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Optimising Educational Materials for Alternative Energy Technologies

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Abstract

The Centre for Education and Research in Environmental Strategies in Melbourne, Australia, needed better educational materials to inform a casual audience on the role of renewable energy technologies in today's society. With guidance from experts at Museums Victoria and the Worcester Polytechnic Institute, we learned how to develop effective educational resources. The resulting design process enabled the creation of informative, attractive, and engaging educational materials. Our team developed an educational display and implemented a collection of web pages for the CERES biogas digester. We provided recommendations for the further use of our design process in the improvement of the remaining technological displays and in the aesthetic development of the renewable energy park.

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Executive Summary

Climate change continues to cause damage to our ecosystems. With the dramatic increase in the use of fossil fuels in the last few decades, the need to reduce our dependence on non-renewable energy is greater than ever (Boden, 2010). The development of alternative energy technologies is a major step towards reducing carbon emissions and achieving a sustainable way of living. In order to promote the use of these technologies, the general public must be educated on their benefits and their role in a sustainable lifestyle.

Today, the Centre for Education and Research in Environmental Strategies (CERES) works to educate the general public on sustainable practices including the use of renewable energy technologies. Through the implementation of a biogas digester in its renewable energy park, CERES hopes to educate the public on the digester's functionality, applications, and role in the development of a sustainable community. While working with CERES, we developed guidelines for the development of effective educational materials and used these guidelines to create a display and a suite of web pages for the biogas digester. In order to achieve this goal, we developed the following objectives:

- Identify the set of educational criteria that needs to be met in order to satisfy CERES' current educational goals regarding their biogas digester.
- Identify key characteristics of educational materials that are most beneficial in effectively conveying information to the general public.
- Assess CERES' existing biogas digester display and web pages based on these characteristics and educational criteria to determine which are not currently met.
- Propose and develop educational materials that will enhance CERES' display and website for the biogas digester.

Through our initial research on environmental organisations around the world, we determined that education strategies have to be informative, engaging, and attractive. The team conducted interviews with CERES staff to determine their educational goals regarding the biogas digester and create the informative component of our guidelines. We confirmed that CERES was interested in presenting the functionality, inputs and outputs of the biogas digester along with applications in modern Australia. All of these ideas would combine to portray the "big picture" that is the role of the biogas digester in a sustainable cycle of energy. Through interviews with museum education managers and university professors and by observing museum displays, we identified general criteria that must be met for educational materials to be engaging and attractive. In order to effectively communicate information, the criteria included diagrams, flow of information, and an appropriate language level. The criteria required to attract potential learners included colours, sounds and recognisable images.

In order to ensure that the new educational materials would address CERES' educational goals and would be effective at attracting and engaging the general audience, the criteria sheet was used to evaluate the existing biogas digester display and web pages. Through our interviews with visitors to CERES, we determined that many of them did not know of the existence of the energy park and did not recognise the biogas digester as a renewable energy technology. While the existing display covered all required informational goals, the display and website were not able to attract and engage visitors and therefore failed to effectively educate them.

We developed designs for a display and web pages and evaluated them with our educational criteria and additional logistical requirements. The final designs met the majority of the educational criteria while still being achievable with limited resources. The information presented was sufficient to cover the topics of food waste, how the biogas digester works, the outputs of the biogas digester and their use, and applications of biogas digesters around the world.

The display included four single page flipbook signs around the biogas digester. A title and basic information about each particular aspect of the biogas digester were included on the cover of the flipbooks. This represents the first tier of information in the three tier system recommended by the museum managers. The second tiered, more advanced information was presented inside each flipbook. The information was written to satisfy CERES educational goals for the biogas digester and to be understandable to a sixth grade student, the level recommended by educators in order to avoid excluding any of the general audience. Diagrams and other visuals were presented on each flipbook to attract and engage the audience. Questions were also posed on the display to challenge readers and the answers were provided on covered signs.

The website was able to provide the same level material as the display as well as the third tier of more advanced information on the various pages. A tree structure was used for the overall layout to allow for easier navigation from any page. In order to engage users, we created consistent and recognisable graphics, videos and a calculator that determines the amount of energy produced by the user's food waste.

The resulting display and website were created through the implementation of a process that is applicable to all of the alternative energy technologies at CERES. Throughout our development process we identified other areas of the CERES renewable energy park where improvements can be made and developed recommendations for future projects as follows:

- Link the biogas digester educational materials with the school curriculum.
- Create a relatable aesthetic theme for the biogas digester.
- Use a future student team to evaluate the effectiveness of our designs.
- Use our design process to enhance educational materials for the other technologies present in the renewable energy park.
- Create pathways and signage to direct visitors to and through the energy park.

These recommendations can be completed through community projects and future student projects.

1 Introduction

The burning of fossil fuels continues to cause damage to our ecosystems, becoming one of the biggest contributors to climate change. Research shows that the burning of fossil fuels has increased dramatically over the last few decades, leading to higher levels of carbon dioxide (CO_2) emissions (Boden, 2010) and other harmful gases such as methane (CH_4). Carbon dioxide and methane are gases that, when released, can trap more of the sun's radiation inside the Earth's atmosphere leading to changes in our climate. Engineers and scientists are collaborating on a global scale to develop renewable energy technologies that will reduce our dependence on fossil fuels as a primary source of energy and eventually lead to lower carbon emissions and a more self-sustainable society.

Renewable energy technologies are already in use, and various countries including the United States, Sweden, Germany, and Australia are implementing policies that promote their use (Schmidt & Haifly, 2012). In 2009, the world relied on various forms of renewable energy technologies for approximately 13.1% of its energy consumption (International Energy Agency, 2013). However, understanding of these forms of renewable technologies has yet to be addressed thoroughly**.** The general public continues to have many questions regarding their effectiveness and reliability.

Environmental organisations throughout the world are developing strategies that effectively inform the public on the current forms of renewable energy technologies. The EDEN project in the United Kingdom takes pride in their technological displays, which are an attempt to demonstrate and educate the public on renewable energy technologies by displaying these technologies and detailing how they work (Eden Project, 2013). The Clean Energy Council of Melbourne, Australia uses its website to accelerate development and increase deployment of all clean energy technologies (Clean Energy Council, 2013). Commercial organisations such as Biogas Australia use their websites to promote biogas digester technology in Australia and provide a solution for the reduction of greenhouse gas emissions.

In Australia, the Centre for Education and Research in Environmental Strategies (CERES) has been working on raising awareness in the field of renewable energy technologies throughout its community. Today, CERES is interested in displaying information about the effectiveness and potential applications of one of their most recent renewable energy projects, a biogas digester, by improving their educational delivery strategies. As students of the Worcester Polytechnic Institute, we are very aware of the increasing need for environmentally oriented education and the necessity of green technologies for the betterment of our planet, economy and humanity.

The goal of this project is to assist CERES in its mission to better inform its audience on biogas digesters through the improvement of its education and communication efforts. To assist CERES in better informing the general public, we plan to investigate and analyse the strategies that organisations throughout the world are implementing to effectively showcase information on renewable energy technologies. We will evaluate CERES' current education and communication strategies regarding their biogas digester, and determine what could be improved to most effectively convey information to the general public. After analysing the results of our investigations and evaluations, we will develop and propose educational materials that will enhance visitors' knowledge of biogas digesters. The overall purpose of this project is to contribute towards increasing the amount of knowledge people have regarding the biogas digester, its inputs, outputs, applications in Australia and its contribution to a sustainable cycle of energy.

2 Background

For centuries, fossil fuels have been a primary source of energy, whether it is by refining oil into different types of fuels to power our cars, by burning coal to indirectly generate electricity, or through the use of natural gas. This extensive use of fossil fuels has consequences, including the release of carbon dioxide (CO_2) into our atmosphere. Atmospheric carbon dioxide levels have increased dramatically over the last few decades (Dlugokencky & Tans, 2013). Carbon dioxide can remain in the atmosphere for a century after it is released and its accumulation slowly increases the warmth of the planet, a phenomenon known as the greenhouse effect (Alternative Energy, 2012). Unfortunately, our wasteful societies are not only contributing to higher levels of CO_2 but also other gases such as methane, which can be twenty-five times more harmful than CO_2, per unit mass. Evidence exists indicating that climate change is occurring at a faster rate than natural climate fluctuations can reasonably explain. Scientists agree that an increase in the average temperature of our planet over the next few decades will lead to catastrophic shifts in the weather and climate (Environmental Protection Agency, 2012). Our lifestyles, which demand a steady supply of energy, have led us to face these "critical issues on environmental pollution" (Dresselhaus & Thomas, 2001).

Global Environmental Initiatives

In order to meet our current and future demands for energy, without further impairment to the health of our planet, renewable energy sources must be found. As noted by Mildred Spiewak Dresselhaus, a professor of Physics and Engineering at the Massachusetts Institute of Technology, "These alternative sources do not depend on fossil fuels [and are] scientifically possible, environmentally acceptable and technologically promising" (Dresselhaus & Thomas, 2001). Countries are implementing several different methods to help satisfy their power needs and phasing out the use of non-renewable energy resources to prevent further damage to our environment (Schmidt & Haifly, 2012). The United States, for example, has increased the number of renewable energy projects, including 33 offshore wind farms in the Atlantic Ocean, the Gulf of Mexico, and the Great Lakes. In addition, plans for 11 new coal operation plants were cancelled (Singh, 2010). Sweden has also increased investments in renewable technologies, reducing their greenhouse gas emission by 10% (Dopita & Williamson, 2009). Many countries have been looking into their energy production infrastructure to become more efficient and self-sustainable; one such country is Australia.

Australia's Environmental Initiatives

Australia is one of the largest producers of greenhouse gases, ranking 11^{th} in per capital carbon emissions (Carbon Dioxide Information Analysis Center, 2009). Michael Dopita and Robert Williamson from the Australian Academy of Science have researched the ecological impact of Australian lifestyles, and concluded:

> Each Australian produces enough carbon dioxide (CO_2) to replace the column of atmosphere above one square metre of land every year. An average Australian house will, in a person's lifetime, produce enough CO_2 to entirely replace the atmosphere above it with this greenhouse gas (Dopita & Williamson, 2009, p. 1).

Despite the harmful effects of carbon emissions, investments in renewable energy are complicated by economics, politics, and historical sources of energy. Australia is the world's biggest coal exporter and one of the world's largest coal producers (Boden, 2010). Australia's primary domestic fuel source is coal, and its consumption releases 57% of Australia's total CO_2 emissions.

Carbon emissions are not the only environmental issue the Australian society faces today. As Australia experiences economic growth, data published by the Productivity Commission suggests that a direct correlation exists between economic growth and growth in waste generated per capita (Australia Bureau of Statistics, 2013). Over the course of the last decade, Australia's volume of waste produced has increased on average by 5.4% every year (2013). According to the Australian Bureau Statistics, Australians have "a strong dependence on landfill as forms of waste management" (2013). Organic matter deposited in landfills naturally decomposes, releasing methane, polluting air, water and soil and attracting unwanted pests.

In an attempt to decrease the country's environmental impact, the Australian government has passed the Environmental Protection Act in 1970 that lists the 11 principles of environmental protection. Avoidance of waste is the most preferable option and disposal of waste is the least preferable option (Environmental Protection Agency Victoria, 2013). More recently, The Clean Energy Legislative Package, enacted July 1, 2012, placed a price on carbon with the goal of reducing CO_2 emissions by 5% below levels emitted in 2000 by 2020 (Clean Energy Future, 2013; Garthwaite, 2012). However, since this legislative package only targets heavy CO_2 emitting industries, additional efforts need to be focused on smaller groups of people, and individuals, in order to induce change on a local spectrum (Clean Energy Future, 2013).

At the local level, non-profit environmental organisations, supported by local communities and donations from government programs, continue to investigate the potential of renewable energies as an affordable alternative to fossil fuels and other environmental problems. Such organisations want to improve the general public's understanding of renewable energy resources and promote an environmentally stable future for generations to come. One such organisation is the Centre for Education and Research in Environmental Strategies (CERES) located in Melbourne, Australia.

2.1 Centre for Education and Research in Environmental Strategies

CERES is a non-profit organisation, funded by the local organisations, community donations, local government, and their organic food market and café. CERES' goal is to "address the causes of climate change while promoting social wellbeing and connectedness to build local and global equities and embrace and facilitate rapid change through technological displays, social enterprises and both educational and training programs" (CERES, 2012a). Since the opening of the CERES environmental park in 1981, one of their primary objectives has been to educate people on issues related to climate change and environmental conservation practices. CERES has grown to become one of Australia's greatest advocates of environmental education and conservation, well known for concentrating on experiential learning.

Currently, CERES (2012b) is trying to identify community applications for renewable energy technologies and provide models for community-based renewable energy production aimed towards the mitigation of climate change. They have already begun to address this goal in their environmental park through initiatives such as the installation of wind turbines, solar pavilions, a Scheffler dish, and a biogas digester. These implementations of environmentally friendly technologies demonstrate that our lifestyles can be continued for many generations with the implementation of more sustainable practices.

CERES' recent efforts focus on investigating biogas digesters to address environmental issues related to food production, energy production and food waste. CERES' plan is to:

1. Demonstrate the science of anaerobic digesters.

2. Be physically and visually accessible to visitors.
3. Convert food waste into clean energy in the form of cooking gas or electricity.
4. Generate a fertiliser that can be used by organic farmers to complete the nutrient cycle.
5. Provide real-time information on energy production and greenhouse gas abatement.

Shane French, Education Manager at CERES, has been looking to make this technology better known to the general public as a sustainable solution to environmental problems (personal communication, February 7, 2013). CERES needs educational materials that present visitors with the image of, and the road towards, successful renewable energy implementations that solve environmental, social, and economic problems.

2.2 Education Delivery Strategies

CERES recently celebrated their one millionth student visit, demonstrating the potential and effectiveness of their instructor-led education programs (CERES, 2012a). Although their school incursions and guided tours are successful, CERES needs to better demonstrate these technologies to their casual visitors (French, February 7, 2013). This includes people who visit CERES without booking tours or registering for classes; therefore casual visitors do not have the opportunity to listen to instructors sharing their knowledge of renewable energy technologies, as happens with school visits. In order to properly address these visitors CERES must use its technological displays and web pages to present the same "big-picture" conveyed by educators. It is therefore important for us to investigate what makes displays and websites effective learning tools. By examining specific scholarly literature and analysing relevant case studies, a basic contextual understanding of these materials can be attained.

2.2.1 Experiential Learning through Physical Displays

Experiential learning is the process of acquiring knowledge through first-hand experience using strategies such as hands-on activities or interactive displays. The Australian Department of the Environment and Heritage has an outline for experiential learning, explaining that it "engages students in constructing knowledge, skills and values from direct experience and in contexts that are personally relevant to them" (Australian Government, 2005, p. 20). Feedback, reflection, and critical analysis are used to support experiential learning.

In a review of studies on experiential learning, the Association for Business Simulation and Experiential Learning (ABSEL) compared standard education techniques to experiential techniques. Compiled results showed that while educational achievements are comparable on subject matter tests, “the vast majority of studies… found that experience based training has helped trainees acquire new skills or change their behaviour in desired directions” (Gentry & Association for Business Simulation and Experiential Learning, 1990, p. 325). This result suggests that experiential techniques are an effective way to alter behaviours and attitudes toward renewable energy technologies. Therefore, if technological displays make good use of experiential techniques through direct, in context experiences, they can be successful in fulfilling CERES’ mission.

While the ABSEL study demonstrates that experiential methods are effective at conveying information and influencing behaviour, a person must be attracted to a display in the first place. In their guide on *Designing Science Museum Exhibits With Multiple Interactive Features: Five Common Pitfalls*, Sue Allen and Joshua Gutwill, exhibit designers at the Exploratorium in San Francisco, cite several references that suggest that interactive and experiential learning materials provide this attraction themselves. Allen and Gutwill write that it was “found that renovating a diorama exhibition to include multisensory interactive components led to increases in visitor holding time and visitors’ knowledge of the exhibition’s themes” (Allen & Gutwill, 2004, p. 2). While the visually pleasing aesthetics of an experiential display might initially attract the visitor, its engaging and informative properties hold the visitor’s attention and enable them to further the educational process.

The use of interactive/demonstrative displays is an experiential learning method that can be used to introduce renewable energy technologies. If the technology can be presented in a way that relates to an application useful in a person’s life, they are much more likely to have a positive response. Borsari, Elder, and Reynolds (2004) performed a study to assess the educational benefit of the demonstration of a solar powered cultivator to the farmers who would use it. After a demonstration, 72% of the viewers strongly agreed that they would like to learn more about renewable energy technologies. Through demonstrations that are personally relevant to the audience, experiential learning can educate a person on renewable energy technologies as well as provide motivation to seek out further education.

A longstanding physical example of facilitating learning and influencing behaviour through demonstrating a technology and relating it to the audience’s life comes from the Eden Project, an educational organisation in Cornwall, United Kingdom. With several different renewable energy technologies in use on site, the Eden Project educates its visitors by example. Visible from a courtyard, a rooftop 30kW photovoltaic solar panel installation partly powers the education building (Eden Project, 2012). The café uses solar panels to generate electricity as well as solar thermal panels to heat water. On site there is also a 5kW wind turbine and a 300kW biomass boiler. While these energy sources do not fully cover the site's power needs, the demonstration of fully integrated renewable energy technologies is a valuable experiential educational tool. Visitors are attracted to the recognisable technologies that stand out from their surroundings and are able to connect to the ways the technologies are used.

2.2.2 Informing through the World Wide Web

The World Wide Web is a vast resource for information regardless of the measure used. Considering the ever increasing popularity of personal computers and broadband Internet connections, this wealth of information can be instantly accessed; thus it is important to understand if and how the web can be used to effectively distribute knowledge.

Environmental psychologists Rachel and Stephen Kaplan consider that making sense and exploring represent the two basic informational needs. Associated with them are the motivation brought by evidence of future satisfaction, that would bring a user back, and a distinctive element, that facilitates finding the way back to the respective resource (Rosen & Purinton, 2004). The Kaplan Preference Framework (Kaplan, Kaplan, & Ryan, 1998) is applicable to the highly cognitive and information rich environment that the web comprises. Direct association between the elements of the matrix, as seen in Table 1, and the technical elements of a web entity can be made: coherence refers to redundancy of elements and textures, complexity is given by the richness of elements, legibility comes from having distinctive elements that facilitate navigation, while mystery is created by having pages linked through content itself (Rosen & Purinton, 2004). Therefore, we can conclude that the important technical aspects that need to be accounted for are uniformity of design, distinctive navigation, and cross-referencing.

Table 1 - Kaplan Preference Matrix

Characteristics of Information	Understanding	Exploration
Immediate	Coherence	Complexity
Inferred or Predicted	Legibility	Mystery

The way the information is displayed has a great impact on users. A study of the effective use of visual design and navigation schemes on reading comprehension and user perceptions identifies key technical features of an effective website (Cuddihy & Spyridakis, 2012). Good navigation schemas, characterised by partial hierarchical tables of content distinctively marked for local navigation, help users map information and reduce cognitive overload, and aid in information comprehension and retention (Cuddihy & Spyridakis, 2012). Hypertext can be used for the same purposes when it is clearly signalled with colours and when it directs towards further clarifying materials. Kuiper, Volman and Terwel (2005), further consider that the use of hypertext "stimulates active, self-directed, and exploratory learning." This technique also reduces disorientation and backtracking by less knowledgeable/experienced readers (Cuddihy & Spyridakis, 2012).

A web entity needs credibility in order to fulfil its mission of distributing knowledge. A 'Source Evaluation and Information Literacy' study performed on science websites identified key aspects of the credibility of a website. Web objects need to portray a complete picture of a particular subject. This includes current information from unbiased, scholarly sources and a multiplicity of views on the subject if they exist (Nora, Claire, & Stewart, 2010). The same study touches on memorability, considering that the most important factors are content, authority and perhaps functionality, while graphics and style are located towards the end of the hierarchy (Nora et al., 2010).

It is difficult to analyse in greater depth the effectiveness of websites in transferring information without analysis of a specific case study. The reviewed scholarly literature enables us to enumerate key factors involved in making an effective information resource online such as uniformity of design, distinctive local and global navigation elements, and visually emphasised cross-referencing. Other factors will be observed from designs that can be considered effective in covering the same topics of information as CERES.

The predominant method of finding information on the World Wide Web is making inquiries on search engines and then following the resultant web links towards the needed resources. Search providers use complex algorithms to determine the most useful pages for particular keyword combinations. Websites with high rankings are commonly among the most referenced pages on particular topics and pages where users are spending comparatively large amounts of time. This way, the top results of a search are pages successful in attracting visitors and convincing them of the value of the presented information. A few inquiries via popular search engines such as Google, Bing or Yahoo yield similar top results for pages related to “renewable energy” and “biogas digesters” and provide valuable examples for the CERES Biogas web pages.

