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AUSTRALIA

The Case for Transcritical Cold Storage in Australia

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Cold Storage in Australia

As of 2013:

- Small Cool Rooms – 65,700 units
- Medium Cool Rooms – 20,200 units
- Large Cool Rooms – 12,200 units
- Industrial Cold Storage – 13.05 Million m^3

Common Refrigerants Used

- Small and Medium Cool Rooms ← Generally Synthetic Refrigerant Systems
- Large Cool Rooms ← Synthetic Refrigerant, Ammonia
- Industrial Cold Storage ← Ammonia, Synthetic Refrigerant

As HFC Refrigerant is phased down, how do end users negotiate their options?

‘Traditional’ Cold Storage Refrigerant Options

Ammonia (R717) – 150kW +

- Overfeed
- Flooded
- Low Charge DX

Synthetic Refrigerant

- DX
- Cascade

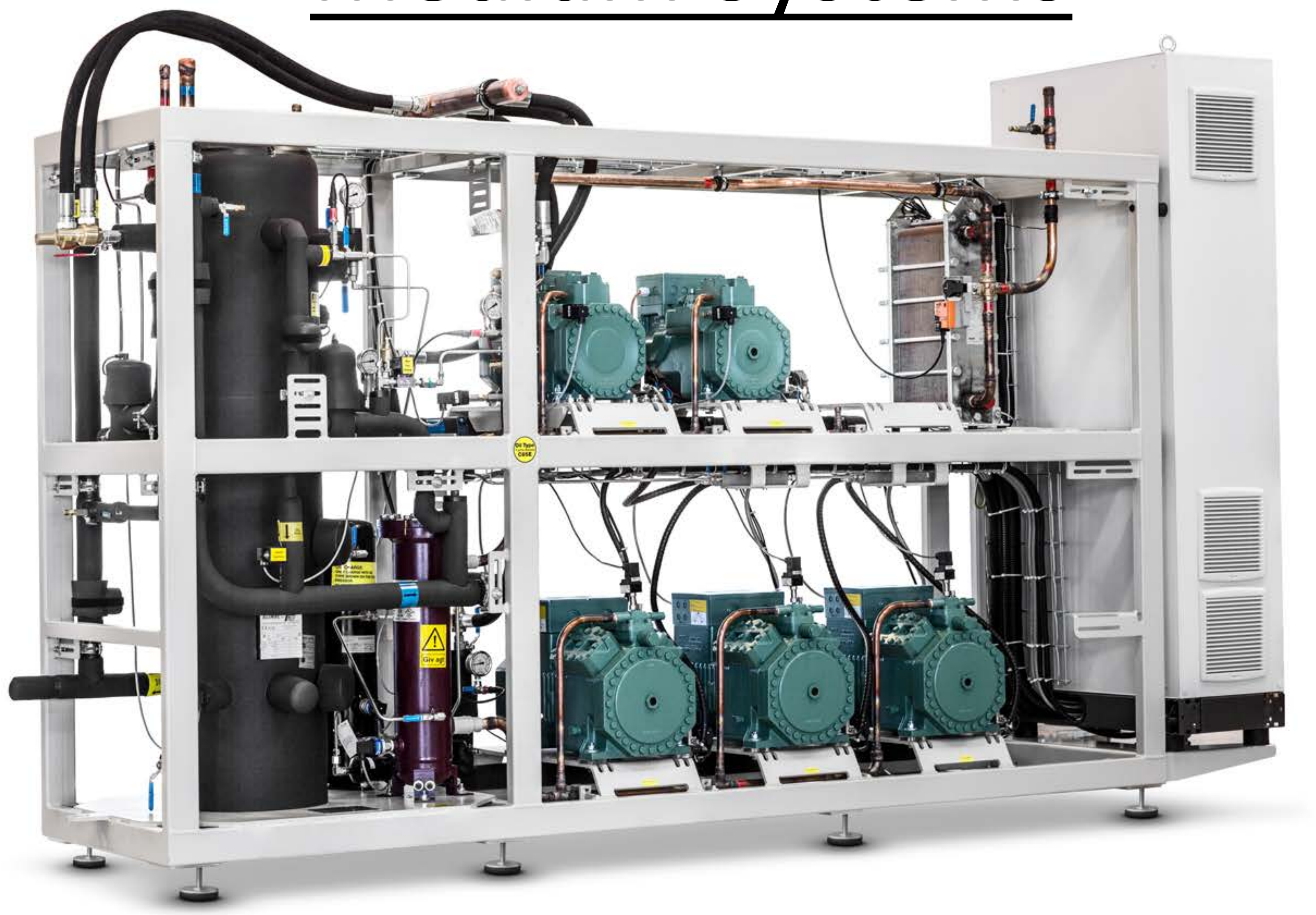
Opportunities for CO2

CO_2 Transcritical Systems are:

- Proven Technology (Thousands of Systems Operational Worldwide)
- Proven IN Australia

