Appendix E Case study: OptiCOOL

SUMMARY OF KEY FINDINGS

- CSIRO research has created a building energy management system for heating, ventilation and air condition (HVAC) that can reduce the energy consumption in commercial buildings by between 10 and 30 per cent.
- CSIRO gains a revenue stream from licencing the OptiCOOL technology to BuildingIQ.
- The benefits generated as a result of the OptiCOOL technology include BuildingIQ's contribution to Australia's GDP, a reduction in energy costs for building tenants and reduced greenhouse gas emissions.
  - The present value of the benefits that can be attributed to CSIRO is estimated to be $79.7 million in 2014/15 dollars over the period 2014/15 to 2024/25, under a 5 per cent real discount rate.

E.1 Introduction

E.1.1 Purpose and audience

This independent case study evaluation has been undertaken to assess the economic, social and environmental impact of CSIRO research into building monitoring and control systems designed to improve the energy efficiency of commercial buildings. This case study has been prepared so it can be read as a standalone report or aggregated with other case studies to substantiate the impact and value of CSIRO's activities.

The report is provided for accountability, reporting, communication and continual improvement purposes. Audiences for this report may include Members of Parliament, Government Departments, CSIRO and the general public.

E.1.2 Background

The installation of heating, ventilation and air-conditioning (HVAC) systems in Australia has contributed to substantial flexibility in building design and form. HVAC systems have permitted indoor comfort regardless of external climatic conditions, particularly in buildings with inferior thermal performance.

HVAC systems account for 43% of energy use in buildings

However, HVAC systems have added significant costs to commercial buildings. In 2012, HVAC end use accounted for 43% of total building energy use, while commercial buildings contributed a total of 34.7 Mt of CO_2-e that same year (Department of Climate Change and Energy Efficiency, 2012). In addition, HVAC systems have been found to be an important driver of electricity demand across the network (Wall *et al.*, 2007).

CSIRO first began its research into ways to improve the efficiency of HVAC systems in the early 2000s. Its main goal was to develop new technologies to reduce electricity consumption in buildings by improving the efficiency of HVAC systems (CSIRO, 2010).

E.1.3 Approach

The approach taken in this case study aligns with the nine-step process described in the CSIRO's impact evaluation guide namely:

1. Initial framing of the purpose and audience of the impact evaluation.
2. Identify nature of impacts (*what is the impact pathway, what are the costs and benefits*)
3. Define a realistic counterfactual (*what would have occurred in the absence of CSIRO*)
4. Attribution of research (*CSIRO vs. others' contribution*)
5. Adoption (*to date and in future*)
6. Impact (*timing, valuation, distributional effects among users, effects on non-users*)
7. Aggregation of research impacts (*within program of work*)
8. Aggregation of impacts (*across program of work*)
9. Sensitivity analysis and reporting.

Note that steps 7 and 8 above are less relevant for this individual case study as the OptiCOOL project is being considered in isolation. The impacts identified in this case study will be aggregated with those from other aspects of CSIRO's work to provide an insight into the overall benefits arising from the Organisation's work.

E.1.4 Project origins and inputs

The aim of the CSIRO's Energy Flagship is to collaborate with industry, research organisations and government to create cost-competitive, low-emission energy technologies to plan for a secure and clean energy future in order to help Australia to protect and ensure its long term environmental, economic and social welfare (CSIRO, 2014b). The stated goal of the Energy Flagship is to:

> Deliver by 2020 technology options and science that will enhance Australia's economic competitiveness and regional energy security while enabling the transition to a lower emissions energy future, by unlocking $100 billion of *in-situ* value from our energy resources and contributing 32 Mt p.a. of greenhouse gas abatements by 2030.

CSIRO's OptiCOOL technology is illustrative of the organisation's efforts to deliver the Energy Flagship's goals. The technology functions as a supervisory control system that enhances heating and cooling operation and efficiency in commercial buildings. OptiCOOL further improves occupant comfort, reduces peak demand and can be retrofitted in the majority of existing buildings (CSIRO, 2012).

History of project

The OptiCOOL technology is some 10 years in the making

Interviews with an original member of the team that developed the OptiCOOL technology indicated that the genesis of the project can be traced back to June 2004. At the time, the project team was testing systems to intelligently control electricity loads and generators. These tests eventually extended to include functionalities to monitor and analyse advanced control strategies for those systems in order to save on energy and operating costs. The tests involved the placement of small wireless sensors around commercial buildings at high resolution in order to collect data seldom analysed on a large scale. Encouraging results from these tests led to a more substantial trial in partnership with Sustainability Victoria in 2006-2007.

