
CampusEnergy2021
BRIDGE TO THE FUTURE
Feb. 16-18 | CONNECTING VIRTUALLY
WORKSHOPS | Thermal Distribution: March 2 | Microgrid: March 16

Variable Speed Drive for High Load Chiller Operation

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Trekking in a Dam

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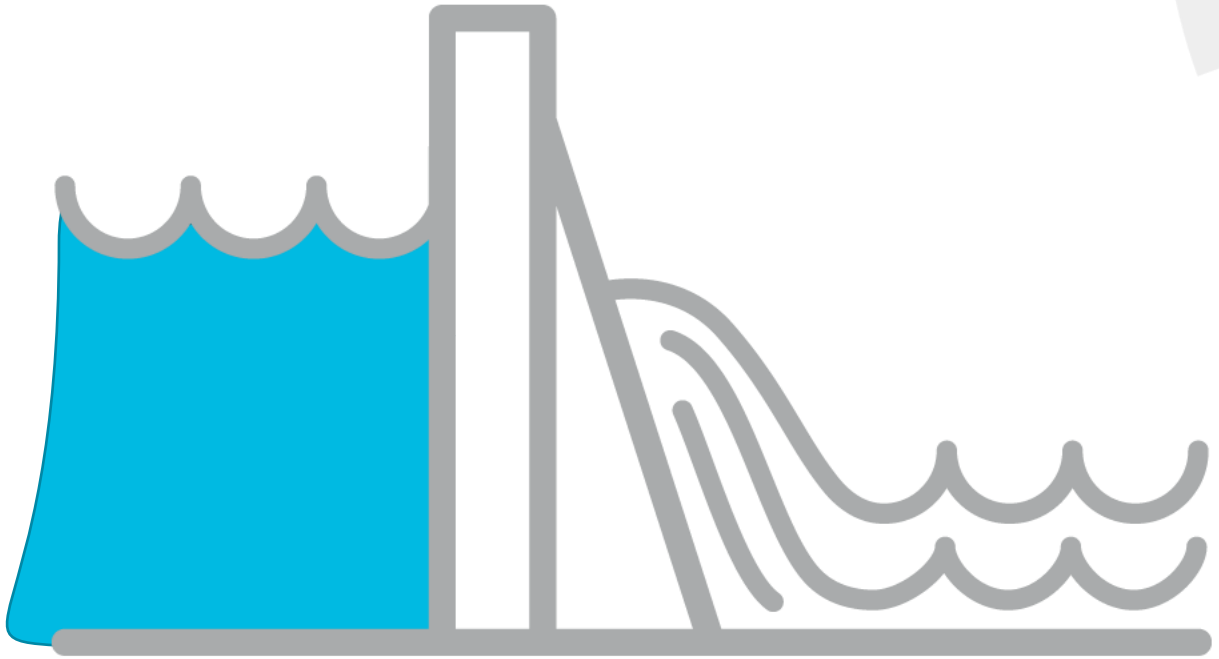
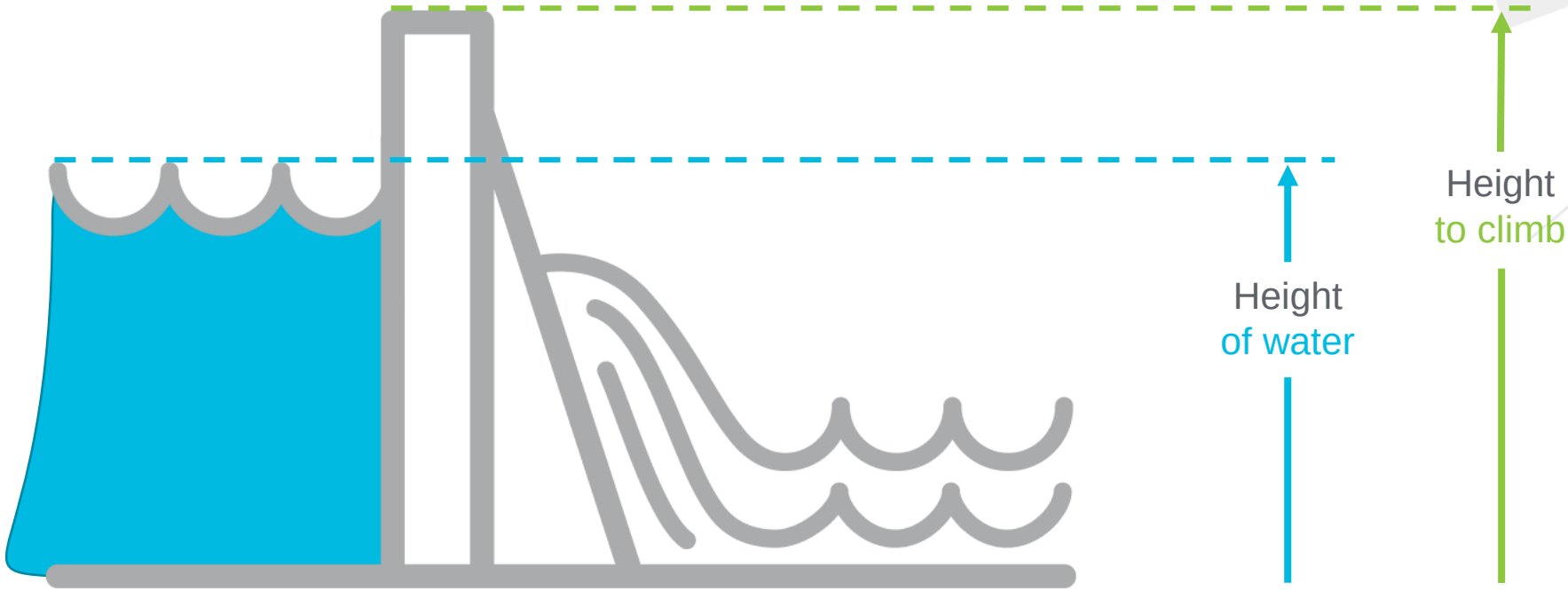
Trekking in a Dam



