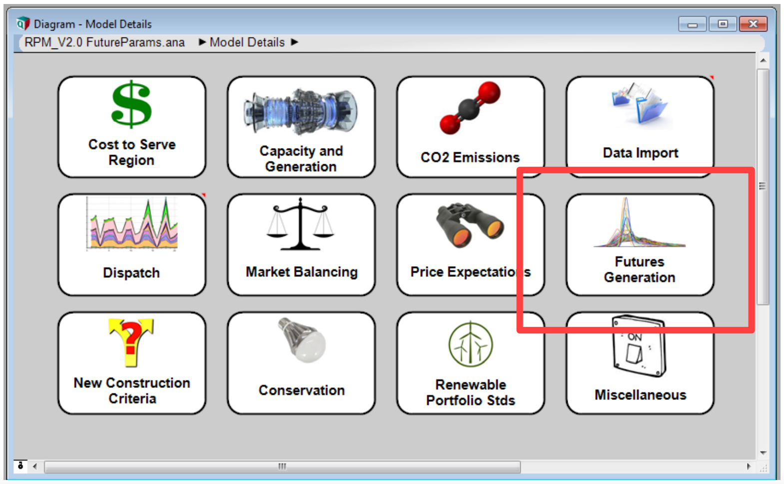
Future Generation in RPM

Good News…

- You don't need to understand the math in this presentation, each step can be examined in RPM through Analytica
- The methodology is substantially the same for future generation so for some this will be covering familiar ground



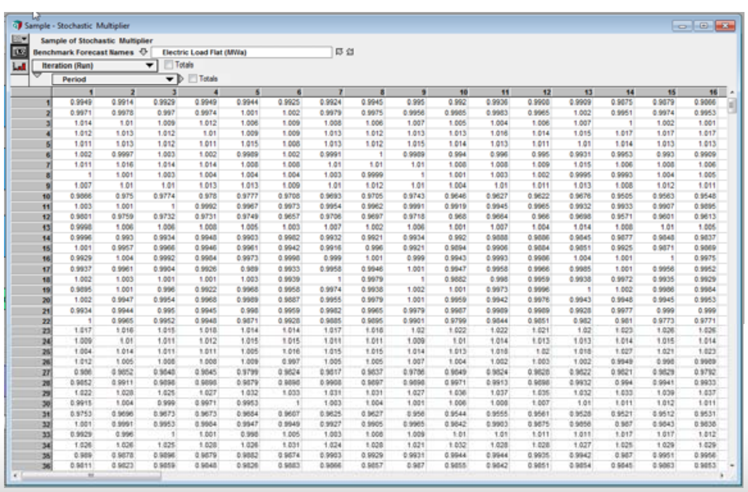
RPM Futures Risk Models

- Load
- Natural Gas
- Carbon Tax
- Electricity Price
- REC
- PTC

Scaling Forecasts

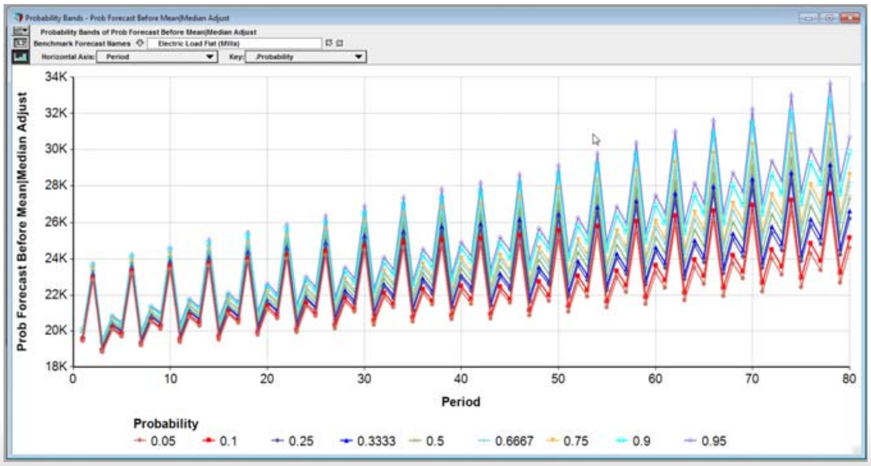
1. Forecasts such as load are input.
2. Factors that scale the input forecast are simulated. These factors are different for each future. The range of the factors is controlled by model parameters.
3. Each "future" is based on applying the factors from that future to the input forecasts.

