AWRI Refrigeration Demand Calculator

Resources and expertise are readily available to wine producers to manage efficient refrigeration **supply** and plant capacity. However, efficient management of winery refrigeration **demand** and associated heat transfer efficiency has been identified by AWRI collaborators as an area where further understanding is required to achieve reliable efficiency gains.

The AWRI Refrigeration Demand Calculator is a spreadsheet-based tool designed to provide wine producers with enhanced capability for analysis and management of winery refrigeration demand and associated heat transfer efficiency, with simulation capability for different insulation types, tank layout and solar loading.

This project builds on the demonstrated capability of the AWRI in best practice refrigeration operation (as demonstrated with the AWRI publication *Improving Winery Refrigeration Efficiency*) and engineering simulation (as demonstrated by the AWRI Ferment Simulator and bioenergy R&D) with the development of heat and energy balance process models for simulating winery refrigeration demand. These models have been developed with the specific purpose to simulate winery operations and so identify opportunities for producers to reduce energy demand and operating costs.

The Calculator allows producers to enter grape intake and production data to simulate refrigeration demand across the entire annual production cycle. Capability has been included for users to assess the impact of various factors – such as cellar storage and cold stabilisation temperatures, fermentation conditions, climate, brine temperature, tank size and insulation – on refrigeration demand and energy costs. The following documentation details these operating procedures, from entering grape intake data and fermentation conditions to operational parameters such as storage temperatures or the percentage of tanks equipped with insulation. The impact on wine-wine heat exchange for energy recovery during cold stabilisation can also be assessed.

The AWRI Refrigeration Demand Calculator is provided as an unlocked Excel file (compatible with Office 2007 onwards). The source code is also unlocked, allowing wine producers to adapt the simulator functionality to interface directly with LIMS/PLC/SCADA systems for automatic data acquisition if desired.

Please feel free to contact AWRI with any queries, comments, and suggestions regarding the Calculator, or for assistance in use of the package.

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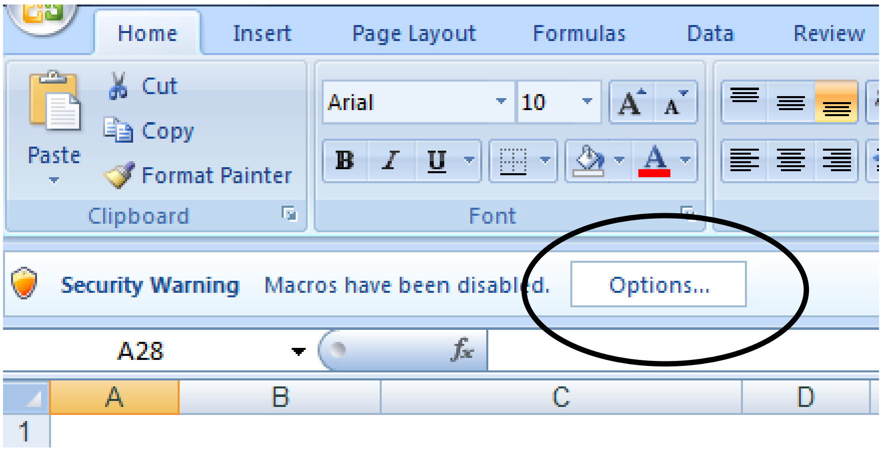
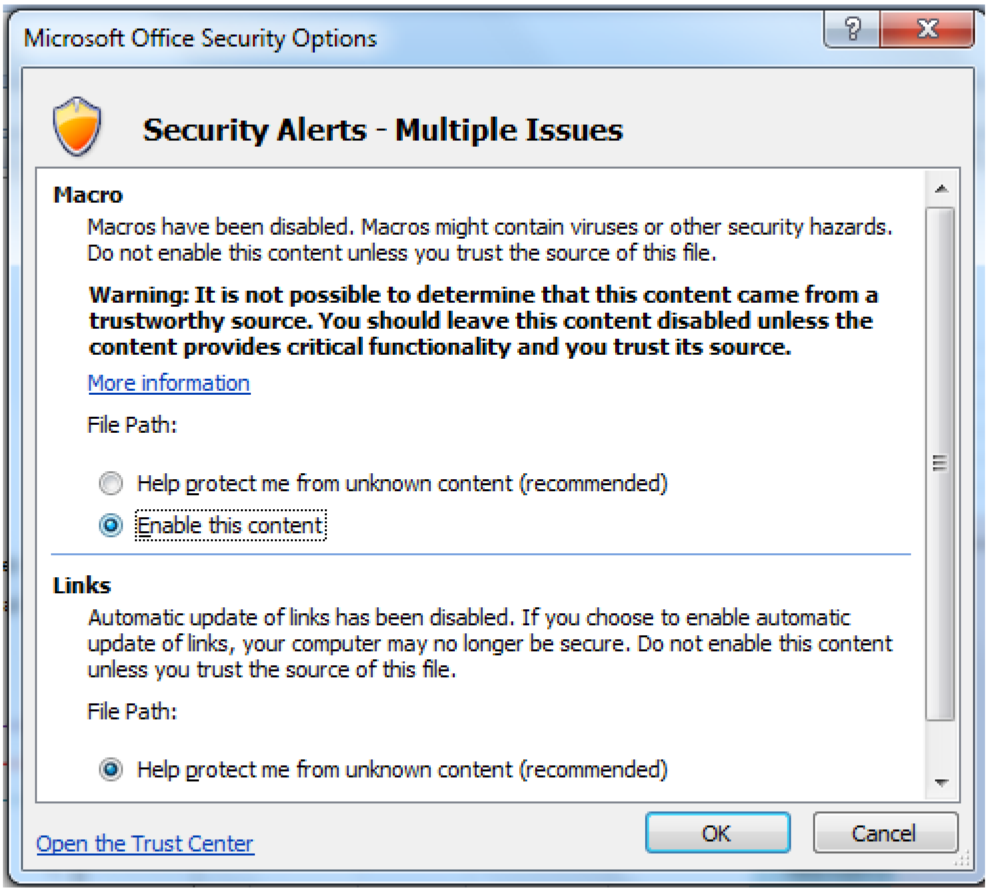
AWRI Refrigeration Demand Calculator

Operating Procedure

1. Enable Macros (if required)

Upon opening the Calculator, please ensure that macros are enabled.





Click OK

2. Worksheets – Overview

Demand and Usage – this worksheet provides a table of simulated demand and usage in 12 hour increments throughout the entire year. At the bottom of the table the peak demand and total usage are shown, which may then be compared with overall site electricity usage figures. Typically refrigeration would account for 40-70% of total site electricity consumption.

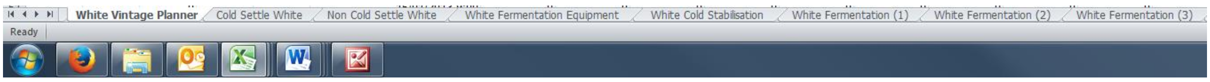
Demand Chart The 'Demand Chart' screen gives a graphical representation of the demand in both $kW_{refrigeration}$ and $kW_{electrical}$ throughout the entire year. Key features of this graph will typically be demand peaks for white and red production during vintage, as well as required demand for cold stabilisation.