The Biogas Australia website (www.biogasaustralia.com.au) is one of the top search results for “biogas digesters” in every major search engine; therefore, it is a natural landing spot for any internet user interested in biogas digesters. This is a suite of web pages created by Biogas Australia in an effort to promote its business of “bringing biogas digester/generator technology to Australia as well as providing a … solution to the reduction of greenhouse gas emissions” (Biogas Australia, 2013). Even though this organisation is a commercial enterprise focusing on farm-specific biogas digesters, it is similar to CERES in that it is trying to promote biogas digesters and thus properly present them on the web.

Figure 1 - Biogas Australia Website Screenshot (Biogas Australia, 2013)

Biogas Australia greets users by first showing all of the main informational points from across the website on the left hand side menu (highlighted in blue) and then summarising the content in short sentences or paragraphs on the main prose content part of the page (right side). The landing page offers a recognisable and easy to remember logo as well as an image that depicts the classic biogas digester. These features allow users to quickly find their way to the needed information and also see other related topics that might further spur their curiosity. This way, through targeted and related information easily available, the website keeps users engaged. The main page also graphically depicts the idea behind biogas digesters through a diagram comprised of clickable, linked images.

The website uses a light blue/green colour scheme that matches the logo. The pages are commonly less than or equal in height to about two average screens (2000 pixels); this avoids the users becoming bored scrolling to find the needed information. The distinctive headings and the bolded, colour fonts facilitate finding information and cross-linking content to keep users on the website (as opposed to directing them to outside resources). For the purpose of bringing users to the website and therefore appealing to the search engines, the website has hidden attributes such as keywords and a brief description of their content; this also helps users see an excerpt of the website upon searches.

From a brief analysis of the Biogas Australia website it is clear that it can provide a good starting point for investigating what makes a biogas-focused website effective. Features that allow for this high search ranking and overall efficiency can be observed in the form of main informational points relevant through the menu items, area-clickable concept maps or distinctive heading and link mark-up.

The Clean Energy Council website (www.cleanenergycouncil.org.au) is one of the highest ranked search results for “renewable energy” and represents one of the first sites seen by any internet user interested in this topic. This website was created for the Clean Energy Council, a not-for-profit association based in Melbourne, Australia, that represents companies operating in the renewable energy and energy efficiency fields. The CEC’s mission is to promote awareness, accelerate development and increase deployment of all clean energy technologies (Council, 2013). The Clean Energy Council is similar to CERES in that both organisations address the causes of climate change, through facilitating/accelerating change in the area of renewable energy. Since this organisation’s efforts are popular with internet users, its website and the way it depicts alternative energy technologies can be considered an appropriate example for CERES.

The CEC website starts the process of informing its audience through a news-focused landing page that is up to date on what is happening in the field of clean energy. This strategy drives curiosity and helps retain users. An element that stands out is the image of a working renewable energy technology with a caption that points towards the "bright future."

Figure 2 - Clean Energy Council Website Screenshot (Clean Energy Council, 2013)

The website dedicates a whole section to presenting renewable energy resources and how they are currently being harvested. The technologies section uses a left column menu to name and link towards the different technologies, and an array of similarly designed logos for each technology. These two strategies facilitate navigation, depict complex technological concepts through simple images, and provide memorable connections to the readers.

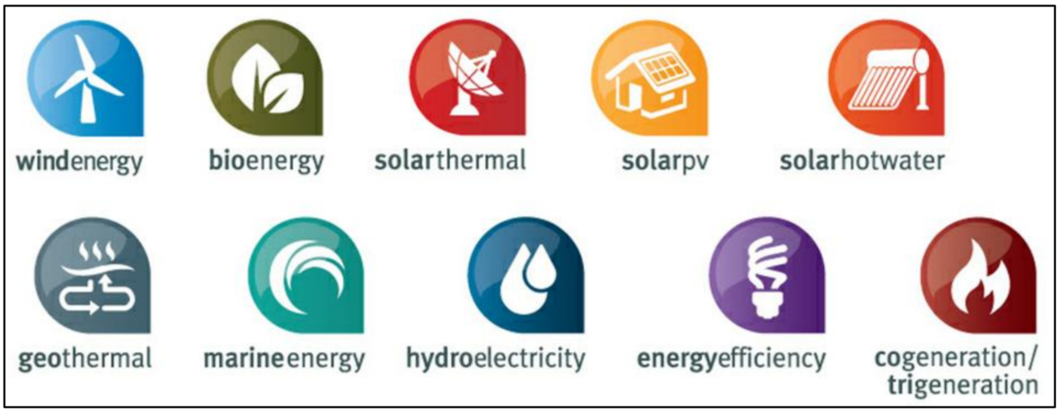


Figure 3 - Clean Energy Council Website Logos

The idea that energy generation can be entirely renewable and the idea that energy use can be made more efficient by using technology are reinforced through having all of these concepts in the same place. For each one of these 'clean energy' concepts, there is an information page that has the most important facts written in distinct paragraphs, separated by multiple headings. The break-up of information and abundant use of subtitles allow the user to see the available information before pursuing a particular topic. As a whole, this website section provides an array of useful links, materials, and a video explaining the main concept ("Clean Energy in Australia"). These materials always reside on the right side of the pages, thus allowing users to easily find more information pathways through a consistent design, facilitating dwell time and decreasing bouncing rates.

A quick overview of the Clean Energy Council website shows that it represents a good resource for determining what makes online renewable energy depictions effective. More than the Biogas Australia web pages, the CEC's website shows how multiple technologies can be presented together to amplify the impact on the audience.

To summarise the investigation of educational delivery strategies, from the scholarly literature reviewed we conclude that both displays and websites can effectively inform the casual CERES visitors by attracting them to the information source and engaging them through experiential methods. Relating to the visitors and providing connections with everyday life is one of the main methods used successfully on both physical and virtual displays of information by the organisations we studied. Demonstrating that renewable energy technologies are working successfully through physical and virtual examples is another key concept used to promote and create interest. Such techniques will be considered throughout the duration of our project.

3 Methodology

Our project assisted the Centre for Education and Research in Environmental Strategies (CERES) in its mission to better inform current visitors on emerging energy technologies, specifically the biogas digester, through the improvement of their education and communication materials.

Our objectives were:

- Identify the set of educational criteria that needs to be met in order to satisfy CERES' current educational goals regarding their biogas digester.
- Identify key characteristics of educational materials that are most beneficial in effectively conveying information to general public.
- Assess CERES' existing biogas digester display and web pages based on these characteristics and educational criteria to determine which are not currently met.
- Develop educational materials that will enhance CERES' website and display for the biogas digester.

Through our background research, we were able to determine that an educational material was being used effectively by an organisation if it met the criteria under the following three components:

- the ability to convey information to the general public,
- the ability to attract the general public,
- the ability to engage the general public;

The first category determined if the educational material was informative: if it portrayed all the information CERES was trying to convey including energy production, how the biogas digester works, and its applications. The second category determined if the educational material (technological displays and informative websites) was effective in attracting visitors based on criteria such as if it was colourful, recognisable or well structured. The last category determined if the educational material was engaging based on its ability to portray information in a logical form, keep people interested, and allow visitor interaction.

3.1 Identifying Informative Criteria

The identification of CERES' educational goals in regard to the biogas digester and the strategies CERES uses to effectively accomplish them was the first step in determining how to effectively educate the environmental park's visitors. Based on discussions with our project liaison, our focus was narrowed down to an interactive display and a website. To determine the key informational criteria that need to be fulfilled for a display and a website to express all of the information CERES was trying to convey, we interviewed six members of the CERES educational staff and the CERES biogas digester expert, John Burne.

The educational staff members are responsible for distributing information to the public and thus have the most knowledge of the demographics of the park's visitors and the overall educational experience. More importantly, educational team members are crucial in the decision-making process since they know exactly what they want to illustrate through the biogas digester display and website. The educational staff members provided feedback on our required criteria sheet for an effective display and website. We also asked the employees for any suggestions they believe to be important for designing and implementing changes to improve the biogas digester educational materials.

In order to familiarise ourselves with the display and identify key components of the digester, we interviewed CERES biogas digester expert and engineer John Burne. This interview provided us with knowledge on how the current biogas digester works and how it was designed and implemented, specific characteristics of the biogas digester, and an opportunity to learn more about the aspects or applications CERES wishes to convey to the general public through the physical biogas digester in the energy park.

The staff members were contacted in person or through email a few days in advance asking them to participate in an interview. The interviews were structured to last approximately 20-30 minutes and took place within the CERES Park. The exact location was determined based on the participants' preferences. Two students conducted the interview and the conversations were recorded using a handheld device, while notes highlighting main points of the conversation were taken. The recordings and notes taken were transferred to a computer and locked in password-protected files. If the participant did not give consent to record the interview, only notes on the conversation were taken. One student served as the lead of the conversation while the other served as a scribe. The questions and responses for these interviews can be found in appendices A and B.

3.2 Identifying Attractive and Engaging Criteria

In order to learn more about the techniques and process involved in designing an effective display, educational experts were interviewed and direct observations were performed on effective displays at Scienceworks and the Melbourne Museum. For these interviews and observations, our focus shifted from the required informational component in our criteria sheet to the more general attractive and engaging components that make a website and a display more effective. By capitalising on the experience of those who have been involved with education for a number of years, we were able to gather information critical to refining the required criteria sheet and evaluating CERES' current educational materials. More importantly, we were able to gather ideas that could be implemented to improve CERES' biogas display and website.

3.2.1 Interviews with Experts

In order to determine which criteria were more effective in satisfying the criteria sheet's attractive and engaging components for interactive displays and informational websites, educational experts were contacted and asked to participate in semi-structured interviews. Recommendations for expert interviewees were gathered from "*Building Sustainable Behaviours: Interactive Displays for Community Empowerment*," a previous interactive qualifying project report submitted to the Worcester Polytechnic Institute by Dunne, Marakhovsky, Su and Sylvia in 2011. These educational experts were also confirmed and approved by CERES staff members. Educators with experience on different educational strategies were identified at various education-focused institutions including Melbourne's Scienceworks Museum, Museums Victoria, and the Worcester Polytechnic Institute. We contacted Pennie Stoyles, the Education and Community Programs Manager at Scienceworks Museum, as well as Mirah Lambert, Project Coordinator of Online Learning, Ely Wallis, Manager of Online Collections, Aziz Yacoub, ICT Projects Manager and Jonathan Shearer, Program Coordinator of Digital Education, all from Museums Victoria. We also interviewed Dr Andrea Bunting, adjunct professor at the Worcester Polytechnic Institute, and Holly K. Ault, Mechanical Engineering professor at Worcester Polytechnic Institute, who we considered perfect candidates for our interviews due to their experience in the field of education. From the museum visits and the expert interviews we were also able to discover the elements of a display and a website that are considered to be best practices. This information was later used to develop similar display and website ideas that would help CERES in their journey to better demonstrate the possibilities and the advantages of using a biogas digester.

The interviewees were contacted several days in advance and asked to participate in an interview after we described the purpose of our project and the need for their expert opinion. We then set up a convenient time and place to meet. The interviews were recorded through the use of a hand held device if allowed by the interviewees, and notes highlighting key aspects of the conversation were taken. Again, these recordings and notes were transferred to a computer and placed in password-protected files. Questions for these interviews along with the summarised results can be found in Appendix B.

3.2.2 Observation of Effective Displays

While visiting the museums for the interviews with educational experts, we observed the displays that museum managers believe to be the most effective at educating their visitors. This allowed us to determine the specific characteristics of the displays that keep younger visitors at the sixth grade level engaged while still being appropriate for an adult audience. We took detailed notes on the specific characteristics that make each display effective according to the experts. We also took note of the layout of information on the displays and the amount of text relative to pictures and other visual representations. Pictures of the displays were taken. Observations of visitor interactions with the displays were not conducted since the purpose of these observations was to learn about the physical characteristics that make the displays attractive and engaging and therefore more effective. This information allowed us to further develop our ideas for creating our own display and website for the biogas digester at CERES. Our results and detailed observations along with images of the displays themselves are kept in Appendix C.

3.3 Assembling Required Criteria Sheet

Based on the educational goals expressed by the educational staff at CERES, the characteristics that CERES educators and museum managers find to make education effective, and the components of effective museum displays, we determined the final criteria that need to be met to create an effective educational display and website for all of CERES' visitors. Common ideas mentioned by CERES staff members were identified in order to modify the set of criteria our display and website had to meet; previously, the criteria set was based solely on the research done on environmental education organisations. These data were primarily used to modify the informational component. The information we gathered from interviewing educational experts and observing effective museum displays (Scienceworks Museum and Melbourne Museum) and websites (Museums Victoria) was analysed to determine the common characteristics that allow information to be conveyed effectively through displays and websites. These characteristics were then incorporated into the previously determined criteria for the attractiveness and engagement components of the display and website. This process provided us with a final set of criteria for both the information that needs to be portrayed and the physical characteristics necessary to convey it.

3.4 Evaluating Existing Educational Materials

Once we completed our interviews with CERES staff and educational experts, performed the necessary observations of effective displays in the local museums, and compiled the fully developed Required Criteria Sheet (which can be found in Appendix E), we used the sheet to evaluate CERES' existing biogas digester display and website. To accomplish this, we decided to interview park visitors and gather information on their understanding of the biogas digester prior to and after being exposed to the display. By comparing CERES' informational goals with the data from the visitors, we were able to determine the informational components missing from the display. In order to determine how to make CERES' display and website more attractive and engaging, we used the required criteria sheet to evaluate both of the existing educational material and determine which elements were missing from the display and website. This information helped better understand features derived from the information, engagement, and attractiveness criteria that would make CERES' display and website more effective in educating the general public.

3.4.1 Participant Structured Interviews

We decided to use feedback from CERES visitors to determine which educational criteria were not met by the existing display. According to Guest, Bunce, and Johnson (2006), 12 interviews provide a large enough sample to collect almost all relevant data to a study and the frequency of collecting new information significantly decreases after this point. In order to be confident that we gathered sufficient data, we decided to interview a larger sample of visitors.

The interviews were conducted by teams of two students and took place on Saturday March 23th, during CERES annual Harvest Festival. The visitors were chosen to participate in our interview as we saw them approach the renewable energy section of CERES Park between 10:00 am and 1:30 pm and were asked to complete a structured interview. Although some of the participants being interviewed entered the renewable energy technologies park alone, some entered in pairs or groups of three. The interviews with the individuals in groups were not conducted separately but their opinions and answers were counted separately since they built on each other's responses. Protocol for these interviews dictated that questions were strictly followed. Notes were taken during the interview process. The interview contained question that assessed the visitors' knowledge on the biogas digester before and after being exposed to CERES biogas digester display. Questions for these interviews can be found in Appendix D.

In order to keep track of the results from our interviews in a simple and efficient way, we decided to employ free listing as our primary method for compiling their responses. Once their responses were clustered into main categories, we decided to compare this result to the information CERES wants to convey. These data were important in determining which informational goals were not met by the current educational display.

3.4.2 Identifying Unmet Criteria

To gain an understanding of why CERES' existing educational materials were not effective and identify issues to address, we used the required criteria sheet (Appendix E) and the results of the participant interviews. The data gathered from the interviews with visitors was used to determine which informational criteria the display met and where there was room for improvement. To determine if the attractive and engaging components were being properly addressed, we used the required criteria sheet to grade CERES' existing display and website.

3.5 Developing Educational Materials

For the development of the final deliverables, the team started by outlining the development process. We determined the most important educational and logistic aspects and composed a list of priorities and constraints that needed to be considered. Then, we used all of the interview feedback to brainstorm ideas and compile a few design options. The criteria sheet and a weighted grading matrix were used to optimise the designs and assure that they could be completed and implemented. A design review allowed us to choose the best designs and make the final adjustments. After defining the final designs, we identified all of the needed resources and completed the full designs.

3.5.1 Initial Design Considerations

In order to know what aspects to focus on during the design process, we ranked the educational and logistical components of the educational materials from most to least important. The factors we considered were attractiveness, level of engagement, amount of information provided, time to complete, cost, and frequency of maintenance required. In order to create a pairwise comparison chart for weighting the relative importance of each factor, we used data from the CERES and expert interviews, the amount of time we estimated to be left for the completion of the deliverables, and the budget and availability for maintenance time as reported by CERES staff. Finally, a grading rubric and decision matrix were created to allow us to grade, rank and optimise our designs. The pairwise comparison chart can be found in Appendix F and the grading rubric and decision matrix can be found in Appendix G.

In order to determine the physical and virtual constraints for the designs of our deliverables, we pieced together answers from interviews with CERES staff, engineers, network administrators, and conversations with our project liaisons and advisors. We were particularly careful with the structural changes that could be made to the biogas digester and the amount of content that we could add, edit or remove from the Biogas section of the website. CERES design rules for both web pages and displays were investigated to allow us to create products that are compatible with the centre's existing educational materials. Finally, we inquired about the technologies available at CERES that could be used for implementation of the website and the possible preferred and/or available materials that could be used for creating the display.

3.5.2 Development of Design Options

With a good understanding of the project's priorities and constraints, we started to brainstorm ideas for enhancing the display and website by considering suggestions from CERES staff, visitors, and educational experts as well as our own creative outlooks. The result of this process was a list of possible characteristics and layouts for the display and website. These ideas were then combined into several designs for a display and a website which were evaluated using the required criteria sheet, and then graded using the decision rubric and matrix with our weighted criteria. The score from the rubric for each criterion was multiplied by the corresponding weight and the resulting values from each criterion were then added together into a final score. Through this evaluation, we were able to adjust our designs and make sure that they meet most, if not all, of the criteria determined to be necessary for effective educational materials. More importantly, we made sure that the ideas presented realistic scenarios for full design and implementation in the available time frame. The optimised designs for displays and websites were then presented during the design review process.

3.5.3 Design Review and Edits

After defining and optimising our preliminary designs, we drafted a plan of the alterations we would be making to CERES current biogas digester display and educational website for each case. We also created a few visual previews for each of the designs by using graphic manipulation tools and 3D modelling and rendering software such as Adobe Photoshop and D.S. Solidworks. A meeting with members of the CERES educational staff and the project advisers allowed us to share findings and designs for improving the CERES educational materials, and to receive feedback and any other ideas that could be added. Monetary constraints, time constraints, and future maintenance issues were also discussed during this meeting. Ideas and opinions from CERES educational experts as well as the staff that will be using our designs were taken into account, allowing us to put forth the most effective display and website that could be implemented.

3.5.4 Completion of the Deliverables

To begin the development process, we identified all of the resources needed for piecing together the complete design layouts and for implementing the designs on the biogas digester display and website. The team used the informative section of the required criteria sheet, the gaps identified in the CERES biogas related materials, the reviewed designs, and advice from CERES staff and experts in order to organise the information themes that need to be researched. Prose was written with a level of detail more advanced than the one required for the display and website in order to allow us to select and condense the most important information for both deliverables. The CERES guidelines for branding and design along with the information that needed to be graphically depicted or included into the overall theming allowed us to find and/or create the graphic elements needed for finalising and implementing the selected designs. We then proceeded to create the final, complete layouts for the products we wanted to create, along with the plans for how to obtain the necessary resources. For the remainder of the project allotted time, the team created the designed educational materials along with guidelines for how they should be used.

4 Results and Analysis

The team used feedback from staff to determine what information CERES is trying to convey and data from museum experts to identify how information can be conveyed effectively through physical displays and web pages. These ideas were assembled into a criteria sheet that was used to evaluate CERES' original biogas related materials. The assessment yielded the necessary changes and additions. The development process took us through brainstorming, outlining, design review, decisions and finally implementation.

4.1 Informational Goals

Interviewing six members of the CERES staff gave us a much better understanding of the informational topics they wanted to cover in regards to the biogas digester. We used free-listing as our primary method to extract key educational points from our interviews. The chart below illustrates a summary of the main educational components CERES is trying to convey.

