Future vision – expected impacts of climate change on intensive horticulture.

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Summary

This paper is primarily about change. It is written for the audience of the Australian Hydroponics and Greenhouse Association Conference, and assumes that a higher than average proportion of such an audience will be prepared to consider change. This is because growers who attend such conferences are more likely to consider their enterprises primarily as businesses, as well as farms. To quote the business academic Peter Drucker, "The entrepreneur always searches for change, responds to it, and exploits it as an opportunity."

The paper provides some context for the changes, as well as the implications and a range of response, in terms of risks and opportunities. More specifically, it focuses on change in relation to the climate itself or to changes in climate policy

Regarding the first area - changes in the climate itself - in many ways the greenhouse industry is uniquely placed to manage these. The industry is already based on technology that enables it to manage the climate (or at least the series of microclimates within a greenhouse structure).
Regarding changes in government policy, there is currently enormous uncertainty as to the exact form this will take and how this will affect agricultural producers.

A framework is provided to assess responses that may be required from greenhouse growers in terms of:
(i);Mitigation (reducing the impact of the changes);
(ii) Adaptation to the changes; and
(iii) Responding to changes in market behaviour.
This three-way framework enables growers and other investors in the industry to assess and manage the potential risks and opportunities. As such, it aims to be of value, whatever the views held by readers regarding either climate change itself or related policy.

The issue of climate change is one of enormous scope and complexity. This paper takes a very narrow slice of this and aims to highlight some areas of the subject that are particularly relevant to the greenhouse cropping industry. The scope does not allow for detailed explanations of the various aspects of climate change, but a very brief background to scientific opinions, policy responses and consumer reactions to climate change is included.

Context

1. Climate Change Itself

Governments across a range of political persuasions around the world are attempting to mitigate (reduce) and adapt to, or prepare for, climate change. In addition, they are continuing to collaborate in examining emerging data on the multiple factors that are believed to affect the Earth's climate.

This section is included for those readers who are concerned about the veracity of claims that the climate is undergoing change and/or that it is related to human activities. It is included only to provide some context about the way in which evidence for or against these claims is examined.

A major assessment was published by the Australian economist, Professor Ross Garnaut in late 2008. The review considered options for Australia to play a proportionate part in global mitigation efforts. From an economics perspective, this focussed on maximising the "gains from reduced risks of climate change" compared to the costs of mitigation.

This approach is consistent with the application of the precautionary principle in the Kyoto Protocol. This states that 'where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation'. However, it is envisaged that such measures 'should be cost-effective so as to ensure global benefits at the lowest possible cost'.
While chapter 2 of the Garnaut Review provides a useful summary of the science of the Earth's climate system and the factors involved in its energy balance, it does not attempt to review the science. Instead, it states:

> "The Review takes as its starting point, on the balance of probabilities and not as a matter of belief, the majority opinion of the Australian and international scientific communities that human activities resulted in substantial global warming from the mid-20th century, and that continued growth in greenhouse gas concentrations caused by human-induced emissions would generate high risks of dangerous climate change."

In a similar manner, it would not be appropriate for this paper to attempt to review the science of climate change. This task is undertaken on an ongoing basis by the Intergovernmental Panel on Climate Change (IPCC). The IPCC released its Fourth Assessment Report (AR4) in 2007. This involved several hundred contributors and a peer review process involving large numbers of experts reviewing the draft documents.

Although this process appears to be very rigorous and involves experts with strong credentials in a large range of specialised fields, there are scientists and others who dispute the findings of the IPCC reports. The widely publicised Australian publication "Heaven and Earth. Global Warming: The Missing Science" by Professor Ian Plimer is a recent example.

It may be helpful to point out that the scientific method is "a process by which scientists, collectively and over time, endeavour to construct an accurate (that is, reliable, consistent and non-arbitrary) representation of the world.[1]" It relies on the step-by-step collection and evaluation of evidence, building on preceding hypotheses, models, theories and laws.

This is important because it distinguishes science from rhetoric (persuasion) and scenarios where "Smart people (like smart lawyers) can come up with very good explanations for mistaken points of view.[2]"

In science, as in other forms of investigation there is always the possibility that a new observation or a new experiment will conflict with a long-standing theory. The role of an investigator is to maintain an open mind to new ideas while maintaining scepticism about propositions that are poorly supported by evidence. Therefore, healthy scepticism is an essential element in building knowledge and understanding.

As such, scepticism is quite distinct from "denial", which is a fixed position based on belief/unbelief and is immune to fresh insights. Science uses standard procedures and criteria in order to minimise any inherent bias that might be introduced by underlying personal, cultural or political beliefs. The IPCC is an iterative and continuous process, by which each report examines new data, new systems of measurement and alternative interpretations in order to build on earlier findings.

