Evaluation of Water Curtailment on Energy Use and Plant Net Profitability

June 4, 2015
Industrial Energy Technology Conference

Kathey Ferland
Texas Industries of the Future
The University of Texas at Austin

Peter Phelps
Phelps Engineering

Texas Industries of the Future

Topics

- Background
- Water/energy Nexus in Process Industries
- Reference Plant and Methodology
- Curtailment Scenarios
- Modeling Results
- Conclusions
- Next Steps

Background

- Severe drought in 2011 in Texas. Texas process plants faced possible curtailment, water quality degradation, or physical shortage.
- Texas IOF, with funding from IIP, held a "*Technology Forum: Sustaining Industrial Energy Efficiency in Process Cooling in a Potentially Water-Short Future*" on June 19, 2013.
- "water is cheap until it's not there" → challenging to engage management and secure capital for technology investment before there is a crisis.

Risk Management

Strategy: Develop comparable information on cost and performance of new technologies

- Barriers
  - Technologies not proven in chemical plants or refineries
  - Differing formats/metrics on new technologies
- Possible Solutions
  - Process to speed demonstration of technologies in relevant applications; tool to allow an end-user to screen technologies for themselves.
  - Develop a common evaluation template; frame the issue using multiple scenarios.
- Next Step
  - Compare technologies under several water restriction scenarios for a reference plant.

Evaluation of Water Curtailment on Energy Use and Plant Net Profitability

Goals of project include:

- Develop a case study of the impacts on a process plant's profitability and energy usage, comparing evaporative, hybrid or dry process cooling technologies, under two water curtailment scenarios.
- Increase end-user awareness of process cooling technology options and their associated water/energy impacts, benefits and costs.
- Present results in a framework that communicates the risk of action or no-action.
- Test the approach for potential use as a web-based tool which would allow the user to customize process plant operating data.

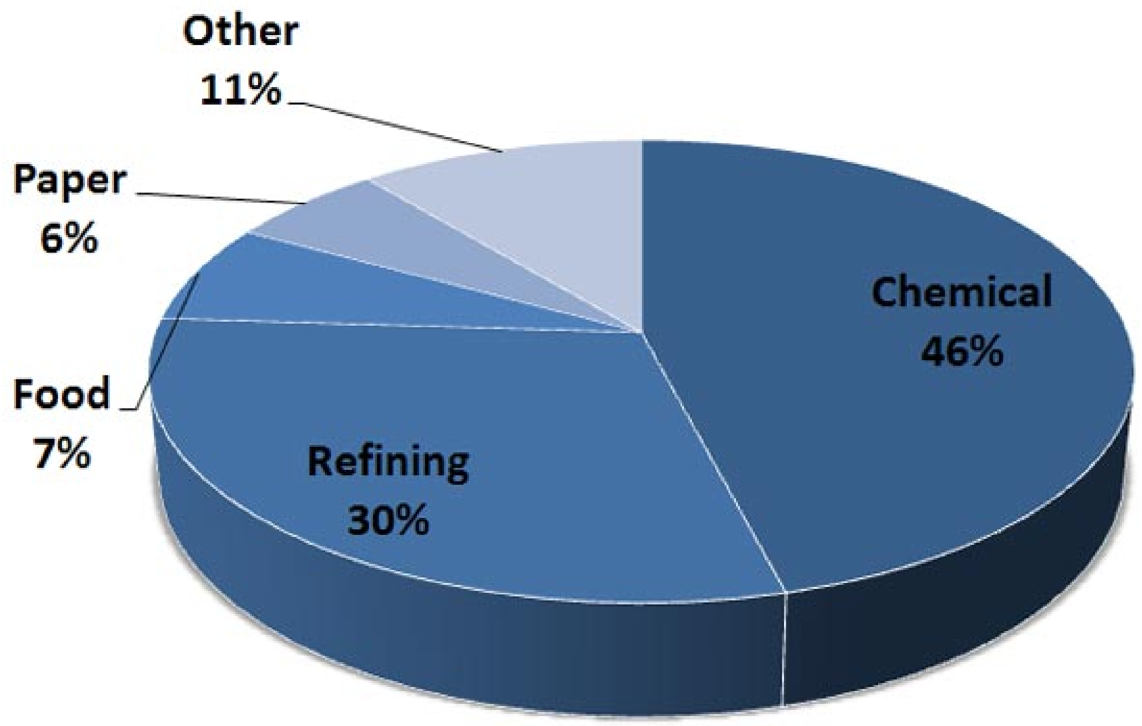
Funded by the Texas State Energy Conservation Office

