Automated Chiller Demand Control

John Bartlik, PE

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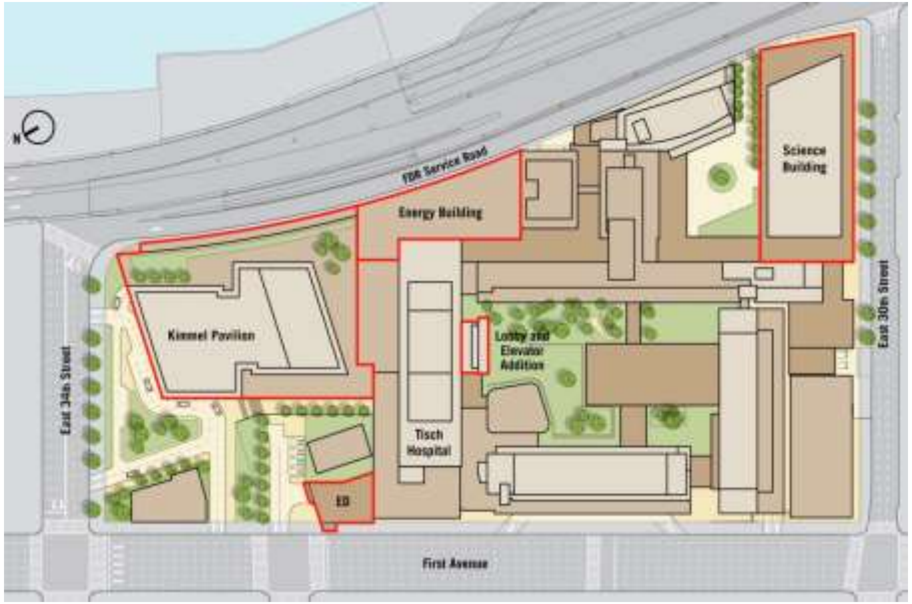
Introduction to NYULH

- 3.6 M SQFT Main Campus.
- Centralized Steam and CHW systems
- 2 CHPs – Primary 7 MW Gas Turbine w/ 2.4 MW Steam Turbine combined cycle
- Secondary 2.9 MW reciprocating gas engine CHP (in progress)
- 3 Electric + 1 Steam Turbine Chiller Plant feeding single loop



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1980s
Campus converts from stand alone to distributed chilled water distribution

Skirball Building and Electrical Centrifugal Chiller Plant is constructed

2007
NYULH Energy Management Program begins with hire of John Bartlik

Smilow Building & Electrical Centrifugal Chiller Plant opens

New Tisch Steam Turbine Chiller Plant is built

2012
Construction of Energy Building begins

Hurricane Sandy causes extensive damage

2013
Construction of Kimmel Pavilion and Science Building begin along with Campus Restoration.

2016
CHP Gas Turbine start-up

30% carbon reduction goal achieved

2018
Kimmel Pavilion & Science Building opens

Kimmel Chiller Plant opens

NYULH achieves USGBC Peer Platinum certification

$100M total energy savings achieved

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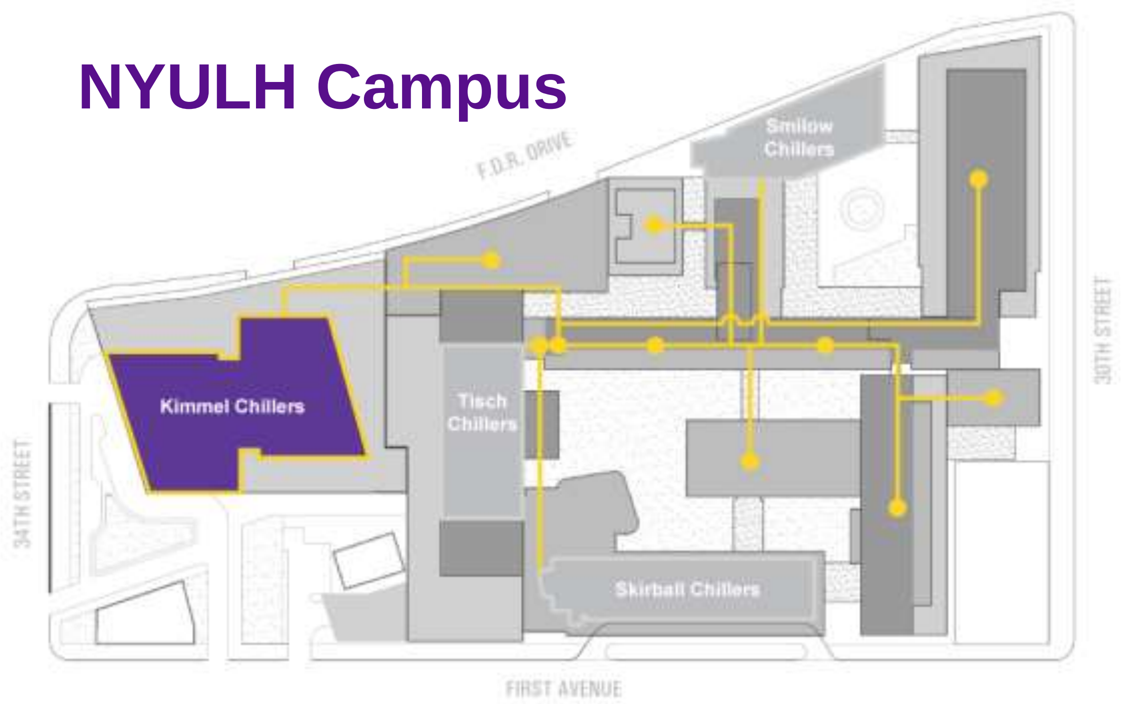

KIMMEL CHILLERS

- 5 x 1,360 Ton York Electric
- 1 x 400 Ton York Electric
- 1,400 Tons Plate & Frame
- Primary Electrical Service Tariff
- Daily Demand
- Demand Cost (Summer): $.8335/kW/day
- Demand Cost (Non-Summer): $.4521/kW/day

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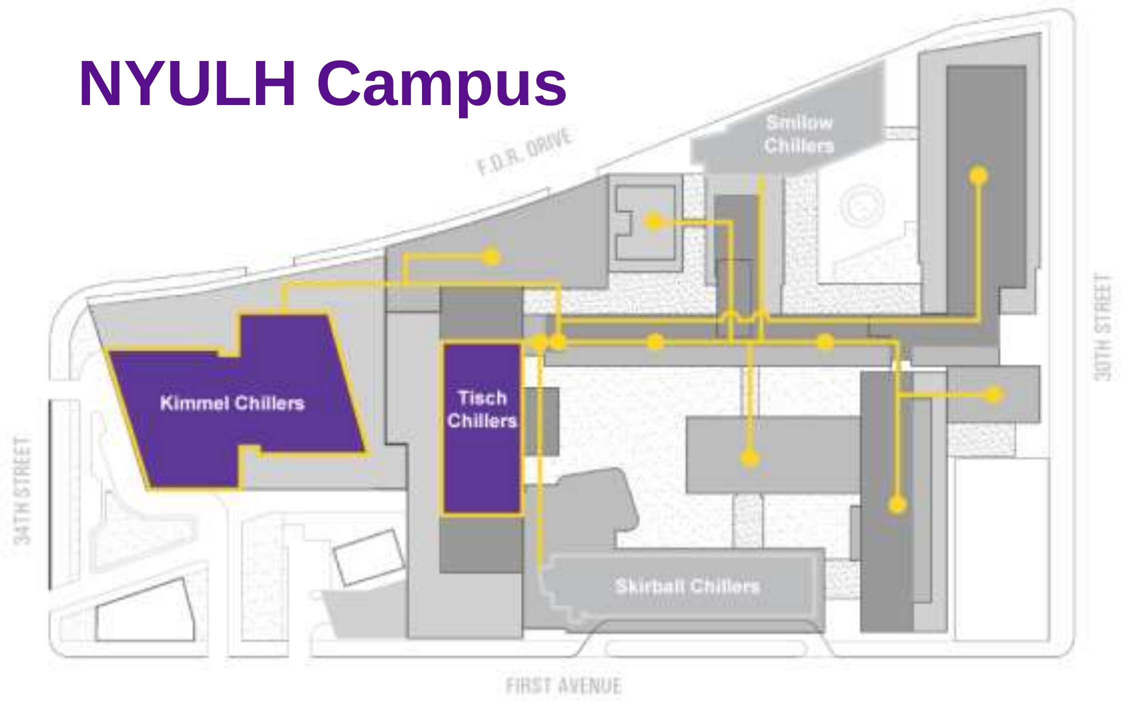

