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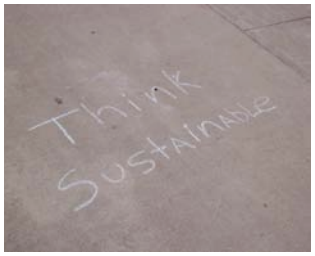

MET 2007 RESEARCH PROJECT

Sustainability through Technology: The Californian Model

Overseas Research Project

Manufacturing Engineering Tripos: Part 2
2nd – 17th July 2007

Institute for Manufacturing
Cambridge University Engineering Department
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1 Foreword

This report details an Overseas Research Project carried out by forty recent graduates from The Masters in Manufacturing Engineering at Cambridge University[1]. This report expresses the findings of the project in alignment with the chosen topic; *Sustainability through Technology: The Californian Model.*

The two week overseas research project carried out in July 2007 was conducted in the Californian Cities of San Francisco and San Diego, visiting a total of 17 companies[2]. The investigation sought to explore sustainable practice in California and the method of technological investment in order to achieve this.

The opinions expressed within the report are of the authors unless otherwise stated.

The group would like to thank all the companies who hosted visits on the project, along with all sponsoring partners. A great note of recognition must also be made to all members of staff and participating students who dedicated much time and effort into enabling the project to take place.

[1] www.ifm.eng.cam.ac.uk/met
[2] See Appendix 16.1 for company profiles

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2 Project sponsors

The overseas research project would not have been possible without help from our sponsors. We would like to express our gratitude to the following organisations:

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3 Acronyms

AB Assembly Bill
ARB California Air Resources Board
bdp Barrels per day (oil)
CO_2 Carbon Dioxide
CSR Corporate Social Responsibility
DFE Design for Environment
DOE Department of Energy
EPA Californian Environmental Protection Agency
EU European Union
IPCC Intergovernmental Panel for Climate Change
IPR Intellectual Property Rights
LA Los Angeles
LCA Life Cycle Analysis
PG&E Pacific Gas and Energy Company
PV Photo-Voltaic Cells
R&D Research and Development
RoHS Restrictions of Hazardous Substances
SME Small-Medium Enterprise
UK United Kingdom
UN United Nations
US United States
WEEE Waste Electrical and Electronic Equipment

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4 Executive Summary

This report describes the findings of a two week research project carried out in California by forty recent graduates in manufacturing engineering. The topical issue of sustainability formed the inspiration for this research. With a base of knowledge in business and technology, the group was able to explore and identify important factors for discussion. The chosen field of thought is in exploration of sustainability through technology, where the term *sustainable* has been taken to indicate practice that satisfies the needs of the present without compromising the ability of future generations to meet their own needs.

California appears to be investing heavily in new technologies in the hope of providing sustainable solutions to global and every day issues. As in any developed nation or state, it has developed a significant reliance on utilities to maintain high standards of living. The government have initiated many policies and programmes to help try and lead the nation towards a more sustainable way of life.

The visits made to a selection of companies drew on the main problems that businesses are facing as a result of a rising concern for the environment. What is being done about these issues, the impacts they are having and any future consequences were also recorded. This research facilitated examination of the extent to which technological innovation will drive future change in California.

Drivers for activity in this area are identified and some suggestions are made for ways in which California could be more sustainable. Debates and controversy run alongside solutions such as biofuels and alternative energies, and it is clear that there is a lack of full understanding regarding the impacts of many technological solutions. The influences some technologies or practices have upon one another is summarised by this project.

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It is concluded that although technology may help in the search for a sustainable future, correct dissemination of technology and appropriate solutions are of greater importance. It can finally be noted that greater pushes from government and businesses will aid the short term solutions to sustainability issues, however education in building an awareness of this subject is the most vital component in ensuring a systematic approach to existing and future services, practices and products.

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5 Introduction

The term *"sustainability"* has in recent years featured prominently in national decision making, vastly in the media and often as part of our everyday lives.

This interest in the environment and sustaining the way we live comes primarily from concerns for global warming and a rise in atmospheric levels of carbon dioxide (CO_2). The way we produce items, trade, travel and consume in high quantities has led to the unnatural balance of our ecological systems. Figure 1 below is taken from the fourth assessment by the Intergovernmental Panel for Climate Change[3] and illustrates the increase in global temperatures over the last 150 years.

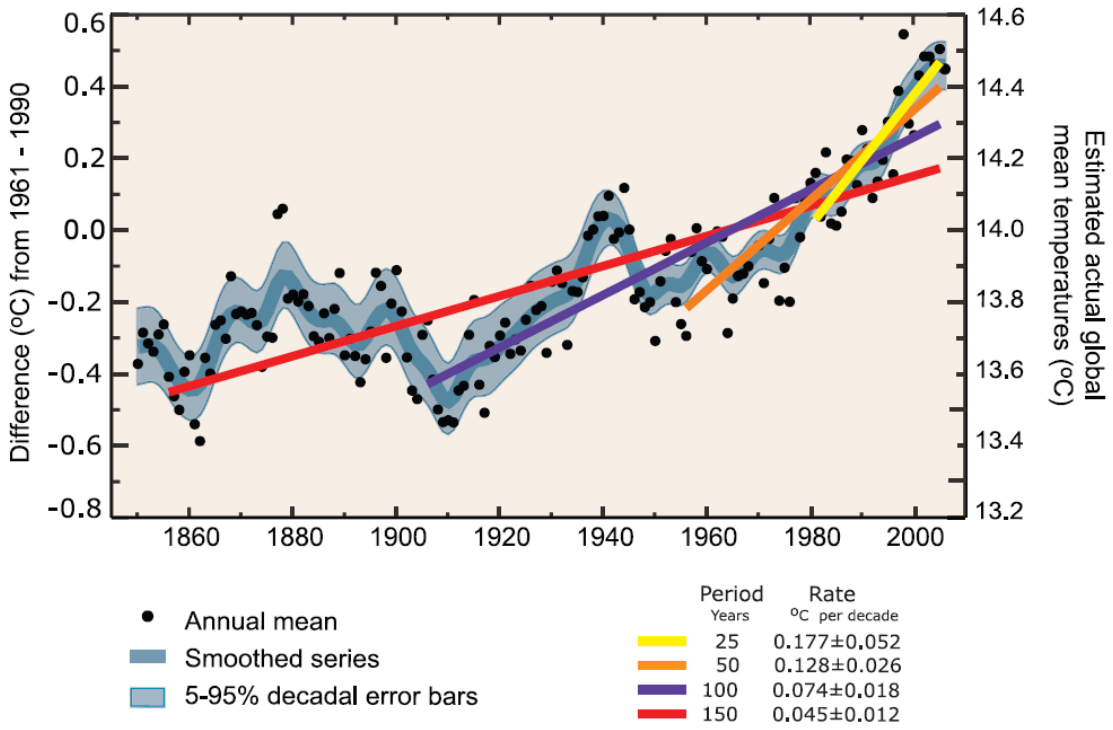

Figure 1

Temperature rises are due to an increase in CO_2 levels in the atmosphere, as the solar energy received on the planet cannot then escape as efficiently. A large

[3] www.ipcc.ch, 2007

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proportion of CO_2 and greenhouse gases come from the industrial sector; in 2005 37% of CO_2 emissions were from the energy industry and 18% from other industries[4]. This presents the sector with challenges, but opens up opportunities for improvement and innovation.

The volume of global manufactured production has increased two-fold in the last 30 years, and still continues to rise[5]. This demand fuels an increasing challenge for the manufacturing industry. Balancing greater production with sustainable practices in the coming future will be required to meet social, environmental and economical targets.

As manufacturing engineering students, it is fascinating to see the industrial environment making changes for the forthcoming generation. European policies and initiatives have begun to engage the topic of sustainability and legislate towards achieving sustainable manufacture and lowering carbon emissions. Some of these include The European Directives on Waste Electrical and Electronic Equipment (WEEE) and Restriction of Hazardous Substances (RoHS). In addition to policies and regulations, a number of industrial projects and visits made by this research group have highlighted behavioural changes taking place in manufacturing and business here in the United Kingdom (UK). With the topic of sustainability to hand and existing knowledge of business, manufacturing and technology, the group attempts to explore the complexities of sustainability and technological advances in the state of California.

From the outset California looks as if it is approaching this topic from a different angle to that seen in Europe. This project takes the opportunity to investigate how California is aiming to achieve *sustainability through technology*.

[4] Defra Statistics, 2007, www.defra.gov.uk/environment/statistics/globatmos/gagccukem
[5] Finbarr Livesey, 2006, *A Future in Manufacturing High Value?*, Lecture Slides; http://www.cranfieldfellowship.com/pdf/2_Finbarr_Livesey.pdf

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5.1 Sustainability and California

As early as the 18th Century, concerns have been expressed with regards to population growth and the limits of agricultural productivity[6]. Despite predictions of climate change and the unsustainable use of resources, it wasn't until the 1960's when environmental bodies arose within governments. The Agenda 21 put forward by the United Nations (UN) in 1992 presents the argument that resources and wealth must be re-distributed globally in order to sustain the environment. This would mean that the standard of living would need to decrease in the United States (US). Al Gore believes that the way the world needs to develop will create a *"wrenching transformation"* of American society.

In an analysis presented by Richard G Saxon of RIBA[7], two types of values on sustainability are identified. The e*co-puritan* view is that as a society we must embrace a *"green"* life and not create any waste or emissions. Where as the t*echno-fixers* believe that technology will bring the answer to the issues raised by sustainability. Of course one argument is that neither of these views (at their extreme) are viable. An *eco-puritan* approach would not complement the global economic system as it stands, and equally we are far from finding complete and affordable technological solutions. The interesting thing to note is the tendency of certain nations to adopt these approaches. Germany and Northern Europe certainly tend towards an *eco-puritan* belief system, whereas The US appears not to fall strongly on either side although it is moving towards a more technology based approach. Despite the apparent scepticism of the US, California is putting a lot of effort and investment into technology and seems to hold a strong *techno-fixers* viewpoint. Along with Japan it appears that California has identified an economic opportunity in sustainable practices, or are they just doing it for the good of the planet?

California is the largest populated state in the US, with a population of 37.3

[6] T.Malthus, 1798, *An essay on the principle of population*
[7] The Royal Institute of British Architects, 2007, www.architecture.com

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million residents in 2006[8] which has grown by over 17.5 million in the last 30 years. This has meant that strains on resources are evident and California is now globally the 12th largest emitter of carbon emissions.

The US Department of Energy (DOE)[9] in 2006 announced one of its award programmes contributing $34.6 million towards energy efficiency in the country. Of this, California has been allocated considerably more than other states, with $2,269,000 towards various research and development projects. The geology and natural environment of the Californian state has historically caused a shortfall in resources such as water, however it has also played an important part in creating alternative sources of energy. California's Mojave Desert is home to the world's largest concentrating solar power facility[9], in 2004 wind power provided 1.5% of the states energy[10] and geothermal plants (discussed further in section 8.2.2) are just some examples of areas in which California is one step ahead.

US Law has stated that carbon emissions must be reduced by 20%, of 1990 levels by 2020 and 33% by 2030. California however has set its own more rigorous targets to drop 25% by 2020 and to 80% by 2050. California's Governor Schwarzenegger is aiming to set an example to the rest of the country in its drive for sustainability, and has recently invested $40 million in research initiated by BP at Berkeley University. Numerous other investments of this type and in-state initiatives exemplify California's search for a *"sustainable solutions"* through technological advances.

Particularly interesting for this study is the contrast observed between practices in companies in the UK and that apparent in California; of high technological investment for sustainability. With a continual flow of new start-up companies from Silicon Valley and a strong government drive, California appears to believe

[8] www.ca.gov, 2007
[9] www.energy.gov/news/3704, 2006
[10] www.energy.ca.gov/wind, 2007

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that technology is the answer, whilst the EU is seen to be setting a focal point towards everyday behavioural change in order to combat global warming systems. By visiting a wide range of companies, institutions and talking to those working at all levels within organisations, one can gain a greater insight into the way Californian business is dealing with *sustainability*. This project will provide insight on whether California can sustain its standard of living through technology alone, and how much is being done in reality, behind the face of the campaign for sustainability.

5.2 Defining sustainability

"Sustainability" is a common term that holds many different meanings. Discussion on this topic has evolved over the past 300 years and is today a more pressing concern than ever before. As there are many definitions of sustainability, the opportunity is taken to look at a few examples before identifying the definition selected for this research project.

