CARBON EMISSIONS, ENERGY, WATER AND MALT – THE JOE WHITE MALTINGS PERSPECTIVE

G Hughes, A Marafioti, D Hill, A Cox, M Sheehy, D Stewart
Joe White Maltings, 124-130 South Terrace, Adelaide, South Australia 5000

ABSTRACT

Environmental impact and sustainability are now key areas of concern for all businesses, with increasing pressure to be more accountable for energy and resource usage. The concept of a carbon footprint is to capture all carbon emissions associated with generation of a product stream. A carbon footprint is often expressed as CO_2 equivalents (usually in kilograms or tonnes), which accounts for the global warming effects of different greenhouse gases.

This paper explores the potential to reduce the carbon footprint of Joe White Maltings (JWM) plants in Australia. The study aims to challenge the concept of traditional malting practices, to see how far the boundaries can be pushed in order to achieve a meaningful reduction in energy usage. A number of scenarios were investigated, including altering the malting program, changing in-process target parameters, alternative malt styles and the impact of different barley varieties. The most readily achievable means of decreasing the carbon footprint of the malting process is increasing the final malt moisture to at least 6% or 7%. Future work will involve considering the impact of technical challenges posed by process conditions that successfully reduce the carbon footprint and can these challenges be overcome to produce high quality malt for the brewing and food industry.

Keywords: ***carbon footprint, malting and utility reduction***

INTRODUCTION

Joe White Maltings has eight malthouses with at least one malthouse in every state of Australia and produces around 500 000 metric tonnes (mT) of malt per annum for the domestic and export market. It has been long recognised that the malting process is an energy intensive process requiring electricity to run motors, cooling plants and fans and gas or other fuel sources, for kilning. As a substantial energy user, the malting industry needs to carefully look for opportunities to reduce energy use to remain environmentally sustainable.

In addition to Joe White Malting's desire to be a good corporate citizen there are also financial drivers. Firstly, the direct savings that can be realised through energy reduction and secondly, pressure from an Australian Federal Government initiative that will see the introduction of a carbon emissions tax, with a recently introduced target of 5% reduction of CO_2 by 2020.

The aim of this paper is to recognise and quantify the carbon emissions associated with generation of malt, known as a carbon footprint. A series of scenarios are also discussed involving the modification of typical malting parameters and how these changes impact on the carbon footprint of the malting process. This paper limits the carbon footprint for the production of malt to the malting process itself and does not take into consideration the upstream barley or downstream beer situation.

RESULTS and DISCUSSION

The carbon footprint of various JWM malthouses

Three JWM malthouses are compared in this section to provide a snapshot of the company's carbon footprint. A summary is provided in **Table I**.

- Plant 1 - Port Adelaide 'Limited/Older Technology'. The Port Adelaide Plant is an older malthouse with a gas fired kiln and limited energy saving technology in place.
- Plant 2 – Tamworth 'Older Technology/Alternate Energy Source'. Tamworth is an older malthouse with a coal-fired kiln with some energy saving technology in place.
- Plant 3 – Perth 'Modern Design'. Perth is a malthouse that employs modern design incorporating energy saving features.

TABLE I
A comparison of the Port Adelaide, Tamworth and Perth malthouses

Plant Location	Capacity (mT)	Design	Plant components/processes that have an impact on energy usage
Port Adelaide	80 000	Germination Kiln 60% Drums 40%	No kiln heat recovery system Square kiln No recirculation on GK boxes
Tamworth	45 000	Saladin Box 50% Drums 50%	Coal usage, which has a higher carbon tax implication Square kiln No kiln heat recovery system No recirculation on drum kilns
Perth	200 000	Circular Germination Vessel	Kilns are fitted with an efficient control and data logging system which includes direct control over approach air temperature (heating), fan speed (air velocity) and proportion of recirculation. Circular kiln is approximately 98% heat efficient with glass tube heat recovery which uses 23% less energy per tonne of malt Shallow kiln bed design

The processes that will be measured to determine the carbon footprint of each plant are germination, kilning, refrigeration, product handling and malt cleaning; with the carbon comparison determined in carbon tonnes per day as well as mT of carbon per mT of malt. Electricity usage is spread across all four production components, whereas gas and coal usage are effectively limited to kilning.