Texas Industries of the Future

The Energy-Water Nexus in Chemical Manufacturing and Refining

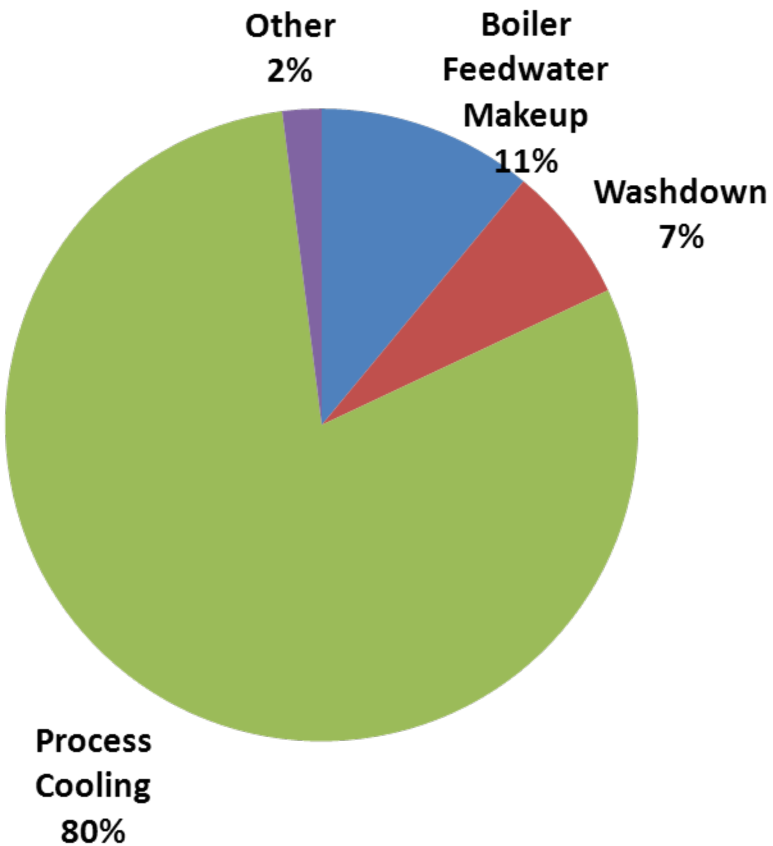
- Current Practice: 67 to 92% of water use is for process cooling or steam systems
- Future: What happens if there is a decrease in water available for energy systems, resulting in:
  - Increase in energy use
    - Substitute chillers for cooling water
    - Substitute other cooling systems for cooling towers
  - Impacts on production
    - Decreased production due to less efficient product recovery (not operating at optimum temperature) or
    - Change processes to avoid energy/production penalty