The objective of the 'Smart Thermostats' trial in 2006-2007 was to provide sufficient evidence of the functionality of the technology and to examine:

- the costs and benefits of smart thermostat technology
- the potential energy reductions from variations in temperature set-points
- the appropriateness of thermostat technology for retail and network peak demand reductions
- the level of acceptance of smart thermostat technology by occupants of buildings (Ward and White, 2007).

Early trials demonstrated the potential of the technology

The trial successfully demonstrated the possibility of adjusting temperature set points as a method to reduce greenhouse gas emissions or for temporarily decreasing peak demand on the electricity industry. However, the results also showed that testing on additional buildings was required in order to collect a larger sample of successful implementations to improve confidence in the demonstrated performance of the technology (Ward and White, 2007).

Importantly, results from the trial showed that the system would have benefitted from more sophisticated controls that would allow for prediction, forecasting and include a self-learning capability (Ward and White, 2007). This finding inspired the research that ultimately led to the development of the OptiCOOL technology in June 2007.

The OptiCOOL technology is designed to achieve several goals, including: enhancing energy efficiency; reducing excessive energy consumption; and reducing operating costs without foregoing the comfort of building occupants. The technology can utilise feedback from occupants through online comfort feedback software that measures the comfort level of occupants, whereby individuals can register whether they are too cold/hot and dispatch this information to a controller. The OptiCOOL technology subsequently adjusts the air-conditioning accordingly.

OptiCOOL controls HVAC operations based on user feedback and weather forecasts

The intelligent controller can be installed onto any suitable HVAC control system and utilises weather data, energy market pricing and the aforementioned feedback from building occupants to modify the operation of the building's air conditioning in order to achieve:

- reductions in energy consumptions
- reductions in greenhouse gases
- cost savings
- increased productivity through enhanced staff comfort (CSIRO, 2013).

As OptiCOOL is primarily a software-based technology, there is limited additional capital cost or need to install additional hardware, assuming buildings are already fitted with modern HVAC and data collection systems.

Project inputs

CSIRO R&D contributions, including labour and operating costs, are outlined in Table E1.

Table E1 **CSIRO OptiCOOL R&D funding**

Date	Labour + Operating costs	External Revenue	Royalties
Jul 2006 – Jun 2007	-$11,532	$29,688	-
Jul 2007 – Jun 2008	-$212,836	-	-
Jul 2008 – Jun 2009	-$158,225	-	-
Jul 2009 – Jun 2010	-$7,758	-	-
Jul 2010 – Jun 2011	-$21,315	$48,487	$50,000
Jul 2011 – Jun 2012	-	$32,803	$75,000
Jul 2012 – Jun 2013	-	-	$100,000
Jul 2013 – Jun 2014	-	-	$100,000
Mar 2015	-	-	($100,000)
Mar 2016			($100,000)
October 2016			($540,000) incl. buyout + royalties
Total (to date)	***-$411,666***	***$110,978***	***To date: $325,000 With buyout: ($1,065,000)***

Source: CSIRO

Funding from other sources to CSIRO is also outlined in Table E1. In addition to the funding outlined below, Building IQ, which obtained the licence to sell OptiCOOL in 2009, pays ongoing royalties to CSIRO, the proceeds from which are dedicated to continuing CSIRO research that aims to extend CSIRO's technological innovation related to advanced HVAC system control, peak demand management and self-learning fault diagnosis.

E.2 Project activities

E.2.1 CSIRO research

The invention of OptiCOOL technology can be attributed to Dr John K Ward, Dr Josh Wall, Mr Sam West and Dr Glenn Platt, with a range of underlying CSIRO R&D activities and capability also supporting the development of the technology. Development of OptiCOOL technology utilised the CSIRO's capabilities shown in Table E2.

Table E2 **CSIRO Capabilities used in developing OptiCOOL**

Capability	Description
Automatic Control	Advanced control theory for dynamic systems and process control.
Artificial intelligence	Mathematical modelling of dynamic multi-variable systems, including data driven self-learning models and prediction algorithms.
Computer Optimisation	Optimisation algorithmics and mathematical modelling.
Advanced HVAC Controls	Knowledge and application of advanced HVAC control techniques and human comfort models.

Source: CSIRO

Development and testing of prototypes

Development of OptiCOOL commenced in 2007 when a new tranche of funding was provided to enable CSIRO to expand on research into Smart Thermostat technology. The first complete prototype of OptiCOOL was developed in July 2007 and installed in the

CSIRO Energy Centre lab for testing. The prototype went through a number of improvements and enhancements following ongoing comprehensive testing and evaluation in the CSIRO Energy Centre lab and in a number of other CSIRO operated commercial office buildings across Australia.