One tonne of CO_2=AxE.F/1,000, where A is energy usage and E.F. is the energy efficiency factor used to convert an energy value into mT of CO_2.

Table II provides the breakdown of energy use for the Port Adelaide plant. The data indicates that the single most energy demanding process is kilning with 71.8% of the total CO_2 produced during this final malting process. Similarly, kilning produced the majority of the CO_2 at both Tamworth and Perth, with 65.6% and 65.4% of the CO_2 emissions, respectively (**Tables III, IV**).

The two older plants have a similar carbon footprint, at 0.35 and 0.41 mT of CO_2 per mT of malt for Port Adelaide and Tamworth, respectively. On the other hand, Perth with its energy efficient modern design has a considerable lower carbon footprint at 0.26mT of CO_2 per mT of malt (**Tables II, III, IV**) (***Figs. 1, 2, 3***).

TABLE II
Port Adelaide Plant energy breakdown

PORT ADELAIDE (LIMITED/OLDER TECHNOLOGY)				
Production Malt mT / year	**Annual Electricity (KWh)**		**Annual Gas (Gj)**	**Total mT CO_2 / mT malt**
77,684	**12,123,518**		**291,800**	**0.35**
ELECTRICITY				
PLANT PROCESS	**% Usage**	**KWh / Day**	**mT CO_2 / day**	**mT CO_2 / mT malt**
Germination	29	9,766	8.2	0.04
Kilning	45	15,154	12.7	0.06
Refridgeration	12	9,082	7.6	0.04
Product handling / Cleaning	14	4,715	4.0	0.02
		TOTAL	**32.5**	**0.15**
GAS				
PLANT PROCESS	**% Usage**	**Gj/Day**	**mT CO_2 / day**	**mT CO_2 / mT malt**
Kilning	99	803	41.2	0.19
Other	1	9	0.4	0.002
Indirect scope 2 (June 2008)			1.0	0.005
		TOTAL	**42.6**	**0.20**
	GAS / ELEC TOTAL		**75.1**	
	Total mt CO_2 / malt mt			**0.35**

TABLE III
Tamworth Plant energy breakdown

TAMWORTH (ALTERNATE FUEL SOURCE)				
Poduction Malt mT / year	**Annual Electricity (KWh)**		**Annual Gas (Gj)**	**Total mT CO_2 / mT malt**
44,153	**7,568,316**		**175,593***	**0.41**
*** Coal GI conversion**				
ELECTRICITY				
PLANT PROCESS	**% Usage**	**KWh / Day**	**mT CO_2 / day**	**mT CO_2 / mT malt**
Germination	29	6,097	5.4	0.04
Kilning	45	9,460	8.4	0.07
Refridgeration	12	5,046	5.0	0.04
Product handling / Cleaning	14	2,943	4.0	0.03
		TOTAL	**22.8**	**0.19**
COAL				
PLANT PROCESS	**% Usage**	**Gj/Day**	**mT CO_2 / day**	**mT CO_2 / mT malt**
Kilning	99	483	24.8	0.20
Other	1	49	2.5	0.02
Indirect scope 2 (June 2008)			0.6	0.00
		TOTAL	**27.8**	**0.22**
	GAS / ELEC TOTAL		**50.6**	
	Total mT CO_2 / malt mT			**0.41**

TABLE IV
Perth Plant energy breakdown

PERTH (MODERN PLANT)				
Poduction Malt mT / year	**Annual Electricity (KWh)**		**Annual Gas (Gj)**	**Total mT CO_2 / mT malt**
190,437	**21,460,070**		**488,782**	**0.26**
ELECTRICITY				
PLANT PROCESS	**% Usage**	**KWh / Day**	**mT CO_2 / day**	**mT CO_2 / mT malt**
Germination	30	17,883	15.6	0.03
Kilning	40	23,845	20.7	0.04
Refridgeration	15	17,883	15.6	0.03
Product handling / Cleaning	15	9,942	8.7	0.02
		TOTAL	**60.6**	**0.12**
GAS				
PLANT PROCESS	**% Usage**	**Gj/Day**	**mT CO_2 / day**	**mT CO_2 / mT malt**
Kilning	99	1,344	69.0	0.13
Other	1	136	7.0	0.01
Indirect scope 2 (June 2008)			0.5	0.00
		TOTAL	**76.5**	**0.14**
	GAS / ELEC TOTAL		**137.1**	
	Total mT CO_2 / malt mT			**0.26**