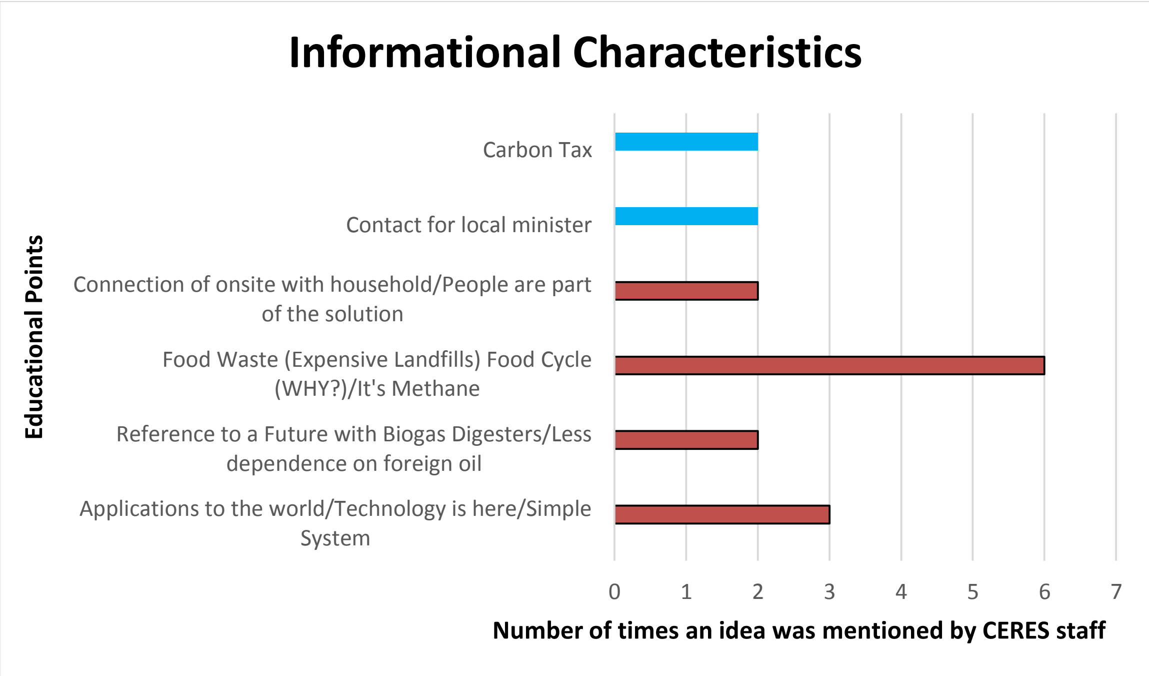


Figure 4 - Informational Characteristics as mentioned by CERES staff

All of the interviewed staff agreed that their primary educational objective is to convey the "big picture." CERES wanted their visitors to understand that a biogas digester decomposes organic food waste and produces methane, a gas that can be used for cooking or producing electricity, and also fertiliser, which can be used for the production of food. It was necessary to note that, without using a biogas digester, food waste ends up in landfills, creating yet another environmental threat. Naturally decomposing food waste releases methane that contributes to climate change, pollutes waterways and attracts pests which endanger the health of the nearby communities.

The second most mentioned educational component was presenting the applications this technology has throughout the world while highlighting the fact that biogas digesters are being used and available now, in Australia and throughout the world, and are not a futuristic idea. One third of CERES staff mention that they wanted the general public to see a future with biogas digesters and a connection between onsite (CERES display) and everyday life by allowing people to understand they are part of the solution to the environmental problems associated with waste. These educational goals allowed us re-develop our questions for CERES visitors and refine the informational part of the required criteria sheet.

4.2 Characteristics for Effectively Delivering Information

In order to learn more about the specific characteristics of displays and websites that make them effective educational tools, we decided to talk to educational experts and to conduct observations of effective displays found in Melbourne museums. This involved both educators from the CERES Environment Park and educators from local museums and the Worcester Polytechnic Institute. In this process, we discovered guidelines for developing an effective educational strategy and we refined our criteria sheet, which can be found in Appendix E.

4.2.1 Displays

Apart from determining what CERES' educational goals were regarding their biogas digester from our interviews with CERES staff, we decided to capitalise on the opportunity of speaking with them and learn about their ideas and opinions for making educational displays effective. The information represented on the graph below was extracted from our interviews in a similar manner as the informational characteristics that defined CERES educational goals. Five out of six CERES staff interviewees mention diagrams to display information as being a critical part of educational displays. Shane French, the Education Manager at CERES also mentioned that a key component to creating effective displays was that "anyone can understand it." Two thirds of the interviewed staff agreed, saying that if the public could not understand what was being presented to them, they would simply walk away without learning anything. After our first interview with Judy Glick, the Partnership Manager at CERES, we determined that our audience would be the general public and the information presented would need to be tailored to grade six students. Glick mentioned that if a sixth grader was engaged with the material being presented and understood this material, everyone older than this group would too. Half of the staff interviewees also mentioned that containing appealing visuals and being interactive are important factors in engaging an audience.

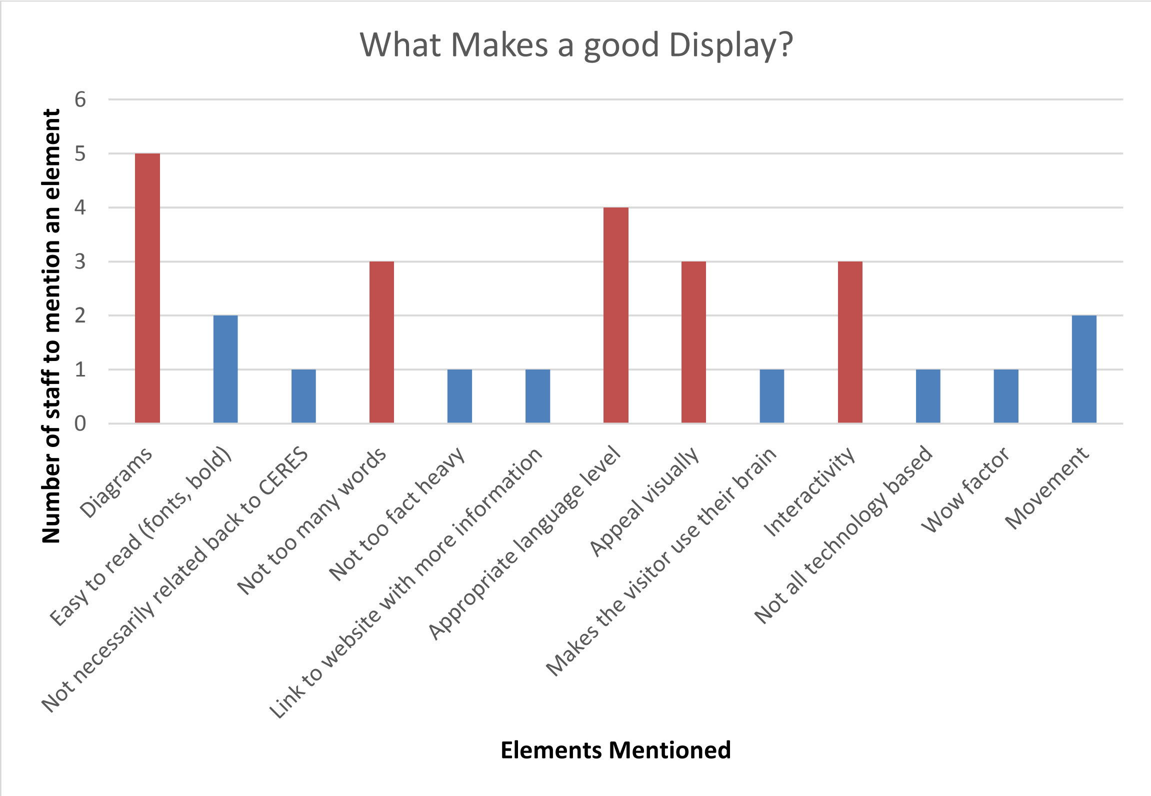


Figure 5 - Key elements of effective displays as mentioned by CERES Staff

The information we gathered from the interviews with CERES' staff laid the foundation for the rest of our interviews with educational experts. Through our interview with Pennie Stoyles, the Education and Community Programs Manager at Scienceworks Museum in Melbourne, Australia, we realised that a lot of the material CERES educational staff had mentioned before was being repeated. One of the major components of design for educational displays as Stoyles mentioned was that less information is better, and Jonathan Shearer Program Coordinator of Digital Education from Museums Victoria, agreed by saying that if students and the general public can learn three ideas, the display is doing its job effectively. Stoyles concluded that large clusters of information would only cause the visitors to feel uncomfortable and walk away. Therefore, a good approach is to have the information structured on three tiers to allow people to stop at the level they feel most comfortable while still getting the whole story. She also mentioned that having diagrams with pictures and colour coded sections to match certain parts of the digester with the information being delivered would catch the visitors' attention more effectively. Mirah Lambert, the Project Coordinator of Online Learning at Museums Victoria, added to the list of elements that comprise the engaging component through considering that in education, research elements are welcome, especially when students can create content and then share it. Dr Andrea Bunting considers that developing one's own ideas draws in enthusiasm. Therefore, a display should have some degree of challenge and ideally allow for creativity.

Regarding the interactivity of an educational strategy, Dr Andrea Bunting considered that building interaction into a display limits the activities that can be done with it. Professor Holly Ault advised the team not the make the interactivity the display into a 'cookbook' but provide the visitors with some degree of freedom. Lambert agreed with this idea, revealing that in the case of Melbourne Museum's interactive displays, people will generally start fiddling without reading the instructions and then move on when nothing happens. She and her team concluded that we should restrict our interactivity to very basic instructions, if any, and make it as intuitive as possible.

An idea we learned from Stoyles was that in order for a display to be attractive, it needs to show something visitors can easily relate to. Bunting supports this idea by considering that "people don't learn abstractly, they need to make connections to something they already know in different light"; consequently, displays should have elements that are easily recognisable by the general public. Adding to the list of attractiveness features, Lambert said "movement and novelty are great to attract people, but you need to keep them there in order for the display to be effective, you need engage them." Stoyles noted that sounds are also effective at attracting people, especially children. Both experts consider that surroundings are important for drawing in visitors and recommend that signs and labels are good ways of directing people towards a display. Our observations also provided some of the physical characteristics that make displays attractive and popular, such as the "Race Cathy Freeman" exhibit at Scienceworks. This display's major attraction was the very recognisable figure of an Australian Olympic runner. In general, the displays were very colourful, exhibited images, and displayed information in an easy to read manner. We also noticed the information being easy to see, on big signs, with related pictures and easily understandable everyday life examples. Another important general display characteristic we noticed was that the information was placed at a height where a child as young as age 7 could see it, thus making it easy to see for the whole audience spectrum. To confirm the experts' opinion, we observed that every working display in the museums had names and details pointing out its function and was placed in a thematically related area, with a path leading people in.

4.2.2 Websites

In order to learn more about the characteristics that make a website both attractive and engaging, we interviewed Mirah Lambert and her Museums Victoria colleagues, Ely Wallis, the Online Collections Manager, Aziz Yacoub, the ICT Projects Manager, and Jonathan Shearer, the Digital Education Program Coordinator. During our interview, Lambert and her team shared some of their insight and their journey developing Biodiversity Snapshots, an innovative educational online learning tool designed to assist students and teachers report on local fauna during their fieldtrips.

One of the things Lambert considers we should be careful with is the idea that people would spend a countless amount of time in our website. Most web users are driven to a page from a search engine, get the information they are looking for and leave; our goal should be to provide them with just enough information at first sight and to try to keep them on the website by providing more information through hyperlinking. The museum staff stressed the fact that writers for the prose web content should have strict length limits and should coordinate with the designers in order to break up the content and create visual paths for the users. According to their expertise, each page's structure should start with a 'hook': the basic info should start the path or the 'flow' and more detailed information should end it. Another useful observation that Lambert and her colleagues made is that we can expect people to click on everything, so we should make images, headers and keywords clickable links. Still, we need to be careful to "not have terms or topics that people won't know as links." To do this, the museum experts consider that we should only hyperlink basic words while keeping the frequency of linked content consistent throughout each page.

Pennie Stoyles from Scienceworks confirmed most of the suggestions we were offered by Mirah Lambert and her team. Relating to the flow of a website, Stoyles considers that we should start from one big picture sentence to draw people in and present the information on multiple levels. More on the structural aspect, Mirah says that each page should be independent of but still related to the others, so that each page shows a complete picture for the purpose of not confusing the users. An idea that was shared by experts from both museums is the beneficial presence of short videos on the website. The Melbourne Museum staff considered that concise 1.5-minute long videos could attract and catch the interest of the more visually oriented learners. Stoyles thinks that the optimum length is 2 minutes and that the videos should have a knowledgeable and passionate person using simple language to explain ideas. Lambert also mentioned that our team could include research elements into the website by giving the students the opportunity to share their findings and provide them with yet another tool of engagement. This would allow them to prove their creativity, by creating a challenging and social atmosphere. For the creative and challenging elements, some level of interactivity is obviously needed. The team considered that all of the ideas about interactivity previously presented, although directly meant for the display, pertain to the website as well. Thus, we decided to be careful not to constrain the interactive elements on the website while making them simple and intuitive to give users the opportunity to engage and thus to learn.

4.3 Required Criteria Sheet

The most important elements that make an educational strategy attractive, engaging and informative were compiled into a required criteria sheet. The information gathered for the attractive and engaging components was generalised so that it can be applicable to any educational material or technology. Apart from a few general features, the informative component needed to be tailored to meet educational requirements particular to the CERES biogas digester. The resulting criteria sheet can be seen below. Detailed explanations about what the requirements for each individual criterion as well as an example of the usage of the criteria sheet can be found under Appendix E.

Table 2 - Final Criteria Sheet

Component	Criterion
Informative	Biogas cycle
	Applications of this technology
	Technology is here
	Inputs and outputs (waste, methane, fertiliser)
	How does the biogas digester work?
	Using waste, reducing impact on landfills
	Personal connection
	Link to school curriculum
Attractive	Recognisable
	Easy to see information
	Directed to display or website by surroundings or references
	Colour
	Motion (videos in the website)
	Sound
Engaging	Multiple tier structure
	Logical flow of information
	Target age appropriate language
	Certain degree of challenge
	Allows for creativity
	Interactivity
	Visuals
	Diagrams

4.4 Existing Display and Website Evaluation

After determining the final criteria for evaluating educational displays and websites, we used them to evaluate the CERES biogas digester display. The attractive and engaging components of the display and website were graded by observing the biogas digester and the related web pages.

As shown in Figure 6, the biogas digester did not meet any of the attractiveness criteria. There was no motion or sound in any part of the display and the only part of the entire digester that shows any attractive colours was the small informational poster on the side of the digester. There was also nothing in the entire park to direct people to the biogas digester or even the energy park as a whole. In our interviews with visitors we discovered that none of the visitors were aware that they were in the energy park; most were not able to identify the biogas digester as an renewable energy technology and a few even mentioned that they thought it was an aviary.

Figure 6 - Original Biogas Digester Installation and Display

The biogas digester also did not satisfy the criteria for engagement. There are a few pictures and diagrams on the display but they are very small and can only be seen by visitors close to the display. Although the existing display has a logical flow of ideas, the text is all in one big block, discouraging visitors from reading it; the language used is more advanced than

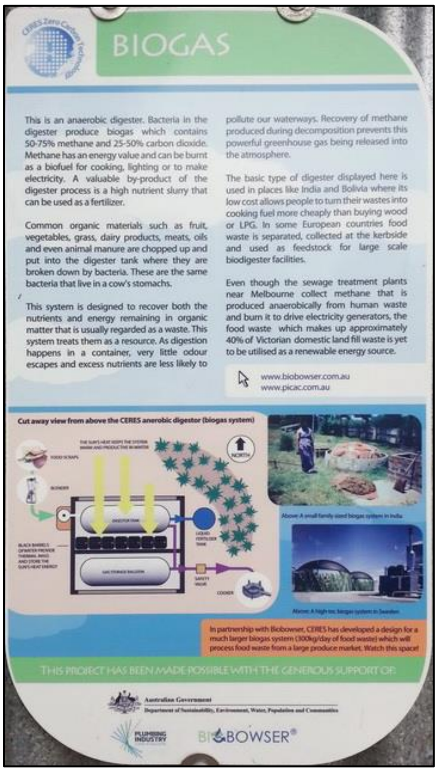


Figure 7 - Original Display Board

the recommended sixth grade level. There is also no interactive component to the display and no challenging elements to allow for creativity.

The informational component of the display was evaluated through interviewing 17 CERES visitors. Since none of the people we interviewed knew anything about the biogas digester before being directed to the display, all of the information they provided during the interview was learned from the display. Out of 17 visitors that we interviewed, 15 were able to tell us about the majority of the inputs and outputs of the biogas digester. However, only seven of the visitors demonstrated some understanding of how the digester works beyond inputs and outputs. One group was able to make a personal connection to their use of composting at home but none of the other visitors connected to the technology. Almost everyone we interviewed was able to identify a few applications of the technology and saw a use for it in on large scale. The final informational goal we were evaluating was an understanding of the biogas cycle. Only three groups for a total of seven people were able to put together the entire picture and show their understanding of the cycle. It was worth noting that the two groups of people who were interested in the energy park and had already begun reading displays in the area seemed to learn more about the biogas digester from the display than all of the other people we interviewed.

From this information, we concluded that while much of the information that CERES wants to convey was present on the existing display, it was not shown in a way that gets people interested. If visitors have an existing interest in renewable energy, they are willing to read through the display and learn, but the display is not attractive or engaging enough to keep everyone interested long enough to learn.

The biogas digester section of the CERES website, shown in Figure 8, satisfies six out of eight criteria for being considered informative. The page contains information on the biogas cycle, applications of the technology, inputs and outputs, how the biogas digester works, how it makes use of waste, and shows that the technology can be used today. All of the information determined to be necessary is presented. However, the page does not enable a connection between the user and the technology and has no link to the school curriculum.

The attractiveness aspect of the biogas digester web section scored one out of the six possible points. The single biogas page has one image and coloured graphics, therefore it can be said that it is colourful. However, this attribute mostly belongs to the website as a whole (headers, menus), not particularly the biogas related content. There is no moving graphics or text and no video are included. There are a few textual links towards videos, but they are not labelled as references to video content. For the audience being directed to the biogas section from other sources, the team did not observe anything in the CERES park pointing towards green technology information on the website. The main menu has the first and most important link, focused on 'Green Technology', but users need to take a lot of navigational steps to access the actual 'BioGas' page. Also, the main CERES page focuses on the commercial aspect and does not emphasise anything about green technology. For the recognisability aspect, the biogas page has a large title, "Biogas Digester," but no clear, common depiction of a digester to provide a visual landmark.

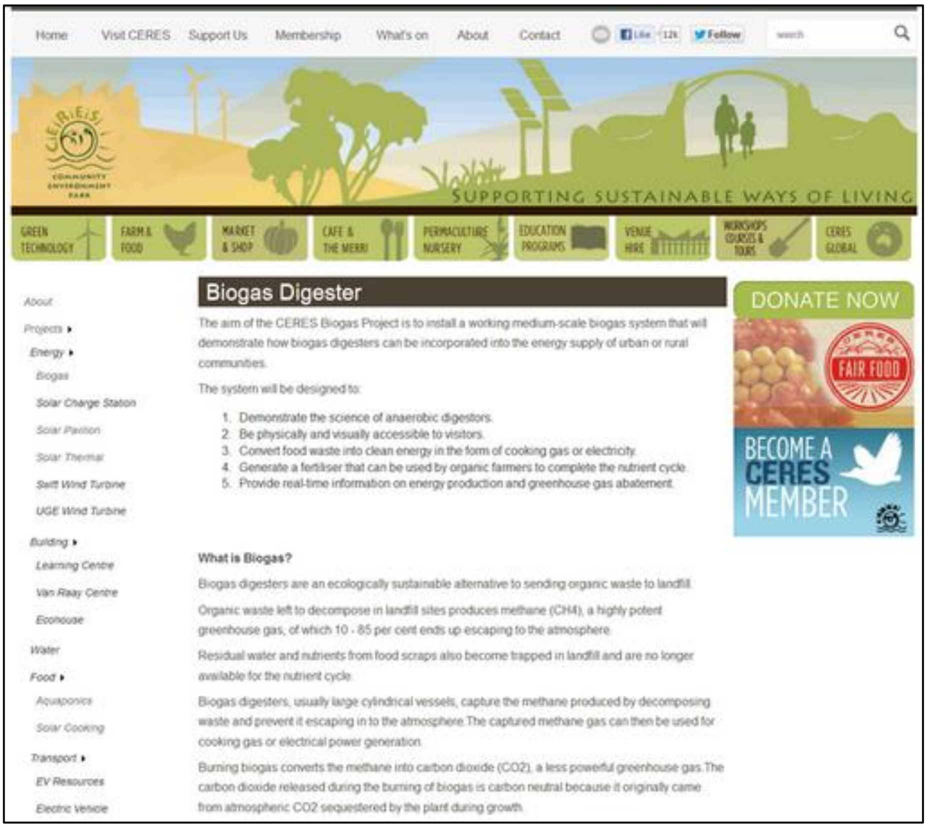


Figure 8 - Original Biogas Digester Page

The engaging component of the Biogas page scores 2/8. While the page is a simple prose form, it does have an appropriate language for a general audience (sixth grade level) and presents some logical flow, provided that an interested user actually reads that much text all at once. For the unfulfilled criteria, there is no multiple tier structure, the user is not challenged in any way, there are no particular visuals, there is no interaction, and the page does not allow for creativity. The page does have one diagram that summarises the main idea of the page, the biogas digester cycle. However, small font size, thin arrows, asymmetry and small, zoomed-out pictures make the diagram difficult to understand. Considering that the diagram is also placed below the first readable screen height, there are no assigned points for diagrams.