Height to Climb vs Height of Water Level



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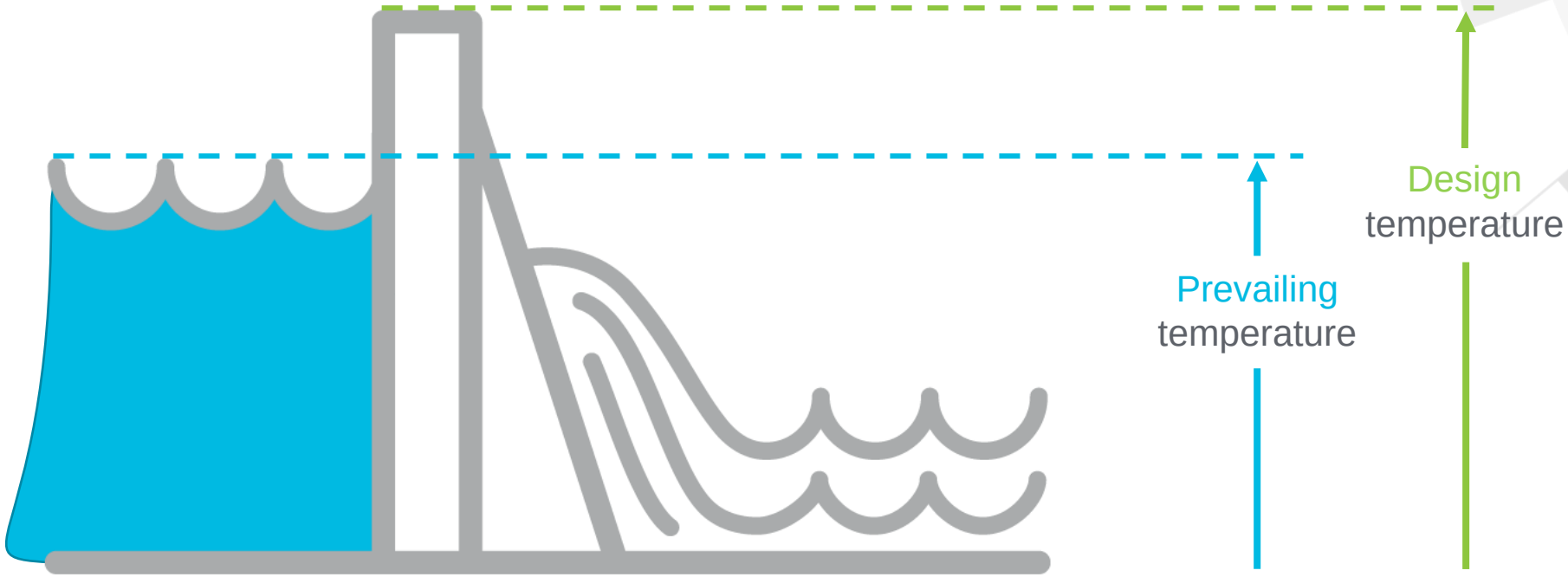

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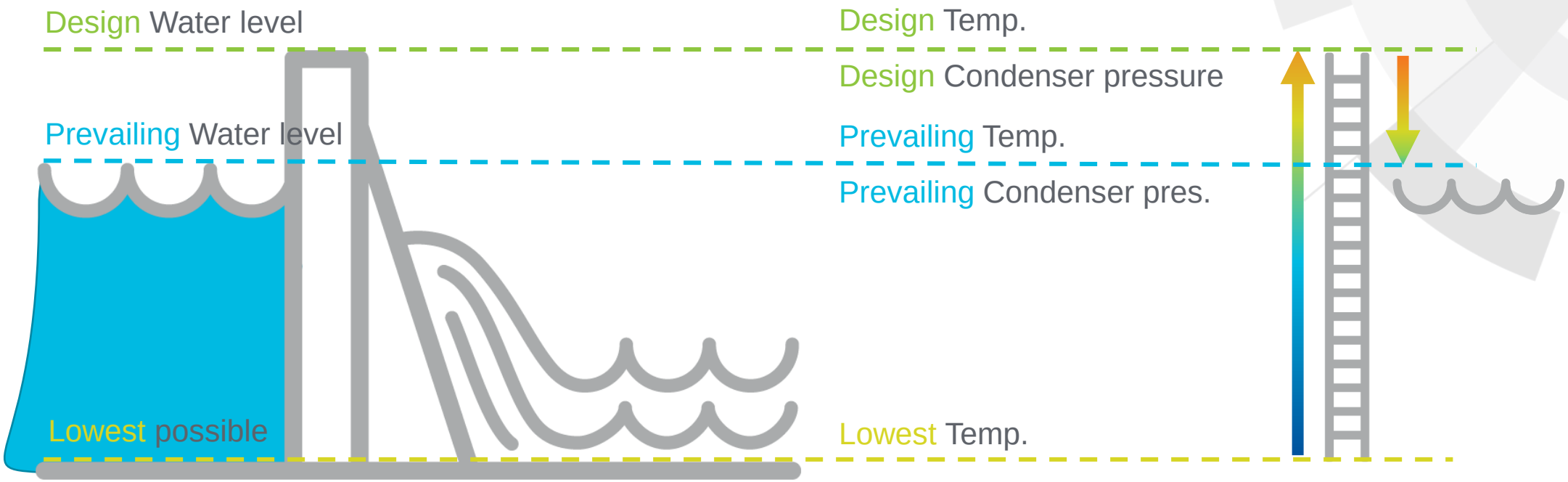

