Wind Power Trends at Multiple California Sites

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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

- Obtained representative hourly power generation data for year 2002 at multiple California resource areas
  - Tehachapi Mountains
  - San Gorgonio Pass
  - Altamont Pass
- Wind generation adjusted to match annual average capacity factor for each wind resource region as recorded in the Wind Performance Reporting System (WPRS)
- California statewide electrical demand data normalized against peak demand value for the year
- Time dependent energy valuation based on statewide electrical demand

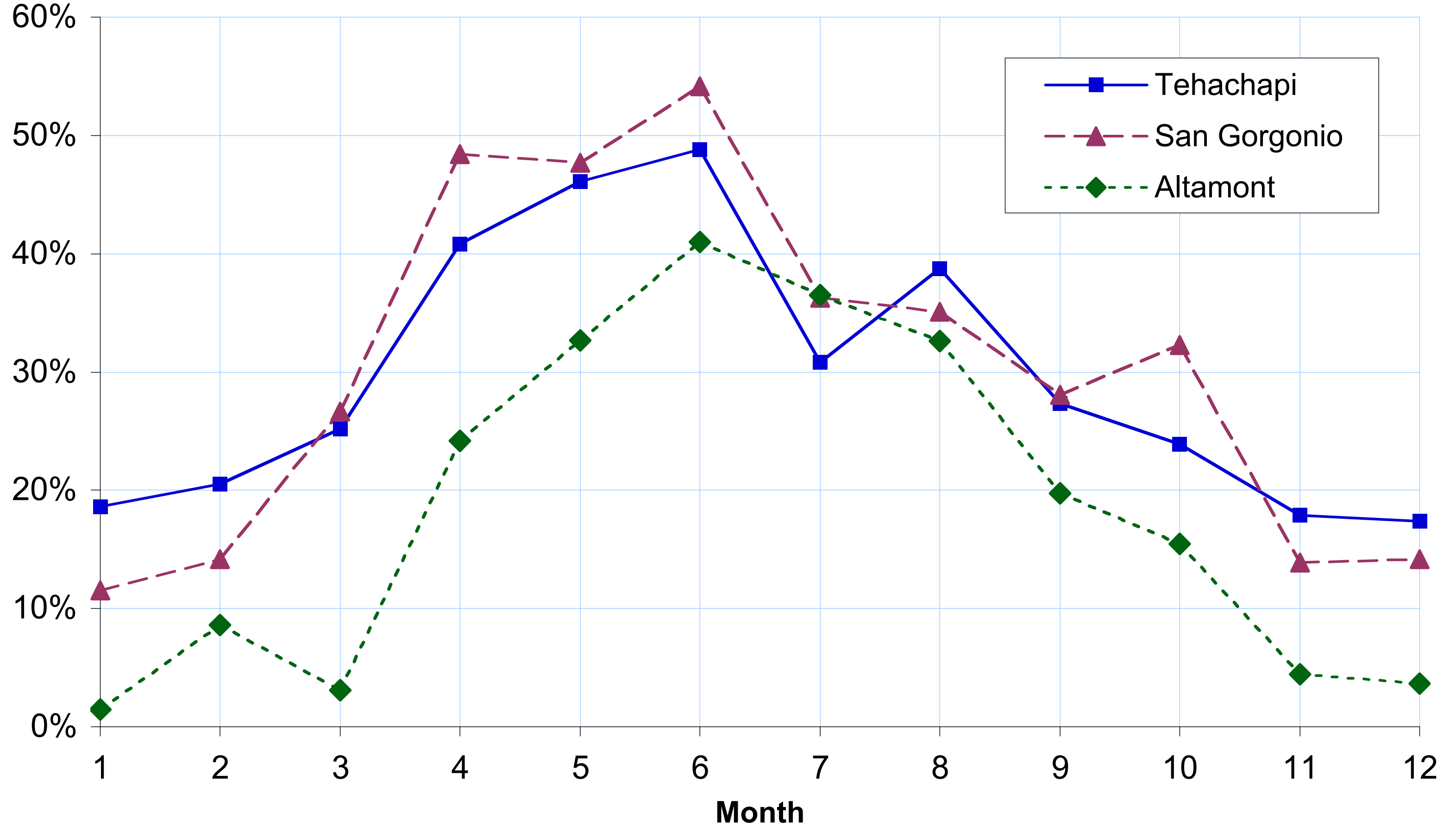
Wind Performance Reporting System

- Public database maintained by the California Energy Commission
- WPRS provides long term data for wind generation

Year	Annual Capacity Factor (%)		
	Tehachapi	San Gorgonio	Altamont
1996	26	31	17
1997	23	26	17
1998	25	34	14
1999	25	27	19
2000	28	28	17
2001	26	26	22
2002	29	30	18
Mean	26.0	28.9	17.7

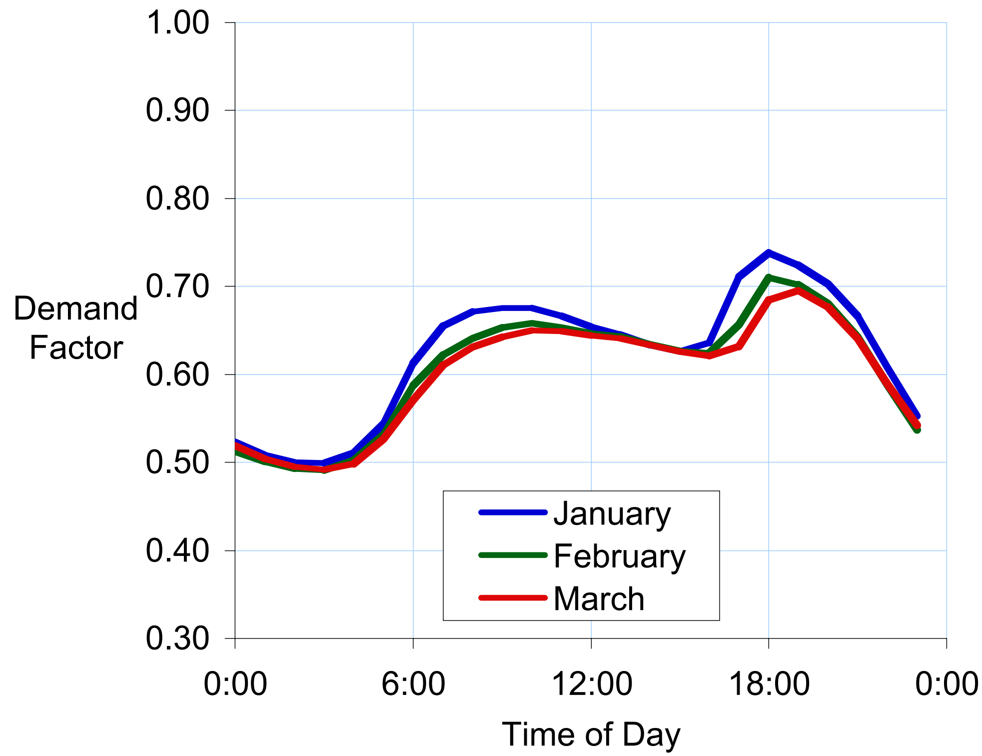
Year	Q3 Capacity Factor (%)		
	Tehachapi	San Gorgonio	Altamont
1996	23	29	28
1997	16	27	28
1998	19	28	24
1999	22	29	33
2000	29	33	27
2001	27	28	46
2002	32	33	30
Mean	24.0	29.6	30.9

