DARTMOUTH

European HW Technology-Installation Cost Analysis from Real Projects in North America

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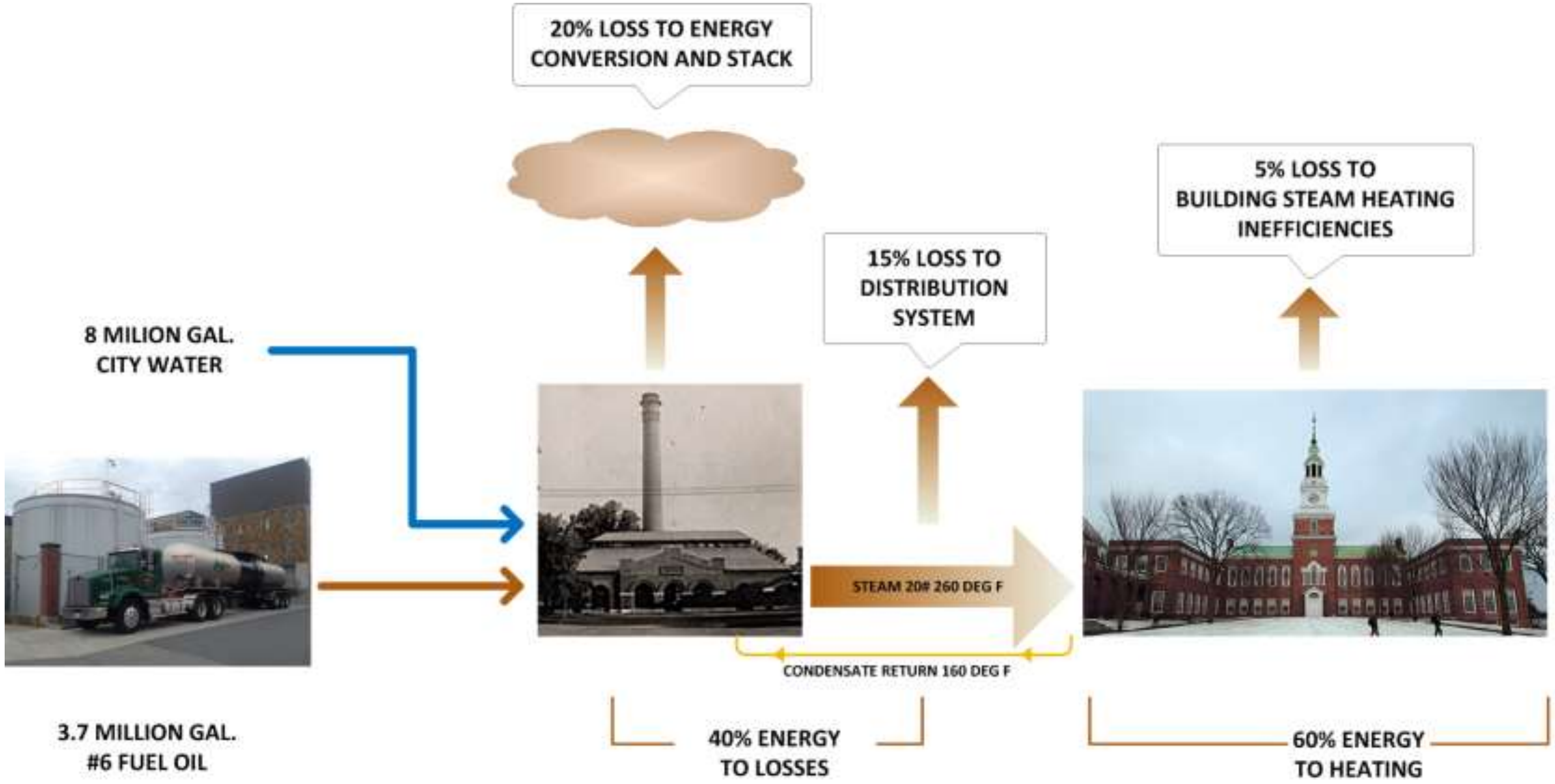
Dartmouth 2018 – Steam Heating Efficiencies



Steam System Limitations:

- No opportunity to supplement with alternative energy sources (geothermal, solar, heat pumps, etc.)
- Steam has to follow load directly (cannot store steam heat to reduce plant peak loads)

Steam Distribution System - Present State

Steam distribution system:
In need of renewal

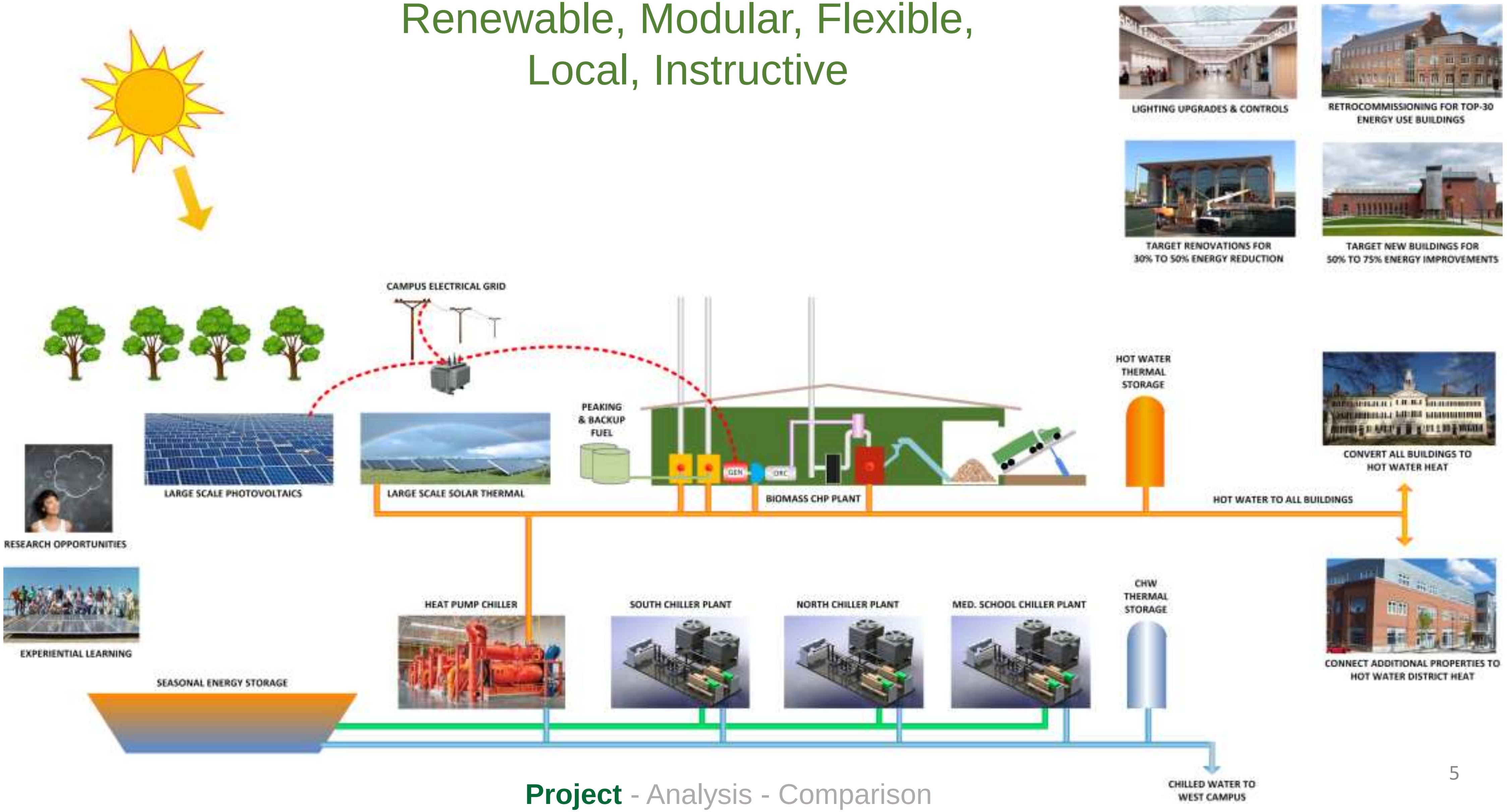
- Total steam & condensate piping: 5 miles
- 3,000 + steam traps
- Aging system: 20% > 65 yrs; 30% > 50 yrs.
- Renewal next 30 years - $61 Million