Water Use by Texas Industries



Texas Water Development Board
2008 Water Use Survey

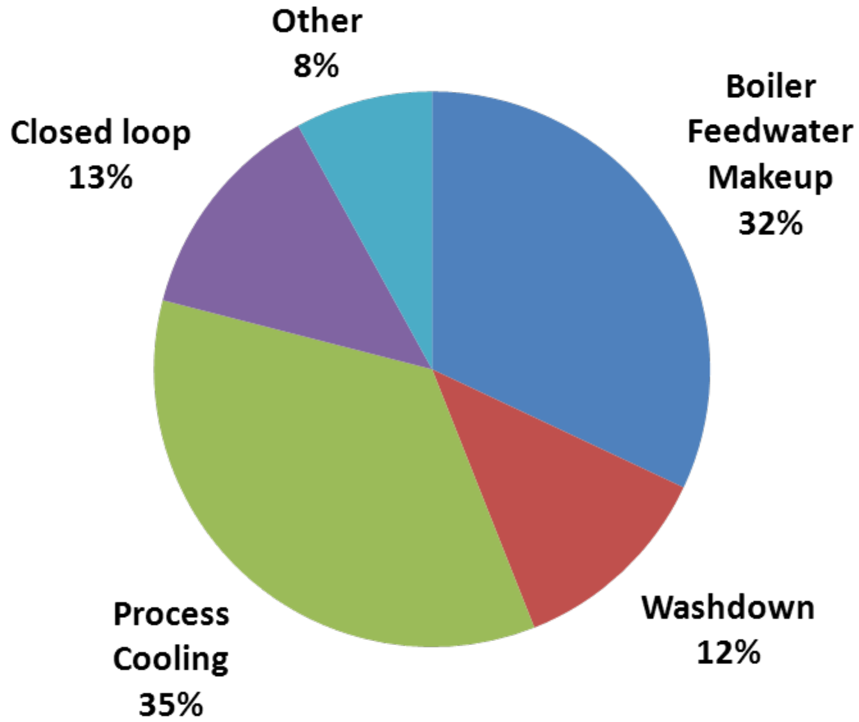
Estimated Water Use by Energy-Intensive Plants*



Source: Anonymous US petrochemical company
*Includes refineries and ethylene plants

Texas Industries of the Future

Estimated Water Use by Less Energy-Intensive Plants (Polymers)



Source: Anonymous US petrochemical company

Texas Industries of the Future

Reference Plant and Methodology

- Developed scenarios with input of Texas IOF Chemical Manufacturing and Refining Advisory Committee.
- Chemical plant in Houston area. Used historical weather data from Hobby Airport weather station.
- Water use for process cooling in cooling tower over 12 month period with no curtailment defines Business as Usual (BAU) and sets the baseline for plant net profitability, water use and energy use. Basis of calculating Monthly Average Water Use.
- Curtailment limits calculated as a percent of the Monthly Average Water Use.
- Licensed software developed by Johnson Controls, Inc. (Generic Process System Simulation Program) to model water curtailment impacts on the Reference Plant.

Texas Industries of the Future

Reference Plant Specifications

Design Plant Capacity, Units/Year	500,000,000
Design Production Rate, Units/Hr	57,078
Maximum Production Rate, Units/Hr	60,000
Design Cooling Tower CWT, °F at Design Production Rate	89
Waste Heat Generated Per Unit, BTU	1,270
Minimum Process CWT, °F at Max Production Rate	67
Maximum Process HWT, °F	120
Change in Waste Heat / °F Change From Design CWT	1.00%
Water Allocation (GPM)	200
Circulating Flow (GPM)	5,000

Basic Scenarios Modeled

- **Length of Curtailment:** 0, 1(August) or 4 months (June-Sept)
- **Severity of Curtailment:** 15% or 30% per month, calculated as a reduction from the Average Monthly Use
- **Penalty for Lost Production** Included in All Scenarios: 10% of cost to manufacture
- **Constraint:** meet monthly water curtailment limits
- **Output:** As a function of the length and severity of curtailment, for each process cooling technology, model:
  - Plant Net Profitability (includes capital and operating costs)
  - Energy use of heat rejection system

Process Cooling Technologies

- Open cooling tower
- Dry cooling system technology company approached, but could not provide the data in sufficient lead time for modeling
- Second hybrid system technology developer was contacted, but was in the middle of a business change.
- Thermosyphon Cooler Hybrid System (shown below)

  Johnson Controls, Inc.

Plant Net Profitability= Revenue Minus Expenses

Revenue equals the number of units produced multiplied by the sale price per unit of product.

Expenses include all raw material and energy expenses per unit multiplied by the number of units produced, in addition to labor and plant capital costs.

This includes costs for the cooling tower fan and pump energy, as well as the chemicals for water treatment, and the cost for the make-up water and any blowdown charges. For the hybrid technology scenario, expenses also include the annualized equipment cost, as well as operational costs associated with the technology (pump and fan electricity).

For any scenario which resulted in a reduction in production from BAU, a penalty of 10% of cost to manufacture these units was included.