2002 Monthly Capacity by Resource Area



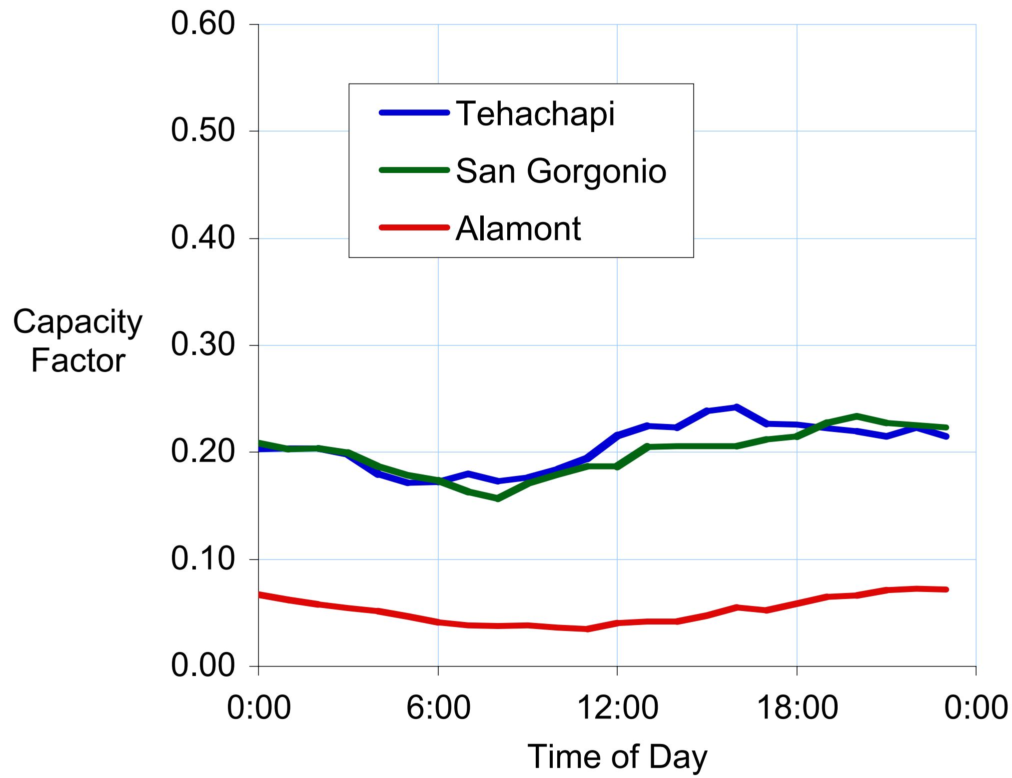
Winter Power Demand Trends

- First Quarter
  - January
  - February
  - March
- Electric power demand shows modest morning and evening peaks



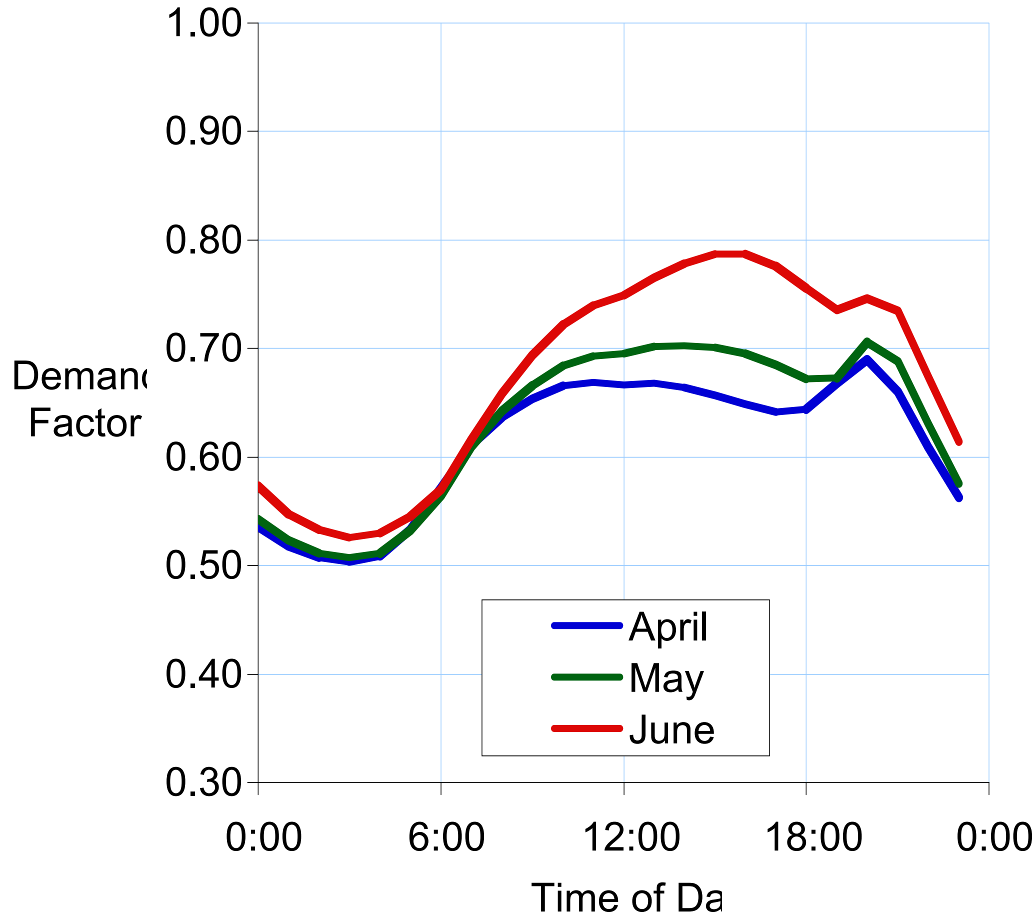
Winter Wind Capacity Trends

- First Quarter
  - January
  - February
  - March
- Tehachapi and San Gorgonio have similar characteristics
- No strong diurnal tendency at any of these three sites