Considerations

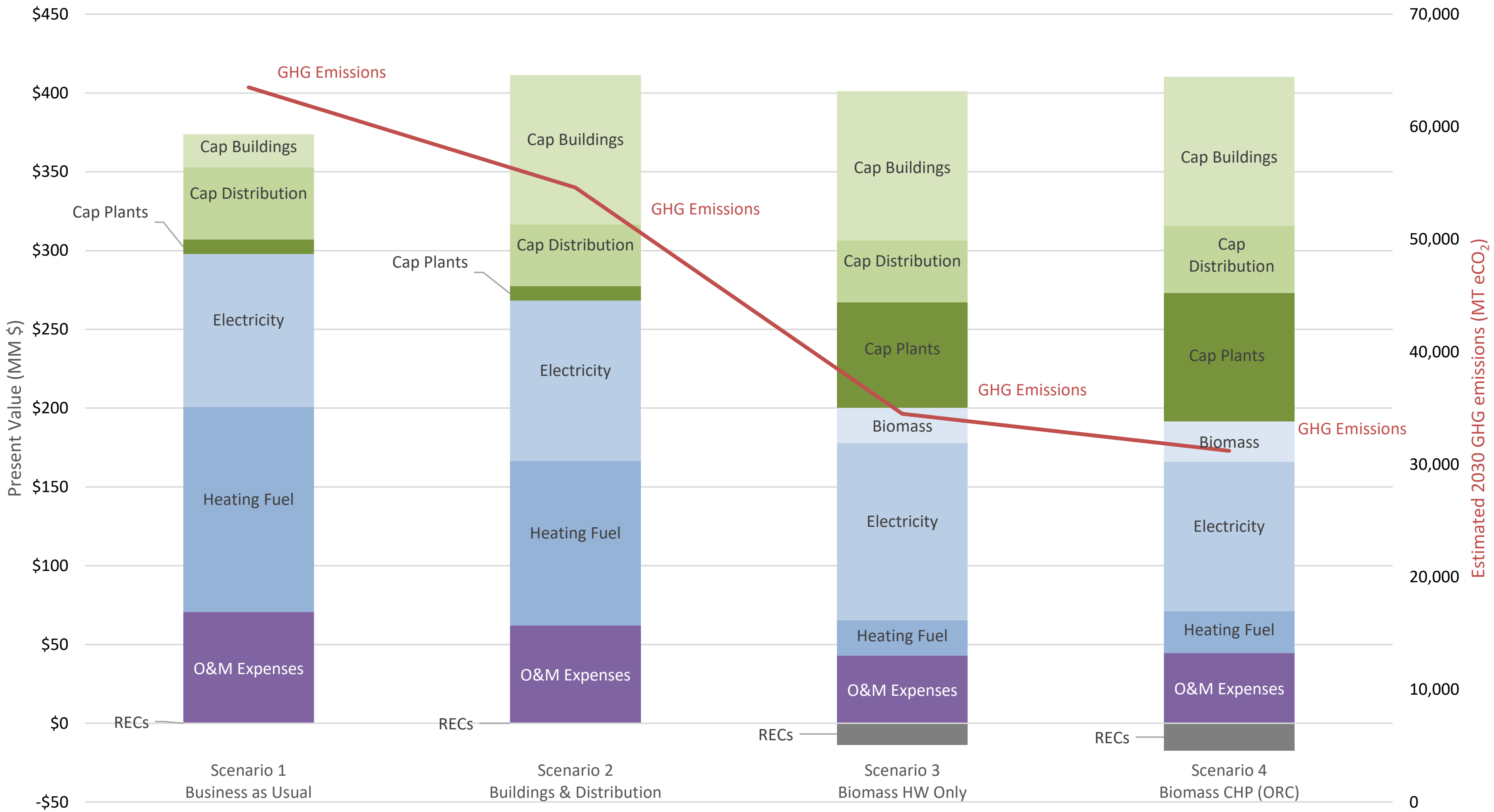
- Mitigate Risk
- Reduce energy/O&M expenditures
- Intelligently modernize and invest in energy infrastructure
- Re-establish Dartmouth as a Leader in Energy
- Provide experiential learning and research opportunities
- Convert to renewable energy
- Reduce greenhouse gas emissions
- Improve energy supply chain impact

