BASE LEVEL AUDIT REQUIREMENTS – REFRIGERATION SYSTEMS

1. SITE DATA COLLECTION

Business Name	
Site physical address (Street, Suburb, City)	
Nature of site / business operation	

Electricity Supplier	
Power factor correction equipment in use	
Delivered electricity cost per kWh	

Thermal energy type	
Thermal energy supplier	
Delivered thermal energy cost per kWh	

Site contact 1:	**Name**	
	Designation	
	Telephone (DDI)	
	Email	
Site contact 2:	**Name**	
	Telephone (DDI)	
	Email	

Comments:

2. SYSTEM DATA COLLECTION

Network Schematic			
System Reference			
Generation Information			
Refrigerant		Air- / Water-Cooled	
Fluid Chilled		Estimated Run Time	
Open / Closed System		System Scheduling	
Maintenance Practices			
Other Notes			
Compressor Information			
Makes		Models	
Types of Compressor		Motor Sizes	
Suction / Discharge Pressures		Suction / Discharge Temps	
Multiple Compressor Control			
Other Notes			
Network Information			
Circulation Pump Details		Circulation Pump Control	
Refrigerant Pipework		***Cooling Fluid Pipework***	
Material / Size		Material / Size	
General Condition		General Condition	
Insulation Condition		Insulation Condition	
Valves			
Valve Types		General Condition	
Insulation Condition		Operation	
Evaporator / Demand Information			
Heat Loads / Air Infiltration	Description / Comments	Evaporator Fan Control	
		Evaporator Pump Control	
		Evaporator Defrost Cycle	
		Evaporator Fouling	
Condenser / Heat Rejection Information			
Heat Recovery Opportunity	Description / Comments / General	Condenser Fan Control	
		Condenser Pump Control	
		Cooling Line Fouling	

3. ENERGY USE DATA

Refrig. System		**Description**			
Electricity Energy Use Details					
Delivered Electricity Cost: Cents per kilowatt hour					
User ID	***Make / Model***	***Rated kW (electrical)***	***Load Factor***	***Annual Run Hours***	***Annual Energy Consumption***
Total Electrical Energy Use					
Annual Electrical Energy Operational Cost					
Other Energy Use Details					
Fuel Type		Fuel Cost			
User ID	***Make / Model***	***Rated kW (other)***	***Load Factor***	***Annual Run Hours***	***Annual Energy Consumption***
Total Other Energy Use					
Annual Other Energy Operational Cost					
Total System Energy Use Data					
Total Refrig. System Energy Use					
Total Refrig. System Energy Cost					
Relevant Production Measure (e.g. units produced)					
Estimated Annual Production Throughput					
Estimated Energy Use Index (EUI)					

4. EFFICIENCY IMPROVEMENT OPPORTUNITY CHECKLIST

	Assessment Checklist	Potential for Efficiency Improvement				
	Efficiency Opportunity Element	**N / A**	**LOW**	**MED**	**HIGH**	**Further Comments**
DEMAND / EVAPORATOR	System user isolation					
	Peak load shedding opportunity					
	Heat load reduction opportunity					
	Surface infiltration					
	Door seals and air infiltration into stores					
	Freezing time optimisation					
	Analysis of cooling load					
	Evaporator fan control					
	Evaporator pump control					
	Evaporator fouling					
	Optimise evaporator defrosting cycle					
SUPPLY / COMPRESSORS	Changes to initial system design					
	High compression ratio					
	System scheduling and control					
	Optimise multiple compressor control					
	Compressor economiser potential					
	Compressor suitability					
	Absorption refrigeration opportunity					
	System maintenance practices					
	Booster compressor for multiple temperatures					
	VSD trim compressor potential					
	Separate smaller system for after-hour loads					
	Motor efficiency					
CONDENSOR / HEAT REJECTION	Heat recovery opportunity — desuperheater					
	Heat recovery opportunity — cooling water					
	Cooling water line fouling					
	Condenser fan control					
	Condenser pump control					
	Optimise condensing temperature					
NETWORK	Circulation pump control					
	Changes to initial network design					
	System pressure losses					
	Network maintenance practices					
	Pipe configuration					
	Insulation of cold pipework					