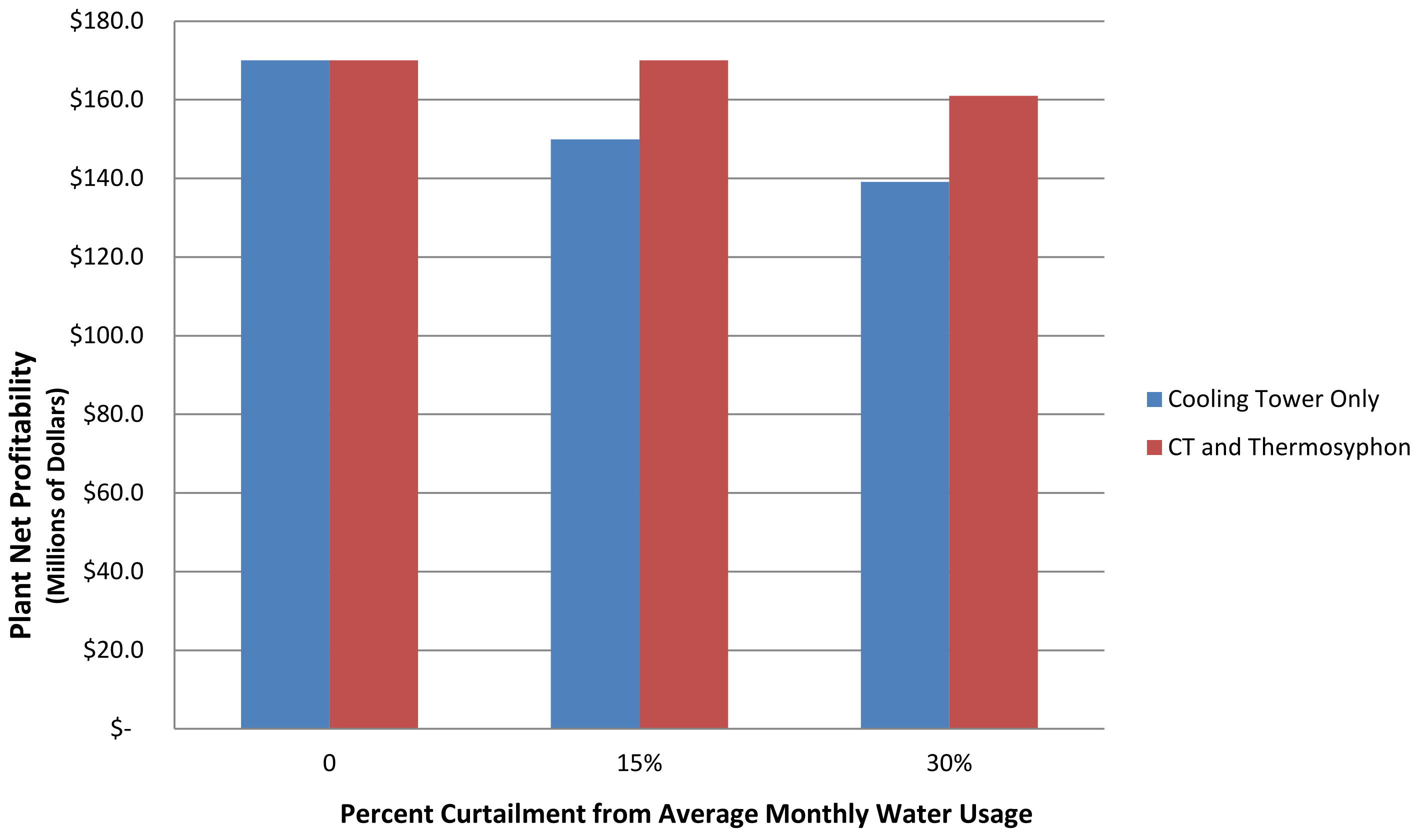
Impacts of Curtailment Severity and Technology Selection on Production, Net Profitability and Energy

(4 month curtailment scenarios)