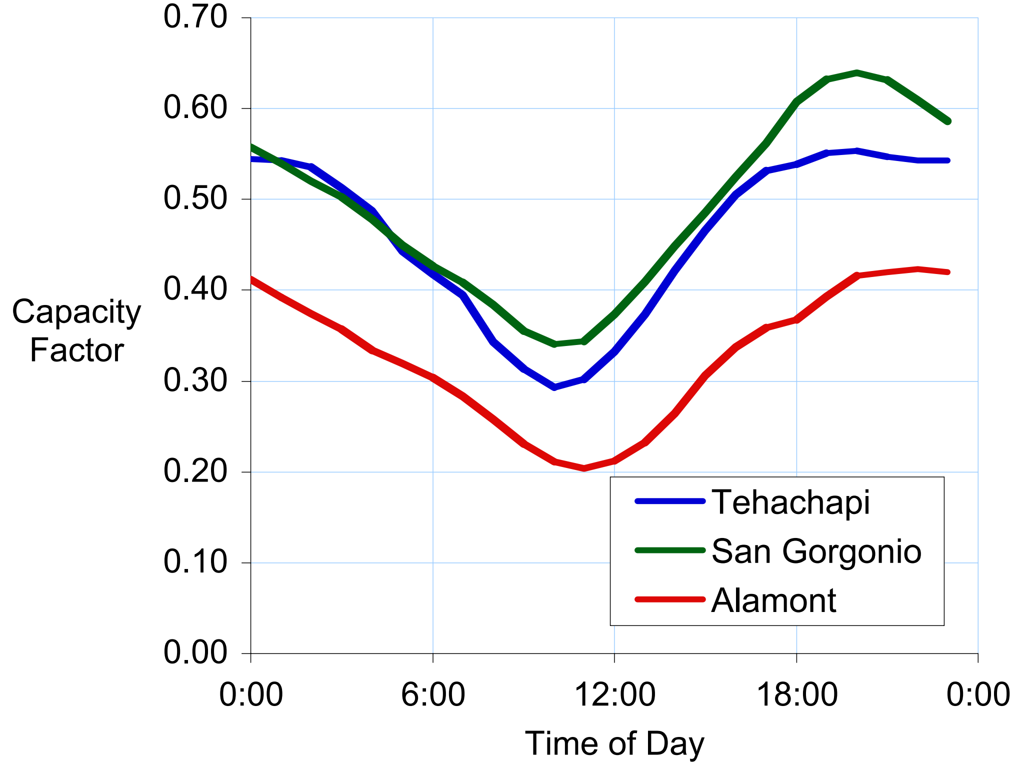
Spring Power Demand Trends

- Second Quarter
  - April
  - May
  - June
- April and May show consistent electrical demand from morning into the evening hours
- June shows mid-day peak characteristic of summer months



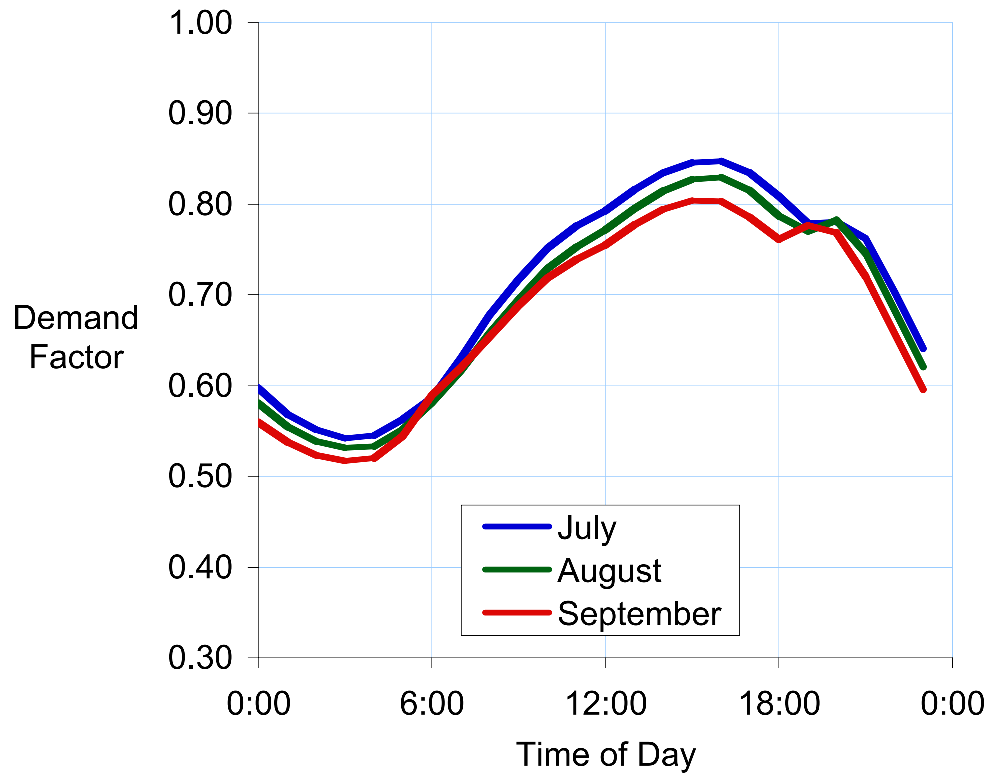
Spring Wind Capacity Trends

- Second Quarter
  - April
  - May
  - June
- Tehachapi and San Gorgonio have similar characteristics
- Strong daily trends are apparent at all three sites