The evaluation of CERES' existing educational materials for the biogas digester showed that the existing display and website need some improvement to meet CERES' educational goals. For the display, we were able to determine that almost none of the individual attractiveness and engagement criteria were met. Although the original display did well in explaining most of the topics required and could have been reused or included in a later design, there was a strong need for a more attractive and engaging display. In the case of the website, the evaluation revealed that the current biogas page could not be considered attractive or engaging. Although the website was only evaluated by our team of four, the unanimous conclusion was that the ability to be informative was the only component where the website was effective. The website contained all of the information needed to fulfil the informational goals mentioned by CERES; still, there was an noticeable need for restructuring the information and changing the overall appearance of the 'Biogas' page for the purpose of making everything more appealing.

4.5 Educational Materials Development

During the initial phase of the development process, the team ranked priorities and determined boundaries for the two needed designs, outlined two options for the display and a single configurable design for the website, and then reviewed the preliminary designs with the project's sponsors and advisers. For the latter development stage, we drafted the final product outlines, identified the necessary resources, gathered or created them, and assembled a suite of website pages and a display design complete with implementation and maintenance instructions.

4.5.1 Design Priorities and Constraints

The first step in the design process was to prioritise the educational and logistical components through a pairwise comparison chart and to create weighted decision matrix (Appendix G). The highest ranked criterion was determined to be the time to complete the website and the design for the display since we wanted to offer our sponsor a fully functional website and a detailed display design. Cost was determined to be the second most important factor since the budget was limited to $2000. However, since no funds were required to complete the website, cost was not considered in the decision process for the website. The attractiveness and level of engagement were the subsequent factors in terms of importance because members of the CERES educational team and educational experts agreed that both are more important than being informative. Most elements of the biogas digester display will be exposed to the elements so they need to be designed to last without repairs. Website elements that gather feedback will require maintenance from the website administrators. Consequently, maintenance required was the next most important component. Because a large part of the audience has no prior knowledge or interest in the biogas digester and thus the amount of information that can be effectively transmitted is limited, the amount of information provided was considered the least important component.

The second development step was to determine the physical constraints for our designs. For the biogas display, it was obvious that there can be no structural changes and the location or orientation of the digester cannot be modified. An important component not to be modified was the “Danger – Flammable gas” sign that deters potential visitors from approaching the digester but is required by regulations. For the signage, the CERES branding guidelines have to be followed (colour palette, fonts and general shape). Not much area of the north side of the biogas digester can be covered with signs or boards since this can affect the sunlight exposure of the stomach and impact the digester’s operation. Any added measurement instruments such as probes and gauges have to be as non-intrusive as possible, not to damage the thin digesting and gas-holding bags. For the website we were asked to follow the CERES design guidelines, not to change the standardised header and left side-bar navigation elements, and to only work on the main content area. More importantly, our content had to be easy to integrate with the current content management system and easy to duplicate for the other renewable energy technology sections. This means that the code for the interactive elements had to be thoroughly commented for further development and maintenance, and the code for the purely informative sections had to be kept to a minimum complexity level.

4.5.2 Design Options

With the criteria for effective educational strategies in mind and considering all of the suggestions and ideas gathered from interviews, we were able to brainstorm several designs for the display and a versatile design for the website. Using the required criteria sheet and the decision matrix we optimised each individual design and graded it for later review purposes.

Ideas for the display

The two ideas we conceived for the display focused on getting visitors interested in the topic by distributing the information around the entire digester to make the individual components easier to identify and the clusters of information easier to read.

The first idea for the display was a flipbook placed by the feeder of the digester as well as a few “satellite” displays around the digester. The flipbook would contain five pages with information on how the digester works, the biogas cycle, waste, and current and potential future use. Additionally, the flipbook would create a personal connection to the amount of waste and answer frequently asked questions. The additional displays would contain factoids and diagrams that make each part of the biogas digester clearly recognisable. The flipbook provides an interactive experience as well as extra space to provide information that can be ordered to flow logically and structured in tiers. A challenge can also be provided through questions in the flipbook that are answered on the satellite displays around the digester. However, the display would not be very visible from a distance and all of the information being located in one place could seem daunting. Overall, this idea meets three of the attractiveness criteria, all of the engagement criteria, and all of the informational criteria.

The second idea for the layout of the display was a sequence of signs around the digester following the flow of material. The display board already present on the digester would be moved to a post in front of the digester where it can be placed at a low height and angled to allow easy visibility for all viewers and to serve as the first tier of information. New displays would be placed at the feeder, the stomach, the gas bag, and the fertiliser tank to provide more detailed information on the function of the part, related and recognisable images and diagrams, applications and uses for the methane and fertiliser, and links to the biogas cycle. A chart with the amount of energy produced and what it could power and live plants around the fertiliser tank would provide personal connections. Arrows would be placed along the pipes between the main components to make the material flow clear. This idea meets four of the attractive criteria, including “easy to see information” and directing the viewer to each component of the display, criteria not met by the first idea. However, there is no interactivity involved. The design also meets five of the engaging criteria and all of the informational criteria.

Both of these display layout ideas contain signs that would require almost no maintenance and would take just over a week to fully design. The second idea would be more expensive since there are several large signs that need to be able to withstand the weather, while only the outer part of the first idea flipbook would have to meet this demand. These two ideas were placed into the decision matrix and received scores of 1200 and 1080, respectively, out of 1500.

Ideas for the website

The idea for the array of web pages starts from a tree structure, optimal for a general audience that can land on any page when directed by search engines (as opposed to being directed by educators). A main page summarises all of the information to be offered and links towards more advanced, secondary pages to offer a second tier of information. The third tier of information is offered by linking content to renowned and trusted outside sources. The main page starts from a map of the biogas cycle, hyperlinked on certain areas to allow users to visually select the page that contains the desired idea, and then presents the summarised prose with necessary pictures and videos. The secondary pages start from 'hook' or topic sentences and then present the content to provide flow and structure. All of them contain a biogas digester clipart or logo on the top right corner in order to provide a recognisable item and link back to the main page. For more conventional users, a subtle linear top menu provides connections between pages.

The initial design fulfils all of the informative aspects of the criteria sheet through the main page and the following secondary pages: How it works, Real world examples, Food waste, Energy from biogas, Education, FAQ. More detailed descriptions of the pages can be found in Appendix H. To complete the attractive criteria, the design incorporates videos and animations. Users are directed in through references on the display to the website as a place for using calculators to find their "biogas potential," or through QR codes (see Appendix I). For the engagement criteria, a good flow of information comes from page topic sentences and graphic map linking. Directly asking the users what benefits they can obtain from their waste creates a challenge. Calculators answer the questions and make the experience more interactive. Leave-a-comment/question boxes on each page also give some level of interactivity. The “Share your data” page allows for creativity. User-adjustable charts with the typical operational parameters of the CERES biogas digester (peak temperature and acidity) on the “How it works” page attract through styling and colours and engage through zoom and tooltip capabilities. More importantly, they show that a functional example of the biogas digester technology can be found in the CERES renewable energy park. Three pages closed to the public, used by CERES staff to administer dynamic sections such as the FAQ’s, charts and shared data are also included in the design.

The elements that will be discussed during the implementation process are the animations, the references placed on the biogas digester display and the number of headings involved in breaking up information. The elements that we considered to be optional or extras are the leave-a-comment/question box, the “Share your data” page, the FAQ and the Educators page. The interactive elements and the FAQ page require maintenance and the administrative tools that allow it. The Educators page is primarily meant to be a prototype for integrating all of the technological pages into the Australian Curriculum.

For the purpose of aiding the design review of the optional elements, we estimated the maximum and minimum time required for implementation to range between 17 and 21 full days of work done by a single person. By applying the decision rubric and matrix, the minimalistic and the full design scored 1130 to 1300 points.

4.5.3 Design Review

The two ideas for the layout of the display were presented to our project liaisons, Shane French and Ian Culbard. They expressed interest in both of the preliminary display ideas and suggested a hybrid design. This idea takes the strongest elements of the two and combines them by having several displays around the biogas digester that flip open. This addresses the weaknesses of each of the original designs that were determined in the decision making process. Each display board would be easily visible from a distance since it would have basic, first tier information on the outer cover. Each would then flip open and provide the interactivity of the flipbook while also providing more space for material and shielding the bulk of the informational components from the elements. A challenge will also be provided through questions with hidden answers. This final display idea meets all of the attractiveness criteria apart from sound, all of the engaging criteria apart from allowing for creativity, and all of the educational goals. A 3D virtual model was created to enable our reviewers to visualise the deployment of display elements at the biogas digester site within the energy park, as shown in Figure 9.

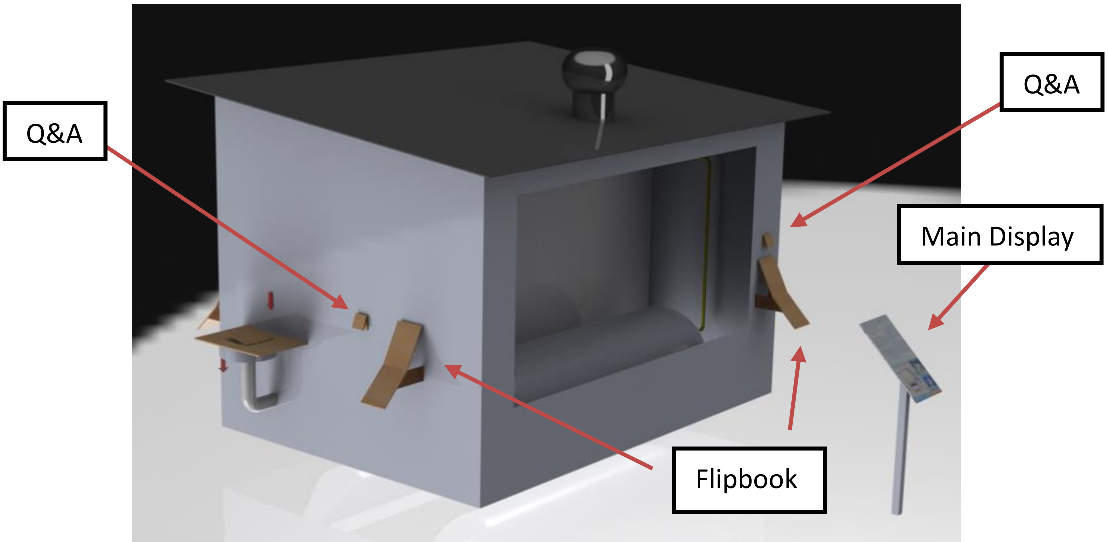


Figure 9 - Virtual Model of Proposed Display Deployment at Biogas Digester Site

French and Culbard also approved the layout of the website and provided their input on the optional components. Both agreed that question boxes were a bad idea due to the staff time required to respond to each question and the additional work needed by the project team for implementation. Instead, they suggested providing a link to the sustainability forum on the CERES website where questions would be answered by outside experts. The “Share your data” page was also declined due to the amount of maintenance required and the implementation time. The sponsors liked the idea of a page for educators and one for FAQ, but decided that they represent a lower priority and that they could be created once everything else is complete. On the “How it works” page, data should be embedded in the CERES biogas digester parameters charts and, if time allows, a page for editing individual data points (“Biogas charts administration”) could be added. Sample screenshots of the main page and a secondary page can be seen in Figures 10 and 11.

Figure 10 – Proposed Main Website Page Design Template

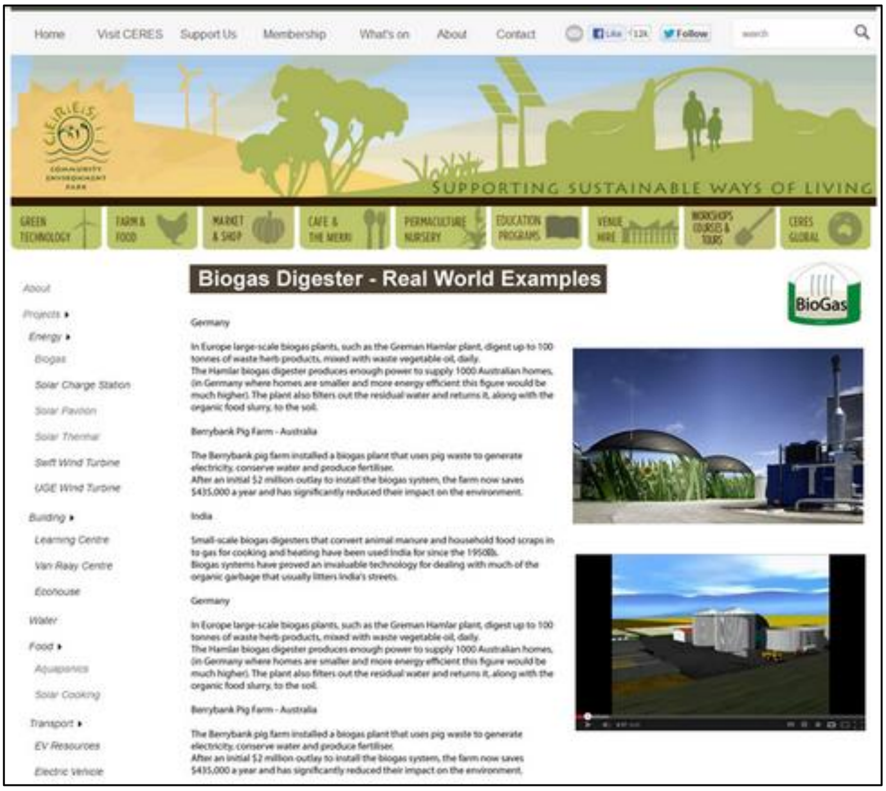


Figure 11 – Proposed Secondary Website Page Design Template

4.5.4 Final Products

The first steps of the implementation were to identify the main topics that we needed to present on the display and the website, the graphics that we wanted to use and the style guidelines that we needed to follow. By using the informative section of our criteria sheet and the reviewed designs, the team identified and researched the following information topics:

- Waste: how much is produced in Australia and other countries, where it comes from and what type it is – how much biomass and the environmental damage that comes from landfill produced methane
- Biogas digesters: how they work in terms of inputs, outputs, bacteria, usage, optimal conditions and the particularities of the CERES digester
- Energy from biogas: how much energy and fertiliser can be obtained from biogas digesters and what the differences are when various scales are implemented or certain types of biomasses are used
- Examples of digesters: effective biogas digester plants, their purpose (heating, base load power), feed stock and quantity of outputs
- The Australian Curriculum of Science: how the biogas digester technology and the materials CERES uses to portray it can be useful to educators

Observations of the CERES displays and web pages gave us the necessary style guidelines. The display designs should have rectangular shape, long side horizontal, with all corners rounded apart from the top left. Pictures and diagrams on the current display also have the three rounded corner rectangle shape, therefore for the purpose of the display, this design feature should be used. The colours to be used are predominantly light, de-saturated greens and blues; other "earthy" colours can be used for highlighting as long as they are homogeneous with the design, not too distinctive. The font used on special sections of the CERES website and on the displays is the more uncommon "Yanone Kaffeesatz" with an Arial – serif fall-back, so this should also be used for headings and titles. For the more common sections, both displays and web pages use Arial sans-serif, therefore it should be used on the main part of the prose.

Display Design

For the biogas display, we decided to incorporate a total of four different flipbooks, each similar to the pages found on the website but simpler and much shorter in terms of content. The first flipbook which will be placed at the mouth or feeding section of the biogas digester talks about food waste and the environmental problems this unsustainable practice causes. This flipbook was aimed towards satisfying the “inputs” and the “using waste to reduce impact on landfills” criteria that would satisfy our informative component. The second flipbook, which will be placed on the side of the digester where the actual decomposition occurs, satisfies the “how it works” criterion. The third and fourth flipbooks, placed on the side with the fertiliser tank and the side with the methane container, talk about the outputs in terms of energy production and fertiliser and provide real world applications to demonstrate that the “technology is here.” Through the layout and content of the flipbooks, visitors will be able to make personal connections, see and experience the biogas cycle. The original CERES display board will be used as a fifth element as depicted in Figure 14. The overall layout can be seen in the top view section of our virtual model of Figure 12.

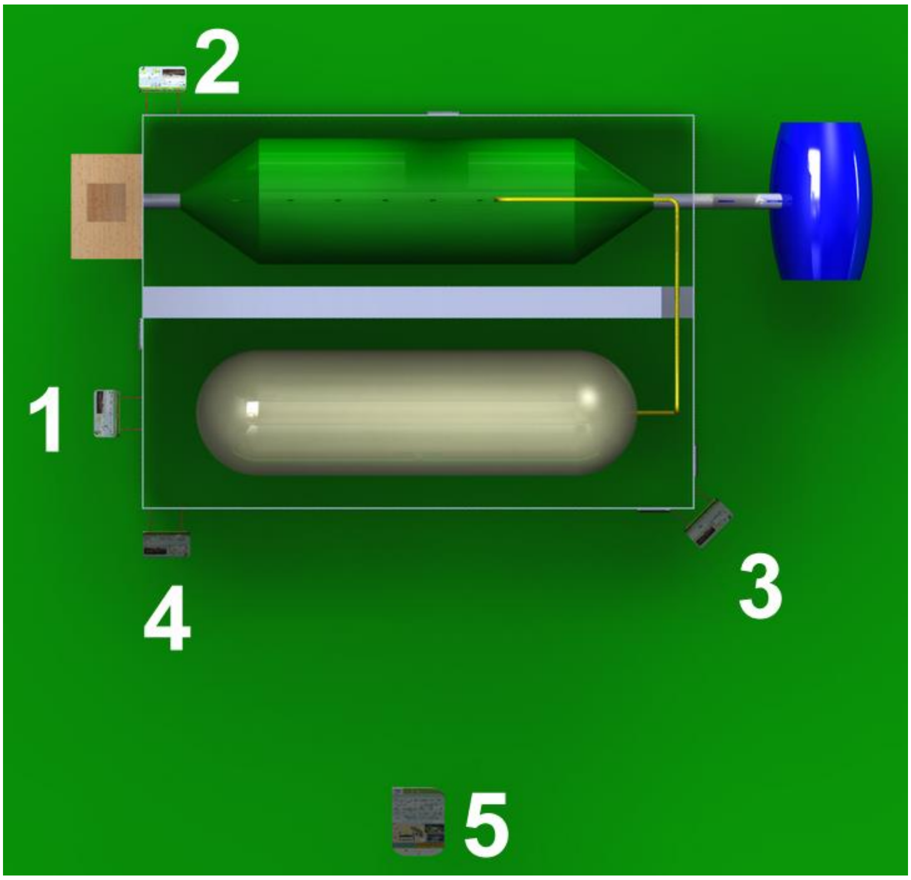


Figure 12 – Virtual Model Section with Approved Information Boards Layout

Each flipbook is designed to meet specific criteria that satisfy the attractive and engaging components. This includes recognisable images such as Australia’s rubbish bins, food waste in local supermarkets, fluorescent light globes, and large-scale biogas digester plants. The information is presented through a large, 24 point font with few lines of text to make the information easy to read. The colour of the displays follow CERES' design guidelines, which include light shades of green and blue as well as other "earth colours."

Figure 13 – Virtual Model with Open Flipbook and Closed Q&A

In order to keep the general public engaged, our flipbooks and display layout meet 7 out of the 8 established criteria. Each flipbook begins with a cover page, which broadly introduces the topic. As it is opened, more details are provided in order to create multiple tiers of information. Each flipbook will be placed around the biogas digester in a thematically related location. Pictures and diagrams included in each page clearly represent the topics being presented, simplifying the concept when possible. The prose is appropriate for a 6th grade level, suited to the general public. Next to every flipbook there will be a small flip-up question/answer board as shown in Figure 13. The Q&A's will have challenging questions on the outside and answers inside. The detailed designs for each flipbook and question board can be found in Appendix I.