Build commercial product

OptiCOOL was licensed to BuildingIQ in 2009

OptiCOOL was commercialised in December 2009 under an exclusive license to the start-up company BuildingIQ (CSIRO, 2013). As part of the license agreement, CSIRO provided regular support to BuildingIQ and developed an extension to the technology in 2010 to accommodate heating functions. CSIRO also provided support to BuildingIQ to guide the first few commercial installations of OptiCOOL, and provided BuildingIQ with training hours and guidance on building data collection. CSIRO's interaction with and support for BuildingIQ concluded in November 2011; however the licensing agreement specifies a royalty flow to CSIRO based on BuildingIQ's annual profits.

Current strategy period

CSIRO is continuing to improve the OptiCOOL technology

Since licencing OptiCOOL in 2009, CSIRO has engaged in research work to extend the technological innovations achieved as a result of the OptiCOOL project. Current research areas include adapting OptiCOOL for application in smaller buildings or residential homes, intelligent controls for large refrigeration systems and matching air conditioning load with distributed PV solar power output.

Lessons learnt as a result of the OptiCOOL project also formed the foundation for the development of CSIRO's fault detection and diagnostics (FDD) technology, which automatically senses faults and sub-optimal operation in HVAC systems to enable timely maintenance and more efficient operation of HVAC systems in commercial buildings.

E.3 Project outputs

E.3.1 Key outputs of the project

The major output of the project was the OptiCOOL technology. The technology improves energy efficiency, reduces energy consumption and reduces operating costs without sacrificing the comfort of building occupants, although it can only be installed in large buildings with a minimum floor space of 30,000 m^2 in order to be cost-effective.[11] It achieves these goals through an intelligent controller that can be retrofitted to any existing HVAC control system. The technology was licenced to BuildingIQ in 2009. In 2010 it was extended to include heating optimisation functionality.

CSIRO also transferred technology and knowledge of OptiCOOL to BuildingIQ, a process that involved the creation of manuals, specification standards and training materials.

[11] Personal communication with Textor, August 2014.

E.3.2 Key publications

CSIRO has published a number of conference and journal papers in relation to the OptiCOOL project, several of these were published in leading journals with strong citation rates. The papers with the greatest impact include:

- West S, Ward J.K., Wall J. (2014). Trial Results from a Model Predictive Control and Optimisation System for Commercial Building HVAC. Energy and Buildings, Elsevier, Vol. 72, 2014.
- Platt G., Ward, J.K., Wall J. (2011). Optimal Supervisory HVAC Control: Experiences in Australia. HVAC&R Research, Vol. 17 Issue 3, 297. 21 Jun 2011.
- Platt G., Li J., Li R., Poulton G., James G., Wall J. (2010). Adaptive HVAC zone modelling for sustainable buildings, Energy and Buildings, vol. 42, no. 4, pp. 412–421, 2010.
- Wall J., Ward J.K., West S., M. A. Piette, Comfort , Cost and CO_2 – Intelligent HVAC Control for Harmonising HVAC Operating Principles, in IIR HVAC Energy Efficiency Best Practice Conference, 2008.
- Ward J.K., Wall J., West S., de Dear R, (2008). Beyond Comfort – Managing the Impact of HVAC Control on the Outside World, Proceedings of 5th Windsor Conference: Air Conditioning and the Low Carbon Cooling Challenge, UK, 2008.

E.3.3 Awards and public recognition

The technology has received a large number of awards

BuildingIQ has received a range of awards in Australia and globally for the OptiCOOL technology. These awards are outlined in the following table:

Table E3 **Awards and recognition**

Year	Award
2010	▪ Reader's Choice Award Winner for Environmental Design & Construction and Sustainable Facilities Magazines ▪ Tech23's Greatest Potential Award ▪ Red Herring Asia 100 Winner ▪ NSW government Technology Voucher grant winner (involving a government grant of $15,000)
2011	▪ AIRAH award for Excellence in Innovation ▪ Ed+C Readers' Choice Awards (Alternative Energy Systems category) ▪ EcoGen Award for Most Outstanding ▪ Sustainable Engineering Association Award for Excellence in Innovation (with Western Power) ▪ Connectivity Week's Buildy Award
2012	▪ Buildings Magazine names Building IQ a Top Money Saving Product ▪ GoingGreen 200 Winner ▪ Global Cleantech 100
2013	▪ Bloomberg New Energy Pioneers Award ▪ Global Cleantech 100 shortlisted ▪ Groom Energy Solutions Top-10 Enterprise Smart Grid Leaders ▪ Recognised by Gartner as a Cool Vendor in Green IT and Sustainability ▪ Environmental Design + Construction and Sustainable Award ▪ Fierce Innovation Award – Energy Edition – Best In Show
2014	▪ Global Cleantech 100 ▪ Selected by US Federal Government General Services Administration for its the highly selective Green Proving Ground Program ▪ Selected by the US Department of Energy for a multi-year Commercial Building Demonstration Grant

Source: BuildingIQ 2014a, 'Awards', <http://www.buildingiq.com/the-company-and-product-story/awards/>, accessed 21 July 2014.