4. (CONTINUED) EFFICIENCY IMPROVEMENT OPPORTUNITY CHECKLIST

Type	Initiative
DEMAND / EVAPORATOR	**System User Isolation** Ensuring all users of chilled water and/or refrigerant are isolated when not required, e.g. when an industrial machine that uses chilled water for cooling is taken off-line, it should be isolated from the chilled water circuit. This reduces the heat load on the refrigeration system as well as potential pumping costs.
	Peak Load Shedding Opportunity Includes opportunities related to the shedding or shifting of electrical loads from peak demand periods where the electricity supply costs (energy and/or network costs) are higher than during other periods.
	Heat Load Reduction Opportunity Reducing heat loads can lead to a significant reduction in the refrigeration system's energy use and is often overlooked. Heat loads include those associated with packaging, product being too warm before chilling or freezing, and lighting.
	Surface Infiltration This relates to the effectiveness of coolstore insulation. Heat transfer through poorly insulated surfaces can account for a large proportion of a refrigeration system's load.
	Door Seals and Air Infiltration Poor door seals let warm and sometimes humid air into refrigerated areas. The heat gain increases refrigeration loads and the moisture increases the frequency of evaporator defrosting. Incorporating seal inspection and repair as part of routine maintenance ensures that seals are kept in good condition. There may also be better alternative doorway sealing methods suitable for retrofit.
	Freezing Time Optimisation Although shorter freezing times may reduce product weight loss, this initial high cooling load may lead to high peak demand charges. Increasing the freezing time may reduce peak loading with minimal overall effect on cycle length. Product shape, packaging and materials all affect heat transfer effectiveness and therefore freezing times. Air flow is an important factor in blast freezers.
	Analysis of Cooling Load The cooling load may itself be larger than required. For instance, the holding temperature of a storage area may be lower than required and therefore use more energy and incur more efficiency penalties than at a higher temperature. This relates directly to the system's compressor suction temperature/pressure.
	Evaporator Fan Control Constant-speed evaporator fans circulate air within a space so that heat is removed from the space via evaporator coils, although the energy the fans consume is also an additional heat load. A temperature switch or VSD turns off or slows the fans when possible, saving power and ensuring more stable temperatures.
	Evaporator Pump Control Savings can be made by ensuring that evaporator pumps are turned off with the evaporator fans. There may be minimum flow requirements, in which case a pump's speed can be reduced via a VSD. There will be direct savings from the pump power consumption and indirect savings from the fact that transfer of heat is reduced.
	Evaporator Fouling Closed-circuit refrigerant lines may develop fouling, causing high pressure drops and low flows, resulting in inefficient evaporator operation, reduced heat transfer effectiveness and higher loads on circulation pumps.
	Optimise Evaporator Defrosting Cycles Moisture in humid air condenses on evaporator coils, freezes and forms an ice layer which reduces the heat transfer efficiency. Defrosting removes the ice, though this takes energy. The optimum defrost strategy keeps defrosts to the minimum necessary to keep evaporators free of ice. Defrost sensors that detect when to start and stop defrosts help to achieve this.
SUPPLY / COMPRESSORS	**Changes to Initial System Design** This includes opportunities related to changes that have occurred in the refrigeration system design since original installation, such as compressor replacement to meet new demands. As systems are modified, their inherent efficiency may decrease as a result.
	High Compression Ratio Compressors running at higher compression ratios than necessary consume more power and operate at lower isentropic efficiency. Some reasons for a high ratio could be due to a lower than required suction pressure (low evaporator temperature), higher than required discharge pressure (high condenser temperature), incorrect compressor use or control and incorrect operation of multistage systems.