Statements about climate change that contradict the IPCC broadly fall into the following categories:
Claims of data that have been ignored;
Claims of data that have been incorrectly measured;
Claims of data that have been incorrectly interpreted; or
Combinations of the above.

It may be wise to fully examine any such claims to assess whether the issue has, in fact , already been addressed by IPCC. If so, then continued pursuit of the issue may be based more on denial than it is on scepticism and therefore impede, rather than develop better understanding.

A brief venture onto the internet will reveal that many discussions about climate change quickly descend into unhelpful point-scoring. While interesting insights may be raised, it is difficult for the layperson to assess their veracity or even their significance, given the complexity of the field. This is why scientific progress relies on the existence of a rational, independent process of data collection, analysis and external review by experts in the field. Any such process must itself be carefully managed and open to rigorous review, in order to avoid risks such as "group think".

Climate science involves the integration of many different scientific disciplines. It studies the interaction of multiple natural and man-made physical, chemical and biological factors over lengthy timeframes. As with any branch of science, it continues to collect and re-examine data in order to challenge existing theories and improve understanding.

2. Climate Change Policy

The complexity of the factors involved in climate science is reflected in the complex nature of the policy response, as well as the terminology involved. For the purposes of this paper it is only necessary to state:

1. The policy agenda is extremely fluid at present, and is under development at international, sovereign state and provincial levels.
2. In November-December 2009, a United Nations Climate Change Conference in Copenhagen will aim to develop a global climate agreement for the period from 2012 when the first commitment period under the Kyoto Protocol expires[3].
3. The Australian Government has developed legislation to introduce a National Emissions Trading Scheme, termed the Carbon Pollution Reduction Scheme (CPRS). This was originally to take effect on 1 July2010, but implementation has been postponed to 1 July 2011 due to the Global Financial Crisis. Passage of this legislation is currently being negotiated and it is currently unclear whether, or in what form, it will take effect.
4. The mechanism adopted by the CPRS is a "Cap and Trade" approach. This requires those entities that are covered by the scheme to account for and to obtain and surrender permits for their greenhouse gas emissions. The total number of permits issued by the Government will be capped, but will be supplemented by approved "offsets" from emissions reductions outside covered sectors, including eligible forestry activities in Australia and certain emissions reductions overseas. The balance of permit supply and demand will drive the market price of these permits. This in turn will provide an incentive for those entities that can do so, to invest in systems or technology that reduces their emissions and, therefore, their cost of compliance.

5. As the overall CPRS focus is initially on the major sources of emissions, agriculture will not initially be covered; this means that industry participants will not be liable for their greenhouse gas emissions. This was to be reviewed in 2013 under the Government's original proposals[4]. Although agriculture as a whole is a major source of emissions, these are (a) dispersed across large numbers of separate enterprises and (b) unevenly distributed, with the livestock industry responsible for the main "climate forcing" emissions, from methane.
6. Agriculture is also a major source of carbon sequestration (absorption), through long-term capture of organic matter in the soil, as well as through re-vegetation. Again, this is unevenly distributed among the many industries making up agriculture and between different enterprises. Some enterprises or sectors see opportunities to benefit from selling their sequestered carbon on the offsets market. However, this requires the development and acceptance of appropriate methodologies, cost-effective technology to monitor changes in soil carbon and potentially legal liability for release of greenhouse gas emissions.

3. Market Behaviour

The purpose of the hydroponic and greenhouse industry is to meet consumer requirements and to do so in a profitable way. Consumer requirements are made up of many, sometimes contradictory, factors. Professor David Hughes, of Imperial College London, monitors and reports[5] on what he describes as global "mega trends" in consumer attitudes and behaviours towards food. One example is changes in population, demographics and spending power and how these differ between developed economies and emerging economies. He describes three overlapping drivers of demand, namely health, convenience and pleasure.

Interest in the health benefits of different foods can benefit fresh produce sales generally as well as create opportunities for products such as high-lycopene tomatoes. Demand for convenience has helped drive the growth of the food service sector and fresh-cuts. Pleasure aspects of food reposition it from "food as fuel" to place greater value on components such as flavour, novelty and other sensory factors.

Consumer behavior is also affected by shorter-term issues such as oil price spikes, interest rates and recessions. The food industry is described as particularly oil-price sensitive[6], with its reliance on oil-based inputs such as fertilizers, pesticides and plastics.

1. **Food Miles**. This concept attempts to evaluate the carbon emissions resulting from the transport of a product from its point of origin to its

point of consumption. It has gained some credence in some markets, particularly such as the UK, where significant volumes of food are imported. However, it is also criticised as being over-simplistic.