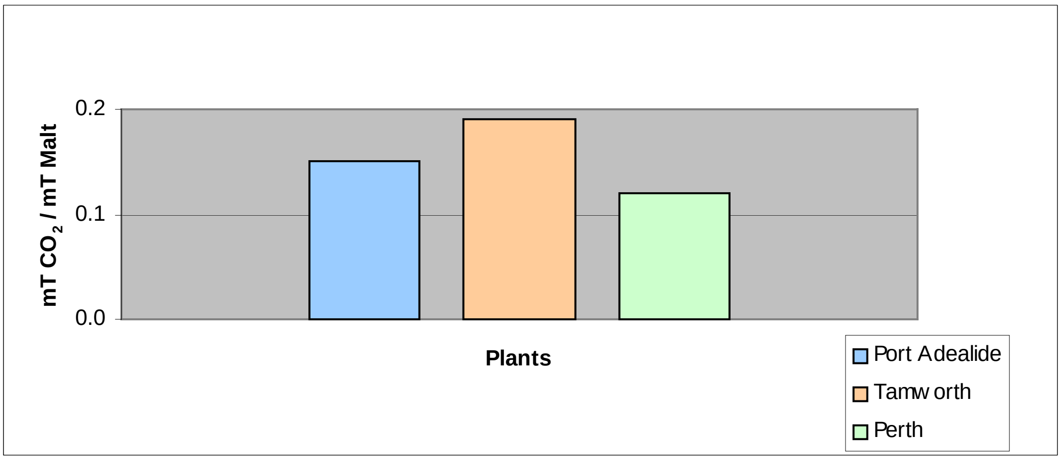

Fig. 1 Electricity usage per plant per mT of malt as CO_2 equivalents

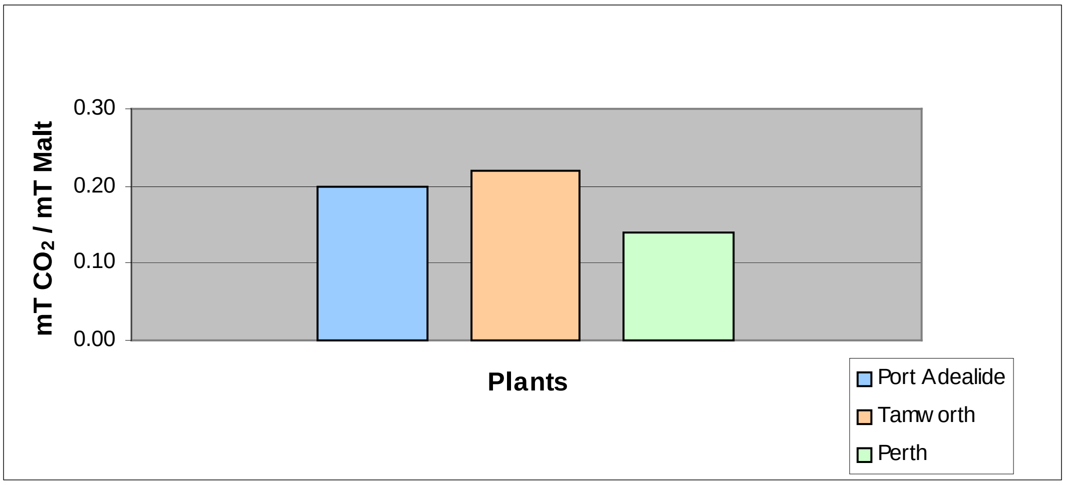

Fig. 2 Gas/coal usage per plant per mT of malt as CO_2 equivalents

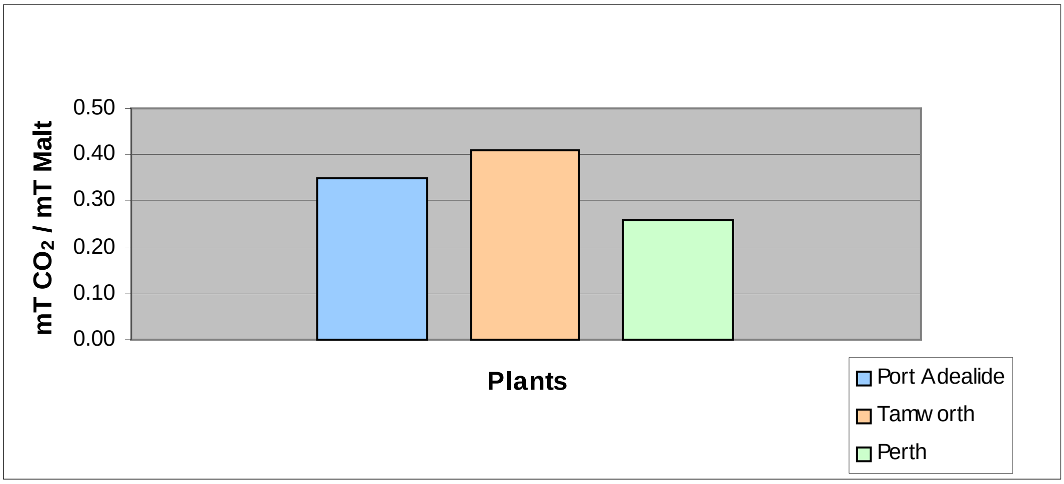

Fig. 3 Combined electricity and gas/coal usage per plant per mT of malt as CO_2 equivalents

Two points can be drawn from the data above. Firstly that energy saving improvements have a considerable effect on the carbon footprint of a malthouse and secondly to make further improvements in reducing the carbon footprint, the high energy demand kilning step needs to be targeted.

Decreasing the Carbon Footprint – A series of Scenarios

In order to make a substantial reduction in the carbon footprint of a malthouse it is necessary to challenge the currently accepted malting practice to identify potential reductions in carbon emissions. It is of course a possibility that these changes to processes will be unacceptable to the maltster or brewer, but should be investigated nonetheless. The acceptance of these changes must of course be considered in the context of the global environment and what seems unacceptable today, may be far more palatable in 10 years time.

1. Decreased germination time