Electric Load Example


Sample - Stochastic Multiplier
Sample of Stochastic Multiplier
Benchmark Forecast Names: Electric Load Flat (MWa)
Iteration (Run) ☐ Totals
Period ☐ Totals

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	0.9949	0.9914	0.9929	0.9949	0.9944	0.9925	0.9924	0.9945	0.995	0.992	0.9936	0.9908	0.9909	0.9875	0.9879	0.9866
2	0.9971	0.9978	0.997	0.9974	1.001	1.002	0.9979	0.9975	0.9956	0.9985	0.9983	0.9965	1.002	0.9951	0.9974	0.9953
3	1.014	1.01	1.009	1.012	1.006	1.009	1.008	1.006	1.007	1.005	1.004	1.006	1.007	1	1.002	1.001
4	1.012	1.013	1.012	1.01	1.009	1.009	1.013	1.012	1.013	1.013	1.016	1.014	1.015	1.017	1.017	1.017
5	1.011	1.013	1.012	1.011	1.015	1.008	1.013	1.012	1.015	1.014	1.013	1.011	1.01	1.014	1.013	1.013
6	1.002	0.9997	1.003	1.002	0.9989	1.002	0.9991	1	0.9989	0.994	0.996	0.995	0.9931	0.9953	0.993	0.9909
7	1.011	1.016	1.014	1.014	1.008	1.008	1.01	1.01	1.01	1.008	1.008	1.009	1.015	1.006	1.008	1.006
8	1	1.001	1.003	1.004	1.004	1.004	1.003	0.9999	1	1.001	1.003	1.002	0.9995	0.9993	1.004	1.005
9	1.007	1.01	1.01	1.013	1.013	1.009	1.01	1.012	1.01	1.004	1.01	1.011	1.013	1.008	1.012	1.011
10	0.9866	0.975	0.9774	0.978	0.9777	0.9708	0.9693	0.9705	0.9743	0.9646	0.9627	0.9622	0.9676	0.9505	0.9563	0.9548
11	1.003	1.001	1	0.9992	0.9967	0.9973	0.9954	0.9962	0.9991	0.9919	0.9945	0.9965	0.9932	0.9933	0.9907	0.9895
12	0.9801	0.9759	0.9732	0.9731	0.9749	0.9657	0.9706	0.9697	0.9718	0.968	0.9664	0.966	0.9698	0.9571	0.9601	0.9613
13	0.9998	1.006	1.006	1.008	1.005	1.003	1.007	1.002	1.006	1.001	1.007	1.004	1.014	1.008	1.01	1.005
14	0.9996	0.993	0.9934	0.9948	0.9903	0.9982	0.9932	0.9921	0.9934	0.992	0.9888	0.9886	0.9845	0.9877	0.9848	0.9837
15	1.001	0.9957	0.9966	0.9946	0.9961	0.9942	0.9916	0.996	0.9921	0.9894	0.9906	0.9884	0.9851	0.9925	0.9871	0.9869
16	0.9929	1.004	0.9992	0.9984	0.9973	0.9998	0.999	1.001	0.999	0.9943	0.9993	0.9986	1.004	1.001	1	0.9975
17	0.9937	0.9961	0.9904	0.9926	0.989	0.9933	0.9958	0.9946	1.001	0.9947	0.9958	0.9966	0.9985	1.001	0.9956	0.9952