Vision – Putting the Pieces Together

Renewable, Modular, Flexible, Local, Instructive



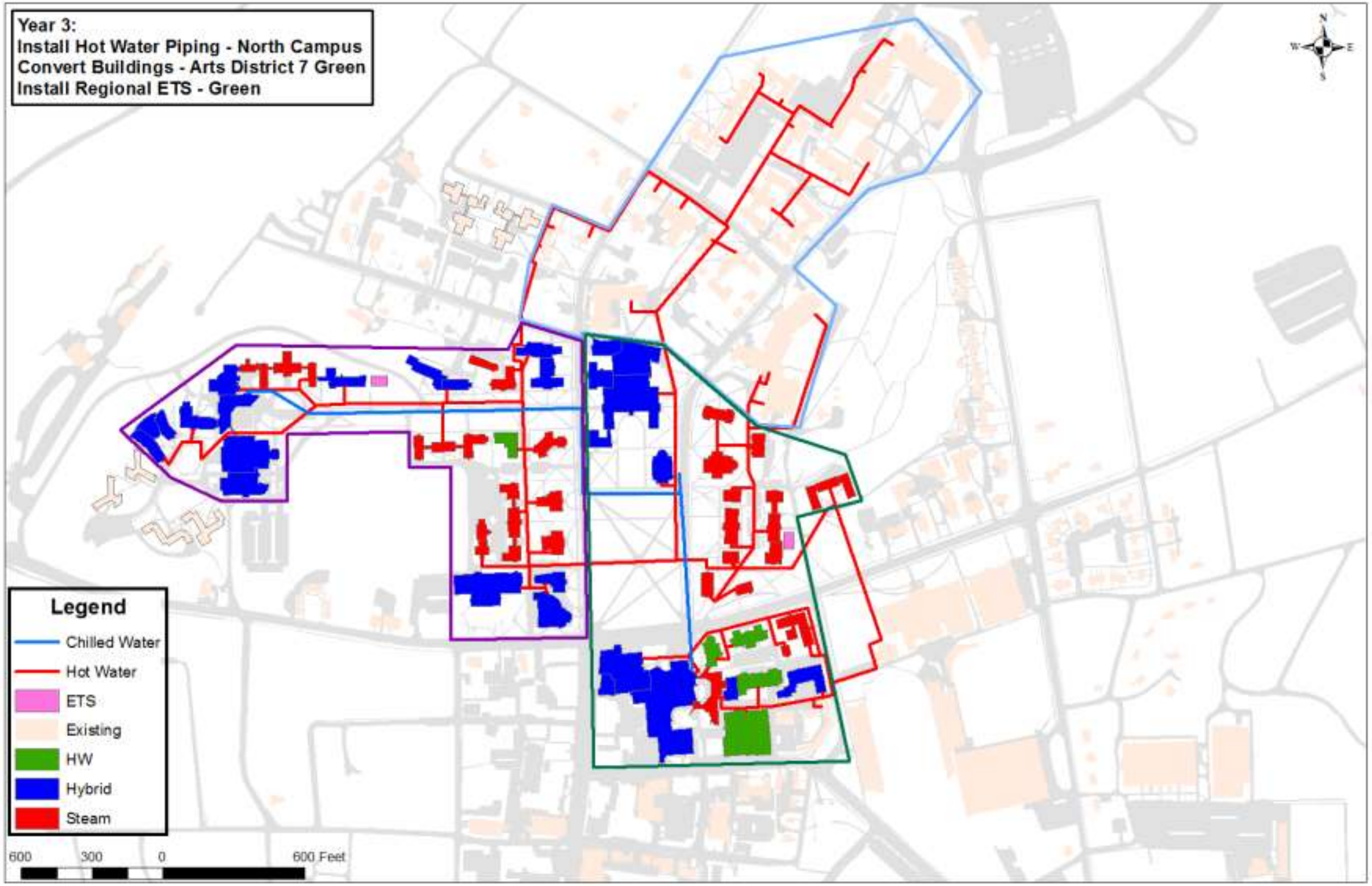
30 Year NPV & Projected GHG Emissions



Scenario Comparisons

	SCENARIO 1 Business as Usual	SCENARIO 2 Buildings & Distribution Only	SCENARIO 3 Biomass HW + Conversions	SCENARIO 4 Biomass CHP + Conversions
Capital Cost	Lowest	Medium	High	Highest
Construction Impact	Lowest	High	Highest	Highest
O&M Costs	High	Reduced	Lowest	Low
Fossil Fuel Burned	Most	Reduced	Lowest	Low
Energy Price Volatility	High	High	Low	Low
Energy Supply Chain Impact	Worst	Worst	Best	Best
Building Comfort	Low	High	High	High
System Efficiency	Low	Better	High	Highest
Carbon Footprint	High	Reduced	Low	Lowest

District Energy & Building Conversion Phasing



Dartmouth Campus pipe in ground estimates have significant variation in $/LF.