One of the earliest definitions of sustainability is thought to be that of Sir MacFarlane Burnet in 1966;

> *"Resources of the Earth must be maintained for the use and enjoyment of future generations in a measure not less than we now enjoy".*

In the 1980 IUCN[11] World Conservation Strategy sustainable development is defined as;

> *"The integration of conservation and development to ensure that modifications to the planet do indeed secure the survival and well-being of all people".*

[11] The International Union for the Conservation of Nature and Natural resources

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The term adopted for use in this project however, is as defined by The UN World Commission on Environment and Development in their report *"Our Common Future"* in 1987;

> *"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs"*

Although this definition remains somewhat unqualified in its terms, it is hoped that through examples in industry this project can aim to understand what needs are to be met and how they can be sustained for the short term and long term future.

More recently *the triple bottom line* is thought of as a *"popular way of understanding sustainability"* according to the 2006 Forum for the Future[12]. This suggests that only through the consideration and measurement of the trio of environmental, social and economical influences can we truly lead industry in a sustainable manner.

This report explores the main drivers for meeting the triple bottom line and the issues it generates. Through visits and meetings at political, business and academic levels; the opinions of the people involved in sustainable outcomes for manufacturing and business are invaluable to this investigation.

5.3 Technology and sustainability

Sustainability and technology have been interconnected in debates for many years, with technology typically seen as having both a negative and positive influence on the environment. Over 30 years ago, in his book "Small is Beautiful"[13], Schumacher identifies the fact that it is technology and the increasing population that has led to environmental damage. It follows that

[12] www.forumforthefuture.org.uk
[13] E.F.Schumacher, 1973, *Small is Beautiful, A study of economics as if people mattered*

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science and technology need to be re-directed in order to provide *"inventions and machines which reverse the destructive trends"* we have created on our planet. An emphasis is placed, in Schumacher's argument, on the need for solutions suitable for small-scale application as well as being sustainable and cheap. This opens up another interesting topic for exploration later, in section 10.3, upon technology and sustainable activities at a small-medium enterprise (SME) level compared to that within larger corporate firms.

In 1971 Ehrlich, Commoner and Holdren (US biological researchers) created the IPAT formula to measure society's impact on the environment:

Impact = Population x Affluence x Technology (I=PAT)

This of course does not provide a quantitative measure, but it is interesting that technology is seen to be directly proportional to environmental impact, and can contribute either negatively or positively to it. Discussion around this equation is of interest since it has created some controversy on the topic. Ehrlich and Holdren disagree that technology is solely responsible for the environmental problems we encounter today and believe that although technology may help delay environmental consequences it certainly cannot eliminate them. Commoner has a much stronger opinion towards the great influence technology has in global issues. He believes that *"ecologically faulty technology"* is the cause of today's environmental problems. Commoner went on to write "The poverty of power" in 1976 as a response to the energy crisis of 1973 where he highlights that the linkages between the ecosystem, production system and economic system are not fully understood and that it would be dangerous to keep using energy without thought for the future. Ehrlich, Holdren and Commoner had a powerful influence on thought in environmental issues. Although discussions today tend to be more optimistic in the hope for technology to provide a more sustainable future, there is still an emphasis on how much more understanding is still required within the field.

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An article on the changing views of technology and the definitions of the IPAT equation[14] concludes that technology is often easier to manage than human behaviour, especially in the US where this thought comes from the *"faith in the power of scientific advance"*. Having already identified this as an observation from the UK during preliminary investigations, the research project provides a tool for exploring this further.

5.4 Vision

From afar California certainly seems to be ahead of its neighbouring states with regards to its sustainable ethos and beliefs. California's Governor Arnold Schwarzenegger promotes a strong vision for the state and is seen to be putting a lot of effort into the global environmental forum. He has stated that his priorities lie in this promotion to the global arena and that creating *Clean-tech*[15] for future generations will also offer a great opportunity for business generation. Governor Schwarzenegger claims that through efforts in research and policy-making California can *"save the planet and boost its economy"* as well as lead other states and influence federal government.

> *"California leads the way on one of the most important issues' that is facing our time, that is; the fight against global warming."* Gov. Schwarzenegger[16]

The Californian Environmental Protection Agency (CalEPA) has an environmental and economic awards programme. The awards seek to identify exceptional activities from the individuals or businesses that have voluntarily

[14] M.R.Chetrow, 2001, *The IPAT Equation and Its Variants, Changing views of Technology and Environmental Impact*, Journal of Industrial Ecology
[15] Clean Technology abbreviated to "clean-tech" to group new advances in technology that are efficient and globally responsible
[16] Sept. 2006, *Press release on signing of Landmark Legislation to Reduce Greenhouse Gas Emissions*, AB-32.

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contributed to sustaining resources or protecting California's environment. Amongst the winners from 2006 are a solar schools programme from Pacific Gas and Electricity (PG&E), a vineyard practicing sustainable agriculture and a recycling scheme in San Francisco.

It is not only at a governmental level that California appears to be working hard to provide sustainable solutions to improve climate change and protect the environment. Many corporations and large businesses include some sustainable visions as part of their mission statements and policies.

> *"Together with our employees, Sony in America is working to improve our communities and the world around us."* Sony USA Corporate Philanthropy.

> *"We believe sustainable winegrowing goes above and beyond the methods of organic farming and focuses on sustainability as a long-term goal"* Kunde Estate Winery & Vineyards California.

By visiting a variety of Californian companies and organisations the project hopes to find that these visions will be somewhat measurable. Since the Greenpeace movement in the 1960's, there has been doubt over the reality of corporate statements. The term *"Greenwash"*[17] has been adopted to stand for the environmentally conscious image that some boldly proclaim, with no action or truth behind them. As companies and business aspire towards a sustainable future, this research can assess the authenticity of their statements as well as look at any real impacts they may be having.

5.5 Report outline

Having defined the terms used in this project, the report will endeavour to explain the findings of the group. When visiting companies and organisations it was

[17] *A Brief history of Greenwash*, March 2001, CorpWatch

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important to obtain their definitions of sustainability in order align the investigations of this report, these outcomes are explained in section 6. In order to form some thinking into why businesses might engage in sustainable practices the group predicted some drivers as part of their preliminary work. The next section explains these predictions and formulates an extension of the drivers as presented by organisations when on the visits.

Section 8 provides the main bulk of the findings and discusses the challenges for sustainability in California, and more specifically what is being done in order to combat them. Section 9 presents the knock on impacts of the sustainable solutions seen on the visits and summarises them in the form of a sustainability web. With examples of sustainable activity and initiative, section 10 looks at how sustainable practice affects business and what barriers exist to preventing them from *"being green"*, in this respect the section focuses on how small firms compare to large companies. The concluding chapters take a look at sustainability through technology, some alternatives to this and how California could improve its activity in this field. Finally the report draws on a few lessons learnt to bring back to the UK before finally concluding the findings for the project.

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6 What does sustainability mean to California?

Sustainability is a term that is often ill-defined. Having selected a definition for the content of this project it was important that those interviewed were in agreement with this and that any other definitions were recorded.

All of those questioned agreed with the definition of *meeting the needs of the present without compromising the ability of future generations to meet their own needs*. However, it was found that sustainability within each organisation often appears to be represented more in line with their individual operations. Those at a building design company, Organic Architect, indicated that they preferred to use the term *"responsible"* over *"sustainable"* due to the ambiguity and generalisation it has adopted.

Sustainability in these terms requires a higher level thinking that is hard to link directly to everyday practices and operations. It is apparent that sustainable activity within companies may be a means or an end. Only where companies can integrate awareness at all levels and not solely in the final product they produce, are they working by means to a more sustainable business. It is clear that in order to operate for more than just a sustainable end result proves challenging for most businesses.

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7 Drivers of sustainability

7.1 Predicted drivers

Four main drivers for sustainability have been identified for the purpose of this research. Motivations for seeking sustainable solutions within business were discussed and led to the following predicted drivers; legislation, dissatisfaction, profitability and energy security, Table 1 below notes describes each driver in further detail.

Legislation Legislation is an obvious driver for companies and industries to act sustainably. In order to meet regulations there is often some change required within a business. Examples of technological and behavioural change have been seen here in the UK with the WEEE and RoHS directives, these have also had an impact in California since WEEE and RoHS regulations must be met on all imports to the EU.	**Energy security** The California energy crisis of 2000 and the unstable industry structure have left Californian energy resources vulnerable to climate change (see Section 8.2 regarding the energy industry). The threat of oil shortages and dependence on foreign imports will drive the search for alternative energy resources and lower consumption rates.
Profitability Without investors or profit businesses cannot operate, this factor is therefore another obvious driver for any change in a company. With regards to sustainability, it is thought that companies who focus on developing new technologies or meeting new demands in the market will only do so if it is profitable.	**Dissatisfaction** California's geology, geography and history have lead to dissatisfactions caused by poor air quality, shortages in water resources and energy supply. It is therefore thought that this factor must play a significant part in driving the general public and individuals in a push for sustainable solutions.

Table 1

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7.2 Drivers – The reality

This section represents the opinions of those interviewed at organisations and companies. All of the drivers for sustainability, as expressed during these interviews, are embodied here. Views outside that of the employee's however, were less obvious and beyond the scope of the visits made.

When asked about the drivers for sustainable practice, the responses received from the organisations tended to vary. All of those interviewed agreed with the highlighted drivers and were asked to identify the one key driver that had most influence on their business. Figure 2 shows the distribution of key drivers for acting sustainably, as expressed by 13 of the organisations visited.

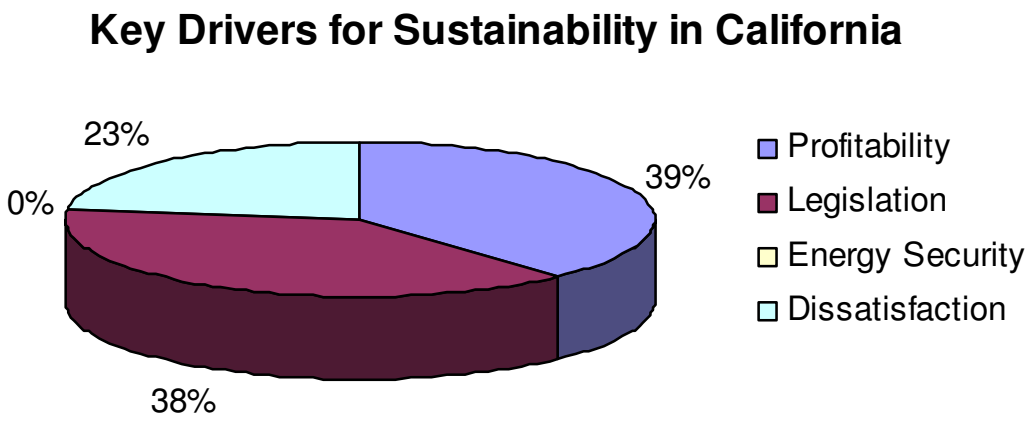

Figure 2

Profitability and legislation were viewed as the strongest drivers, and energy security did not feature at all. It is surprising that energy security was not conveyed as a major driver or concern. This may be because energy security is a higher level consideration that poses a threat at a national level but not directly at an organisational level. It can be argued that businesses that are investing in research and development in biofuels would not exist without the threat of energy security, as they try to find alternatives to oil. Maximisation of energy resources was certainly a key component in the business focus at CalEnergy and some

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members of the biofuel cooperatives. During visits it was also noted that the majority of projects are funded by the Department of Energy (DOE) and that energy security is clearly an important factor for the environment. The energy industry is discussed in more detail in section 8.2.

Although most companies were able to identify key motivations for their organisation, it is clear that the drivers discussed here have an impact on one another and are closely interlinked. In addition to the four factors identified, other drivers were indicated as being the main propellers for an organisations sustainable behaviour. These included health issues, such as illnesses experienced due to poor air quality, and also care for future generations.