Large Systems

Medium Systems



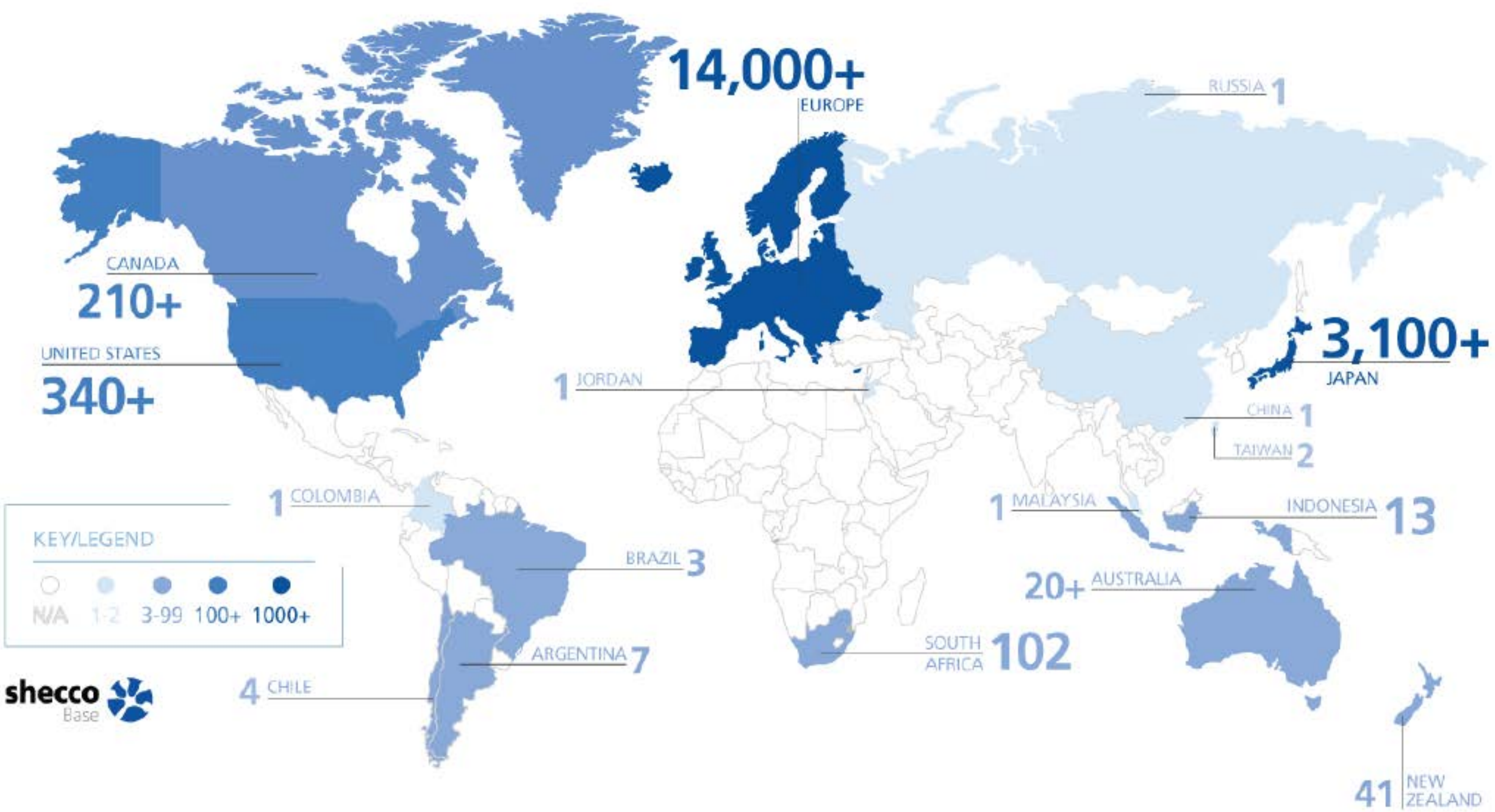
Small Systems

Transcritical CO_2: Current Market

- Majority Supermarket Systems
- Small Scale Condensing Units

- Number of Larger Systems Growing

CO_2 transcritical stores in the world



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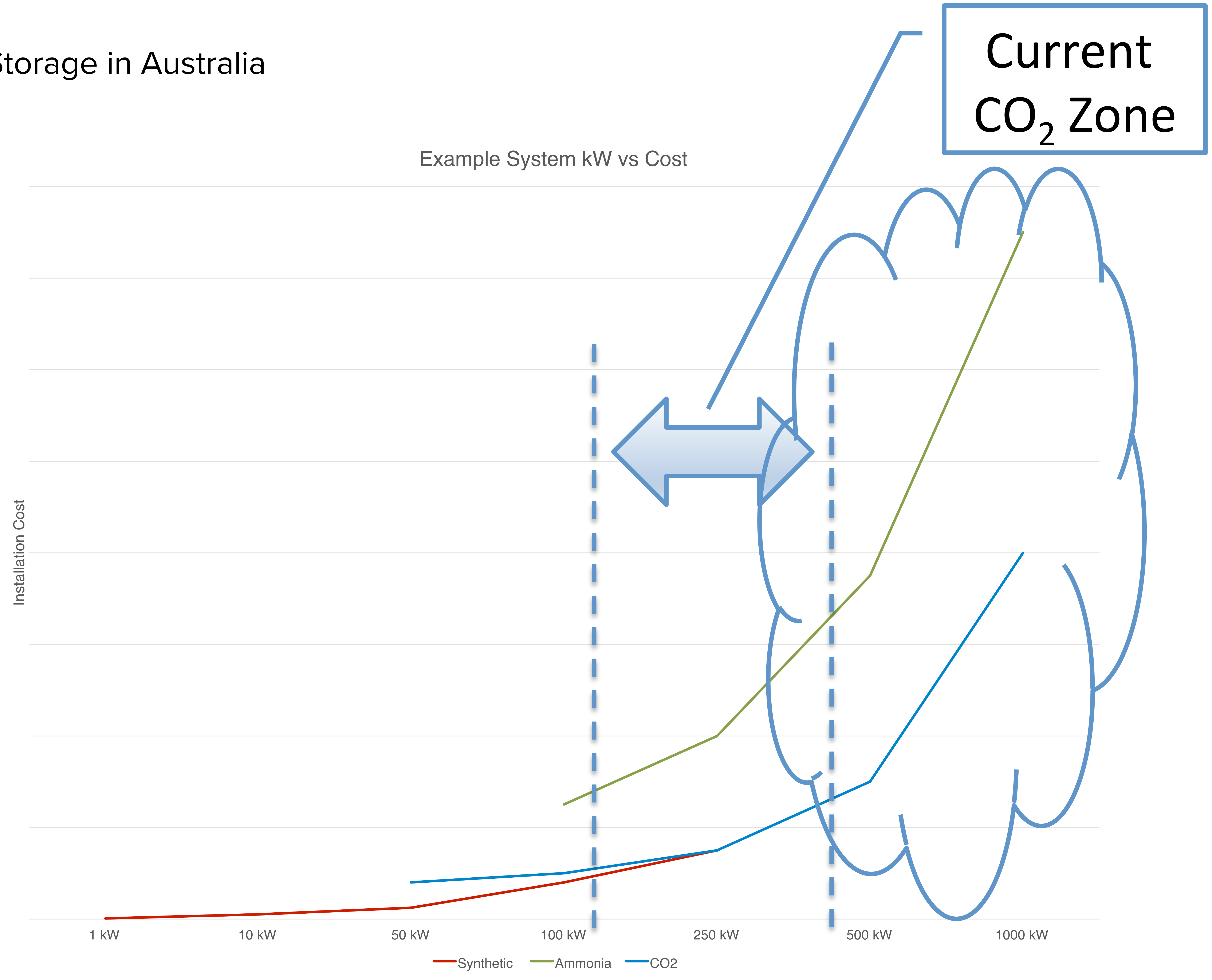
Future Growth for CO_2

<u>Smaller Systems will become more competitive:</u>

- Equipment & Components more economical
- HFC Phase-Down

<u>Larger Systems will be based on:</u>

- Individual System Requirements
- Business Cases & Return on Investment (ROI)



Benchmarking in Refrigeration

<u>Specific Energy Consumption</u>

- Normalizing the Energy Consumption of a refrigeration system with specific criteria

<u>Specific Cost</u>

- Normalizing the First or Lifecycle Costs of a refrigeration system with specific criteria

Using Benchmarking in Refrigeration can:

- Allow for End Users to know ‘where they sit’ in terms of energy consumption / performance
- Presents a better comparison of energy efficient (& Natural Refrigerant) equipment vs. cheaper alternatives
- Enable more confident decision-making for Contractors & End Users
- Enable Lower Global CO_2 Emissions