E.4 Status of Outcomes and Impacts

E.4.1 Nature of Outcomes and Impacts

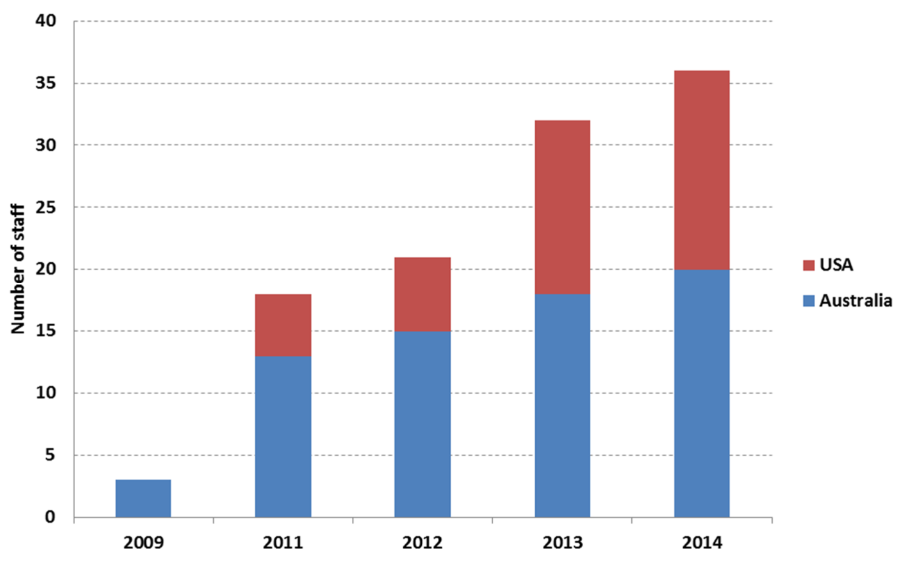
Outcomes

The chief outcome of the OptiCOOL project has been the licencing and commercialisation of the technology, followed by the installation of the technology by BuildingIQ in both Australia and the United States (US). As of August 2014, the technology was responsible for controlling approximately 15 million square feet (1.39 million square meters) of floor space in Australia and the US, including buildings such as the Rockefeller Centre in New York City (BuildingIQ 2014b). Adoption rates in the US are still relatively low as would be expected for a new technology (BuildingIQ, US Department of Energy, 2011). Adoption rates in Australia are also low. However, there is an expectation that adoption rates of OptiCOOL in Australia will increase now that the technology has been deployed and proven in the US market.

OptiCOOL technology has assisted building owners to decrease their energy consumption by between 12 and 30 per cent (CSIRO 2013). The largest US science and engineering research laboratory, Argonne National Laboratories, confirmed that a trial of the OptiCOOL technology decreased HVAC energy consumption in their buildings by between 22 and 45 per cent (CSIRO, 2012 and BuildingIQ, 2014 (c)).

As a result of the commercialisation of OptiCOOL technology through BuildingIQ, development of the technology has also created employment opportunities in Australia (and the USA). At present BuildingIQ employs 20 staff in Australia and 16 staff in the USA (see Figure E1).

Figure E1 **BuildingIQ employment**



Note: No employment data was available for 2010

Source: BuildingIQ, personal communication, August 2014

Box E1 **Extensions of OptiCOOL capabilities: fault detection and diagnostics**

The techniques and capabilities developed as part of the OptiCOOL project have fed into further research on automation and optimisation of HVAC systems in commercial buildings. This extension research has yielded further technology development, such as CSIRO's fault detection and diagnostics (FDD) technology. FDD technology automatically scans HVAC systems to detect areas where the HVAC system is operating sub-optimally or to detect faults. Like OptiCOOL, FDD uses standard sensor systems, meaning that users of FDD do not need to invest in additional hardware upgrades, assuming that modern HVAC and sensor systems are already installed in the building. CSIRO has ongoing contact with BuildingIQ as well as other companies in the industry, which has helped to inform this further research. There is a patent pending on CSIRO's FDD technology.

Improperly controlled HVAC systems, degradation in performance over time and inadequate maintenance wastes an estimated 16% of total energy used in commercial buildings with a payback time of 1.1 years (Mills, 2009). By contrast, the faults identified by CSIRO showed average energy savings of 10% up to 25% on whole building energy consumption.

Source: CSIRO

Impacts

CSIRO's development of OptiCOOL technology has led to several impacts. These can be categorised as either environmental or economic impacts. Using CSIRO's triple bottom line benefit classification approach, Table E4 summarises the nature of the outcomes and impacts to date.

