Energy Utilities Investments for Alternative Cooling Technologies: A Real Options Approach

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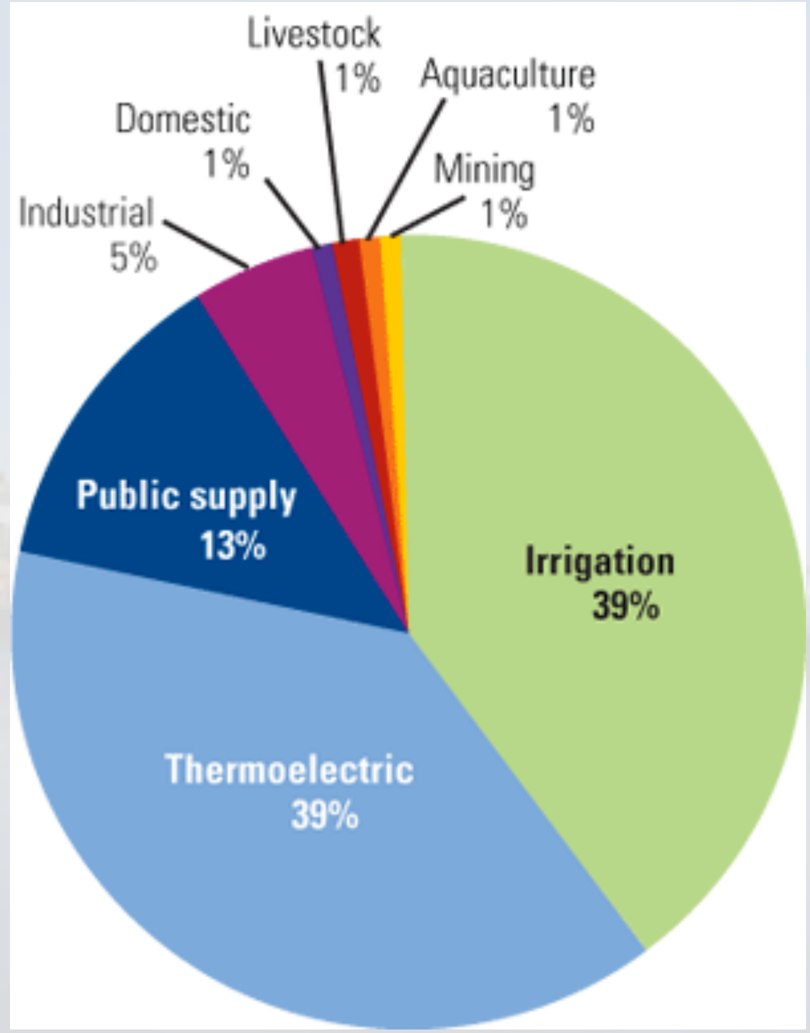
Purpose

- Investigation into the use of a real option valuation approach for capital budget decisions and strategic investment decisions surrounding environmental technologies

- Investment in water conservation technologies at power plants

Power Industry and Water

- Thermoelectric power plants account for almost 40% of water withdrawals
- Once through Cooling systems are extremely water intensive on withdrawal basis
- Water is a critical input into the power plants using once through cooling systems



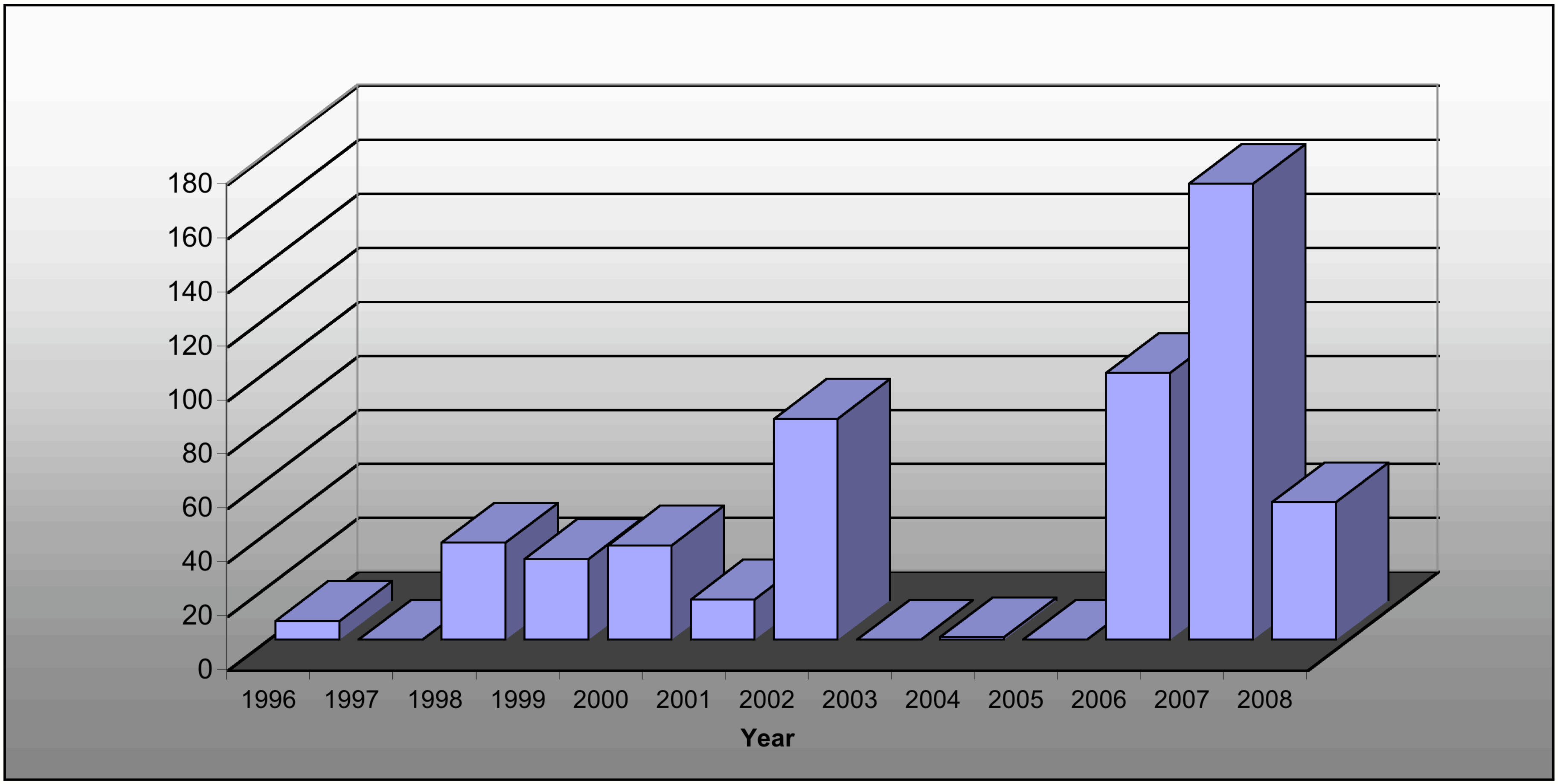
Inability to access water results in the forced curtailment of plant operation – "de-rating event"