Some markets may be particularly sensitive - half of the vegetables and ninety five percent of the fruit eaten in the UK comes from overseas, with a sizeable proportion arriving by air. Agricultural and food produce accounts for 28% of goods transported on UK roads[7]. The government there has set up the Carbon Trust to calculate the carbon footprint of groceries, including fresh and processed produce. UK retail giant Tesco have started a two-year trial on a range of own-label products including potatoes and orange juice. Also, a major potato chip producer is highlighting the carbon footprint in grams per packet.

Planet Ark in Australia recently announced that it has been licensed by the Carbon Trust to implement a similar scheme here.

2. **Life Cycle Analysis** (LCA) or "Environmental Footprint". This approach involves a broader, "cradle to grave" analysis of the environmental impact of a product at every stage from production, through the supply chain to eventual disposal (in the case of durable goods). It may be limited to carbon emissions, or may extend to other factors such as water use, land degradation, noise or contamination.

3. **Local Food Movement**. As with Food Miles, this movement may be criticised for focussing only on a single factor – distance from the farm. However, proponents argue that it aims to enhance the economic, environmental and social health of a particular place, by supporting local growers, processors and distributors. An example relevant to a Sydney-based conference is the Hawkesbury Harvest initiative, which is committed to "preserving the farming and agricultural heritage of the region[8]". This in turn is related to issues related to peri-urban agriculture, urban sprawl and even food security.

Implications

Putting climate science theory, evidence and debate to one side, the issue for any enterprise boils down to managing any resultant risks and opportunities. The first step is to identify these and to assess the likelihood and the impact of each one.

The potential risks and opportunities may be identified according to:
1. mitigation (measures to reduce emissions);
2. adaptation (measures to manage the impacts of climate change), or

3. Market Behaviour

Figure 1 provides some examples, with a more detailed analysis following below under "Responses".

Figure 1: Framework for identifying impact of climate change

	Risk	Opportunity
Mitigation Measures	**Failure to properly assess low-emissions technology options**	**Use of heat sinks to reduce emissions from energy use**
Adaptation Measures	**Increase in pest pressure possible**	**Use of new shading materials to reduce heat gain**
Market behaviour	**Perception of high energy use could harm hydroponic image**	**Food Miles could be advantage for local enterprises**

The second step is to establish the range of options for managing the risks or opportunities.
The final step is to implement a plan to manage risks and opportunities efficiently and effectively, in order to protect and benefit the enterprise.

It is important to recognise that there are two aspects of change related to climate that are driving these risks and opportunities. Firstly, those posed by changes in the climate itself and secondly, those posed by changes in policy by governments in response to climate issues

Changes to the Climate itself

It is important to distinguish between climate, which is the description of meteorological elements for a given place over long periods of time, and weather, which is the current activity of those elements.

As discussed in the background, trends over many years indicate that the climate is warming and becoming more variable. Climate models also suggest a trend to less rainfall in some areas (such as Southeastern Australia) and more rainfall in others (such as Northwestern Australia).

In addition, scientists expect an increased incidence of severe weather events, such as storms or heatwaves, resulting from an overall increase in climate variability.

What will this mean for greenhouse growers? It is important to consider the possible direct effects of these climate changes on the enterprise, but also the indirect effects on the suppliers or customers of the enterprise.

Changes to Climate Change Policy

Uncertainty over the outcomes of current national and international climate change negotiations makes it difficult to predict the impacts. However, it appears likely that some form of emissions reduction policy will be introduced. As with changes in the climate itself, there is the potential for policy to impact directly on growers, as well as indirectly.

Under current policy proposals, the direct impact of policy on growers is likely to be nil. This is because, firstly, the CPRS is not likely to cover agriculture, at least in the short term, as discussed in the background. Secondly, if agriculture is included at some point, most enterprises would be too small to fall within the threshold for direct reporting. However, policy could have major indirect impacts, with many inputs, such as fertilizer, fuel and power increasing in price.

Therefore, the focus here is on understanding the risks and opportunities in adapting to the new world, once climate change policy is implemented.

Responses

1. Mitigation Measures- reducing emissions and the impacts of climate change policy

Risks:

- Most horticulture enterprises would not be major direct emitters of greenhouse gases when compared, for example, with the transport or livestock enterprises. Therefore emissions reduction should be possible without major disruption. The major risk would be to embark on an emissions reduction program without first analysing where the best gains can be made, compared to any investment required.

- Compliance costs could become a major issue, were agriculture to be covered by the Australian scheme at some point in the future (depending on the nature of the coverage and eligibility thresholds). It would be important for industry to collaborate to minimise these costs, as it has done with food safety and environmental assurance requirements. Another concern would be the reduced competitiveness of Australian products, were they subject to policies that did not apply to their overseas

competitors. This will depend on the shape of any future international agreement.