The main beneficiaries of the project include: commercial building owners who save on operating costs; building tenants who benefit from improved energy efficiency and reduced energy consumption; electricity grid utilities, who benefit from reduced peak demand, and; electricity users, who may benefit from lower peak electricity prices, depending on the degree to which the technology is used by large HVAC system users connected to any single grid/electricity market.

Table E4 **OptiCOOL R&D - impacts and outcomes**

Impact	Detail
Economic impact category	
Increased productivity and managerial oversight *Reach: National / Sector* *Category:* Management and productivity	OptiCOOL introduces the capability to influence the behaviour of commercial building managers by altering patterns of energy supply and demand, while at the same time reducing operating costs.
New products or services *Reach: Global* *Category: International trade, new products and services*	Through research and innovation CSIRO led the development of the OptiCOOL technology which was eventually commercialised as BuildingIQ. The technology has been widely adopted in both Australia and the US.
Greater electricity grid stability, reduced peak demand *Reach: National* *Category: The macro economy*	OptiCOOL technology can be calibrated to automatically reduce energy consumption when electricity prices are high, during times of peak electricity demand on the grid. Widespread use of OptiCOOL could potentially reduce peak electricity demand across the grid and contribute to increased electricity supply stability in times of extreme demand peaks, particularly when combined with smart grid technologies.
Potential for reduced peak electricity prices *Reach: National* *Category: The macro economy*	Potential for reduced peak demand could also contribute to lower peak electricity prices.

Impact	Detail
Environmental impact category	
Reduction in greenhouse gas emissions *Reach: Global* *Category: Energy generation and use, Climate and climate change*	OptiCOOL allows commercial building owners to achieve greater energy efficiency. Buildings that are more energy efficient have the impact of reducing greenhouse gas emissions by reducing peak energy demand from the electricity industry.
Social impact category	
Increased employee comfort *Reach: National* *Category: Life and health*	OptiCOOL can be calibrated to prioritise employee comfort. The technology involves an automated process in which employees can provide information on whether they are too hot or cold. Moreover, OptiCOOL uses weather forecasts to predict outside weather patterns and pre-emptively adjust the internal temperature. This creates a more consistent internal building temperature through the day. Increased employee comfort may deliver productivity gains.

Source: ACIL Allen Consulting; CSIRO

E.4.2 Counterfactual

CSIRO accessed global research that focused on smart controller technology in the preliminary stages of OptiCOOL's development. The research indicated that other organisations were unsuccessful in their efforts to develop similar technology because of their focus on pure-optimisation. CSIRO noted that pure-optimisation was too complex to implement practically as it included too many variables, such as: physical building characteristics; the existing HVAC system; building occupants; and the building's energy supply.

OptiCOOL adopts a different approach for optimising building operations

CSIRO and BuildingIQ contacted several academics and experts in the UK to determine the market gap for smart controller technology prior to the commercialisation of OptiCOOL. The feedback they received suggested that various efforts were then underway to successfully introduce a cost-effective technology that offered features similar to OptiCOOL. The feedback further emphasised that CSIRO and BuildingIQ would be the first to market their technology if their trials were successful.

This gave the technology a strong market advantage

Science and research bodies as well as private organisations were unable to develop technology that was cost-effective and capable of utilising existing HVAC systems prior to OptiCOOL's introduction in 2009. CSIRO's efforts to commercialise OptiCOOL through BuildingIQ successfully introduced the technology to a market with few competitors. Indeed, several of the BuildingIQ's largest and most well-established competitors in the HVAC systems market partnered with BuildingIQ by offering venture capital. This suggests that these industry leaders were unable to develop technology that is equivalent OptiCOOL in-house. Notable venture capital partners include Siemens and Schneider Electric.

Competitors to BuildingIQ currently include:

— **private start-up firms**: SCIEnergy, Viridity Energy, Optimum Energy, SureGrid
— **major vendors**: Honeywell, Siemens (BuildingIQ VC partner), Johnson Controls, Schneider Electric (VC partner), AE Smith (VC partner)
— **energy service companies**: EnerNOC, EPS

OptiCOOL's current and growing presence in Australia and the US may owe to circumstances where it was one of the earliest providers of cost-effective and environmentally efficient smart controller technology. However over time BuildingIQ's competitors may have developed similar technology to OptiCOOL in the absence of CSIRO.

OptiCOOL has a market lead of around 10 years

The commercial value of first mover advantage is difficult to determine precisely, but given the lack of equivalent technology available to even the largest players in the HVAC industry at the time that OptiCOOL was commercialised, ACIL Allen estimates that it would have taken roughly ten years for other researchers to develop technology that is similar to OptiCOOL in the absence of CSIRO. The counter-factual commercial case to establishment of BuildingIQ would have been reliance on imported solutions (either licenced to a domestic firm or provided from offshore) after a substantial lag time. The benefits to the Australian economy would therefore have been lower by an amount corresponding to roughly ten years' worth of net energy efficiency gains plus the returns to the economy from having a domestic rather than imported service provider.

