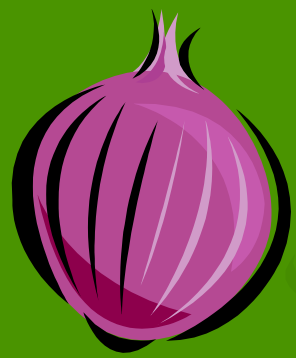
Benefits of Hydropower Decision Support Systems

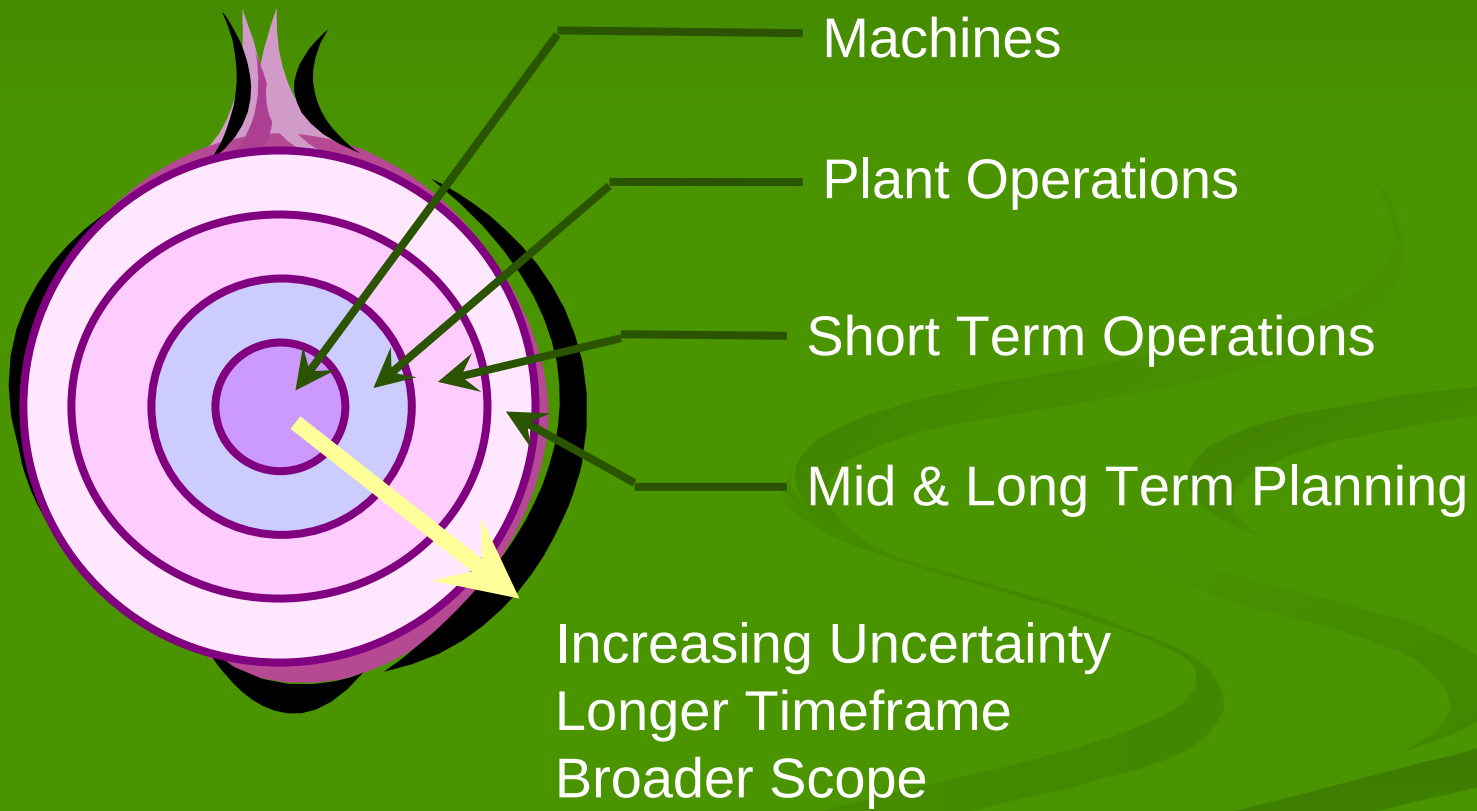
Optimizing the Onion



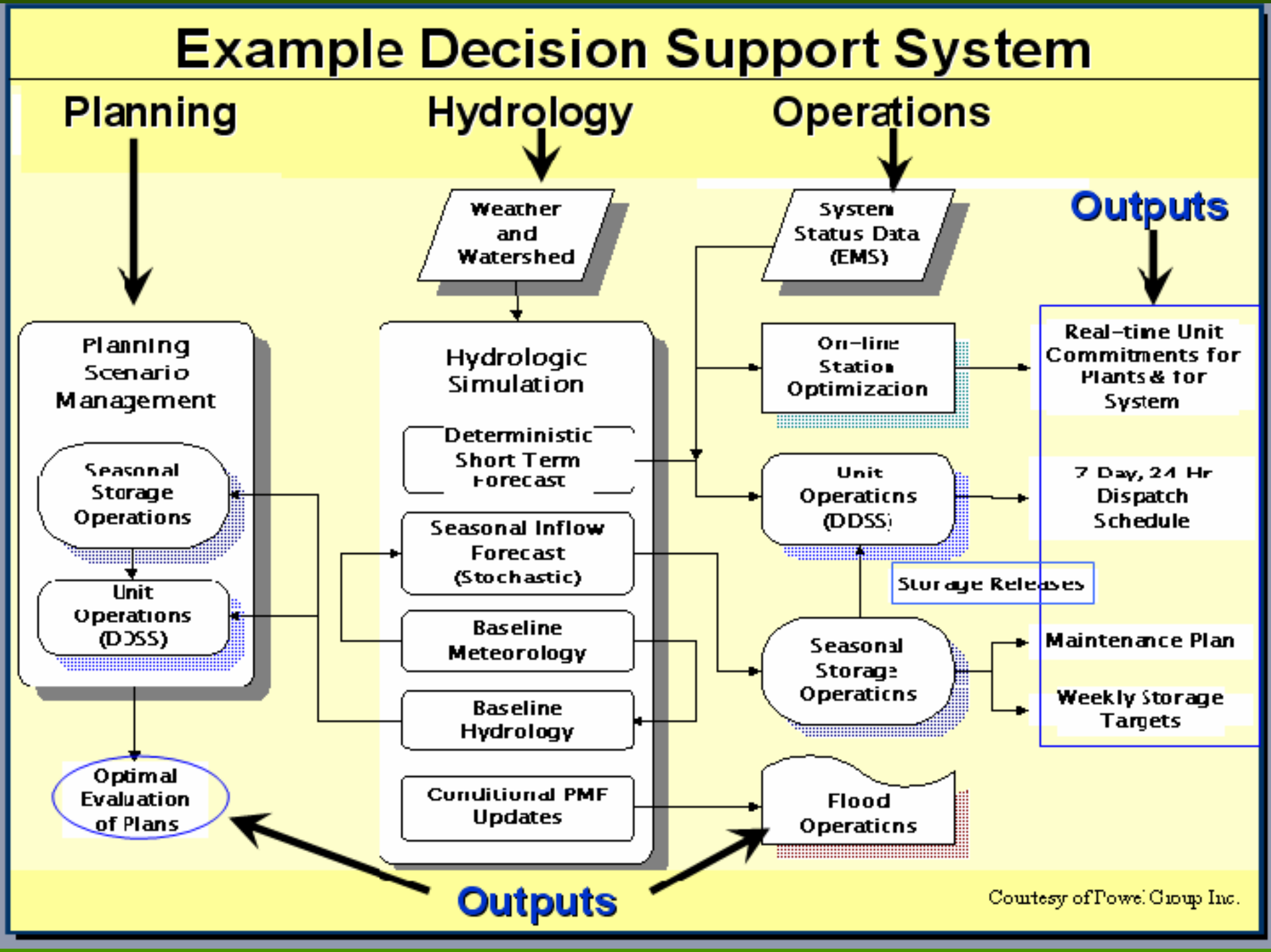