- Lack of access due to:
  - Physical scarcity:
    - Issues of population growth, drought, consumption patterns, etc.
  - Temperature Constraints
    - Environmental regulations to maintain health of stream downstream
    - Loss of efficiency as intake water increases

Potential technology investment at "Plant A"

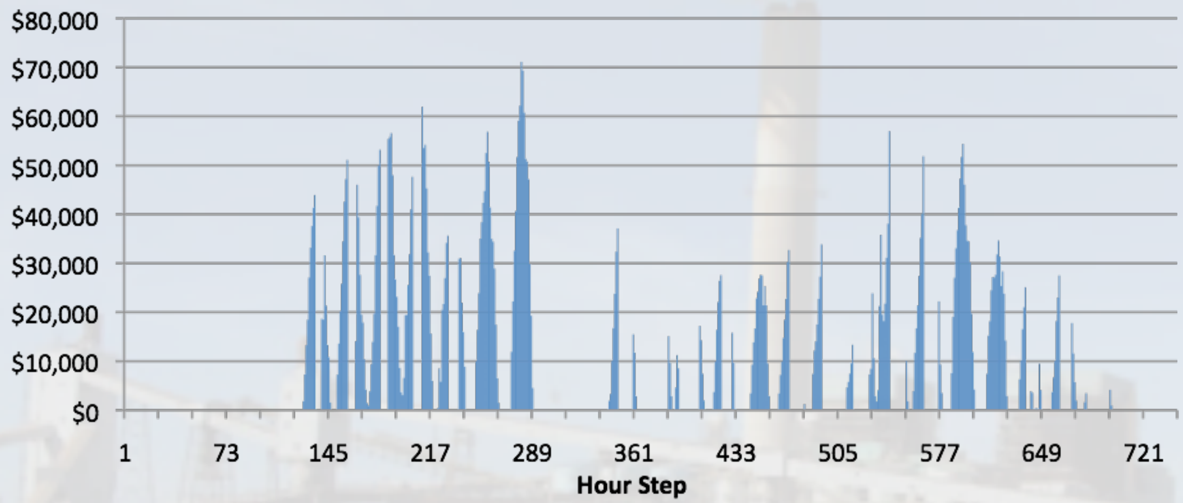
- Plant located in North Carolina
- End of pipe thermal limit: 95^{0}F – 102 ^{0}F (depends on month)
- De-rating events typically occur in very hot or dry months (typically May-September)
- Number and severity of derating events is uncertain from year to year and month to month

Yearly number of thermal related de-rating events (1996-2008)



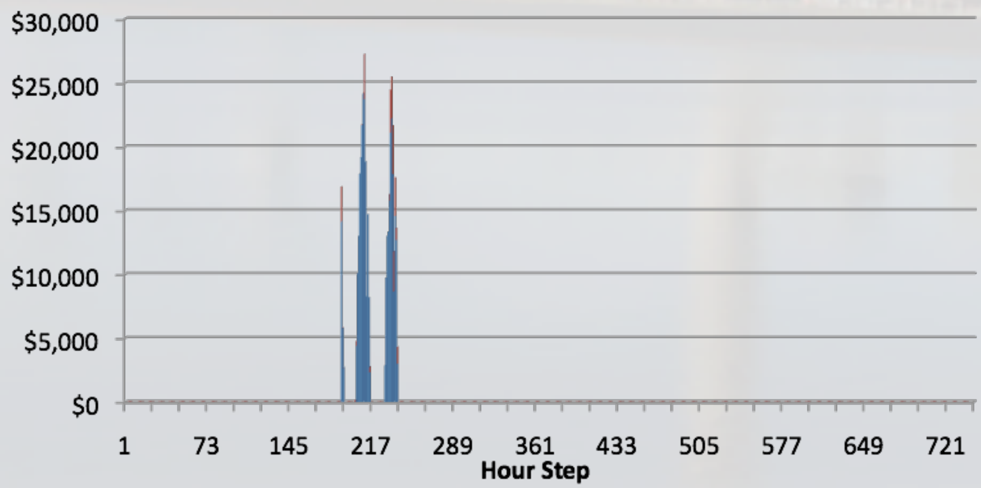
De-rate costs variable in frequency and severity

Thermal derate cost by hour (August 2007)



Cost: $5.9 M

Thermal derate cost by hour (August 2008)