- Greenhouse growers will have to adapt to the indirect effects of policy, namely increased input costs. Energy, whether in transport or stationary (such as electricity generation) is a major source of emissions. Suppliers will not be able to absorb the costs of investment in emissions reduction or the costs of permits and will pass on the costs to their customers. The risk to growers and others in the chain will be governed by their ability to pass these increased costs further up the chain to the consumer.

Opportunities:

- The first major opportunity for growers is to reduce their exposure to energy-related costs. This will require a full review of temperature management practices and any energy efficiency options. This might include the form of energy, the tariff, method of conversion into heating or cooling, identification and use of waste energy, always considering the impact on the crop. Other factors are technologies to reduce excessive heat gain or loss, such as shading and thermal screens. All these options require an analysis of their pay-off period, which in turn calls for a review of the potential to pass on extra costs by increasing income.

- This introduces a second opportunity – to use increasing costs as an incentive for careful supply chain analysis, to maximise returns. There may be "hidden" costs in the supply chain of inputs to the farm or in the supply chain for farm produce to the consumer that already far outweigh any extra costs from the CPRS. Efforts to collaborate with supply chain partners can reveal efficiencies, but also deliver benefits to marketers and consumers that can earn a premium.

- In a world of even more uncertain weather, particularly water supply, the efficiency and reliability available from greenhouse and hydroponic production may be increasingly valued by the marketplace.

- Many of the emissions related to greenhouse production are indirect, such as those involved in infrastructure. Greenhouses may contain large amounts of "embodied emissions" in their structures. Concrete, steel and aluminium production all result in significant carbon emissions. It is up to the suppliers to make reductions, (eg alternative forms of cement are under development which generate significantly lower emissions). The same goes for consumables, such as growing media, plastic or fuel, as well as coolrooms that may contain greenhouse-unfriendly CFCs as refrigerants. Growers can reduce the carbon footprint of their crop by

using "low emission" infrastructure and consumables and by looking for efficiencies in their use. In particular, high emissions consumables such as energy could be a particular focus area. For field-grown crops, there could be opportunities to reduce emissions of CO2 and Nitrous Oxide from soil by changes to soil management. However, hydroponic production technology already minimises such losses.

- Broadacre agriculture may be able to engage in the CPRS in the future by sequestering carbon in the soil or through revegetation. By its nature, greenhouse production does not create these opportunities. However, there is other government policy, outside the CPRS, aimed at encouraging the adoption of low-emission technologies. Some businesses, as well as households, may qualify for assistance from government grant programs to subsidise heat pump, gas or solar hot water heating systems.

2. Adaptation Measures- what can be done to adapt to the change?

Risks:

- For field-grown crops, significant shifts in climate could lead to crop failure (for example, where plants have a minimum winter chilling requirement to stimulate flowering). The ability of greenhouse growers to control the environment for their plants removes this risk. However, the possibility of regular heatwaves will require greenhouse growers to upgrade to the latest technologies for shading and cooling (or consider changing the crop grown).

- Greenhouse crops may be at risk if such systems are not responsive enough to rapid weather changes, expected as a result of increased climate variability. Growers in Australia are considered to be experienced in dealing with an incredibly varied climate and so may be well-placed to manage this aspect of climate change.

- Despite this, the long drought in the Murray Darling Basin has pushed many growers well beyond their previous ability to access or afford water. Greenhouse production is claimed by AHGA to be one of the most efficient ways to use water, but any grower should be aware of the risks of scarcity and increasing price.

- Even slight shifts in climate can have major effects on insect pests and adverse consequences for growers. For example silverleaf whitefly (SLWF) is a serious pest of many crops and also a vector of important viral

diseases. The Sydney Basin region is at the limits of its range in outdoor crops, only supporting less than seven generations per season. Once SLWF completes eight or more generations, major outbreaks are likely, which will inevitably impact on greenhouse growers and risk disrupting IPM programs. So, a hardly noticeable change in seasonal conditions could have a big impact on this one pest. Failure to understand how temperature affects the various different life stages of each pest, as well as their natural enemies and other factors that may interact with their lifecycles, could incur significant risk.

Opportunities:

- For cool climate greenhouse producers, less energy may be required to maintain temperatures in winter months. This could even bring opportunities to grow crops previously considered unsuitable for the area. Some field grown crops may benefit from higher temperatures and/or freedom from frosts and thereby compete with greenhouse crops. However, others may be seriously affected by climate variability, providing protected crops with a market advantage.

- Greenhouse producers are already familiar with the concept of increasing Carbon Dioxide (CO2) levels inside the greenhouse to boost growth. Although "background" CO2 levels are increasing, this is still nowhere near the levels that many greenhouse crops require for optimum production. Supplementary CO2 remains an option to consider although increased temperatures and resulting ventilation requirements make this difficult.