Drivers for sustainability

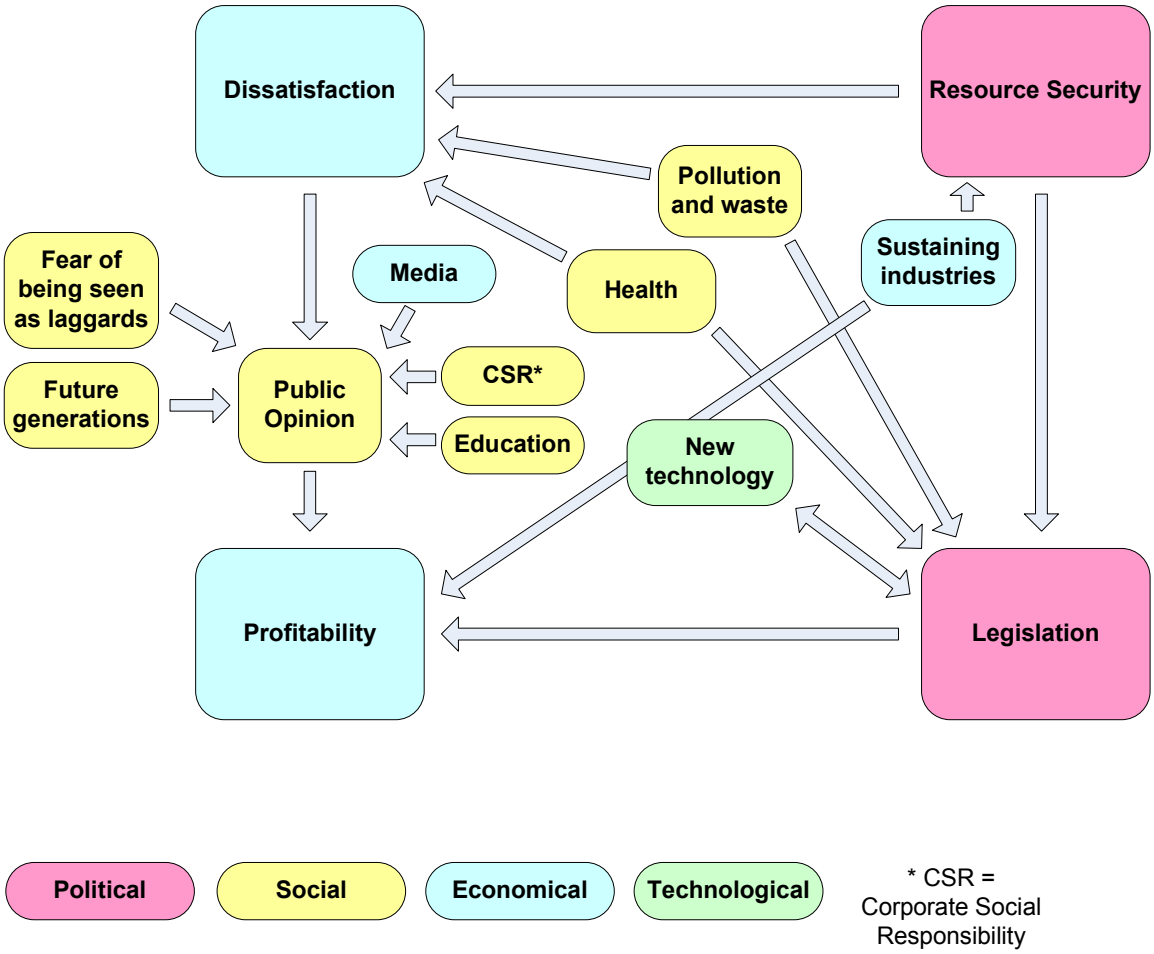

Figure 3

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The schematic in Figure 3 illustrates all of the identified drivers from company visits made, with the arrows representing the knock-on impacts that some drivers have upon one another. An example here is that new technology may initiate new legislation should it create pollutants that need to be restricted, or alternatively, in the case of the catalytic converter, the technology enabled the legislation to be enforced. Similarly in order to meet new legislations an advance in technology may be required. New technology can drive sustainable activity; this was seen at Maxwell Capacitors where advances in their products are leading to outstanding energy saving products and systems. Technology is a less common driver for sustainability since its application relies on identifying how it can bring sustainable benefits to a product or company.

As climate change and the environment enter the public domain it is not only personal dissatisfaction that influences the opinion of the nation. The forward thinking attitude of many Californians has created some global awareness and therefore created a new market that demands more sustainable products and services. At the Environmental Energy Technology Division (EETD) laboratories at Berkeley, it is believed that despite the new market in this area, the demand from the public is not as strong as it needs to be and that more should be done in order to drive this forward.

If legislation and profitability truly are the main drivers for companies to be more sustainable then a greater focus should certainly be made in these areas, along with a market push, in order to influence them. One possible way of achieving this may be better education about the issues at hand; the resulting dissatisfaction based on the current state of affairs would reflect in customer preferences and the introduction of new laws due to public pressure.

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8 What is being done in the field of sustainability?

This section explores the main issues for sustainability in California in order to analyse the reality of what is happening in this state and the impact it is having. Clearly there are many more issues beyond the scope of this project that would have been interesting to analyse.

8.1 Emissions

8.1.1 The issue

The Californian city of Los Angeles (LA) sits in a valley and from as early as the 1940's smog and air quality issues have been of concern to health and quality of life. Long Beach in LA is California's largest port for Chinese imports and therefore adds to the air quality issues in this city. Research at California's leading universities has led to greater understandings of the issues. Half of California's energy use is in transportation fuel; the state has 30 million registrations, 18 of which are automobiles[18]. Hence 92%[19] of the states CO_2 emissions are from transportation and energy production; it is here that focus needs to be made.

8.1.2 What is being done

California was the first state to impose air quality standards in 1959, and the Air Resources Board (ARB) was created in 1967 to meet the challenges presented by the smog. Cleaner cars were manufactured but smog levels only marginally improved. The population of California grew significantly and car ownership was high. A video produced by ARB[20] states that California was leading the US and the world in air pollution control because it had no choice. The health of the public was at high risk. Throughout the 80's and 90's California succeeded in being home to some of the cleanest cars, and whilst air pollution has improved it is still a considerable concern today. Dissatisfaction of this sort creates a need

[18] *Balancing California's Energy*, 2005, Laurence Berkeley National Laboratory
[19] Taken from California's Sustainable Energy Policies, 2006, NRDC
[20] *Clearing California Skies,* 2004, Video: http://www.arb.ca.gov/videos/clskies.htm

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for change and development. Technological advances play a great part in fighting discomforts such as the smog explained here. The Governor has budgeted nearly $36 million[21] for the implementation of The Global Warming Solutions Act set in 2006, AB32, the majority of which is allocated to the ARB.

A visit to Tesla Motors highlighted its high-performance electric sports car. The 100% electric Roadster has managed to succeed in creating a fast yet energy efficient vehicle. The car has an energy storage system that contains a battery of lithium-ion cells which can drive the car for up to 245 miles. The battery status is fed back to the driver and the power electronics module ensures that it is recharged as efficiently as possible. The enabling factor of the Tesla Roadster is the development of its unique battery technology. The electric motor is on average 90% efficient and is therefore very competitive in its performance. Figure 4 below shows how the Roadster compares to some high performance cars in the market. The miles per gallon along the x-axis indicates the efficiency of the cars where the Roadster stands out against its competitors.

[21] Legislative Analyst's Office, www.lao.ca.gov

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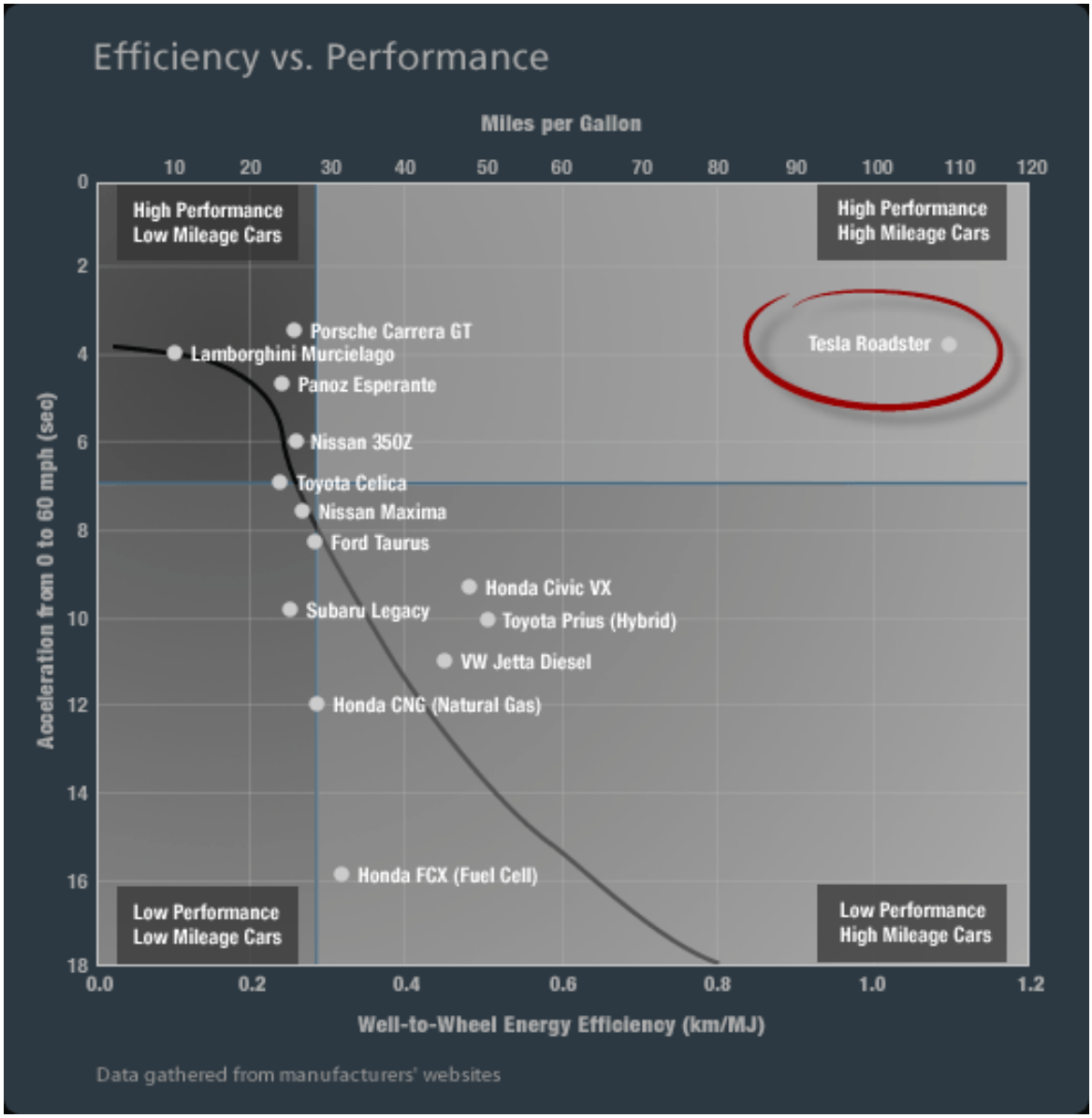

Figure 4[22]

Tesla technology is a good example of how sustainability can be addressed by cutting back carbon emissions. However there are some limiting factors to the introduction of electric vehicles that include high component costs, infrastructure readiness and maintenance (although the battery life of the Roadster is 100,000 miles). Tesla have targeted their car at the high-end performance market but at the same time managed to maintain an affordable price.

[22] www.teslamotors.com

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Figure 5[23]

Tesla also emphasised that their car can be powered with 100% renewable energy. They have set up a partner scheme with Solar City[24], a solar energy systems supplier, to encourage customers to install solar panels in their home, which can then be used to re-charge the vehicle.

8.1.3 What are the impacts

Activity towards the elimination of emissions has led to more serious studies on the topic. The Energy Commission and U.S. Department of Energy carried out research into geologic carbon sequestration to meet the requirements of the Bill

[23] Photo of the research group at Tesla Motors and pictures of the Roadster taken from the Tesla website
[24] www.solarcity.com

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1925 passed in 2006 which focuses on energy savings. The project concluded that although more technological research must be carried out, the other main barriers were regulatory control and lack of public education on the topic.

Figure 6[25] below shows California's per capita CO_2 emissions over the last 30 years. Efforts have meant that levels are below the rest of the country and are decreasing.

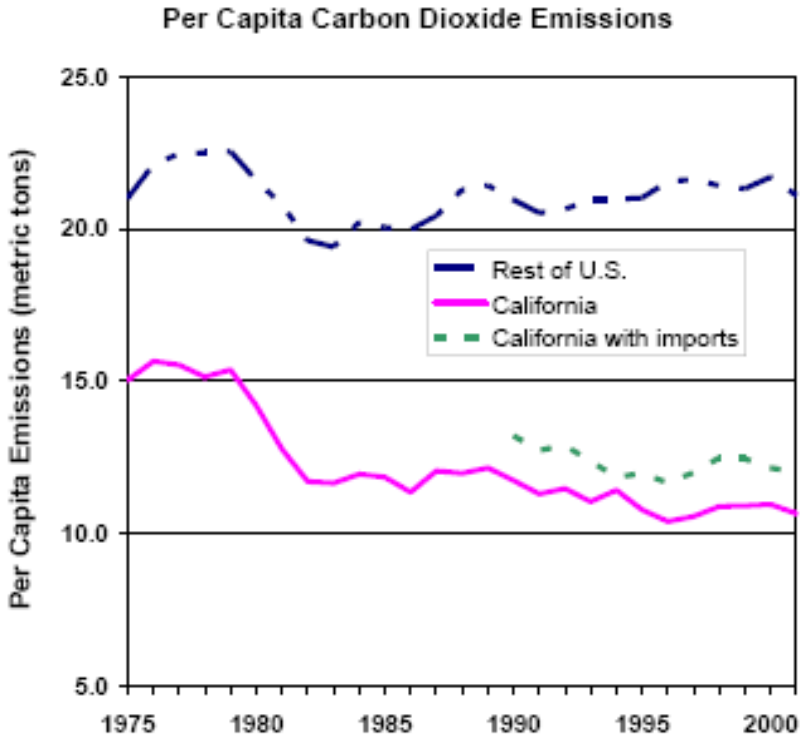

Figure 6

Despite attempts to lower emissions California is still the 12th largest emitter of greenhouse gases globally. The population has grown significantly and the consumer-driven lifestyles mean that people still want to drive around in their large, highly gas-consuming, vehicles. Small initiatives and products such as the Tesla Roadster are great at providing solutions to high emissions and pollution,

[25] Taken from California's Sustainable Energy Policies, 2006, NRDC

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however the impacts are also small, and a lot more is needed in order to make a significant difference.