3 ESTIMATE SOURCES

EPCM

International Engineer's Estimate

NCM

National Construction Manager's Estimate

DESIGN BUILD

Local Underground Utility Design/ Builder's Estimate

ADDITIONAL COMPARISON PROJECT

LCM

10% Scope

Local Construction Manager's Estimate

ESTIMATE **RANGE** OF

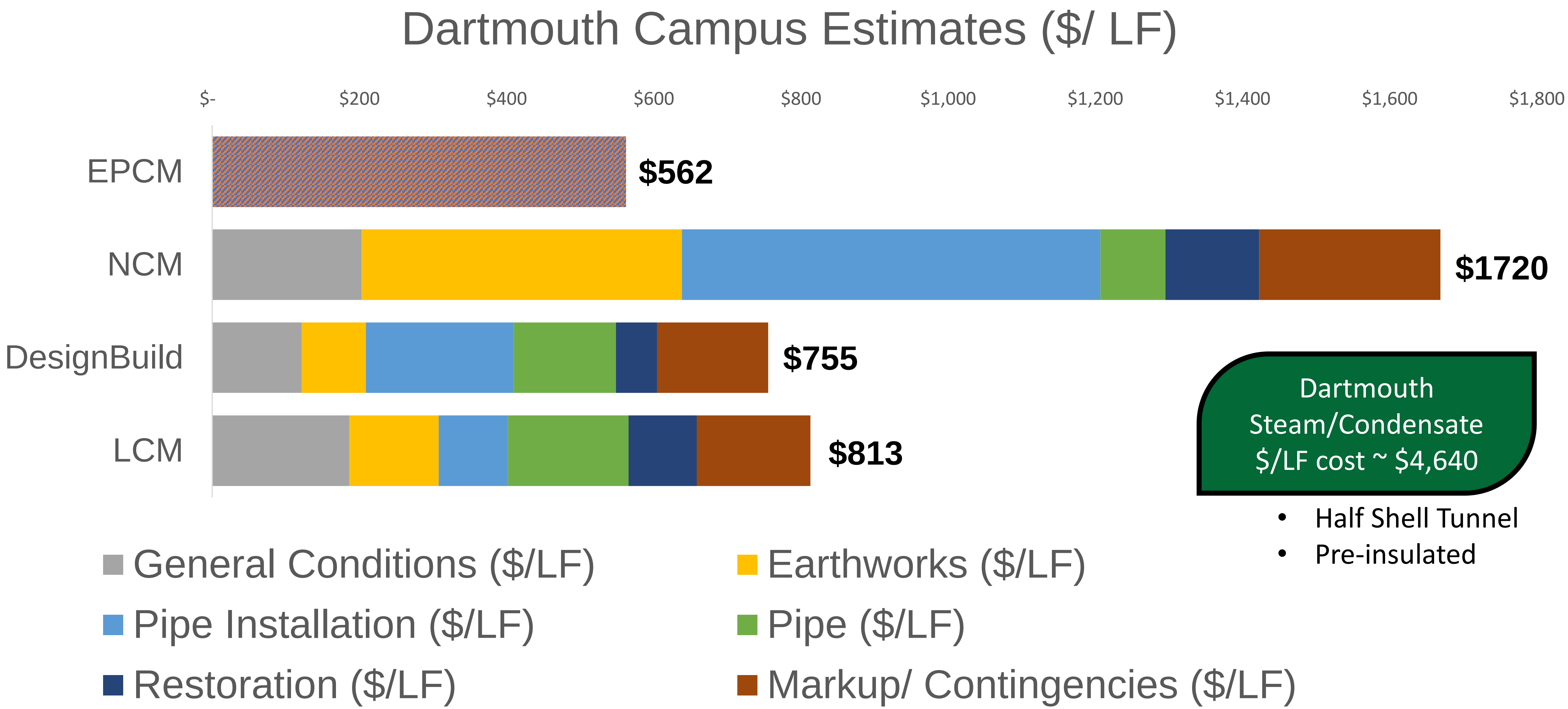
$562-$1720 PER LINEAR FOOT

Pertinent costs categories were selected to compare estimates.

GENERAL CONDITIONS	EARTHWORKS	PIPE INSTALLATION	PIPE MATERIAL	RESTORATION	MARKUP/ CONTINGENCY
• Design Assist • Construction overhead • Traffic Control	• Excavation • Shoring • Backfill • Labor/equip	• Pipe handling • Welding • Leak detection • Pipe Commissioning	• Supply and return pipe per LF	• Paving • Curbs • Hardscape • Softscape	• Typically 25%

- Excluded select items for apples to apples comparison

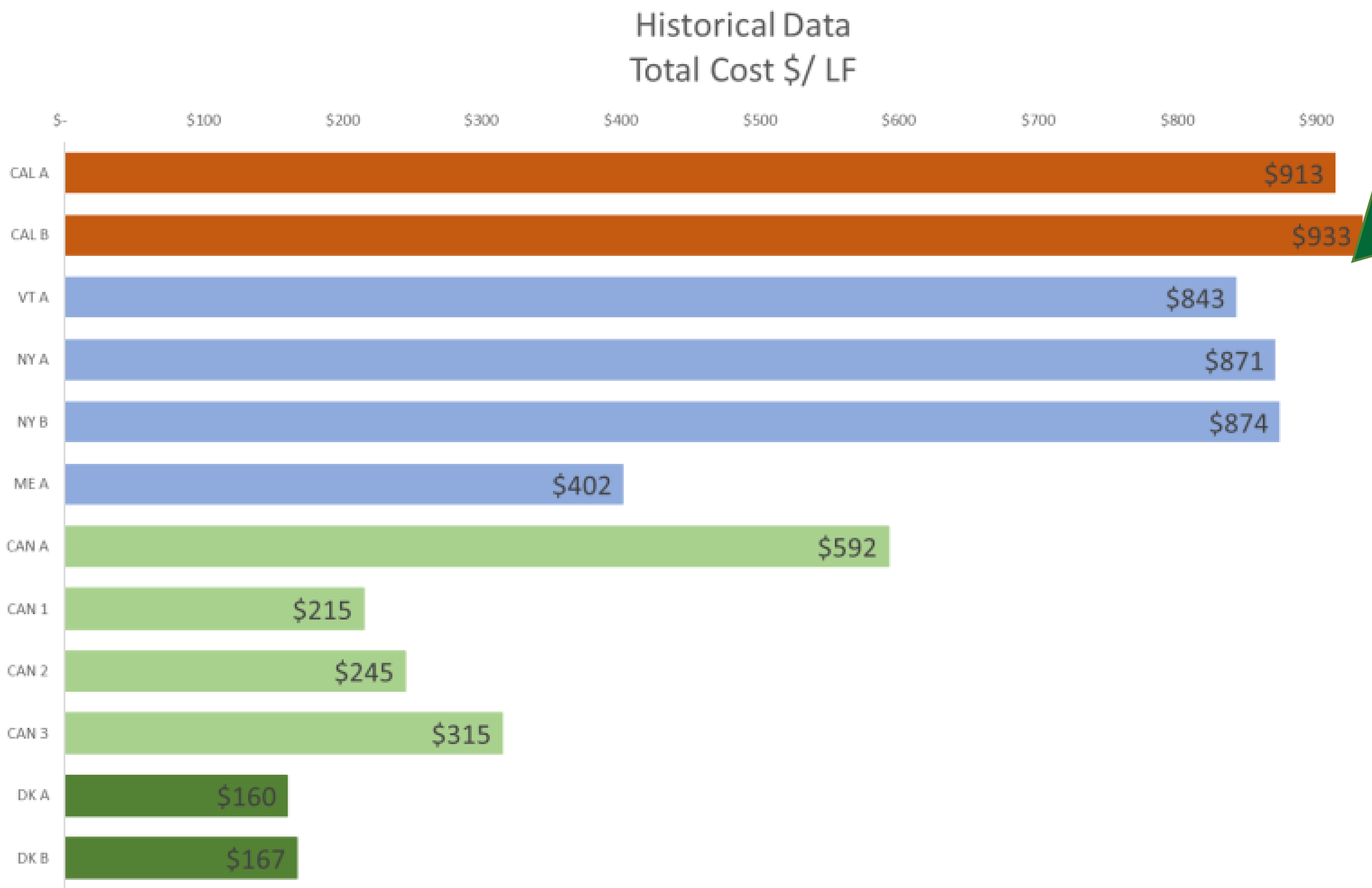
The NCM emerges as an outlier; remaining estimates need validation from real projects.