Red Vintage Planner – this worksheet tab is where information on daily red grape intake (throughout vintage) is entered, as well as requirements for must chilling and cold soaking. The allocation of fruit to different fermenter and storage tanks is entered here, as well as cold stabilisation requirements.

Cold Soak Red & Non-Cold Soak Red– these worksheets are used for internal model calculations relating to cold soaking. No input from the user is required on these worksheets.

Red Fermentation Equipment – the Calculator allows the user to specify up to three different red fermenter vessel designs. This worksheet is where fermenter equipment details such as volume and insulation are provided.

Red Fermentation (1) – (3) – The Calculator allows the user to specify up to three different fermentation profiles (corresponding to Red Fermenter vessels 1-3). These sheets are used for calculation of refrigeration demand for each ferment profile.



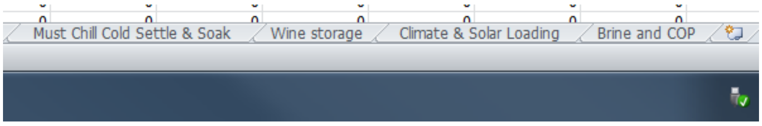
White Vintage Planner – this worksheet tab is where information on daily white grape intake (throughout vintage) is entered, as well as requirements for must chilling and cold settling. The allocation of fruit to different fermenter and storage tanks is entered here, as well as cold stabilisation requirements.

Cold Settle White & Non-Cold Settle White - these worksheets are used for internal model calculations relating to cold settling. No input from the user is required on these worksheets.

White Fermentation Equipment – the Calculator allows the user to specify up to three different fermenter vessel designs. This worksheet is where fermenter equipment details such as volume and insulation are provided

Red Fermentation (1) – (3) – The Calculator allows the user to specify up to three different white fermentation profiles (corresponding to White Fermenter vessels 1-3). These sheets are used for calculation of refrigeration demand for each ferment profile.

Worksheets – Overview (continued)



Must Chill Cold Settle & Soak – this worksheet is where information on flowrates and temperatures for must chilling, cold settling and cold soaking are entered.

Wine Storage - the Calculator allows the user to specify up to three different storage vessel designs. This worksheet is where equipment details such as volume and insulation are provided.

Climate and Solar loading – the Calculator takes ambient temperature max/min data into account when modelling refrigeration demand requirements. This worksheet is where the user would enter information on average monthly max/min temperature data and solar radiation relevant to their geographical location.

Brine and COP – this worksheet is where information relating to brine temperatures and brine storage tank volume is entered. If the site employs the use of cold rooms then this information is captured on this worksheet also.

1. Getting Started- Enter the Vintage Start Date

B	C	D	E
Vintage Start Date	1-Jan-14		
	TOTAL		
Date	**kWr refrigeration**	**kWe refrigeration**	**Electricity Usage**
1/01/2014 9:00	84.16	39.92	
1/01/2014 21:00	10.52	4.99	59.87
2/01/2014 9:00	91.26	43.29	519.44

1. First, go to the “Demand and Usage” worksheet to enter the vintage Start Date into cell c2 (colour coded grey). This can either be the beginning of the calendar year, or the actual first day of crushing.

2. Using the Red Vintage Planner

E	F	G	H	I	J
	Start date	1-Feb-14			
		1-Feb-14	2-Feb-14	3-Feb-14	4-Feb-14
	Red Intake (tonnes)	10	15	20	25
	Must Chill (%)	0%	0%	0%	0%
Cold Soak	Cold Soak (%)	50%	50%	50%	50%
	Fermenter Type 1 (%)	40%	40%	40%	40%
	Fermenter Type 2 (%)	40%	40%	40%	40%
	Fermenter Type 3 (%)	20%	20%	20%	20%
Non-Cold Soak	Non-Cold Soak	50%	50%	50%	50%
	Fermenter Type 1 (%)	40%	40%	40%	40%
	Fermenter Type 2 (%)	40%	40%	40%	40%
	Fermenter Type 3 (%)	20%	20%	20%	20%
	Maturation Storage Type 1 (%)	50%	50%	50%	50%
	Maturation Storage Type 2 (%)	30%	30%	30%	30%
	Maturation Storage Type 3 (%)	20%	20%	20%	20%
	Cold Stabilisation (%)	5%	5%	5%	5%

1. Go to the Red Vintage Planner worksheet.
2. For each date of crushing, the corresponding grape intake value (in tonnes) is entered by the user into the yellow cells.
3. The percentage of red fruit (on average) which is to be must chilled is specified in the cell G7 (colour coded blue).
4. The percentage of red fruit (on average) which is to be cold soaked is specified in cell G8 (colour coded light-green). In the above example, 50% of the red fruit intake is to undergo cold soak. Note that this percentage figure is used to calculate the refrigeration energy required for *maintaining* the cold soak temperature only, and not the additional energy required to initially chill the fruit to the cold soak temperature.
5. The Calculator allows the user to specify up to three different red fermenter vessel designs. The percentage of *cold soak* fruit which is to be fermented in vessel 1, 2 or 3 is entered into cells G9-G11 (colour coded dark-green). In the above example, 40% of the cold soak fruit will be fermented in Fermenter Type 1, 40% in Fermenter Type 2 and 20% in Fermenter Type 3.
6. The percentage of *Non-cold soak* fruit which is to be fermented in vessel 1, 2 or 3 is entered into cells G9-G11 (colour coded dark green). In the above example, 40% of the cold soak fruit will be fermented in Fermenter Type 1, 40% in Fermenter Type 2 and 20% in Fermenter Type 3.
7. The Calculator allows the user to specify up to three different red storage vessel designs. The percentage of red wine production which is to be stored in Maturation Storage Type 1, 2 or 3 is entered into cells G12-G14 (coloured light-purple). In the above example, 50% of red wine production will be matured in Maturation Storage Type 1, 30% of red wine production

will be matured in Maturation Storage Type 2, and 20% of red wine production will be matured in Maturation Storage Type 3.

8. The percentage of red wine production which is to be cold stabilised is entered into cell G15 (coloured coded dark-purple).

3. Specify details for Red Fermentation Equipment

Red Fermenter Type 1		
Fermenter Capacity	3.5	tonnes
Volume	4.9	kL
Aspect ratio (ie ratio of height to diameter)	2	
Heat transfer area (per tank)	13.41	m2
Cooling jacket area	30.00%	(percentage of tank wall height)
Insulation area	35.00%	(percentage of tank wall height)
U (jacket region)	0.8	W/m2/C
U (rest of tank)	10	W/m2/C
Overall U	0.00678	kW/m2/C
Red Fermenter Type 2		
Fermenter Capacity	1	tonnes
Volume	1.4	kL
Aspect ratio (ie ratio of height to diameter)	2	
Heat transfer area (per tank)	5.82	m2
Cooling jacket area	30.00%	(percentage of tank wall height)
Insulation area	35.00%	(percentage of tank wall height)
U (jacket region)	0.8	W/m2/C
U (rest of tank)	10	W/m2/C
Overall U	0.00678	kW/m2/C
Red Fermenter Type 3		
Fermenter Capacity	1	tonnes
Volume	1.4	kL
Aspect ratio (ie ratio of height to diameter)	2	
Heat transfer area (per tank)	5.82	m2
Cooling jacket area	30.00%	(percentage of tank wall height)
Insulation area	35.00%	(percentage of tank wall height)
U (jacket region)	0.8	W/m2/C
U (rest of tank)	10	W/m2/C
Overall U	0.00678	kW/m2/C