8.2 Energy

8.2.1 The energy industry

Energy usage and supply have been somewhat of a delicate topic for California over the last decade. In the year 2000, high demand from its large population and regulated energy industry led to the energy crisis that is still ongoing.

The Californian energy crisis of 2000 was the result of an unexpected hot spring that meant energy providers were unable to cope with the high demand; the majority of energy used in buildings in the state is consumed in air conditioning units. Regulation of energy prices meant that energy providers could not afford to supply the demand and had to resort to out-of-state resources, thus leaving the industry with major financial difficulties. The crisis led to the deregulation of the industry so that energy prices were no longer fixed. There are a few main private energy suppliers in California and the US; PG&E is one of the largest gas and electric utilities in the United States and owns nearly 60%[26] of all electric transmission lines that run for over 100 miles. Despite large in-state plants California still relies on import for some of its energy. Figure 7 shows California's major sources of energy and its dependence on imports[27].

[26] California Energy Commission
[27] Figures summarised from 2005 & 2006 California Energy Commission

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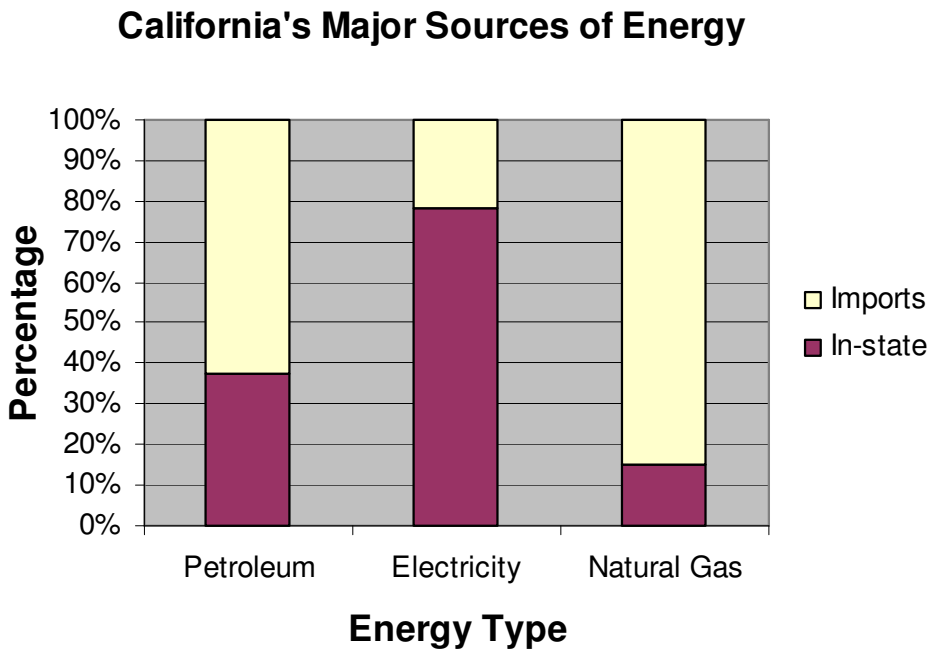

Figure 7

California has set itself targets to meet 33% of its energy needs from renewable sources by 2010, and 80% by 2050, but how are these targets going to be met? Visits made on this project offered a glimpse at some efforts in the energy industry towards more sustainable supply and use.

8.2.2 Geothermal

The geothermal plant visited at Salton Sea (Figure 8) has a net capacity of 335MW and is run for 24 hours every day, extracting energy from hot molten rock deep underground. The capital and operating costs are higher than for a gas power station but still has a theoretical payback of 30 years. The plant is not subsidised by the government but does serve 1.3 million customers in the state.

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Figure 8

Figure 9[28] below shows the layout of the geothermal plant and the basic steps in its energy extraction process.

[28] For virtual tour see http://www.calenergy.com/html/aboutus4.asp

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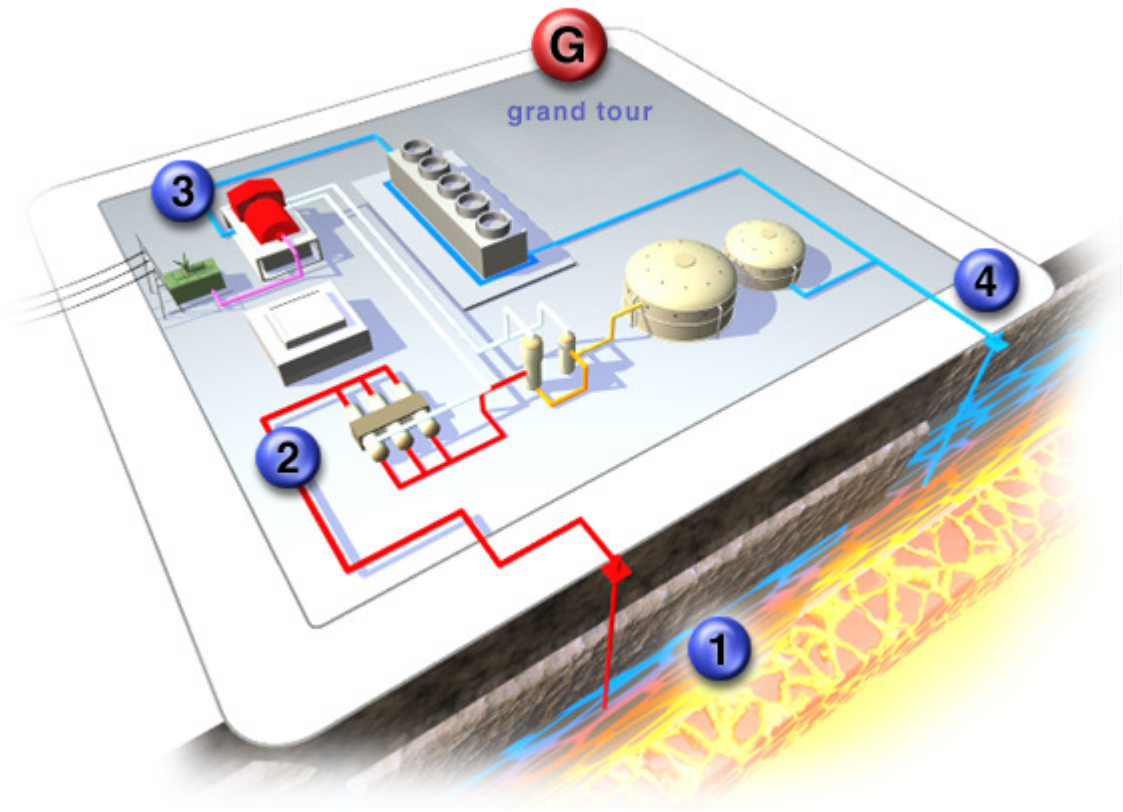

Figure 9

(1) Superheated fluid at magma thousands of feet under ground (5,000ft – 10,000ft) extracted through a production well.
(2) The solids are separated from the steam.
(3) The steam is used to drive the turbines to generate electricity.
(4) The fluid left is injected back into the underground reservoirs via injection wells.

A geothermal reservoir will normally provide energy for up to 200 years and provided the fluid is not extracted quicker than it is replenished by rain water, it will act as a sustainable source of energy. California already uses 10% renewable energy, 8% of which comes from geothermal plants, this is included in the 1% of geothermal energy used in the whole of the US.

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Like all solutions there are both advantages and disadvantages to this technology as summarised in Table 2.

Problems of geothermal energy	**Advantages of geothermal**
▪ Getting the energy to the customer. ▪ Expensive capital costs. ▪ Four to five times more power needed than gas energy plants result in high operating costs. ▪ High cost in pipes (titanium cased) to prevent or slow erosion.	▪ Is not destructive to environment or agriculture. ▪ Low CO2 emission in energy generation compared to coal and gas. ▪ California has the largest geothermal resource in the world (approximately 20% of world capacity). ▪ Geothermal potential in California alone is 3,465MW. ▪ Creates jobs and energy price security for the state. ▪ Produces the equivalent of 274,000bpd of oil (typical Saudi Arabian oil well produces 10,000bpd).

Table 2

Geothermal is therefore a good source of power for California; however transmission is an issue here, since there is resistance to the construction of new transition lines. More lobbying at federal level is needed in order to combat problems of this type.

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8.2.3 Domestic

Electricity use in the home accounts for 40% of the total energy use (another 40% in commercial and only 14% in the industrial sector)[29] An Executive Order on green buildings was issued in 2004 for California, which says that new state buildings had to be 20% more efficient by 2015, it also encourages the private sector to follow these guidelines too. A rating system from the Leadership in Energy and Environmental Design (LEED) is used to measure performances in the building sector.

One visit was made to a small business that provides sustainable designs for homes: Organic Architect, a unique architectural practice providing sustainably designed homes. The founder does not want to expand the business into a large company and holds a vision of gaining greater community and social interaction through the incorporation of his designs. He believes that people will not ask for sustainable buildings, and instead his company will need to adopt a push approach to sales. The focus within this company is on material resources, indoor air quality, maximum air/light/water/energy use and appropriate siting of buildings. Organic Architect has changed the value proposition of its services from an upfront cost to a lifecycle cost when talking to clients, through this long term benefits can be recognised. Figure 10 shows the priorities Organic Architect sets for itself and the impacts targets may have on the environment.

[29] 2005 stats for Electricity usage in peak periods from the Energy Commission

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In comparing relative measures it's useful to consider the environmental issues affected by each measure and the scale of impact.

	Related Environmental Categories						Scale of Impact		
	Air Quality	Water Quality	Land & Soil Quality	Virgin Resource Depletion	Biodiversity	Occupant Health	Global	Regional	Local
Save Energy									
Recycle Buildings									
Create Community									
Reduce Material Use									
Protect/Enhance Site									
Select Benign Materials									
Maximize Longevity									
Save Water									
Make the Building Healthy									
Minimize C&D Waste									
Green Your Business									

	High Relevance
	Some Relevance
	Minimal Relevance

Figure 10

Organic Architects have initiated partnerships with the developers of the Green Home Guide, the Green Business Certification and *"Gigacrete"*[30]. *"Gigacrete"* hydraulic cement is made from ash from coal power plants and cement, which means that landfill volumes are decreased.

[30] See www.gigacrete.com

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Figure 11

Figure 11 shows an example of the work carried out at Organic Architects. This passive solar house, in Bernal Heights in San Francisco, is built of Insulated Concrete Forms (ICF's). The intention is that solar gains are made during the day to keep the house warm in the evening. Solar shading on the western side is achieved using bamboo rods in a wave pattern.

California State is also working in this area. The California Solar Initiative (state funded) was launched at the start of 2006 whereby $2.9 billion over ten years is available for installation of solar panels on roofs. The aim is to increase the energy gained from solar power by 3000MW by 2017[31]. Additional tax has been implemented on energy use in order to fund education programs to teach people how to use energy more efficiently in their home. PG&E and the Energy Centre dedicated to this have a billion dollars to help meet the targets set for their company in line with California state objectives.

[31] See http://www.cpuc.ca.gov/Static/energy/solar/index.htm for more information

8.2.4 What are the impacts?

Figure **12** 12[32] shows electricity consumption in California compared to the rest of the US. Although California is the state with the lowest energy consumption per capita, as the highest populated state in the US its energy demands are still significant.