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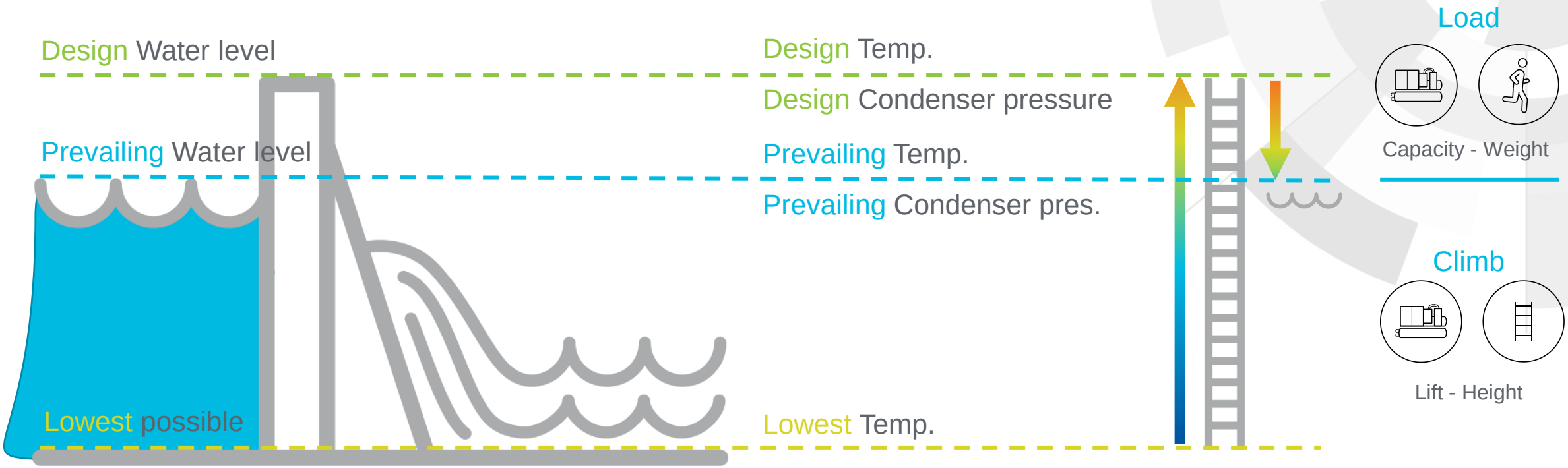
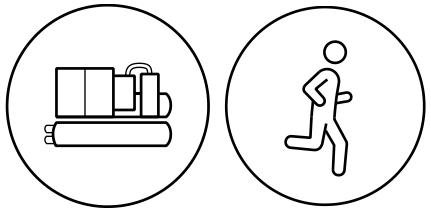


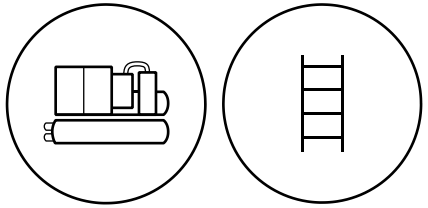
Energy spend

Load



Capacity - Weight

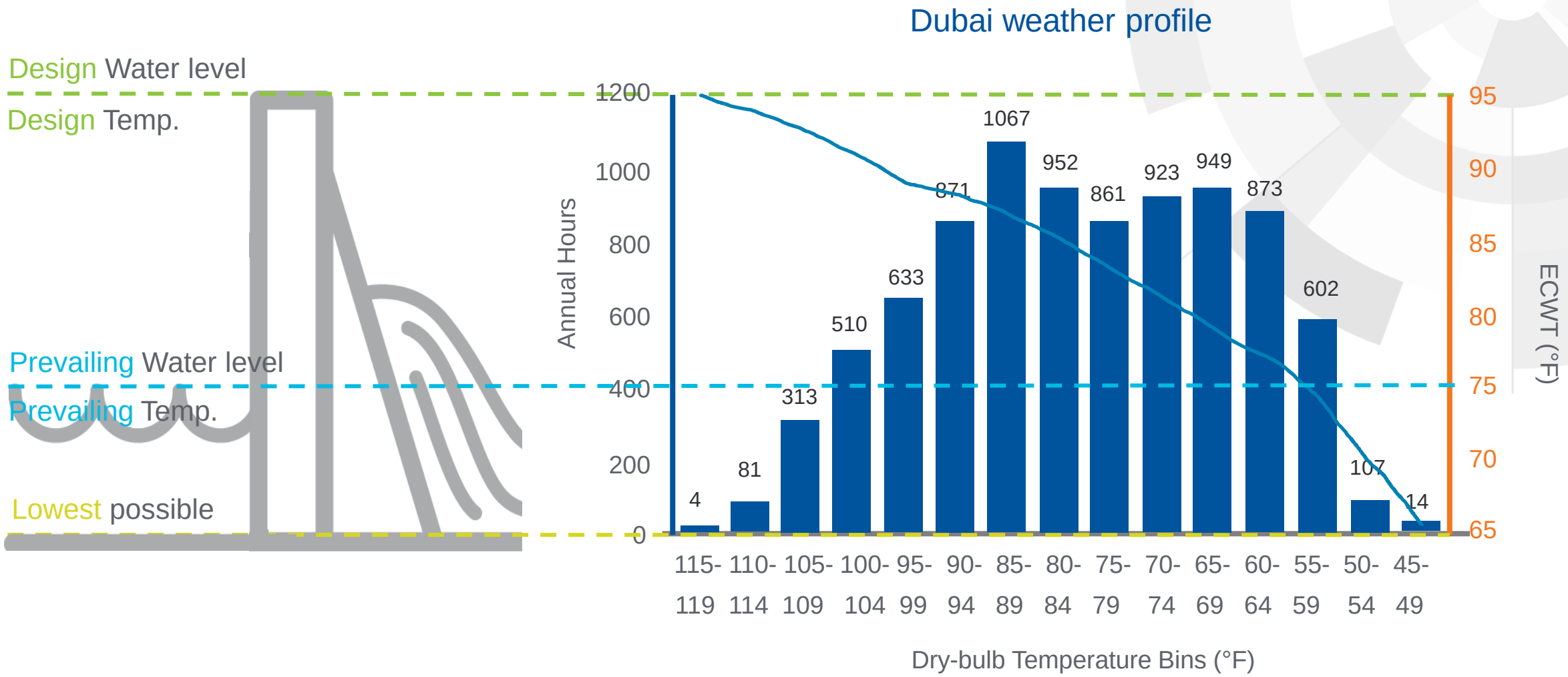
Climb



Lift - Height

$$\text{Energy spend} \propto \frac{\text{Capacity \& Lift (Chiller)}}{\text{Weight \& Height (Person)}}$$

Lift – Mother Nature



Capacity

Low Delta T syndrome

Design Delta T = 9⁰C							
Delta T (deg C)	9.0	8.7	8.4	8.2	7.9	7.6	7.3
Reduction	0.0	-0.3	-0.6	-0.8	-1.1	-1.4	-1.7
Chiller load	100%	97%	94%	91%	88%	85%	81%