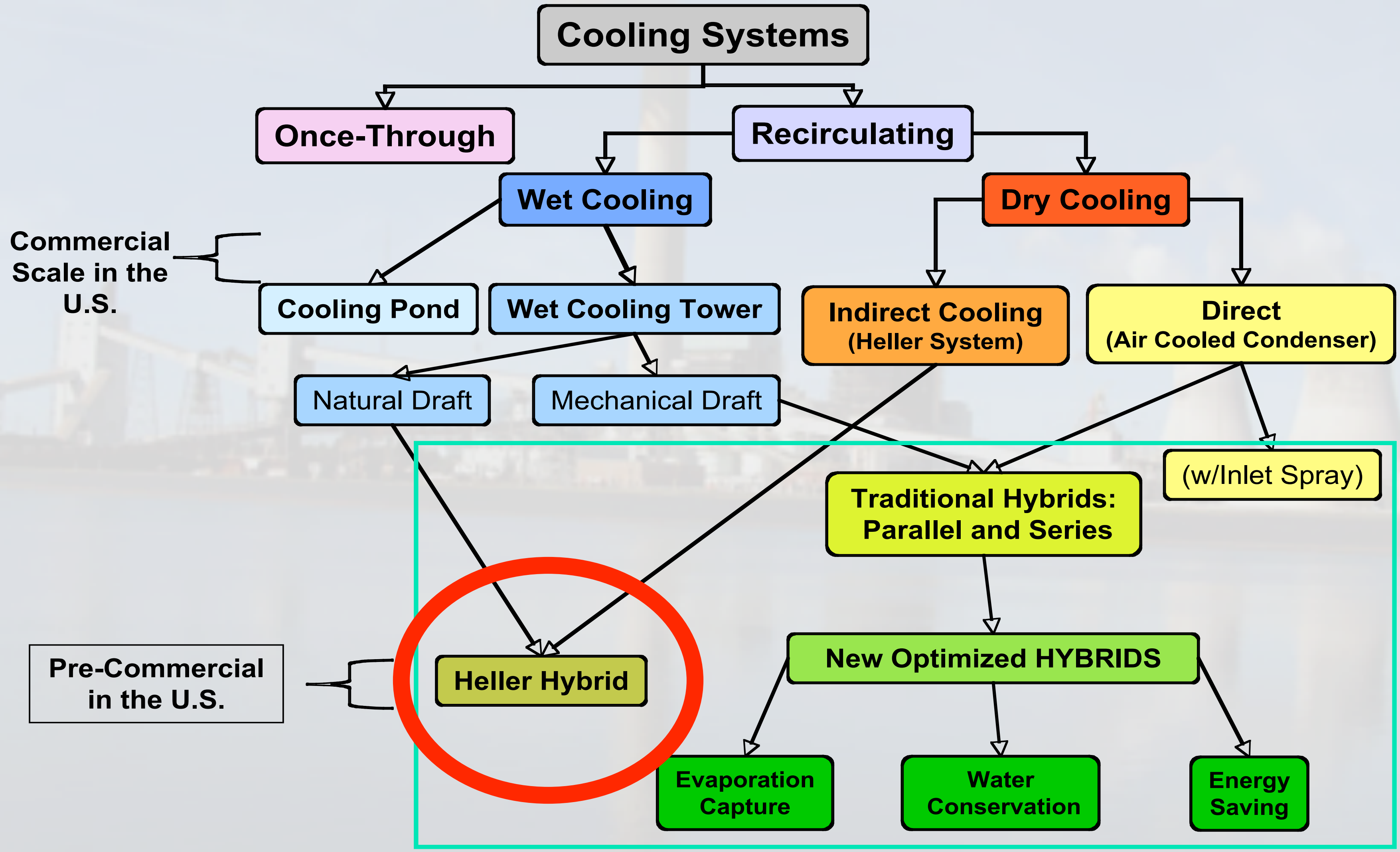
Cost: $390 K

Cost from year to year are uncertain (35%+ volatility)

Uncertainty in derate cost presents an investment challenge for management

- Frequency and severity of derating events are unknown
- Costs associated with each events are uncertain (partially tied to volatile electricity prices)
- Other variables (i.e policy frameworks, regulation)
- Questions
  - Should the Power Plant invest in a technology that reduces or eliminates water use?
  - If yes, when does Power Plant invest in the technology?

Water Cooling Systems Alternatives



DCF vs ROA: The reality of real world investments

- Uncertain outcomes in terms of cash flows
- Investments are often irreversible
- Managers exercise flexibility in timing of irreversible investment
- Risk profile of investment changes over time

These attributes make real work investments attractive for the use of a strategic valuation technique known as Real Option Analysis

Mathematics of real options is based on financial option theory

- **Financial Option:** A contract conveying the right, but not the obligation to buy or sell designated securities or commodities at a specified price during a stipulated period
  - <u>Call option</u>: contract to buy
  - Put option: contract to sell

  - *European Option* gives the owner of the option contract the right to buy/sell the designated securities *only* on the expiration date of the option
  - <u>*American option*</u> gives the owner of the option contract the right to buy/sell the designated securities at *anytime* before expiration date of the option

Real option definition

- A **real option**, is the right—but not the obligation—to undertake some business decision; typically the option is to make, or abandon, a capital investment.
  - For example, the opportunity to invest in the Heller system over the remaining life of the plant

A Real Option: Water Technology

- To determine whether the option (American) to install cooling towers should be exercised we compare the cost of installing today to the value of the option to construct the facility in the future. When value of option to build in future exceeds value of construction today, utility owner of Plant A should wait, and vice-versa

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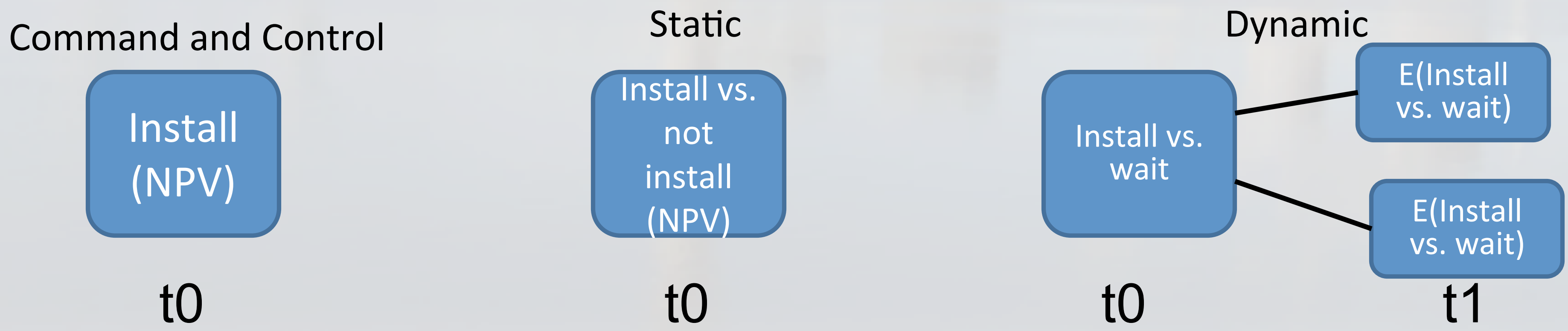
Binomial Lattice Approach

- Underlying asset of the option is the cost often derating event
  - Model cost over time based on historical volatility (Up ,down (u, d)

Yealry Derate Cost For Plant A

Year	2009	2010	2011	2012	2013	2014	2015
Node	**0**	**1**	**2**	**3**	**4**	**5**	**6**
0	($1,000,000)	($1,419,068)	($2,013,753)	($2,857,651)	($4,055,200)	($5,754,603)	($8,166,170)
1		($704,688)	($1,000,000)	($1,419,068)	($2,013,753)	($2,857,651)	($4,055,200)
2			($496,585)	($704,688)	($1,000,000)	($1,419,068)	($2,013,753)
3				($349,938)	($496,585)	($704,688)	($1,000,000)
4					($246,597)	($349,938)	($496,585)
5						($173,774)	($246,597)
6							($122,456)
7							

