Case Study

Supermarket energy and TEWI comparisons

prepared by the AIRAH Natural Refrigerants Special Technical Group

This case study compares five different options of providing refrigeration to a large supermarket of around 4000 m^2. The TEWI (Total Equivalent Warming Impact) method of calculation has been used to compare the global warming effect of each of the options.

Scenario

- The store is laid out in a conventional manner, with low temperature refrigerated cases being in the ratio of 60/40 towards glass doors, with wide island open-type cases the balance.
- The medium temperature cases are standard multi-deck cases, arranged in back to back rows.
- Delicatessen cases are the glass-fronted forced draught type.
- Cool rooms make up the total refrigerated kW, No air conditioning load is calculated.
- Splitting the load requirement is as follows:

Low temperature load requirement:	50kW @ -35°C SST, -4°C SCT
Medium temperature load requirement:	169kW @ -8.5°C SST, 52.5°C SCT
High temperature load requirement:	198kW @ -5°C SST, 52.5°C SCT
Ambient design temperature:	45°C

Several options are up for consideration: To include a conventional parallel rack system; using reciprocating or screw compressors, with air cooled condensers; and to utilize heat reclaim from the two medium and high temperature racks. The medium and high temperature circuits each have dedicated air cooled condensers.

Design selection and justification

The final selection for the plant was to use the Hybrid 3 system, of low temperature CO_2 R744 with reciprocating compressors, connected to an inter stage condenser. The condensing duty was carried out by the medium temperature rack, using a heat exchanger. The lead compressor on the medium temperature rack was connected to a VSD drive.

The medium temperature and high temperature racks ran on R134a refrigerant with screw compressors, with a variable speed control to one of the two compressors per rack, giving a close control and load matching profile. The oil cooler requirement of the medium and high temperature stage racks was served by air-cooled condensers. Electronic TX valves were used for the low temperature loads, while medium and high temperature loads were controlled with suction pressure regulation.

The system designs evaluated have been designated as follows:

Detail	Conventional	Hybrid 1	Hybrid 2	Hybrid 3	Cascade CO_2
Compressor type	Recip LT/MT/HT	Recip LT /MT/HT	Screw LT/MT/HT	Recip/ Screw LT- Recip MT/HT- Screw	Recip LT/MT/HT
Refrigerant	R404a	R404a/R134a	R404a/R134a	R744/R134a	R744 /R134a
Charge kgs	1100	320/840	320/880	280/920	900-R744 500-R134a
Leakage rate %	20	20	20	20	20

The Hybrid 3 option was seen as a good fit for not only the project budget, but satisfying the TEWI and power requirements. It also provided a reliable solution that would be able to run at full load from day one of commissioning.

It is noted that the Cascade CO_2 system had the lowest overall TEWI rating. This type of system has a higher capital cost, but is being used where the true cost of CO_2 emissions is considered. The application is well suited for use in warmer climates such as Australia. Further TEWI rating reductions would be achieved if the condensing duty was also using a natural refrigerant (e.g. ammonia).

The calculation and definition of TEWI is as below:

$$TEWI = (GWP \times \{ L/100 \} \times n \times m) + (GWP \times m \times \{1-\alpha_{recovery}\}) + (n \times E_{annual} \times \beta)$$

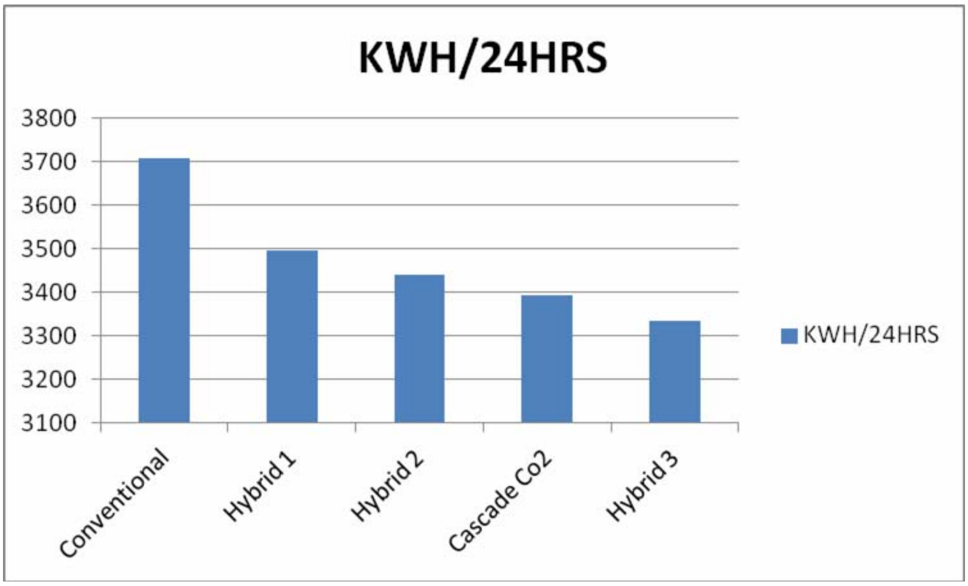
= Leakage + Recovery losses + Energy Consumption