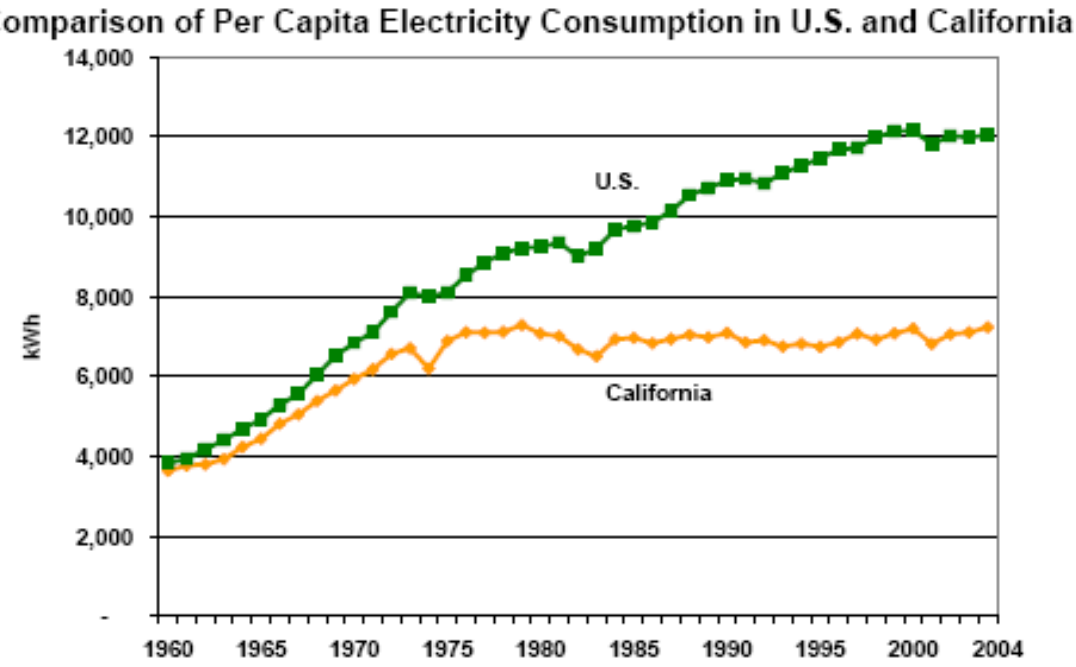

Figure 12

The impact of small start up firms, such as Organic Architect, is the creation of a niche market as well as building awareness for its customers and the general public. With solutions such as this people are able to continue to maintain their quality of life without the same negative impact on the environment.

8.2.5 Future

Other examples of energy projects include research seen at the molecular foundry, still in their early stages; improvement of PV cells and hydrogen energy storage have not yet been commercialised. Some impressive solutions to

[32] Taken from the California Energy Commission 2005 statistics

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providing alternative energy to California have been observed and the government is clearly aware of the needs in this sector. In spite of good efforts in California the struggle to meet demands from an ever increasing population are clear pressures on energy supply and usage. The majority of funding currently comes from the energy commission but perhaps this industry could diversify in its support to projects by pushing for more research and growth in new technologies.

8.3 BioFuels

8.3.1 Why biofuels?

The main drive for finding alternative fuel sources is energy security, as well as trying to lower CO_2 emissions. Biofuels offer some answers to these problems, but like most solutions there are both positive and negative outcomes.

Biofuels are liquid fuels extracted from biomass. Biofuels have been used historically and some of the first cars relied on this fuel source. Today biofuels are mixed with existing fuel such as diesel and help relieve some dependence on other sources. Cars manufactured in the US since 1988 are legally required to be capable of running with at least 20% biofuels (B20) in their fuel mix.

First generation biofuels come from food crops such as vegetable oil, palm oil, sugar cane and so on. Bio-ethanol can then be created by fermentation of these crops and bio-diesels are made through chemical reactions with alcohol. Second generation biofuels are now being explored further and come from agricultural crops or waste such as wood chippings to create fuels like cellulosic-ethanol. These have advantages over first generation fuels since they do not compete for land area with food crops and make use of all of the plant material, unlike first generation fuels that only use part of the crop. Second generation fuels use biomass-to-liquid technologies that are not well developed or ready for commercialisation.

According to the conference attended on biofuels in San Francisco; there was a 300% growth in 2005 in the biodiesel market, however ethanol is still more widely used than Biodiesel in the US.

8.3.2 What is being done

The US DOE, in 2006, implemented the Biofuel Initiative (BFI) that aims to make cellulosic-ethanol cost competitive with gasoline by 2012, and to replace 30% of fuel usage today with biofuels by 2030. There is debate however over the extent of biofuel use and its limitations.

Small biofuel organisations are dedicating research into biofuel use and development. Cooperatives have been established in order to share knowledge and spread awareness; The San Francisco Biofuels Cooperative has one fueling station to provide biofuels to its members. A Biofuel school bus campaign is another example of a small cooperative project. School buses are run on waste oils from restaurants and other sources of biofuels, there are also lower emissions inside the bus. Many of these projects, as well as biofuel related Silicon Valley start-ups, such as LS9, are funded by the US Department of Energy, as part of their focus in biofuel development.

LS9 is a Biotechnology Company that is investigating the commercialisation of biologically synthetic fuels. Figure 13 represents some alternative fuel options as viewed at LS9. Comparison of cost and the difficulty in developing and using them as a fuel alternative are indicated. The difficulties are being tackled here in order to try and create a suitable biofuel for the market.

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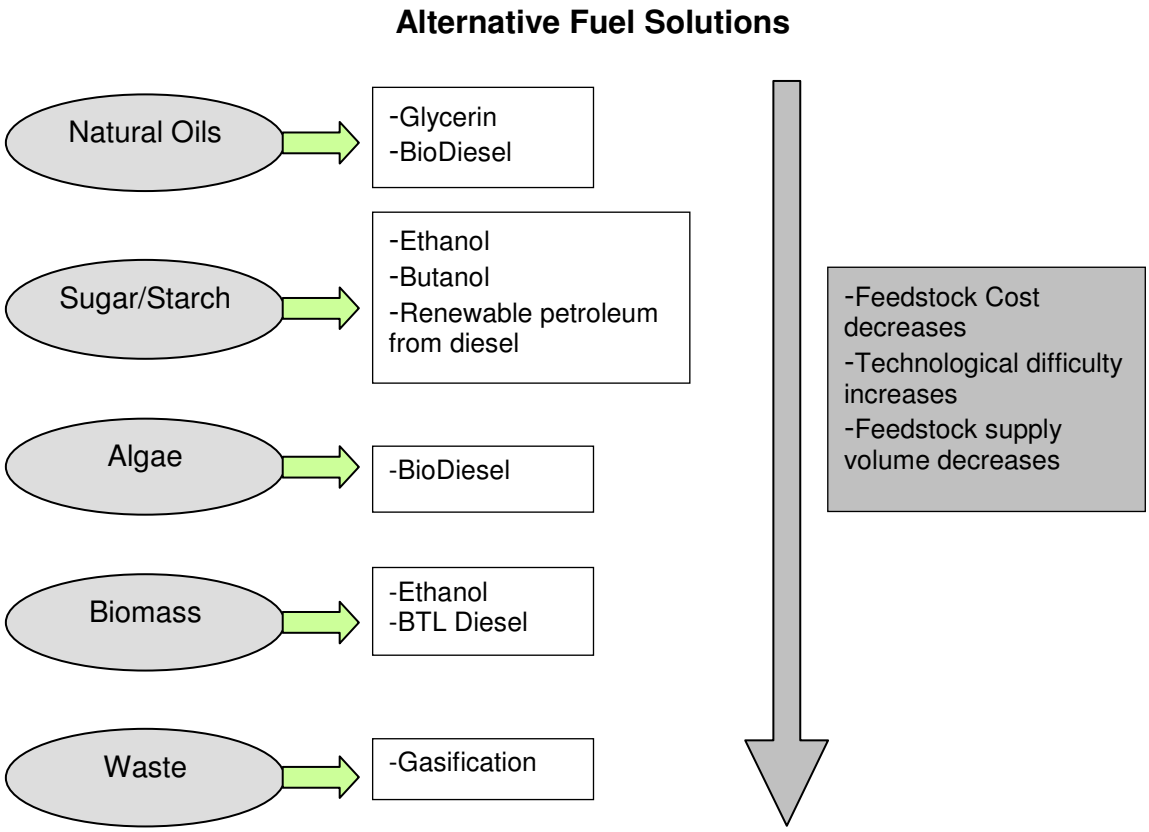

Figure 13

8.3.3 What are the impacts

One main topic in the biofuel debate is the amount of arable land area required for their growth. Biofuel harvest puts pressures on food-crop resource and in some cases results in deforestation. This is of global concern since many countries depend on others for food stock. As well as the high demand for land, a fast turnover of crops is needed to meet even just a small percentage of fuel demand. Inevitably soils will be affected from this high level of users.

It is questionable as to how much is really known about this technology and its impacts, California appears to be leaping ahead in this field without much

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concern for its consequences. One example given in an article from Professional Engineering[33] is that biofuels could be damaging to car engines.

Biofuels claim to provide a *"carbon neutral"* solution. During growth of the biomass or crop, carbon is sequestrated from the atmosphere thus offsetting the carbon released when it is burnt as a fuel. The total amount of carbon released in growth, production and use can be analysed through Life Cycle Analysis (LCA). This analysis is important since biofuel production may be very energy intensive. Only when fuels are grown, processed and distributed appropriately, are biofuels any better than oil with regards to their carbon impact. Consideration of varying conditions during growth can play a large part in optimising this process. LCA can be used for other products besides biofuels and at EETD they took pride in the LCA methodology achieved through DOE funded research.

Issues surrounding biofuel development are discussed in a 2007 paper from the UN[34]. The paper concludes that regulations, definitions and measures of biofuels and sustainability need to be made in this area and that technologies and knowledge need to be shared at an international level.

During the visits and through discussions with biofuel companies and researchers, biofuel was described as a *"transitional fuel"* and a short-term solution to energy security. It is clear that more research is required in order to fully understand the use of biofuels, but that funds would be better spent looking at long-term solutions such as the electric car, or one that tackles the root problems of high fuel demand?

[33] "Biofuels prove their worth…", 2007, *Professional Engineering*
[34] "Sustainable Bioenergy: A Framework for Decision Makers", 2007, *UN Paper*

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8.4 Electronics

8.4.1 The issue and activity

In California there are strict regulations and guidelines for environmental impacts of electronic manufacturing; which are considered to be a contributing factor to the decline of this industry in the US. Sony is now the last television manufacturer in the country where 45 different models are produced annually. It is large companies like these that need to focus on their impacts and look at the LCA of their products. Employees in larger organisations did not seem very aware of the corporate social responsibility (CSR) practices or sustainability of their companies. Since this research project was carried out, Sony launched the first recycling management scheme of its type in the US. The scheme works in cooperation with a national waste management company; Waste Management Inc. The Sony *"Take Back Recycling"* programme has been started free of charge, whereas in many parts of America a fee has been put in place for the recycling of electronic goods.

Maxwell Capacitors, an electronic company visited, has three high-tech production lines in San Diego where 25% of its manufacturing takes place. The company aims to create products for increasing energy efficiency and lowering CO_2 emissions. Capacitors of up to 3000F are produced with long life, very high efficiencies and low operating temperatures. These have potential in applications such as electronic devices for industrial and consumer markets as well as wind energy storage and hybrid buses. They are used in addition to batteries and extend their life by adding surge capacity to the battery power source, called tandem power sources. Their low cost manufacturing process and research into new electrolytes have allowed Maxwell to take advantage of their technological advances in this field. Maxwell is already working with auto racing teams where they have achieved great efficiencies in batteries. The sustainable impact of Maxwell's work is the "green" end effect of their products as well as environmental benefits of their production process. The energy efficiency of the

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processes has been a great achievement and has considerably lowered the cost of manufacture. They have also reduced solvent use from 70 types to just 2 in their designs to create a 100% recyclable product.

Maxwell provides a good example of how a company can make extensive monetary savings as well as providing sustainable solutions through the use of new and developed technologies. Larger companies and businesses have the potential to play a huge role in protecting the environment and working towards sustainability. In some larger organisations visited, it was apparent that an understanding of sustainability, whilst present in corporate literature, was not well dissipated to employees at lower levels. Building awareness in companies needs to be a target for change to occur, and more forward thinking should be allowed in order to help aid innovative solutions for a more sustainable world.

8.4.2 Future

It seems likely that the future of the electronics industry will be more influenced by technological advances than behavioural change. There is a limit to what the consumer can (and will) do to aid sustainable living.

In the short term, there will be benefits from rising quality standards. Products will have a longer life and therefore reduce waste, whilst more efficient products and operations will consume less power. Manufacturing processes will continue to be cleaner, and with appropriate legislation, utilise more environmentally-friendly materials and processes. Reclamation programmes, in which the manufacturer takes responsibility for used products, are also becoming more widely adopted, promoting a more sustainable product life cycle. The other side to this issue is the fast turnover of products that a consumer may purchase in order to keep up with current trends or fashion. In this case the importance of correct waste disposal and clean manufacturing becomes more prevalent.

In the long term, newer, more efficient and more sustainable technology will emerge, performing similar or improved functions compared to existing products. For example, the innovations at Maxwell Capacitors in the field of heavy-duty capacitors promises to change methods of power supply to electronics. It is expected that the future will see similar innovations in larger markets, and most importantly, in transportation and domestic consumerism.