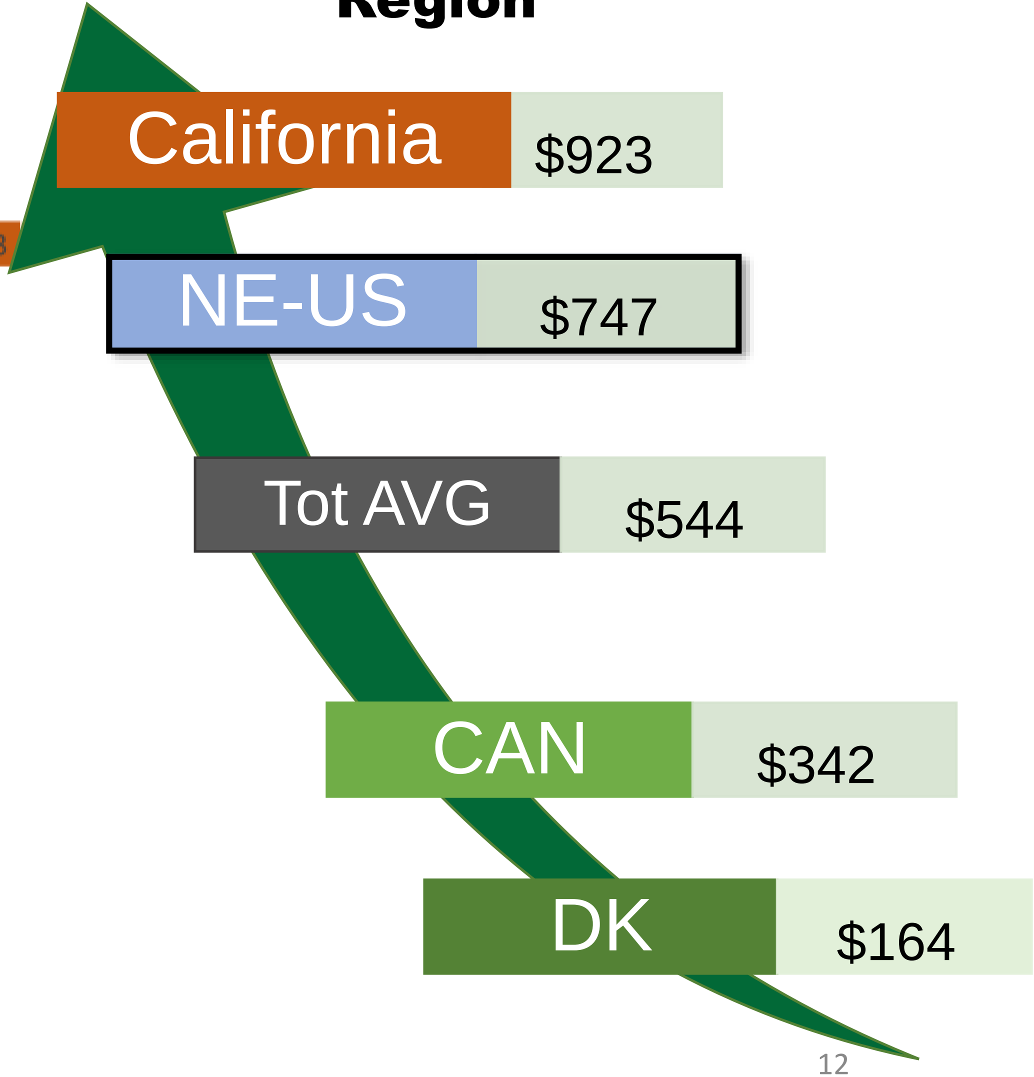
Dartmouth Steam/Condensate $/LF cost ~ $4,640

- Half Shell Tunnel
- Pre-insulated

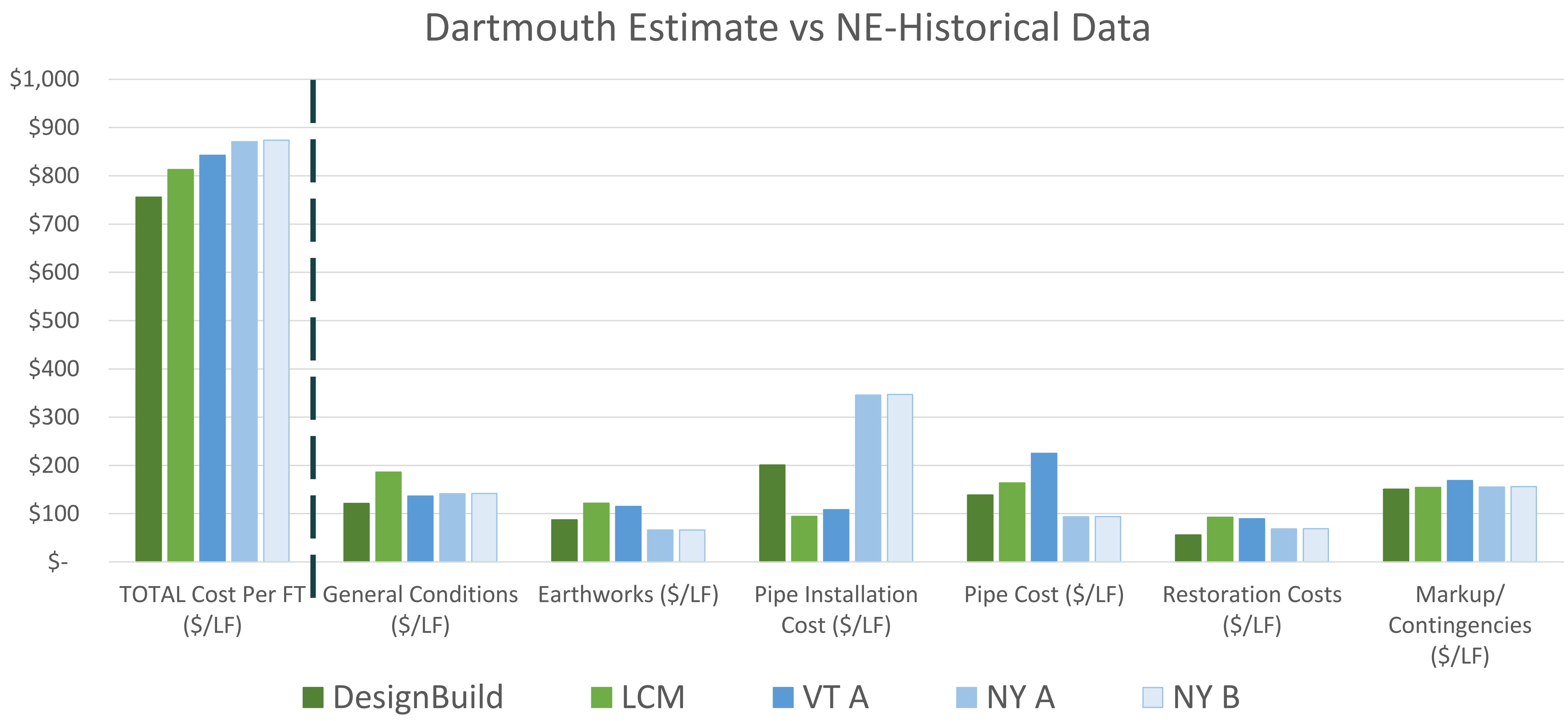
Cost data was collected from 12 European thin-wall HW projects, regional trends appear.



