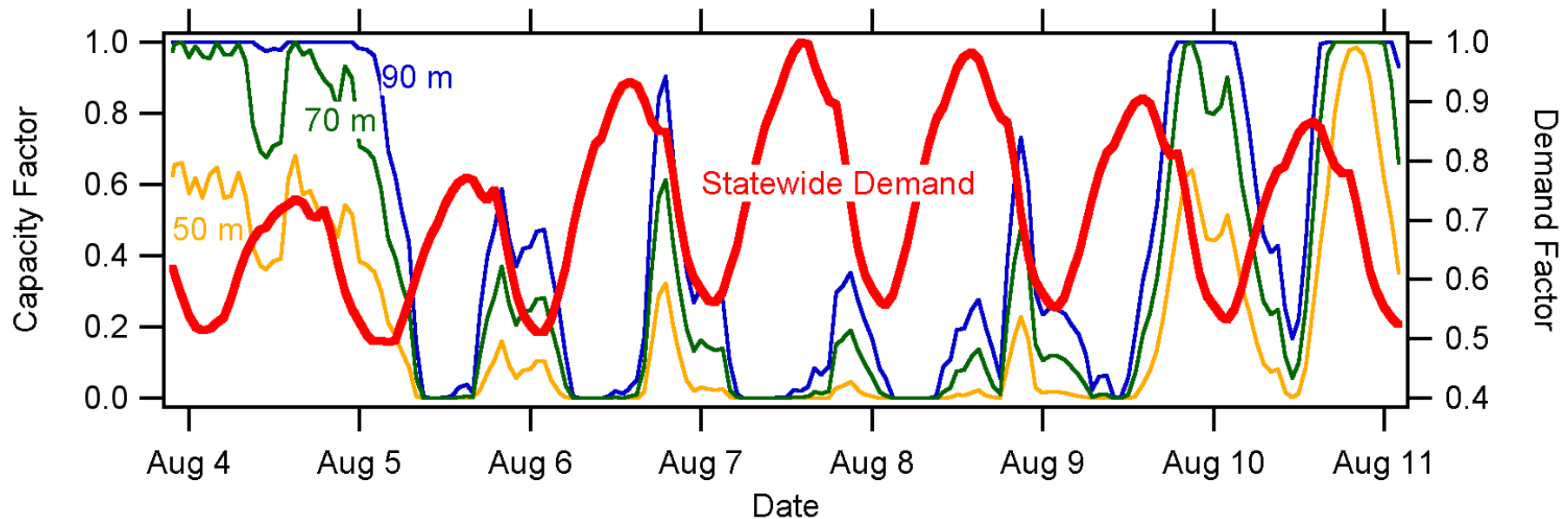
- Average wind generation capacity is high
- Late morning to early afternoon wind lulls
- 7 m/s average wind speed case





Summer Peak Period

- Statewide peak demand period is short in duration
- Peak demand corresponded to low wind conditions
- 7 m/s wind speed case