1. Go to the Red Fermentation Equipment worksheet.
2. For each fermenter type, enter the vessel capacity in tonnes (into the yellow cells)
3. Enter the cooling jacket area (as a percentage of the tank wall height) into the green cells. If barrels are to be used in a temperature controlled room (instead of using a stainless or concrete tank for fermentation), then set the 'cooling jacket area' to zero.
   [NOTE: if internal cooling coils are used in place of a cooling jacket, an equivalent 'cooling jacket area' can be calculated using the calculation box located on this worksheet. Users type in the coil length and diameter, as well as the tank heat transfer area for the tank in question. The calculation box will then give an 'Equivalent Cooling Jacket Area' value, which should then be entered by the user into the relevant 'Cooling jacket area box (colour coded green).]
4. Enter the insulation area (as a percentage of the tank wall height) into the blue cells.
   NOTE: The default calculation assumes a stainless steel tank. If concrete tanks or barrels are to be used instead, then an insulation value of 0% should be used here. The user should also manually update the 'U (rest of tank) value as per the following:
   concrete tank: 5.75 W/m2/C
   oak barrel: 7.2 W/m2/C

4. Specify Red Fermentation Profiles

		= user adjustable field
Volume	1	kL
Initial Cell mass		g/L
Initial N	0.25	g/L
Desired ferment time	8	days
Prediction score	4.706	
Refrigeration cost	$ 11.85	

Solve Red Ferment

Refrigeration COP	2.10833
Electricity Cost ($/kWe)	0.25
Overall Tank U value (W/m2/C)	6.8

Commercial Ferment

Day	Baume – actua	Temp C	DAP additi	Mixing (0 t	Nutrient A	Pump ove	Aeration	Yeast Innoc.
0	10.3	15						
0.5	10.2	15						
1	10.1	16						
1.5	9.8	17						
2	9.5	18						
2.5	9.1	20						
3	8.2	20						
3.5	7.2	20				1		
4	6	20						
4.5	4.5	20						
5	3.4	20						
5.5	2.5	20						
6	1.6	20					1	
6.5	1	20						
7	0.5	20						
7.5	0.2	20						
8	-0.4	20						
8.5	-0.6	20						
9	-1	20						
9.5	-1	20						
10								
10.5								
11								
11.5								
12								
12.5								
13								
13.5								
14								
14.5								
15								
15.5								

Simulation model

Day	dBe/dt	Baume – I	Required F	Active Cel	Ethanol	Nitrogen	Corrected	Low range	High range
0	7.19655	10.2	0.18915	0.31997	0	0.25	15	10.2	10.2
0.5	4.59707	10.1	0.32924	0.76172	0.88816	0.21947	15	10.0973	10.0973
1	5.8843	10.0	0.20215	1.00662	1.50282	0.19868	15.2	10.0262	10.0262
1.5	3.79387	9.9	0.3122	1.3995	2.54139	0.16432	16.2	9.90607	9.90607
2	6.25709	9.7	0.19556	2.11127	4.65455	0.09893	17.2	9.66175	9.66175
2.5	4.95817	9.1	0.38256	3.1014	9.45267	0.00752	18.4	9.10754	9.10754
3	6.83319	8.1	0.31199	3.24798	18.418	0.00052	20	8.07373	8.07373
3.5	8.25308	6.8	0.45337	3.27013	29.0907	0.00101	20	6.84474	6.84474
4	15.5331	5.7	0.30966	3.29679	39.3203	0.00224	20	5.66787	5.66787
4.5	23.3564	4.6	0.41573	3.32784	48.8679	0.00409	20	4.57062	4.57062
5	33.2232	3.6	0.26716	3.35341	57.655	0.00462	20	3.56202	3.56202
5.5	40.9014	2.7	0.36742	3.35988	65.57	0.00246	20	2.65478	2.65478
6	38.7358	1.9	0.21306	3.3484	72.5035	0.00048	20	1.86116	1.86116
6.5	43.154	1.2	0.31108	3.32972	78.4222	3.2E-05	20	1.18458	1.18458
7	39.4582	0.6	0.15897	3.30907	83.3756	8.1E-07	20	0.619	0.619
7.5	41.1248	0.2	0.26202	3.28734	87.4576	9.4E-09	20	0.15336	0.15336
8	42.9535	-0.2	0.11619	3.26479	90.7823	6.5E-11	20	-0.22564	-0.22564
8.5	42.8827	-0.5	0.22589	3.24163	93.469	3.6E-13	20	-0.5318	-0.5318
9	42.7494	-0.8	0.08645	3.21801	95.632	2E-15	20	-0.77828	-0.77828
9.5	43.7029	-1.0	0.20189	3.19407	97.3734	1.4E-17	20	-0.97673	-0.97673
10	47.0905	-1.1	0.06734	3.16991	98.7795	1.2E-19	20	-1.23362	-1.04045
10.5	36.5444	-1.3	0.18679	3.14561	99.9208	1.6E-21	20	-1.36511	-1.04045
11	31.4419	-1.4	0.05544	3.12125	100.853	2.7E-23	20	-1.47295	-1.04045
11.5	28.8883	-1.5	0.17739	3.09687	101.622	6.3E-25	20	-1.56216	-1.04045
12	26.8303	-1.5	0.048	3.0725	102.259	2E-26	20	-1.63662	-1.04045
12.5	27.8894	-1.6	0.17147	3.04819	102.793	7.9E-28	20	-1.69934	-1.04045
13	25.2897	-1.6	0.04325	3.02395	103.244	4E-29	20	-1.75264	-1.04045
13.5	27.815	-1.7	0.16764	2.99981	103.627	2.5E-30	20	-1.79835	-1.04045
14	29.6405	-1.7	0.04013	2.97577	103.955	1.8E-31	20	-1.83789	-1.04045
14.5	24.4977	-1.8	0.16508	2.95186	104.239	1.6E-32	20	-1.87236	-1.04045
15	22.7527	-1.8	0.03802	2.92807	104.485	1.7E-33	20	-1.90265	-1.04045
15.5	16.6579	-1.8	0.16332	2.90443	104.701	2E-34	20	-1.92947	-1.04045

1. The Calculator allows the user to specify up to three different fermentation profiles (corresponding to Red Fermenter vessels 1-3). The worksheets Red Fermentation (1), Red Fermentation (2) and Red Fermentation (3) are used for calculation of refrigeration demand for each ferment profile.
2. The ferment trajectory for each ferment profile is entered into the appropriate baume and temperature columns for Ferment Profile 1, 2 and 3. This is exactly the same as the way ferment data is entered into the AWRI Ferment Simulator.
3. Once ferment data has been entered into each of the three ferment profiles, click on the ‘Solve Red Ferment’ button on the Red Fermentation (1) worksheet to calculate the required refrigeration demand for each ferment profile. (Note: This operation requires that the user has enabled Macros in Excel).