E.4.3 Attribution

CSIRO's initial trialling of 'smart agents' in 2004 provided it with the direction and guidance for R&D in the OptiCOOL technology. Successful tests and recognition of a market gap eventually led to the commercialisation of the technology with BuildingIQ. Roughly 75% of the impacts of the smart controller technology can therefore be attributed to CSIRO. BuildingIQ played an integral role in successfully marketing, enhancing and implementing the technology on a global level, a process that involved a certain amount of adaptation work on the technology. The remaining 25% of the impacts of OptiCOOL can therefore be attributed to BuildingIQ.

E.4.4 Adoption

OptiCOOL technology is being installed in both Australia and the US. The technology is currently responsible for controlling some 1.4 million square metres of floor space in Australia and the US. Adoption rates are still relatively low. However, this is to be expected with any new technology. BuildingIQ is projecting that installation of the technology and revenue growth will grow dramatically over the coming years. While the projected growth is very significant, it is in line with projections of the potential market by industry analysts.

Patent applications have been submitted to several other countries in order to increase adoption rates of the technology in the future. These countries, and the patent applications, are outlined in Table E5.

Table E5 **OptiCOOL patents**

Patent organisation/country and number	Publication date
World Intellectual Property Organisation (WIPO): WO 2011/072332 A1	Jun 23, 2011
Australia: AU 2010/333708 A1	Aug 2, 2012
United States: US 2012/0259469 A1	Oct 11, 2012
Euro-zone: EP 2513/568 A1	Oct 24, 2012
Korea: KR 2012/0123335 A	Nov 8, 2012
China: CN 102812303 A	Dec 5, 2012
Japan: P 2013/514510 A	Apr 25, 2013

Source: Interviews with CSIRO.

The chief barrier to greater adoption of the technology, currently and in the future, is existing building management systems. Those systems need to meet a minimum set of criteria to be suitable for OptiCOOL installation.

E.5 Assessment of impacts

E.5.1 Impacts to date

OptiCOOL has economic, environmental and social impacts

The development of OptiCOOL technology led to several impacts that occurred over time and can be linked to its commercialisation through BuildingIQ in December 2009.

Economic impacts

Increase productivity and managerial oversight

OptiCOOL's smart controller introduces the capability to influence the behaviour of commercial building managers by altering patterns of energy supply and demand, while at the same time reducing operating costs. BuildingIQ notes that its energy management technologies can offer commercial buildings payback on the original cost of buying and installing OptiCOOL within 12 months (Renew Economy, 2012).

Potential for greater electricity grid stability and reduced peak electricity prices

OptiCOOL technology can be calibrated to automatically reduce energy consumption when electricity prices are high, during times of peak electricity demand on the grid. As a result, widespread use of OptiCOOL could act to reduce peak electricity demand across the grid and contribute to increased electricity supply stability in times of extreme demand peaks (for instance during heatwaves or cold snaps). When combined with smart grid technologies, OptiCOOL could give electricity service providers and utilities greater leeway to intervene in HVAC systems in order to reduce peak demand. BuildingIQ has partnered with Nirvana Energy, a US electricity utility, to explore uses of OptiCOOL in combination with smart grid technologies.

Were the OptiCOOL technology to be installed on many large HVAC systems across a single grid, then the technology's ability to respond automatically to high peak electricity prices by lowering demand could in turn lower the peak price of electricity, delivering savings to electricity users across the grid.

Environmental impacts

Lower greenhouse gas emissions

By making commercial buildings more energy efficiency, OptiCOOL reduces building energy demand and contributes to lower greenhouse gasses from electricity production. CSIRO estimates that use of OptiCOOL can help reduce energy consumption by 12-30%. Taking into account findings from the Australian Department of Climate Change and Energy Efficiency that HVAC systems account for 43 per cent of energy consumption in large commercial buildings, and that total CO_2-equivalent emissions from commercial buildings were 34.7 MT in 2012, if all commercial buildings in Australia were fitted with OptiCOOL, immediate CO_2 savings from lower power demand could range between 1.79 and 4.48 MT CO_2-e. Over the longer term, were OptiCOOL to be adopted on a widespread scale and used to lower peak demand, reduced need for peak electricity supply would feed into to lower electricity demand forecasts, potentially influencing investment decisions in the construction of new peaking electricity generation plants. Fewer peaking electricity plants (which are often natural gas powered or hydropower), would contribute to lower potential emissions as a result of lower overall electricity generation capacity.