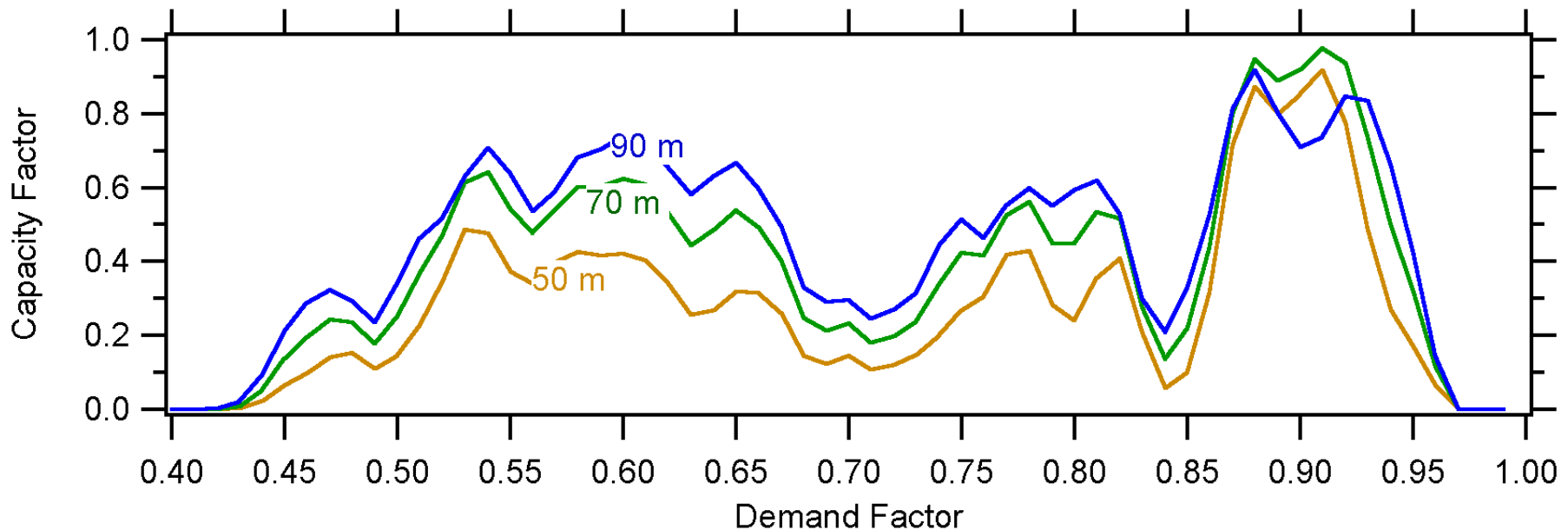
Peak Demand Summary

Date	Time	Demand (GW)	Demand Factor
June 21	3:00 PM	39.6	96.1%
June 22	1:00 PM	38.1	92.5%
July 2	3:00 PM	40.2	97.6%
July 3	3:00 PM	40.1	97.3%
August 7	3:00 PM	41.2	100.0%
August 8	3:00 PM	40.5	98.3%
August 16	3:00 PM	39.9	96.8%
August 17	2:00 PM	40.0	97.1%
August 27	3:00 PM	40.4	98.1%
August 28	3:00 PM	39.4	95.6%



Capacity vs Demand

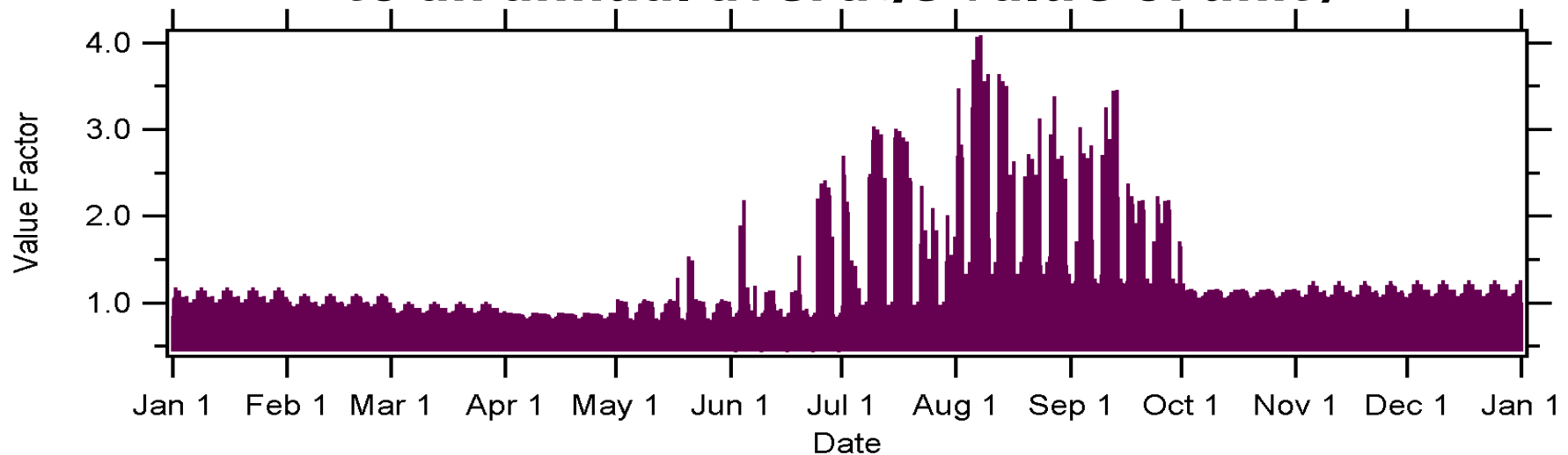
- **Correlation of wind capacity at specific demand level using method-of-bins approach**
- **Wind generation capacity factor is high when demand factor is high**