Sequencing

Plant load	**25,000**	**24,500**	**24,000**	**23,500**	**23,000**	**22,500**	**22,000**	**21,500**	**21,000**	**20,500**	**20,000**	**19,500**	**19,000**	**18,500**	**18,000**
	100%	98%	96%	94%	92%	90%	88%	86%	84%	82%	80%	78%	76%	74%	72%
No. Running Chiller	10	10	10	10	10	9	9	9	9	9	8	8	8	8	8
Each Chiller loading	2,500	2,450	2,400	2,350	2,300	2,500	2,444	2,389	2,333	2,278	2,500	2,438	2,375	2,313	2,250
	100%	98%	96%	94%	92%	100%	98%	96%	93%	91%	100%	98%	95%	93%	90%

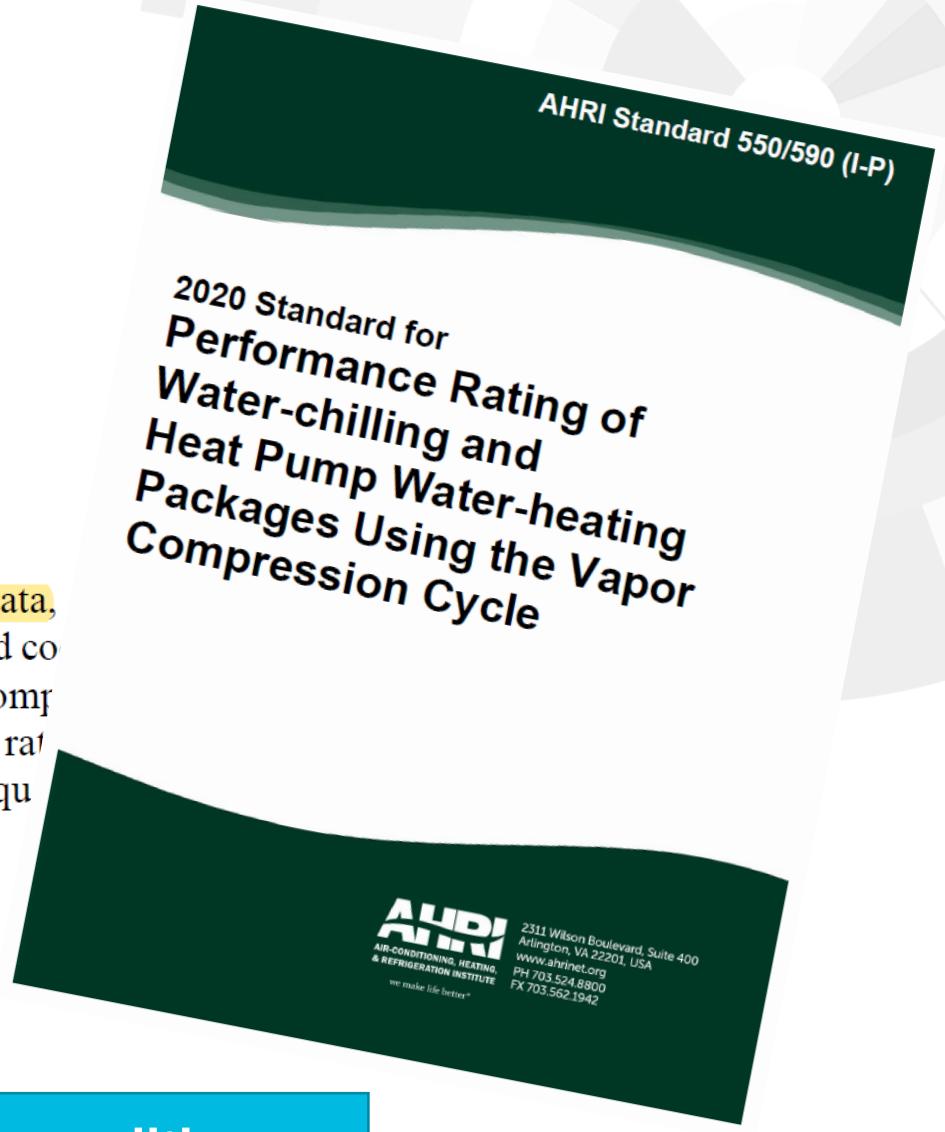
99% of chiller lifetime spend at off-design condition

Real-world conditions – Search for solution

- ANSI/ASHRAE & AHRI
- IPLV / NPLV

IPLV/NPLV	
Load	Time
100%	1%
75%	42%
50%	45%
25%	12%

In summary, it is best to use a comprehensive analysis that reflects the actual weather data, operational hours, economizer capabilities and energy drawn by auxiliaries such as pumps and co the chiller and system efficiency. The intended use of the IPLV.IP (NPLV.IP) rating is to comp technologies, enabling a side-by-side relative comparison, and to provide a second certifiable rat by energy codes. A single metric, such as design efficiency or IPLV.IP shall not be used to qu