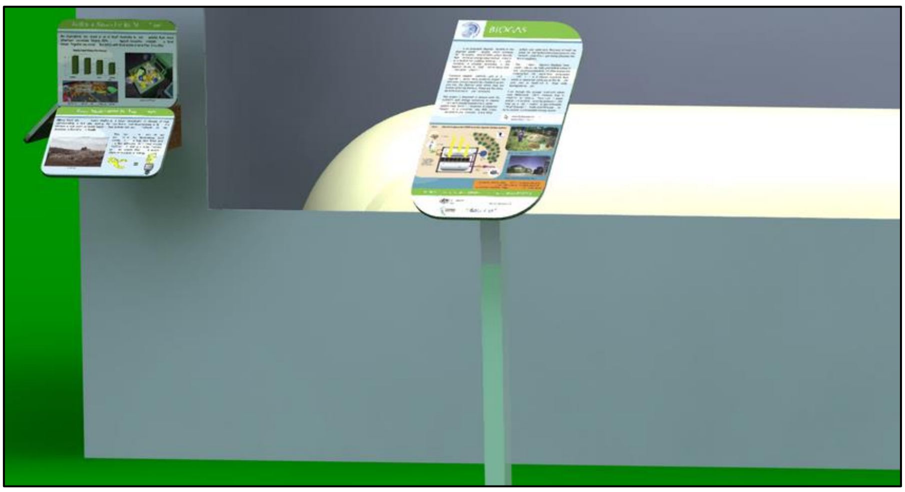


Figure 14 – Virtual Model with Original Information Board and Open Flipbook

In the end of the design process, we handed the CERES staff all the materials they need for implementation in both print and electronic format. We provided designs for flipbooks and Q&A's, ready for printing, dimensioned drawings for building the flipbooks and Q&A's, and a map with the locations of each physical element on the biogas digester installation. We also included the files used to generate the designs, for future edits: Photoshop format graphics, PowerPoint format content and a SolidWorks 3D virtual model.

Website Pages

The web pages fulfil the vast majority of the informative, attractive and engaging criteria and meet all CERES requirements. Due to maintenance concerns, the criterion that requires the educational material to allow for creativity could not be met.

The pages are recognisable through the ubiquitous biogas digester logo. This particular graphic can be found on the biogas cycle map of the main page and in the top right corner of the content area of every secondary page, as shown in Figure 15. In both cases, it provides navigation, first towards the main page and then towards the "How Biogas Digesters Work" page.

Figure 15 - Biogas Logo on a Secondary Biogas Page

The custom-designed biogas cycle map on the main page (Figure 16) integrates all of the essential parts of the concept and presents it in a simplified, age-appropriate manner. The thematically homogeneous graphics both attract and engage the audience.

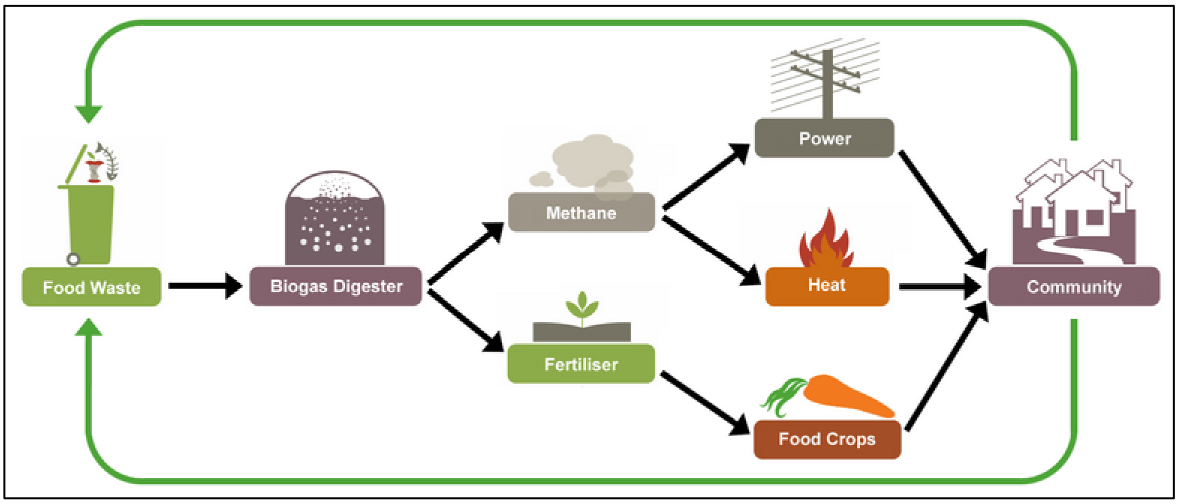


Figure 16 - Biogas Cycle Map for Main Biogas Page

The “Energy from Biogas” page challenges the users by posing a direct question and then allowing them to use the calculator to find the answer. The calculator provides recognisable and relatable information based on the user’s input. This mix of interactivity and recognisable elements builds towards the web page being both engaging and attractive.

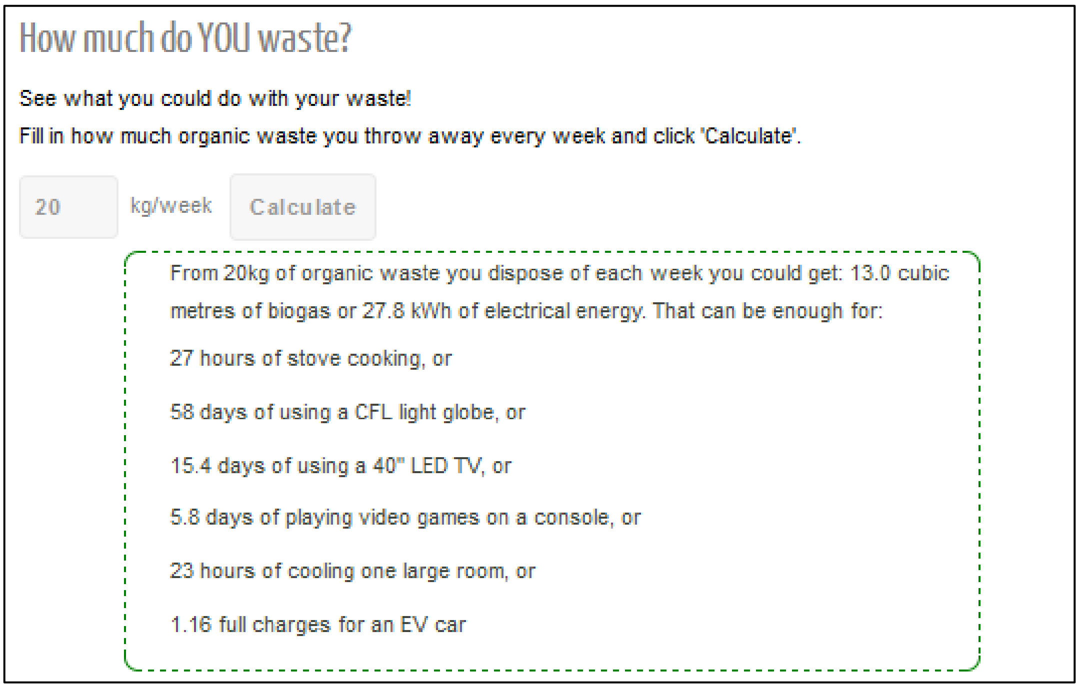


Figure 17 - Biogas Website Calculator

The “How Biogas Digesters Work” page features a video in which CERES engineer John Burne demonstrates how the device is operated; the video both attracts and informs visitors. The custom 3D animation achieves the same goals through offering a basic, age appropriate description of the biogas digester.

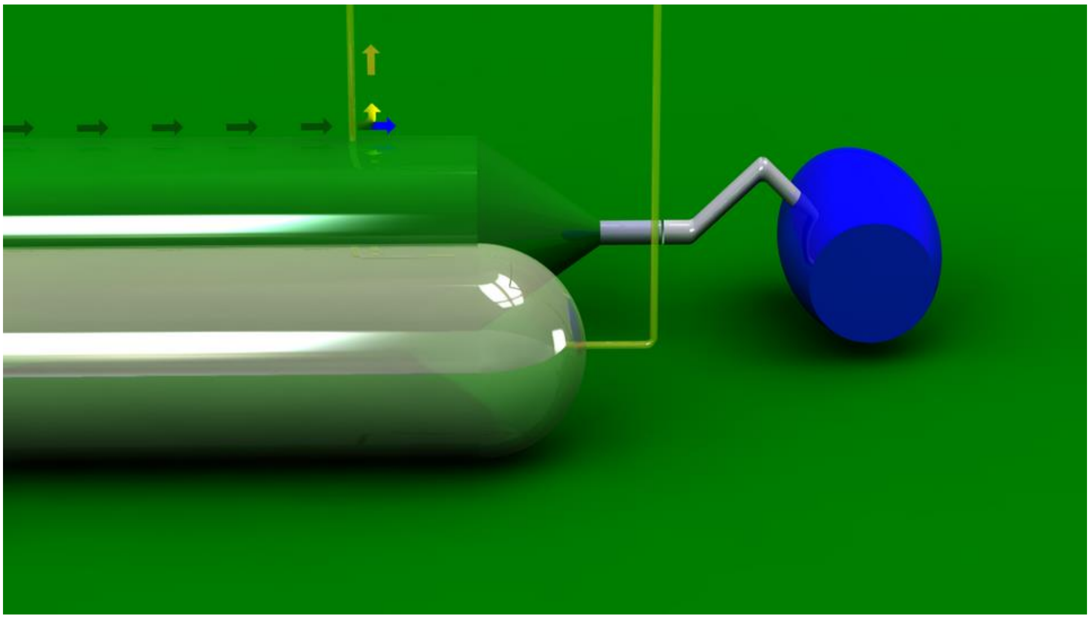


Figure 18 - "How the CERES Biogas Digester Works" Video Frame

The data plots present visitors with a sample of the operational parameters of the CERES biogas digesters. On a parallel page, more advanced versions of the same plots allow the staff to record pressure, temperature and acidity inside the digester and additional notes when needed. The public page attracts the audience and the parallel page, accessible only to CERES staff, provides a valuable tool for the CERES engineers using the biogas digesters.

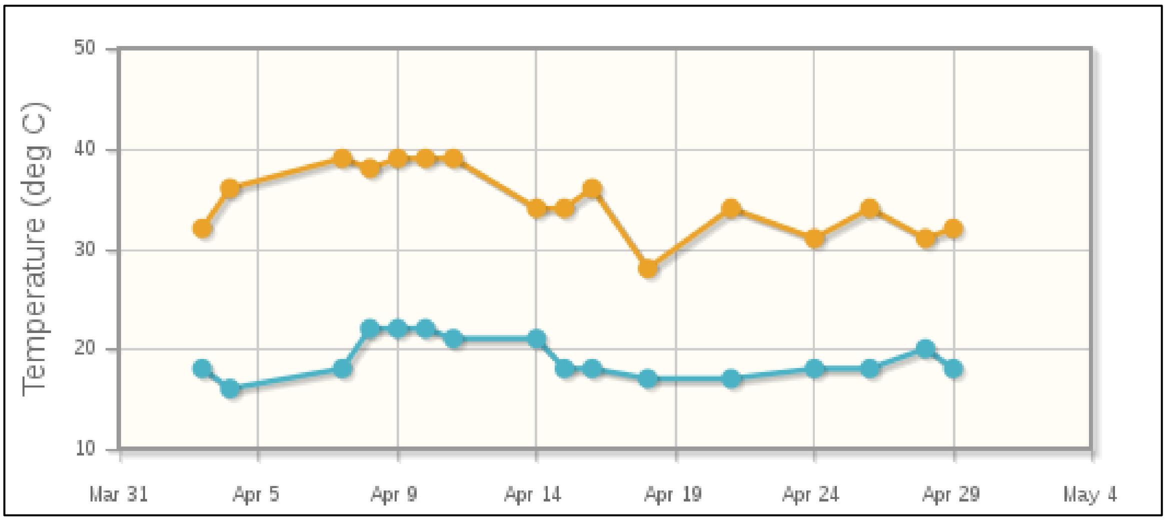


Figure 19 - Biogas Website Sample Temperature Plot

During the web development phase, the team used a virtual server. Following the completion of our design, the content was integrated on the CERES website. Detailed comments for the functional code were included. We also provided electronic copies of the Photoshop files used to generate the graphics. Therefore, we offered CERES IT staff fully editable content for future maintenance. The implemented web pages can be found at the following address: http://www.ceres.org.au/greentech/Projects/Energy/BioGas.html .

5 Conclusion

The outcome of this project is an educational display design and collection of web pages for the biogas digester at CERES. These educational materials are meant to better educate the public on renewable energy technologies and their role in today's society. The display design and the website were created with guidance from educational experts at local museums and universities. A set of criteria was created for determining if educational materials are attractive, engaging, and informative. By considering these criteria in the design process, our products can effectively meet CERES' educational goals for the biogas digester and provide a template for future improvements to CERES' educational materials for other renewable energy technologies within the CERES energy park.

6 Recommendations

Throughout our development process we identified other areas of the CERES renewable energy park where improvements can be made and developed recommendations for future projects.

1. We recommend linking the biogas digester educational materials with the school curriculum.

Although the primary audience for the developed educational materials was the casual CERES visitor, the development of the displays and web pages was informed by a review of the Australian Curriculum of Science. Educators that bring school groups to CERES would benefit from a guide on how to integrate the technology displayed in the energy park with their subjects. The results of researching the curriculum can be found under Appendix J.

2. We recommend creating a relatable aesthetic theme for the biogas digester.

From our interviews we determined that a major problem with the biogas digester was its failure to attract visitors. During the design process, we came up with a few ideas on increasing the overall attractiveness of the display. The first of our ideas was to paint the entire digester in a dairy-cow pattern and to relate the different parts of the digester to corresponding parts of a cow. This analogy was suggested by a few of the educational experts and CERES staff members due to the similarities between biogas digesters and cows in terms of digesting food and producing methane. The second theming idea was to paint a mural on the digester to depict a community-level biogas digester. Food scrap models could also be placed at the feeder of the digester and flowers could be planted by the fertiliser tank in a manner that looks like an organised garden. These features would be visible from a distance and could attract visitors to the display. Once there, they may notice the educational value of the display and learn.

3. We recommend using another student project team to evaluate the effectiveness of our designs.

Our display and website designs were based on criteria developed using the input of educational experts. However, this does not guarantee their effectiveness. An evaluation of the effectiveness of the display and web pages should be performed, and any necessary improvements to the educational materials or the overall design process could be made. These tasks can be successfully accomplished within a future student project.

4. We recommend using our design process to enhance educational materials for the other technologies present in the renewable energy park.

While some of the other renewable energy technologies may be more recognisable, we observed that the displays themselves are in general neither attractive nor engaging. Similarly, the Green Technology section of the website seems to be informative but not attractive or engaging. Using the design process implemented by our team along with any improvements made as part of the previous recommendation, the displays in the renewable energy park and the associated web pages can be improved to better serve CERES' mission. Our display and web pages can be used as a template for these improvements. The criteria for engagement and attractiveness are generalised and thus applicable to educational material for other technologies. The informative component would need to be tailored to any specific technology. This implementation can be performed as part of a future student project.

5. We recommend creating pathways and signage to direct visitors to and through the energy park.

Interviews with visitors to CERES showed that many people are not aware of the renewable energy park and its educational opportunities. Signs at each CERES entrance can direct visitors towards the renewable energy park. Maps at each entrance can help avoid missing educational displays through pinpointing the locations of each physical object. Pathways can add to this by naturally leading the way to each display. This can help bring the casual visitors to the displays.

Bibliography

Allen, S., & Gutwill, J. (2004). Designing Science Museum Exhibits With Multiple Interactive Features: Five Common Pitfalls. *Curator, 47*(2), 13.

Alternative Energy. (2012). Alternative Energy,. Retrieved February 24, 2013, from http://www.altenergy.org/

Australia Bureau of Statistics. (2013). Waste Generated Per Person. Retrieved March 22, 2013, from http://www.abs.gov.au/ausstats/abs@.nsf/Lookup/by%20Subject/1370.0~2010~Chapter~Waste%20per%20person%20(6.6.3)

Australian Curriculum Assessment and Reporting Authority (ACARA). (2013). Australian Curriculum.

Australian Government. (2005). *Educating for a Sustainable Future*. Retrieved from www.deh.gov.au/education.

Biogas Australia. (2013). Biogas Australia Home Page. Retrieved April 23, 2013, from www.biogasaustralia.com.au

Boden, T. A., G. Marland, R.J. Andres. (2010). *Global, Regional, and National Fossil-Fuel CO2 Emissions*. Carbon Dioxide Information Analysis Center.

Borsari, B., Elder, T., & Reynolds, T. (2004). Assessing the educational opportunities from a solar powered cultivator at Slippery Rock University of Pennsylvania. *International Journal of Sustainability in Higher Education, 5*(2), 190-198.

Carbon Dioxide Information Analysis Center. (2009). Ranking of countries by 2009 per capita fossil-fuel CO2 emission rates. Retrieved February 19, 2013, from http://cdiac.ornl.gov/trends/emis/top2009.cap

CERES. (2012a). About. Retrieved February 24, 2013, from http://www.ceres.org.au/about/About.html

CERES. (2012b). Board of Management. Retrieved February 24, 2013, from http://www.ceres.org.au/about/Board.html

Clean Energy Council. (2013). CEC - About CEC. Retrieved April 23, 2013, from http://www.cleanenergycouncil.org.au/aboutus.html

Clean Energy Future. (2013). Our Plan. Retrieved February 19, 2013, from http://www.cleanenergyfuture.gov.au/clean-energy-future/our-plan/

Council, C. E. (2013). CEC - About CEC. Retrieved April 23, 2013, from http://www.cleanenergycouncil.org.au/aboutus.html

Cuddihy, E., & Spyridakis, J. H. (2012). The effect of visual design and placement of intra-article navigation schemes on reading comprehension and website user perceptions. *Computers in human behavior, 28*(4), 1399-1409.

Dlugokencky, E., & Tans, P. (2013). *Trends in Atmospheric Carbon Dioxide*. Earth System Research Laboratory Retrieved from www.esrl.noaa.gov/gmd/ccgg/trends/.

Dopita, M., & Williamson, R. (2009). Australia's Renewable Future. Canberra, ATC: Australian Academy of Science.

Dresselhaus, M. S., & Thomas, I. L. (2001). Alternative energy technologies. *Nature, 414*(6861), 332-337.

Eden Project. (2012). Cutting energy and carbon, on site, emissions. Retrieved February 24, 2013, from http://www.edenproject.com/whats-it-all-about/climate-and-environment/sustainability-at-eden/cutting-energy-and-carbon-at-eden

Eden Project. (2013). School trips to the Eden Project, Cornwall. Retrieved February 19, 2013, from http://www.edenproject.com/learn-with-us/school-trips

Environmental Protection Agency. (2012). Climate Change Basics. Retrieved February 28, 2013

Environmental Protection Agency Victoria. (2013). Waste in Victoria. Retrieved March 22, 2013, from http://www.epa.vic.gov.au/your-environment/waste

Garthwaite, J. (2012). Coal-Fired Australia, Buffeted by Climate Change, Enacts Carbon Tax. *National Geographic News*. http://news.nationalgeographic.com/news/energy/2012/10/121005-australia-carbon-tax/

Gentry, J. W., & Association for Business Simulation and Experiential Learning. (1990). *Guide to business gaming and experiential learning*. East Brunswick; London: Nichols/GP Pub. ; Kogan Page.

Guest, G., Bunce, A., & Johnson, L. (2006). How many interviews are enough? An experiment with data saturation and variability. *Field methods, 18*(1), 59-82.

International Energy Agency. (2013). FAQ:Renewable Energy. Retrieved February 24, 2013

Kaplan, S., Kaplan, R., & Ryan, R. L. (1998). *With People in Mind: Design & Management of Everyday Nature*. Covelo, CA, USA: Island Press.

Kuiper, E., Volman, M., & Terwel, J. (2005). The Web as an information resource in K-12 education: Strategies for supporting students in searching and processing information. *Review of Educational Research, 75*(3), 285-328. doi: 10.3102/00346543075003285

Nora, J. B., Claire, R. M., & Stewart, M. (2010). SOURCE EVALUATION AND INFORMATION LITERACY: Findings from a study on science websites. *Communications in information literacy, 4*(2), 170.

Rosen, D. E., & Purinton, E. (2004). Website design: Viewing the web as a cognitive landscape. *Journal of Business Research, 57*(7), 787-794. doi: http://dx.doi.org/10.1016/S0148-2963(02)00353-3

Schmidt, J., & Haifly, A. (2012). Delivering on renewable energy around the world: how do key countries stack up. from http://www.nrdc.org/energy/files/delivering-renewable-energy.pdf

Singh, V. (2010). U.S. must switch to renewable energy faster, says expert at WestConn. Retrieved February 24, 2013, from http://www.newstimes.com/news/article/U-S-must-switch-to-renewable-energy-faster-822356.php

Appendix A: Interview Questions for CERES Educational Team

Opening Statement from Interviewer
Good Morning (or Afternoon). We are a group of students working on a project for CERES and Mr. French. Our project will assist CERES in its mission to better inform current visitors on emerging energy technologies, specially the biogas digester through the improvement of their education and communication efforts. We would be very appreciative if you could spare time talk with us and answer our questions that would help us better achieve or goal and help CERES.