Robert W. Dies and Charles D. D. Howard
http://www.CddHoward .com

Acknowledgements

The Optimization Onion



Example Decision Support System



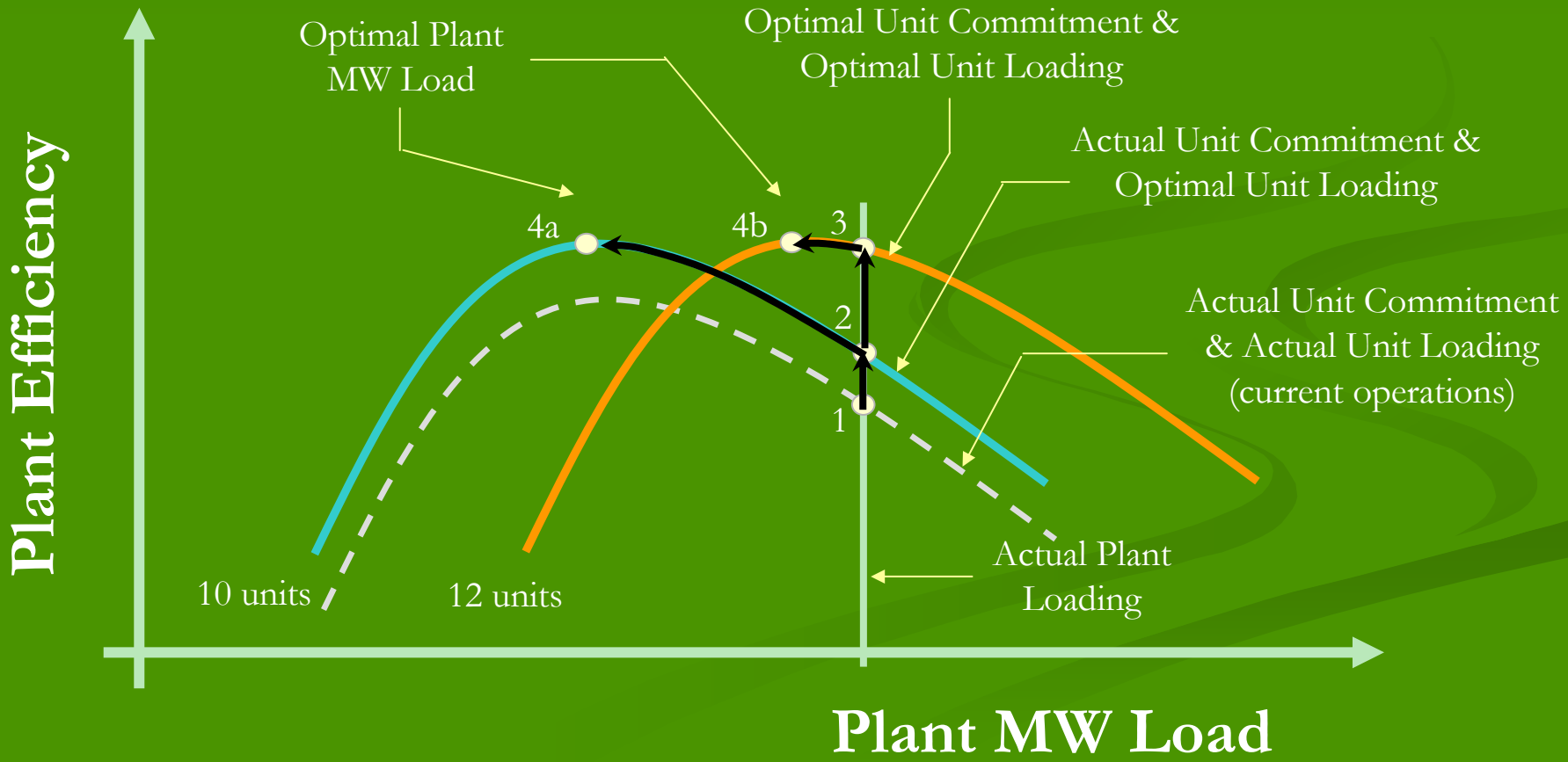
Courtesy of Power Group Inc.