- The alternatives



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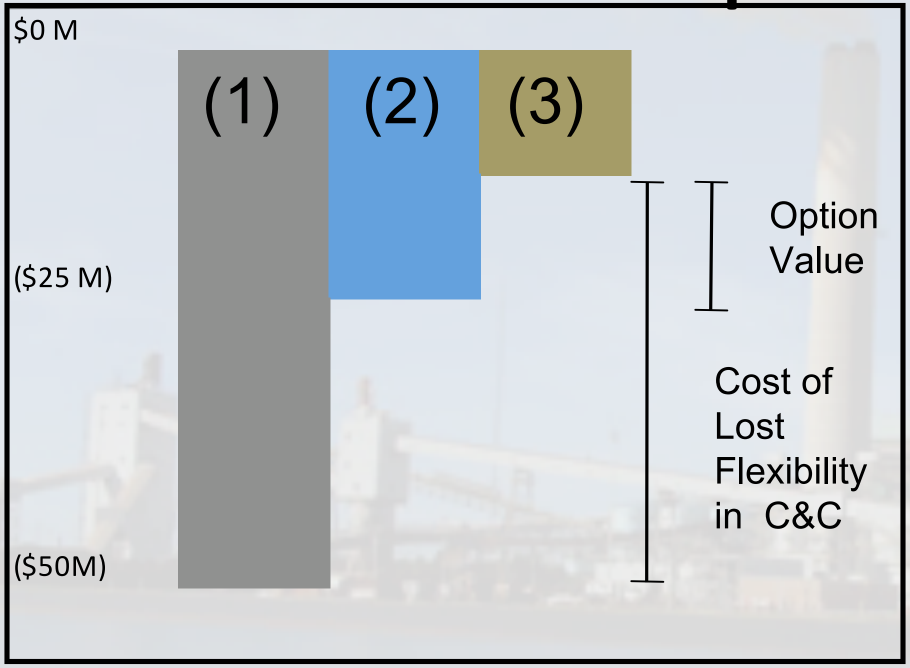
Model Inputs and Outputs



Inputs

- Capital Cost for Cooling System
  - ($39 million)
- Volatility in yearly de-rate costs
  - 35%
- Cost of Technology
  - Constant (real)
- Increase in electricity prices
  - 2% (real)

Outputs

- Present Value of Command and Control Alternative **(1)**
  - ($51 million)
- Present Value of Static Alternative **(2)**
  - ($25.5 million)
- Present Value of Dynamic Alternative **(3)**
  - ($16.3 million)
- Option Value = Static – Dynamic
  - $9.2 million
- First time period to install: 2015

Interpretation and Next Steps

- An option value of $9.2 million
  - How can this information be used?
- Incremental investment and multistage investment – R+D
- "Seek gain from uncertainty and maximize learning"

Questions?

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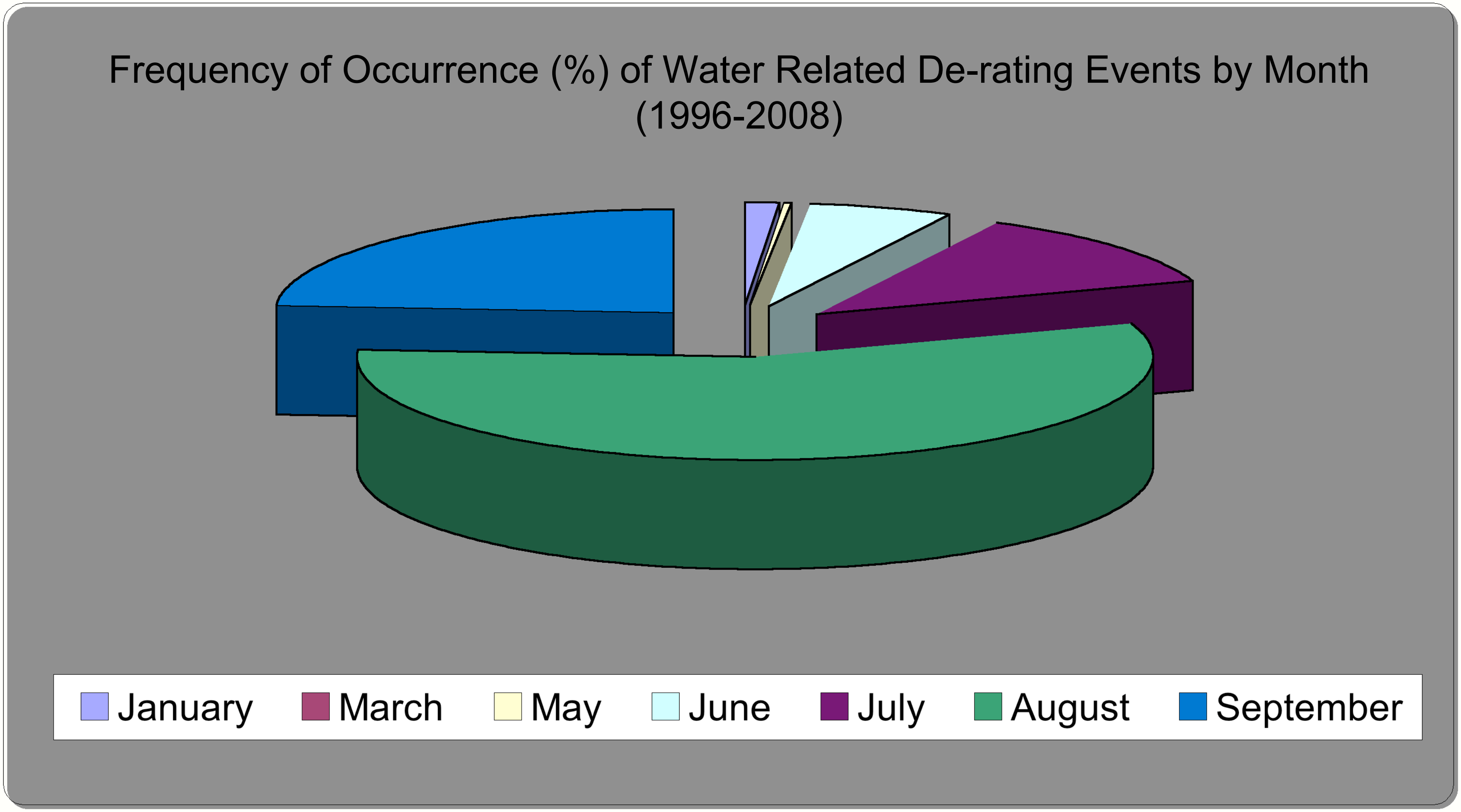
De-rating events mainly localized to 4 summer months of the year



Option lattice construction

Derate Cost Tree (based on 40% volatility)

Calculate NPVs of Option 1

Calculate NPVs of Option 2

Populate NPV lattice of Option 1

Populate NPV lattice of Option 2

Real Options Framework

- ROA offers a nuanced approach to strategic investment that quantitatively takes into account investment risks and the value of the open options for budget decision-makers.
- Static vs. Dynamic Alternative

Yealry Derate Cost For Plant A

	Year	2009	2010	2011	2012	2013	2014	2015	2016
Node		0	1	2	3	4	5	6	7
0		($1,000,000)	($1,419,068)	($2,013,753)	($2,857,651)	($4,055,200)	($5,754,603)	($8,166,170)	($8,000,000)
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5							($173,774)	($246,597)	($349,938)
6								($122,456)	($173,774)
7									($86,294)
8									
9									
10									
11									

Investment Decisions using DCF approach

- Traditional project appraisal valuation is a Net present Value (Discounted Cash Flow Approach)
  - The DCF method is very popular
  - Method:
    - Forecast future cash flows through time
    - Discount back those cash flows using an appropriate cost of capital(discount rate)
    - Sum up all discounted cash flows = Net Present Value
    - If NPV> investment, then proceed with project
    - Do scenario analysis