This study examines potential energy savings from reducing germination time of a typical four-day process down to three or even two days. **Table V** and ***Fig. 4*** indicate the potential savings from reduced germination time, being a simple function of daily electricity usage for refrigeration and fans. Reducing germination by just one day represents a reduced carbon footprint of 7.8% for Adelaide, 7.7% for Tamworth and 8.2% for the Perth plant.

Substantial changes would however be required to produce quality malt with only two or even three days of germination. The type of strategies that could be employed could include:

- using high vigour barley varieties. Presently Australian varieties such as Baudin and Flagship may be somewhat successful, however targeted breeding would be required to produce barley varieties that are suitable.
- the use of gibberelic acid.
- modified steeping conditions, such as a pre-steep step, may be useful.

The adoption of a strategy to reduce the number of germination days would come at a considerable decrease in production capacity and subsequently financial cost, as Joe White Maltings' plants are currently configured for four days of germination.

TABLE V

CO_2 emissions for the standard four-day germination *vs.* three and two-day scenarios

Plant	mT of CO_2 / day of germination	mT of CO_2 for 4 days of germination	mT of CO_2 for 3 days of germination	mT of CO_2 for 2 days of germination
Pt Adelaide	8.2	32.8	24.6	16.4
Tamworth	5.4	21.6	16.2	10.8
Perth	15.6	62.4	46.8	31.2