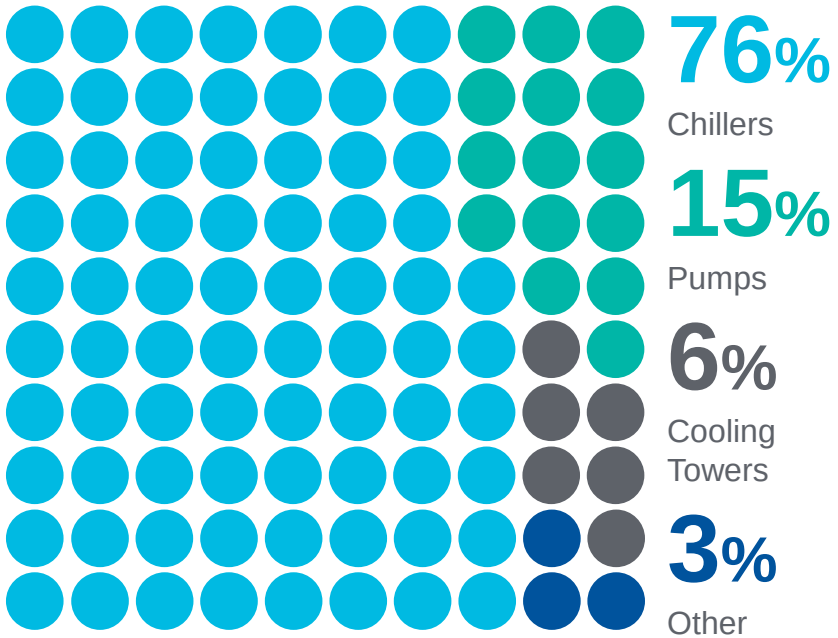


99% of chiller lifetime spend at off-design condition

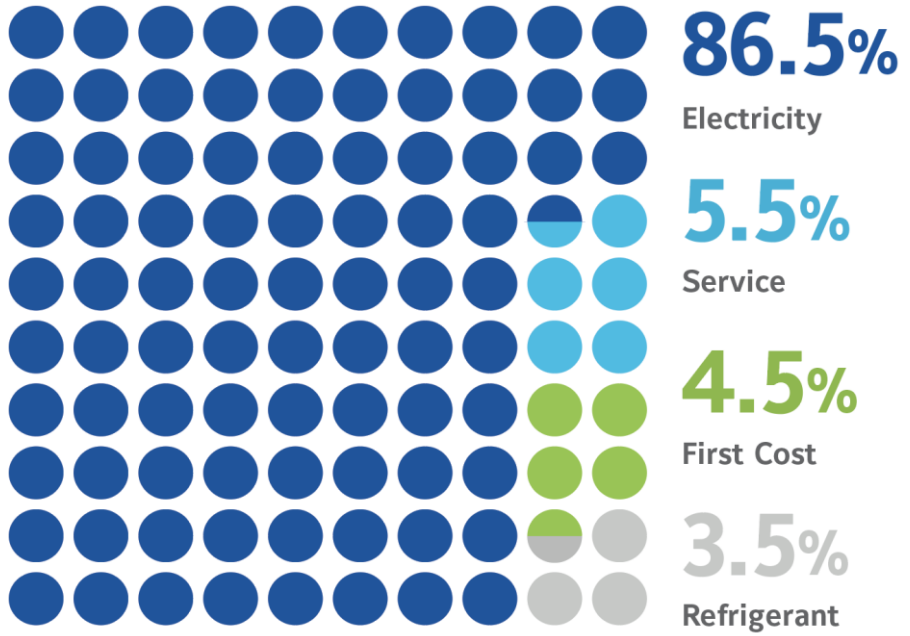
Why to focus Chiller?

- Chillers have the biggest impact
- Operational cost has become a major criterion

Total Chiller Plant Energy Use



Lifetime chiller cost



Solution for off-design chiller efficiency

Entering Cond water temp (°F)	% Input power saving with VSD Chiller compared over CSD chiller									
	100%	98%	96%	94%	92%	90%	88%	86%	84%	82%
95°	-3%	-2%	-2%	-2%	-1%	-1%	-2%	-1%	-2%	-1%
93°	-2%	-2%	-1%	-1%	0%	0%	-1%	-1%	0%	0%
91°	-1%	-1%	0%	0%	0%	1%	1%	1%	1%	1%
89°	-1%	0%	0%	1%	1%	2%	2%	2%	3%	2%
87°	0%	1%	1%	2%	2%	3%	3%	3%	4%	4%
85°	1%	2%	3%	3%	4%	4%	5%	5%	5%	5%
83°	3%	4%	4%	5%	5%	6%	6%	7%	7%	7%
81°	5%	5%	6%	6%	7%	7%	8%	8%	9%	9%
79°	6%	7%	7%	8%	9%	9%	10%	10%	11%	11%
77°	8%	8%	9%	10%	10%	11%	11%	12%	12%	13%
75°	9%	10%	11%	12%	13%	13%	14%	15%	15%	15%
73°	11%	12%	13%	13%	14%	15%	15%	16%	17%	17%
71°	13%	14%	15%	15%	16%	17%	18%	18%	19%	20%
69°	15%	16%	17%	17%	18%	19%	20%	20%	21%	22%
67°	17%	18%	19%	19%	20%	21%	22%	22%	23%	24%
65°	19%	19%	20%	21%	22%	23%	24%	24%	25%	26%
63°	20%	21%	22%	23%	24%	25%	26%	26%	27%	28%
61°	22%	22%	23%	24%	26%	27%	28%	29%	30%	31%

Typical operation

Typical % energy saving for Chiller with VSD

Real-world conditions – Search for solution – High load plant

Annual Specific Power Input

- How can an off-design conditions be taken into efficiency calculation?
- ASPI will help System designers accurately evaluate the performance of different equipment against each other

Capacity	ECWT in DegF	% hours in Year	Number of Hours in year	Performance of the Chiller
Design Point Load (Full Load)	95	10	876	A
	85	25	2190	B
	80	30	2628	C
	75	25	2190	D
	65	10	876	E

$$\text{Annual Specific Power Input (ASPI)} = \frac{A \times 876 + B \times 2190 + C \times 2628 + D \times 2190 + E \times 876}{8760}$$

Capacity	ECWT in DegF	% hours in Year	Number of Hours in year	Performance of the Chiller
80% Design Point Load	95	10	876	A
	85	25	2190	B
	80	30	2628	C
	75	25	2190	D
	65	10	876	E

$$\text{Annual Specific Power Input (ASPI)} = \frac{A \times 876 + B \times 2190 + C \times 2628 + D \times 2190 + E \times 876}{8760}$$

Case Study

Past & Present

- DC Plant snapshot
  - ✓ 7 - 1800TR Constant Speed MV Chillers
  - ✓ 7 - Constant Speed Primary Pump
  - ✓ 7 - Constant Speed Condenser Pump
  - ✓ 7 - Constant Speed Cooling Tower motor