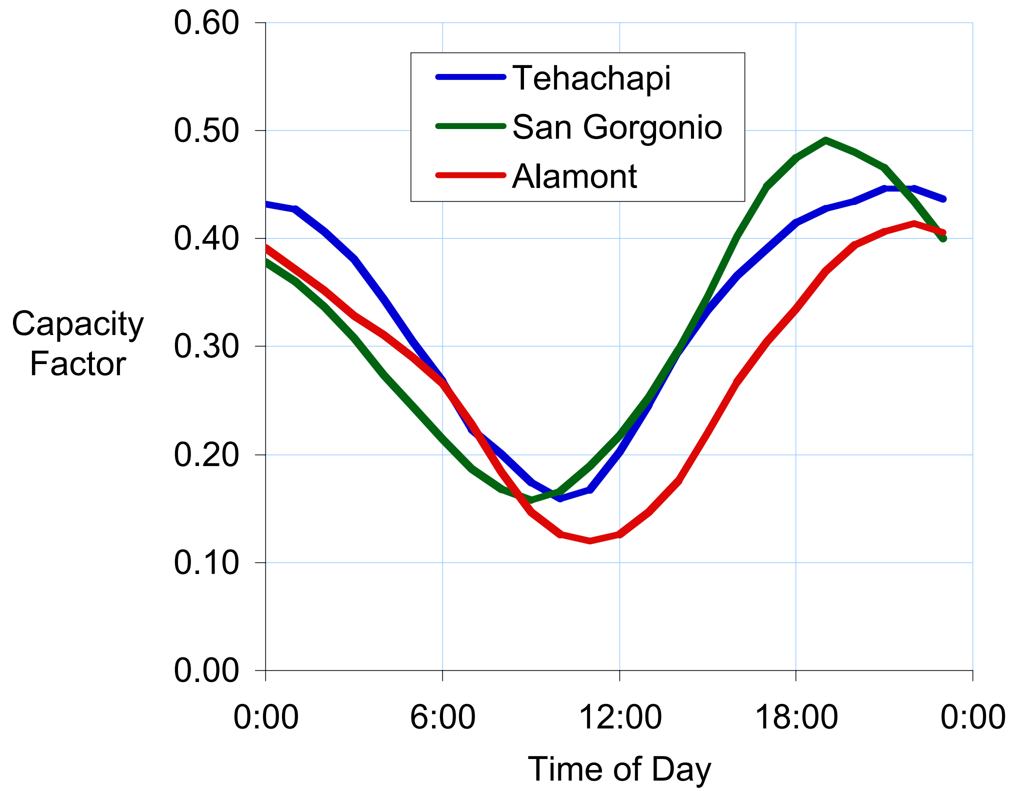
Summer Power Demand Trends

- Third Quarter
  - July
  - August
  - September
- Consistent diurnal power demand pattern with peak at 15:00 to 16:00 PST



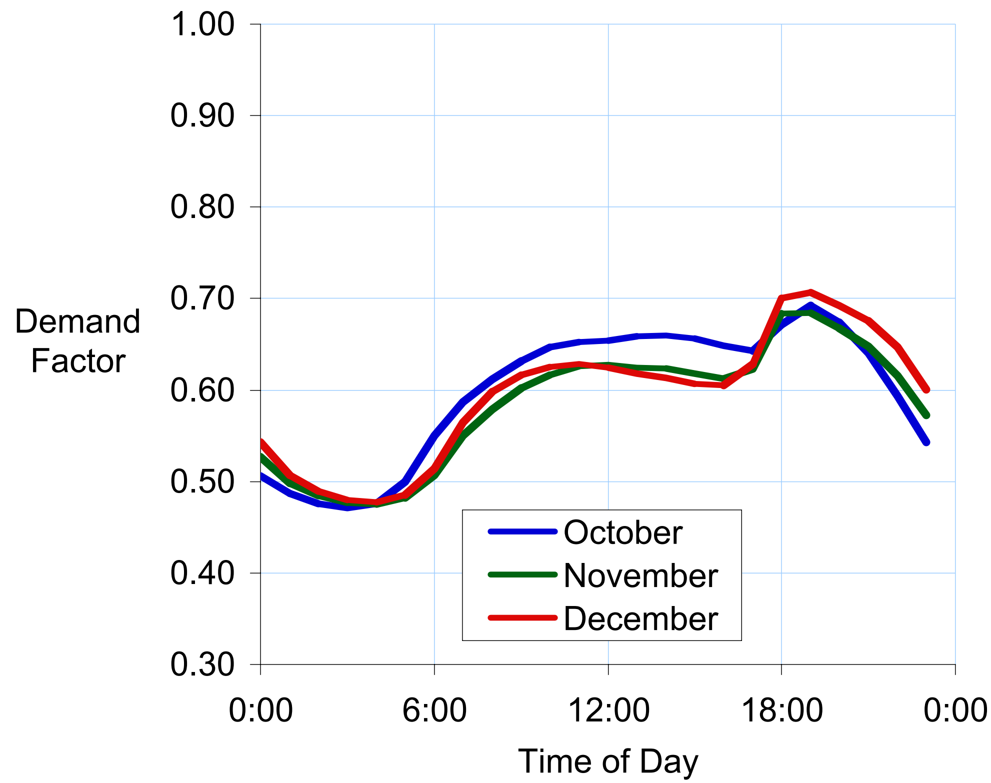
Summer Wind Capacity Trends

- Third Quarter
  - July
  - August
  - September
- Strong diurnal trends at all three resource areas
- Capacity factor at 15:00 demand peak
  - 0.37 Tehachapi
  - 0.40 San Gorgonio
  - 0.27 Altamont