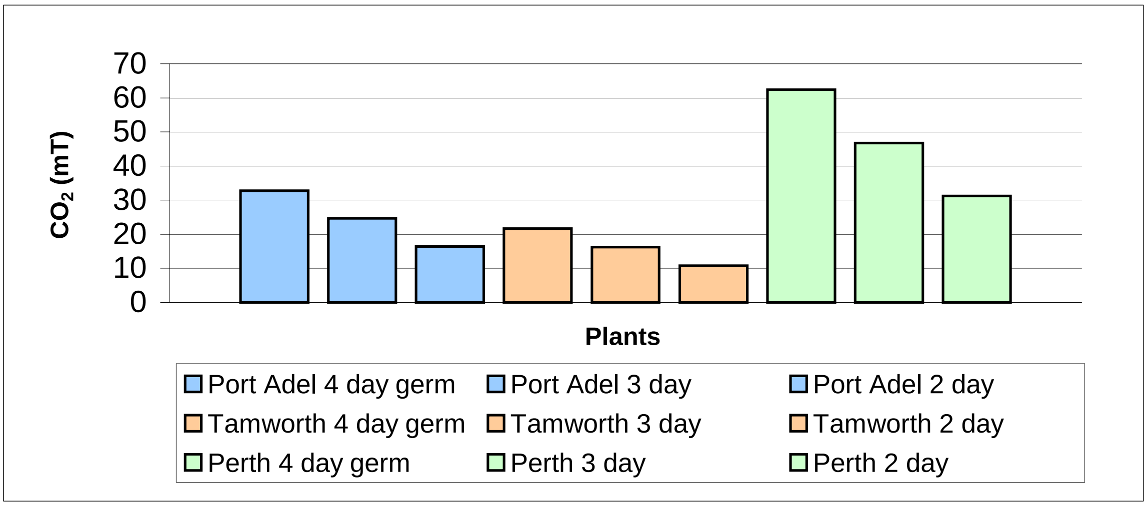

***Fig. 4** CO_2 emissions (mT of CO_2) for the standard four-day germination vs. three and two-day scenarios*

2. Lower green malt moisture to kiln

The typical final moisture of green malt on the fourth day of germination prior to kilning is approximately 42%. A reduction in the carbon footprint for malting may be achieved by altering the malting programme to attain moisture of 38% prior to kilning, whilst still fully modifying the green malt and hence not compromising malt quality, as malt moisture is strongly related to physical grain modification. Through this action there is a 4% reduction in the amount of moisture needed to be driven from the grain and subsequently a reduction in electricity to drive fans and gas (or coal) for kiln burners (or boilers).

To determine the energy saving, the difference in energy can be calculated using standard kilning curves (***Fig. 5***). In simple terms, the difference between the line at 38% (theoretical moisture) and the line at 42% (typical moisture from the Perth plant) represents the energy saved. This difference was calculated using mathematical modelling and represents a saving of 11% of kiln energy usage per batch which translates to a saving of 9.9 mT of CO_2 and a 7.2% reduction of the overall carbon footprint.

It is assumed that similar savings would be realised at most malt plants if the assumption that the drying dynamic is used.

At present, however, Australian barley varieties are not suited to reduced green malt moisture and targeted breeding would be required to produce varieties that are suitable[1].