Logistics
Date and Time:
Interviewer:
CERES Staff Member:

Preliminary Questions

1. How long have you worked at CERES?
2. And on the education team?
3. What programs do you teach?

Main Questions

4. Could you please provide a quick distribution of the visitor demographics? (to be asked in the first interview)
5. What is the targeted audience? (Question for Judy Only).
6. In your experience, what are key qualities that make an educational strategy effective?
7. (Referring to evaluation rubric in Appendix E) Are these factors important in educating visitors to the park? How important is each variable?

Conclusion Questions

8. What are some of your suggestions for improving the educational experience in terms of biogas digester?
9. What suggestions have you heard from visitors on improvements for CERES?
10. What information would you like to see visitors getting out of new educational material, in terms of biogas digester?

Summarised Results

CERES Staff Members: Judy, at CERES for 17 years, Shane, 8 years, Glenn, 7 years, Nick, 5.5 years, Matthew, 3.5 years, John, 2.5 years

Our target audience:
The general public, present information at the sixth grade level so it is appropriate for everyone

Qualities for an Effective Educational Strategy

- Show only a few key messages and show the big picture
- Use an appropriate language level for your audience
- Make it interactive
- Excite people by connecting the information to them
- Focus on the positive aspects of the topics presented
- It doesn't need to be technology based, not everyone will use it if it is
- Not too much text, break it up with images
- Simple, understandable images and diagrams
- Provide links to more information
- Make a display stand out from its surroundings
- Include something you can touch and move

Importance of Attractive, Engaging, and Informative

- Engaging is important to get people excited and have a lasting impact, they can look up more information later
- It must be attractive to be engaging

Suggestions for Improvement of Biogas Digester Display and Website

- Direct people to the digester
- Make the website interactive and show the future powered by biogas
- Make the digester recognisable, it just looks like a shed
- Videos on the website
- Pressure gages and a thermometer on the display
- Compost heap near the digester to link it to the decaying food waste
- Mural on the digester showing the big picture

Informational Goals for the Biogas Digester

- Show the potential for a community biogas digester with food waste sorted out at home, show that this is possible now
- Information on how much food waste is produced, make it clear food waste is not a good thing
- Inputs and outputs of the digester, the full cycle
- Show how using a biogas digester can change your lifestyle
- How the digester works, what the different parts are

Appendix B: Interview Questions for Educational Experts

Opening Statement from Interviewer

Good morning (or afternoon) as part of a group of students from Worcester Polytechnic Institute in the United States, we are here to help CERES achieve their goal to improve their educational delivery methods regarding their biogas digester. Our target audience is students in grade 6 and above and all adult visitors. Therefore we are researching to create an interactive display and website for their biogas digester. We would be very appreciative if you could spare time talk with us and answer our questions that would help us better achieve or goal and help CERES.

Logistics

Date and Time:
Interviewer:
Educational Expert:

1). How long have you worked at the (Scienceworks Museum/Museum of Melbourne) or been involved with education?

2). What kinds of educational strategies have you been involved with?

3). What process do you implement for developing an interactive display for the museum?

4). What is your typical targeted age range?

5). What displays have proven to be very popular to the museum visitors? Do you know what caught the visitor's interest?

6). What are some of the key characteristics that make your displays or website, engaging, informative and attractive? (Refer to criteria found of Appendix E).

7). How important do you think attractiveness and engagement are relative to one another in an educational strategy?

8). What are some suggestions or advice you may have for us, so we can accomplish our goal in a successful and professional manner?

Summarised Results

Dr Andrea Bunting

- Building what something can do into the display is problematic – it limits the activities you can do with it
- Show connections to different things in a way people can relate to
- With a cow and biogas – people can relate the inputs and outputs, bacteria in the stomach, fermentation is similar…
- People don't learn abstractly, they need to make connections and see something they already know in a different light
- Let them develop their own ideas to get enthusiasm
- Attractiveness is less important if you want to engage people, it is only useful for drawing people in
- People need to relate to the digester to be able to learn
- Need to get the message across that it is renewable energy technology

Pennie Stoyles (Scienceworks)

- less information is better
- Grade 6 knowledge level is a good level for teaching the general public
- The text on a display goes through a lot of hands, experts on the subject, proof readers and outsiders to read it and see if it makes sense
- Educators tie all information into the school curriculum
- See Gardner's Intelligences
- There are many types of learners – visual, auditory, emotional, kinaesthetic, address as many as possible in a display to engage as many people as possible
- Start by addressing an individual to get them interested – relate to him/her, then show them the information
- For kids, sounds can catch their attention
- Motion is very attractive for younger audience
- Surroundings are important for drawing in visitors – overarching signage in the technology park
- Start from one 'big picture' sentence
- Tie different technologies together with one main message to relate everything
- Symbols or colours to reflect different types of energy, connect everything together
- One exhibit out of context wouldn't engage people – need to get people interested in the first place before they can engage with display
- 3 tiers of information – lets someone stop at the level they are comfortable at while still getting a whole story at each level, from essentials to details
  - Show the big picture with one sentence first to draw people in
  - Then give more detail
  - Then give even more detail
  - For biogas
    - Start with basic inputs and outputs
    - Continue with information about bacteria digesting plant matter and producing methane to be used for…
    - Then link to the whole cycle, examples of use…

    - Have all 3 on both the website and the display so if someone doesn't see both, they still get the full picture
- Use appropriate language – what does anaerobic mean? Explain it
- Diagram with colour coding – match the diagram colours to the actual parts of the digester
- Display shows top-down, actual digester is side-on view – difficult to relate one to the other
- Relate it to the curriculum but make it more fun, maybe add some animations, a character…
- Short videos (2 minutes) with an explanation by someone knowledgeable and passionate about the subject and using simple language, can be used by families, kids, teachers in class; Look at Museums Victoria learning lab online
- Expert at CERES – video explaining feeding the biogas digester
- QR code is helpful, can take people to videos/audio materials
- On the website, most people will get to a page in the middle of it from Google, so make each page independent but still related to the others
- Biogas Information
    - Show what happens to waste – both if it goes to a biogas digester and if it doesn't
    - If waste goes to a landfill, methane is still produced but it is wasted and has a negative impact on the environment
    - If it goes into a biogas digester, the methane is harvested and used to produce energy, show the win-win situation
    - Show kids what happened to their food waste at lunch, adults at the café too
- Sounds triggered by motion sensor – attracts people as they walk by
- Painting it like a cow – gets people interested, they want to see why it looks like that

Professor Holly Ault, Ph.D.

- For designing an activity / interactive display:
    - Look at what I want students to learn, the learning goals
    - Look at equipment, resources, facilities
    - Look at students' background
    - Don't make it 'cookbook', not step by step
- Students are excited about design projects (feedback from teachers)
- Students are excited about engineering that helps people (feedback from teachers)

Mirah Lambert and Melbourne Museum Staff

- Learning outcomes drawn from school curriculum
- research element, students create some content, be able to share it
- If you have a young audience, the images and text you use are very different than those used with high school students – more mature audience, they want different experiences, their teachers will be put off by material that is too simple
- How to build program into curriculum? Teachers want the program and ideas on how to use it, not very detailed instructions.

- QR codes
    - ugly, doesn't fit museum aesthetic, issue with explaining how to use them, some people know how to use it, many don't, might as well not be there
    - Using mobile devices – careful how much data it uses, you can get people to the website but don't have videos popping up
- Catching visitors' interest:
    - cutaways, see inside things
    - Movement and novelty are great to attract people but you need to keep them there, engage them
    - Short videos – 1.5 minutes, to the point
    - Low, angled displays – visible to kids and adults
    - Something tactile, be able to touch something
- interactive things can't have instructions, people will start fiddling without reading the instructions and then nothing happens so they move on
- to get people to the display – when you walk in, signs for it, ways to direct you to it, symbol on parts that are around it, label displays to direct people
- Engaging, informative, attractive:
    - Nice design, good pictures, right amount of text, give writers limits on length, keep target audience in mind
    - Break up text, headings, graphics
    - Write for your audience but cover your content, write it then check it with the experts
    - Don't put things online if you can't fit them on the display, not a good experience
    - Ask questions, leave a comment box: If text is too long, people will ask questions on information that is included on the page – people don't read it
    - People don't stay on the website long, know your goal – keep people on the website – provide short info to give people what they want quickly
    - Teachers just go to the education section, they expect it to be there
    - Provide multiple ways to the same info
- 3 learning outcomes everyone should get from it, most people will not learn more than 3 things so pick the top 3
- Website:
    - 3 simple learning outcomes from display, have more available on the website
    - Consider the order they see things, jumping into the middle of website with students, easier just to have their teacher direct them
    - Show people ideas for feedback when you still have a chance to change things – best stage for website, before aesthetic design, just things to click around
    - Make images clickable links, it will be expected, people click everything
    - Good structure with info – start with hook, basic info, more detail later
    - Don't have terms or topics that people won't know as links, explain things with basic info, link to more details
    - Links throughout info

- Users are bad at following sequence, guide them and make them follow a logical flow but allow them to choose
- Allow people to visually choose what they want to go to
- Introduce topic on page, then link for more info
- Gradually increase level of detail and facts, most detailed info last
- Depending on how you get people to it-
  - Google – need to make it flat since you are dropped into the middle
  - If you are just directing people to the front page, make it sequential

Appendix C: Journal Entries for Museum Observations

In our research we went to two different museums, Scienceworks and the Melbourne Museum. From each, we found two exhibits that exemplified efficient display design and drew design points and notable characteristics.

Recycling Display (Scienceworks)

1. Concept of having a sequence of information boards
2. Flip ups, or moveable parts
3. 50 words per display
4. Colour scheme
5. Simple sentences

Figure 20- Scienceworks Recycling Display

The recycling display can be found on the second level of Scienceworks. It details how recycling is separated using 6 video information panels. The first introduces the concept of recycling, while the last one describes the benefits. The four placards in between detail the kerbside pickup of recycling, the removal of metals, the removal of paper, and the separation between plastic and aluminium. Secondary information panels with moveable covers for additional information were also present on the recycling display, facilitating basic interaction. The information added helped users relate to the concept through statistical data (factoids). The recycling display used strong primary colours. The number of words per information board was kept to a minimum with simple concepts and concise sentences. Each of the four main information boards had around 50 words.

Figure 21 - Scienceworks Recycling Display Factoids

Race Cathy Freeman (Scienceworks)

1. Famous public figure
2. Competition with peers

The Cathy Freeman display, also at Scienceworks, demonstrated a strong, real-world connection through the figure of a famous Australian Olympic runner. The display gave the visitors a chance to run against each other and Cathy Freeman. This provided a real-world connection, competition, and interactivity. This display also exhibited attributes present on the recycling display: simple sentence structure, good colour scheme, and moderate number of words per poster.

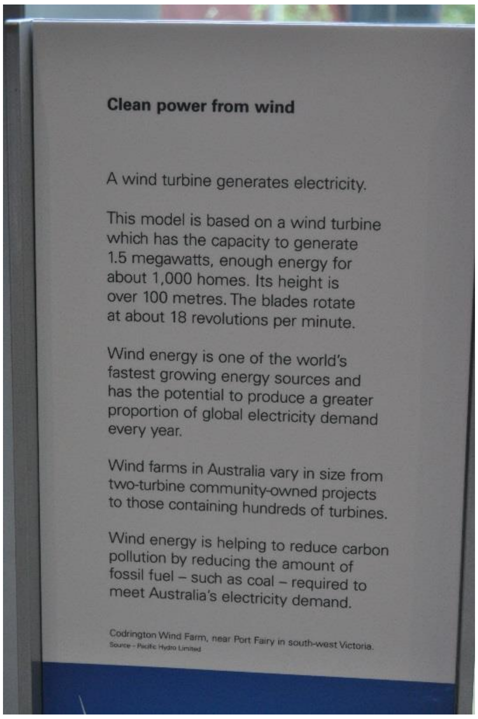


Figure 22 - Melbourne Museum Windmill Display Information Board

Dinosaur Display (Melbourne Museum)

1. How it works/seeing inside

This Dinosaur display had a glass covered "archaeological scene" that showed the visitors a recreated dinosaur site. This design concept demonstrated how the process of bringing the dinosaurs to the museum works, an important design concept for us.

Windmill Display (Melbourne Museum)

1. Appropriate level of technical information

Also at the Melbourne Museum there is a small exhibit on wind power as a form of alternative energy. This display set the level of technical information that a renewable technology display should use. Megawatts, metres, and revolutions per minute are all simple units of measurement used in the windmill display.

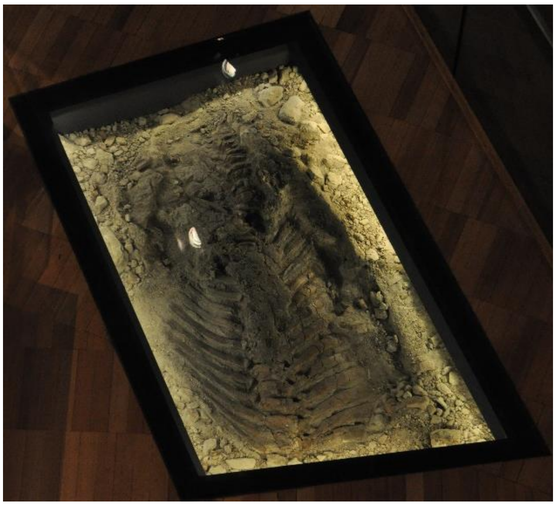


Figure 23 - Melbourne Museum Dinosaur Display

Appendix D: Interview Questions for CERES visitors

Opening Statement from Interviewer

Good morning (or afternoon) as part of a group of students from Worcester Polytechnic Institute in the United States, we are here to help CERES achieve their goal to improve their educational delivery methods regarding their biogas digester. Our target audience is students in grade 6 and above and all adult visitors. Therefore we are researching to create an interactive display and website for their biogas digester. We would be very appreciative if you could spare time talk with us and answer our questions that would help us better achieve or goal and help CERES.

Logistics

Date and Time:
Interviewer:
Demographics: Gender & Age

Pre-exposure Questions

1. Why did you come to the Technology Park Section of CERES today?

2. What do you currently know about the biogas digester?

Post-exposure Questions

3. What did you learn about the Biogas Digester after looking at the display?

4. Having read the display can you describe what goes into the biogas digester?

5. What comes out of the biogas digester?

6. How do you think this technology could be used by people in your community?

7. What other information would you like you know about the biogas digester?

Summarised Results

Logistics
Demographics: Males: 5 middle aged, 3 young adult
Females: 2 middle aged, 7 young adult

Pre-exposure

1. Why did you come to the Technology Park Section of CERES today?

- Number of interviewees with this response - response
- 5 - Interested in the technologies
- 2 - Curious as they walked by
- 10 - Just passing through

2. What do you currently know about the biogas digester?

- 16 – Nothing
- 1 – It creates gas

Post-exposure

3. What did you learn about the Biogas Digester after looking at the display?

- 13 - It produces gas/methane for energy or cooking
- 1 - It is similar to composting
- 2 - It uses bacteria
- 3 - It is explosive

4. Having read the display can you describe what goes into the biogas digester?

- 4 – Waste
- 14 – Food waste
- 2 – Manure

5. What comes out of the biogas digester?

- 15 - Gas/methane
- 12 – Fertiliser
- 5 - CO_2
- 2 - Energy

6. How do you think this technology could be used by people in your community?

- 11 - Large, community based digester
- 3 - collect food scraps
- 5 - Use it in individual homes

- 3 - Use it for cooking and heating
- 2 - Only useful in third world countries

7. What other information would you like you know about the biogas digester?

- 3 - Is the gas used the same way as natural gas?
- 3 - Is the fertiliser produced better than compost?
- 2 - How much food waste goes to landfills?
- 2 - Can it save you money?
- 1 - Where does the waste for input come from?
- 1 - Where can you buy one?
- 2 - What scale is it usable on?
- 2 - How do you store the gas?
- 2 - Make it identifiable
- 3 - Nothing

Appendix E: Required Criteria Sheet

Table 3 - Criteria Sheet with Evaluation of Original CERES Materials

Subject Under Study	Education Method	
	Display	Website
Measures of Effectiveness	***29.17%***	***38.90%***
Informative	50%	75%
Biogas cycle	No	Yes
Applications of this technology	Yes	Yes
Technology is here	Yes	Yes
Inputs and outputs (waste, methane, fertiliser)	Yes	Yes
How does the biogas digester work?	No	Yes
Using waste, reducing impact on landfills	Yes	Yes
Personal connection	No	No
Link to school curriculum	No	No
Attractive	0%	16.70%
Recognisable	No	No
Easy to see information	No	No
Directed to display or website by surroundings or references	No	No
Colour	No	Yes
Motion (videos in the website)	No	No
Sounds	No	No
Engaging	37.50%	25%
Multiple tier structure	No	No
Logical flow of information	Yes	Yes
Target age appropriate language	No	Yes
Certain degree of challenge	No	No
Allows for creativity	No	No
Interactivity	No	No
Visuals	Yes	No
Diagrams	Yes	No

Expectations for each criterion:

Attractive:

- Recognisable: visitors need to make connections to something that is familiar through recognisable figures, objects or activities portrayed.
- Easy to see information: the main information displayed cannot be presented in small text or be hidden from the main display; it needs to jump out to the visitors so that they can as quickly as possible see what the display is about.
- Directed to display or website by surroundings or references: for making sure that visitors are exposed to the information to be presented, a display needs to be referred to by either maps, paths, signs or educators during tours. If the display itself is composed of various parts, there have to be instructions to allow the visitors to know exactly where to go and what sequence to follow. A web page, since it is not a "physical" object people can see, needs to be referred to by visible addresses (URLs), QR codes posted on displays or by search engines (i.e. Google, Yahoo, Bing, etc.) as a primary listing.
- Colour: displays and web pages must have some degree of colour diversity in their components (images, text, graphics, paintings, murals, etc.).
- Motion: displays gain enhanced attractiveness through working mechanical parts or involving the visitor in motion. For web pages, videos, animations or any non-static element achieve the same effect.
- Sound: people are attracted to displays that involve their auditory senses through generating sounds, especially in a surprise manner such as triggered by sensors. This practice is generally avoided for websites; therefore the criterion does not apply.

Engaging:

- Multiple tier structure: information should be depicted on different levels of depth, each more descriptive than the previous, offering the reader a good representation of the subject at any point.
- Logical flow of information: the pieces of information that are presented within a single display or web page need to organised in a logical fashion, structured sequentially or in a "tree," linked chronologically, through similarities, or by themes.

- Target age appropriate language: information must be presented on a level that allows the great majority of users to easily comprehend it, using not too simple but not too professional terms. For the CERES audience, a sixth grade language is appropriate.
- Certain degree of challenge: visitors can be kept involved in the learning process through questions found in text on displays and web pages or by being directly engaged by a tour guide.
- Allows for creativity: an educational strategy or material should allow the audience to view information from their own perspective and create content such as a design, a drawing, a music piece or even the answer to a question.
- Interactivity: this can be achieved through creating a display that follows a sequence, a display where certain aspects light up or make sounds at the touch of different buttons, or a display that asks the visitor to participate. For a web page, any programmable elements that respond to the users' input can be considered interactive.
- Visuals: educational displays and websites have to contain thematically chosen graphics and images in order to better keep the audience involved.
- Diagrams: for representing more complex ideas, displays and websites have to use simplified diagrams to engage the wide public before offering the details to the more advanced and interested part of the audience.

Informative:

- Biogas cycle: with this educational point, CERES searches to address the complete cycle of the biogas digester. This entitles the idea that the biogas digester creates a sustainable cycle, which takes in food waste and converts it to usable forms of energy through cooking or electricity as well as a nutrient rich fertiliser that can be used to further grow food crops.
- Applications of this technology: this educational point searches to illustrate to the visitors that the technology can be applicable almost anywhere. It isn't simply a technology that can be used in third world countries but it's a technology that can be used on a larger scale in modern countries, including Australia.

- Technology is here: through this educational point CERES wants to communicate that the technology is not futuristic and it can be used now. In other words, CERES is looking to eradicate the idea that the technology only works on small scale implementations in third world countries, and show that it is already being used effectively in the developed world.
- Inputs and outputs: through this idea CERES wants to assert that their visitors will understand that this technology takes in waste and produces methane and fertiliser, which can be used for the generation of energy and production of food.
- How does the biogas digester work: this point shows the workings of the biogas digester. It introduces the idea of the natural breakdown of waste through the use of anaerobic bacteria and how this process generates methane. Recognisable images such as those of cows can be presented to link the breakdown of bacteria in a cow stomach to what is happening inside the digester.
- Using waste, reducing impact on landfills: this idea searches to show that the waste generated by daily activities such as eating can be used to generate electricity as opposed to sending it to landfills and creating environmental issues.
- Personal connection: this point underlines that the information needs to be presented in a way that allows the visitors to see themselves as part of this sustainable cycle and understand that their practices can impact change and create a more self-sustainable society.
- Link to school curriculum: this criterion requires that the information, especially that on the website, makes connections to Australia's school curriculum and presents educators with the opportunity to use it as a learning tool.