8.5 Environmental

8.5.1 Agriculture

The agricultural industry in California makes nearly $32 billion[35] in annual sales, making it the largest industrial sector in this state. Consequently this industry is also a high consumer of energy, mainly through the electricity required for water irrigation systems. A visit to Kunde winery provided an insight into some of the issues and sustainable practices within this industry. In California the soils and climate are ideal for grape production and other agriculture alike, but are threatened by the risk of low water supplies.

Wineries are traditionally family driven businesses, and in order to produce the best products sustainability appears to be in line with existing practices. Minimal use of water and treatments along with efficient harvesting are in the interests of the business as well as being environmentally friendly. The concept of "Biodynamic farming" however goes one step further towards making sure that no pesticides are used and that all natural processes are practiced. Followers of this technique do believe that it ensures products have the best flavour and are of a high standard. Although Kunde does not yet practice biodynamic farming it is within the 15% of wineries to have a climate controlled cave in place of a warehouse; meaning that less energy is consumed in its maintenance and the visual impact is reduced, since the cave is underground.

[35] www.cdfa.ca.gov

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The concept of sustainability can be taken to different degrees of morality and the sustainable behaviour of some wineries may be emotive rather than economic; attachment to the land and the wine are of utmost priority and sales can grow as a result of this. Water availability appears to be the major threat to this industry although the issue does not receive explicit attention in winemakers' literature.

Although good practices were observed at Kunde there remains a lack of convergence to a single standard for sustainable winemaking. Twenty wineries (about 0.3% of all US wineries) are certified to be biodynamic by the Demter Association[36] in the US and only a further forty are certified worldwide. This is certainly an area for improvement since although winemakers do naturally care for the future of their individual business, some guidance and support could help to make sure they are prepared for resource shortages or climate change.

8.5.2 Waste Control

Americans consume more than 9 billion gallons of water in plastic bottles each year, most of them made of polyethylene terephthalate. Plastic water bottles require 1.5 million barrels of oil each year to manufacture[37], this and the waste produced by the used bottles has led San Francisco to ban the purchase of plastic water bottles in city-owned offices. The City has also banned the use of plastic grocery bags. There have recently been some actions of this type here in the UK, where a town in Devon was the first in the EU to ban plastic-bags; however this was as a result of activist campaigning rather than government initiative. Other examples can also be exemplified by companies such as Marks and Spencer in their Plan A report[38]. The water bottle ban in San Francisco may help to relieve some landfill pressures but there is a question as to whether it will put an increased demand on the already short water supply.

[36] www.demeter-usa.org
[37] www.idealbite.com/tiplibrary/archives/bottled_up1
[38] M&S, 2007, *Plan A*, http://www.marksandspencer.com/gp/node/n/50890031

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In 1989 California initiated the Integrated Waste Management Act that followed planning for solid waste and landfill compliance. Many other statutes have been enforced including recycling of electronic waste (2003). Today in some cities there is a payback scheme for recycling of waste; hence California has adopted a capitalist model to encourage public engagement on this issue. It is interesting to look at some statistics for waste in the US; Figure 14 is taken from the Environmental Protection Agency.

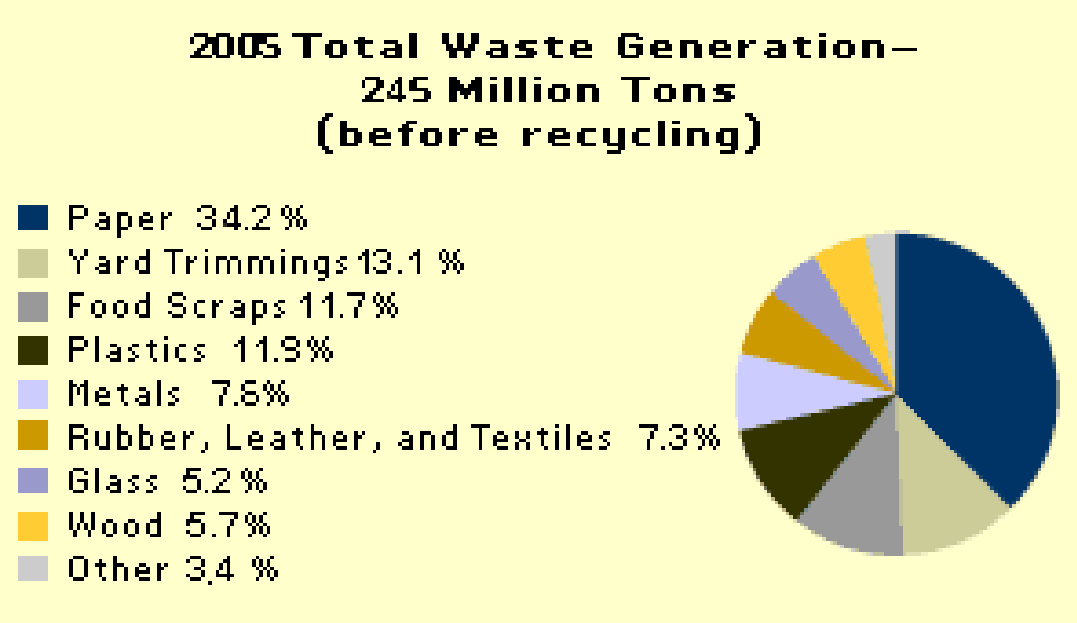

Figure 14

Figure 15 below takes the opportunity to compare statistics from the Environmental Protection Agency and the UK Department for the Environment Food and Rural Affairs looking at the recycling rates of some selected materials. Where 0% is shown data was not available for the specific material.

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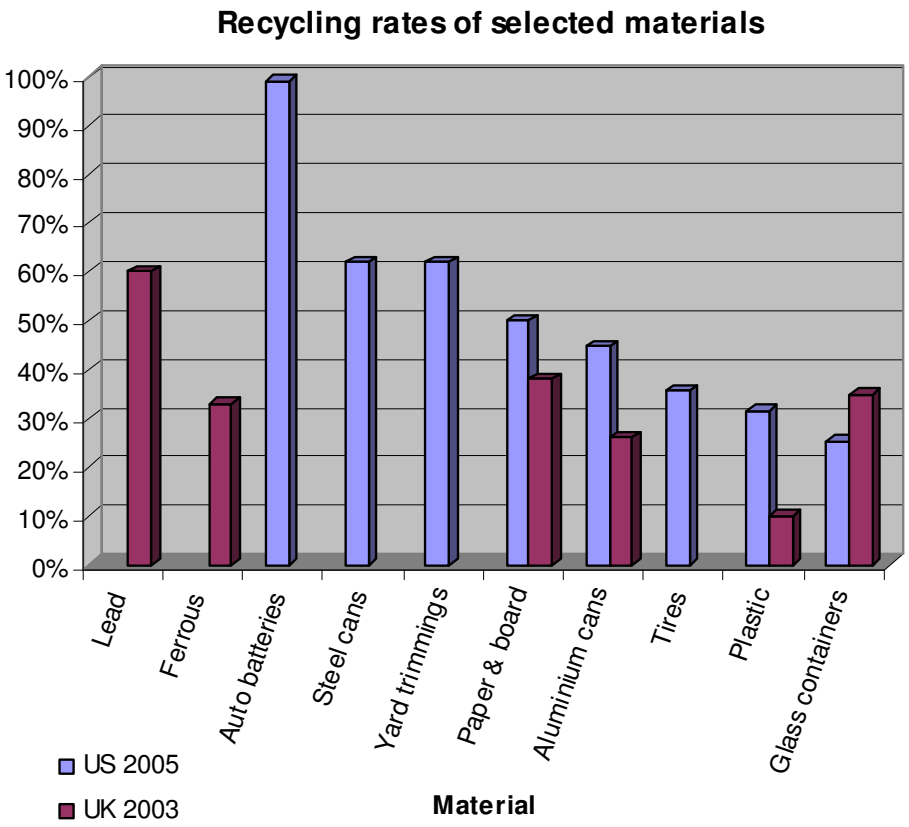

Figure 15

It is clear that actions are being taken in this area, not just in California, but throughout the country. Statistics, although from different years, show that perhaps the US is slightly further ahead in some areas for recycling compared to the UK. However there is a lot of scope for improvement to encourage and provide a means for waste management. For example; technology in this area appears to be minimal in the US, and research and development into recycling technologies should be an important item to address for the future.

8.6 Water

8.6.1 The issue

Water has historically been a valuable resource in California. Dating from as early as 1849 and the Goldrush, battles over water have been quite frequent.

Ongoing water shortages meant that water quality issues also occurred and 30 years ago this led to the establishment of The State Water Resources Control Board.

Water supply volumes have needed to grow with the large increase in population; from the year 2000 the population has risen from just below 34 million to 36.5 million in 2006[39]. Through a ballot initiative in the early 20th Century, voters passed a Constitutional amendment declaring that users of the water resources *"shall put water to the highest beneficial use possible and shall not waste water or use it unreasonably".* Water shortages mean that people are aware of using it sparingly in California. These concerns are an example of a huge driver in California and have meant that it has become a *"greener state"* in this regard, simply because it has no other choice.

The book *"When Rivers Run Dry"*[40] talks about the pressures on the US water supply, highlighting that the biggest demand is agriculture, *"water is the new oil",* and is consumed in goods such as rice and grain. The US is the biggest exporter of *"virtual water"* where one third of its water is exported through products.

8.6.2 What is being done

The Coachella Valley Water District visited is one example of where water supply issues are causing action to be taken. The valley's water supplies are stored in an aquifer and withdrawn from the groundwater. This is sustained by tapping into the Colorado River, inputting six to ten feet per day. North of the valley is a high value agriculture industry, valued at $1 billion per year. It uses a 128-mile canal system to distribute the water. The costs of keeping this reserve are estimated at $9 billion plus an additional $0.4 million per year in operating costs, however without it over 100,000 businesses and homes would have no water.

[39] US Census Bureau, www.quickfacts.census.gov
[40] Fred Pearce, 2006, *When the Rivers Run Dry*

Coachella Valley is also supporting the restoration of the Salton Sea (a saltwater lake), as part of a government led project to maintain it. The lake was created in 1905 when the Colorado River overflowed into the valley. The lake previously acted as a recreational area but is depleting rapidly and thus the salinity is increasing; it is now 25% more saline than the sea. This has meant that wildlife cannot live here easily and that recreational use has also lowered. There is some controversy as to what should be done with the depleting lake, since there are concerns of airborne particulate pollution should the lake dry out completely. It is hoped that the redevelopment of this area will increase tourism and recreation on the sea. One question raised is whether there should be so much investment into trying to maintain a naturally unsustainable resource?

Desalination technology is one option for fighting a shortage of water and is already being applied in California. Only 3% of drinking water world wide is provided in this way. The process is energy intensive, meaning it is expensive and not yet a sustainable or economically viable solution. According to Food and Water Watch[41]; Marin County has been considering a proposal to build a salt water desalination plant. The proposed project will cost at least $111 million, and could more than triple the water district's energy use. Another negative impact of desalination plants is the environmental impact they have on sea life due to the high concentration of salt released as a bi-product.

Water shortages have also meant that water waste and pollution are of high importance. A visit to Point Loma Wastewater Treatment Plant highlighted a solution to the waste being pumped directly into the bay. Opened in 1963 the plant is owned by the state and is completely self-sufficient in providing all its energy requirements. The methane gas drawn from the waste digestion is used to power two engines. Figure 16 below outlines the process.