3. Market Behaviour – how might consumer demands change?

Risks

- As discussed in the background, some consumers are becoming more concerned about the carbon emitted as a result of food production, storage and distribution. The concept of food miles has been around for some years. Despite being criticised as over-simplistic and misleading, it may be starting to take effect. The food miles issue can be a negative trend for enterprises sited far from markets, whether in Australia or overseas.

- An alternative concern could arise over the perception of greenhouse and hydroponic production involving high levels of inputs, including buildings and energy for heating or cooling.

- The marketplace is dynamic and needs to be continually monitored. While areas of health, convenience and pleasure are considered to be long-term trends, they may be affected by changing consumer attitudes to climate change, as well as other factors. A major risk to the greenhouse and hydroponic industry (and shared by much of the horticulture industry) is the low level of investment in ongoing monitoring of supply and demand and the trends affecting these.

Opportunities

- In contrast to the risk above, consumer demand for "locally grown" food may provide opportunities for enterprises close to population centres. Some hydroponic enterprises have established retail outlets or "pick your own" facilities to cater for this. (It should be noted that this may not necessarily result in a smaller carbon footprint, compared to shoppers buying produce along with their other groceries at the supermarket.)

- At a further extreme, considerable interest in urban horticulture and food production has developed in recent years. It has even been suggested that some supermarkets could license hydroponic herb or salad production facilities in rooftop installations. While this may appear fanciful, or a fringe activity at best, it may illustrate a desire by consumers to know the origin of their food.

Recommendations

This paper offers a starting point and a framework for considering the impacts of Climate Change and Climate Variability. It suggests that there are likely to be positive and negative impacts for greenhouse and hydroponics growers and that industry members can and should position themselves to manage any changes required. In many ways, greenhouse producers have an advantage over field crops in having more tools available to manage the plant environment.

Some responses would most effectively be handled by growers working in collaboration a an industry body. For example, It is difficult for individual enterprises to monitor and analyse the many factors that affect consumer behaviour. Climate change adds a further layer of complexity to the challenge of meeting consumer needs, profitably. Industry should consider an ongoing, collective approach to monitoring and analysing markets, while looking to minimise costs through alliances with other horticultural groups, where possible.

Similarly, industry participants need to ensure that they remain abreast of the ever-changing climate change policy situation. Again, this can be efficiently managed through a collective approach and strategic alliances. While the

greenhouse and hydroponics industry has some unique characteristics, it should nevertheless align itself with other primary industries research and policy initiatives, as described in the references.

The fact that climate change is a global issue, prompting a global response, underlines the fact that it will impact all members of the chain, from input suppliers to consumers. This makes it easy to assume that it is too "big" to be addressed by individual enterprises. In fact, individuals can take steps to position themselves to minimise the risks and maximise the opportunities from whatever changes transpire in due course. In contrast to "going it alone", this means developing the skills to build strategic partnerships in order to compete and prosper.

Climate Change and the policies that are implemented to address it, is likely to increase production and distribution costs for greenhouse and hydroponics growers. These costs are difficult to pass on, even when operating in a strategic alliance in support of a specialised product. They are virtually impossible to pass on when marketing as an undifferentiated commodity.

This principle applies to all channels of supply, large or small. For example, even growers who market direct to local consumers through farmers' markets rely on the other parties involved – other stallholders, organisers and site managers – to invest in the growth of the farmers market category and protect its integrity.

Growers have a range of options to improve their negotiating position and avoid falling victim to the cost:price squeeze. This requires an investment of time and resources in exploring these options and developing the skills and understanding to apply them.

Another area of skill development for individual enterprises to build competitiveness applies to monitoring and investing in new technology. Some increases in production costs may be offset by greenhouse technologies that save energy, as mentioned. Others may be offset by further adoption of mechanization, with a significant amount of research now occurring on the use of robotics for labour intensive activities such as de-leafing and harvesting.

In conclusion, greenhouse and hydroponic production involves long-term investment in capital and in skills development. Investment decisions should take into account the impacts of climate change and consider these in context with the many other factors that define the competitive prospects of an enterprise.