Appendix F: Pairwise Comparison Chart and Weighting

Table 4 - Pairwise Comparison Chart

	Attractive	Engaging	Informative	Cost	Time to complete	Maintenance	**Total**
Attractive		½	1	0	0	½	**2**
Engaging	½		1	0	0	½	**2**
Informative	0	0		0	0	½	**0.5**
Cost	1	1	1		0	1	**4**
Time to complete	1	1	1	1		1	**5**
Maintenance	½	½	½	0	0		**1.5**

Table 5 - Weighting Rubric

Component	**Comparison score**	**Weight**
time to complete	5	100
cost	4	80
attractive	2	40
engaging	2	40
maintenance	1.5	30
informative	0.5	10

Appendix G: Grading Rubric and Decision Matrix

Table 6 - Grading Rubric

Score	0	1	2	3	4	5
Time to Complete	More than 3 weeks	3 weeks	2.5 weeks	2 weeks	1.5 weeks	1 week or less
Engaging	Meets none of the criteria	Meets two of the criteria	Meets four of the criteria	Meets all but two of the criteria	Meets all but one of the criteria	Meets all of the criteria
Attractive	Meets none of the criteria	Meets two of the criteria	Meets three of the criteria	Meets all but two of the criteria	Meets all but one of the criteria	Meets all of the criteria
Informative	Meets none of the criteria	Meets two of the criteria	Meets four of the criteria	Meets all but two of the criteria	Meets all but one of the criteria	Meets all of the criteria
Cost	Costs over $2500	Costs between $2000 - $2500	Costs between $1500 - $2000	Costs between $1000 - $1500	Costs between $500 - $1000	Costs less than $500
Maintenance	Requires daily maintenance by CERES staff or more	Requires maintenance every other day	Requires maintenance every week	Requires maintenance every two weeks	Requires maintenance once a month	Requires maintenance less than once a month

Table 7 - Decision Matrix

Design Idea	Attractive	Engaging	Informative	Cost	Time to Complete	Maintenance	Total
Flipbook	2*40	5*40	5*10	4*80	4*100	5*30	1200
Sequential signs	3*40	3*40	5*10	3*80	4*100	5*30	1080
Website (all extras)	5*40	5*40	5*10	5*80	3*100	5*30	1300
Website (no extras)	5*40	4*40	5*10	5*80	2*100	4*30	1130

Appendix H: Website Pages Descriptions

How it works: this page shows general information about the processes inside of a biogas digester, inputs, outputs and environmental benefits. It also shows a condensed case study of the CERES digester and its particularities, numbers of inputs, outputs and typical charts of operational parameters versus time.

Real world examples: this page talks about a few modern and effective plants around the world, details on what the inputs are and how much energy and fertiliser are being produced. It also points towards resources for the audience interested in how such implementation can be started or completed.

Food waste: this page underlines the problem of landfills and shows how the biogas digester can solve part of it, gives numbers on potential financial and environmental benefits.

Energy from biogas: this page explains the benefits of large scale biogas digesters in terms of base load power and waste management. It also allows users to calculate how much gas or energy they or their community can gain from waste.

Education: this page mentions where the info on the 'Biogas' section can fit with the curriculum depending on the year and the subject. It also provides a model for integrating the whole Renewable Energy Technologies section of the CERES website with educational programs.

FAQ: this page provides and answers the most common questions about the biogas digester, some of which we identified through the visitor interviews.

Share your data administration: this page allows users, particularly students, to post a story about what can be obtained from their families' / communities' waste, what can be done with that energy and fertiliser, and how much can be saved on garbage collection and emissions.

Biogas charts administration: this page allows CERES staff to change the numbers behind the temperature and acidity charts on the "How a biogas digester works" page.

Edit FAQ: this page allows CERES staff to add, edit or remove the questions and answers on the FAQ page.

Biogas parameters logs: this page was specifically requested by and discussed with CERES staff. It is designed to be a database interface that allows them to keep track of biogas digester parameters (pressure, temperature and acidity) and graphically see how they evolve in time for the purpose of optimising the biogas digester.

Appendix I: Detailed Display Design

Physical description:

The original display board will be placed at the West (gas bag) face of the biogas digester on its own pole at a 60 degree angle (from the vertical), 1 meter above the ground.

There will be four, two page, A4 information boards added. These “flipbooks” will be hinged on the top side and fixed on the hidden side of the second page. There will be three useful, landscape-oriented, areas, one on the outside, professionally printed on plastic, and two on the inside, made from simple laminated cardboard. The pages will have rounded corners, as shown in the engineering drawing of Figure 26.The placement will be 1 meter above the ground, at a 60 degrees angle from the wall, such that the hinges rest against the wall of the digester, as in Figures 24 and 25.

Figure 24 - Virtual Model of Open Flipbook and Q&A

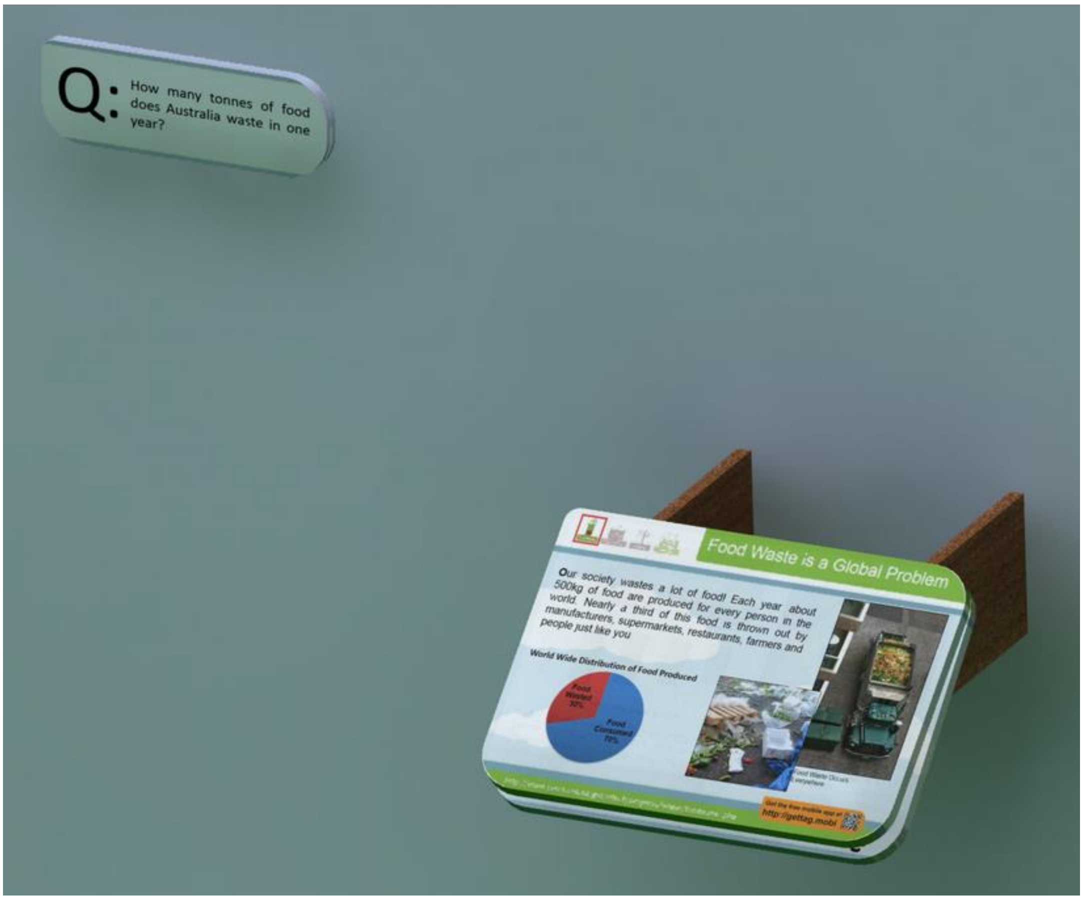


Figure 25 - Virtual Model of Closed Flipbook and Q&A

Alongside the flipbooks there will be Q&A panels with questions on front side and answers on the back side. These will be placed vertically against the biogas digester wall at the same level with the flipbooks. Their build is identical in terms of materials and basic shape, but the size is smaller (Figure 27). The overall layout of the four flipbook-Q&A pairs and of the original display board can be seen in the top view section of the virtual model of Figure 12, Chapter 4.5.4.

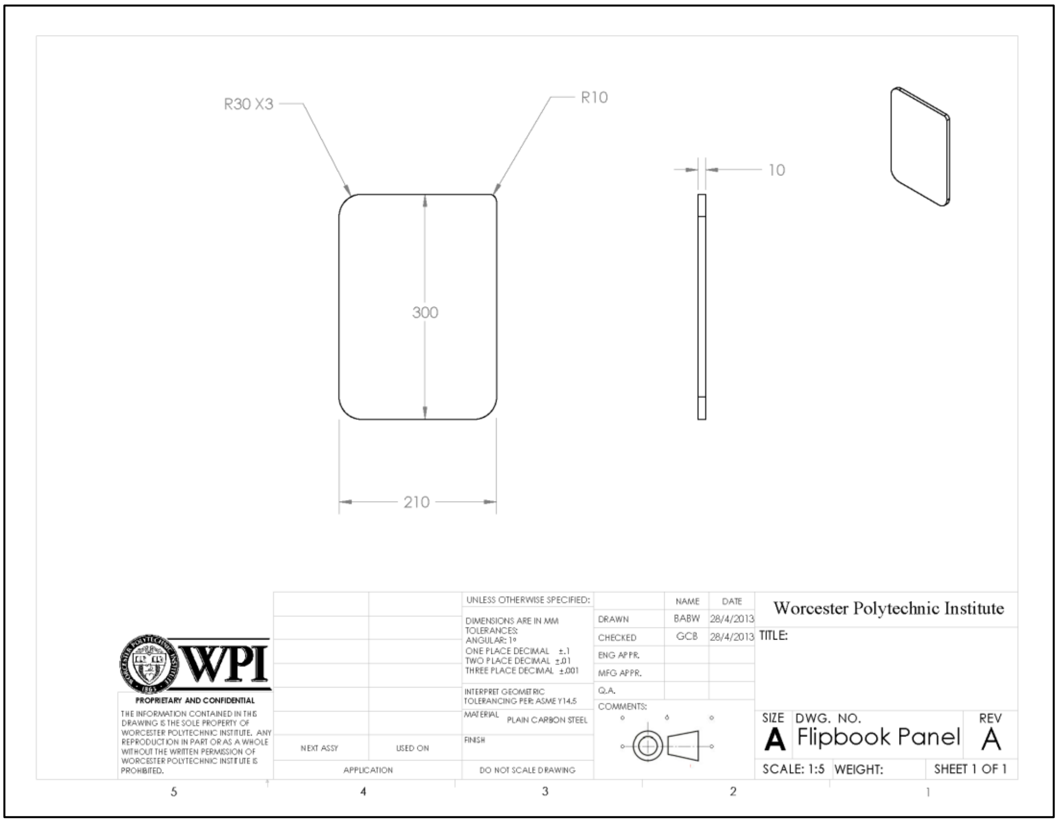


Figure 26 - Flipbook Panel Engineering Drawing Screenshot

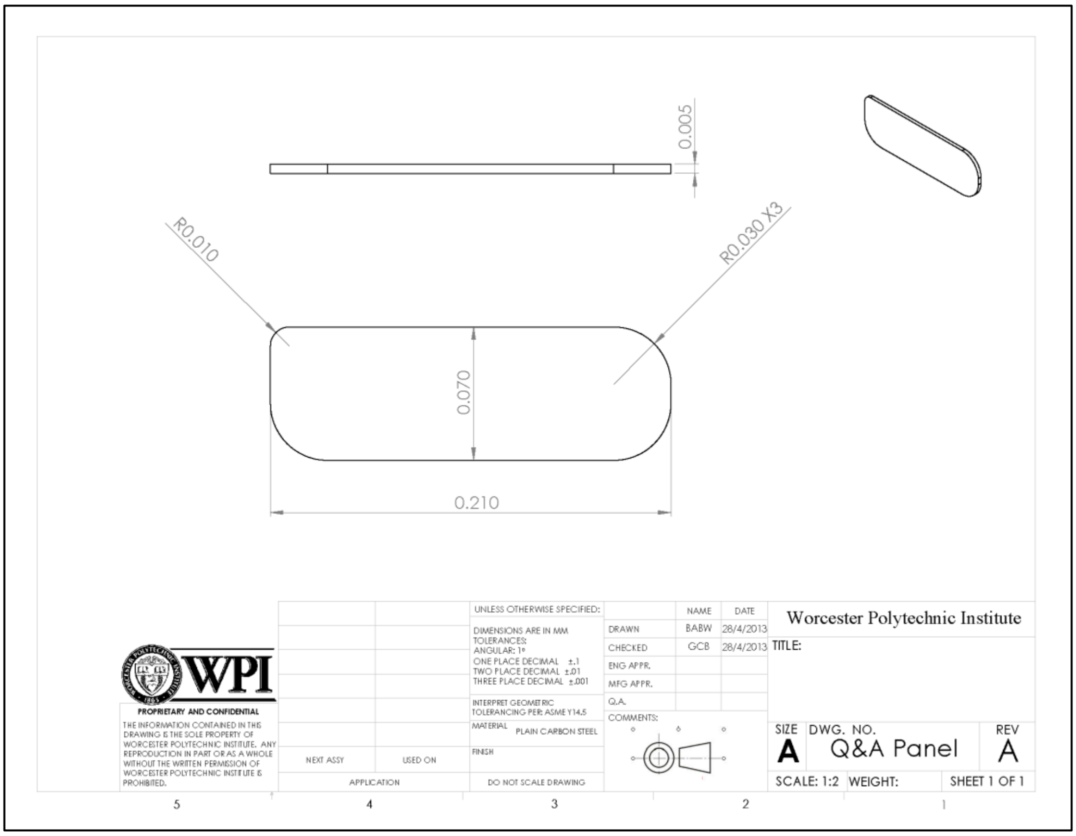


Figure 27 - Q&A Panel Engineering Drawing Screenshot

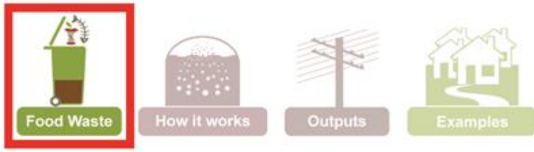
Appendix J: Biogas Digesters and the Australian Curriculum of Science

By studying the Australian Curriculum (Australian Curriculum Assessment and Reporting Authority (ACARA), 2013), we determined that biogas digester technology can have a significant presence in the Science Understanding and the Science as a Human Endeavour strands for years 2, 6, 7 and 8. A sub-strand of Science as a Human Endeavour is the use and influence of science. Year 2 science students under this sub-strand are required to learn about how "people use science in their daily lives to care for the environment and living things (ACSHE035)" (ACARA, 2013). As suggested in the educational curriculum, a way of doing this is to "identify ways humans manage and protect resources, such as reducing waste and caring for water supplies" (ACARA, 2013). An application that demonstrates waste reduction is the biogas digester. The year 6 Physical Sciences sub-strand dictates that students should understand how "energy from various sources could be used to generate electricity (ACSSU219)" (ACARA, 2013). The biogas digester can be used along with other technologies such as wind turbines and solar panels to exemplify sustainable energy sources. Under the Science as a Human Endeavour strand for year 6, the biogas digester can be used to show how people from different cultures have used sustainable sources of energy. This can include the Nature and Development of Science as well as the Use and Influence of Science sub-strands. These dictate that students should understand how "important contributions to the advancement of science have been made by people from a wide range of cultures (ACSHE099)" (ACARA, 2013), how "scientific knowledge is used to inform personal and community decisions (ACSHE220)" (ACARA, 2013) and consider how their personal and community choices can influence their use of sustainable sources of energy. Years 7 and 8 pose more thought-intensive applications of biogas digester technology. Under Nature and Development of Science and Use and Influence of Science, students are required to understand how "science and technology contribute to finding solutions to contemporary issues (ACSHE120)" (ACARA, 2013) and "investigate requirements and the design of systems for collecting and recycling household waste (ACSHE135)" (ACARA, 2013). Biogas digesters can portray solutions to the environmental problems of landfills and their carbon dioxide and methane emissions, as well as solutions for avoiding climate change and resource depletion, both issues associated with non-renewable energy sources.

Appendix K: Display and Webpage Contents

The next pages contain our final products:

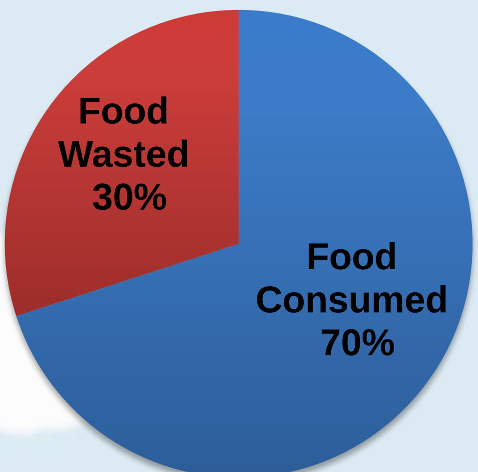
1. Flipbooks:
    - Food Waste Flipbook (3 pages)
    - How it Works Flipbook (3 pages)
    - Biogas Digester Outputs Flipbook (3 pages)
    - Renewable Energy for Today Flipbook (3 pages)
    - Flipbook Board Engineering Drawing (1 page)
2. Q&A (8 pages)
3. Q&A Board Engineering Drawing (1 page)
4. Web Pages:
    - Biogas Digester Home Page (2 pages)
    - Food Waste Page (3 pages)
    - How Biogas Digesters Work (4 pages)
    - Energy from Biogas Digesters (2 pages)
    - Biogas Digesters Example Page (3 pages)
    - Alternative Energy Technologies and the Australian Curriculum of Science (3 pages)
    - Biogas FAQ (2 pages)



Food Waste is a Global Problem

Our society wastes a lot of food! Each year, about 500kg of food are produced for every person in the world. Nearly a third of this food is thrown out by manufacturers, supermarkets, restaurants, farmers and people just like you.

World Wide Distribution of Food Produced



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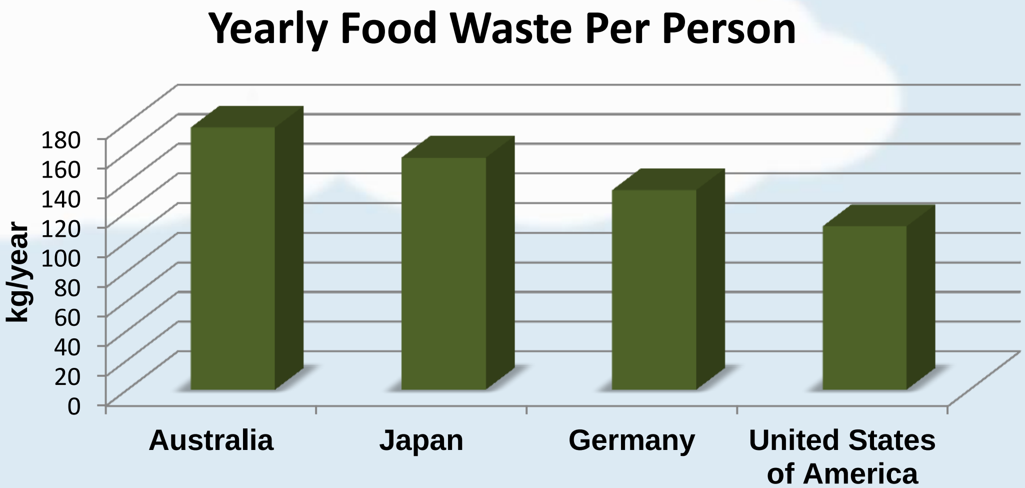
Australia Wastes a lot of Food

As Australians, we are more wasteful than most countries. Nearly 40% of our typical household rubbish bin is food waste. Together we could fill the MCG with food waste in less than 3 months.