18	1.002	1.003	1.001	1.001	1.003	0.9939	1	0.9979	1	0.9882	0.998	0.9959	0.9938	0.9972	0.9935	0.9929
19	0.9895	1.001	0.996	0.9922	0.9968	0.9958	0.9974	0.9938	1.002	1.001	0.9973	0.9996	1	1.002	0.9986	0.9984
20	1.002	0.9947	0.9954	0.9968	0.9989	0.9887	0.9955	0.9979	1.001	0.9959	0.9942	0.9976	0.9943	0.9948	0.9945	0.9953
21	0.9934	0.9944	0.995	0.9945	0.998	0.9959	0.9982	0.9965	0.9979	0.9987	0.9989	0.9989	0.9928	0.9977	0.999	0.999
22	1	0.9965	0.9952	0.9948	0.9871	0.9928	0.9885	0.9895	0.9901	0.9799	0.9844	0.9851	0.982	0.981	0.9773	0.9771
23	1.017	1.016	1.015	1.018	1.014	1.014	1.017	1.016	1.02	1.022	1.022	1.021	1.02	1.023	1.026	1.026
24	1.009	1.01	1.011	1.012	1.015	1.015	1.011	1.011	1.009	1.01	1.014	1.013	1.013	1.014	1.015	1.014
25	1.004	1.014	1.011	1.011	1.005	1.016	1.015	1.015	1.014	1.013	1.018	1.02	1.018	1.027	1.021	1.023
26	1.012	1.005	1.008	1.008	1.009	0.997	1.005	1.005	1.007	1.004	1.002	1.003	1.002	0.9949	0.998	0.9989
27	0.986	0.9852	0.9848	0.9845	0.9799	0.9824	0.9817	0.9837	0.9786	0.9849	0.9824	0.9828	0.9822	0.9821	0.9829	0.9792
28	0.9852	0.9911	0.9898	0.9898	0.9879	0.9898	0.9908	0.9897	0.9898	0.9971	0.9913	0.9898	0.9932	0.994	0.9941	0.9933
29	1.022	1.028	1.025	1.027	1.032	1.033	1.031	1.031	1.027	1.036	1.037	1.035	1.032	1.033	1.039	1.037
30	0.9915	1.004	0.999	0.9971	0.9953	1	1.003	1.004	1.001	1.006	1.008	1.007	1.01	1.011	1.012	1.011
31	0.9753	0.9696	0.9673	0.9673	0.9684	0.9607	0.9625	0.9627	0.956	0.9544	0.9555	0.9561	0.9528	0.9521	0.9512	0.9531
32	1.001	0.9991	0.9953	0.9984	0.9947	0.9949	0.9927	0.9905	0.9965	0.9842	0.9903	0.9875	0.9856	0.987	0.9843	0.9838
33	0.9929	0.996	1	1.001	0.998	1.005	1.003	1.008	1.009	1.01	1.01	1.011	1.011	1.017	1.017	1.012
34	1.026	1.026	1.025	1.028	1.026	1.031	1.024	1.028	1.021	1.032	1.028	1.028	1.027	1.025	1.029	1.029
35	0.989	0.9878	0.9896	0.9879	0.9882	0.9874	0.9903	0.9929	0.9931	0.9944	0.9944	0.9935	0.9942	0.987	0.9951	0.9956
36	0.9811	0.9823	0.9859	0.9848	0.9826	0.9883	0.9866	0.9857	0.987	0.9855	0.9842	0.9851	0.9854	0.9845	0.9863	0.9853