Historical Cost [$/LF] by Region

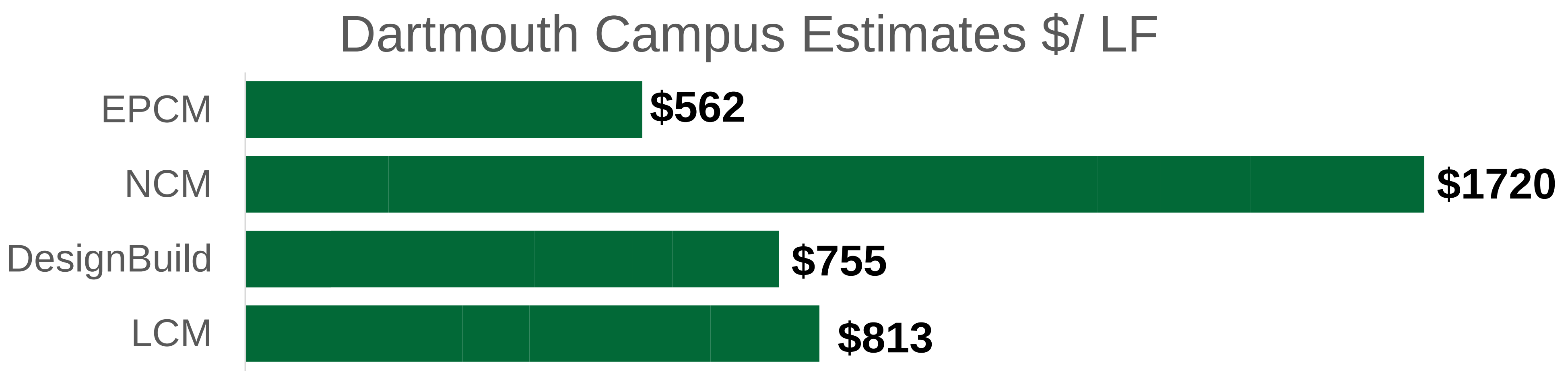


With the Dartmouth Estimates compared to NE-US projects, we can rationalize the two DB and LMC $/LF estimations.



Dartmouth Campus Estimate Conclusion

- NCM too high
- EPCM too low
- **LCM & DB Pricing Reasonable for Budgeting**



Assumes Status Quo

- US Fixed Price Model
- No productivity gains with contractor experience

Why are Danish and Canadian prices lower?

-79%

Danish Projects

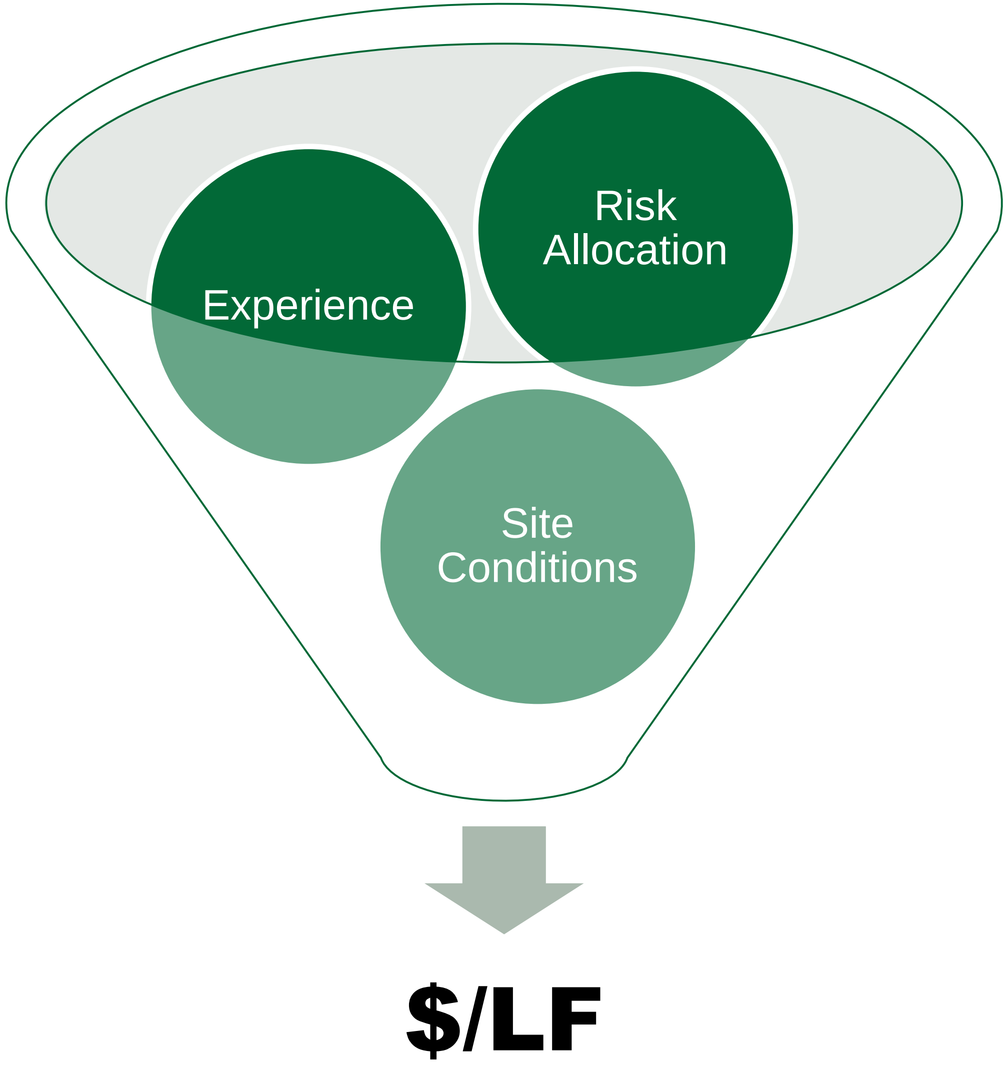
- 30 yrs Experience (Designer, Suppliers and Contractors)
- Procurement Method
  - Unit Pricing (Reduces Cost/ Transfers Risk to Owner)
- EN 13941 – Well defined design, construction, rigorous QA/QC process