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Past & Present

- DC Plant snapshot (Past)
  - ✓ 7 - 1800TR Constant Speed MV Chillers
  - ✓ 7 - Constant Speed Primary Pump
  - ✓ 7 - Constant Speed Condenser Pump
  - ✓ 7 - Constant Speed Cooling Tower motor
- DC Plant snapshot (Present)
  - ✓ 7 - 1800TR Variable Speed MV Chillers (1300 kW)
  - ✓ 7 - Variable Speed Primary Pump (45 kW)
  - ✓ 7 - Variable Speed Condenser Pump (110 kW)
  - ✓ 7 - Variable Speed Cooling Tower motor (75 kW)
  - ✓ Advanced Chiller Plant Optimization Programs

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Retrofit

- 1790TR centrifugal WC chiller – 1300kW (11kV) motor
- LV VSD’s on Primary, Condenser, CT motor
- Custom logic / advanced sequences in plant automation system
- Auto-Adaptive Process + Machine learning

PREDICTIVE COST-BASED OPTIMIZATION

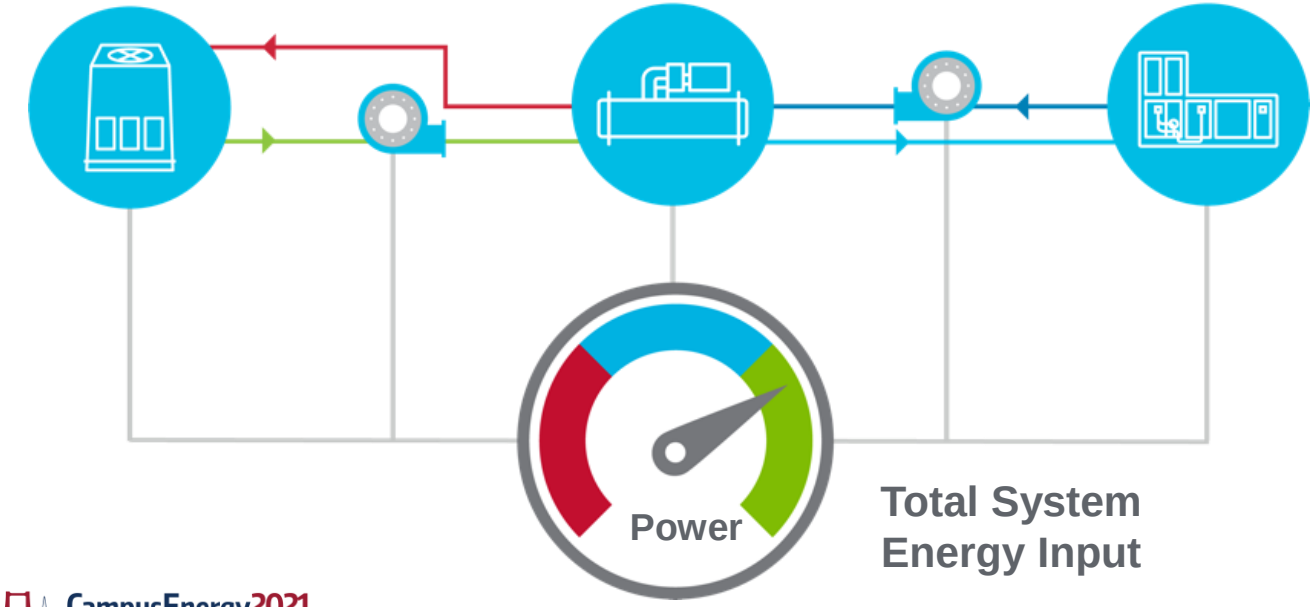
REVENUE GENERATION

RESILIENCY & RELIABILITY

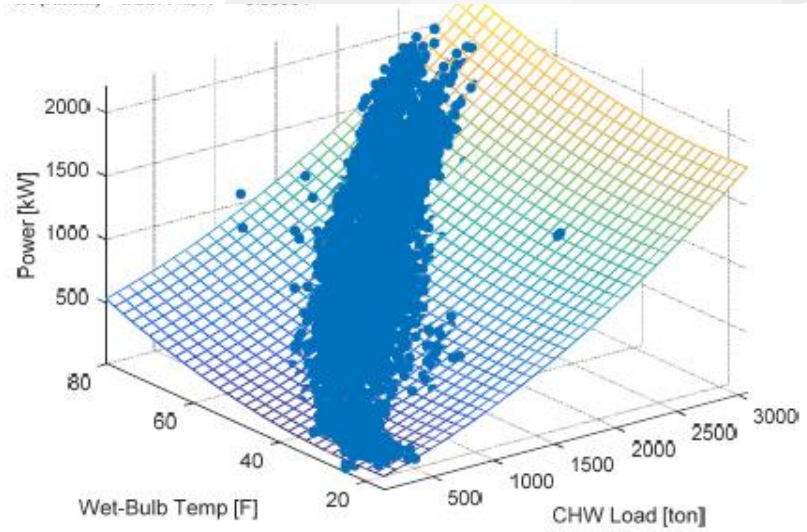
Retrofit - Truly minimizing utility cost

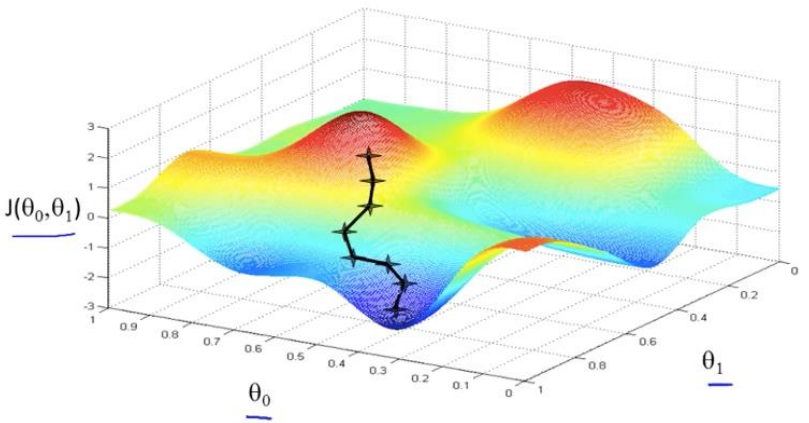
Total System Cooling Output

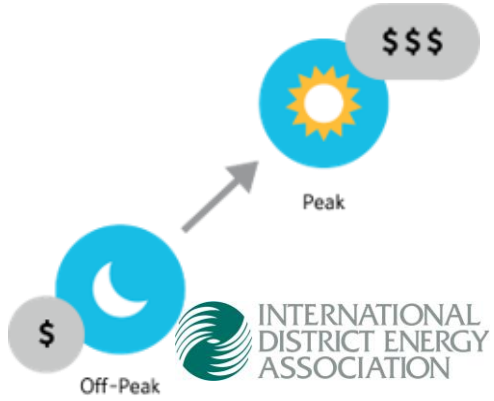
Cooling Tower Fan Speed | Condenser Pump Speed | Chiller Vane & Speed | Primary Pumps | Secondary Pumps