5. Specify Red Cold Stabilisation Conditions

Cold Stab Temperature	-4	
Start date for cold stab	31/05/2014	
Total Volume to be cold stabilized	4	kL
Cold Stab Batch Size	160	kL
Aspect ratio (ie ratio of height to diamete	2	
Heat transfer area (per tank)	137.04	m2
Number of concurrent batches	5	
Total volume per concurrent batch	800	kL
Total Heat transfer area	685.20	m2
Cooling jacket area	30.00%	(percentage of tank wall height)
Insulation area	100.00%	(percentage of tank wall height)
U (jacket region)	0.8	W/m2/C
U (rest of tank)	15	W/m2/C
Overall U	0.8	W/m2/C
Energy required to cool to cold stab temp	32076000	kJ
Efficiency	90%	
Time taken to cool to cold stab temp	7	days
Power required to cool to cold stab temp	58.928571	kW
Duration at cold stab tempeerature	28	days
Total days	35	
Required number of sequential batches	0.004375	
Wine-Wine heat exchange	0	<--- Please type 1 for "Yes" or 0 for "No"
Heat recovery	80%	
Residual power required for cold stab	58.928571	kW

1. Go to the Red Cold Stabilisation worksheet
2. Enter the Cold Stabilisation Temperature
3. Enter the Cold Stabilisation Batch Size (in kL)
4. Enter the typical number of concurrent cold stabilisation batches
5. Enter the typical time taken to cool to the cold stab temperature
6. Enter the typical duration at the cold stab temperature
7. The Calculator allows the user to simulate the impact of wine-wine heat exchange for refrigeration energy recovery during cold stabilisation. To simulate wine-wine heat exchange, enter a 1 into the blue cell labelled “Wine-Wine heat exchange”, otherwise enter a 0.

NOTE: The calculator only models a 12 month production cycle. Users should be aware that due to this limitation, cold stabilisation requirements which extend beyond the 12 month period (e.g. because there is insufficient time to complete sequential batches within the 12 month window) will not be included in the calculations.

6. Using the White Vintage Planner

E	F	G	H	I	J
	Start date	15-Jan-14			
		15-Jan-14	16-Jan-14	17-Jan-14	18-Jan-14
	White Intake (tonnes)	5	10	15	20
	Must Chill (%)	50%	50%	50%	50%
Cold settle	Cold Settle (%)	50%	50%	50%	50%
	Fermenter Type 1 (%)	40%	40%	40%	40%
	Fermenter Type 2 (%)	40%	40%	40%	40%
	Fermenter Type 3 (%)	20%	20%	20%	20%
Non-Cold Settle	Non-Cold Settle	50%	50%	50%	50%
	Fermenter Type 1 (%)	40%	40%	40%	40%
	Fermenter Type 2 (%)	40%	40%	40%	40%
	Fermenter Type 3 (%)	20%	20%	20%	20%
	Maturation Storage Type 1 (%)	50%	50%	50%	50%
	Maturation Storage Type 2 (%)	30%	30%	30%	30%
	Maturation Storage Type 3 (%)	20%	20%	20%	20%
	Cold Stabilisation (%)	95%	95%	95%	95%

1. For each date of crushing, the corresponding grape intake value (in tonnes) is entered by the user into the yellow cells.
2. The percentage of white fruit (on average) which is to be must chilled is specified in the cell G7 (colour coded blue).
3. The percentage of white fruit (on average) which is to be cold settled is specified in cell G8 (colour coded light-green). In the above example, 50% of the red fruit intake is to be cold settled.
4. The Calculator allows the user to specify up to three different white fermenter vessel designs. The percentage of *cold settled* fruit which is to be fermented in vessel 1, 2 or 3 is entered into cells G9-G11 (colour coded dark-green). In the above example, 40% of the cold settled fruit will be fermented in Fermenter Type 1, 40% in Fermenter Type 2 and 20% in Fermenter Type 3.
5. The percentage of *Non-cold settled* fruit which is to be fermented in vessel 1, 2 or 3 is entered into cells G9-G11 (colour coded dark-green). In the above example, 40% of the cold settled fruit will be fermented in Fermenter Type 1, 40% in Fermenter Type 2 and 20% in Fermenter Type 3.
6. The Calculator allows the user to specify up to three different white storage vessel designs. The percentage of white wine production which is to be stored in Maturation Storage Type 1, 2 or 3 is entered into cells G12-G14 (coloured light-purple). In the above example, 50% of white wine production will be matured in Maturation Storage Type 1, 30% of white wine production will be matured in Maturation Storage Type 2, and 20% of white wine production will be matured in Maturation Storage Type 3.

7. The percentage of white wine production which is to be cold stabilised is entered into cell G15 (coloured coded dark-purple).

7. Specify details for White Fermentation Equipment

	A	B	C	D	E
1					
2	**White Fermenter Type 1**				
3	Fermenter Capacity	14.28571429	tonnes		
4	Volume	10	kL		
5	Aspect ratio (ie ratio of height to diameter)	2			
6	Heat transfer area (per tank)	21.58	m2		
7	Cooling jacket area	30.00%	(percentage of tank wall height)		
8	Insulation area	100.00%	(percentage of tank wall height)		
9	U (jacket region)	0.8	W/m2/C		
10	U (rest of tank)	10	W/m2/C		
11	Overall U	0.0008	kW/m2/C		
12					
13	**White Fermenter Type 2**				
14	Fermenter Capacity	1.428571429	tonnes		
15	Volume	1	kL		
16	Aspect ratio (ie ratio of height to diameter)	2			
17	Heat transfer area (per tank)	4.65	m2		
18	Cooling jacket area	30.00%	(percentage of tank wall height)		
19	Insulation area	100.00%	(percentage of tank wall height)		
20	U (jacket region)	0.8	W/m2/C		
21	U (rest of tank)	10	W/m2/C		
22	Overall U	0.0008	kW/m2/C		
23					
24	**White Fermenter Type 3**				
25	Fermenter Capacity	1.428571429	tonnes		
26	Volume	1	kL		
27	Aspect ratio (ie ratio of height to diameter)	2			
28	Heat transfer area (per tank)	4.65	m2		
29	Cooling jacket area	30.00%	(percentage of tank wall height)		
30	Insulation area	100.00%	(percentage of tank wall height)		
31	U (jacket region)	0.8	W/m2/C		
32	U (rest of tank)	10	W/m2/C		
33	Overall U	0.0008	kW/m2/C		
34					
35					

1. Go to the White Fermentation Equipment worksheet.
2. For each fermenter type, enter the vessel volume in kL (into the yellow cells)
3. Enter the cooling jacket area (as a percentage of the tank wall height) into the green cells. . If barrels are to be used in a temperature controlled room (instead of using a stainless or concrete tank for fermentation), then set the 'cooling jacket area' to zero.
   [NOTE: if internal cooling coils are used in place of a cooling jacket, an equivalent 'cooling jacket area' can be calculated using the calculation box located on this worksheet. Users type in the coil length and diameter, as well as the tank heat transfer area for the tank in question. The calculation box will then give an 'Equivalent Cooling Jacket Area' value, which should then be entered by the user into the relevant 'Cooling jacket area' box (colour coded green).]
4. Enter the insulation area (as a percentage of the tank wall height) into the blue cells.
   NOTE: The default calculation assumes a stainless steel tank. If concrete tanks or barrels are to be used instead, then an insulation value of 0% should be used here. The user should also manual update the "U (rest of tank)" value as per the following:
   concrete tank: 5.75 W/m2/C
   oak barrel: 7.2 W/m2/C