= ← Direct Emissions → + ← Indirect Emissions →

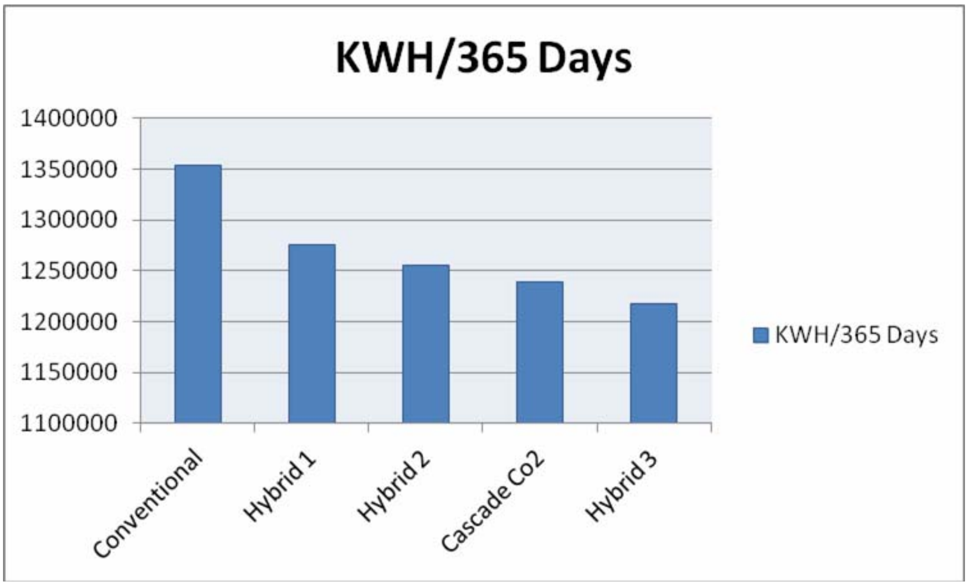
GWP= Global Warming Potential
L= Leakage rate per year
n= system operating life (years)
m= Refrigerant charge (kg)
$\alpha_{recovery}$= Recycling factor
E_{annual} =energy consumption per year (kWh)
B= CO_2Emmission per kWh

Recovery losses are a measure of the refrigerant that is not recovered at the end of the equipment life.

Below are a number of graphs that demonstrate the effectiveness of the Hybrid 3 option.



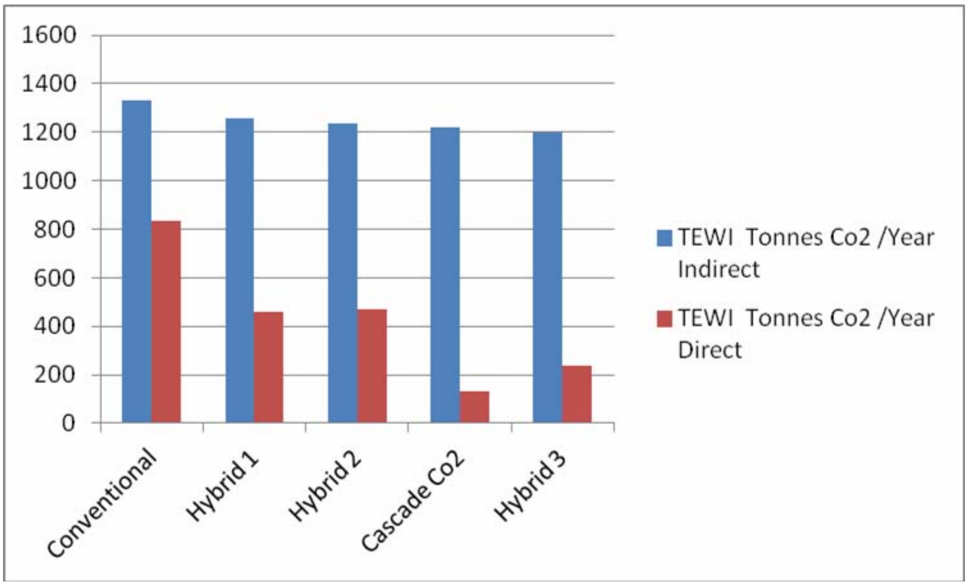
In actual run time the Hybrid 3 option provided the lowest kWh per 24 hours, with 3336 kWh.



When measured over an annual period, the Hybrid 3 option provided the lowest kWh at 121,764 kWh

By quantifying the indirect emissions due to electricity usage and also incorporating the direct emissions due to refrigerant leakages, the overall TEWI can be calculated.