Technology	Water Curtailment Scenario	Units Produced (Millions)	Plant Net Profitability ($ Millions)	Electricity Consumed by Heat Rejection System (kWh)	Energy Intensity Attributed to Heat Rejection System (kWh/unit)	Percent Change in Energy Intensity from BAU[1]
Cooling Tower Only	0% (BAU)	500	170	2,308,400	0.0046	0%
	15%	456	150	2,195,400	0.0048	4%
	30%	433	139	2,118,900	0.0049	6%
Cooling Tower and TSC	0%	500	170	1,964,000	0.0039	(15%)
	15%	499	170	2,188,000	0.0044	(5%)
	30%	481	161	2,163,100	0.0045	(3%)

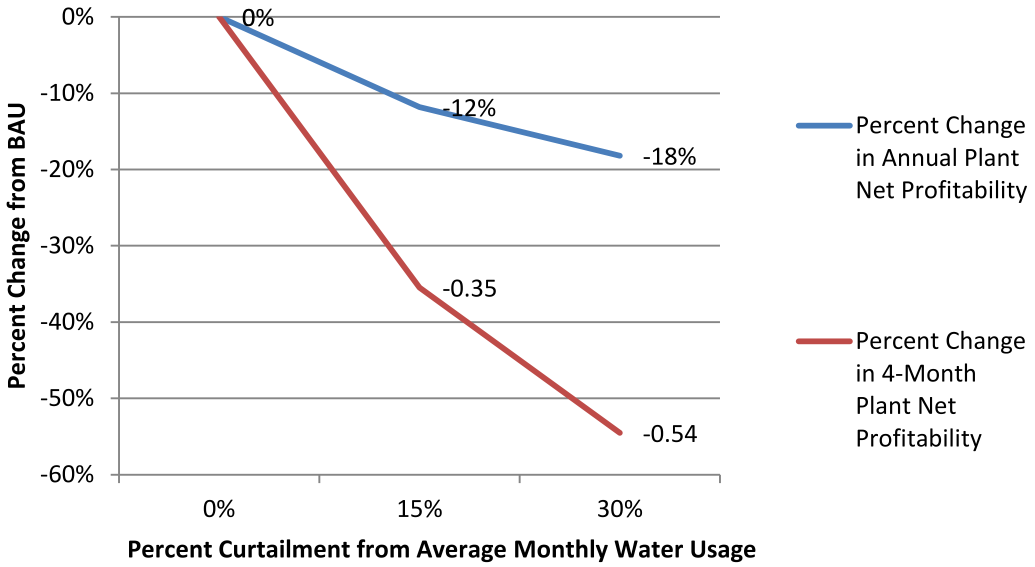
[1] A number in ( ) indicates a decrease in energy intensity from the Business as Usual (BAU) case. A decrease in energy intensity is one indicator of an improvement in energy performance.