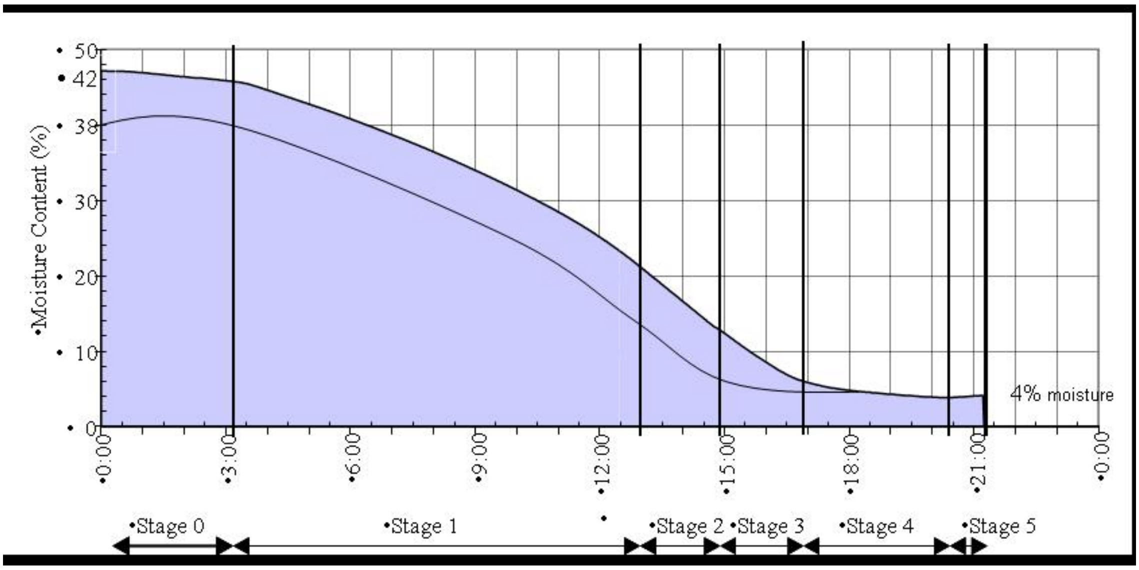

Fig. 5 Kiln bed moisture content curve

3. Higher final moistures

Another means of reducing the carbon footprint of the malting process would be to increase the final malt moisture value. Since kilning is the most energy consuming process of malting it is conceivable that increasing the final malt moisture to 5%, 6% or 7% rather than a more typical 4% may deliver considerable energy savings. By increasing final target moistures, energy is saved during the curing stage 4 (***Fig. 6***) that starts at 17 hours into the process for a typical kiln. At this stage the gas burners are reduced to 50% output and fans are reduced to 75% output.

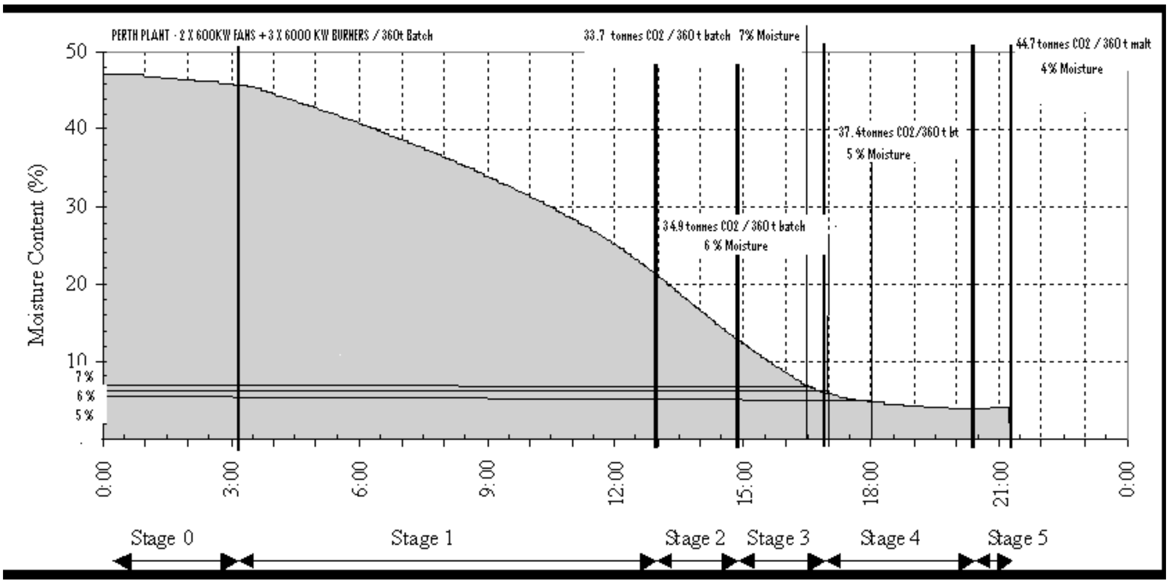

Fig. 6 Kiln Bed Moisture Content Curve

A relatively simple approach was used to calculate the carbon footprint of the various final malt moisture scenarios. ***Fig. 6*** shows that by extrapolating 5%, 6% and 7% moistures across a kiln moisture area curve, the completion of kilning at 18, 17 and 16.5 hours respectively was determined. These values can then be used to determine the energy savings corresponding to the various final moistures. Below is a sample calculation for 5% final moisture in comparison to typical 4% final moisture. The same calculations were used for the other moisture levels. This calculation is for a 360mT batch as per the Perth plant.