Graph of TEWI split into indirect and direct portions



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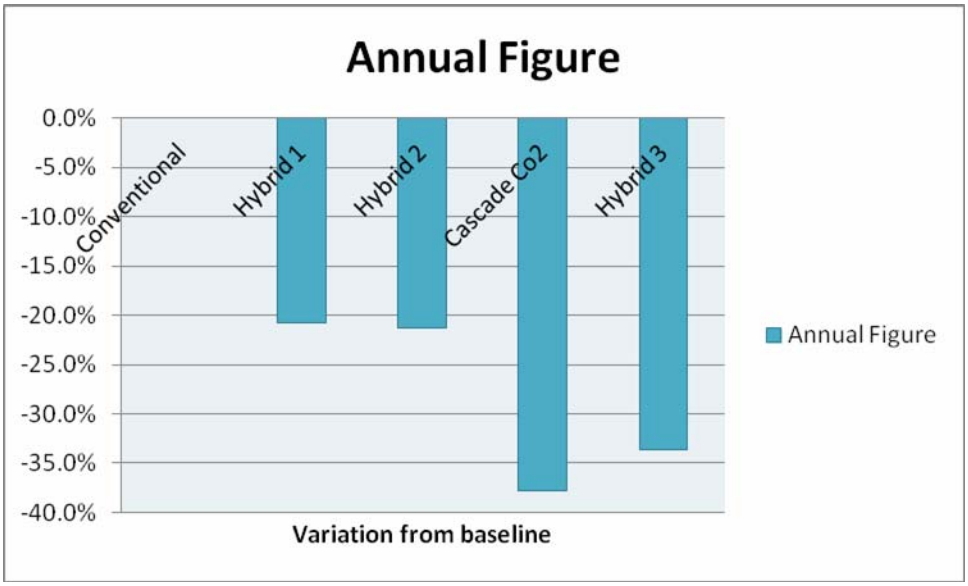
The indirect calculations for all five options are reasonably close. The conventional system, as expected, is marginally higher. The direct emissions are lower with the Cascade CO_2 system due to the use of the low Global Warming Potential (GWP) CO_2 refrigerant and the relative reduction of the higher GWP R134a refrigerant.

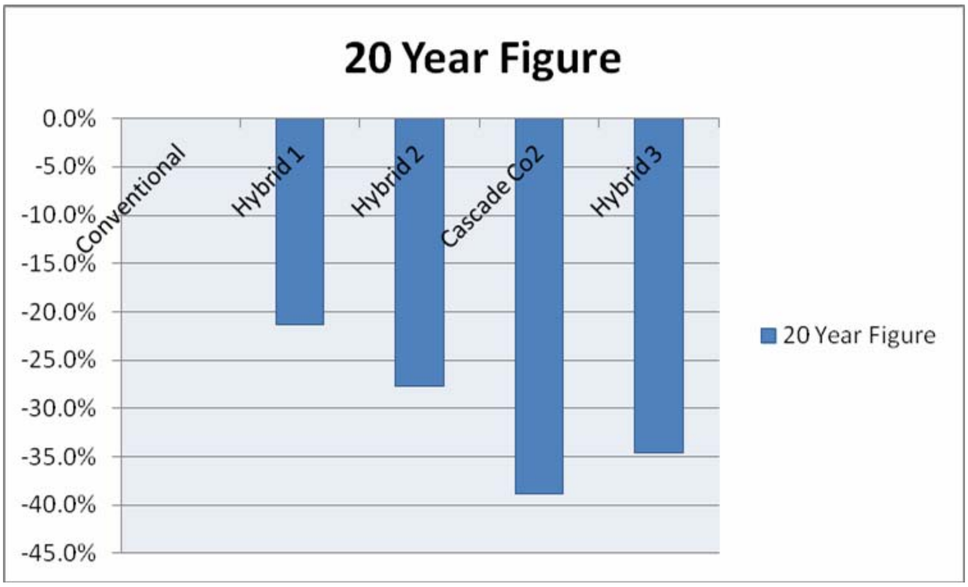
The direct and indirect TEWI components have been added together and then compared to the baseline conventional R404a system. See below:

Graph of combined TEWI results



The graph shows the variation from the TEWI baseline, being the R404a conventional rack option.
Note: Since it is the baseline the conventional system is shown as 0.

The total TEWI calculated over the life of the plant, including any recovery losses due to unrecovered refrigerant, is calculated and shown in the graph below.



This graph shows the estimated 20-year TEWI variation from the baseline.

Emissions reductions

The 20-year figure graph (above) shows that both the Hybrid 3 option and the Cascade CO_2 options can result in significant savings in CO_2 emissions as tabulated below.

	Conventional system R404a	Hybrid 1 R404 and R134a	Hybrid 2 R404a and R134a	CO_2 R134a Cascade	Hybrid 3 CO_2 and R134a
Total TEWI per year Tonnes CO_2	2100	1700	1630	1310	1410
Savings Tonnes CO_2 compared to conventional	0	400	470	790	690

Significant savings in greenhouse gas emissions of approximately 690 to 790 tonnes per year are possible with cost-effective equipment and technologies that are currently available.