Time Dependent Value Factor

- Time dependent valuation methodology for Title 24 standards and Mojave climate zone
- Value factor calculated by normalizing to an annual average value of unity





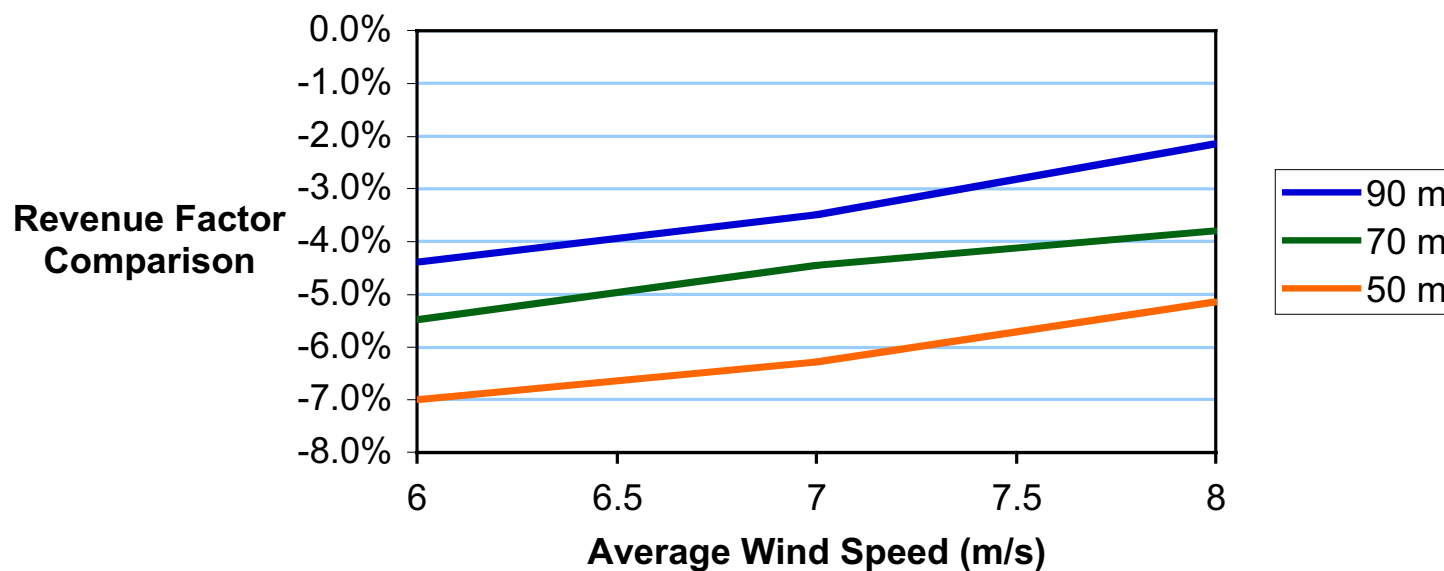
Annual Revenue Factor

- Revenue factor equals capacity factor multiplied by value factor

Wind Speed (m/s)	Annual TDV Revenue Factor		
	Rotor Diameter (m)		
	50 m	70 m	90 m
6	17.3%	29.3%	39.2%
7	25.3%	38.6%	46.8%
8	33.2%	45.6%	50.1%



Comparison of Time Dependent and Constant Value Revenue



Wind Speed (m/s)	TDV vs Constant Revenue Factor		
	Rotor Diameter (m)		
	50 m	70 m	90 m
6	-7.0%	-5.5%	-4.4%
7	-6.3%	-4.5%	-3.5%
8	-5.1%	-3.8%	-2.1%



Conclusions

- **Results show strong seasonal trends in wind generation according to time of day and season of year**
- **Wind generation provided high capacity during periods when system demand was between 85% and 95% of annual peak**
- **Turbine rotor optimization for specific power depends upon wind conditions of a given site and the time valuation of the energy generated**
- **The time dependent value of the wind generation was somewhat less than would be produced by time constant valuation.**