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TISCH CHILLERS

- 3 x 2,000 Ton York Steam Turbine
- Electrical Centrifugal
- 800 Tons Plate & Frame
- Primary Electric Service Tariff
- 100% Cogen → 100% Duct Fire
- ~ 9 lbs Steam/Ton Hour = ~1.3 COP
- Cost: $.044/Ton Hour year round due to fixed gas price

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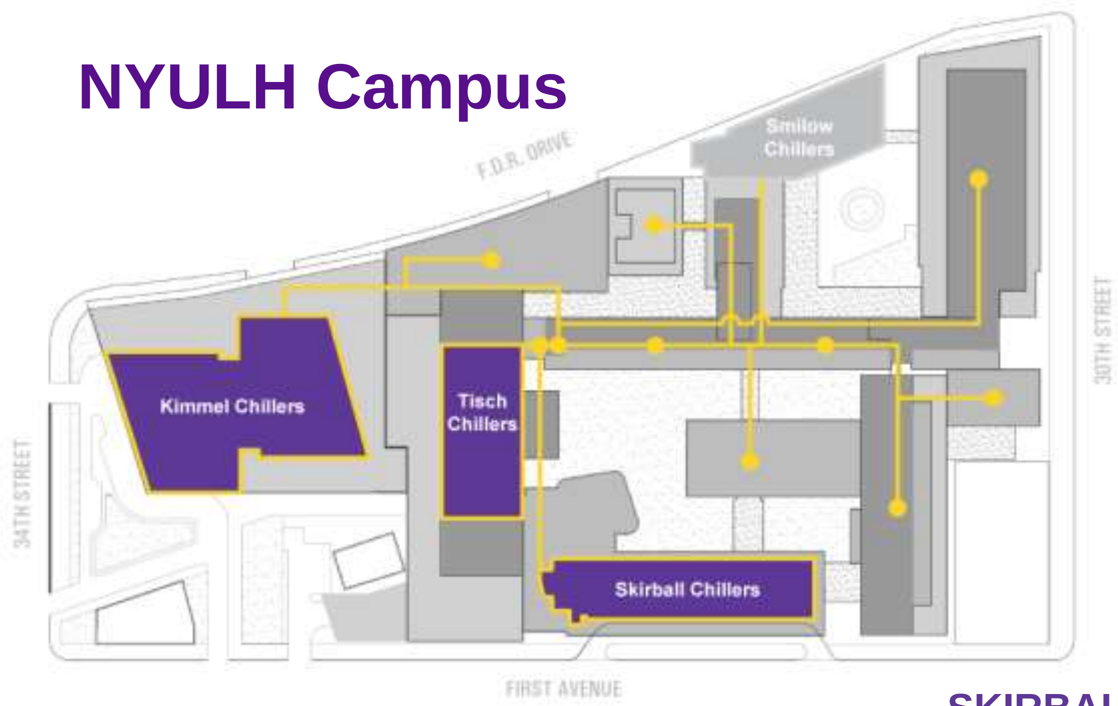

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SKIRBALL CHILLERS

- 3 x 1,200 Ton York Electric, 1 w/VFD
- Electrical Centrifugal
- Secondary Electrical Service
- Daily Demand
- Demand Cost (Summer): $1.52/kW/day
- Demand Cost (Non-Summer): $.7577/kW/day

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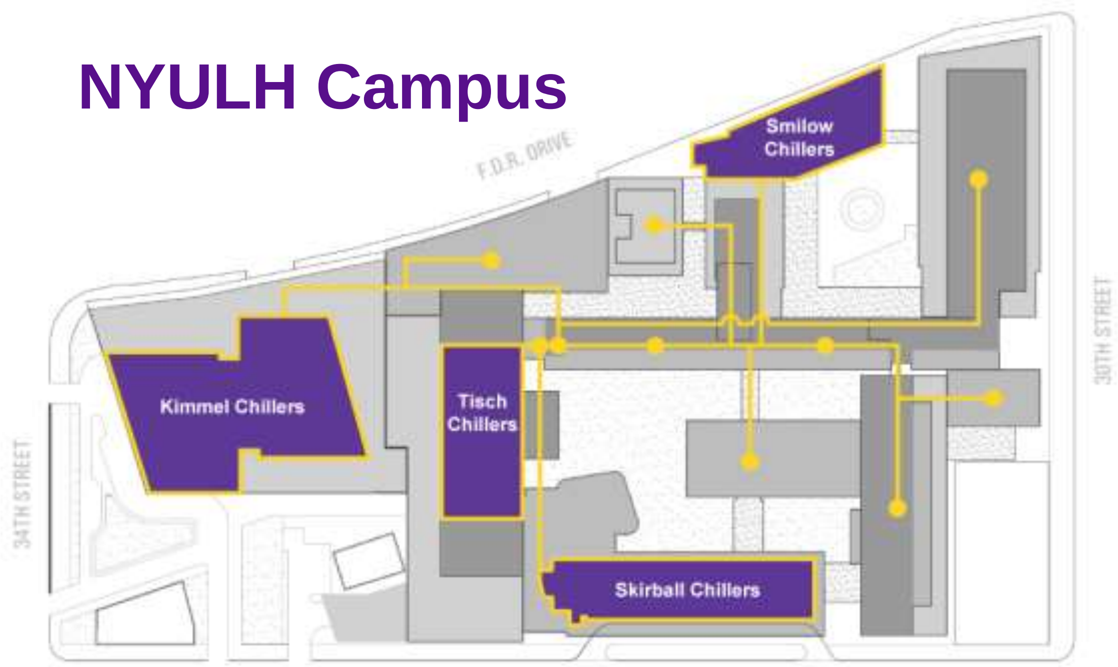

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SMILOW CHILLERS

- 3 x 1,200 Ton York Electric Chillers
- Electrical Centrifugal
- Secondary Electrical Service w/ kWh T&D
- Monthly Demand
- Demand Cost (Summer): $40/kW/month
- Demand Cost (Non-Summer): Plant Not Used

SKIRBALL CHILLERS

- 3 x 1,200 Ton York Electric, 1 w/VFD
- Electrical Centrifugal
- Secondary Electrical Service
- Daily Demand
- Demand Cost (Summer): $1.52/kW/day
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Past Challenges

- **Chilled water plants operated in parallel**
  - Chilled water pump speed controls based upon differential pressure at plant wall. No end of line sensing.
  - Differential pressure controls in parallel pump control caused minimum flow control issues and chiller trips.
  - Due to issues with reliability operating in parallel, plant operators would isolate the plants and lose fuel source flexibility, decrease efficiency of chillers.

- **Operators Issues:**
  - Personal preference on how to run their plant creating additional demand charges and excessive steam use.
  - Misguided operation of plant to design values (e.g. always running at design CW temp).

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Requirements for Chiller Dispatch

- Use lowest cost chiller at all times
- Easy procedure for operators to understand
- Highly automated
- Ensure adequate flow in all parts of campus
- Avoid unnecessary demand exceedances
  - Monthly Demand In Smilow Plant
  - Daily Demand Kimmel/Skirball Plants

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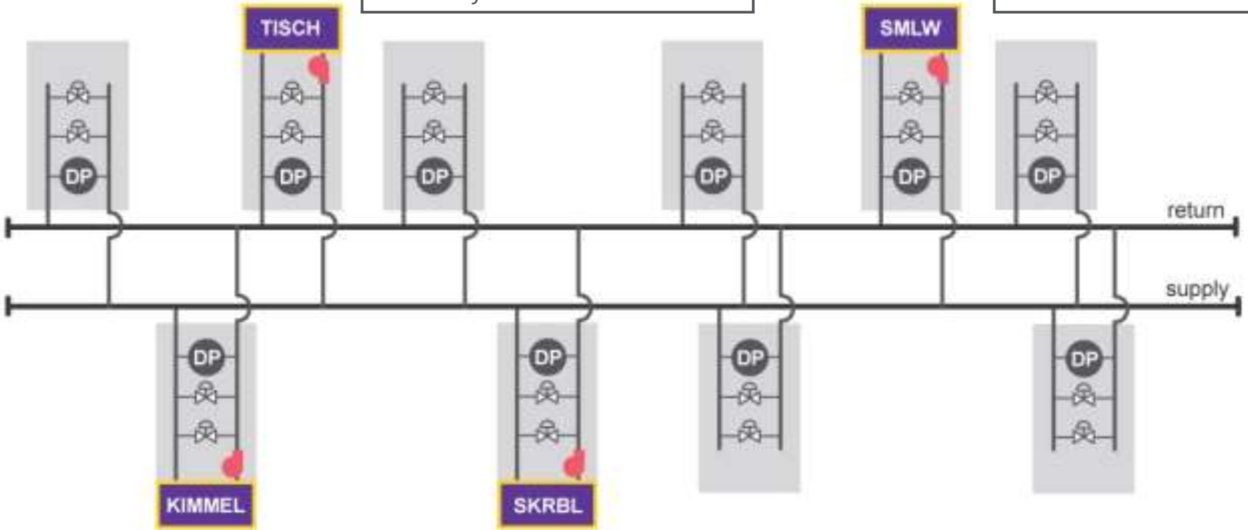
System Layout