8. Specify White Fermentation Profiles

		= user adjustable field
Volume	1	kL
Initial Cell mass		g/L
Initial N	0.25	g/L
Desired ferment time	14	days
Prediction score	3.178	
Refrigeration cost	$ 5.69	

Solve White Ferment

Refrigeration COP	2.10833
Electricity Cost ($/kWe)	0.25
Overall Tank U value (W/m2/C)	0.8

Commercial Ferment

Day	Baume – actua	Temp C	DAP additi	Mixing (0 t	Nutrient A	Pump ovei	Aeration	Yeast Innoc.
0	10.3	15						
0.5	10.2	15						
1	10.1	16						
1.5	9.8	17						
2	9.7	15						
2.5	9.4	15						
3	8.5	15						
3.5	8	15				1		
4	7.2	15						
4.5	6.6	15						
5	6	15						
5.5	5.5	15						
6	5	15					1	
6.5	4.5	15						
7	4.1	15						
7.5	3.7	15						
8	3.3	15						
8.5	2.9	15						
9	2.5	15						
9.5	2	15						
10	1.8	15						
10.5	1.5	15						
11	1.1	15						
11.5	1	15						
12	0.8	15						
12.5	0.5	15						
13	0.2	15						
13.5	0.1	15						
14	0	15						
14.5	-0.2	15						
15	-0.4	15						
15.5								
16								
16.5								
17								
17.5								

Simulation model

Day	dBe/dt	Baume – I	Required I	Active Cel	Ethanol	Nitrogen	Corrected	Low rang	High range
0	7.19655	10.2	0.02232	0.32802	0	0.25	15	10.2	10.2
0.5	4.59707	10.1	0.05192	0.78894	0.90492	0.21808	15	10.0953	10.0953
1	5.8843	10.0	0.04245	1.05773	1.56279	0.19527	15.2	10.0193	10.0193
1.5	3.79387	9.9	0.07144	1.49774	2.70359	0.15673	16.2	9.88732	9.88732
2	6.25709	9.6	0.10536	2.30117	5.09766	0.08257	16.6	9.61057	9.61057
2.5	4.95817	9.1	0.18534	3.1348	9.64442	0.00501	15	9.08538	9.08538
3	6.83319	8.4	0.17946	3.20019	15.2034	3E-05	15	8.44361	8.44361
3.5	8.25308	7.8	0.19002	3.19812	20.7359	1.7E-07	15	7.80501	7.80501
4	15.5331	7.2	0.16968	3.19496	26.0819	9.6E-10	15	7.18807	7.18807
4.5	23.3564	6.6	0.17888	3.19107	31.2282	5.7E-12	15	6.59427	6.59427
5	33.2232	6.0	0.15814	3.18648	36.1682	3.5E-14	15	6.02439	6.02439
5.5	40.9014	5.5	0.16702	3.18122	40.8963	2.2E-16	15	5.47906	5.47906
6	38.7358	5.0	0.14602	3.17533	45.4077	1.5E-18	15	4.95884	4.95884
6.5	43.154	4.5	0.15468	3.16884	49.6987	1.1E-20	15	4.46415	4.46415
7	39.4582	4.0	0.13354	3.16179	53.7668	8.6E-23	15	3.99526	3.99526
7.5	41.1248	3.6	0.14213	3.1542	57.6108	7.3E-25	15	3.55231	3.55231
8	42.9535	3.1	0.12099	3.14612	61.2308	6.8E-27	15	3.13526	3.13526
8.5	42.8827	2.7	0.12966	3.13757	64.6284	6.9E-29	15	2.74394	2.74394
9	42.7494	2.4	0.10868	3.1286	67.8065	7.9E-31	15	2.37797	2.37797
9.5	43.7029	2.0	0.1176	3.11924	70.7697	1E-32	15	2.03684	2.03684
10	47.0905	1.7	0.09694	3.10951	73.5236	1.5E-34	15	1.71987	1.71987
10.5	36.5444	1.4	0.10625	3.09945	76.0752	2.4E-36	15	1.42624	1.42624
11	31.4419	1.2	0.08604	3.08909	78.4328	4.4E-38	15	1.155	1.155
11.5	28.8883	0.9	0.09585	3.07846	80.6053	9.2E-40	15	0.90509	0.90509
12	26.8303	0.7	0.07618	3.06758	82.6024	2.2E-41	15	0.67539	0.67539
12.5	27.8894	0.5	0.08657	3.05649	84.4347	6.1E-43	15	0.46469	0.46469
13	25.2897	0.3	0.0675	3.0452	86.1125	1.9E-44	15	0.27176	0.27176
13.5	27.815	0.1	0.07849	3.03374	87.6468	6.7E-46	15	0.09536	0.09536
14	29.6405	-0.1	0.06002	3.02212	89.0481	2.7E-47	15	-0.06574	-0.06574
14.5	24.4977	-0.2	0.07159	3.01038	90.3269	1.2E-48	15	-0.21276	-0.21276
15	22.7527	-0.3	0.05368	2.99852	91.4932	6.4E-50	15	-0.34684	-0.34684
15.5	16.6579	-0.5	0.06579	2.98655	92.5567	3.7E-51	15	-0.53423	-0.40397
16	15.3669	-0.6	0.0484	2.97451	93.5265	2.4E-52	15	-0.64613	-0.40397
16.5	10.1224	-0.7	0.06099	2.96239	94.411	1.8E-53	15	-0.74826	-0.40397
17	10.4102	-0.8	0.04403	2.95021	95.2182	1.4E-54	15	-0.84151	-0.40397
17.5	6.95605	-0.9	0.05703	2.93798	95.9552	1.3E-55	15	-0.92674	-0.40397

1. The Calculator allows the user to specify up to three different fermentation profiles (corresponding to White Fermenter vessels 1-3). The worksheets White Fermentation (1), White Fermentation (2) and White Fermentation (3) are used for calculation of refrigeration demand for each ferment profile.
2. The ferment trajectory for each ferment profile is entered into the appropriate baume and temperature columns for Ferment Profile 1, 2 and 3. This is exactly the same as the way ferment data is entered into the AWRI Ferment Simulator.
3. Once ferment data has been entered into each of the three ferment profiles, click on the ‘Solve White Ferment’ button on the White Fermentation (1) worksheet to calculate the required refrigeration demand for each ferment profile. (Note: This operation requires that the user has enabled Macros in Excel).