Plant Operational Benefits

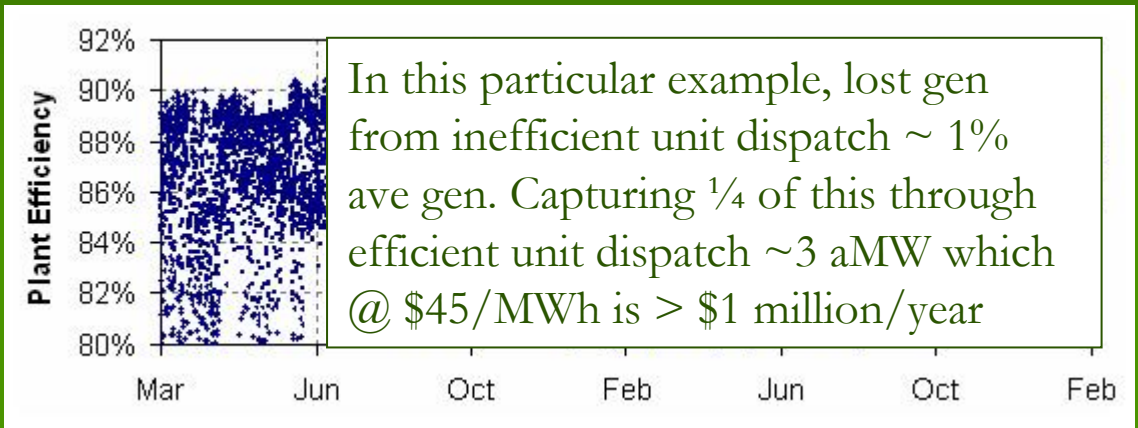
Unit Loading Benefit 1 → 2

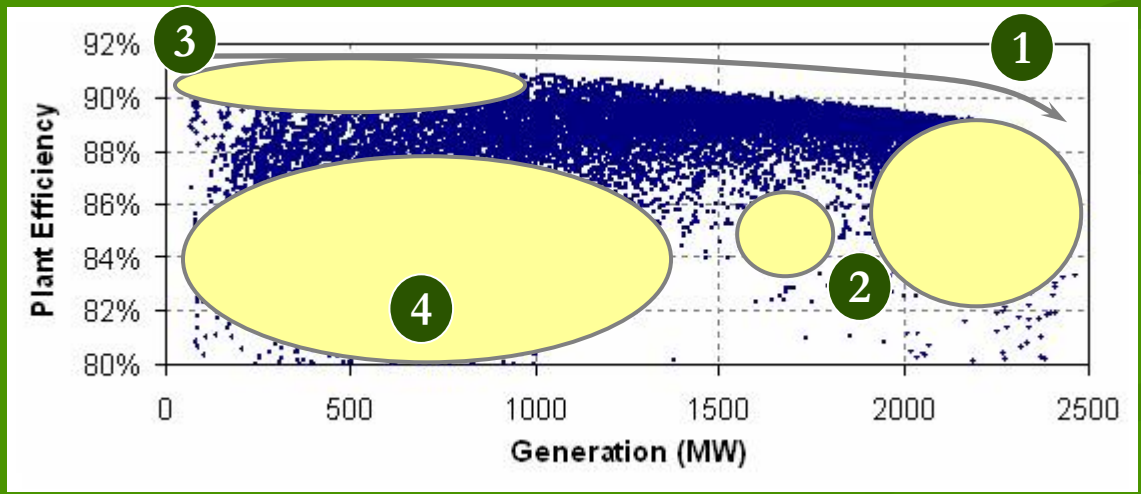
Unit Commitment Benefit 2 → 3

Plant Loading Benefit 2 → 4a, 3 → 4b



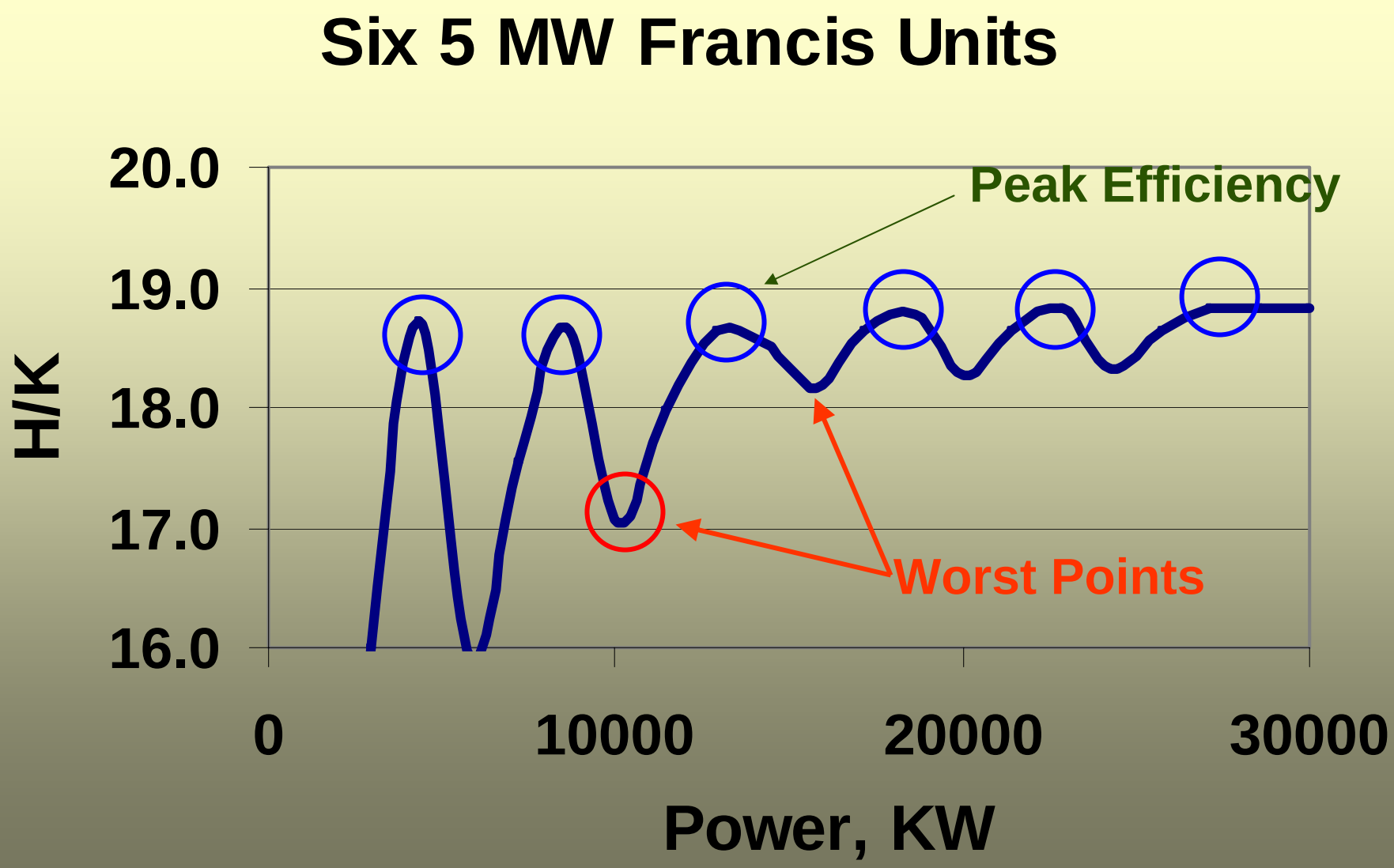
Plant Efficiency Example





1. General decrease in plant efficiency with increasing generation (discharge)
2. Sharp drop in plant efficiency when all units dispatched.
3. Peaks & valleys at low generation/low # units online.
4. Inefficient unit loading &/or unit commitment.

Plant Performance Curve



Weekly Benefits Report

NRTO Summary

From	Monday Jul 24, 2006, 12:00 AM
To	Monday Jul 31, 2006, 12:00 AM
$54	Light load hour price of energy ($/MWh)
$85	Heavy Load hour price of energy ($/MWh)
$75	Average price of energy ($/MWh)
1,449	Average generation (MW)

Summary

Lost generation from 07-24-06 to 07-31-06 averaged 5.7 MW, or 0.39% of average generation (1,449 MW). Historical lost generation for July was 0.61%. The average price of energy was $75 per MWh and so the total potential benefit from optimizing unit commitment was $67,836. Some losses are to be expected - especially at projects with frequent changes in generation where it may be beneficial to incur a small loss in efficiency, from sub-optimal unit commitment, in order to avoid unnecessary unit starts/stops.

Summary

NRTO Indicator	Lost Generation					Description**
	aMW	MWh	% Now	$	% Hist	
Unit Loading*	3.7	629	0.26%	$ 47,046	n/a	Lost generation from sub-optimal unit loading
Unit Commitment	5.7	949	0.39%	$ 67,836	0.61%	Lost generation from sub-optimal unit commitment
Plant Loading	33.2	5,571	2.29%	$ 416,998	n/a	Lost generation from sub-optimal plant loading