TISCH CHILLERS SPECS

- 3 x 2,000 Ton York Steam Turbine
- Primary Electrical Service

SMILOW CHILLERS SPECS

- 3 x 1,200 Ton York Electric Chillers
- Secondary Electrical Service



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- 5 x 1,360 Ton, 1 x 400 Ton York Electric
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SKIRBALL CHILLERS SPECS

- 3 x 1,200 Ton York Electric, 1 w/ VFD
- Secondary Electrical Service

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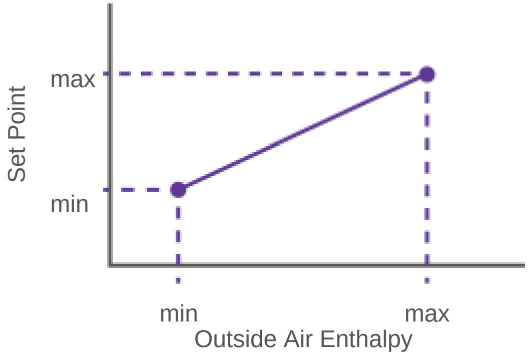
1) Determine Minimum DP Set Point



DP Sensor	DP SP	DP ERR
DP 1	DP 1 SP	DP ERR 1
DP 2	DP 2 SP	DP ERR 2
…	...	...
...	...	...
...	...	...
DP 10	DP 10 SP	DP ERR 10

Establishes the minimum DP SP required at strategic locations in the system and determines a worst case error, lowest DP relative to its SP, to be used to control total plant flow output.

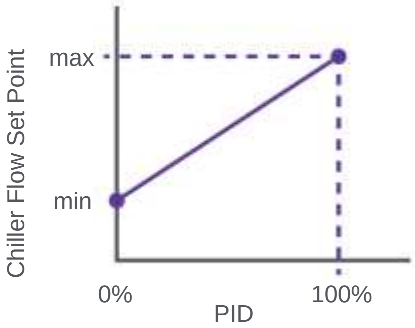
2) Determine PID Output for Worst Case Error

DP Sensor	DP SP	DP ERR
DP 2	DP 2 SP	DP ERR 2

PID
73%

The PID output represents the percentage between each chiller's minimum and maximum allowable flowrate.

3) Determine GPM of Each Chiller Plant



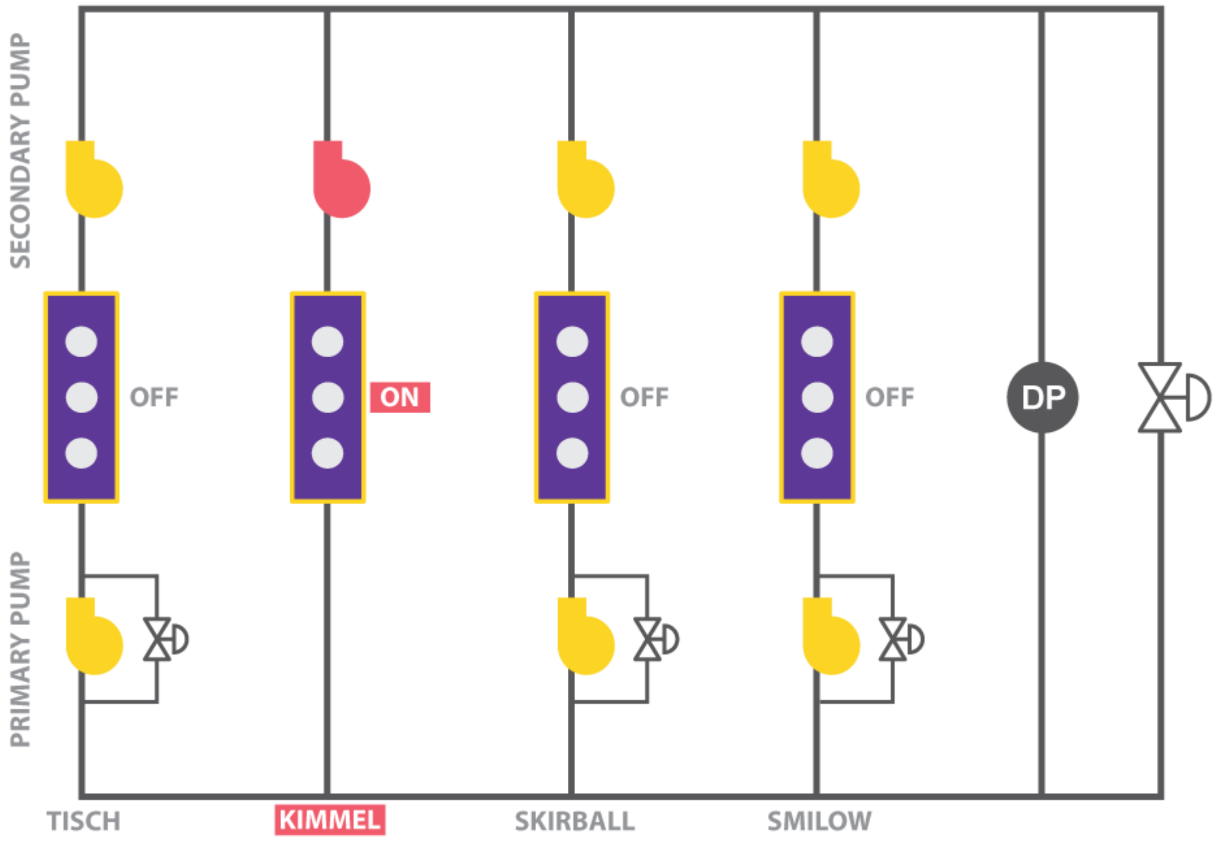
Each plant's chilled water pumps operate to maintain their respective plant GPM SPs. This initial SP is subject to limits based upon plant KW, chiller capacity and load balancing.

Plant	Chiller	DP SP	Pump Speed
Tisch	CH 1	GPM SP	
Tisch	CH 2	GPM SP	Total GPM SP
Tisch	CH 3	GPM SP	
Kimmel	CH 4	GPM SP	
Kimmel	…	….	Total GPM SP
Kimmel	CH 9	GPM SP	
Skirball	CH 10	GPM SP	
Skirball	CH 11	GPM SP	Total GPM SP
Skirball	CH 12	GPM SP	
Smilow	CH 13	GPM SP	
Smilow	CH 14	GPM SP	Total GPM SP
Smilow	CH 15	GPM SP	

Chiller Curtailment Controls

1. **Electrical Service kW Curtailment** – Limit demand cost
2. **Chiller Capacity Control** – Prevents overload and temperature loss
3. **Electric Chiller Plant Load Balancing** – Maximize efficiency