Sources of energy during kilning = (2 x 600kW fans) + (3x6,000kW burners)
4 % final moisture
Total kiln time = 21 hours
Fans kWh = 15,090
Gas Gj = 866
CO_2 tonnes/360mT batch = 44.7
The above data was obtained from a table titled: Perth kiln energy relative to green malt and final malt moisture in CO_2 mT/360mT batch)

Extrapolating from the curve to give a 5% final moisture gives a kiln time of 18 hours.
Kiln time difference = 21-18 hours = 3 hours

Electricity used in the 3 hours
1,200kW (2x600kW fans) x 3 hours x 0.75 = 2,700 kWh
CO_2/mT = A x E.F/1000
= 2,700x0.87/1000
= 2.35mT CO_2 / 360mT batch

Gas used in the 3 hours
18,000kW (3x600 burners) x 3.6 (conversion kW to Mj) x 3 hours x 0.5
= 97,200 Mj
= 97 Gj
CO_2/tonne = 97x51.3/1000
= 4.98mT CO_2/360t batch

Total CO_2/mT = Electricity + Gas = 2.35+4.98=7.33mT CO_2

If 44.7 tonnes CO_2/360mT batch is needed to produced malt with 4% final moisture during a kiln time of 21 hours then malt with a final moisture of 5% would need 44.7-7.33=37.4mT CO_2/360mT batch.

TABLE VI

The energy required to achieve various final moisture values for the Perth plant

Moisture	Process Hours	Reduced Kiln hours	FANS kWh	GAS Gj	mT of CO_2 / 360mT batch
4%	21	0	15090	866	44.7
5%	18	3	12390	769	37.4
6%	17	4	11490	736	34.9
7%	16.5	4.5	11040	720	33.7