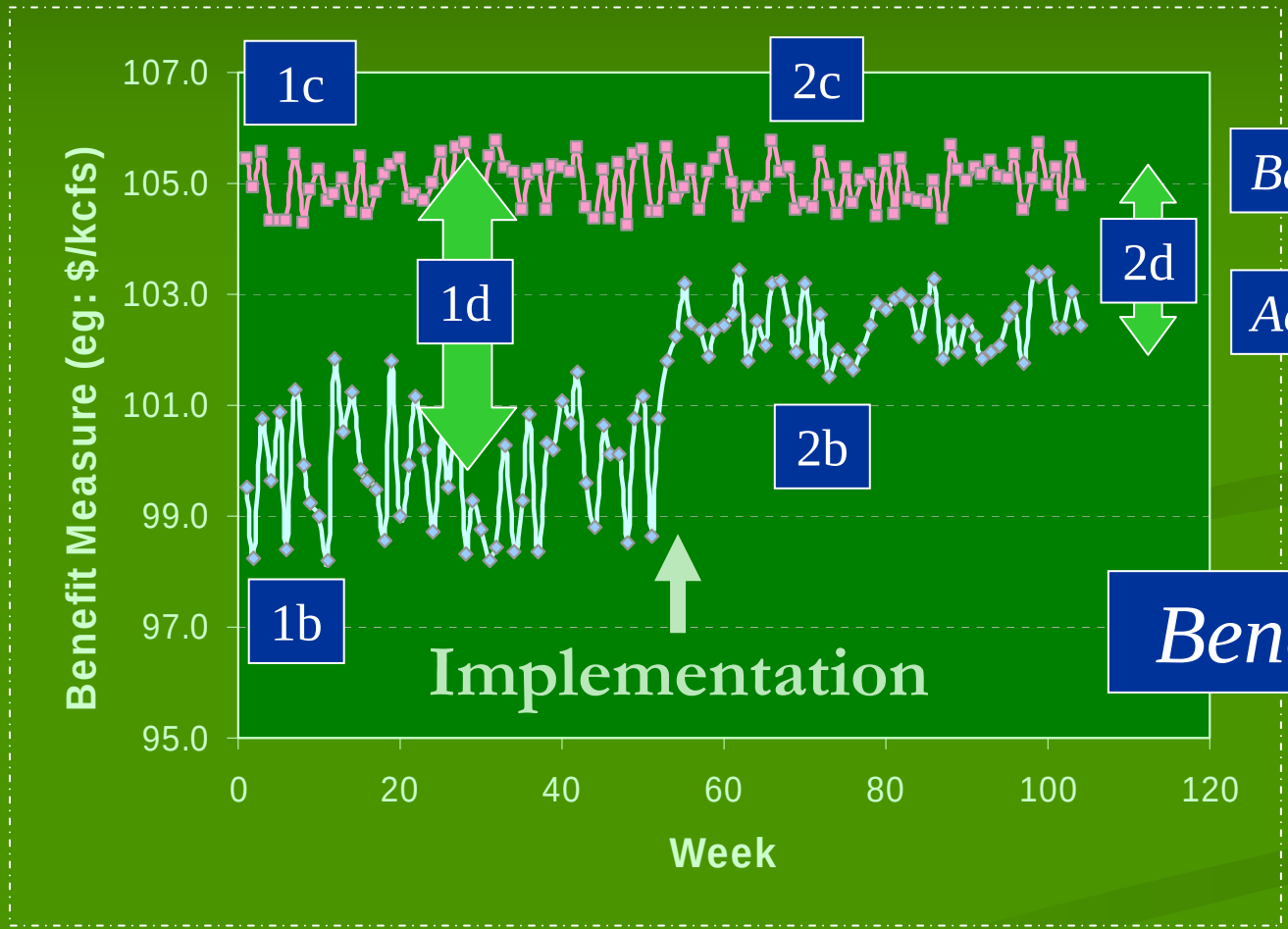
*Estimate **Definitions on page 2

Detailed Summary of Lost Generation (Unit Commitment)

Hour	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Ave (aMW)	Tot (MWh)	Tot ($)
1	11.2	6.6	13.8	17.5	6.3	7.1	6.8	9.9	69	$ 3,745
2	22.0	9.1	1.6	3.1	3.1	9.4	0.2	6.9	49	$ 2,624
3	6.3	11.2	0.0	11.0	10.0	2.5	0.0	5.9	41	$ 2,218
4	10.1	4.7	0.9	5.6	1.3	8.2	0.0	4.4	31	$ 1,664
5	2.7	2.6	2.4	1.2	0.6	14.2	4.3	4.0	28	$ 1,523
6	1.8	5.7	6.3	7.9	0.4	9.1	3.1	4.9	34	$ 1,859
7	2.9	6.0	6.9	35.9	2.6	1.7	0.5	8.1	56	$ 4,815
8	8.4	4.0	16.1	18.7	3.9	3.2	0.0	7.8	54	$ 4,637
9	7.6	2.2	0.8	32.1	16.4	3.4	8.5	10.1	71	$ 6,050
10	1.6	1.4	0.9	39.1	35.9	6.0	1.1	12.3	86	$ 7,329
11	0.0	2.8	1.4	2.1	28.0	5.0	5.9	6.5	45	$ 3,861
12	0.0	2.6	5.7	0.0	0.0	1.1	8.0	2.5	17	$ 1,478
13	0.0	0.0	9.7	0.0	0.0	40.2	7.7	8.2	58	$ 4,912
14	0.0	0.0	17.1	0.0	0.0	14.7	2.3	4.9	34	$ 2,913
15	0.0	0.0	18.4	0.0	0.0	0.0	10.3	4.1	29	$ 2,447
16	14.0	0.0	0.0	0.0	0.0	0.0	12.4	3.8	26	$ 2,256
17	0.0	0.0	0.0	0.0	0.0	0.0	12.8	1.8	13	$ 1,093
18	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.2	1	$ 115
19	0.0	0.0	0.0	0.0	0.0	11.7	1.3	1.9	13	$ 1,105
20	0.0	0.0	3.9	0.0	0.0	5.1	0.1	1.3	9	$ 778
21	0.0	0.0	0.0	0.0	0.0	0.0	1.4	0.2	1	$ 118
22	0.0	1.7	4.0	0.2	0.3	1.7	6.7	2.1	15	$ 1,247
23	3.9	17.9	7.0	24.8	4.3	9.6	30.8	14.0	98	$ 5,314
24	1.5	9.9	11.3	2.1	4.9	22.3	17.2	9.9	69	$ 3,734
Ave (aMW)	3.9	3.7	5.3	8.4	4.9	7.3	5.9	5.7		
Tot (MWh)	94	89	128	201	118	176	143		949	
Tot ($)	$ 6,149	$ 5,431	$ 9,577	$ 14,886	$ 9,110	$ 12,460	$ 10,223			$ 67,836

Notes:

Short Term Operational Benefits



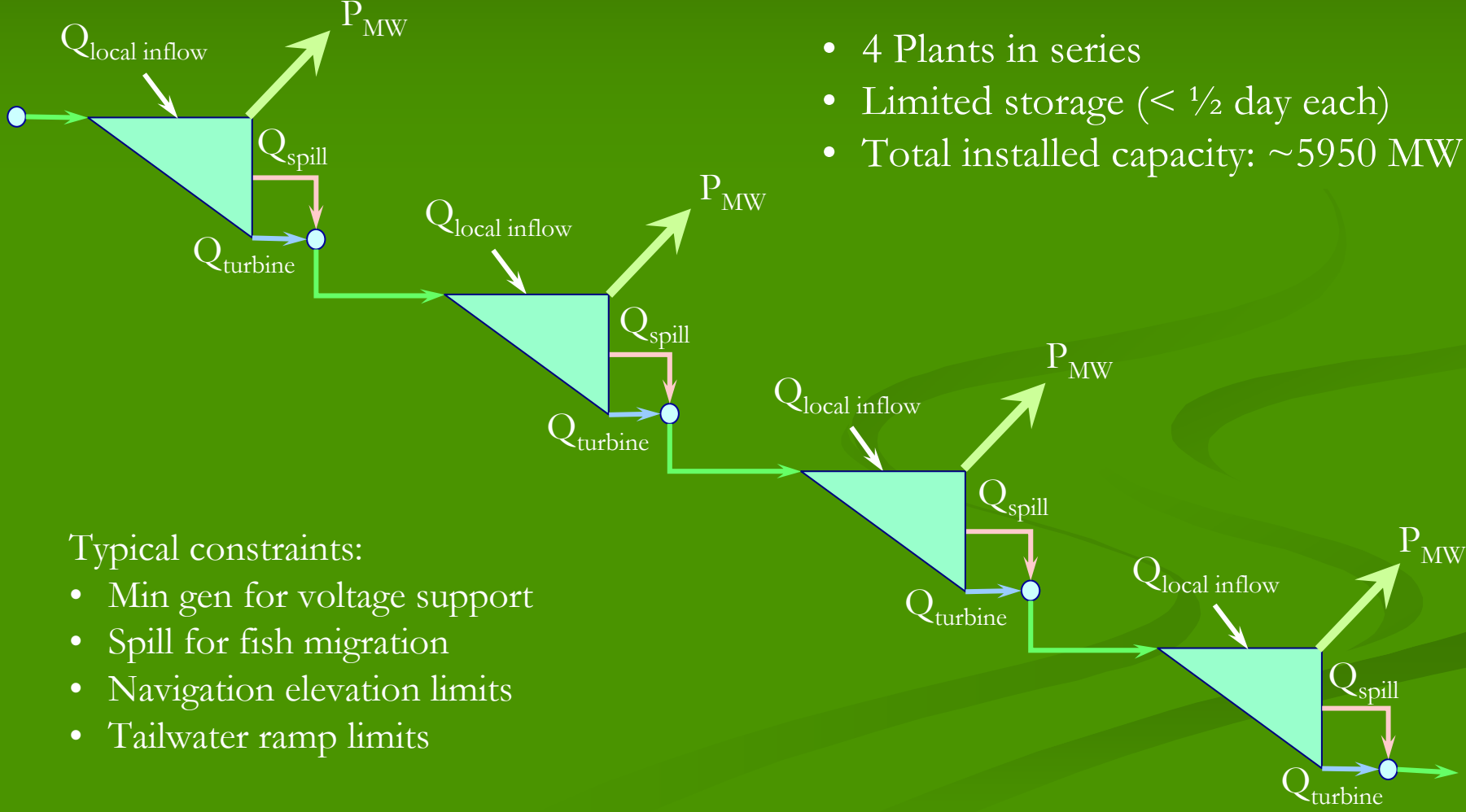
Benchmark(s) ("c")

Actual Operation ("b")

Benefits ~ 1d – 2d

Graph from Synexus Global (www.synexusglobal.com)

Short Term Benefits Example

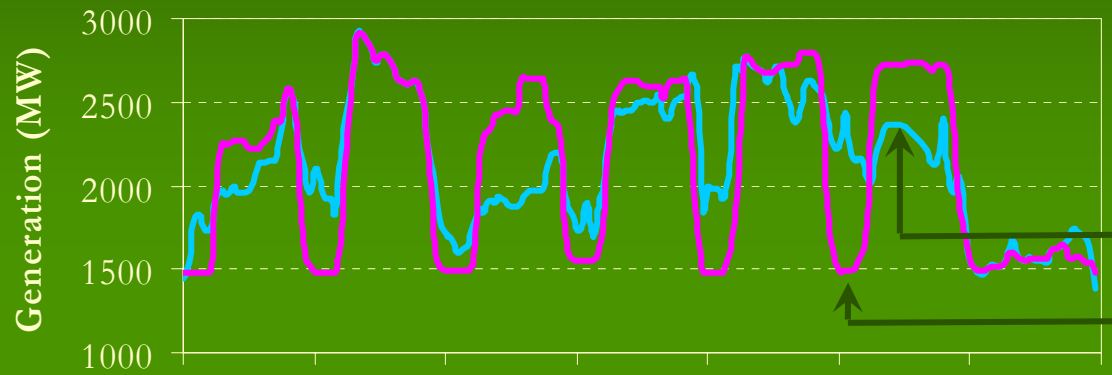


- 4 Plants in series
- Limited storage (< ½ day each)
- Total installed capacity: ~5950 MW

Typical constraints:

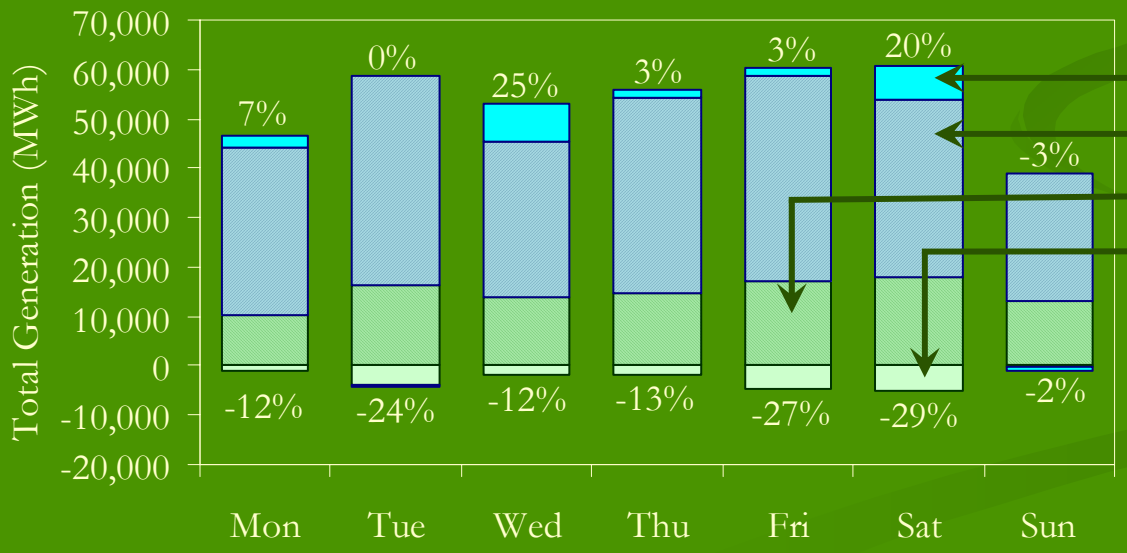
- Min gen for voltage support
- Spill for fish migration
- Navigation elevation limits
- Tailwater ramp limits