Additional benefits for CSIRO

The successful commercialisation of OptiCOOL with BuildingIQ has led to an unexpected spill over benefit for CSIRO. The successful development of the technology, the partnership with BuildingIQ and the licensing arrangements has enhanced CSIRO's reputation and credibility in the energy-for-business domain. CSIRO's increased credibility has led to better engagement with their other clients as well.

E.5.2 Potential future impacts

CSIRO is not expecting any impacts to occur in the future beyond an extension of the existing environmental and economic impacts outlined earlier in Table E3. However, it is currently undertaking research to extend the range of purposes that OptiCOOL technology can be applied to in the future. Current lines of research include:

- Intelligent control of commercial and industrial refrigeration systems (i.e. cool rooms, cold stores, refrigerated warehouses) by using self-learning models and predictive control systems.
- Model predictive control systems for residential air conditioners.
- Matching air conditioner system load (for both commercial and residential applications) to the output from solar photo-voltaic systems. This line of research is part of CSIRO's 'Virtual Power Station' initiative, which aims to link dispersed renewable energy generation and storage systems in order to establish a single virtual power station that can feed into electricity grids (CSIRO, 2009).
- Fault detection and diagnostics (FDD) systems, which can automatically sense mechanical faults, glitches, or situations in which certain parts of HVAC systems are operating sub-optimally.

CSIRO is also benefiting from a stream of royalty payments from BuildingIQ, which has the potential to grow in line with the US market. Royalty payments of $100,000 are scheduled to be paid to CSIRO in March each year. In 2016 Building IQ has the option to purchase the rights to the technology outright for an estimated $540,000.

OptiCOOL could potentially save the building sector $2.6 billion a year in energy costs.

The global market of suitable buildings is around 80,000, of which 32,000 are in the US; there is therefore huge upside potential for application of the technology. The US building market spends some $26 billion on energy a year, and Building IQ believes it is possible to reduce that by at least 10% (saving around $2.6 billion a year).

E.5.3 Cost Benefit Analysis

ACIL Allen has estimated the following benefits arising from CSIRO's development of the OptiCOOL technology for the period 2014/15 to 2024/25:

- BuildingIQ's contribution to Australia's GDP in terms of value added (which is approximately equal to its profits plus its payment of wages and salaries to its Australian employees)
- Reduction in energy costs for building tenants in Australia
- Value of the reduction in greenhouse gas emission enabled by the OptiCOOL technology.

The key assumptions underpinning the benefit valuation analysis and the sources for the assumed parameter values are shown in Table E6.

Table E6 **Key assumptions in benefit valuation analysis**

Assumption	Assumed value	Source
Annual revenue growth of BuildingIQ	15%	Navigant Research, *IT-Based Monitoring and Control Systems for Smart Buildings: Global Market Analysis and Forecasts*
Ratio of value added to revenue	63%	ABS input-output table of the Australian economy, corresponding to the 'Computer Systems Design and Related Services' sector
Australian share of BuildingIQ value added	60%	As of end August 2014, BuildingIQ had 20 employees in Australia and 16 employees in the US
Australian share of BuildingiQ's installed floor area	10%	The share was 11.6% in October 2012
Reduction in energy use enabled by Building IQ	20%	CSIRO estimates energy savings in the range of 12-30%
Annual energy cost per sq m	$35	NABERS, *Energy Management Guide for Tenants*
Annual GHG emissions per sq m	0.5 tonnes	NABERS, *Energy Management Guide for Tenants*
Carbon price per tonne of CO_2-e	$24	Based on Australian price for carbon in 2013-14 before the Carbon Tax was scrapped

Source: ACIL Allen

According to the consultancy Navigant Research, the global market for building energy management systems (BEMS) will grow from just under US$1.8 billion in annual revenue in 2012 to nearly US$5.6 billion in 2020, implying a compound annual growth rate (CAGR) of 15.2 per cent.

The three sources of economic benefits generated by BuildingIQ and the total benefits in each year between 2014/15 and 2024/25 are shown in the shaded columns in Table E7.