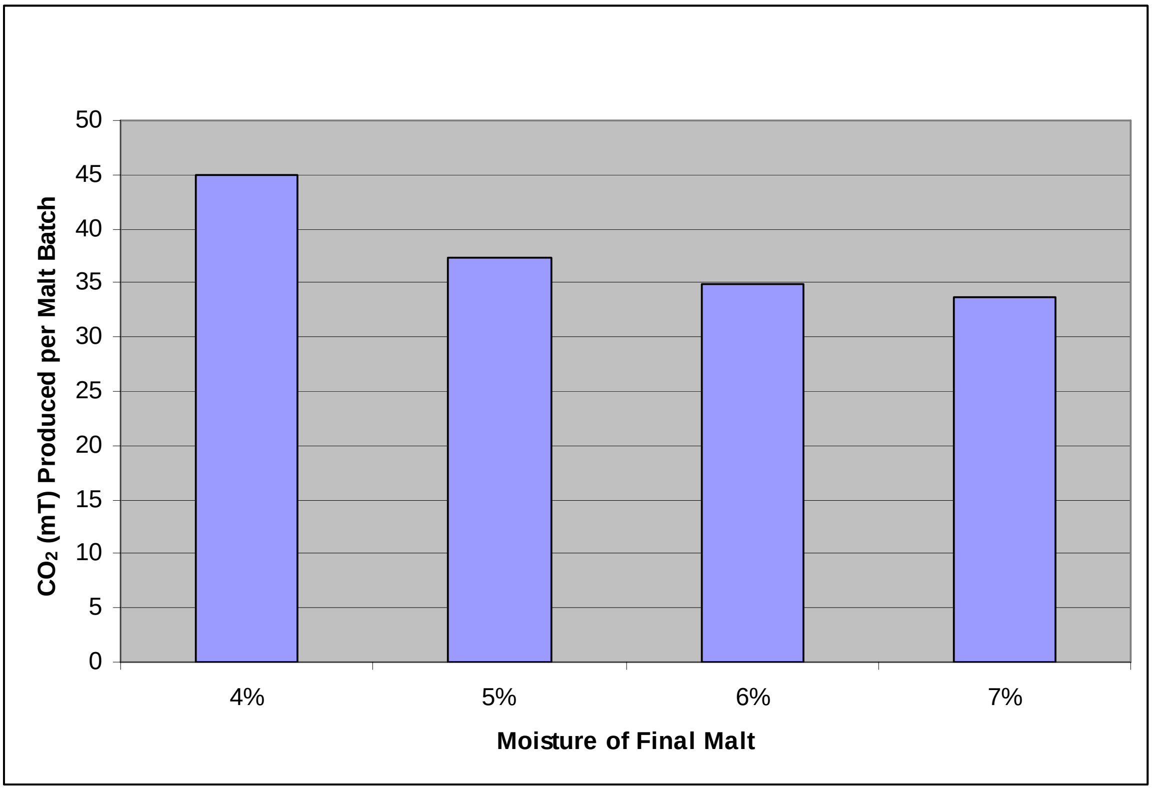

***Fig. 7** The amount of CO_2 produced during kilning to produce a malt batch with a final moisture of 4, 5, 6 and 7*

As demonstrated by ***Fig. 7***, a disproportionately high amount of energy is required to remove moisture from the grain at lower moisture values. **Table VI** and ***Fig. 7*** indicate that by increasing the final moisture of the malt, energy usage and therefore carbon emissions, can be reduced. For example, approximately 17% energy from kilning can be saved by increasing the final moisture from 4% to 5% and 25% of the carbon emissions for the kilning process can be saved at 7% moisture relative to the typical value of 4%, with a 16.3% reduction in the overall carbon footprint for the Perth plant. It is expected that similar savings would be achieved in all malthouses, which translates to an overall reduction of 17.9% for the Port Adelaide and 16.4% the Tamworth plant's carbon footprint, respectively.

Of the three means of reducing the carbon footprint of the malting process, only increasing the final malt moisture content is readily achievable without the need for barley variety development, or incurring production or financial penalties – subject to brewer acceptance. Potentially malt with increased moisture as a result of reduced curing may have elevated levels of DMS, increased enzyme levels, reduced colour and potentially reduced flavour and aroma as such compounds that contribute to flavour and aroma are formed during the curing phase of kilning. These modifications to the malt character may or may not have an impact on malt performance depending on the individual brewery.

Producing malt with increased moisture content is an effective means of reducing the carbon footprint of the malting process as demonstrated above. However the higher moisture content will require additional malt to be shipped to a brewer to make the same amount of beer and the carbon footprint of this additional malt transport needs to be taken into consideration. A typical container vessel with a capacity of around 4200 containers produces approximately 7,500mT of CO_2 on a voyage from Perth to Singapore. For a 50,000mT consignment of malt, an additional 3% malt will be required to be shipped to make up for the difference between 7% and 4% malt moisture. This equates to 1,500mT of malt which has a carbon footprint of 390 mT of CO_2. Further, the shipping of the additional 1,500mT needs to be taken into consideration. The 1,500mT of malt equates to approximately 85 containers, which represent 2% of the capacity of the vessel, equating to 150mT of CO_2. In comparison, the energy savings on 50,000mT of malt at 7% moisture vs. the typical 4%, equates to 1,528mT of CO_2, clearly indicating that the additional malt production and transport requirement of higher moisture has a limited impact on the CO_2 savings. **Table VII** provides a summary of the three different carbon footprint reducing scenarios.

TABLE VII
Summary of potential reduction to the carbon footprint of the malting process

	Carbon Footprint Reduction (%)		
Plant	**Reduced germination (3 days)**	**Lower moisture to kiln**	**Higher final malt moisture**
Port Adelaide	7.8	7.9	17.9
Tamworth	7.7	7.2	16.4
Perth	8.2	7.2	16.3

CONCLUSION

The adoption of energy saving practices is being driven by both financial requirements and environmental sustainability. As demonstrated by the comparison of three JWM malthouses, plants that invest in energy saving technology have a reduced carbon footprint. There are many ways to decrease the carbon footprint of the malting process, with three of those discussed in this paper. Of the three methods discussed, only increasing the final malt moisture is a significant and readily achievable means of substantially decreasing the carbon footprint of the malting process.

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