ST Scheduling Post Analysis



Actual hourly operations

Optimized hourly operations



Additional HLH Sales

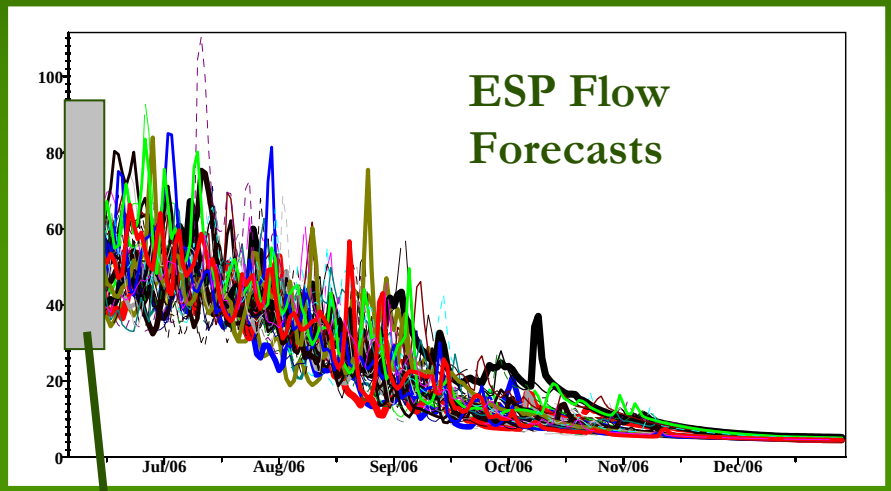
Actual HLH Generation

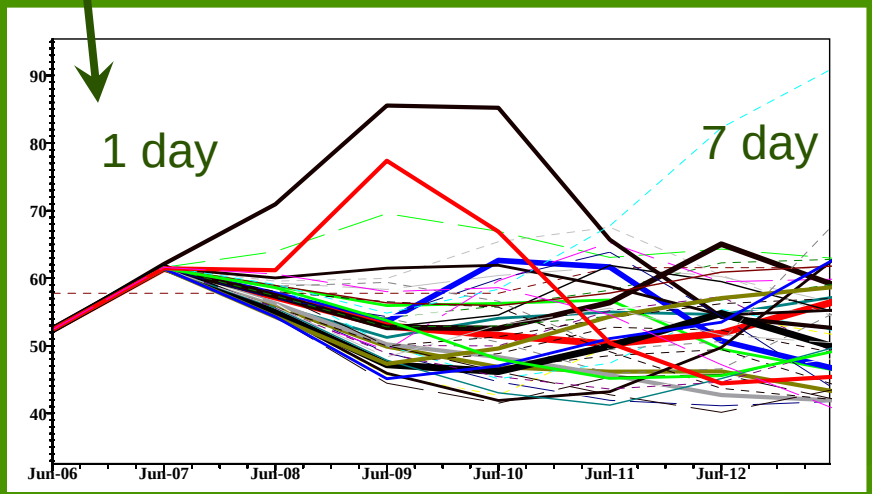
Actual LLH Generation

Additional LLH Purchases

HLH-LLH price diff = $12/MWh
Net revenue benefit = $211,440
(~4% actual real-time trading for this week)

Mid & Long-Term Operations





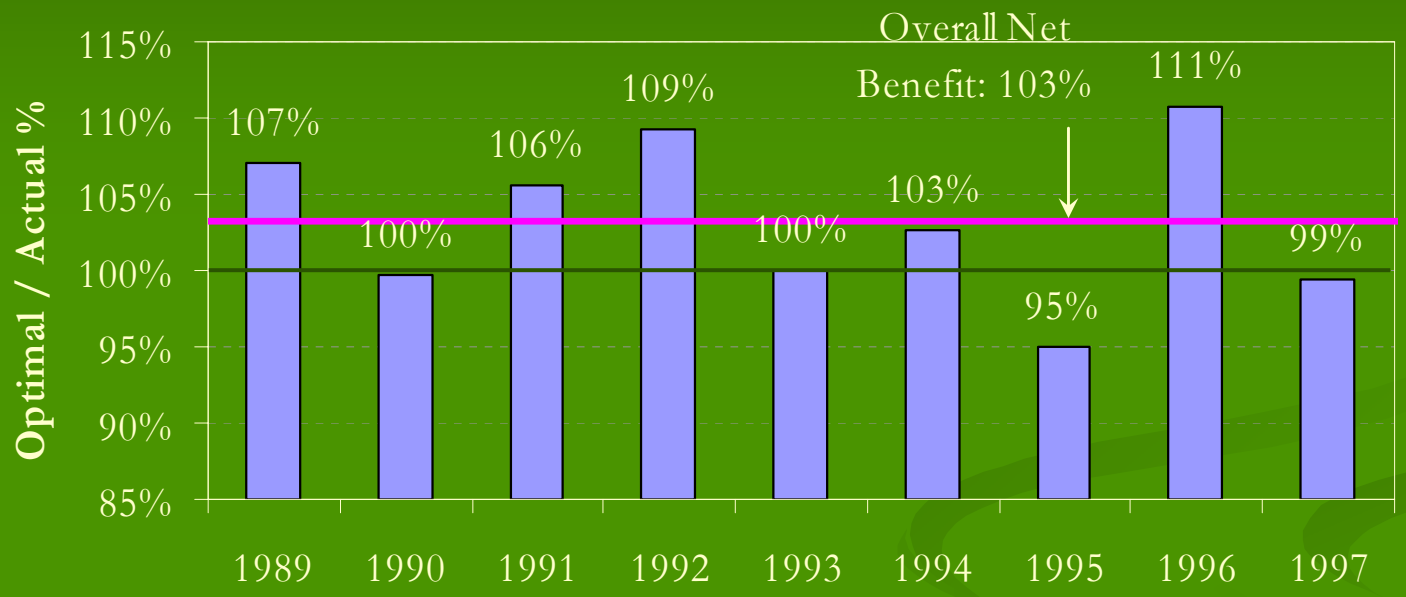
June 6 Ensemble Streamflow Prediction (ESP) for 44 years, initialized to current basin conditions.