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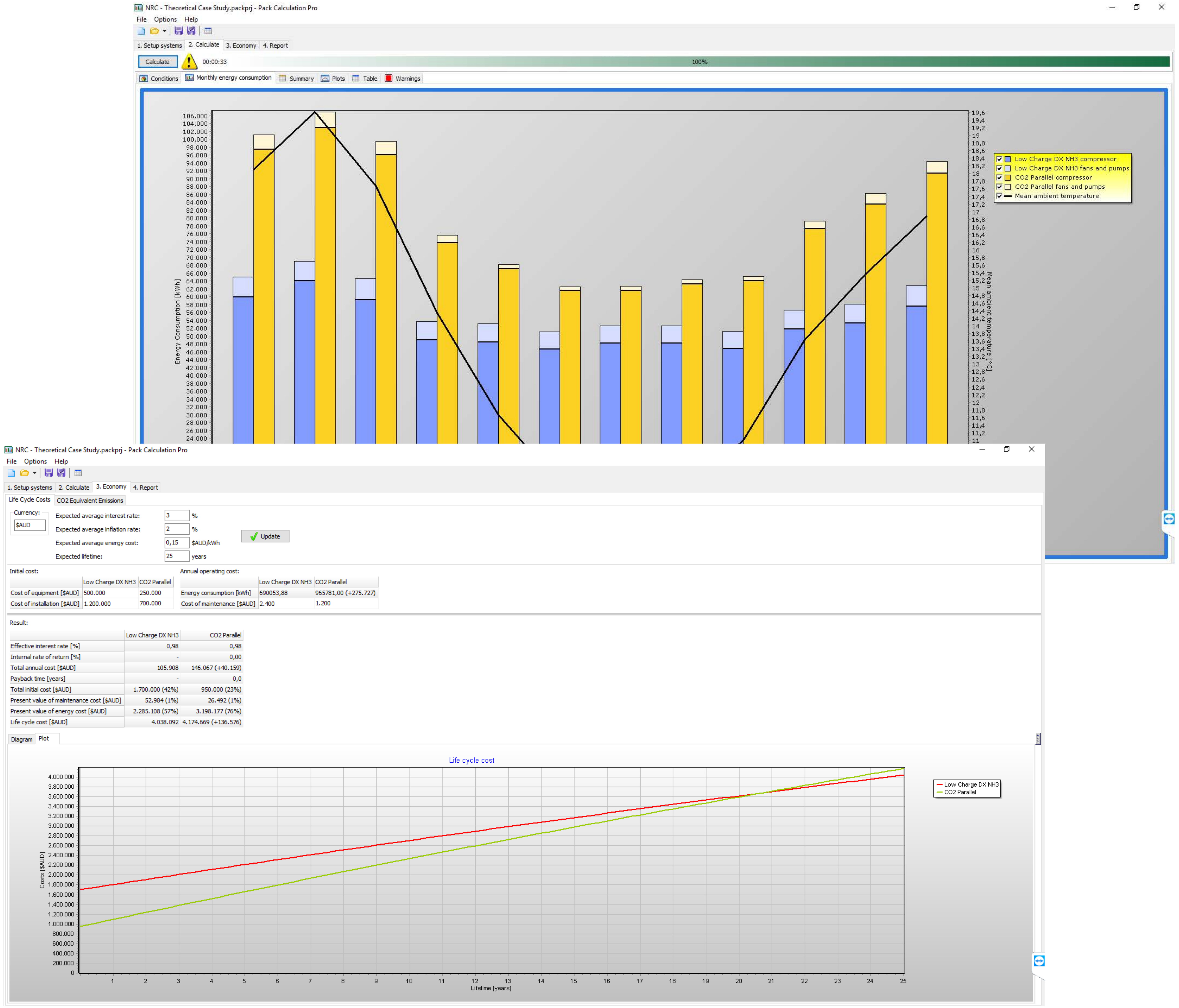
Existing Tools to Estimate Specific Energy Consumption

Pack Calc Pro

- Can be very accurate if used properly
- G.I.G.O

MS Excel

- Basic Calculations can be done simply in MS Excel or other spreadsheet software



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Lifecycle Cost Analysis

Example Site:

- Seafood Cold Storage & Distribution Facility
- Melbourne, VIC
- Loads:
- LT = 170 kW @ -30°C SST
- MT = 60 kW @ -6°C SST

- Transcritical CO_2 System
- Parallel Compression
- Electric Defrost
- Electric Floor Heating

Commissioned Nov. 2017

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Cold Storage Refrigeration Systems

We can compare systems in cold storage distribution centres. These types of warehouses generally have similar degrees of % refrigeration power consumption vs Total building power consumption.

Transcritical CO_2 (R744)

- DX MT & LT
- Parallel Compression
- Electric Defrost
- Electric Floor Heating

Direct Expansion NH_3 (R717)

- DX MT & LT
- Low-Charge
- Hot Gas Defrost
- Waste Heat Glycol Floor Heating

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Lifecycle Cost Analysis

Pack Calc Comparison:

- Melbourne, VIC
- LT = 170 kW @ -30°C SST
- MT = 60 kW @ -6°C SST

System 1

- Transcritical CO_2 System
- Parallel Compression
- Actual Equipment Installed was used in Simulation
- Simulation estimates confirmed with actual meter data (Systems Commissioned Nov. 2017, 4x Months Data Collected)
- Actual System Installation Cost Used in Economic Analysis

System 2

- Direct Expansion NH_3
- 2 – Stage
- 2x Variable Speed Recip. Type NH3 Compressors of Equivalent Total MT Capacity Used in the Simulation
- 2x Variable Speed Recip. Type NH3 Compressors of Equivalent Total LT Capacity Used in the Simulation
- Average & Below Average First Cost / kW Refrigeration of Actual Australian DX NH3 Installations were used to Estimate an Average and 'Below Average' Installation Costs to use in th Economic Analysis