[41] www.foodandwaterwatch.org/water

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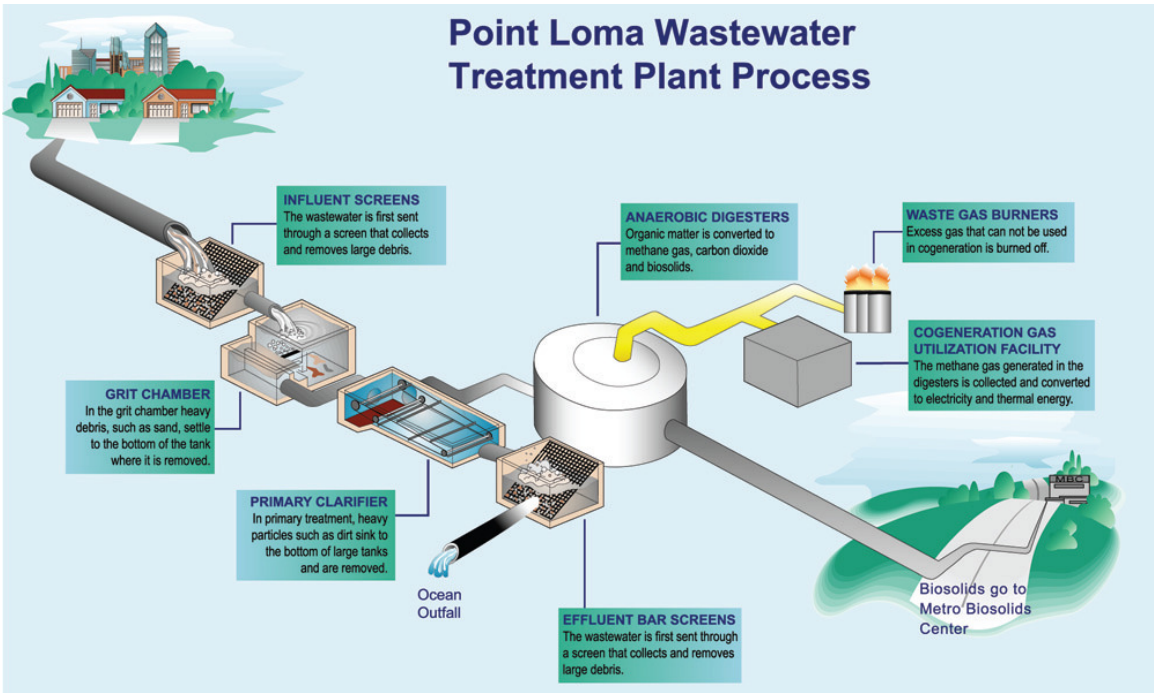

Figure 16

8.6.3 Future

The demand for water is increasing and additional needs are resulting from other solutions to sustainability; the growth of the biofuel market will increase the pressure for more resources. The California Water Plan is updated every five years to help guide the management of water systems, but is this enough? The use of technological research could help this industry by investigating new ways of tackling a historical problem.

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9 Knock-on impacts of sustainable solutions

From the examples of sustainable projects and technological solutions seen in California, the majority seem to be surrounded by some degree of controversy. Although projects solve problems in one area there is often a negative influence upon another environmental issue. In order to understand the relationship between sustainable solutions and their impacts the Sustainability Web summarises some key factors in Figure 17. The items in the larger square boxes show the main sustainability challenges in California. The smaller boxes encompass the solutions seen on the project, including technology-based solutions as well as regulation-based ones, and the oval shapes highlight the main geographic factors in California that also have an affect upon the issues and concerns raised. The Red arrows indicate a negative relationship between the factors and the green arrows represent the positive impacts on sustainability issues. The dotted lines indicates where the relationships are weaker.

The web may be used as a tool to help identify broken links in the overall system or to identify where research is needed in order to turn red arrows green or to eliminate them all together.

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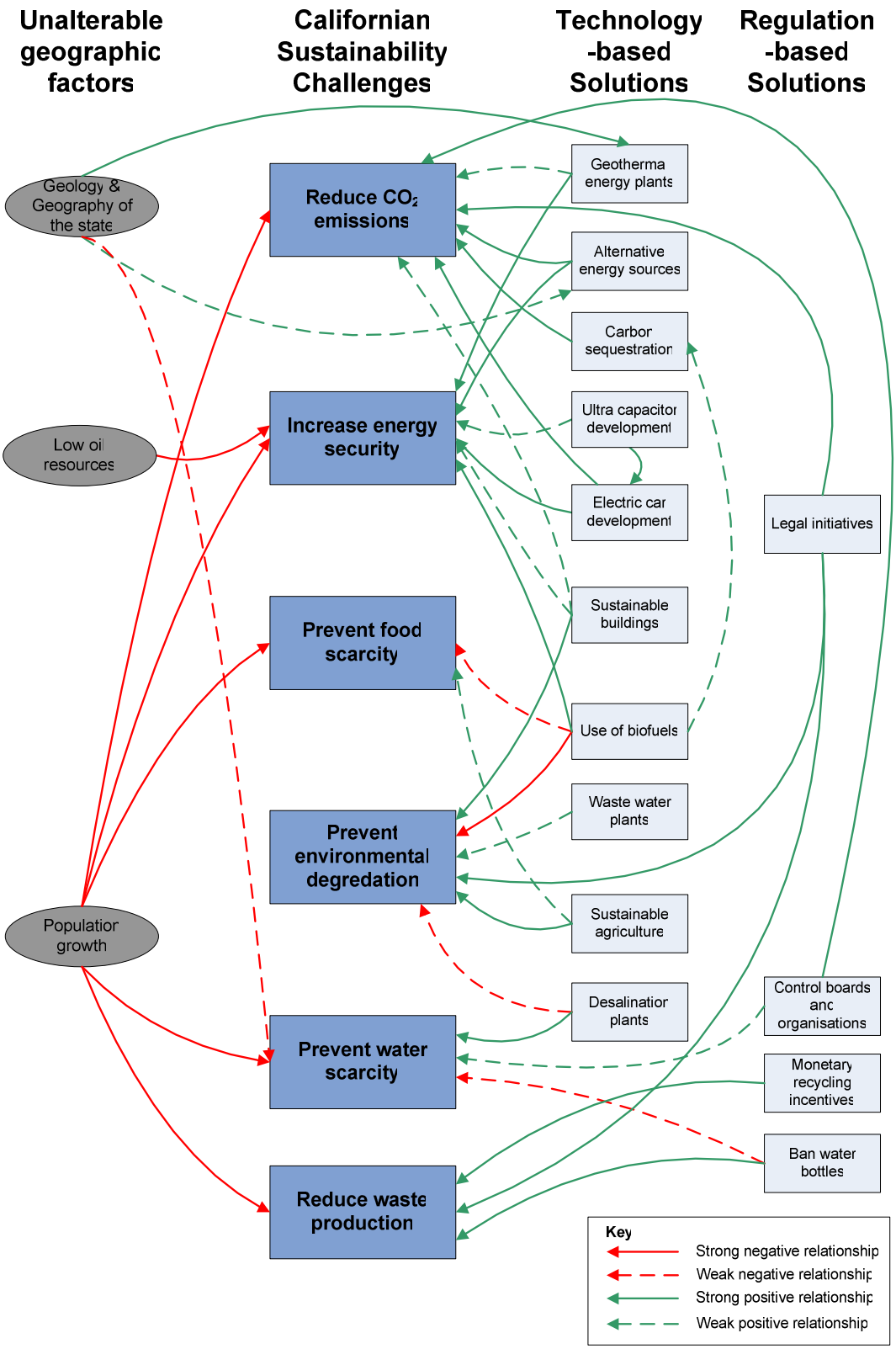

Figure 17

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10 Impacts within a business

Having visited a range of companies and gained an insight into some of their practices and innovations, it is important to look deeper at the affects that sustainable practices have on the business as a whole. This section summarises the opportunities and limitations that companies may experience as a result of trying to carryout activities of this sort. The opportunity is also taken to compare how small companies and larger firms react and where they require additional support.

10.1 Opportunities

Sustainable practice or technology development can offer access to new and growing markets. This opportunity is normally strongly consumer driven but can be caused by new policy and regulation. Companies such as LS9 and other biofuel initiatives would not be possible without the underlying issues in fuel security. Aside from environmental benefits, the Californian government is placing an emphasis on the economic benefits available for businesses engaging in sustainable practices.

10.2 Limitations

At the water district it was pointed out that attempts at being more sustainable make it difficult to balance the overall aims of the organisation. Sustainability seems to create demands on projects that pull in different directions. New legislation has meant that companies need to make changes; but within organisations this is often seen as a distraction and/or expense. These social implications have a great deal to do with the attitudes of people and the management of projects. The general consensus in California was that those in business are forward thinking and more willing to take risks than Europeans.

10.3 Small versus large companies

There is scepticism on whether companies or individuals can be the sole drivers for sustainable activity. Some believe that for changes to occur, policy and harder

regulations need to be made at a government level. However, action is taking place within companies and the firms' size appears to have some influence on the success of these actions.

Infrastructure, water systems, energy distribution, waste disposal, high-value consumerism and reliance on imports are just some of the existing factors that must be considered and improved when considering sustainability. Large industries prove to have a great deal of inertia to change and will only do so if some value can be added to their business. One argument therefore is that companies will only act sustainably if there is profit to be made. It is difficult to draw a general consensus on this, although when looking at the drivers for sustainability earlier in this report it was made clear that economics is one of the main influencing factors. Visits made to large companies made it clear that despite green claims of philanthropy and environmental concerns, these aims are rarely filtered down within the business, if at all practiced. An article in the New America Foundation[42] argues that most large firms are *"fragmented and too deeply bound"* to *"self-interested objectives".*

Smaller enterprises and entrepreneurs appear to be driven by more diverse factors besides profit building. It seems that the nature of start-ups allows for *"out-of-the box"* thinking and greater risks to be taken. Research at an entrepreneurial level is where the greatest changes and technological influences can be derived. A bottom up approach from *"disruptive"* technologies may be a vital step in finding sustainable solutions to the current challenges. One concern however, with SME's, may be that they are focused on short term targets and therefore do not consider environmental impacts as much as larger companies. Examples of this seen on visits were companies who focused on biofuels or technologies that they thought would make a business, when actually little is known about the longer term impacts or the feasibility of the concept.

[42] Andrews, Sustainable Enterprise, New America Foundation, 28 Feb. 2003

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Whilst small companies may have the flexibility and motivation to make a change, it is the larger companies that have the marketing power to influence consumers and regulations. Another argument made in the New America Foundation[42] is that governmental policy and systems support the larger firms much more than they do small enterprises, but also that it is no longer a choice but a necessity to be more sustainable in order to support the fast growing global population.

There are many thoughts on where the drive for sustainability can come from and also on the limitations faced by large and small companies. Table 3 below shows the main traits that could help a business to be more sustainable, and takes a general look at how different sized firms compare.

Good traits for sustainability	SME	Large Company
Easy to change	✓	x
Has good government support	x	✓
Easy access to resources	x	✓
Innovation	✓	x
Flexibility	✓	x
Business experience	x	✓
Long term strategies considered	x	✓
Personal satisfaction	✓	?
Easy to get IPR[43]	?	✓

Table 3

Table 3 can help to identify where companies require support in order to allow them the most freedom to practice sustainably.

[43] Intellectual property Rights

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11 Sustainability through technology

11.1 Is technology a good solution?

As the question of whether technology is the route to sustainability is at the heart of this project, it has become apparent that the issues surrounding the topic and examples seen are extremely complex.

The tragedy of the commons[44] is a concept adopted in order to explain the exploitation of common ground or resources. Where everyone is out to make the best of their own business or life, people will take all the resources needed, regardless of those sharing them. This exploitation goes beyond the use of land for agriculture or basic resources to survive but also extends to waste disposal as touched on in section 8.5.2. The water supply issue in California is another example where a common resource struggles to provide adequately for its users.

The mentality of not respecting or looking after common ground is historically a result of shared resources. This acts as a hurdle in sustainability and many are sceptical that *"technical solutions"*[45] can be found to the tragedy of the commons. The visits made on this project showed that often the technical solutions are not enough, nor do they always exist.

Along side sceptic views, some good examples of where technology *is* providing answers to sustainability have been presented. The concept of electric cars to aid emissions reductions and provide fuel security is one good illustration. As a large scale solution however, it is unlikely that electric battery technology could be utilised in all vehicles in the same way. In cases such as this there needs to be more flexibility and access to wider markets.

[44] John Cairns Jr., The Unmanaged Commons 2004
[45] Garrett Hardin; The Tragedy of the Commons

To a certain extent California appears to be waiting for the market to open up to new technologies or sustainable concepts. A definite drive in pushing ideas forward or attempting to create a market pull would help in making technology more successful in this field.

In considering the future of improved technologies there runs the risk of a *"rebound effect"*. This term is used to describe the effect of higher efficiency leading to even greater demand, and therefore a negative or zero net improvement. This increase in consumption may come from the perceived increase in availability. In the example of the electric car, drivers may use it twice as much as usual because it is cheaper to run. The rebound effect of new technologies will have to be managed with regards to consumer attitudes, awareness building and tight restrictions may help in doing this.

Despite efforts in technological investments this project has assisted in drawing conclusions that technology really is not enough to provide sustainable living for neither the US nor the rest of the globe, and may sometimes create unforeseen problems in other areas.

11.2 What is the alternative?

Technology is not considered to be advanced enough to meet the global demand for sustainability. However high-tech solutions may not be the limiting factor. This research group concluded that perhaps the lack of technology is not the problem, but that the need for correct diffusion is much more important.

As well as correct dissemination of new technologies, appropriately re-designed technology should be brought into the market. Concepts such as Design for Environment (DfE) and Life Cycle Analysis (LCA) need to be emphasised. This stresses the importance of looking at where businesses can have the greatest impact in sustainability, and then acting on it. For example in looking at the

embodied energy from a simplified LCA does not require too much detail in order to identify the most worthwhile area for improvement. For the car; the greatest impact can be made in the use phase, so fuel efficiency is an area worth working on, as identified at Tesla Motors.