9. Specify White Cold Stabilisation Conditions

Cold Stab Temperature	-4	
Start date for cold stab	31/05/2014	
Total Volume to be cold stabilized	4	kL
Cold Stab Batch Size	160	kL
Aspect ratio (ie ratio of height to diamete	2	
Heat transfer area (per tank)	137.04	m2
Number of concurrent batches	5	
Total volume per concurrent batch	800	kL
Total Heat transfer area	685.20	m2
Cooling jacket area	30.00%	(percentage of tank wall height)
Insulation area	100.00%	(percentage of tank wall height)
U (jacket region)	0.8	W/m2/C
U (rest of tank)	15	W/m2/C
Overall U	0.8	W/m2/C
Energy required to cool to cold stab temp	32076000	kJ
Efficiency	90%	
Time taken to cool to cold stab temp	7	days
Power required to cool to cold stab temp	58.928571	kW
Duration at cold stab tempeerature	28	days
Total days	35	
Required number of sequential batches	0.004375	
Wine-Wine heat exchange	0	<--- Please type 1 for "Yes" or 0 for "No"
Heat recovery	80%	
Residual power required for cold stab	58.928571	kW

1. Go to the White Cold Stabilisation worksheet
2. Enter the Cold Stabilisation Temperature
3. Enter the Cold Stabilisation Batch Size (in kL)
4. Enter the typical number of concurrent cold stabilisation batches
5. Enter the typical time taken to cool to the cold stab temperature
6. Enter the typical duration at the cold stab temperature
7. The Calculator allows the user to simulate the impact of wine-wine heat exchange for refrigeration energy recovery during cold stabilisation. To simulate wine-wine heat exchange, enter a 1 into the blue cell labelled Wine-Wine heat exchange, otherwise enter a 0.

NOTE: The calculator only models a 12 month production cycle. Users should be aware that due to this limitation, cold stabilisation requirements which extend beyond the 12 month period (e.g. because there is insufficient time to complete sequential batches within the 12 month window) will not be included in the calculations.

10. Specify conditions for must chilling, cold settling and cold soaking

RED				WHITE		
Must Chilling				**Must Chilling**		
Must Chill Flowrate	6	kL/hr		Must Chill Flowrate	6	kL/hr
	0.001667	kL/s			0.001667	kL/s
Inlet Juice Temp	25	C		Inlet Juice Temp	25	C
Outlet Juice Temp	20	C		Outlet Juice Temp	15	C
cp	3.8	kJ/kg/C		cp	3.8	kJ/kg/C
losses	15%			losses	15%	
Q	39.69417	kW		Q	79.38833	kW
Cold Soak				**Cold Settling**		
Cold Settling Duration	72	hours		Cold Settling Duration	1	hours
Cold Settling Duration	4	C		Cold Settling Duration	15	C

Go to the Must Chill Cold Settle & Soak worksheet

Go to the Basic Ferment Entry worksheet

1. Enter the must chill flow rates for both red and white production
2. Enter the typical inlet and outlet juice temperatures for red and white must chilling
3. For red production, enter the typical cold soak duration (in hours) and temperature.
4. For white production, enter the typical cold settling duration and temperature.

11. Specify Storage Conditions

Tank - Type 1		
Volume	15	kL
Aspect ratio	2	
Heat transfer area (per tank)	28.28	m2
Insulation area	35%	(percentage of tank wall height)
U (jacket region)	0.8	W/m2/C
U (rest of tank)	10	W/m2/C
Overall U	6.78	W/m2/C

Tank - Type 2		
Volume	1	kL
Aspect ratio	2	
Heat transfer area (per tank)	4.65	m2
Insulation area	35%	(percentage of tank wall height)
U (jacket region)	0.8	W/m2/C
U (rest of tank)	10	W/m2/C
Overall U	6.78	W/m2/C

Tank - Type 3		
Volume	1	kL
Aspect ratio	2	
Heat transfer area (per tank)	4.65	m2
Insulation area	35%	(percentage of tank wall height)
U (jacket region)	0.8	W/m2/C
U (rest of tank)	10	W/m2/C
Overall U	6.78	W/m2/C

White Wine		
Storage Temperature	5	C
Storage duration	34	weeks

Red Wine		
Storage Temperature	10	C
Storage duration	40	weeks

1. Additional fields are also provided for users to enter comments, or additional analysis results conducted during fermentation, as well as text fields for yeast and wine type, variety and product description. This information also is optional as it is not used by the simulator for calculating the prediction.
2. Go to the Wine storage worksheet
3. The Calculator allows the user to specify up to three different storage vessel designs. This worksheet is where equipment details such as volume and insulation are provided.
4. For each of the three tank types (Tank Type 1, Tank Type 2 and Tank Type 3) enter:
    a. Volume in kL
    b. Insulation area (as a percentage of the tank wall height)
5. Enter the maturation storage temperature and duration for both white and red wine production into the highlighted fields as shown.

12. Specify Storage Conditions

B	C	D	E	F	G	H	I	J	K	L	M	N	O
Climate Data - sourced from www.bom.gov.au													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Mean Max (°C)	33.1	32.2	28.9	23.9	19.3	15.4	14.4	16.6	19.9	23.8	28.1	30.7	
Mean Min (°C)	17.3	17.2	14.3	10	7.2	4.5	3.4	3.8	6	9	12.8	15.1	
Average Ambient	25.2	24.7	21.6	17.0	13.3	10.0	8.9	10.2	13.0	16.4	20.5	22.9	
Average Daily Solar Radiation (MJ/m2)	30	24	21	18	15	12	12	15	24	30	30	33	
	27	21	18	15	12	9	9	12	21	27	27	30	
Average Daily Solar Ratiation - Average (MJ/m2)	28.5	22.5	19.5	16.5	13.5	10.5	10.5	13.5	22.5	28.5	28.5	31.5	
Sunrise (15th)	6:19:00	6:50:00	7:15:00	6:39:00	7:02:00	7:20:00	7:19:00	6:54:00	6:14:00	6:33:00	6:02:00	5:58:00	
Sunset (15th)	20:30:00	20:08:00	19:34:00	17:52:00	17:22:00	17:12:00	17:24:00	17:45:00	18:07:00	19:29:00	19:58:00	20:24:00	
daylight hours	14.2	13.3	12.3	11.2	10.3	9.9	10.1	10.9	11.9	12.9	13.9	14.4	
Flux average (daylight hours)	558.166863	469.9248	439.7835	408.6181	362.9032	295.6081	289.2562	345.6221	525.9467	612.1134	568.1818	606.23557	kW/m2
Solar Loading													
average insulation	67.50%												
	alpha_sun	alpha_ambient											
white	0.12	0.9											
stainless steel	0.37	0.6											
average	0.20125	0.8025											
# of tanks North-South	20												
# of tanks East-West	10												
% area	7.3%												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Tsurface	46.1631207	42.69867	39.0162	33.93655	29.01099	23.39281	22.20749	25.70763	35.11419	41.00876	42.66409	45.94369	
Weighted ambient	26.7198262	26.0049	22.86267	18.18152	14.39267	10.9246	9.864793	11.3243	14.5569	18.18414	22.06052	24.570668	

1. Go to the Climate & Solar Loading worksheet.
2. The Calculator takes ambient temperature max/min data into account when modelling refrigeration demand requirements. This worksheet is where the user would enter information on average monthly max/min temperature data and solar radiation relevant to their geographical location. If the winery is located inside a building, then the monthly max/min temperature values relevant to that building should be used instead of the outside ambient temperatures.
3. Average max and min temperature data and solar flus for the user's location is entered into the highlighted fields as shown (This information can be accessed from www.bom.gov.au however the default values shown in the calculator should be appropriate for most users.)
4. Solar radiation of the tank farm is accounted for by entering the number of tanks in the North-South and East-West directions.
   NOTE: if tanks are located inside or under cover, then solar loading should not be applied to the calculations. In this case, the number of tanks North-South and East-West should each be set to zero. This will in effect turn off the solar loading component of the calculations.