4. (CONTINUED) EFFICIENCY IMPROVEMENT OPPORTUNITY CHECKLIST

SUPPLY / COMPRESSORS (continued)	**System Scheduling and Control** This relates to the manual or automatic scheduling of supply components such as compressors so that they do not operate when not required. Control methods include timer control or temperature sensors.
	Optimise Multiple Compressor Control When fully loaded, screw compressors are typically more efficient than reciprocating compressors. As screw compressors unload, their efficiency drops markedly, while reciprocating compressors unload reasonably efficiently. Efficiency is maximised by controlling multiple compressors so that, as much as possible, larger screw compressors run fully loaded and capacity is trimmed by partly loading the smallest screw, reciprocating or VSD-controlled compressors.
	Compressor Economiser Potential It is possible to install economisers on some single-stage compressors to bring their efficiency level up towards the level of two-stage compression. Some rotary screw refrigeration compressors have economiser ports to allow compression from an intermediate pressure, which improves the system's thermodynamics and efficiency.
	Compressor Suitability Ensure compressors are selected for efficiency at all loads. Some compressors are well suited to high base loads, while others are better suited to act as trim compressors or at lower loads.
	Absorption Refrigeration Opportunity The economics of absorption refrigeration generally make sense if there are high operating hours, the system operates near full capacity during operation (ideal for base loads), and the heat source is very low in price or "free" (e.g. waste heat) or electricity prices are very high.
	System Maintenance Practices This refers to the regular maintenance of the system so that components operate as designed. This includes minimising refrigerant leakage, ensuring the correct charge and optimising purges.
	Booster Compressor for Multiple Temperature Levels If cooling is required at two different temperatures, i.e. for freezing and for chilling, running the entire system at the low pressure needed for freezing handicaps the system's efficiency at the chilling temperature by 20% – 30%. Consider installing a booster compressor for meeting the low-stage loads.
	VSD Trim Compressor Potential Most refrigeration screw compressors modulate their output using a slide valve. At high turn-down, the compressor's efficiency drops by up to 30%. VSD-controlled screw compressors lose little efficiency when turned down and are ideal for regulating refrigeration output with modulated compressors running at full load to meet the base load. VSD-controlled centrifugal compressors are often operated as the trim compressor.
	Separate Smaller System for After-Hour Loads There may be potential to install smaller systems for after-hour loads if a large system operates particularly inefficiently during these periods because it is designed for much larger loads.
	Motor Efficiency Old motors could be replaced instead of rewound at failure. This is particularly true for compressor motors, which account for a large proportion of total system energy consumption.
CONDENSER / HEAT REJECTION	**Heat Recovery Opportunity — Desuperheater** Refrigerant discharged from the compressor typically has superheat of 20°C to 50°C above the condensing temperature. A desuperheater (heat exchanger) uses this energy to heat water. There must be a demand for hot water at the available temperature, and the payback period depends on the current method and amount of water heating. This may require a significant amount of heat storage if its use is not at the same time that it is produced. In systems which are near the limit of their condenser capacity, the use of a desuperheater can also result in a compressor efficiency gain through a reduction in discharge pressure.
	Heat Recovery Opportunity — Cooling Water Similar to a desuperheater, discharged cooling water can be used as a low-grade source of heat. This can be achieved via a heat exchanger prior to the cooling tower.
	Cooling Water Line Fouling Closed-circuit cooling water lines utilising cooling towers for cooling may develop fouling, causing high pressure drops and low flows, resulting in inefficient condenser operation and higher load on circulation pumps.
	Condenser Fan Control The condenser water temperature depends on the cooling load, the air temperature and humidity, and the fan speed. For air-cooled condensers, evaporative condensers and cooling towers, a constant-fan speed will cause excessive cooling during times of low demand, air temperature, or humidity. A temperature switch or VSD turns off or slows the fan(s) when possible, saving power and ensuring more stable temperatures.

4. (CONTINUED) EFFICIENCY IMPROVEMENT OPPORTUNITY CHECKLIST

CONDENSER / HEAT REJECTION (continued)	**Condenser Pump Control** Savings can be made by ensuring that condenser pumps are turned off with the condenser fans. There may be minimum flow requirements, in which case a pump's speed can be reduced via a VSD. There will be direct savings from the pump power consumption and indirect savings from the fact that transfer of heat is reduced.
	Optimise Condensing Temperature Decreasing the condensing temperature, assuming there is capacity in the cooling tower(s), directly affects the compressor discharge pressure/temperature and therefore efficiency. Keeping the condensing temperature as low as possible can be achieved manually by changing it seasonally or automatically through temperature sensors, e.g. maintaining condenser temperature at 2°C above wet-bulb.
NETWORK	**Circulation Pump Control** Savings can be made by ensuring that circulation pumps are turned off with the compressors and with cooling towers. There will be direct savings from the pump power consumption and indirect savings from the fact that transfer of heat is reduced, requiring less energy to remove it.
	Changes to Initial Network Design This includes opportunities related to changes that have occurred to the network layout since original installation, e.g. changes in pipework to supply more users. As systems are modified, their inherent efficiency may decrease as a result.
	System Pressure Losses Losses in refrigerant pressure related to throttling of flow or narrowing of pipes affect the suction and discharge pressures, which have a significant effect on compressor energy efficiency.
	Network Maintenance Practices This refers to the regular maintenance of the network and heat rejection system so that systems operate efficiently as well as reliably. This includes cleaning condenser tubes regularly, cleaning evaporator tubes and ensuring cooling liquid and/or refrigerant leaks as well as air infiltration are kept to a minimum.
	Pipe Configuration Undersized pipes, complex pipe layouts and large distance from generation to end use all increase the pressure drop in the system. Large networks will also result in high distribution losses.
	Insulation of Cold Pipework This involves ensuring that the insulation of chilled water and/or refrigerant lines is effective so that the chiller demand and energy costs are reduced.