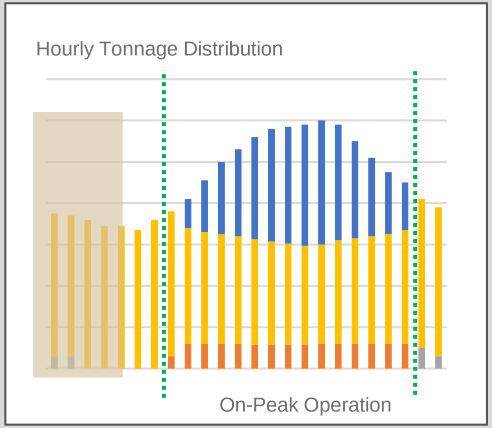
OFF-PEAK OPERATION



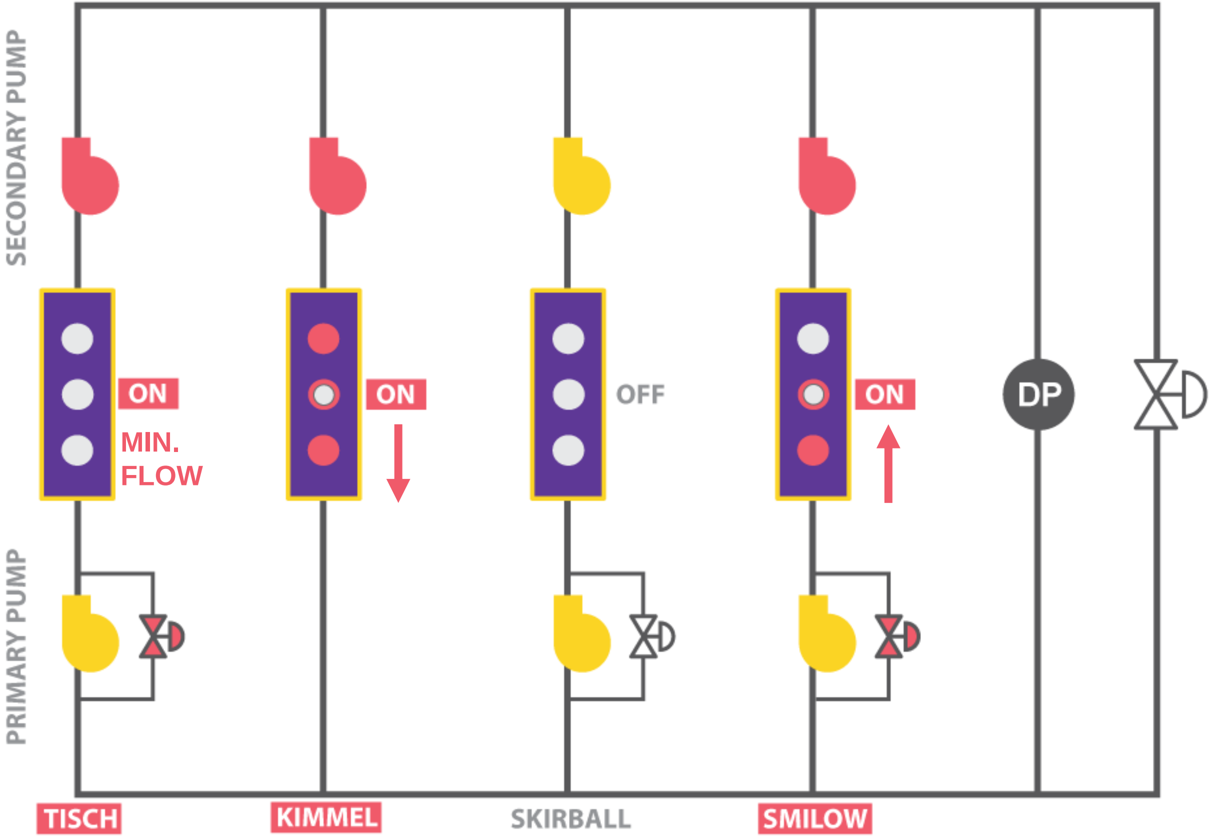
GPM Set Point Curtailment

1. kW Control
2. Capacity Control
3. Load Balance

Time of Operation:



ON-PEAK EARLY OPERATION



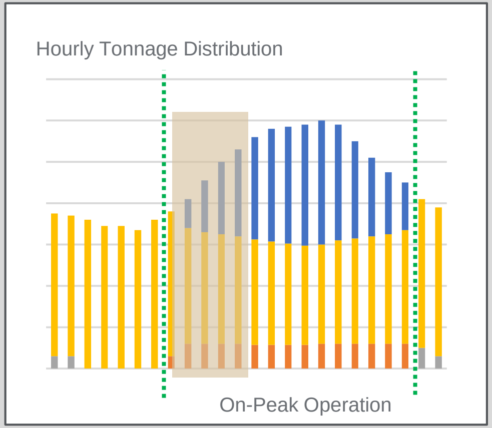
GPM Set Point Curtailment

1 kW Control

2 Capacity Control

3 Load Balance

Time of Operation:



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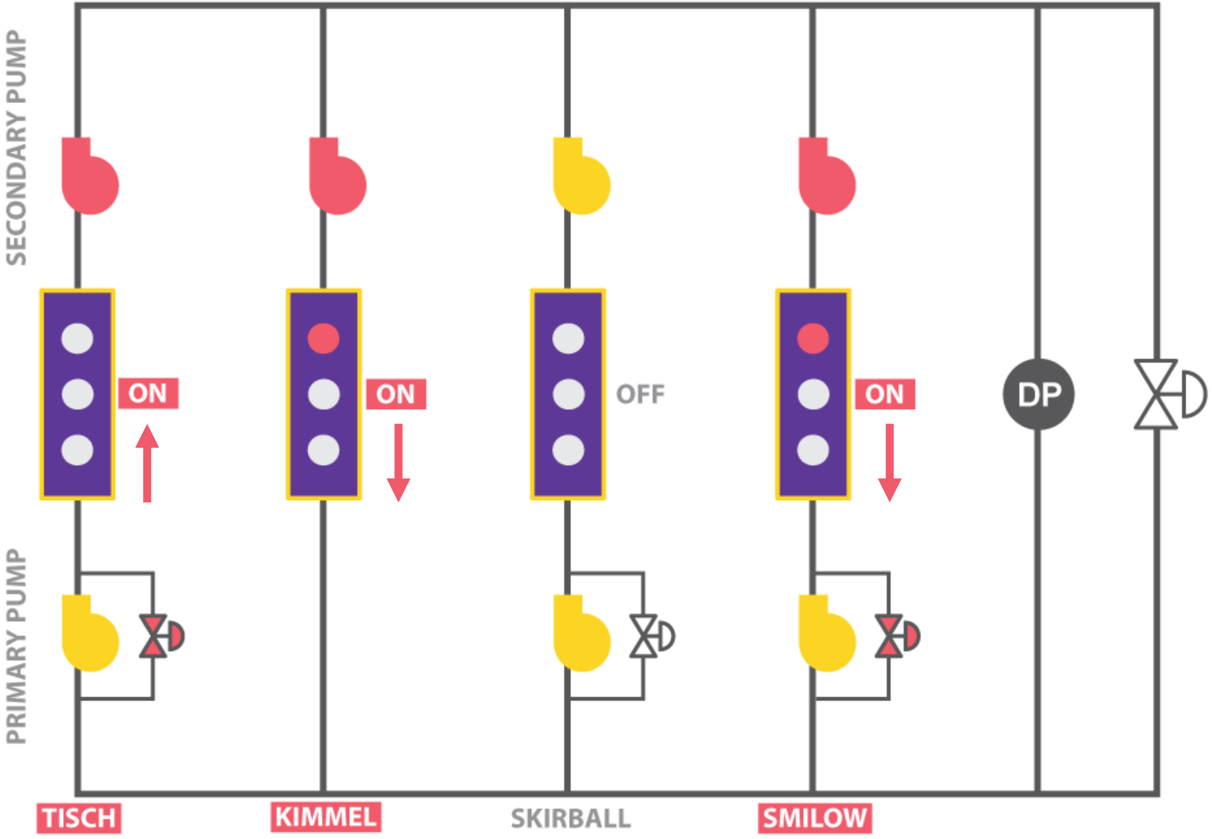


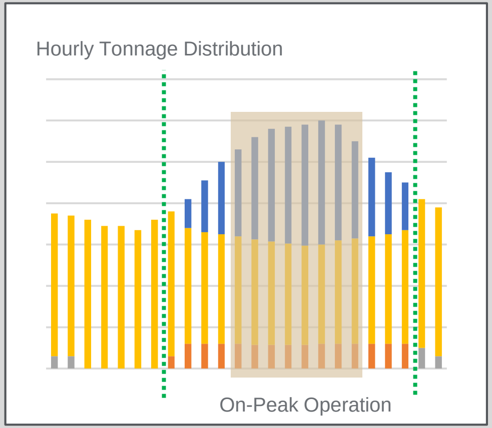
GPM Set Point Curtailment

1 kW Control

2 Capacity Control

3 Load Balance

Time of Operation:



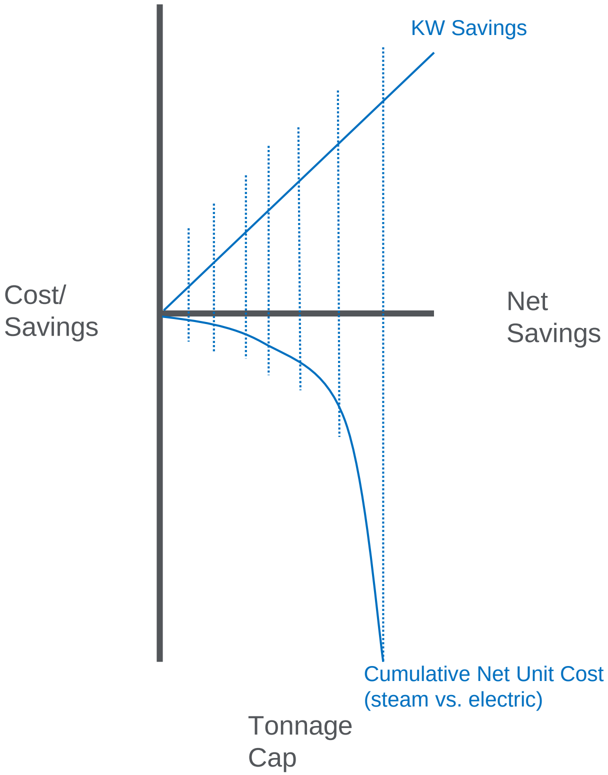
Benefits

- Consistent operations
- System reliability
- Reduced plant trips
- Automation reduces operator error
- Enhanced energy, carbon, and cost savings

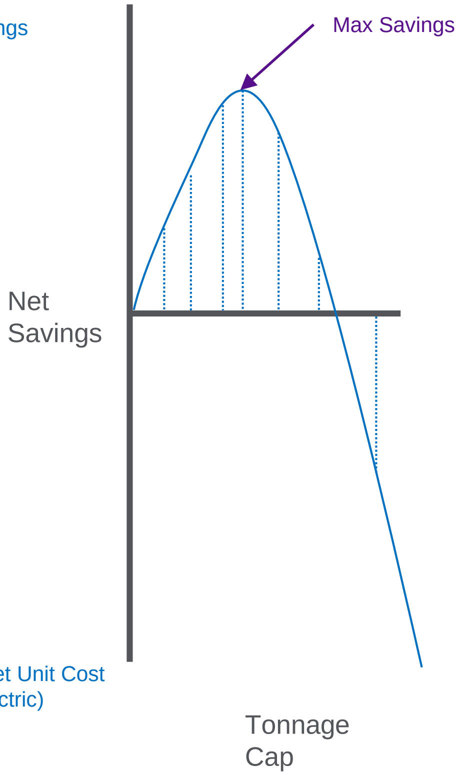
Maximizing Cost Reduction

Pre-CHP Chiller Dispatch Model

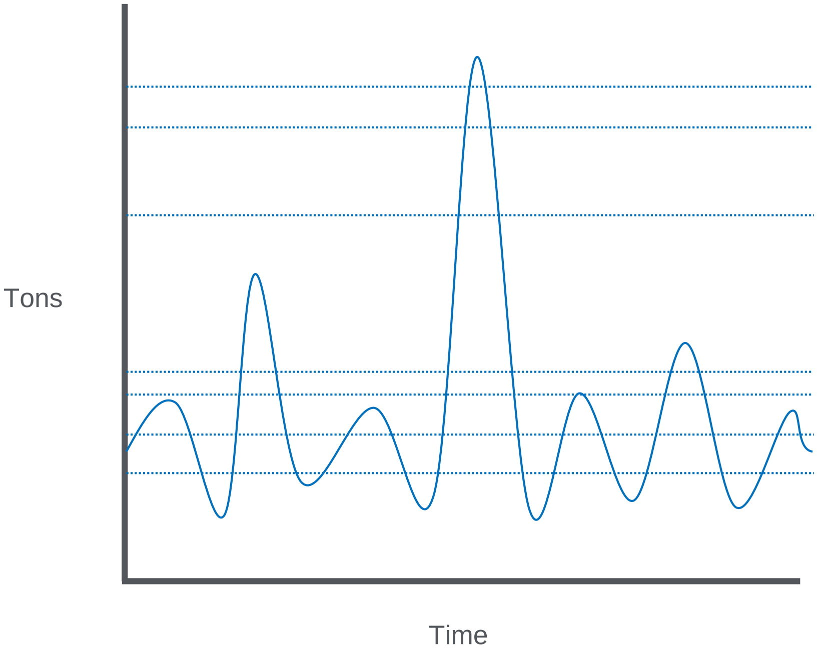
Cost vs. Savings



Net Savings



Tonnage Profile



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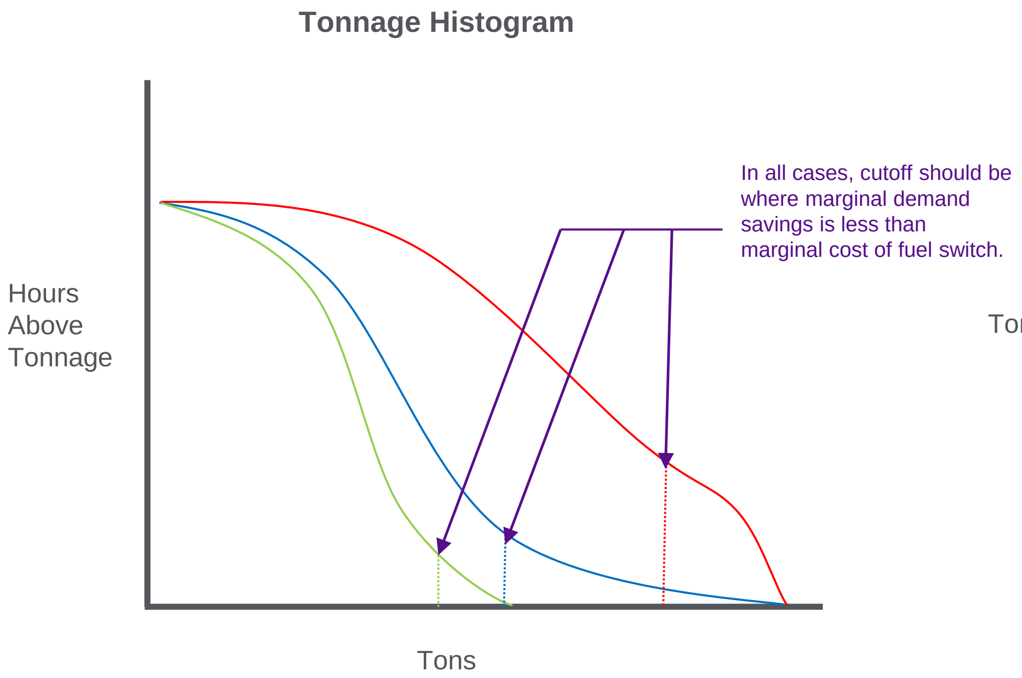
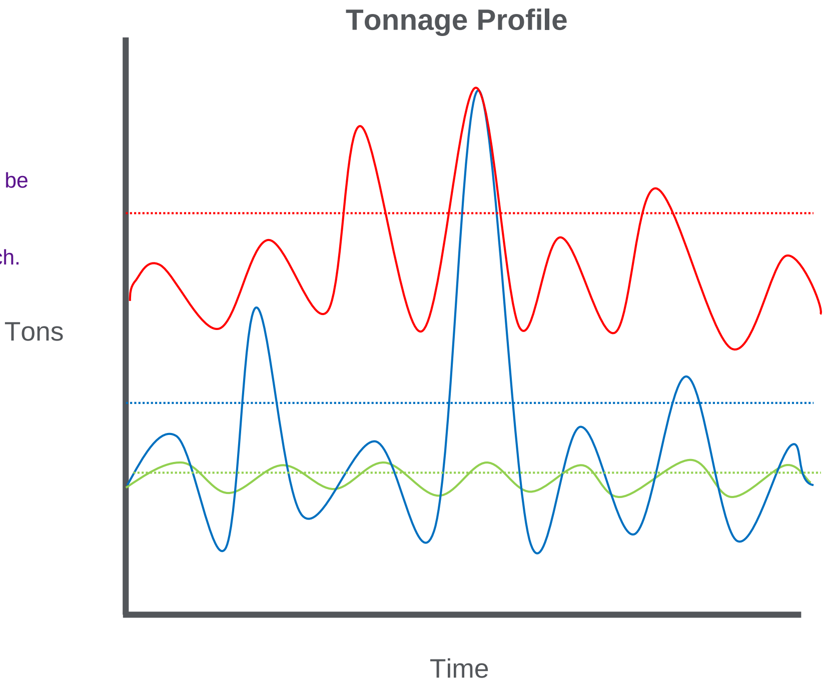
Pre-CHP Chiller Dispatch Model