- Appropriate Methodology?
  - Not for investments surrounded by high levels of uncertainty (most clean tech investments)
  - NPV is unable to properly value these types of investments
  - Can not cope with stochastic behavior of markets (and in this case natural environment and market)

Investment opportunity decisions are real world call options

Investment Opportunity	Variable	Call Option
Present value of project assets	S	Stock price
Expenditure required to acquire project assets (capital expenditure)	X	Exercise price
Length of time the decision may be deferred	t	Time to expiration
Time value of money	r_f	Risk-free rate of return
Riskiness of project assets (volatility)	σ^2	Variance of returns on stock

NPV = S - X; invest ‘yes’ or ‘no’

ROA ≈ NPVq (exercise price) and $\sigma\sqrt{2}$ (cumulative volatility); ‘exercise’ or ‘not’

The "Value" of Water = the Cost of Derating event

- Due to river temperatures, a de-rating event at Plant A results in the need to shift production to Plant B
  - Example: A 100,000 MWh reduction at Plant A will result in an increase of 80,000 MWh production at Plant B in order to satisfy system demand (<u>native load demand)</u>
  - Net system reduction of 20,000 MWh

- Cost of de-rating is a function of:
  - <u>Replacement Cost: </u>$/MWh at Plant B > $/MWh at Plant A
  - <u>Market Cost:</u> Lost revenue from excess capacity (20 MW) not sold into wholesale electric markets

Replacement Cost + Market Cost = Implied Value of Water

DCF limited in its ability to inform capital budgeting and strategic decisions

- Static
  - Assumes project plan is unalterable and management is passive
  - Management does not learn and make adjustments mid project - managerial flexibility

- Implicitly assumes only one investment decision can be made
  - Make the investment now, or do not make it at all
  - Can not make the investment at a later date

- Future cash flows are predictable and deterministic
  - Very difficult to estimate cash flows
  - In our case: What will the cost of derating events be next year?

- Use a standard discount rate (WACC)or sometimes use an arbitrary hurdle rate
  - Discount rates used do not reflect project specific risks
  - Very difficult to estimate appropriate discount rate if try to adjust discount rate
  - Discount rate changes over time

OECD/IEA- 1, Alstad(gas fired Plants),-2 unlocking value of real options-2

Water-Based Uncertainties

- Regulation: EPA's ruling on 316b (impingement and entrainment) discourages once-through cooling systems, in future may try to increase standardization of 316a (temperature)
- New Plant Development or Retrofits: new plants may consume more water, especially if moved to cooling towers, or if carbon capture and sequestration becomes commercial
- State of Technology: currently limited cost effective options, but many nascent technologies under development by government R&D programs and vendors
- Precipitation and global warming: changes in frequency and severity of extreme events or changes in average availability
- Complex Stakeholder Networks: electricity customers may also be our competitors in the water arena - multi-stakeholder water use

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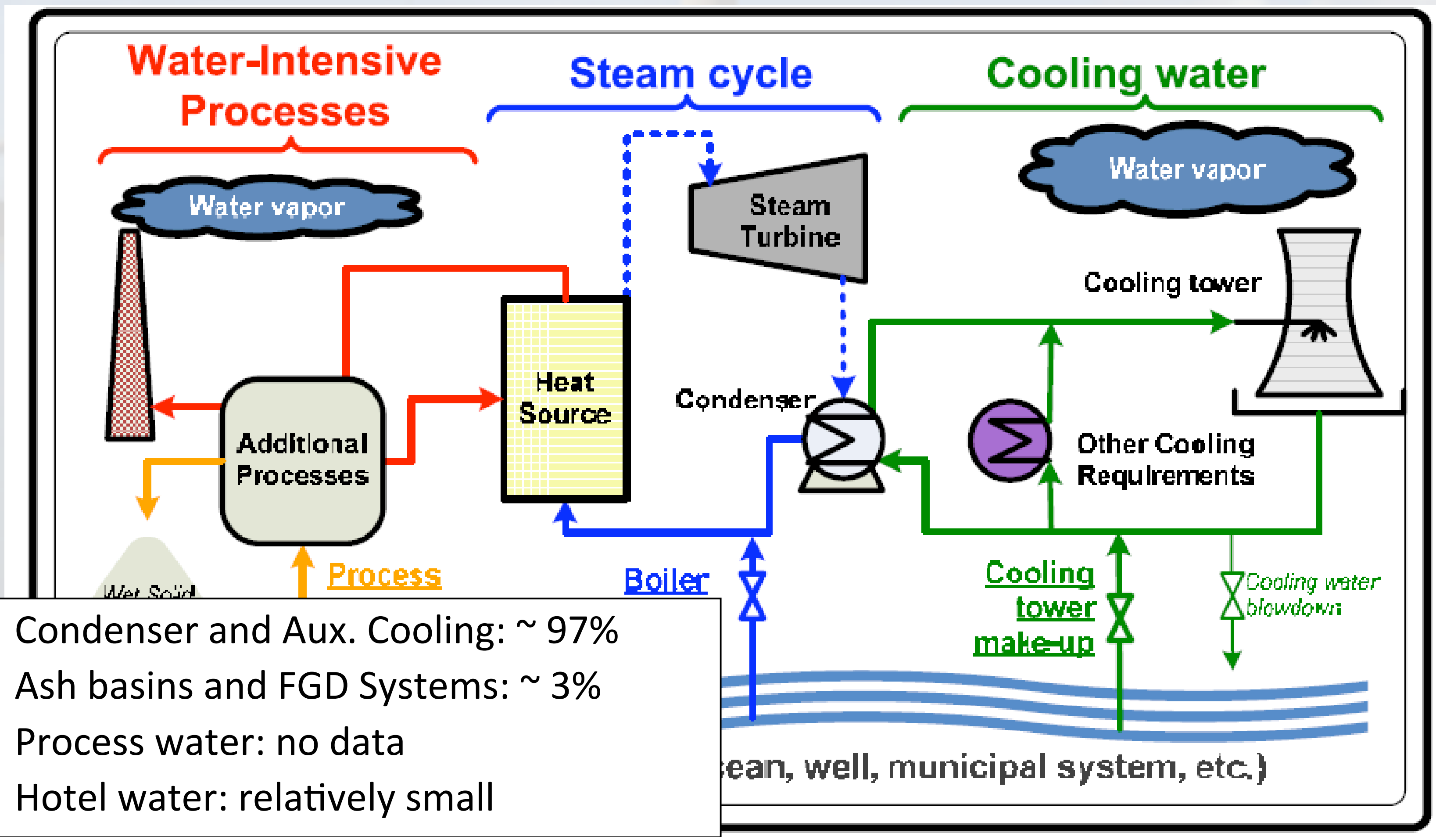
Water Efficiency Objectives

– Potential Priorities
  - Maximize benefit to the environment?
  - Best in class with highest levels of water-use efficiency, g/MWh?
  - Build goodwill with stakeholders?
  - Mitigate risk of drought?
  - Lower long-term risk from exposure to water volatility?
    – Access-Legal, Availability-Physical, Price-Financial

– Potential Benefits/Barriers
  - Current Plant Set-Up –is it once through or already have a tower
  - Regulatory Process – include in rate base?