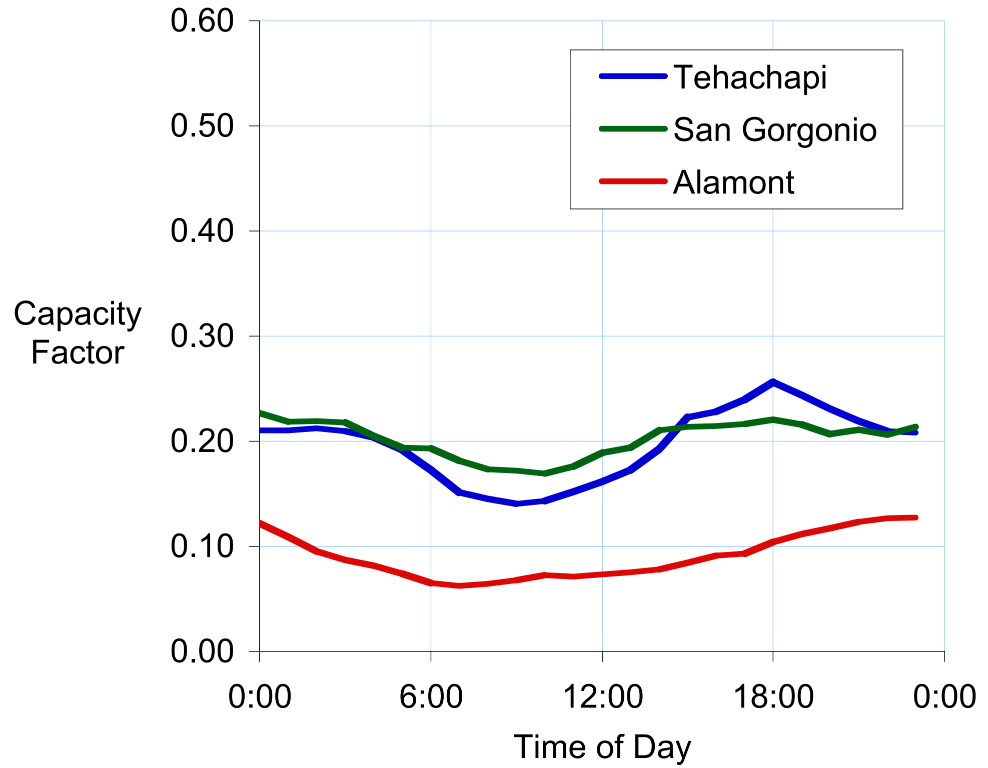
Autumn Power Demand Trends

- Fourth Quarter
  - October
  - November
  - December
- Daily demand pattern is similar to winter and early spring