-56%

Canadian Projects

- Adopted Danish Engineer Active Management Practices
  - Procurement Method
  - QA/QC Process
- Favorable Site Conditions

Conclusions



- In NE a budget of $800/LF is reasonable (no soft costs)
- Costs can be lowered further via Danish Experience
  - Unit Pricing/ Active Management of Project Cost by Engineer
  - Transfer of Risk to Owner
  - Experienced Contractors

Questions?

Backup Slides

Conclusions

- When estimating HW Pipe Installation Costs for Dartmouth's Campus the NCM too high, EPCM too low, and LCM/ DB Firms Just Right ($784 /LF) – *Assumes US Fixed Price Model*

- California Pricing **18%** Higher (Avg. $923 /LF) –Locational (Urban San Francisco)

- Danish Pricing **79%** Lower Due to Mature Market, Educated Contractors, Procurement Method (Avg. $164 /LF)

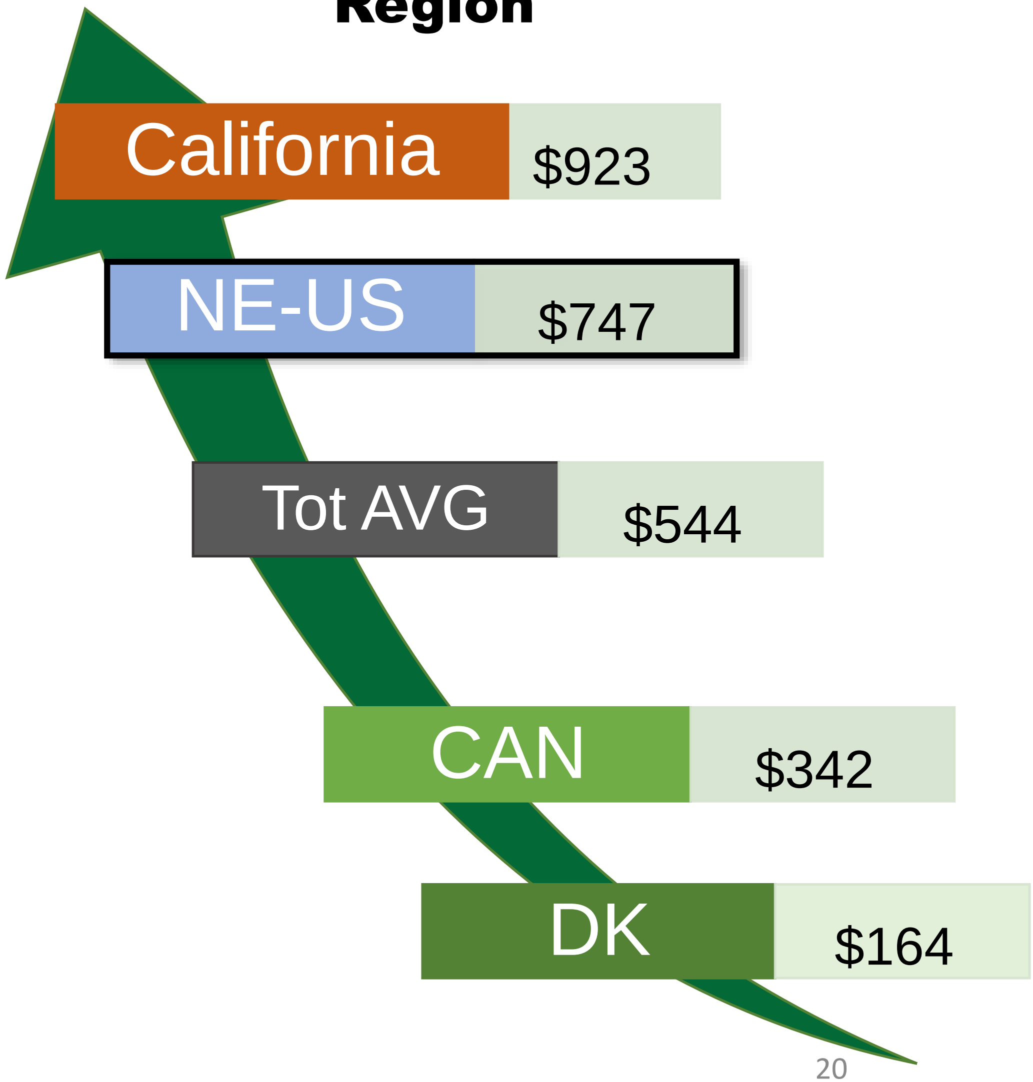
- Canadian Pricing **56%** Lower Due to Danish Procurement Method (Avg. $342 /LF)

- *Danish Procurement Process reduces cost by increasing owner's risk*

Cost data was collected from 12 European thin-wall HW projects, regional trends appear

Project	Year	Size (LF)	Contract Type	Data	Cost [$/LF]
VT A	2015	5050	Design Build-ISH	Cost/ Close out receipt	$ 843
NY A	2017	1043	Design Bid Build	Bid Data/ pipe cost	$ 871
NY B	2015	880	Design Bid Build	Summary/ pipe cost	$ 874
ME A	2016	6000	Unknown	LF Cost	$ 402
CAN A	2013	36000	Unknown	LF Cost	$ 592
CAN 1	2015	Unknown	Design Bid Build	LF Cost	$ 215
CAN 2	2016	Unknown	Design Bid Build	LF Cost	$ 245
CAN 3	2016	Unknown	Design Bid Build	LF Cost	$ 315
DK A	2016	6900	Design Bid Build	LF Cost	$ 160
DK B	2014	4700	Design Bid Build	LF Cost	$ 167
CAL A	2017	3100	Design Bid Build	Accepted Bid Data	$ 913
CAL B	2017	3300	Design Bid Build	Accepted Bid Data	$ 933