Water Use in ThermoElectric Plants



Condenser and Aux. Cooling: ~ 97%

Ash basins and FGD Systems: ~ 3%

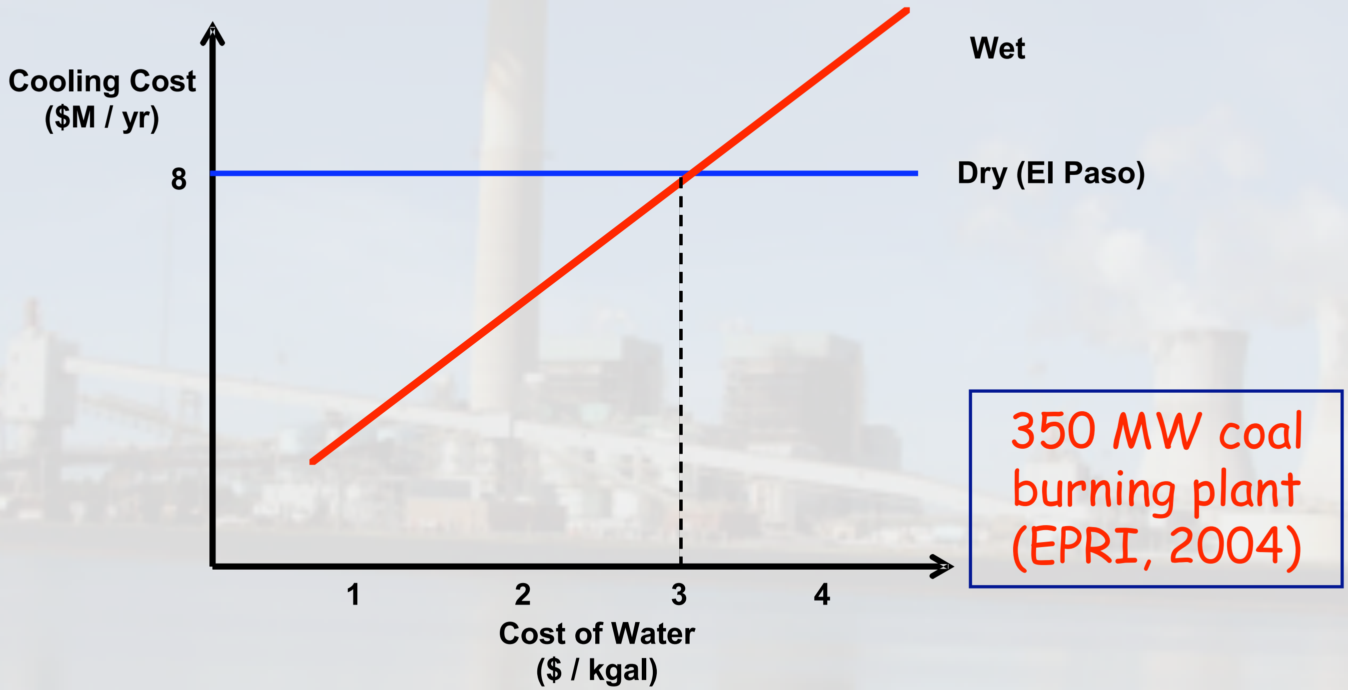
Process water: no data

Hotel water: relatively small

Cost Analysis Tradeoff

- The economic design tradeoff for selecting the optimum cooling system is between:
  - the capital cost of the cooling system, which increases with system size, and the performance
  - penalties—both in heat rate and capacity—that decrease as the cooling system size increases.

Economics of Dry v. Wet Cooling: Cost of Water vs. Cost of Technology



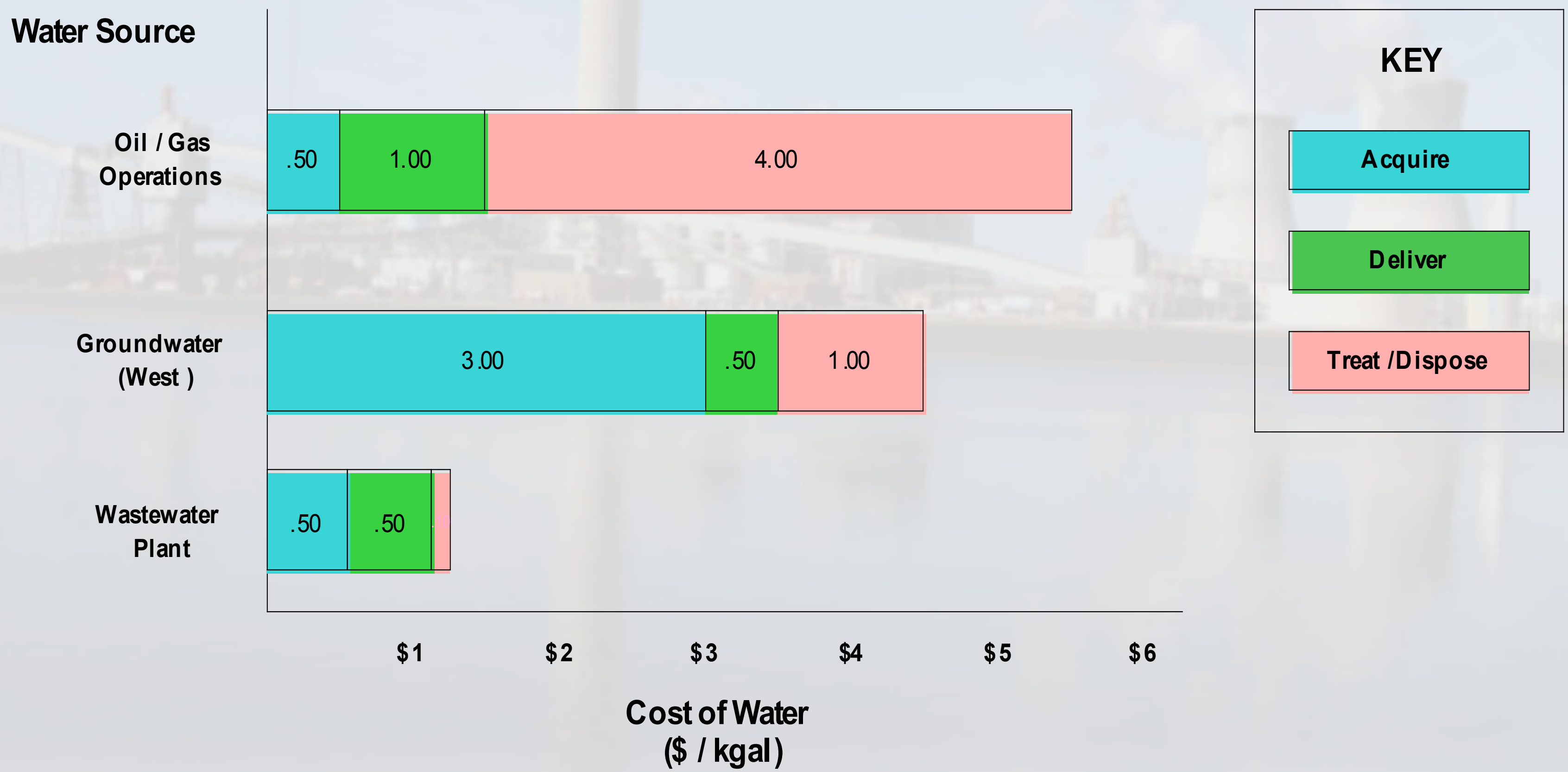
- Dry cooling is more costly, except where water cost is very high
- "Hot weather penalty" accounts for roughly 20% of cooling cost
- A reduction in the cost of water by $1/kgal saves $1.5M/yr (350 MW plant)