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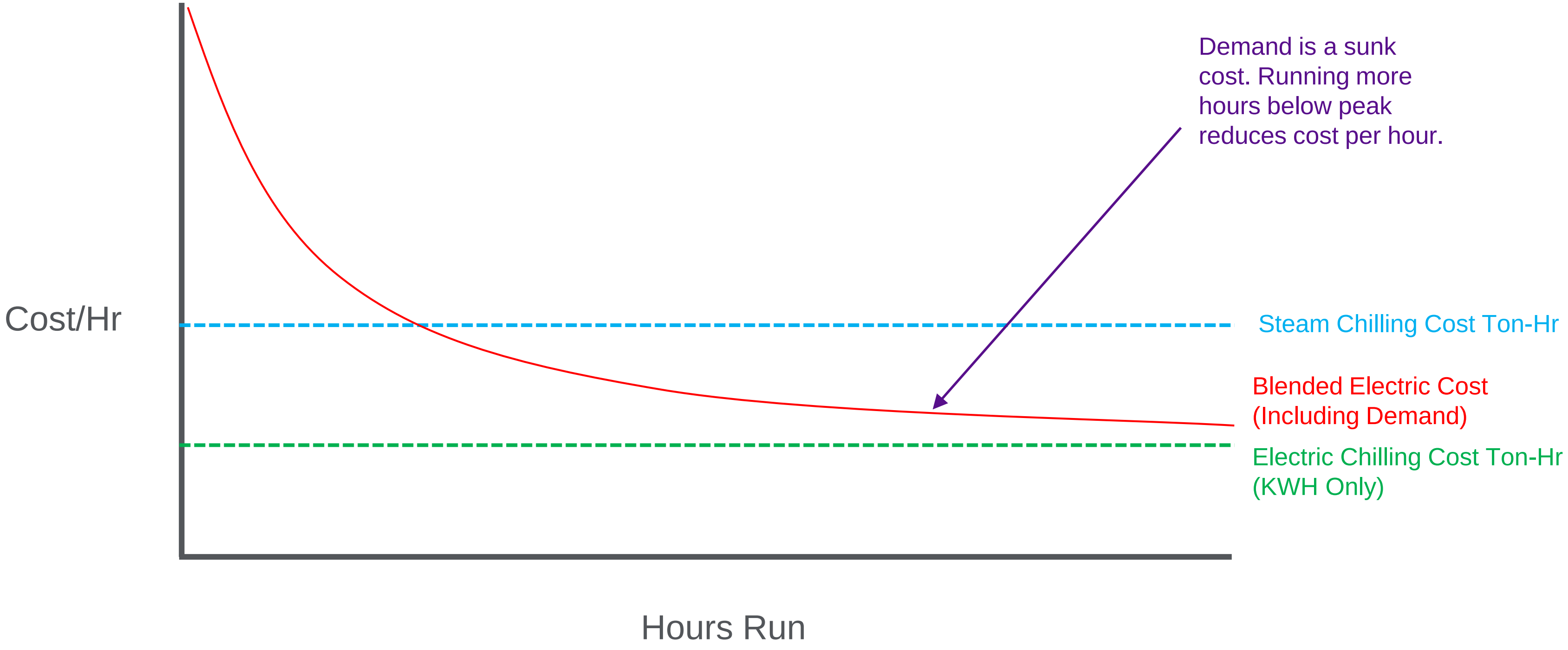
Pre-CHP Chiller Dispatch Model



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NYULH Utility Rate Changes

Utility	Old Model	New Model
Electric	Flat rate commodity, monthly demand, variable T&D.	Floating commodity, primarily contract and as-used daily demand (no ratchet), no T&D. Virtual offset of other accounts.
Natural Gas	Minimal Use (Kitchen Only)	Fixed price firm for CHP, market price IT for boilers
District Steam	Primary heat source. High unit cost, monthly demand in winter only.	High contract demand, reduced rates, tertiary backup only.
Chillers (Steam & Electric Drive)	Lead with electric, peak shave with steam.	Dispatch strategy varies.

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Keys for Developing Dispatch Plan

- Electric costs vary tremendously, marginal unit costs are key
- Steam chilling is *usually* more expensive than electric when demand is ignored, but a cost effective demand reduction method.
- Once a demand threshold his hit, it has <u>no additional marginal cost</u>:
  - Limit monthly demand (at Smilow) for predicted monthly peak. Goal is to max out all other plants
  - Limit daily demand for predicted daily peak

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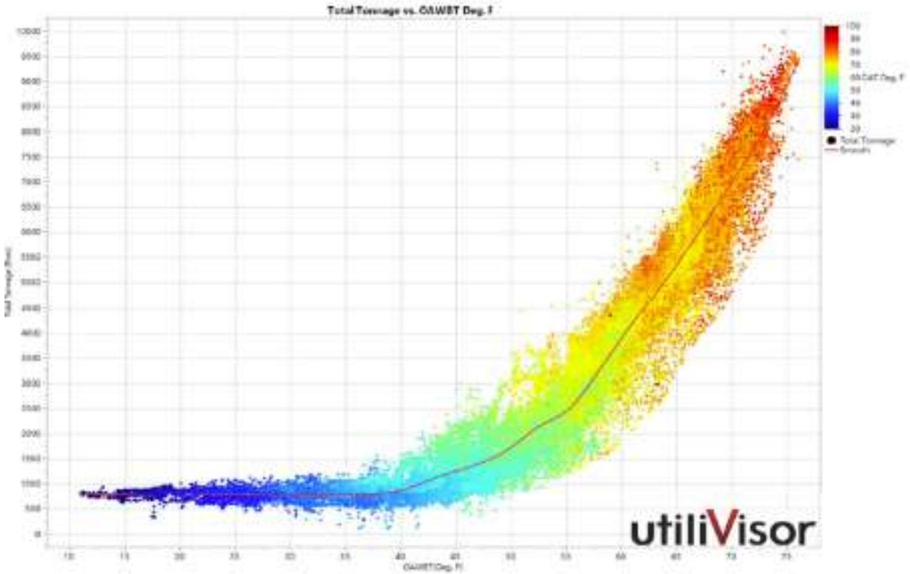
Example Daily Operation

- At beginning of month, it was estimated that monthly peak load would require 1 Smilow Chiller with all other plants at max. Thus, 1 Smilow chiller is run at all times during 8A-10P demand peak to reduce daily demand in other plants as the monthly demand is a sunk cost.
- Predicted peak load is 12,000 tons. At peak of day, optimal conditions are:
  - 6,000 tons (full capacity) from Tisch Steam Plant
  - 1,200 tons from Smilow Electric Plant (limited to monthly peak)
  - 4,800 tons from Kimmel Electric Plant
- Set limit in Kimmel to estimated KW at 4,800 tons



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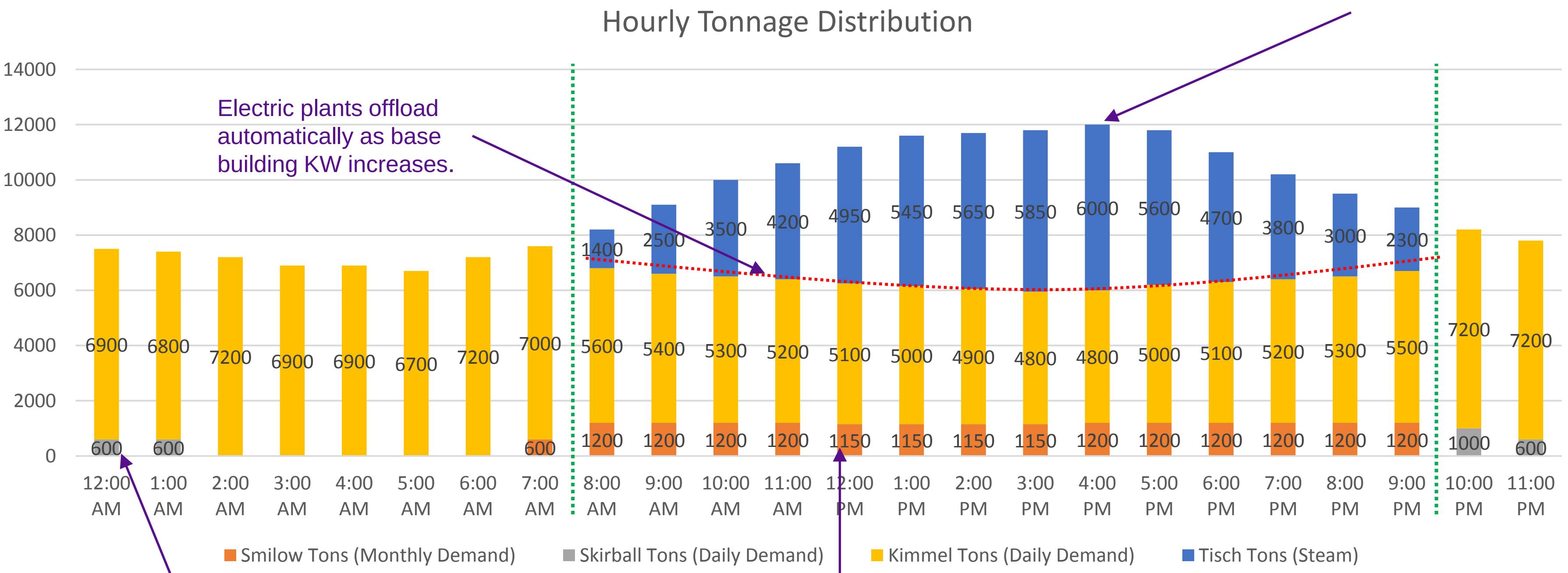
Example Daily Operation