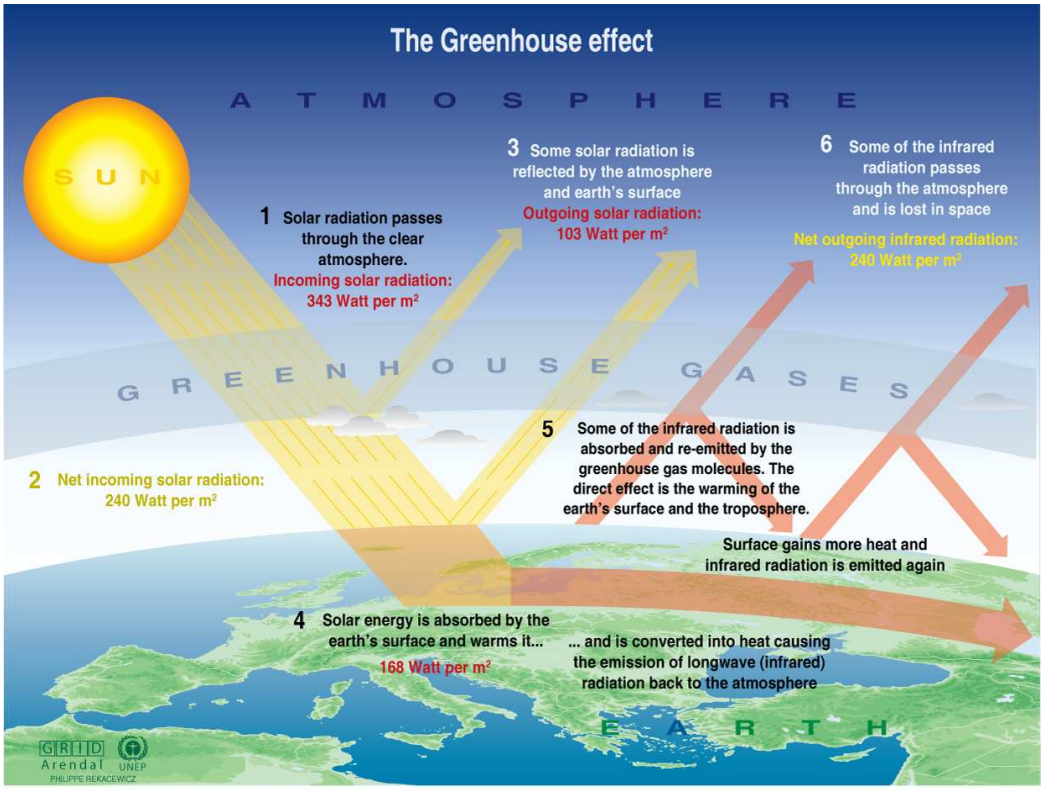
Appendix

The Greenhouse Effect at a global and industry scale

The term "Greenhouse Effect" has largely been dropped in favour of "Climate Change" and "Climate Variability". Nevertheless, there are some parallels between the physical factors that growers are familiar with from managing greenhouse environments and the factors that play a role in regulating the global climate. These may assist some readers to understand some of the particular challenges and opportunities presented to greenhouse growers.

Greenhouse Earth

Without so-called greenhouse gases, the temperature of the Earth would be 33 degrees C cooler, or an average of minus 18 degrees C[9]. As shown in the diagram[10]The sun's radiation is transmitted to Earth across a range of relatively short wavelengths, including ultra-violet (UV), the visible spectrum of light and near-infra red. How much of this radiation reaches the Earth's surface is affected by reflection (from clouds, air pollution and snow cover) and absorption (such as absorption of UV by atmospheric ozone). However, most radiation in these wavelengths passes through the various components of the atmosphere.



Sources: Okanagan university college in Canada, Department of geography, University of Oxford, school of geography; United States Environmental Protection Agency (EPA), Washington; Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge university press, 1996.

Any non-reflective surface on Earth then absorbs this radiation, and re-emits the energy as heat, which has a different range of longer wavelengths in the infra-red (IR) part of the spectrum. Most of the gases making up the atmosphere are also transparent to IR radiation and so do nothing to prevent it being emitted to space. However, the "greenhouse gases" absorb the IR radiation. These, in turn, warm up and re-emit the radiation in all directions. Some is re-emitted to earth, adding to its warming. Some is re-emitted towards space and is thereby re-absorbed by greenhouse gases higher up in the atmosphere, re-emitted again and so on. At the highest layers, the atmosphere is too thin to absorb all the radiation and it is from here that energy escapes back into space.

Each greenhouse gas has a distinct absorption pattern for IR radiation, just as a radio station has a specific band on the dial to send and receive transmissions. However, each greenhouse gas absorbs IR radiation in several different bands and to a greater or lesser extent. The absorption also varies with temperature and pressure. Therefore, the various greenhouse gases vary in importance according to their ability to absorb IR as well as their concentration and their life cycle in the atmosphere.

Water vapour is the most significant greenhouse gas, but can cycle in and out of the atmosphere depending on temperature . Other gases, listed in the table, are in lower concentrations but are more persistent in the atmosphere and have increased significantlydue to human activities. This persistance, together with their relative capacity to absorb IR, is used to compare their Global Warming Potential (GWP) in comparison to Carbon Dioxide (CO2).