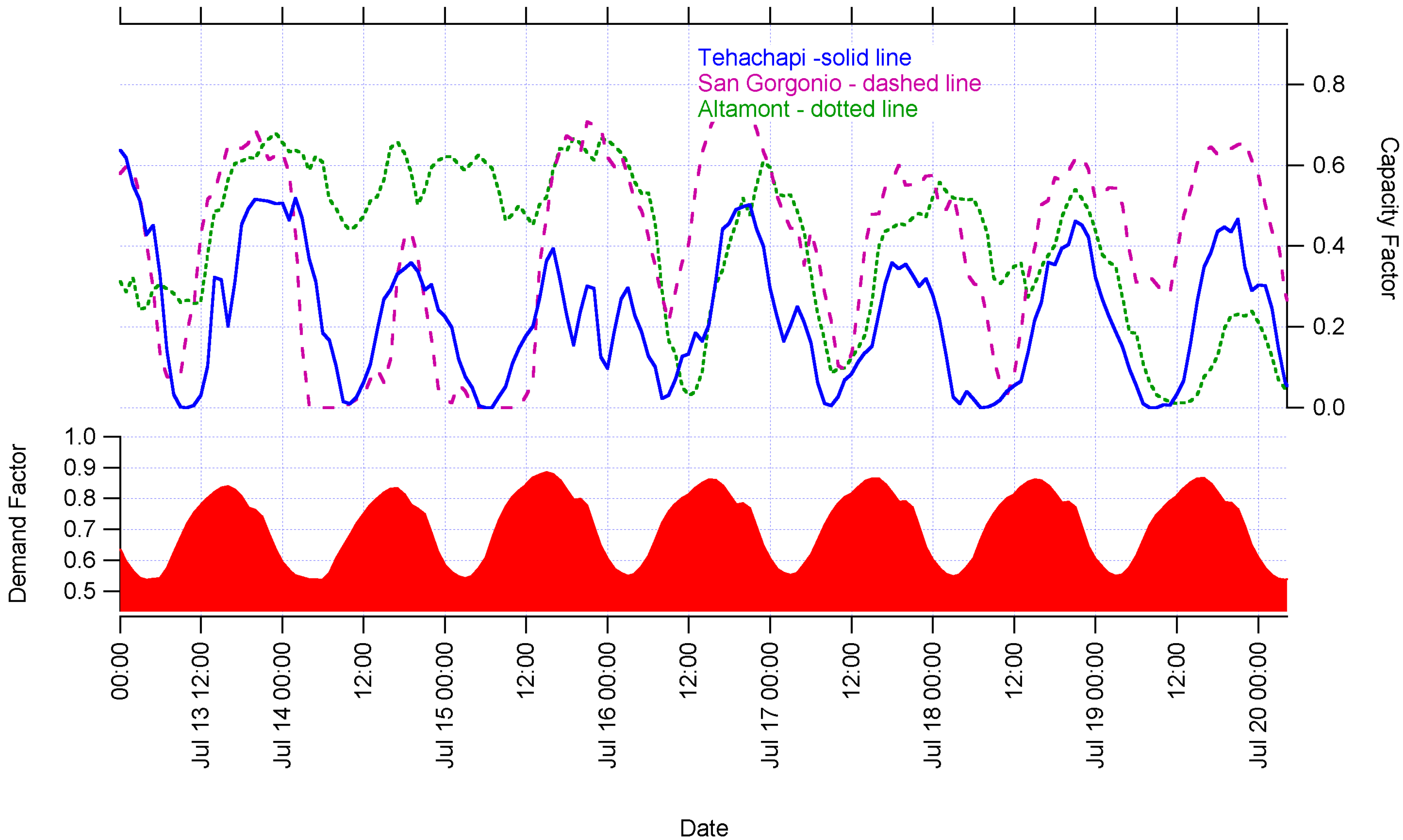


Autumn Wind Capacity Trends

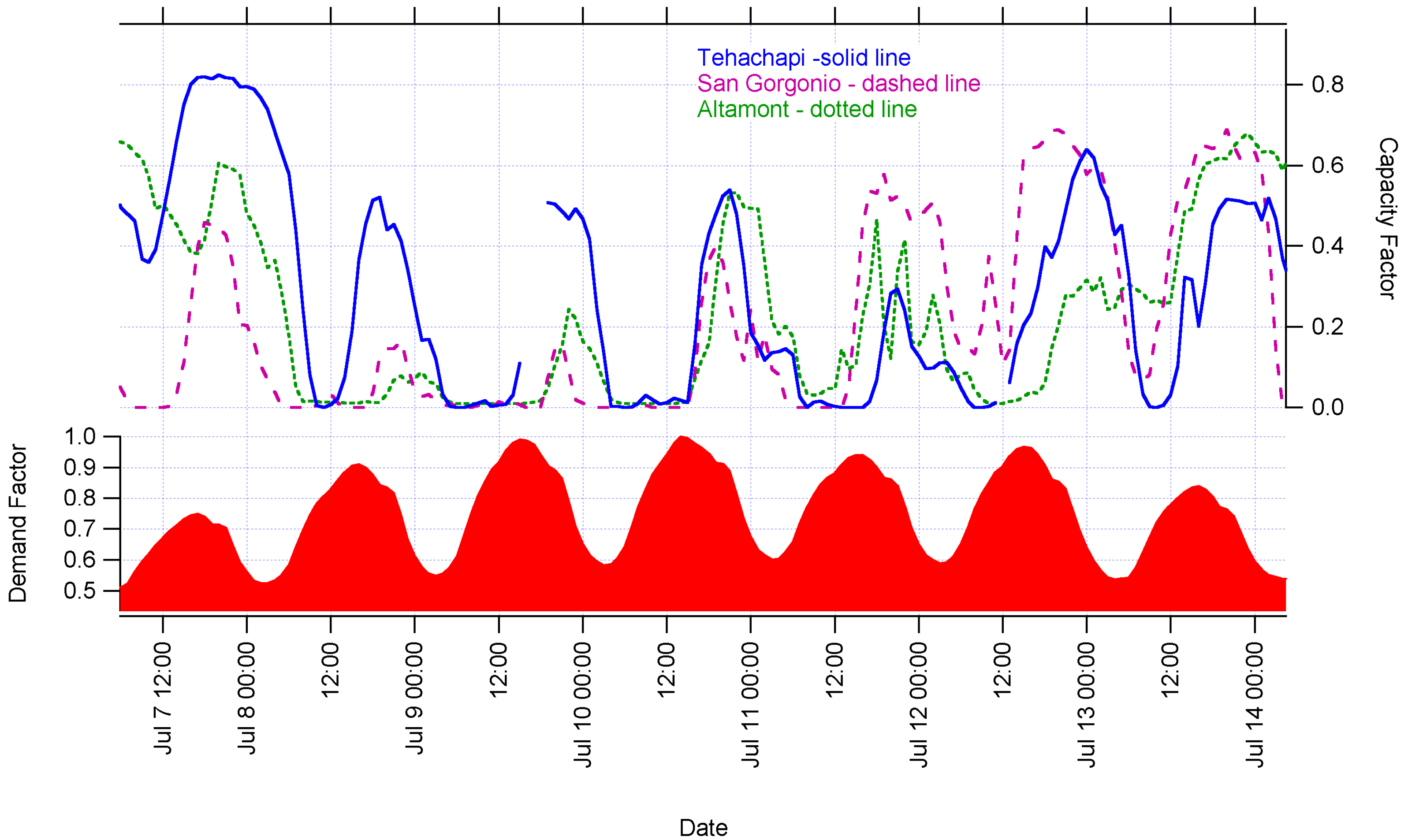
- Fourth Quarter
  - October
  - November
  - December
- Moderate diurnal trends at all three resource areas
- Pattern is similar to winter months



Summer Non-Peak Period



Summer Peak Period



Time Dependent Value Factor

- Used simple relation to define time dependent value factor
- Value is based upon statewise system demand
- Electrical generation is more valuable during high demand periods
- The time dependent value factor was normalized to an annual average of unity

$$\text{Value Factor} = \left| \frac{1}{1 + R - D} \right|$$

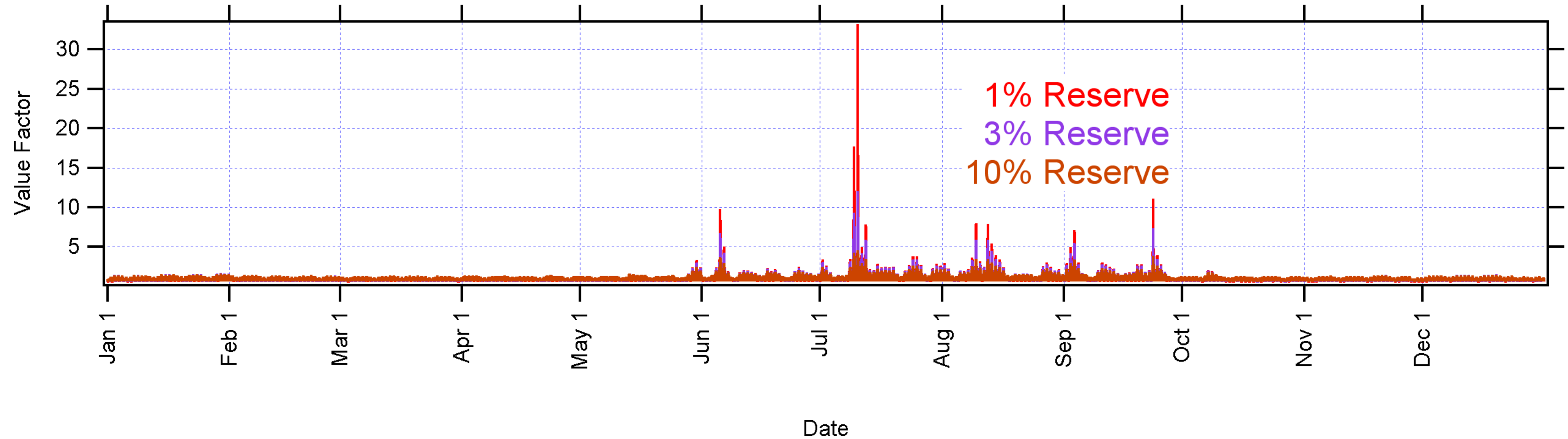
where:

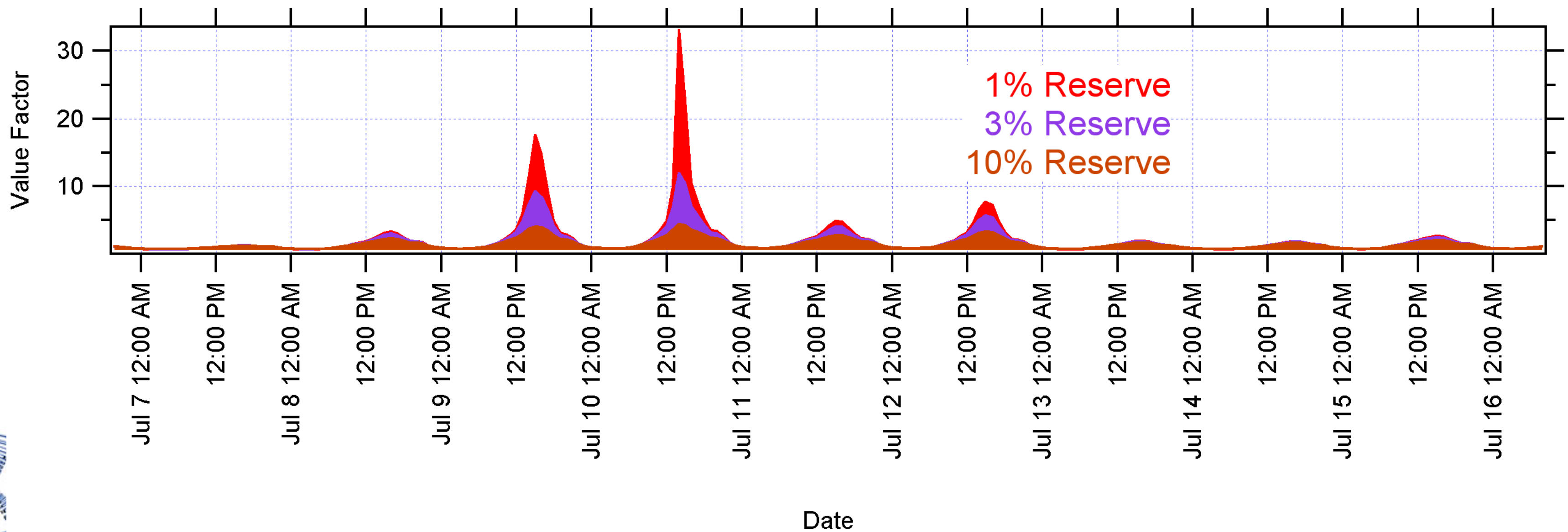
D = demand factor

R = reserve factor (1%, 3%, 10%)

- A range of reserve factors were used to assess the impact of "on-peak" capacity value