13. Specify Refrigeration Plant Conditions

	A	B	C	D
1				
2	**Brine tank**			
3	Brine Tank volume	20	kL	
4	Aspect Ratio	2		
5	diameter	2.335089	m	
6	height	4.670177	m	
7	Area	34.25994	m2	
8	# of brine tanks	1		
9	Total Area	34.25994	m2	
10				
11	**Temperature Maintenance of Brine Tank**			
12	Brine Temp	-7		
13	U	0.8	W/m2/C	
14	Tank Surface Area	34.25994	m2	
15				
16				
17	**Refrigeration Specs**			
18	Temp	COP		
19	-8	2.05	2.05	
20	4	2.75	2.75	
21				
22	slope	0.058333		
23	intercept	2.516667		
24				
25	Refrigeration COP	2.1		
26	Average Electricity Cost (usage + network/dist)	0.25	$/kWh	

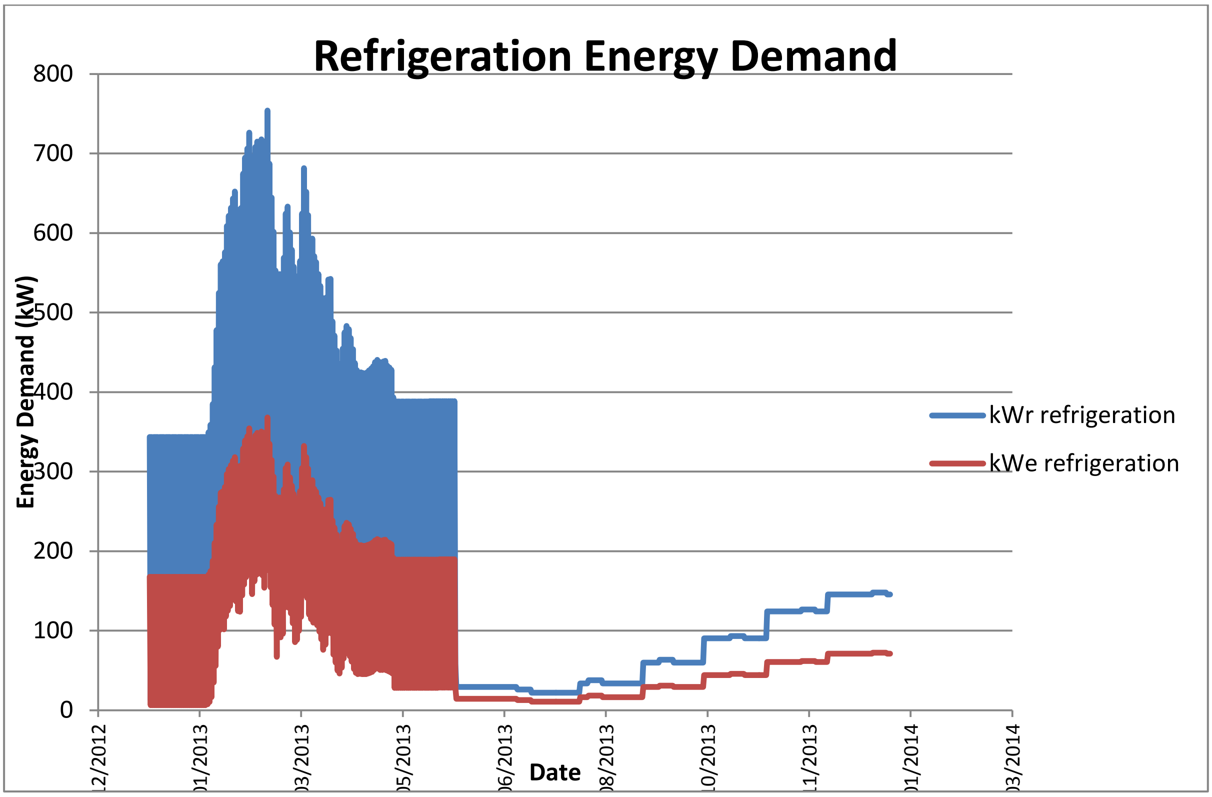
1. Go to the Brine and COP worksheet.
2. This worksheet is where information relating to brine temperatures and brine storage tank volume is entered. If the site employs the use of cold rooms then this information is captured on this worksheet also.
3. Enter the brine tank volume (in kL) and brine temperature set point into the yellow cells as shown.

Heat loss from brine lines		1	2	3	4	5	6	7	8	9	10	11	12
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average ambient Temp	C	26.719826	26.00490385	22.86267465	18.18152	14.392672	10.9246	9.8647929	11.3243	14.5569	18.18414	22.06052158	24.5706675
Brine Temp		-7	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7
U	W/m2/C	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Total length of brine lines	m	200	200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00	200.00
Diameter of brine lines	m	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075
Heat transfer area (total)	m2	47.12	47.12	47.12	47.12	47.12	47.12	47.12	47.12	47.12	47.12	47.12	47.12
Q	kWr	4.7670281	4.665958356	4.221736169	3.559954	3.0243177	2.534031	2.3842039	2.590537	3.047535	3.560323	4.108334449	4.46319797

Heat loss from cool building		1	2	3	4	5	6	7	8	9	10	11	12
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average ambient Temp	C	26.719826	26.00490385	22.86267465	18.18152	14.392672	10.9246	9.8647929	11.3243	14.5569	18.18414	22.06052158	24.5706675
Room Temp		17	17	17	17	15	8	8	8	8	8	17	17
L	m	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
W	m	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
H	m	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Volume	m3	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
U (insulated)	W/m2/C	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
U (uninsulated)	W/m2/C	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00
% insulated	%	80%	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Overall U	W/m2/C	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20	3.20
Air density	kg/m3	1.2041	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
Air change per day		3	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
Mass of air changed per day	kg	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Specific Heat of Air	kJ/kg/C	1.012	1.012	1.012	1.012	1.012	1.012	1.012	1.012	1.012	1.012	1.012	1.012
Heat transfer area (total)	m2	-	-	-	-	-	-	-	-	-	-	-	-
Q	kWr	0	0	0	0	0	0	0	0	0	0	0	0

4. Heat losses from brine lines are also calculated. The total length of brine lines, as well as the brine line diameter (in m) should be entered into the yellow fields as shown.
5. The insulation U value for the brine lines should also be entered as follows:
    a. Completely insulated brine lines: 0.5 W/m2/C
    b. Partial insulation or old/deteriorating/minimal insulation: 3.0 W/m2/C
    c. PVC pipes: 5.0 W/m2/C
    d. Uninsulated steel: 10 W/m2/C
6. If the site uses a cold room then the losses from this can also be calculated on this worksheet. The room temperature set point and dimensions should be entered into the yellow fields as shown.