Electric Load Example



Annual Trend Factors

- Controls Annual Spread in RPM
- Of the form:

$$P_{t,i} = e^{\alpha_F \varepsilon_{F,i} + \alpha_L \varepsilon_{L,i}(y_t - y_0) + \alpha_Q \varepsilon_{Q,i}(y_t - y_0)^2}$$

where $y_t = year\ at\ time\ t$; α_F, α_L and α_Q are parameters; and $\varepsilon_{F,i} \sim \varepsilon_{L,i} \sim \varepsilon_{Q,i} \sim N(0,1)$

Seasonal Factors

- Add deviation from annual trends
- Of the form:

$$S_{t,i} = e^{\tau_{t,i}}$$

where $\tau_{t,i}$ is a normal random variable.

Jump Factors

- Controls temporary deviations from the annual trend, i.e. jumps
- Of the form:

$$J_{t,i} = e^{I_{\{\beta_i < y_t - y_0 < \beta_i + \omega_i\}}^{\xi_i} - I_{\{\beta_i + \omega_i < y_t - y_0 < \beta_i + \omega_i + e^{\xi_i}\}}^{\xi_i / \gamma}}$$

where β_i and ω_i and ξ_i are all uniform random variables and γ is a scaling factor.

Risk Model DNA

- Annual Trend Factor * Seasonal Factor * Jump Factor * Forecast
  - Carbon Tax and PTC being the exceptions
- Heavily Parameterized
- Applied to related model elements, e.g. load risk model applies same factors to heavy and light load forecast

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Estimating Parameters

- Sources of estimation:
  - Forecasts from Advisory Committees, e.g. load and natural gas price forecasts
  - Historical data or adjusted historical data, e.g. weather normalized historic load and historic electricity prices
  - Expert input

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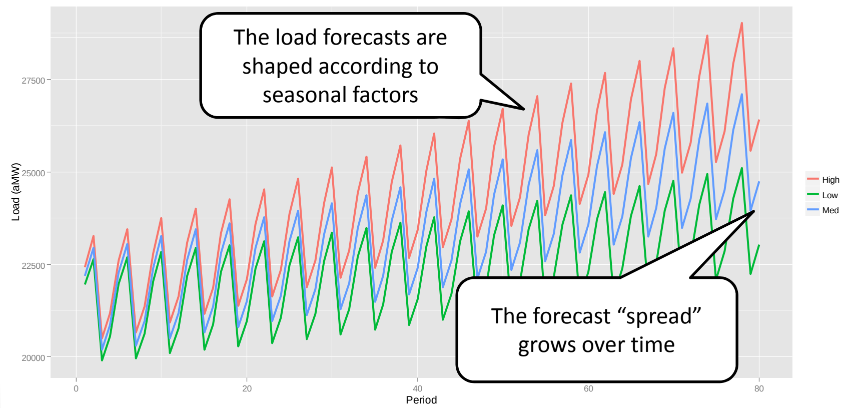
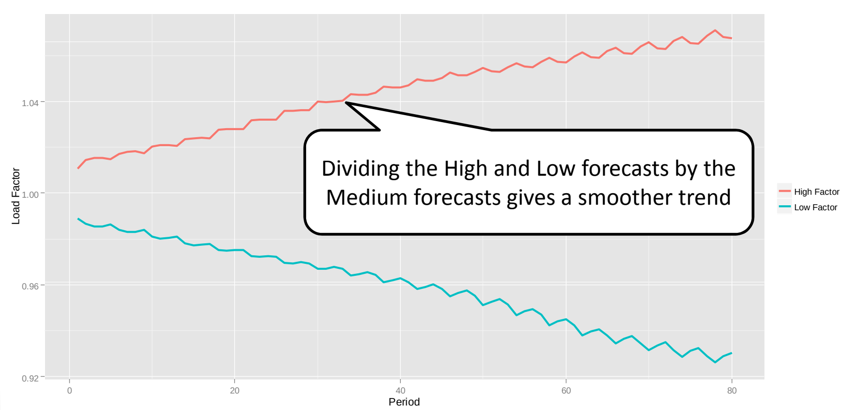
Load Model Example



Load Model Example



Load Model Example

- Factors grow through time relatively smoothly by year
- Combining inputs, some context and RPM parametric assumptions (mostly log-normal assumptions) allows for estimating parameters for the model
- Load high/low forecast **directly** informs the risk model

Load Model Example

- Estimate factors using simple linear regression

That is, if H_t, M_t and L_t are the high, medium and low load forecasts respective then use regression to find a, b and c in

$$\ln(H_t/M_t) = a + b(y_t - y_0) + c(y_t - y_0)^2 + \epsilon$$

Load Model Example

We want a value where the probability of exceeding it is .85, which is the probability associated with the high load forecast. Since we have normality

$$\Pr\left[{}^{\alpha_L}/_{20} * \varepsilon_{L,i} < {}^{\alpha_L}/_{20} * z_{.85}\right] = .85$$