Unfortunately DfE and LCA are concepts that often appear decoupled from manufacturing practice and business strategy. The group on this project have learnt to integrate these as part of their manufacturing engineering course, but it is clear that in industry in general it is difficult to break traditional methods of approach or alter existing systems. It can be concluded therefore, that a systems approach to the problem is required. Everyone appears to be solving the problems from the surface, fixing mistakes that have already been made. However, as all good solutions, the most sustainable ones will only come from innovative thinking, analysis of the base requirements *and* an overall systems approach.

Some performance measures for sustainability seen in companies are listed below;

- Inputs
  - Energy, Water, Materials
- Outputs
  - Waste
- Triple bottom line
- Life cycle analysis
- Benchmarking
  - Certification, regulations, indices, comparison to current non-sustainable methods

Performance measurement could be used to identify un-sustainable practices and help to eliminate them. This approach could benefit businesses that struggle

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to initiate sustainable practice by working from an alternative perspective. Despite its tangible benefits, performance measurement tends to work within existing systems and therefore puts some restriction on analysing the system as a whole.

In conclusion it is obvious that technology can play a part in this move towards a sustainable world, however it will not be the only factor. More appropriate technologies and correct diffusion will help in this area and an overall systems approach appears to hold good potential.

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12 What could California do better?

The correct use and application of technology as discussed, has stemmed from a lack of responsibility in the past. Technology comes with responsibility, and a lot of the problems in the past have occurred as a result of misguided practice. Organic Architects identified the fact that the world has been using technology irresponsibly but is just now emerging from this. It is vital that new innovations in sustainability are correctly researched and implemented. In some cases sustainable issues were not seen to be part of the business in any way; Oakley Fashion explained that their market focus was very image based and that sustainability did not align well with their strategy. This is an example not of technological irresponsibility, but perhaps social irresponsibility. Possible causes of behaviour like this are the short-term and fast moving targets held within certain markets. It is clear that there is sometimes a trade off between long-term and short-term solutions. Biofuels are an example of a short-term transitional solution, but also another area where there is an immense need for longer-term strategy and more holistic problem solving.

One way to ensure projects are correctly employed is to govern these changes and ideas in an appropriate way. Although the Californian Government is driving this as well as encouraging sustainable programmes, the US as a whole could largely benefit from greater integration of governments and businesses both at a federal and state level. This is clearly a difficult thing to achieve due to the large population and vast range of cultures across its 9.16 million sq km of land[46]. Europe has some good schemes, practices and initiatives that may be possible due to its smaller and denser populations and therefore more focused government systems.

Overall however the only means to achieving responsible practice seems to be through education. The topic of education was touched on briefly by some

[46] CIA Factbook

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companies such as the Energy Center at PG&E and at Organic Architect. It was made clear that this is a very important factor to enable us to meet our needs without compromising future generations. This goes back to solving problems from a different and new angle and redesigning the system. Teaching future professionals and engineers to think with a wider understanding of the planet and to learn from the existing problems will surely be the only way forward. This was not emphasised as much as expected on visits, although some were trying their best to understand global impacts.

One discussion raised amongst the project group was that of *"anti-drivers"* for sustainability. In the US it can be seen that attitudes such as disregard for the environment and extreme consumerism provide barriers to sustainable practice. The resistance to change or de-motivations for supporting sustainability are often a result of a lack of understanding. It is here that education could also provide a useful tool in tackling some of these global issues.

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13 Can we learn anything to bring home to the UK?

In a report from Ove Arup on Sustainable Manufacturing[47] it was concluded that the UK industry is fully aware of its environmental responsibilities but few are actually doing anything about it and taking advantage of the consumer-driven market.

It is apparent in California that there exists a strong pioneering spirit. This was particularly evident in Silicon Valley where start-ups stem from the most recent and high-tech research. The positive attitude and drive for success is observable within these ventures that have good access to financial resources. Historically the EU is more settled in its practices as well as appearing to be more business cautious. One theory is that the EU, as an older nation, has had more time to learn from its mistakes than the US. EU business also tends be more risk averse, which may prevent innovative proposals reaching the market. In this analysis it is clear that there are things that both California may learn from the UK but also a great deal that the UK can learn from them; in encouraging entrepreneurship and positive business attitudes.

It may be worth noting that Californian energy use is still almost double that of the developed European nations per capita, and that there is a distance to go before both the US and EU will be providing functional and efficient solutions in sustainability. Despite this understanding it is hoped that as individuals some differences can be made to our everyday lives to help in facilitating a sustainable future.

[47] Arup, Sustainable Manufacturing, A study into UK manufactures' perceptions, www.arup.com.

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14 Conclusions

In conclusion, the main drivers for sustainable practice have been highlighted as dissatisfaction, resource security, legislation, profitability with influences form more specific drivers including; public opinion, heath, media and new technologies. There are many more drivers than initially predicted but it has been interesting to identify the relationships they have with one another. It is important to recognise the links in these drivers when generating enthusiasm and motivations for new sustainable activity and research within a business environment. Perhaps this tool can be taken away for use as a starting point in sustainable business thinking.

Examples of good sustainable practice have been referred to throughout this project; the electric car, ultra-capacitors, sustainable agriculture, government initiatives, green building practices and alternative energy supplies. It can be noted that in order for these projects to be a success and for more to follow, the world needs to see:

- Correct diffusion of technology
- Use and design of appropriate technology
- More focus on DfE and LCA and their integration into manufacture and business
- A systems approach to existing services and processes
- More government support to business to help empower technological entrepreneurship
- Elimination of un-sustainable practice
- More supporting infrastructure (i.e. for energy transmission)
- Creating a market for sustainable business
- Supporting SME's
- Policy making

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The largest factor in achieving these goals however, is education. This can take many forms; from building awareness in order to create a greater market to educating the children who will lead the future in this field.

So California is set to lead its country by example, and investments in technology are taking shape. There is scope for a more integrated response across all fields in both industry and business. By exploring system designs at all levels perhaps we can start reinventing the wheel for a future that does not compromise the needs for future generations.

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Institute for Manufacturing, University of Cambridge; www.ifm.eng.cam.ac.uk/met

International Panel for Climate Change; www.ipcc.ch

Quick facts; www.quickfacts.census.gov

The Royal Institute of British Architects; www.architecture.com

Solar City; www.solarcity.com

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16 Appendices

16.1 Company profiles

BioFuel – Pacific Energy Center Conference

This conference was hosted at the Pacific Energy Center where support is offered in creating energy efficient buildings. There are also several educational programmes run here. This centre was started in 1991 as part of the Pacific Gas and Electricity Company.

www.pge.com

Tellurian Biodiesel

Experts in bio-technology and processing. Their mission is to sustain biodiesel solutions for their partners and customers. This new company was formed in 2006 from the merger of San Francisco Biodiesel and LA BioFuel, two of California's leading biodiesel firms. Tellurian aims to be the largest producer of biodiesel, from recycled materials, in the US.

www.tellurianbiodiesel.com

Biofuels for Schools campaign

This campaign was initiated due to the dangerous emissions released by school buses. The campaign is supported by Blue Sky Biofuels and looks at oil resources from feedstock or recycled from restaurant waste oil for use in biofuel.

www.blueskybio-fuels.com
www.biofuels4schools.org

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Solazyme

Solazyme is a start up company that is looking at transforming algae into biofuel. The focus is to use solar energy/sunlight to grow useful crop that can be used in fuels.

www.solazyme.com

Green Energy Network

The Green Energy Network is a community of individuals who aim to find a solution to our dependence on petroleum. They believe that ethanol is one of the solutions and has a fuel station in San Diego.

www.greenenergynetwork.org

San Francisco Biofuels Cooperative

This cooperative is a partnership of companies and individuals looking at Biofuel use in order to help reduce emissions and dependence on traditional fuels. Started in 2004 the cooperative started providing biofuels to members in 2005.

http://www.sfbiofuels.org/membership.html

Coachella Valley Water District

This Water District is supplier to residents of the Salton Sea area providing water to 102,000 homes and businesses. It trades and stores water, working with the neighbouring water district. It collects waste water and helps provide flood protection. Groundwater basins are recharged using water diversion and lake formation. It operates a joint powers authority with another water district and an Indian authority.

www.cvwd.org

Intel

Founded in 1968 by Noyse and Moore, Intel's expertise saw the first semi-conductor. After the first year Intel had grown to 100 employees, today Intel has 80,000 staff members worldwide. The first microprocessor in 1971 had 2,300 transistors, this rose to 275,00 by 1985 and is today over 1.7 billion, this increase was predicted by Moore as early as 1965 (Moore's Law).

www.intel.com

Jelly Belly

Originally the Herman Goelitz Candy Co. since 1800's, founded by two German brothers. In 1976 the Jelly Bean was invented in the Californian city of Los Angeles when Goelitz Candy was bought the idea of a natural flavoured bean. Jelly Belly is one of North America's largest confectionary manufacturers. A range of confections produced including chocolates and sugar coated candies that are shipped world-wide.

www.jellybelly.com

Kunde Estate Winery and Vineyard

This family owned vineyard has farmed its 1,850 acres over the last 100 years in the Sonoma County. This agricultural business focuses on sustaining its land for the future generations and takes pride in its premium quality wines.

www.kunde.com

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LMAS/EETD Environmental Energy Technology Division of the Laurence Berkeley National Laboratory

LMAS is a research laboratory of the DOE and is working towards meeting state targets for reducing energy loads and emissions. The division has won 100 awards for its various R&D projects.

http://eetd.lbl.gov/

LS9

This new high technology start up was started with venture capital funding one and a half years ago. Their focus is in development of synthetic petroleum biofuels that are compatible with the current infrastructure and fuel system.

www.ls9.com

Maxwell capacitors

Founded in 1965 Maxwell Technologies is aiming for energy efficiency and carbon dioxide reduction through energy storage technologies. Three product lines: high tech, micro-electric, and ultra capacitors – all of which have long life, high power density, 95% energy efficiency, and up to 3000F. 75% of their capacitor production is in China and 25% in San Diego. Extensive work with racing and electric automobile manufacturers has also been carried out.

www.maxwell.com

Mid American – CalEnergy

CalEnergy Generation focuses efforts in alternative energy resources including geothermal, natural gas and hydroelectric and has projects worldwide. It was founded in 1971 and has now grown into a significant energy provider for the

state. There are 10 plants in the Californian Imperial Valley, the visit for this project was made to the one at Salton Sea.

This plant alone has a net capacity of 335MW from extraction of energy from superheated wells. Steam is used to propel turbines up to 36,000rpm and wells go as deep as 8,700ft. It has $37 billion in assets and in theory a payback period of 30 years. This plant is half owned by MidAmerican Energy.

http://www.calenergy.com/html/projects2d.asp

Molecular Foundry

This foundry is a division of the Laurence Berkeley National Laboratory. The brand new facilities provide resources and space for research in Nanoscience. Funded and owned by US Department of Energy (DOE).

www.foundry.lbl.gov

Oakley Sports and Fashion

Oakley takes pride in its high quality sports equipment. It supplies its products to 110 countries and is owner of 540 patents.

www.oakley.com

Organic Architect

Organic Architect was setup by sole founder, Eric Corey Freed in 1997, with the intention of establishing a small and gradually expanding architectural practice for the design of sustainable organic homes. Designs incorporate energy saving techniques, natural products and renewable materials. The degree of sustainability depends on customer specifications; Due to the volume of clients projects are chosen selectively. In his spare time Eric also lectures at the San

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Francisco City College and writes books to educate people and increase awareness.

www.organicarchitect.com

Point Loma Wastewater Treatment Plant

This state owned plant was opened in 1963 as a solution to the waste being put into the bay. It treats approximately 175 million gallons of wastewater per day, with a capacity of 240 million gallons.

www.sandiego.gov/mwwd/facilities

SLAC Stanford Linear Accelerator Centre

This laboratory was founded in 1962 and had Silicon Valley grow around it. It receives $200 million per year from the governments energy divisions and is home to the largest building in the world; the two mile long linear accelerator.

www.slac.stanford.edu

Solar Turbines

Solar Turbines design, manufacture and service gas turbine systems for the power industry worldwide. The rapid reaction power generation manufacturers supply energy to the grid by running engines against generators. Since 1981 the company has been owned by Caterpillar, and exports 70% of its products.

www.mysolar.cat.com

Sony

Founded in 1946 in Tokyo, Japan, Sony was created as a company before having an idea. Its aims were to change the perception of cheap products “made

in Japan" by creating high quality goods. It was not until the 1960's that The Sony Corporation of America was started.

The visit made on this project was to Sony Electronics Inc. where the VAIO computer plant was seen. Like all Sony divisions the San Diego site took pride in its quality assurance on all of its products.

www.sony.com

Tesla Motors

Tesla Motors has developed its 100% electric car; the Tesla Roadster. The vision is to reduce the US's dependence on foreign oil. Tesla is funded by private venture capitalists.

www.teslamotors.com

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