Greenhouse Gas	**GWP (for 100 year time horizon)**
Carbon Dioxide	1 (ie baseline for comparison)
Methane	25
Nitrous oxide	298
HFC-23 (hydrofluorocarbon)	14,800
HFC-134a (hydrofluorocarbon)	1,430
sulfur hexafluoride	22,800

The term greenhouse effect arose from the first theories a hundred years ago that absorption by the atmosphere was responsible for maintaining Earth temperatures capable of sustaining life. Since glass is also transparent to visible light, but absorbs IR radiation, this was highlighted as a model for what occurs in the atmosphere. This analogy is still used, even though it was soon noted that most of the warming effect of a greenhouse is due to the structure preventing heat loss by convection (air currents), rather than by the glass acting as a barrier to IR radiation. As with greenhouse gases, glass re-emits the energy it absorbs

(whether from radiation or conduction) – some within the house and some to the outside.

Managing the Greenhouse Climate

This section is included, not to provide detailed analysis of greenhouse management options, but to link the preceding section to the real-world issues and technology of greenhouse growing.

Clearly, a major benefit of protected cropping is the ability to maintain uniform growing conditions as close to the optimum for the crop as possible. Some factors, particularly light levels, are governed by location, orientation and design of the structure and are more or less fixed once the greenhouse is established. Others, including many heating and cooling systems, shading paints or screens and photoselective paints or covers are independent of site and can be retrofitted.

There is a significant body of research available to assist greenhouse growers in these decisions and the International Society of Horticultural Science (ISHS) runs regular meetings such as the International Symposium on High Technology for Greenhouse System Management: Greensys2007.

Bibliography

The following is a selection of references designed to indicate the range of relevant material. The author can provide further links on request.

Climate Change Science and debate:

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- Plimer, I. (2008) Heaven and Earth: Global Warming, the Missing Science, Connor Court Publishing
- Climate Change Reconsidered: The 2009 Report of the Nongovernmental International Panel on Climate Change (NIPCC) http://www.nipccreport.org
- "How to Talk to a Climate Skeptic," a series containing responses to the most common skeptical arguments on global warming. http://www.grist.org/article/series/skeptics/
- Start Here: a one stop link for resources that people can use to get up to speed on the issue of climate change http://www.realclimate.org/index.php/archives/2007/05/start-here/
- Aerosols May Drive a Significant Portion of Arctic Warming Though greenhouse gases are invariably at the center of discussions about global climate change, new NASA research suggests that much of the atmospheric warming observed in the Arctic since 1976 may be due to changes in tiny airborne particles called aerosols. http://www.nasa.gov/topics/earth/features/warming_aerosols.html

Agriculture/Horticulture and Climate Change:

- R&D organisations:
  - The rural R&D Corporations, including Horticulture Australia Limited (HAL), have formed the National Climate Change Research Strategy for Primary Industries (CCRSPI). This manages collaborative research programs to "assist primary industries to understand, and build capacity to meet, climate change mitigation and adaptation needs". http://www.lwa.gov.au/ccrspi/
  - HAL has funded some projects specific to horticulture, including: Scoping study into climate change and climate variability Vegetable Scoping Study into the Implication of Climate Change Vegetable Industry Carbon Footprint Scoping Study (includes discussion papers and workshop)

http://www.horticulture.com.au/delivering_know-how/Environment/ClimateChange.asp

- NSW DPI have a detailed discussion paper: Climate change research priorities for primary industries (2008) http://www.dpi.nsw.gov.au/research/topics/climate-change/discussion-paper
- The International Society of Horticultural Science (ISHS) has a Commission for Protected Cultivation, and a Commission for Horticultural Engineering, which run regular symposia and workshops. Some recent ones are as follows:

  Acta Horticulturae 807 International Symposium on Strategies Towards Sustainability of Protected Cultivation in Mild Winter Climate (Jan 2009)

  Acta Horticulturae 797 International Workshop on Greenhouse Environmental Control and Crop Production in Semi-Arid Regions (Sep 2008)

  ISHS Acta Horticulturae 801 International Symposium on High Technology for Greenhouse System Management: Greensys2007
- (Includes: Carbon dioxide concentration in mediterranean greenhouses: how much lost production? C. Stanghellini, L. Incrocci, J.C. Gázquez, B. Dimauro
- Solar thermal collectors for greenhouse heating G. Vox, E. Schettini, A. Lisi Cervone, A. Anifantis
- Development of concepts for a zero-fossil-energy greenhouse A. van ¿t Ooster, E.J. van Henten, E.G.O.N. Janssen, G.P.A. Bot, E. Dekker
- Solar energy delivering greenhouse with an integrated NIR filter P.J. Sonneveld, H.J. Holterman, G.LA.M. Swinkels, B.A.J. van Tuijl, G.P.A. Bot
- Cooling and heating of greenhouse in arid area by earth tube heat exchanger G. Sharan, K. Jethva)