Thus we set

$$b = {}^{\alpha_L}/_{20} * z_{.85}$$

Which implies

$$\alpha_L = {}^{20b}/_{z_{.85}}$$

This gives $\alpha_F = .0102$, $\alpha_L = .0632$ and $\alpha_Q = .0221$

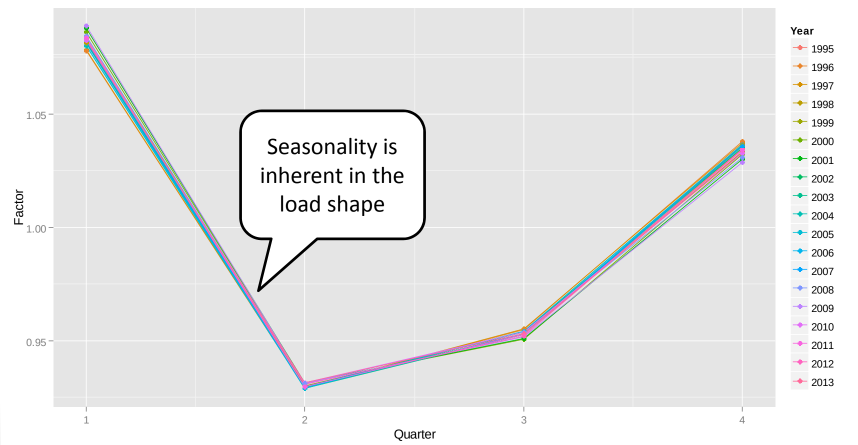
Load Model Example

- Seasonal factor only impacts volatility not the shape
- Historic load must be adjusted for DSIs
- Seasonal shapes can be estimated from the adjusted historic load

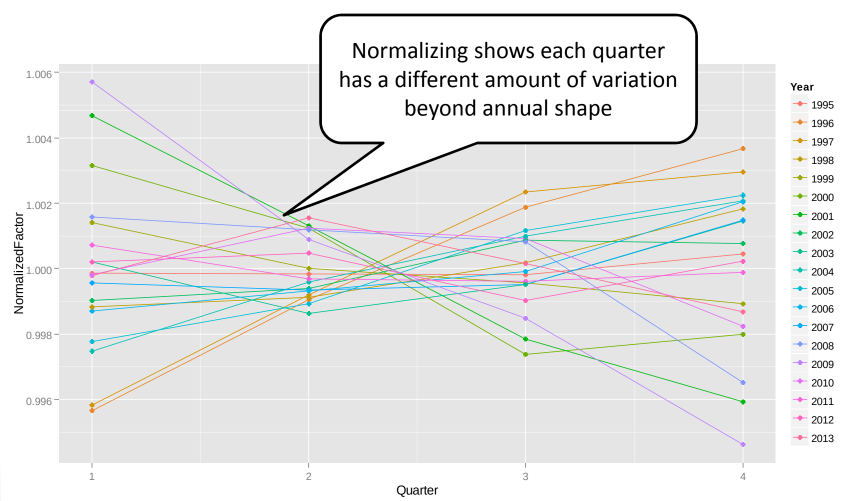
  The factor only depends on the quarter since it is of the form

$$S_{t,i} = e^{\tau_{q_{t,i}}}$$

Load Model Example



Load Model Example

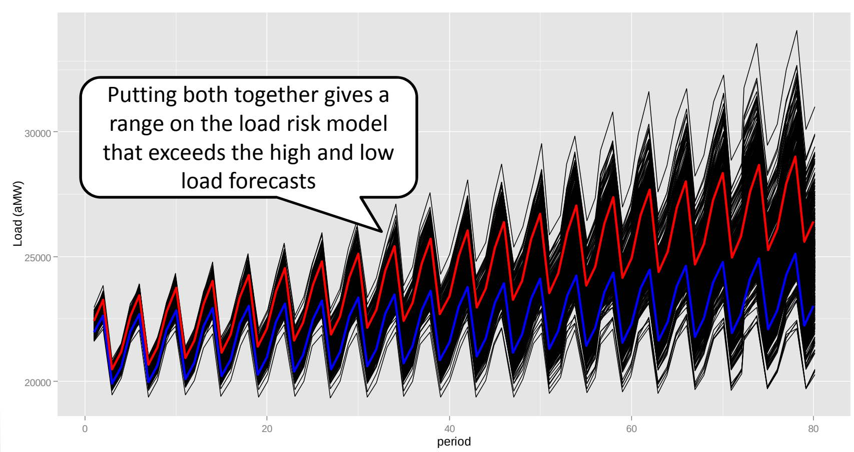


Load Model Example

- Taking standard deviation after normalizing gives for each quarter

Q1	Q2	Q3	Q4
.0030	.0011	.0014	.0030

Load Model Example



Into RPM…

- Switch to Analytica to show parameters in the model and show the future generation module
- Draft technical appendix gives much more detail and covers other models and parameters
- Statistics were done in R, scripts are available upon request

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