Specific Energy Consumption – Based on Cold Storage Volume

(kWh/yr) / m^3 of Cold Storage Volume

Refrigerant	Site No.	Annual Energy Consumption (kWh/Yr)	Total Refrigerated Volume (m3)	Specific Energy Consumption (Based on Volume) (kWh/Yr/m3)
NH3	1	1226016	43289	28.3
NH3	2	409597	9474	43.2
NH3	3	697339	31344	22.2
NH3	4	1098390	42619	25.8
NH3	8	1168479.9	60543	19.3
CO2	1	449316	9264	48.5
Exp. NH3	1	264406.8	9264	28.5

Pros:

- Simple to Calculate
- Easy to Understand

Cons:

- Does Not take into account …
- Load Type
- System Cost(s)
- Ambient Conditions

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Specific Energy Consumption – Based on Refrigeration Capacity/Load Type

(kWh/yr) / kW Refrigeration Capacity

Refrigerant	Site No.	Annual Energy Consumption (kWh/Yr)	LT Capacity (kW)	MT Capacity (kW)	Total Capacity (kW)	Specific Energy Consumption (Based on Total Capacity) (kWh/Yr / Tot. kWr)
NH3	1	1226016	173.8	228.4	402.2	3048.3
NH3	2	409597	43.2	83.1	126.3	3243.0
NH3	3	697339	130.4	112.9	243.3	2866.2
NH3	4	1098390	175.5	139.3	314.8	3489.2
NH3	8	1168479.9	194.8	313	507.8	2301.1
CO2	1	449316	170	60	230	1953.5

Pros:

- Simple to Calculate
- Accounts for System Load Profile

Cons:

- Capacity harder to visualize than Volume
- Does Not take into account …
- System Cost(s)
- Ambient Conditions

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Specific Cost – Based on Refrigeration Capacity

$ First Cost / kW Refrigeration

Refrigerant	Site No.	Annual Energy Consumption (kWh/Yr)	LT Capacity (kW)	MT Capacity (kW)	Total Capacity (kW)	Specific First Cost (Based on kW Capacity) ($FC / (Total kWr))
NH3	1	1226016	173.8	228.4	402.2	$ 3,356.54
NH3	2	409597	43.2	83.1	126.3	$ 5,621.54
NH3	3	697339	130.4	112.9	243.3	$ 5,343.20
NH3	4	1098390	175.5	139.3	314.8	$ 4,542.57
NH3	8	1168479.9	194.8	313	507.8	$ 3,426.55
CO2	1	449316	170	60	230	$ 2,608.70

Pros:

- Easy to Calculate
- Easy to Understand

Cons:

- Does Not take into account …
- Energy Performance
- Ambient Conditions

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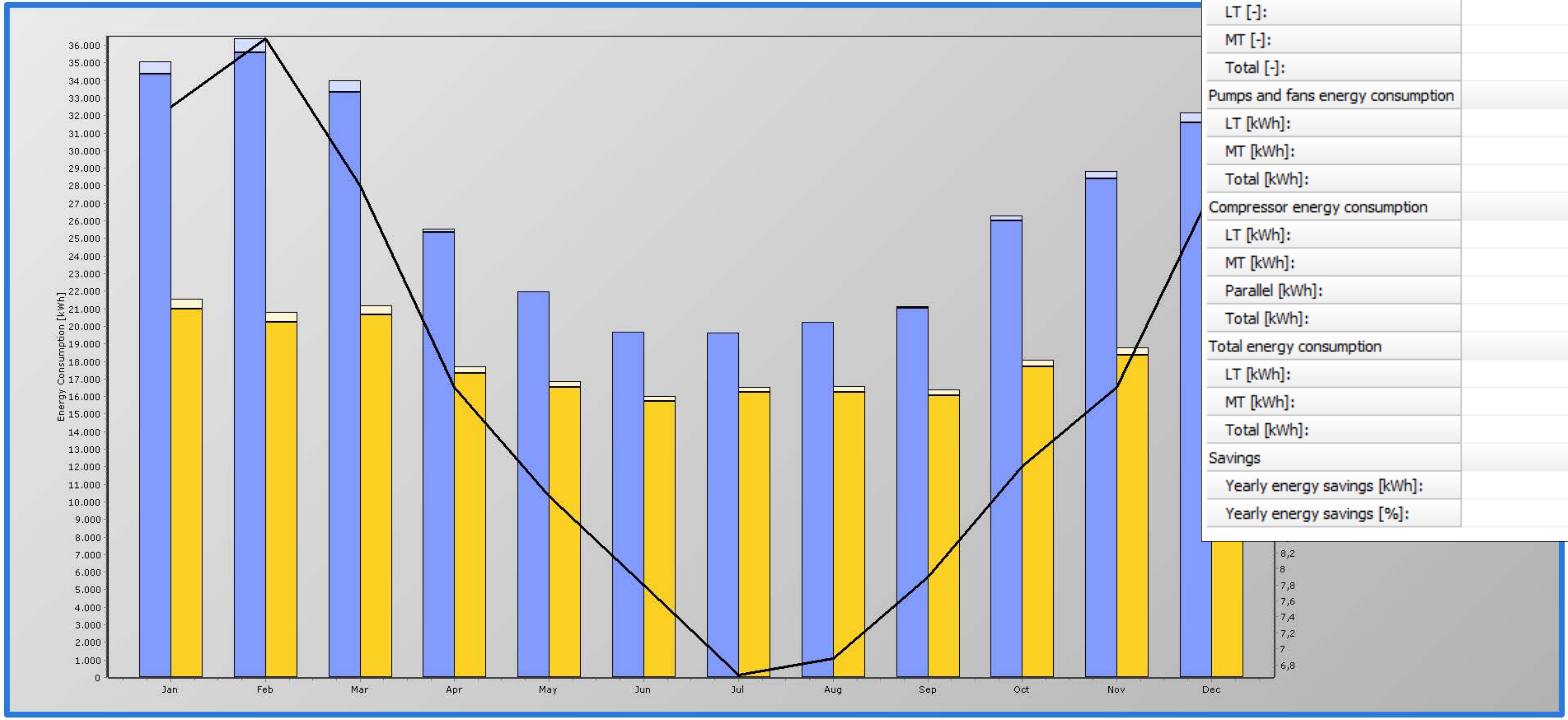
Energy Consumption Analysis