Impact of 4-Month Curtailment on Plant Net Profitability

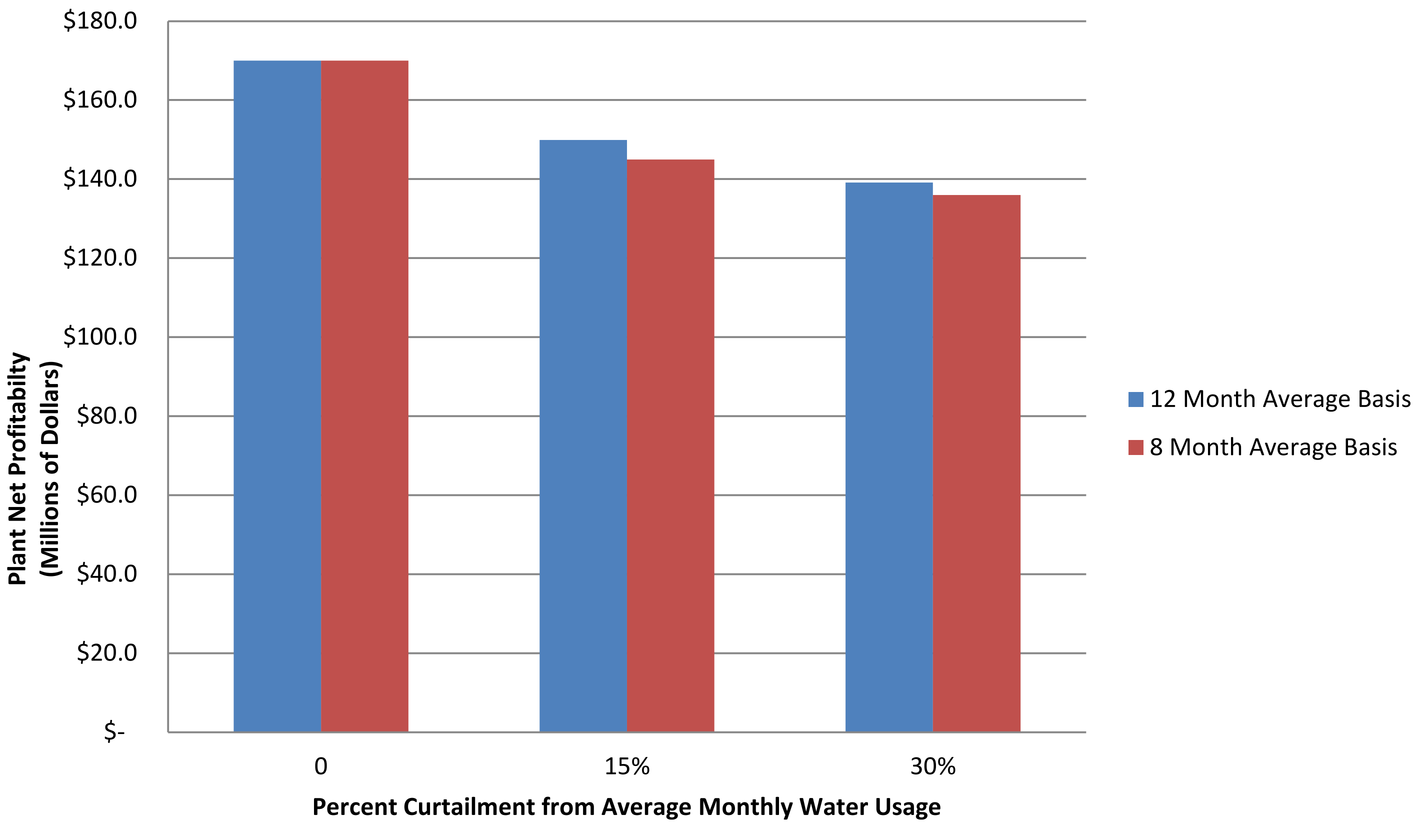


What If Analysis: Comparison of 4 Month versus Annual Net Profitability

Scenario: 4-month curtailment, cooling tower only



Setting the Baseline Water Usage: 8 Month versus 12 Month Averaging



Next Steps Based on Feedback

- Clarify financial assumptions.
- Breakdown costs between capital and operating expenses.
- Additional process cooling technologies to include in the model.

Conclusions:

- A water curtailment of 15% to 30 % for four months has a significant impact on PNP. For the 30% curtailment for 4 months scenario, the worst case scenario, PNP is reduced to $139 million from $170 million, a drop of 18% on an annual basis. However, the drop in plant profitability is not linear as one goes from 0 to 30 % water curtailment.

- The drop in PNP would be experienced over the period of the curtailment, in this case June-September, not throughout the year. Viewed on this basis, the reduction of $31 million would be a 55% drop in PNP for the four-month period.

- The addition of the hybrid technology maintained production levels very close to the BAU scenario, resulting in a negligible reduction in PNP for the 15% curtailment scenario. At 30% curtailment levels, PNP decreased by 5%.

Conclusions

- Energy intensity cannot be assumed to increase from the BAU case when other process cooling technologies are added.

- These results point to the need to fully understand the interaction between water and energy requirements and plant costs for the specific technology under consideration.

- This modeling approach is useful for defining the tradeoffs of different technology selections and provides results in management’s language, profit and risk.

Kathey Ferland
The University of Texas at Austin
Center for Energy and Environmental Resources
512-232-4823
Kferland@mail.utexas.edu
http://TexasIOF.ceer.utexas.edu

Peter Phelps
Phelps Engineering
(949) 246-8418
pphelps@phelpsct.com

Texas Industries of the Future