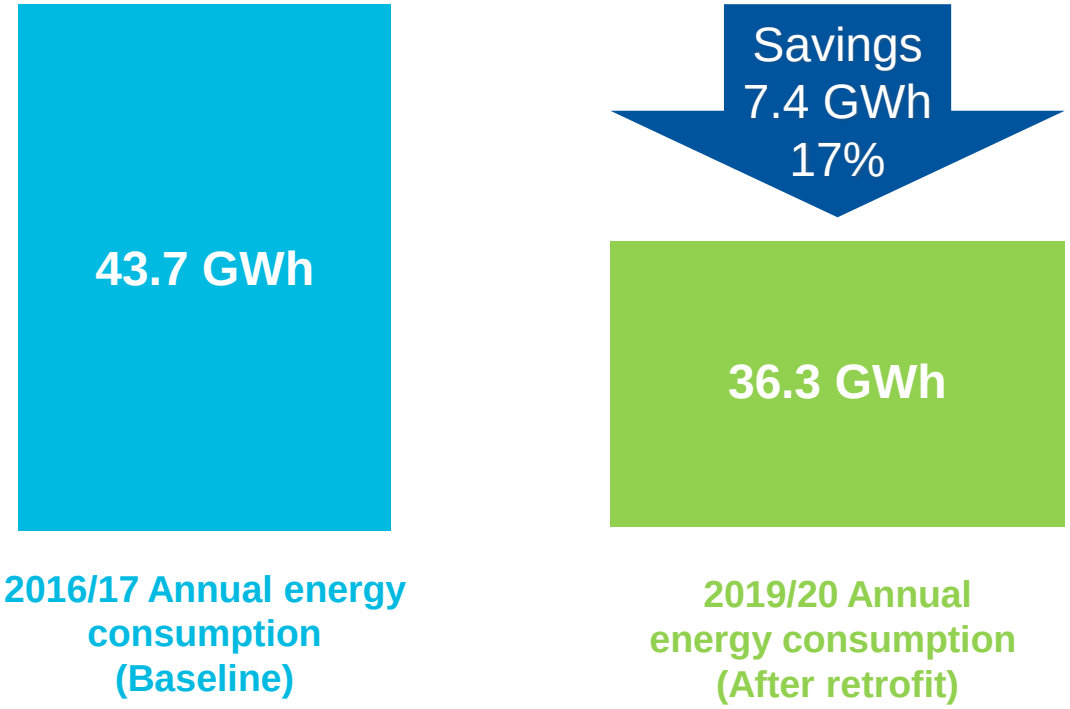
Total System Energy Input







Saving & Return on Investment - **Estimate**



2016/17 Annual energy consumption (Baseline)

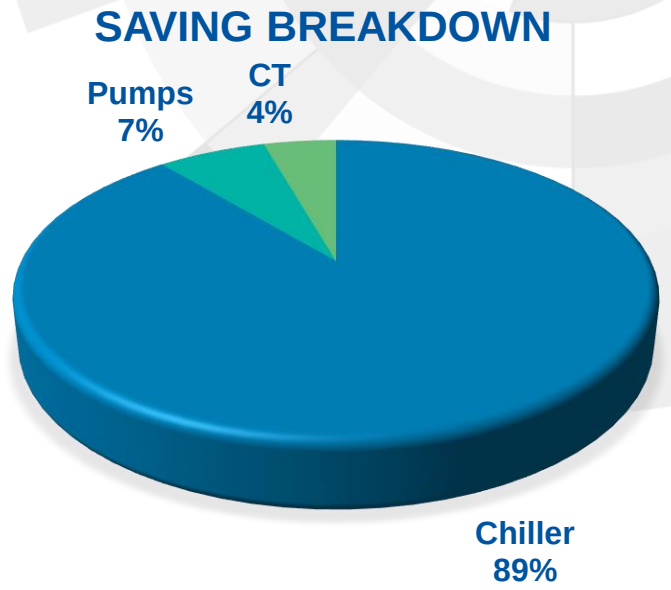
2019/20 Annual energy consumption (After retrofit)