Table E7 **Estimation of benefits**

Year	Revenue	Value added	Value added (Australia)	Total floor area under management (sq m)	Total floor area in Australia under management (sq m)	Reduction in energy costs in Australia	Reduction in Australian GHG emissions (tonnes)	Value of reduction in GHG emissions	Total benefits to Australia
2014-15	$4,579,169	$1,450,933	$870,560	1,390,000	139,000	$973,000	13,900	$333,600	**$2,177,160**
2015-16	$9,603,333	$5,663,951	$3,398,370	2,915,078	291,508	$2,040,554	29,151	$699,619	**$6,138,543**
2015-16	$11,043,833	$6,957,615	$4,174,569	3,352,339	335,234	$2,346,637	33,523	$804,561	**$7,325,768**
2016-17	$12,700,408	$8,001,257	$4,800,754	3,855,190	385,519	$2,698,633	38,552	$925,246	**$8,424,633**
2017-18	$14,605,469	$9,201,446	$5,520,867	4,433,469	443,347	$3,103,428	44,335	$1,064,032	**$9,688,328**
2018-19	$16,796,289	$10,581,662	$6,348,997	5,098,489	509,849	$3,568,942	50,985	$1,223,637	**$11,141,577**
2019-20	$19,315,733	$12,168,912	$7,301,347	5,863,262	586,326	$4,104,284	58,633	$1,407,183	**$12,812,814**
2020-21	$22,213,093	$13,994,248	$8,396,549	6,742,752	674,275	$4,719,926	67,428	$1,618,260	**$14,734,736**
2021-22	$25,545,057	$16,093,386	$9,656,031	7,754,164	775,416	$5,427,915	77,542	$1,860,999	**$16,944,946**
2022-23	$29,376,815	$18,507,394	$11,104,436	8,917,289	891,729	$6,242,102	89,173	$2,140,149	**$19,486,688**
2023-24	$33,783,337	$21,283,503	$12,770,102	10,254,882	1,025,488	$7,178,418	102,549	$2,461,172	**$22,409,691**
2024-25	$38,850,838	$24,476,028	$14,685,617	11,793,115	1,179,311	$8,255,180	117,931	$2,830,348	**$25,771,145**

Source: ACIL Allen

Value added for each year is calculated by multiplying the projected revenue for that year (which is assumed to be growing at 15 per cent per annum) by the ratio of value added to revenue (assumed to be 63 per cent, based on information from the Australian Bureau of Statistics' input-output tables of the Australian economy corresponding to the 'Computer Systems Design and Related Services Sector', the closest match to the activities undertaken by BuildingIQ).

The total floor area of buildings adopting the OptiCOOL technology is assumed to grow at the same rate as BuildingIQ's revenue (that is, 15 per cent per annum). Drawing on information provided by NABERS (part of the NSW Office of Environment and Heritage) in its *Energy Management Guide for Tenants* on the average energy cost per square metre ($35) and the average greenhouse gas (GHG) emissions per square metre (0.5 tonnes) as well as a carbon price corresponding to that set by the Australian Government for 2013/14 before its abolition this year, we have calculated the value of the savings in building tenants' energy costs and the value of the reduction in GHG emissions in each year based on the assumption that the OptiCOOL technology enables a 20 per cent reduction in energy usage on average.

The present value of benefits from the OptiCOOL technology is around $79.67 million.

Our analysis shows that the stream of total benefits of BuildingIQ to Australia for the period 2014/15 to 2024/25 is approximately $106.2 million in 2014/15 dollars under a 5 per cent discount rate and $91.9 million in 2014/15 dollars under a 7 per cent real discount rate. Assuming that 75 per cent of these benefits are attributable to CSIRO (as discussed previously in Section E.4.3), the present value of benefits arising from CSIRO's development of the OptiCOOL technology is estimated to be $79.67 million in 2014/15 dollars over the 2014/15 to 2024/25 period, using a 5 per cent discount rate, and $68.93 million using a 7 per cent discount rate.

Should BuildingIQ's revenue growth turn out to be 25 per cent per annum instead of 15 per cent as assumed, the present value of benefits attributable to CSIRO over the 2014/15 to 2024/25 period will be approximately $133.5 million in 2014/15 dollars. Conversely, should BuildingIQ's revenue growth turn out to be 10 per cent per annum, the present value of benefits attributable to CSIRO will be approximately $62.2 million in 2014/15 dollars.

The commercialisation of the OptiCOOL technology represents a tremendous return to CSIRO's investment in the development of the technology, which totalled approximately $412,000 between 2006/07 and 2010/11 (see Section E.1.4).

E.5.4 Impact pathway diagram

Figure E2 **OptiCOOL – impact**

INPUTS	ACTIVITIES	OUTPUTS	OUTCOMES	IMPACTS
▪ CSIRO funding ▪ BuildingIQ funding	▪ CSIRO research ▪ Development and testing of prototypes ▪ Build commercial product ▪ Provide support to firm licensing the technology	▪ Hardware and software for retrofitting to existing HVAC systems ▪ Patent registration ▪ Publication of manuals, specifications and training materials for BuildingIQ ▪ Journal and conference publications	▪ Licencing and commercialised hardware and software for retrofitting to existing HVAC systems ▪ Widespread uptake of OptiCOOL technology (15 million square feet of floor space in US and Australia) ▪ Employment opportunities in US and Australia ▪ Development of additional new technologies related to HVAC control systems	▪ Improved energy efficiency ▪ Lower building operating costs ▪ Revenue stream from licencing and royalties ▪ Improved comfort for building users ▪ Lower peak electricity demand ▪ Reduced emissions

Source: ACIL Allen

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