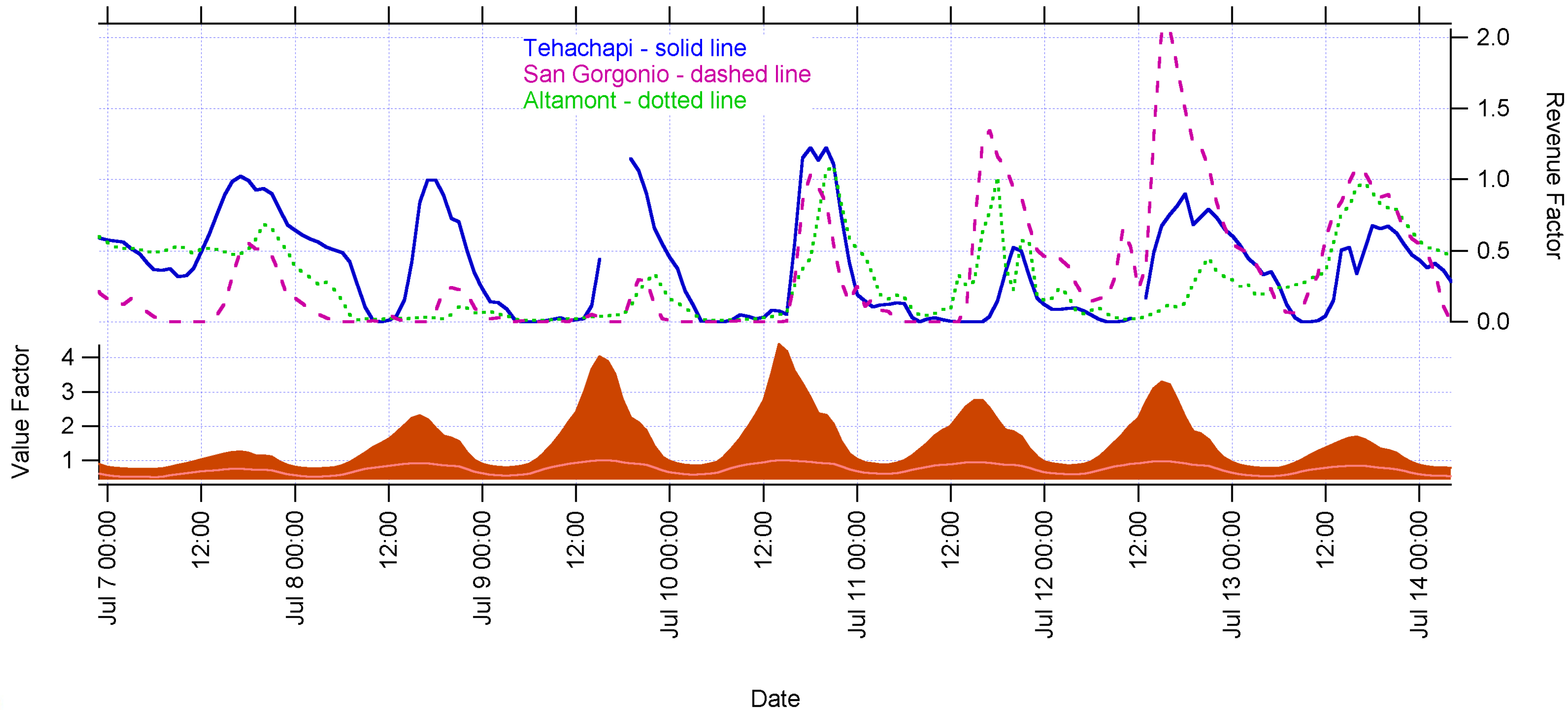
Time Dependent Value Factor





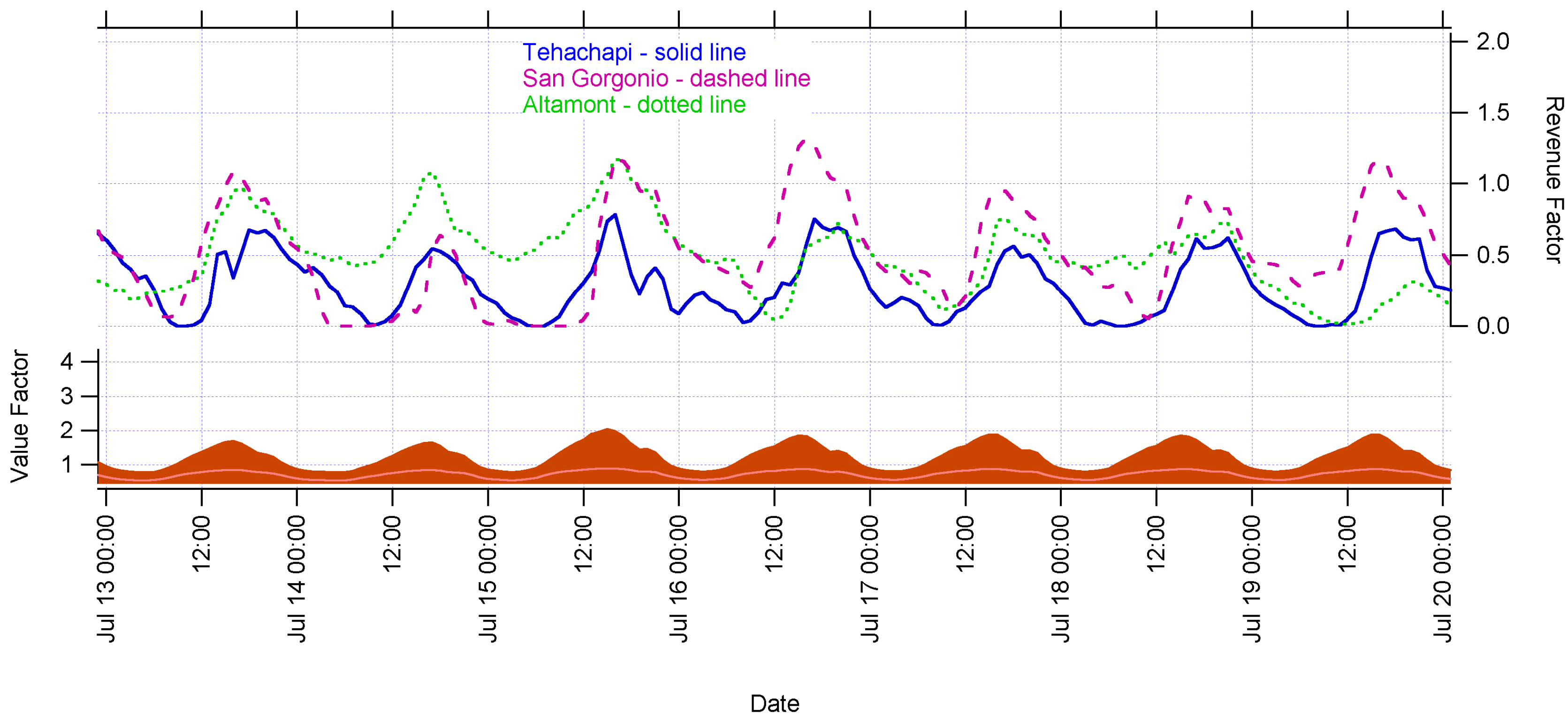
Revenue Factor During a Peak Period

- Revenue factor equals capacity factor multiplied by value factor
- Graph shows revenue factor assuming a 10% reserve factor



Revenue Factor During an Non-Peak Period

- Revenue factor equals capacity factor multiplied by value factor
- Graph shows revenue factor assuming a 10% reserve factor



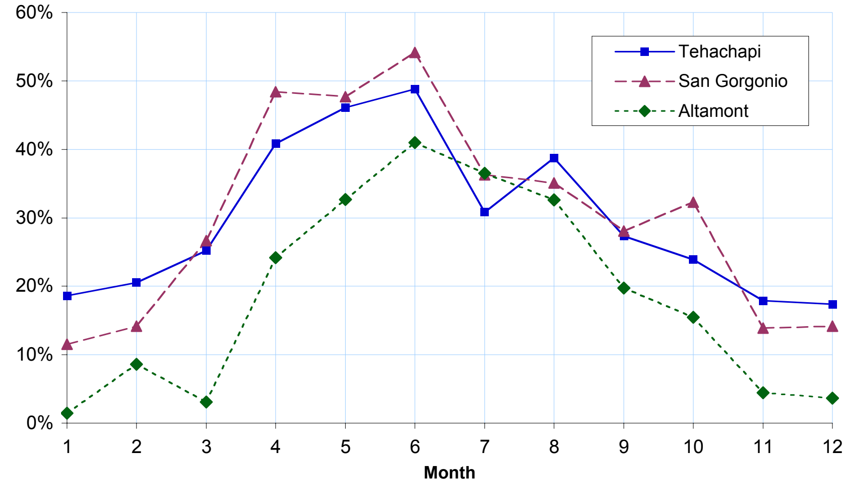
Comparison of Constant Value and Time Dependent Revenue Factors

- Time dependent revenue valuation is nearly equal to constant value for all three resource areas
- Increased reserve margin (broader value peaks) tends to show higher value for wind

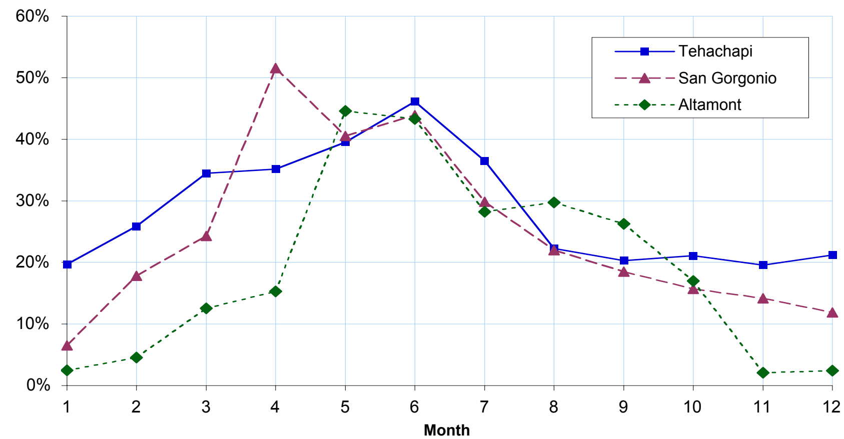
Revenue Factor	Constant Value	Time Dependent Value		
		1% Reserve	3% Reserve	10% Reserve
Tehachapi	29.7%	29.5%	29.6%	29.7%
San Gorgonio	30.2%	30.0%	30.3%	30.4%
Altamont	18.6%	18.6%	18.8%	18.9%

Monthly Capacity by Resource Area

- Substantial year-to-year variation can occur at each of these resource areas
- Single year results are probably not sufficient to characterize differences between resource areas



2002



2003

Conclusions

- Results show strong seasonal trends in wind generation according to time of day and season of year
- Seasonal and diurnal trends vary between resource areas, but have generally similar characteristics
- Single year results are not sufficient to properly compare differences between resource areas
- Time dependent valuation of wind capacity was approximately equal to constant valuation for all sites
- Increased preference for “on-peak” capacity did not materially change revenue factors