--> technology cost (discounted or not) > cost of water

Alternatives Sources to Fresh Surface Water

Technology	Pro	Con
Substratum Intake System: draw water from under lake or riverbed	Currently untapped, reduces heat rate by 5%	Same water source, technical questions, cost?
Megawatershed Fissure Wells: using oil drilling technology to reach >100m below surface, volume may be enough for cooling tower make-up water	New source of water, currently untapped	Technical questions, one successful project site in US, cost?
Impaired Water Treatment and Reuse: Municipal wastewater, blowdown, process water: potential at plants near large metropolitan areas	Proximity to some plant sites, technically feasible	Cost for treatment and transportation, need further R&D on fouling issues
Build New/Enhance Existing Reservoirs: increase usable storage by modifying water intakes, removing sediment, supplemental pumping or raising dam height	History of success, technically feasible	Political and social hurdle, high capital cost

Cost of Water – Treatment



Only treated wastewater would be in same range, if sufficiently abundant

ROA Framework for Water Conservation: Capturing Value from Volatility

1. Climate: water availability and temperature
2. Operational: water temperature and fouling
3. Permitting: Water price and allocation policies
4. Pricing: long term contract agreements
5. R&D: Technological innovation and learning curves

Quantifying Uncertainty of Options

- WARMF (Water Quality Risk Management Framework): Water quality (incl. temp) and quantity modeling
- Frequency/cost of derating events
- Water pricing strategies
- Cost of R&D

Flow

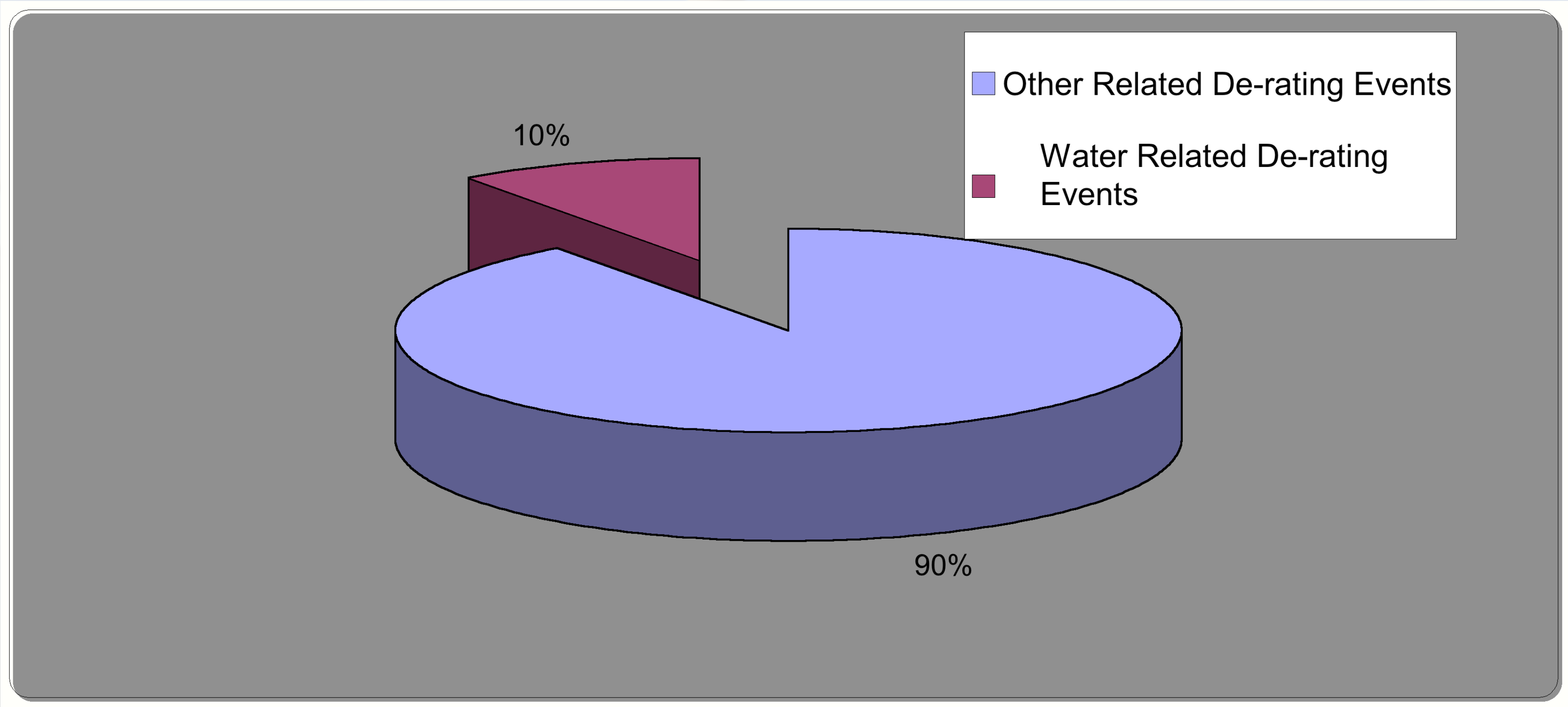
QuickTime™ and a
decompressor
are needed to see this picture.