  Acta Horticulturae 761 XXVII International Horticultural Congress - IHC2006: International Symposium on Advances in Environmental Control, Automation and Cultivation Systems for Sustainable, High-Quality Crop Production under Protected Cultivation (Sep 2007)
  http://www.ishs.org/ http://www.actahort.org/
- Relevant papers may be found in many other areas, such as the following under Acta Horticulturae 831: XVI International Symposium on Horticultural Economics and Management :
- Towards a low emission greenhouse horticulture M.N.A. Ruijs, J.B. Campen, M.G.M. Raaphorst

- Horticultural/Agricultural industry organisations:
  - Horticulture Australia Council (HAC) has recently published a press release regarding the CPRS http://www.hac.org.au
  - Growcom have a dedicated Climate Change policy Officer and have several policy and information documents http://www.growcom.com.au/home/inner.asp?pageID=64

- The Australian Farm Institute (AFI) undertakes and commissions research on farm policy issues including "How do you muster a paddock of carbon?" – a discussion paper on the impacts of climate change and emissions trading in Australian agriculture. AFI has also hosted forums on agriculture and emissions trading. http://www.farminstitute.org.au/publications/project_reports

Government information & assistance

- DPI Victoria: Carbon Toolkits in Agriculture Network: The Network forms part of DPI's Future Farming Strategy Action 3.1 'Preparing farmers for the future climate and emissions challenge'. Sarah.Holland-Clift@dpi.vic.gov.au or 0427 331 627.
- Eligible participants are able to claim up to $1500 per financial year to attend FarmReady approved courses, A part of the Australia's Farming Future initiative, FarmReady is a national program, and available to all primary industries. http://www.farmready.gov.au/

Consumers, Locavores and Food Miles

- Larsen, K, Ryan, C & Abraham, A 2008, Sustainable and Secure Food Systems for Victoria: What do we know? What do we need to know?, Victorian Eco-Innovation Lab, University of Melbourne, Melbourne.
- Smith, A, et al 2005, The Validity of Food Miles as an Indicator of Sustainable Development: Final Report produced for DEFRA
- Pimentel, D & Pimentel, M H 2008, Food, Energy, and Society, CRC Press, Boca Raton.
- NYK has released an initial exploratory design for its NYK *Super Eco Ship 2030*, an energy-efficient ship expected to emit far fewer CO2 emissions than current vessels http://www.eyefortransport.com/content/nyk-reveals-exploratory-design-super-eco-ship-2030
- The Australian National Life Cycle Inventory Database Initiative (AusLCI) will provide a national, publicly-accessible database with easy access to authoritative, comprehensive and transparent environmental information on a wide range of Australian products and services over their entire life cycle. http://www.auslci.com/
- ISHS Acta Horticulturae 429: XIII International Symposium on Horticultural Economics Utility of the environmental life cycle assessment method in horticulture ing. J.K. Nienhuis, i. P.J.A. de Vreede
- ISHS Acta Horticulturae 691: International Conference on Sustainable Greenhouse Systems - Greensys2004 LCA methodology applied to various typology of greenhouses G. Russo, G. Scarascia Mugnozza
- ISHS Acta Horticulturae 767: XXVII International Horticultural Congress - IHC2006: International Symposium on Sustainability through Integrated

and Organic Horticulture Life cycle assessment (LCA) and food miles - an energy balance for fruit imports versus home-grown apples M.M. Blanke

- ISHS Acta Horticulturae 768: XXVII International Horticultural Congress - IHC2006: International Symposium on The Role of Postharvest Technology in the Globalisation of Horticulture Could 'food miles' become a non-tariff barrier? J.A. Heyes, A. Smith
- Chain of Events is a blog of Food Chain Intelligence. This blog is intended to be a source of information for the busy professional who wants to stay abreast of events and trends in the Australian landscape, but cannot always attend forums and seminars of interest. http://www.food-chain.com.au
- Food Climate Research Network, Centre for Environmental Strategy University of Surrey www.fcrn.org.uk To join the FCRN mailing list taragarnett@blueyonder.co.uk

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[1] http://teacher.pas.rochester.edu
[2] Anonymous, sometimes attributed to Nobel prize-winning physicist Richard Feynman
[3] http://unfccc.int/2860.php
[4] White Paper on the CPRS
[5] http://www.profdavidhughes.com/
[6] Hughes, D. (2007) International Trends in the Food Industry: Implications for businesses in Victoria, sourced at http://www.business.vic.gov.au/busvicwr/_assets/main/lib60018/david hughes.pdf 22 June 2009
[7] Pretty, JN et al (2005) Farm costs and food miles: An assessment of the full cost of the UK weekly food basket Food Policy 30 1-19
[8] http://www.hawkesburyharvest.com.au
[9] Henderson□Sellers, A. and Robinson, P.J. (1999) *Contemporary Climatology*. 2nd edn. Harlow: Addison Wesley Longman.
[10] Graphic available from UN Environment Program http://maps.grida.no/