Ammonia System clearly more energy efficient.

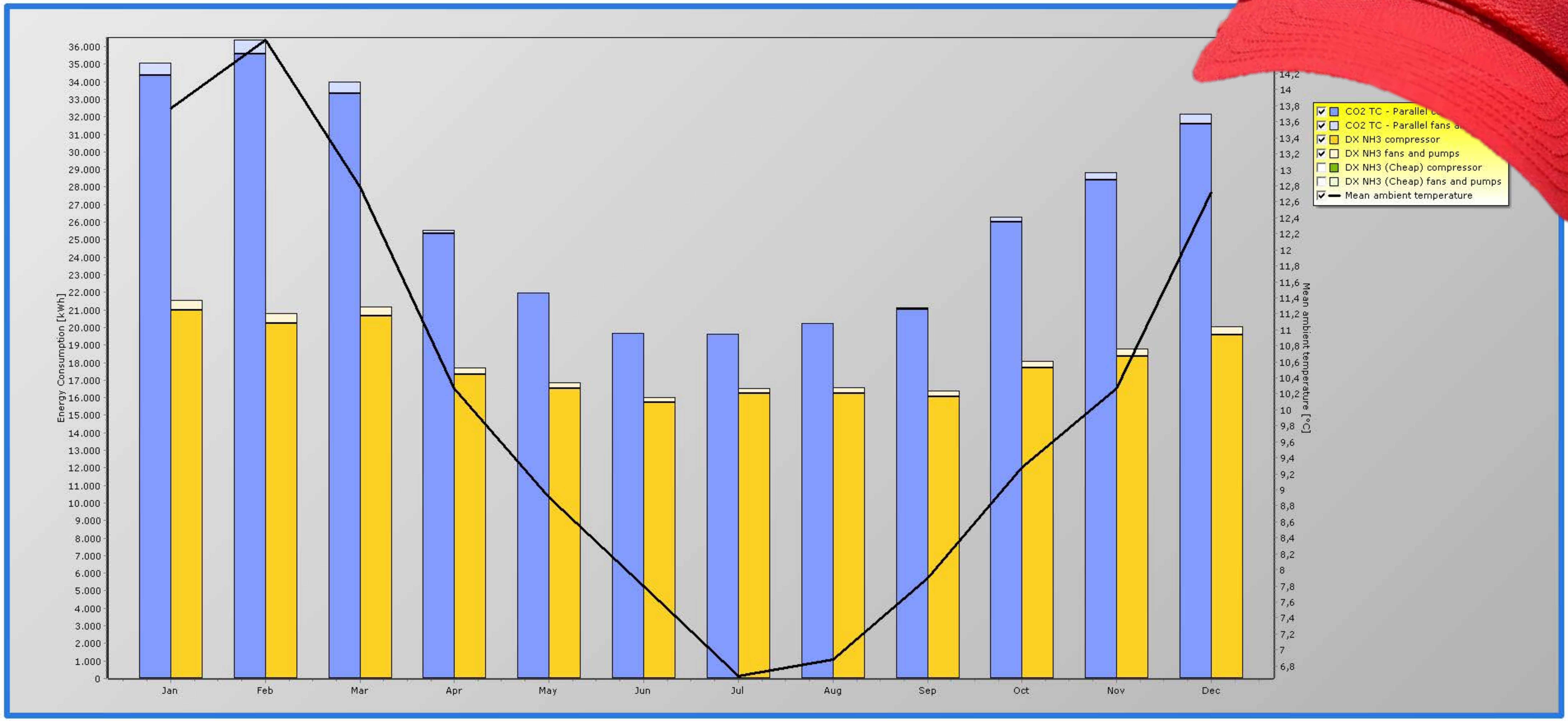


	CO2 TC - Parallel (reference)	DX NH3	DX NH3 (Cheap)
Load fulfillment in % of time			
LT:	100,0	99,5	99,5
MT:	100,0	99,3	99,3
Total:	100,0	99,3	99,3
Load fulfillment in % of energy			
LT:	100,0	100,0	100,0
MT:	100,0	100,0	100,0
Total:	100,0	100,0	100,0
Average COP			
LT [-]:	4,28	6,25	6,25
MT [-]:	3,96	5,15	5,15
Total [-]:	2,11	3,03	3,03
Pumps and fans energy consumption			
LT [kWh]:	0	0	0
MT [kWh]:	3.837	4.823	4.823
Total [kWh]:	3.837	4.823	4.823
Compressor energy consumption			
LT [kWh]:	111.965	75.827	75.827
MT [kWh]:	192.047	139.689	139.689
Parallel [kWh]:	13.091	0	0
Total [kWh]:	317.103	215.516	215.516
Total energy consumption			
LT [kWh]:	111.965	75.827	75.827
MT [kWh]:	208.975	144.512	144.512
Total [kWh]:	320.940	220.339	220.339
Savings			
Yearly energy savings [kWh]:	-	100.601	100.601
Yearly energy savings [%]:	-	31,3	31,3

30% Less Energy Consumption

Energy Consumption Analysis