Temperature

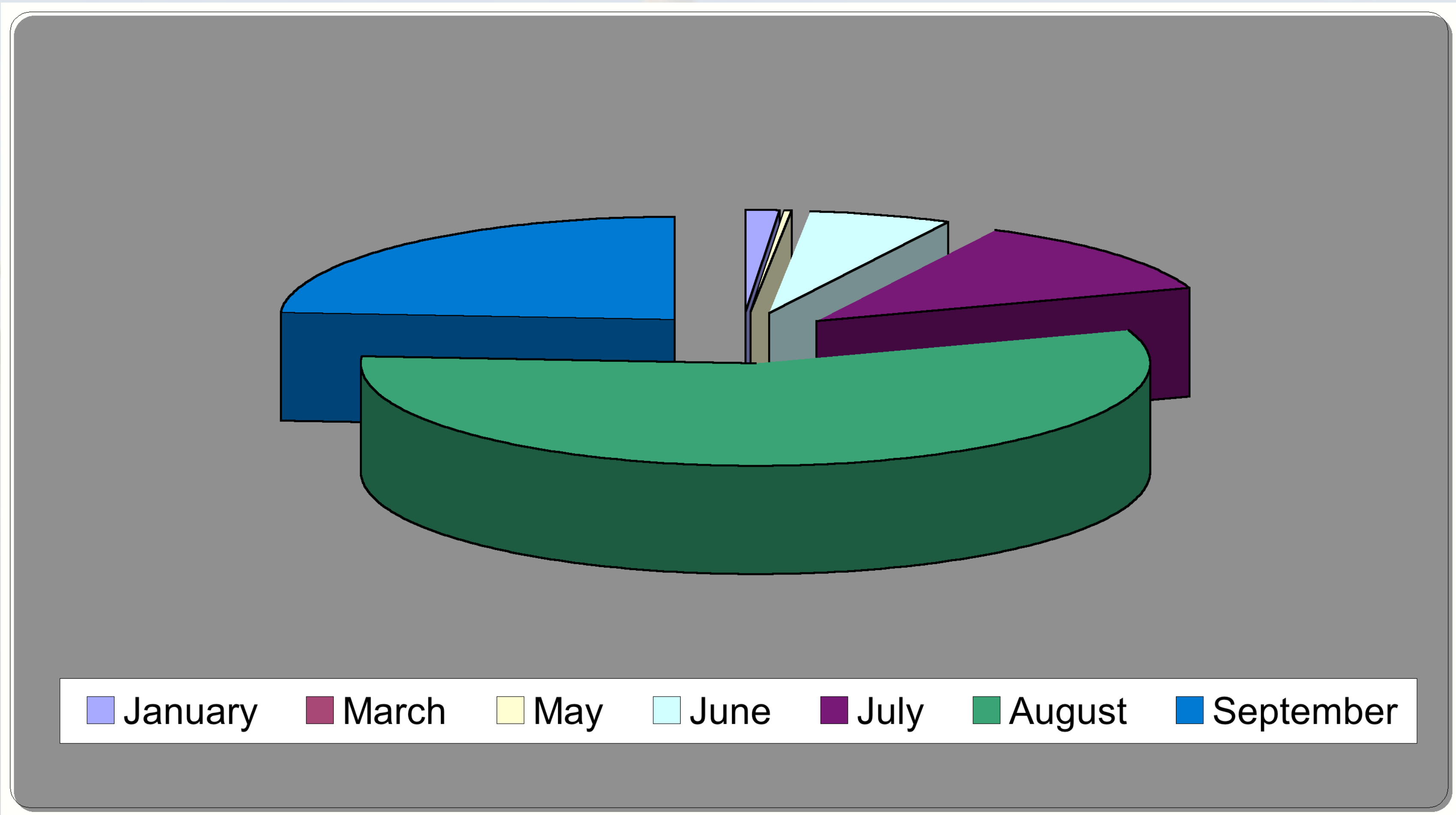
QuickTime™ and a
decompressor
are needed to see this picture.

Current - 2030

Comparison of Water Related to "Other" De-rating Events (1996-2008)



Frequency of Occurrence (%) of Water Related De-rating Events by Month



The “Value” of Water

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  - <u>Market Cost:</u> Lost revenue from excess capacity (20 MW) not sold into wholesale electric markets

Replacement Cost + Market Cost = Implied Value of Water

The "Value" of Water

- Cost of de-rating events at 5 unit coal fired power plant in July/August 2007 and 2008:
  - 2007: $8 - $32 per MWh
  - 2008: $18 - $36 per MWh
- For a 7 million MWh plant, the implied value would total*:
  - 2007: $ 7.2 - 28.8 M.
  - 2008: $ 16.2 - 32.4 M.

- BAU: shift to costlier plants to make up capacity; buy electricity on markets; lease cooling towers
- ROA: capitalize on volatility of options to decide when and in which technology to invest

*Client delivers between 100-150 M. mWh

Variables in Support of ROA for Technology Investment

- Sensitivity analysis around significant variables and options
  - Price of Water: significant impact, moderate likelihood
  - Frequency and Severity of Droughts: significant impact, likelihood questionable in either direction
  - Price of Technology: significant impact, least likely
- How does addressing one benchmark metric affect the others?
- Installing a technology now may limit future options and future technology's ROI.
- Indirect effect on other plants systems
  - Auxiliary power costs,
  - O&M costs are only estimated
  - Compliance with NOx, SOx, Hg regulations

Technologies Considered

Technology	Water Savings	Effect on Heat Rate	Research Stage, Issues	Capital Cost*
Coal Drying w/ Waste Heat and Flue Gas	10%	-3%	Bench Pilot, technical effectiveness	0.5x
Evaporation Capture from Cooling Towers	20%	Depends	Utility Pilot, size and cost	3x
Wet Surface Air Condenser for Aux Towers	Make-up water and blowdown disposal	minimal	Cost, changing condenser, pilot underway	1.5x
Heller Hybrid	80-90%	+1.5%	Cost reduction, minimize parasitic load	4x

*Capital & Installed Cost: closed-loop cooling tower retrofit cost, ~$40m

Should Client Invest in Wet, Dry, or Hybrid Cooling: DCF vs. Real Options

- Investment: $ 40 MM. (hybrid); $25 MM (wet); $ 30 MM (dry)
- Electricity prices stable: Fixed at $60/MWh
- Cost of water stable: Fixed at $1/1,000gal
- Discount rate: 10%

--> DCF NPV <0: No investment in hybrid cooling (or technology)

- Water penalty uncertain*: e.g. $18/MWh (0.3 probability); $27/MWh (0.4 probability); 36/MWh (0.25 probability)

--> ROA may result in NPV > 0, because uncertainty will affect technology options differently; flexible technology similar to call option.

*Probabilities are hypothetical

Conclusions

- Value of water to impact production capacity is significant even if cost is not
- Real options framework capitalizes on volatility to inform investment decisions
- Flexible technology (e.g. hybrid cooling) is similar to call option, dependent on water penalty
- Challenge is to define alternate options and volatility spread
- Need to include R&D to test full scale technology integration