Historical Cost [$/LF] by Region



President Hanlon’s Sustainable Roadmap Energy Goals

- Improve the efficiency of our energy distribution system by 20% by 2030
- By 2025, obtain 50% of Dartmouth’s energy supply from renewables
- By 2050, obtain 100% of Dartmouth’s energy supply from renewables
- A 50% greenhouse gas (GHG) emissions reduction by 2025 with no offsets, using a 2010 baseline
- An 80% GHG reduction by 2050 with no offsets, using a 2010 baseline

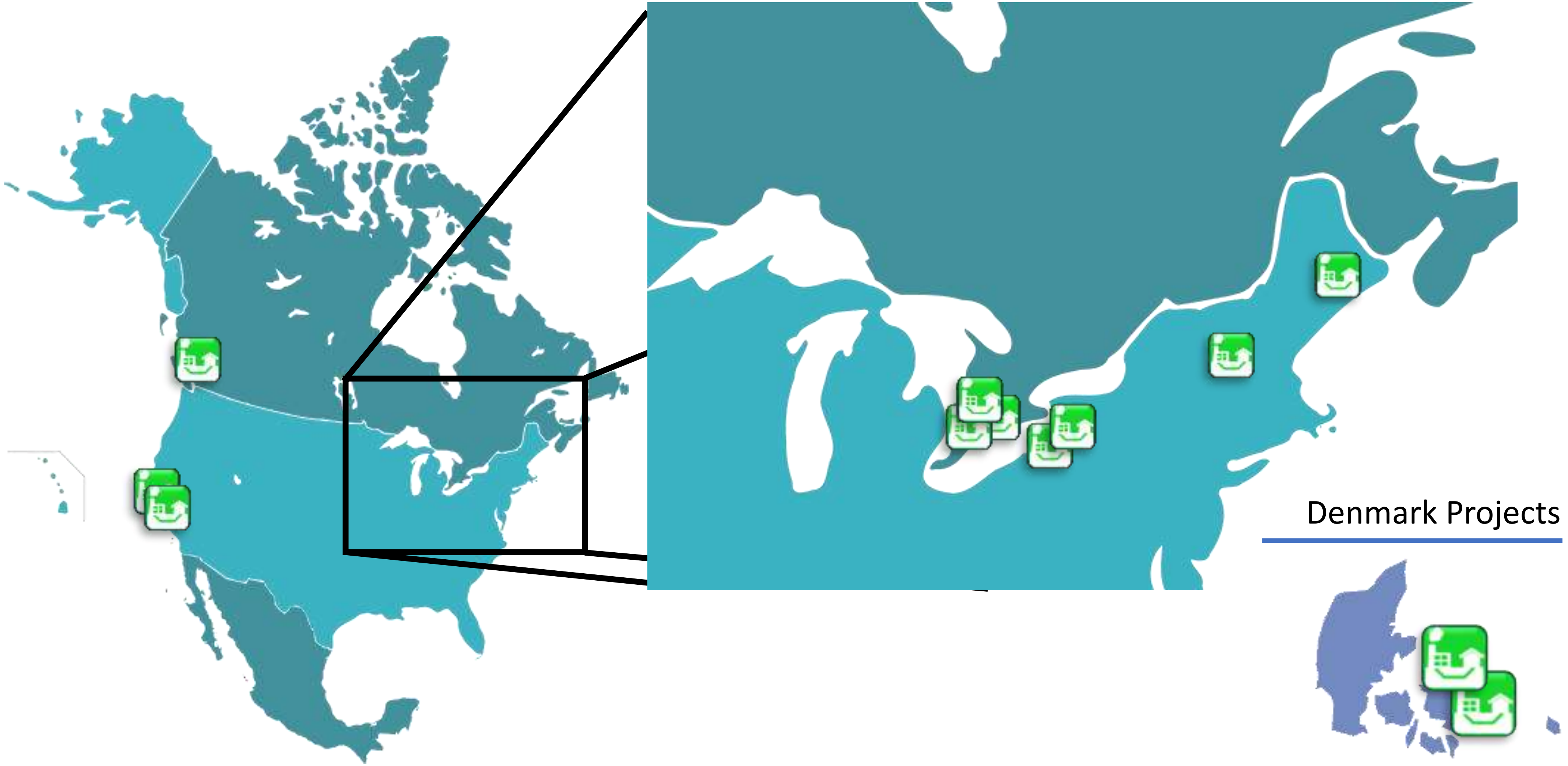
Town of Hanover Sustainable Energy Goals

- Transition to 100% renewable electricity by 2030
- Transition to 100% renewable energy for heat and transportation by 2050

Danish bid procurement practices may explain the price discount in Danish and Canadian projects.

2		**PIPE DELIVERY - North of the Hood Museum**				
		Series 2				
		Straight pipe - 12 m				
	01	(5") ø139,7/250	2	Qty.		0.00
	02	(6") ø168,3/280	8	Qty.		0.00
	03	(8") ø219,1/355	2	Qty.		0.00
		90° Pre-insulated bends - 1000 x 1000 mm				
	11	(5") ø139,7/250	2	Qty.		0.00
	12	(6") ø168,3/280	4	Qty.		0.00
		80° Pre-insulated bends - 1000 x 1000 mm				
	14	(8") ø219,1/355	2	Qty.		0.00
		Pre-insulated redutions - 1100 mm				
	15	(8") ø219,1/355 - (6") ø168,3/280	2	Qty.		0.00
		90° pre-insulated parallel branche				
	16	(8") ø219,1/355 - (5") ø139,7/250 - (8") ø219,1/355	2	Qty.		0.00
		BX casing joint				
	21	(5") ø139,7/250	6	Qty.		0.00
	22	(6") ø168,3/280	14	Qty.		0.00
	23	(8") ø219,1/355	8	Qty.		0.00
		End fitting incl. Weld-on end				
	31	(5") ø139,7/250	2	Qty.		0.00
	32	(8") ø219,1/355	2	Qty.		0.00
		Endcap				
	42	(6") ø168,3/280	2	Qty.		0.00
	51	**Foam Pads** - Size - 1000 x 2000 mm	20	Qty.		0.00
	61	**Warning net** - Size - 0,50 x 100 m	2	Qty.		0.00
		Sum of item 1 transferred to summary page		**USD**		**0.00**

Collected cost data for 12 Installed European thin-wall District HW projects; figures came in varying qualities and types.



When broken down to the $/LF measurement we see significant variation. Continued…