Ammonia System clearly more energy efficient.



<u>30% Less Energy Consumption</u>

Lifecycle Cost Analysis

- NH_3 System is shown to be 30% More energy efficient per annum
- NH_3 Equipment & Installation more expensive vs. more 'commercial' refrigerants

Will that energy savings ever pay off the additional capital????

1. Setup systems | 2. Calculate | 3. Economy | 4. Report

Life Cycle Costs | CO2 Equivalent Emissions

Currency: $AUD

Expected average interest rate: 3 %
Expected average inflation rate: 2 %
Expected average energy cost: 0,14 $AUD/kWh
Expected lifetime: 25 years

Update

Initial cost:

	CO2 TC - Parallel	DX NH3	DX NH3 (Cheap)
Cost of equipment [$AUD]	150.000	300.000	300.000
Cost of installation [$AUD]	500.000	965.000	750.000

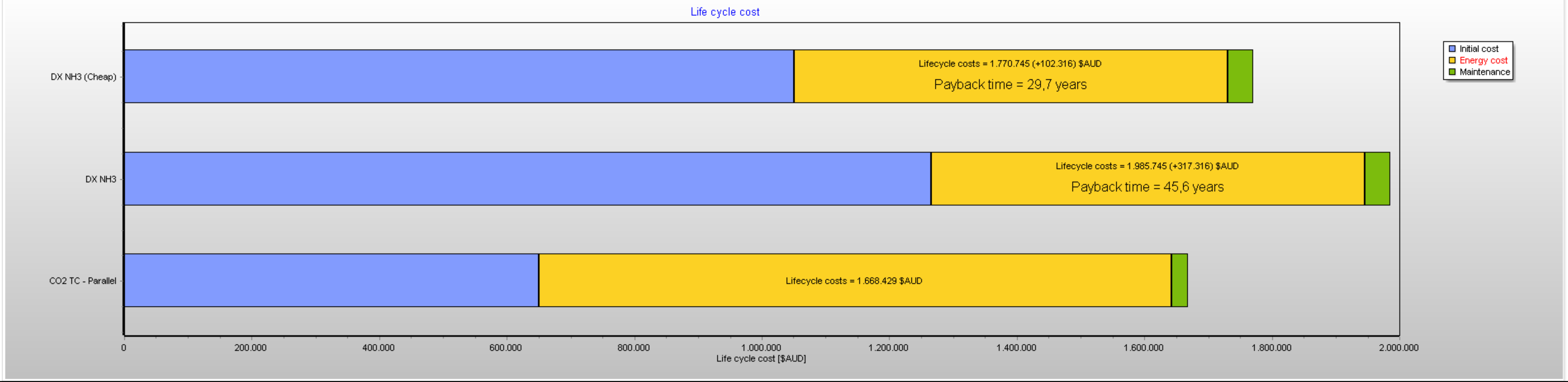
Annual operating cost:

	CO2 TC - Parallel	DX NH3	DX NH3 (Cheap)
Energy consumption [kWh]	320939,76	220338,84 (-100.601)	220338,84 (-100.601)
Cost of maintenance [$AUD]	1.200	1.800	1.800

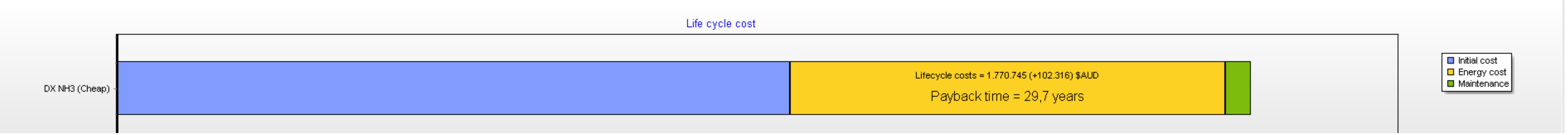
Result:

	CO2 TC - Parallel	DX NH3	DX NH3 (Cheap)
Effective interest rate [%]	0,98	0,98	0,98
Internal rate of return [%]	-	-4,17	-1,27
Total annual cost [$AUD]	46.132	32.647 (-13.484)	32.647 (-13.484)
Payback time [years]	-	45,6	29,7
Total initial cost [$AUD]	650.000 (39%)	1.265.000 (64%)	1.050.000 (59%)
Present value of maintenance cost [$AUD]	26.492 (2%)	39.738 (2%)	39.738 (2%)
Present value of energy cost [$AUD]	991.937 (59%)	681.007 (34%)	681.007 (39%)
Life cycle cost [$AUD]	1.668.429	1.985.745 (+317.316)	1.770.745 (+102.316)

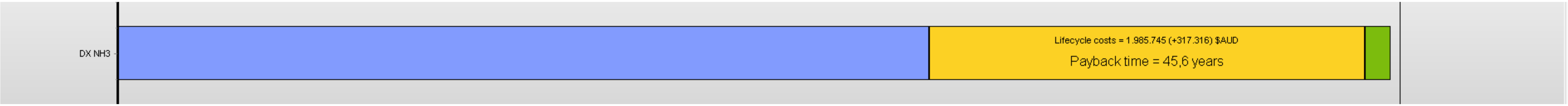
Diagram | Plot



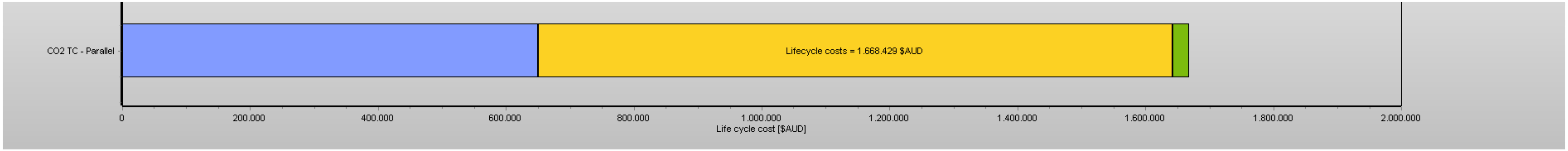
Lifecycle Cost Analysis



Adjusted Payback to include Field Components and Auxiliary Building Systems: 17.7 Years



Adjusted Payback to include Field Components and Auxiliary Building Systems: 27.2 Years



In this case, Average Cost NH_3 System would have to be:

- Further 46% less energy consumption to have a 20 Year ROI
- Further 66% less energy consumption to have a 15 Year ROI

Site Design Considerations

Multiple Sites in Differing Climate Zones

- Need to account for the difference in ambient temperatures and duration time exposed to higher ambient temperatures per year
- Should further normalize data with °C-hr/Day (e.g. Woolworths)

Use of Water Cooled Systems

- Water Treatment & Managing Legionella

Occupied Spaces / Hazardous Goods

- Customers need to understand the nature of the refrigerant offered and if it is suitable for their application
- Risks to Natural Refrigerants are all easily managed
- Design to AS5149 & IIAR-2 standard for NH_3 systems
- Hazardous areas assessments, & approved components for flammable refrigerants

Findings for Further Investigation

Refrigeration Capacity (Wr) / Storage Volume (m^3)

Refrigerant	Site No.	Annual Energy Consumption (kWh/Yr)	Total Refrigerated Volume (m3)	Specific Energy Consumption (Based on Volume) (kWh/Yr/m3)	Total Capacity (kW)	W / m3
NH3	1	1226016	43289	28.3	402.2	9.29
NH3	2	409597	9474	43.2	126.3	13.33
NH3	3	697339	31344	22.2	243.3	7.76
NH3	4	1098390	42619	25.8	314.8	7.38
NH3	8	1168479.9	60543	19.3	507.8	8.38
CO2	1	449316	9264	48.5	230	24.82
Exp. NH3	1	264406.8	9264	28.5	230	24.82

Two Factors that seemed be directly related were:

- kWh/Yr / m^3
- Wr / m^3

Further investigation should look into this relationship, specifically:

- Is SEC directly related to the system capacity design margin? (Or Load Profile?)
- Is there greater scope for macro-scale energy savings in this market by simply reducing multiplexed safety margins?

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Conclusion – Case for Transcritical Cold Storage

- Examples here show a Case for Transcritical CO_2 in terms of both First Cost, Lifecycle Cost, and Return on Investment

- There is NO silver bullet refrigerant
- Each project is different and should be weighed accordingly
- End User priorities should be incorporated into the benchmarking type: First Cost, Performance, ROI, Lifecycle Cost, Site Specific Conditions, Etc…

- AIRAH Refrigeration STG is looking for end user performance data for various systems including cold storage, food processing, etc… to begin to develop some locally sourced benchmarking data. Please feel free to contact me if you would like to participate.

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References

- Scantec Refrigeration Technologies
- Lucas Refrigeration
- United Food Express
- Shecco

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Thank you very much!