Day+1 forecast high certainty
Day+7 forecast lower certainty

Objective: How much to draft/fill for the current week?

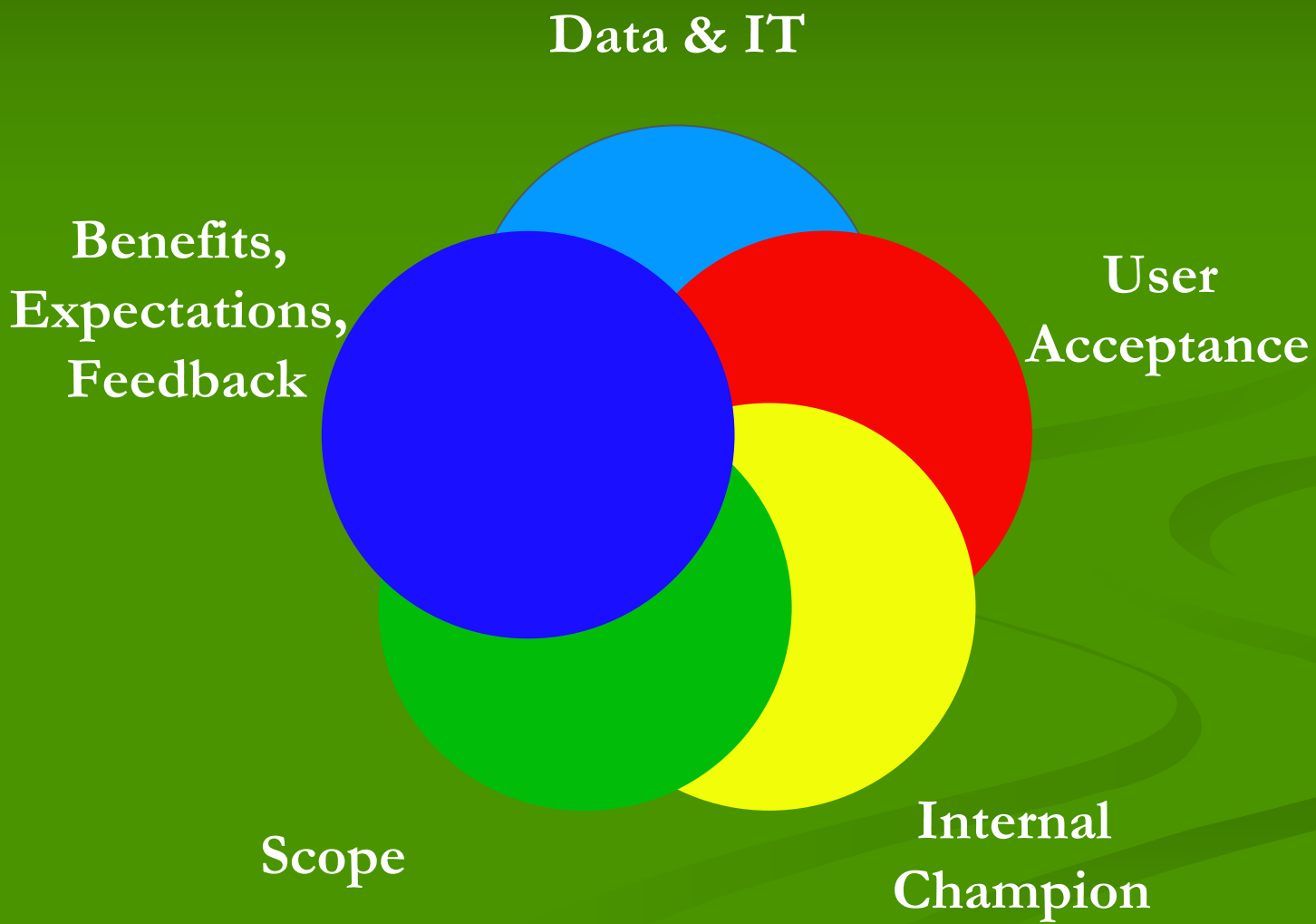
- Quick option: pick average streamflow and run to this.
- Comprehensive option: Week 1 target elevation that minimizes net cost given uncertainty of future hydrology.

Mid/Long-Term Operations



Year:	1989	1990	1991	1992	1993	1994	1995	1996	1997	Avg.
Reservoir 1 (Optimal)	290.1	284.5	352.1	312.9	241.3	335.4	324.2	370.2	349.4	317.8
Reservoir 2 (Optimal)	215.2	210.7	225.5	225.9	192.1	205.4	225.3	233.8	268.8	222.6
Total (Optimal)	505.4	495.1	577.7	538.8	433.4	540.8	549.6	604.1	618.3	540.4
Total (Actual)	472.2	496.7	547.2	492.9	433.4	526.6	578.3	545.3	621.7	523.8
% Optimal / Actual	107%	100%	106%	109%	100%	103%	95%	111%	99%	103%

Important Considerations



Conclusions

- Decision support systems can focus on one or more layers – from the machine layer through to long term operations (ideally integrated)
- Benefits in presentation ranged from 0.5% - 4% relative to efficiency &/or net revenue
- Be prepared for data & IT challenges
- Internal champion takes project from start to finish
- Clearly outline expectations & take care to gain user acceptance.