Steam Plant still peaks at overall daily peak.

Electric plants offload automatically as base building KW increases.



Skirball plant needed to maintain load- 600 ton min capacity.

Slight curtailment of Smilow to offset base building peak.

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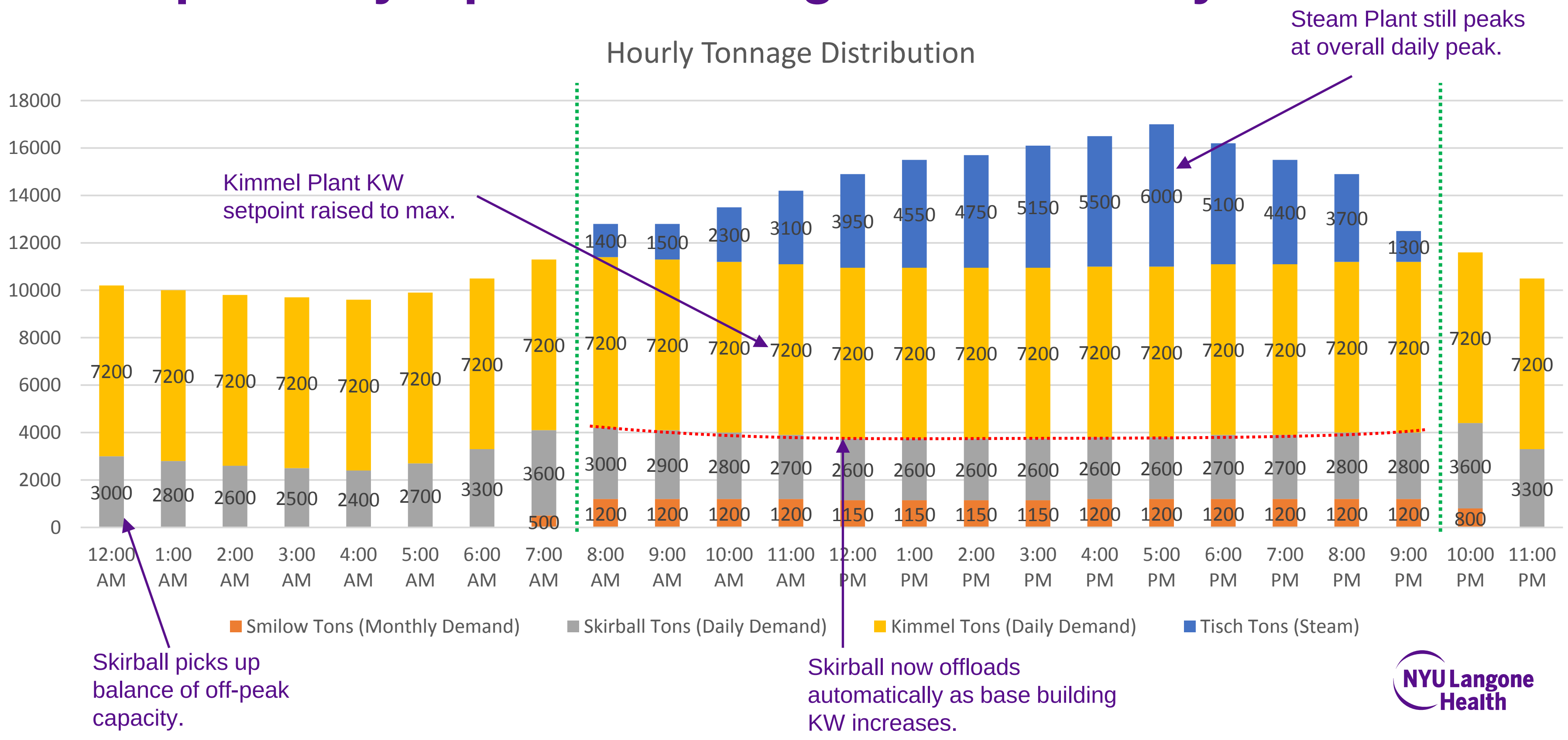
Example Daily Operation – High Demand Day



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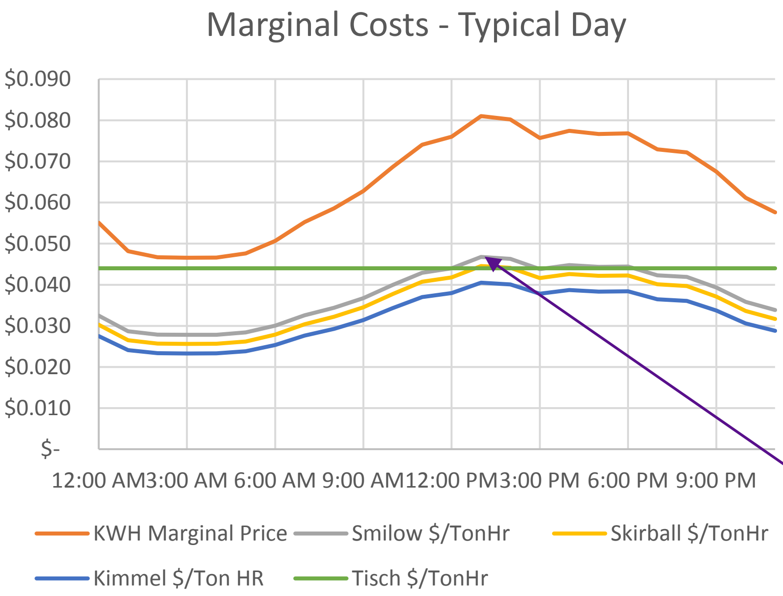
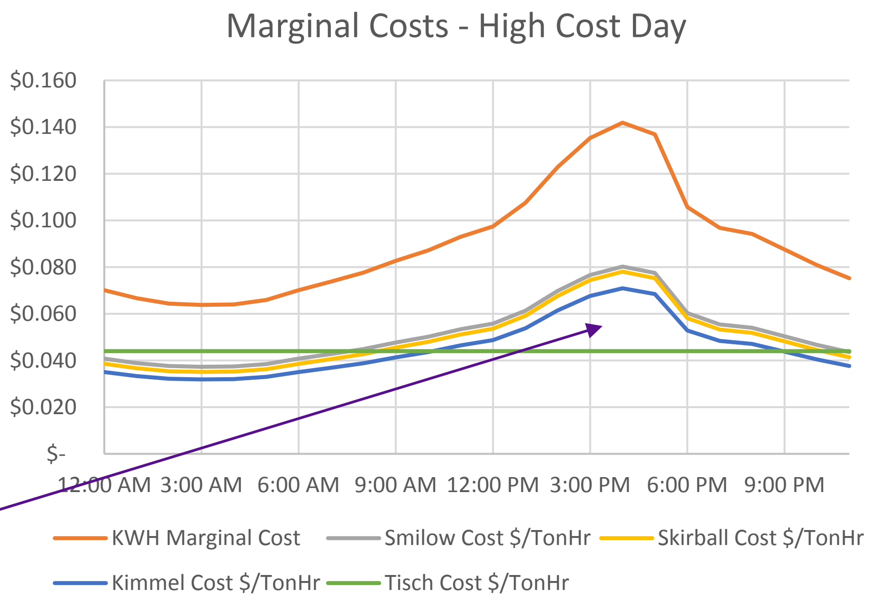
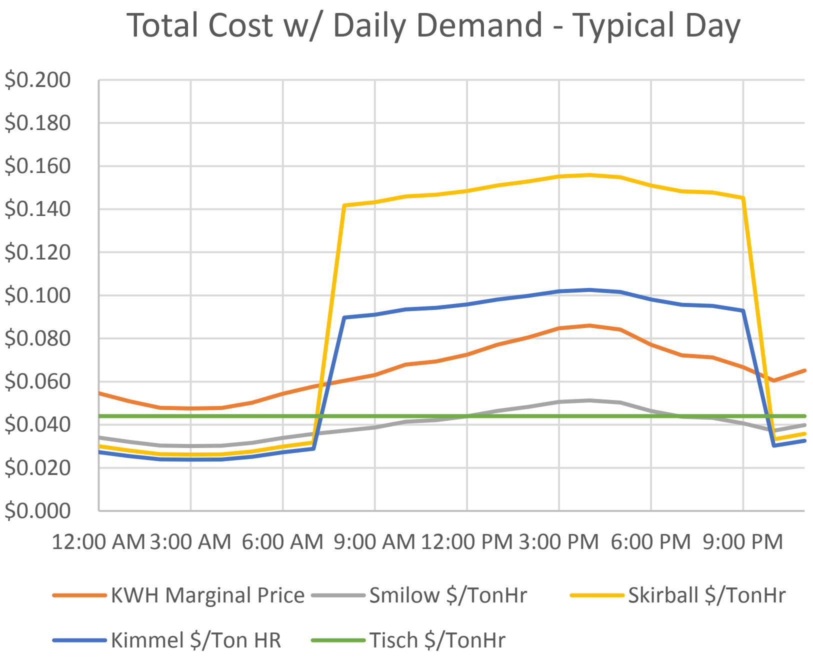
Marginal Cost Changes