14. Results



1. Go to the Demand Chart worksheet.
2. This screen gives a graphical representation of the demand in both $kW_{refrigeration}$ and $kW_{electrical}$ throughout the entire year. Key features of this graph will typically be demand peaks for white and red production during vintage, as well as required demand for cold stabilisation.
3. Note the increasing steps in demand in the second half of the year. This is associated with cold stabilisation across that period, with increasing month-on-month demand due to the increase in ambient temperatures over that period.
4. Go to the Demand and Usage worksheet.
5. Maximum demand and total usage values are given at the bottom of the worksheet as shown on the following page.

	A	B	C	D	E	F
707		18/12/2013 21:00	276.0347002	127.4006	1528.808	
708		19/12/2013 9:00	276.0347002	127.4006	1528.808	
709		19/12/2013 21:00	276.0347002	127.4006	1528.808	
710		20/12/2013 9:00	276.0347002	127.4006	1528.808	
711		20/12/2013 21:00	276.0347002	127.4006	1528.808	
712		21/12/2013 9:00	276.0347002	127.4006	1528.808	
713		21/12/2013 21:00	276.0347002	127.4006	1528.808	
714		22/12/2013 9:00	276.0347002	127.4006	1528.808	
715		22/12/2013 21:00	276.0347002	127.4006	1528.808	
716		23/12/2013 9:00	278.410493	128.4972	1541.966	
717		23/12/2013 21:00	278.410493	128.4972	1541.966	
718		24/12/2013 9:00	278.410493	128.4972	1541.966	
719		24/12/2013 21:00	278.410493	128.4972	1541.966	
720		25/12/2013 9:00	278.410493	128.4972	1541.966	
721		25/12/2013 21:00	278.410493	128.4972	1541.966	
722		26/12/2013 9:00	278.410493	128.4972	1541.966	
723		26/12/2013 21:00	278.410493	128.4972	1541.966	
724		27/12/2013 9:00	278.410493	128.4972	1541.966	
725		27/12/2013 21:00	278.410493	128.4972	1541.966	
726		28/12/2013 9:00	278.410493	128.4972	1541.966	
727		28/12/2013 21:00	278.410493	128.4972	1541.966	
728		29/12/2013 9:00	278.410493	128.4972	1541.966	
729		29/12/2013 21:00	278.410493	128.4972	1541.966	
730		30/12/2013 9:00	276.0347002	127.4006	1528.808	
731		30/12/2013 21:00	276.0347002	127.4006	1528.808	
732		31/12/2013 9:00	276.0347002	127.4006	1528.808	
733		31/12/2013 21:00	276.0347002	127.4006	1528.808	
734						
735		Total Usage (Refrigeration)			419639.9	kWh
736		Max Demand	1108.738002	511.7252		kW
737						
738		Site Total			969356.4	kWh
739						
740		Refrigeration %			43.3%	
741						
742						

6. Enter the site annual total electricity consumption in the yellow field as shown.
7. The Calculator will then display the refrigeration energy use as a percentage of total site electricity use. This value would typically range from 40-60%, depending on the proportion of insulated tanks and whether the site total includes energy use for wine packaging equipment, offices etc.
8. Now that production information has been entered into the Calculator, the user can adjust different parameters to evaluate their impact on refrigeration costs for their winery: eg brine temperature, insulation coverage, tank size, wine-wine heat exchange, cold stab conditions etc

15. Improvement Opportunities – an example

As an example of how this tool can be used to identify improvement opportunities, compare figures A and B below for a hypothetical large winery.

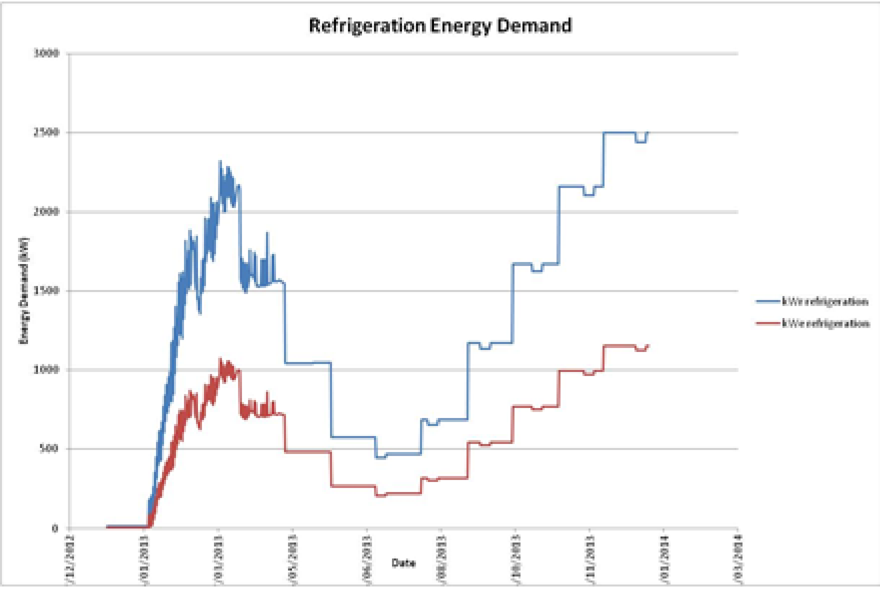


Figure A – Refrigeration demand without tank insulation

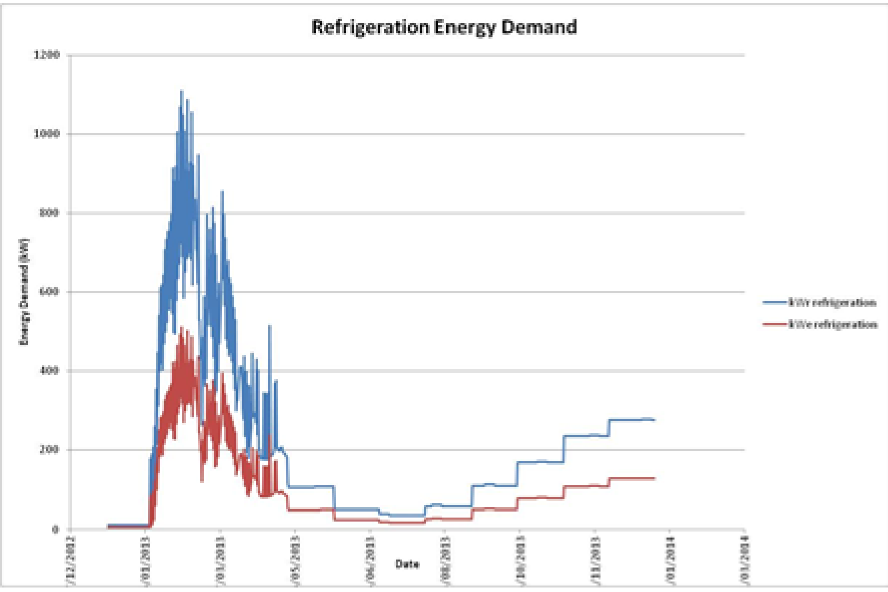


Figure B – Refrigeration demand (in the same winery) with tank insulation

Of particular note is that the refrigeration demand for cold stabilisation (in the second half of the year) is significantly higher when insulated tanks are not used. In this hypothetical case study, this winery would see a reduction in refrigeration electricity consumption of 83%, representing a saving of approximately $1 million using typical industrial electricity cost metrics.