Pay back: **3.7 Year**

Industry standard Measurement and verification program

Saving & Return on Investment - **Actual**

11.9 GWh Saving per year

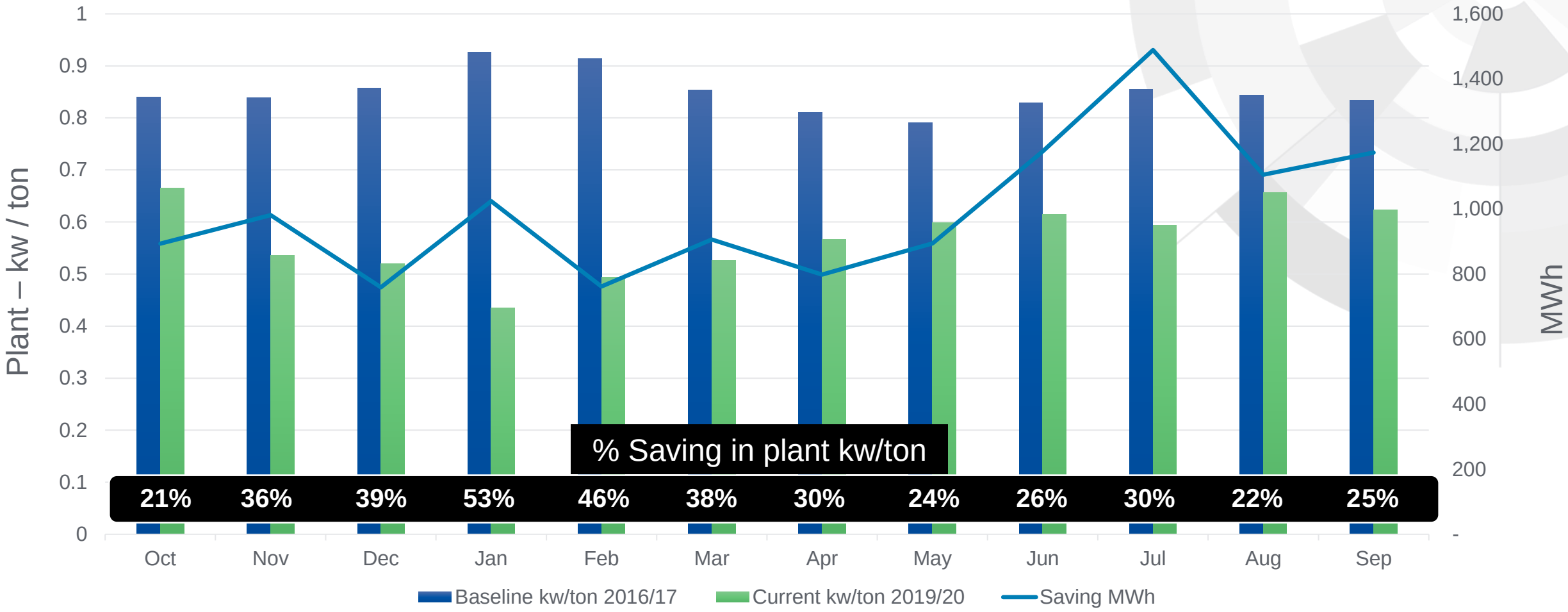


Retrofit

Pay back: 3.2 Year

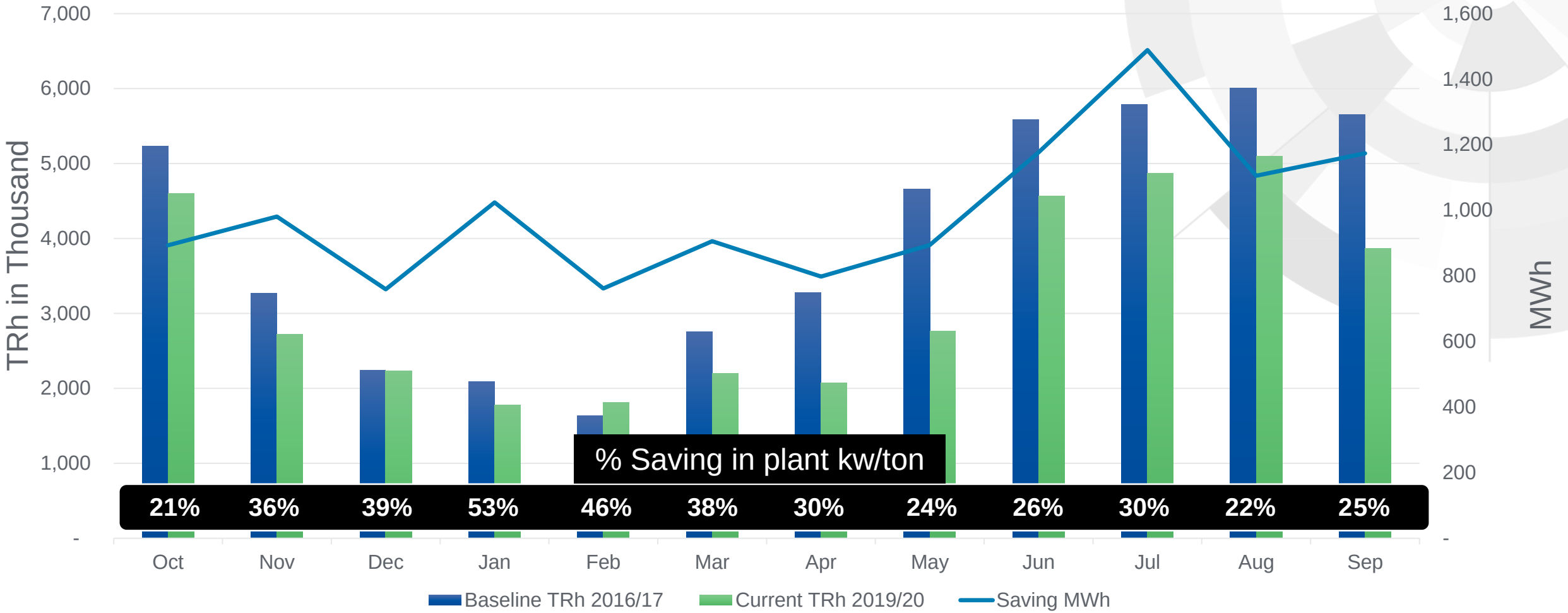
Can we see the data?

Year around comparisons – kw / ton & saving



Base Line estimation in 2016/17 and measurement & verification was done in 2019/20

Year around comparisons – Plant utilization & saving



Base Line estimation in 2016/17 and measurement & verification was done in 2019/20

Myth Busted !

- VSD chillers helps only in winter month
- Variable Speed Drives are expensive, with un-attractive payback
- Plant with Thermal Storage will be operating at design load.
- Chillers must be evaluated for Full Load Efficiency at “Design” Conditions

- VSD chillers reduces power consumption year around
- Latest VSDs are available with reduced cost & size. It’s viable for both retrofit & new projects
- Thermal Storage charging is at off-peak time i.e. lower WB temp – VSD will be more beneficial
- ASPI is critical parameter to evaluate chillers

Additional benefits of a VSD

- Improved and Constant **PF of 0.96**
  - Eliminates PF correction capacitors
- Eliminates **Inrush Current** (<100% FLA)
  - Enhances motor life
  - Reduces emergency power generator size (if required).
- Reduced **driveline wear**
- Reduced **sound level** at lower loads.
- Eliminates inefficiency of **over designing** due to safety.
  - Higher Condenser Water Temp
  - Higher Fouling

Future

- Evaluate plant with ASPI
- Design plant for real world efficiency not full load efficiency
- Reduce carbon footprint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