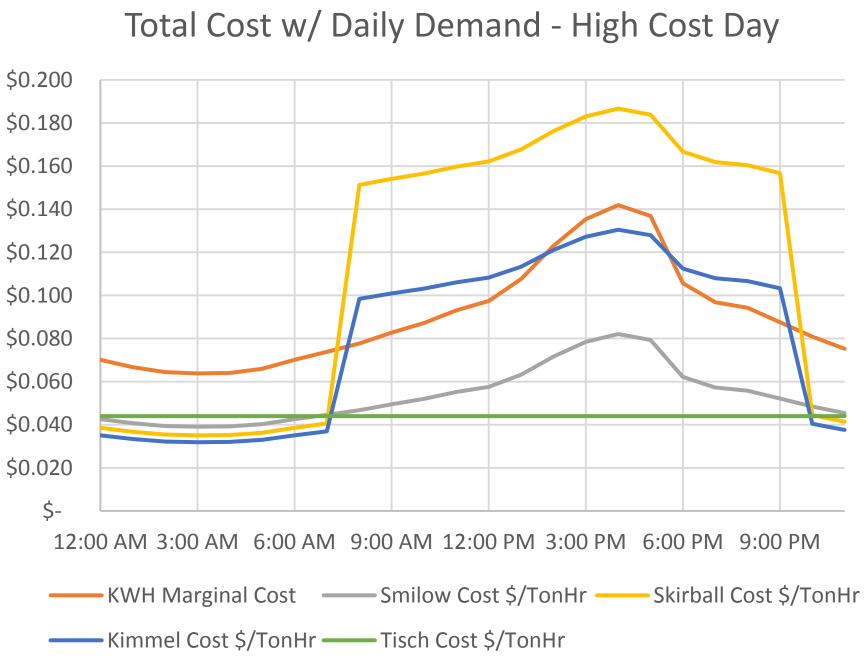




Steam Unit Costs Lowest – Steam Lead Mode

Total Cost Profile





Operator Management

Chiller Dispatch Sequence STEAM LEAD

1 – UTILIZE FREE COOLING	2 – BASELOAD STEAM CHILLERS	3 – OPERATE ELECTRIC CHILLERS This is in order of preferred operation			5 – EXCEED DEMAND SETPOINT		
KIMMEL/TISCH	TISCH	KIMMEL	SKIRBALL	SMILOW	KIMMEL	SKIRBALL	SMILOW
Operate: No steam/electric chillers	Operate: 1-3 steam chillers to meet chilled water baseload	Operate: 0-6 chillers up to demand kW setpoint 1st choice	Operate: 0-3 chillers up to demand kW setpoint 2nd choice	Operate: 0-3 chillers up to demand kW setpoint 3rd choice	Operate: Remaining chillers, exceeding kW 1st choice	Operate: Remaining chillers, exceeding kW 2nd choice	Operate: Remaining chillers, exceeding kW 3rd choice

INCREASING CHILLED WATER LOAD →

1 – UTILIZE FREE COOLING
Operate Kimmel and/or Tisch

KIMMEL/TISCH: During winter weather when there sufficient steam use to keep pace with the Central Energy Plant steam production, there is no need to operate a steam chiller. If the weather conditions are suitable for free cooling, operate the Kimmel plate and frame heat exchanger and if needed the Tisch plate and frame. The Kimmel plate and frame heat exchanger should be the lead and Tisch the lag. A Kimmel chiller and/or a Tisch chiller may be run together with free cooling if beneficial.

2 – BASELOAD STEAM CHILLERS
Fully load steam chillers before electric chillers

TISCH: The Tisch plant must ensure that the Energy Building has sufficient steam load to operate properly. It is the Tisch Engineer's responsibility to ensure that the load is always there and to communicate with the energy building operators upon all plant transitions (chiller starts, stops, trips, rapid load changes, etc.).

Run at least one turbine steam chiller and utilize the minimum chiller flow setting to ensure that the Energy Building has sufficient steam load to reliably operate.

Load the remaining steam chillers before starting electric chillers.

3 – OPERATE ELECTRIC CHILLERS
Chiller operating range to be maintained between 50% - 90% FLA under normal conditions. Max kW SPs are not to be exceeded.

KIMMEL: Is the preferred electric plant, so it should be operated, as the load requires, up to its current demand setpoint (SP) at all times.

SP Weekday Schedule:
8am – 10pm: Changes based on weather
10pm – 8am: 14,000 kW (maximum)

SKIRBALL: is the next preferred electric plant after Kimmel to operate so it should be operated, as the load requires, up to its current demand setpoint (SP) at all times.

SP Weekday Schedule:
8am – 10pm: Changes based on weather
10pm – 8am: 3,450 kW (maximum)

SMILOW: is used to fill in the load that the Kimmel and Skirball plants can't deliver in conjunction with the steam chillers operating at minimum flow setting. Run as required to maintain minimum pressure at end of loop.

The Smilow demand is set monthly at or around the 24th of the month. If chilled water load increases while Skirball and Kimmel are either off or curtailing, load Smilow as required up until it begins curtailing at kW SP.

5 – EXCEED DEMAND SETPOINT
Make sure that Tisch chillers are at full capacity. Exceeding the demand setpoint should be avoided.

KIMMEL: If all Tisch chillers are operating at full capacity and the 3 electric plants are curtailing, Kimmel will be the FIRST plant to be allowed to run through its demand setpoint.

The Kimmel plant will always emergency curtail at 14,000 kW and the engineers should respond by shutting down chillers if necessary to keep demand below 14,000 kW.

SKIRBALL: If all Tisch chillers are operating at full capacity, Kimmel is fully loaded, and Smilow & Skirball are curtailing, Skirball should be the SECOND plant to be allowed to run through the demand setpoint.

The Skirball plant will always emergency curtail at 3,450 kW and the engineers should respond by shutting down chillers if necessary to keep demand below 3,450 kW.

SMILOW: Smilow plant must be carefully monitored to ensure that it does not exceed its demand setpoint. Manager's approval is required to operate this plant above its demand setpoint. Smilow should be the last electric plant to be allowed to run through its demand setpoint.
Always ensure that Kimmel, Skirball, and Tisch are fully loaded before allowing Smilow to exceed its demand setpoint. If necessary, shutdown a Smilow chiller to reduce building demand before exceeding setpoint.

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Next Steps

- **Fan energy reduction program**
  - When steam chilling is available, lower AHU discharge temperature
  - This will cause VAVs to close, reducing fan speeds
  - Spaces will be maintained with less cooler air
- **Advanced submetering & machine learning program**
  - Submetering of each individual buildings
  - Machine learning to predict KW, CHW, and Steam loads
  - Will allow for more accurate KW setpoints

Thank You