Food Waste in Queen Victoria Market, Melbourne, Australia

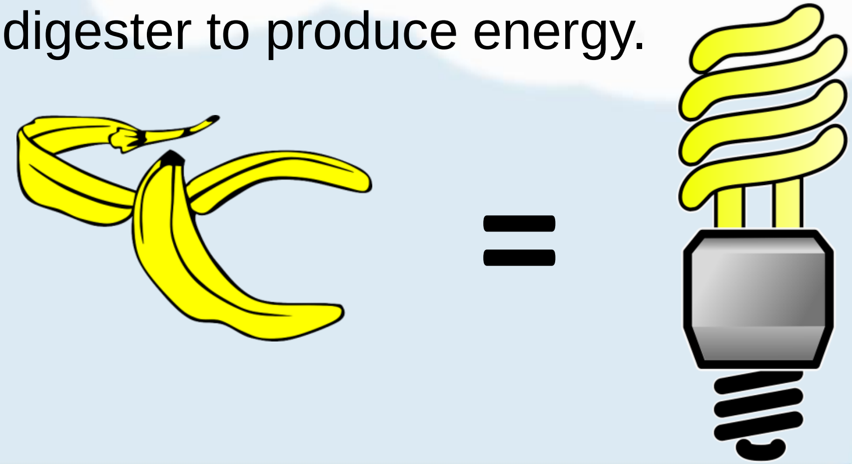
Common Wheelie Bin
Full of Food Waste

Food Waste Harms the Environment

When food rots in an airless environment, it produces methane, a large contributor to climate change. Unfortunately, in Australia, most of the food thrown out decomposes in rubbish tips. This creates a real environmental hazard. Rubbish tips pollute soil and groundwater resources and pose a threat to our health.

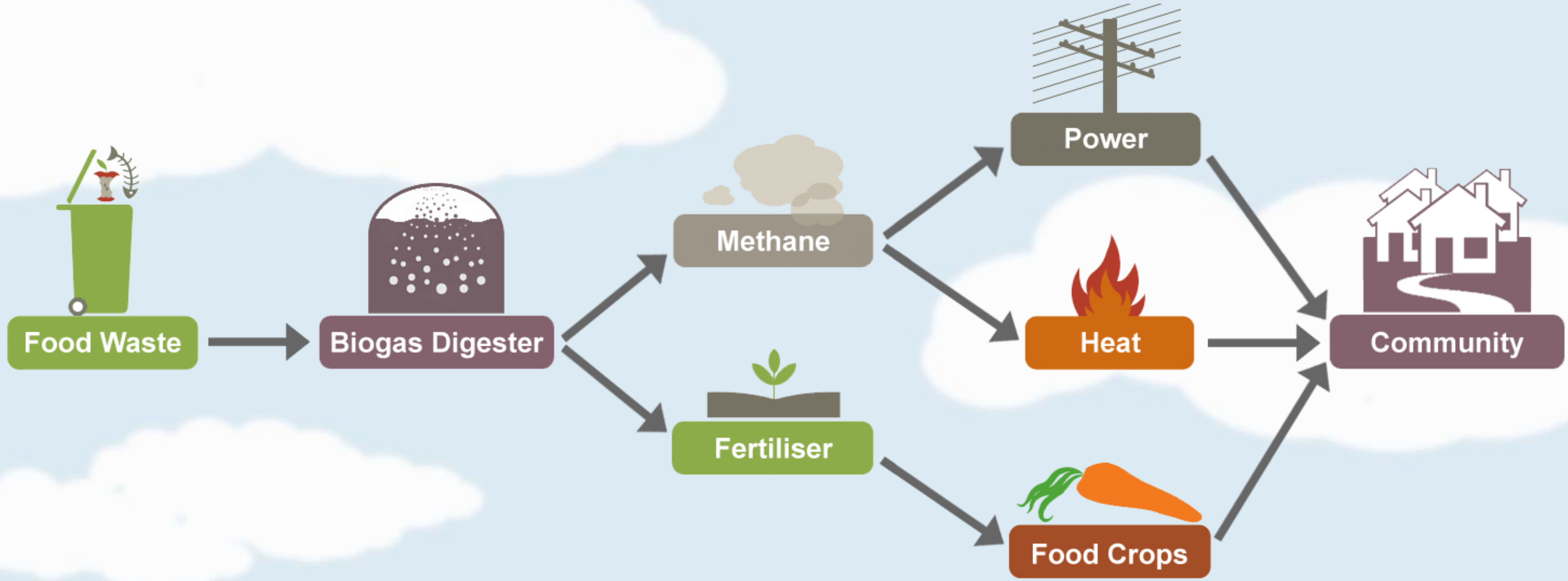
Typical Landfill in Developed Countries

You can help reduce harm to our environment by decreasing food waste. You can buy less food and use the leftovers. Your food scraps don't have to end up in a landfill. Instead you can recycle them in a biogas digester to produce energy.



How it Works

A biogas digester takes in organic waste and produces methane and fertiliser. Methane is a fuel which can be used to produce heat or electric power. Fertiliser can be used to help grow more food crops.



Biogas Digester Cycle

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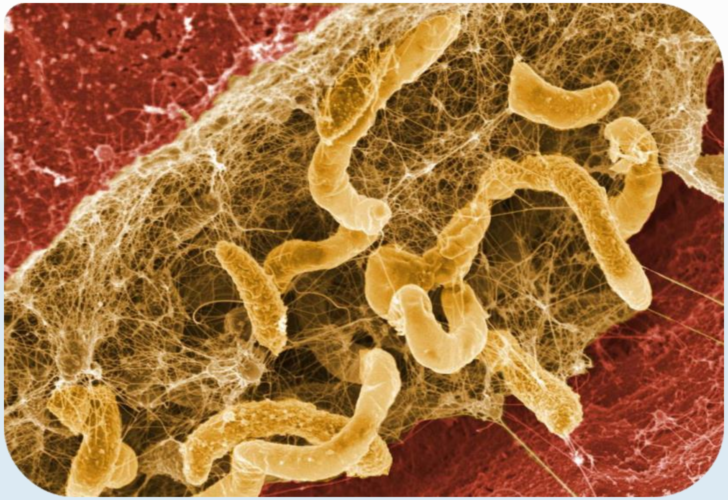
Anaerobic Digestion

Biogas digesters break down organic materials in the absence of oxygen. The process is called anaerobic digestion. It is similar to what happens in part of a cow's stomach.

The anaerobic bacteria in this digester must be kept at 35° Celsius and between 6.5 and 8.3 pH to be productive and decompose waste.

For the waste to digest properly it needs to sit in the digester's stomach for some time. This waiting time is called the hydraulic retention time. For this digester the retention time is about 40 days.

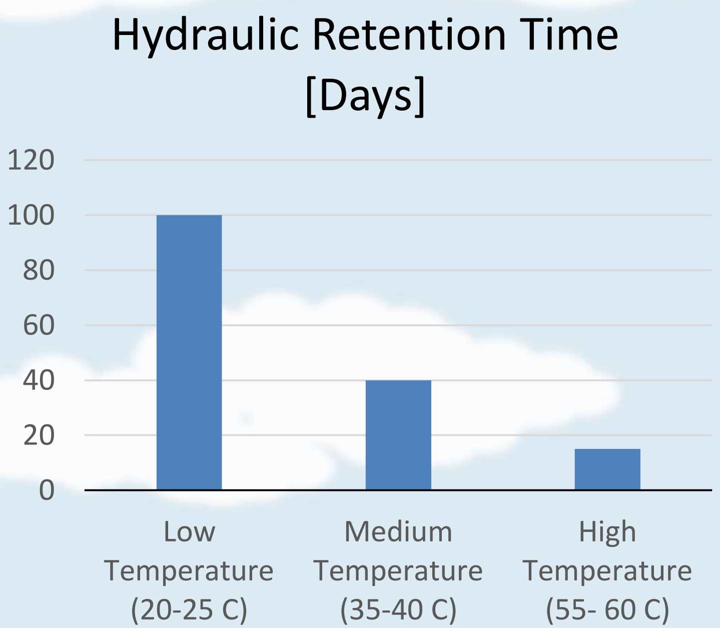
Nature's Biogas Digester

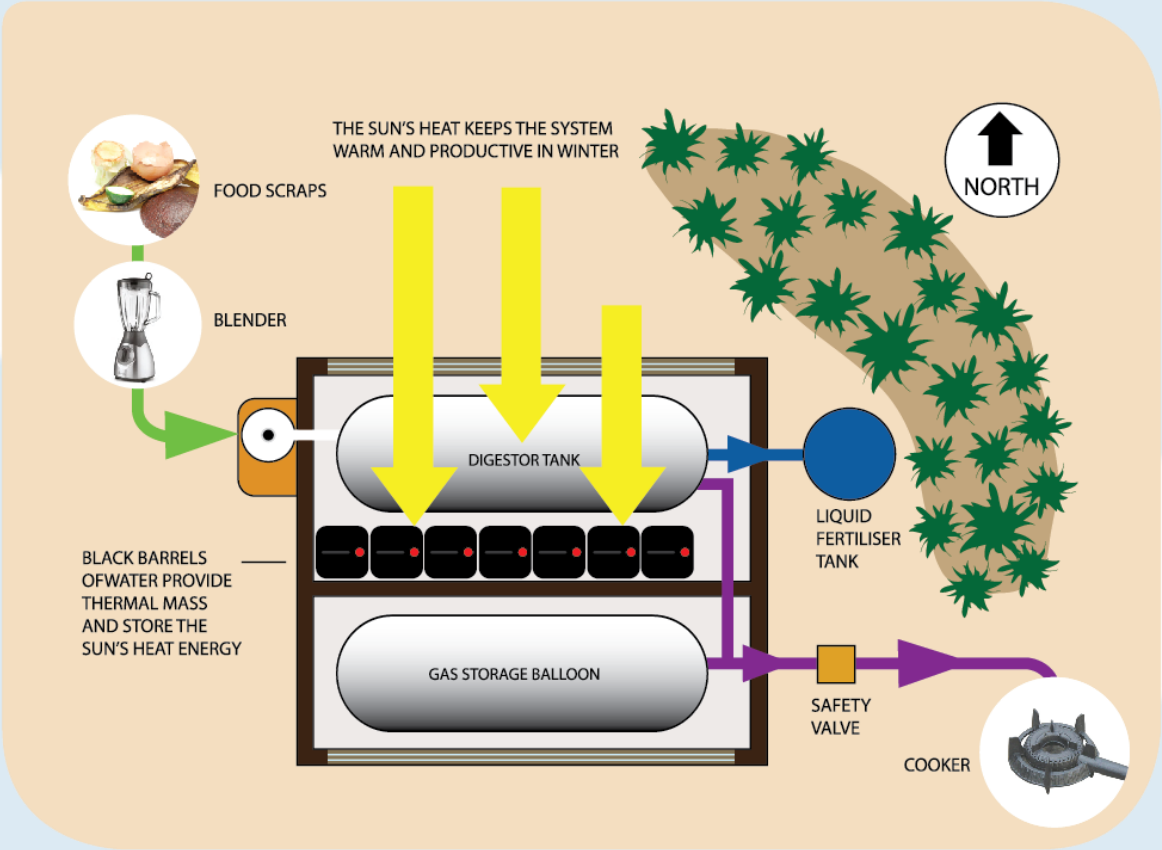


Anaerobic Bacteria

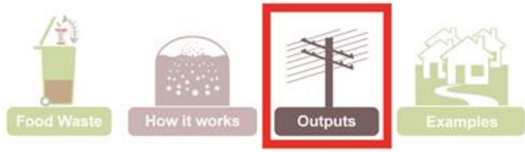
Hydraulic Retention Time

Hydraulic retention time is dependent on temperature. The warmer the digester, the less time it takes to break down organic waste.

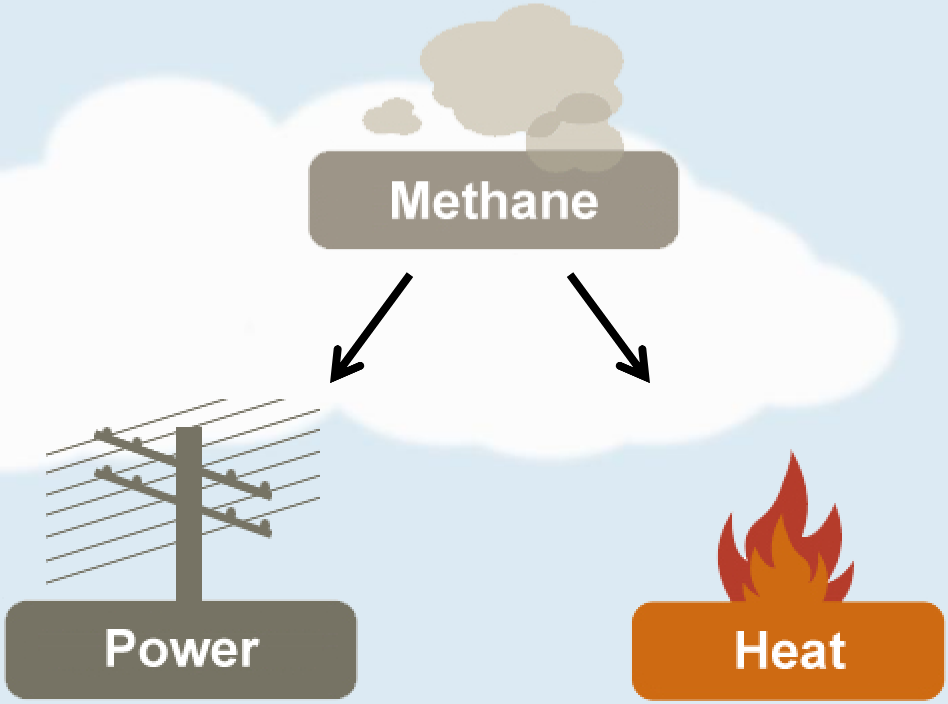


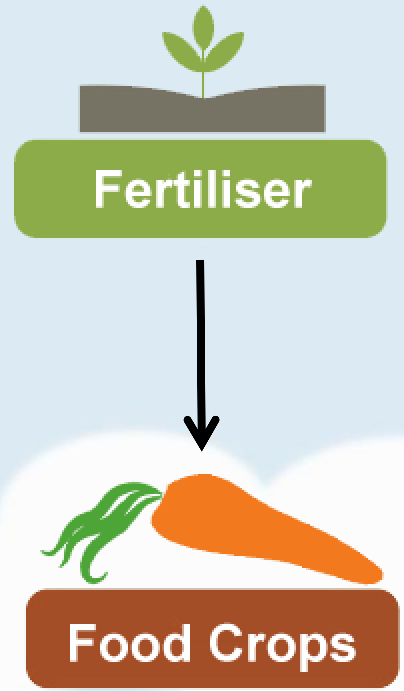


The CERES digester traps heat from the sun in black painted water barrels. This keeps the bacteria warm and productive in winter.



Biogas Digester Outputs





Methane is similar to natural gas. It can be used to cook food, heat buildings and generate electricity to power your house.

Fertiliser replenishes soil with nutrients that support plant growth on farms and in gardens.

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Energy from Biogas

Methane from biogas digesters is used as an energy source. This is renewable energy that can replace wood, coal, oil or natural gas. On average, every kilogram of food waste can produce half a cubic metre of biogas. This is enough to run a gas stove for one hour.

&

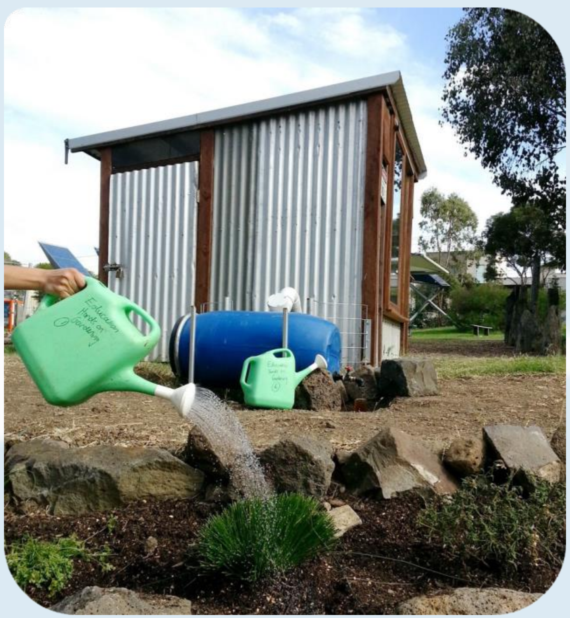
Biogas can be used in generators to create electricity. Every cubic metre of biogas produces around 2kWh of electricity. This can power a common light globe continuously for over a week.

Want to know what you can do with your waste?

Check out the online biogas to energy usage calculator at http://www.ceres.org.au/greentech/Projects/Energy/BioGas.html

Fertiliser from Waste

The liquid that comes out of the digester is a natural fertiliser. It is rich in Phosphorous, Nitrogen, and Potassium that replenish the soil. These nutrients are the main three minerals stripped from the ground during farming.



Natural fertiliser reduces the cost of replenishing the minerals in the soil. It is also environmentally friendly.

Renewable Energy for Today

Food waste is collected from homes in some areas

Your food waste can be collected and recycled in a biogas digester. Some councils in Australia and abroad provide homeowners with a special food waste bin along with rubbish and recycling.

Trucks brings food waste to the biogas digester

One Sydney suburb collects over 9000 rubbish trucks full of food waste each year. This is taken to a biogas digester which produces enough methane to power 3600 homes.

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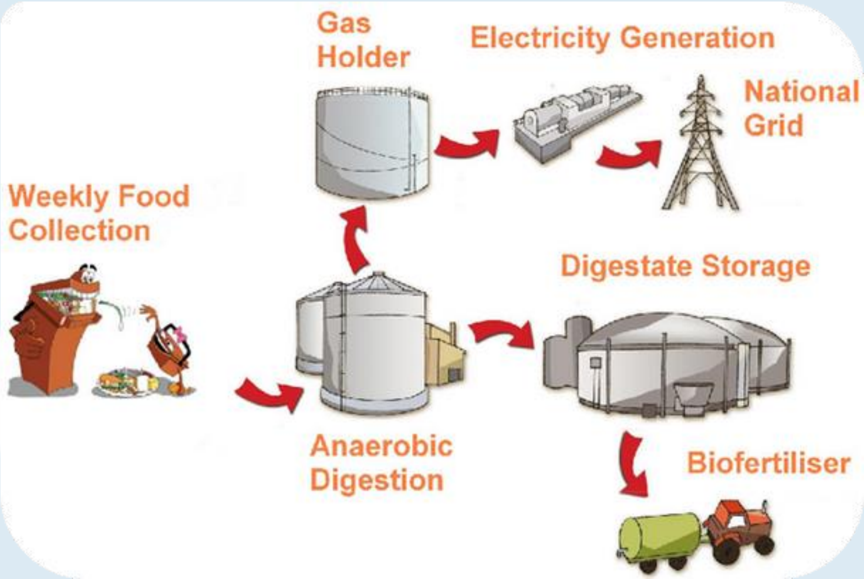
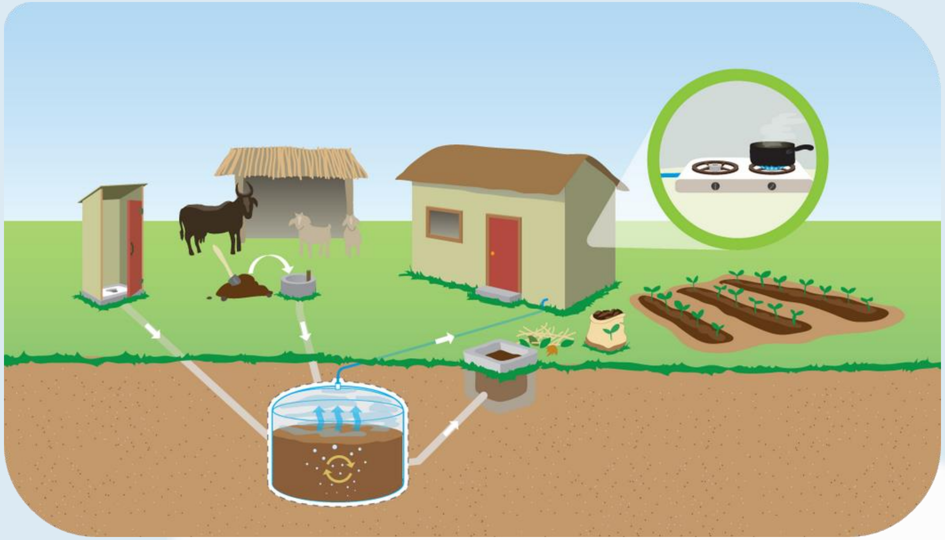
In the Community

Community biogas digesters can be found in countries like the United Kingdom and Sweden. Some generate heat and electricity. Others feed gas into the national gas grid.



Community biogas digesters



Rural biogas digester

Biogas digesters are a common sight in some parts of the world. Millions of homes in farming areas of India and China are powered by human and animal waste. The biogas digester can produce most of a family's energy needs.

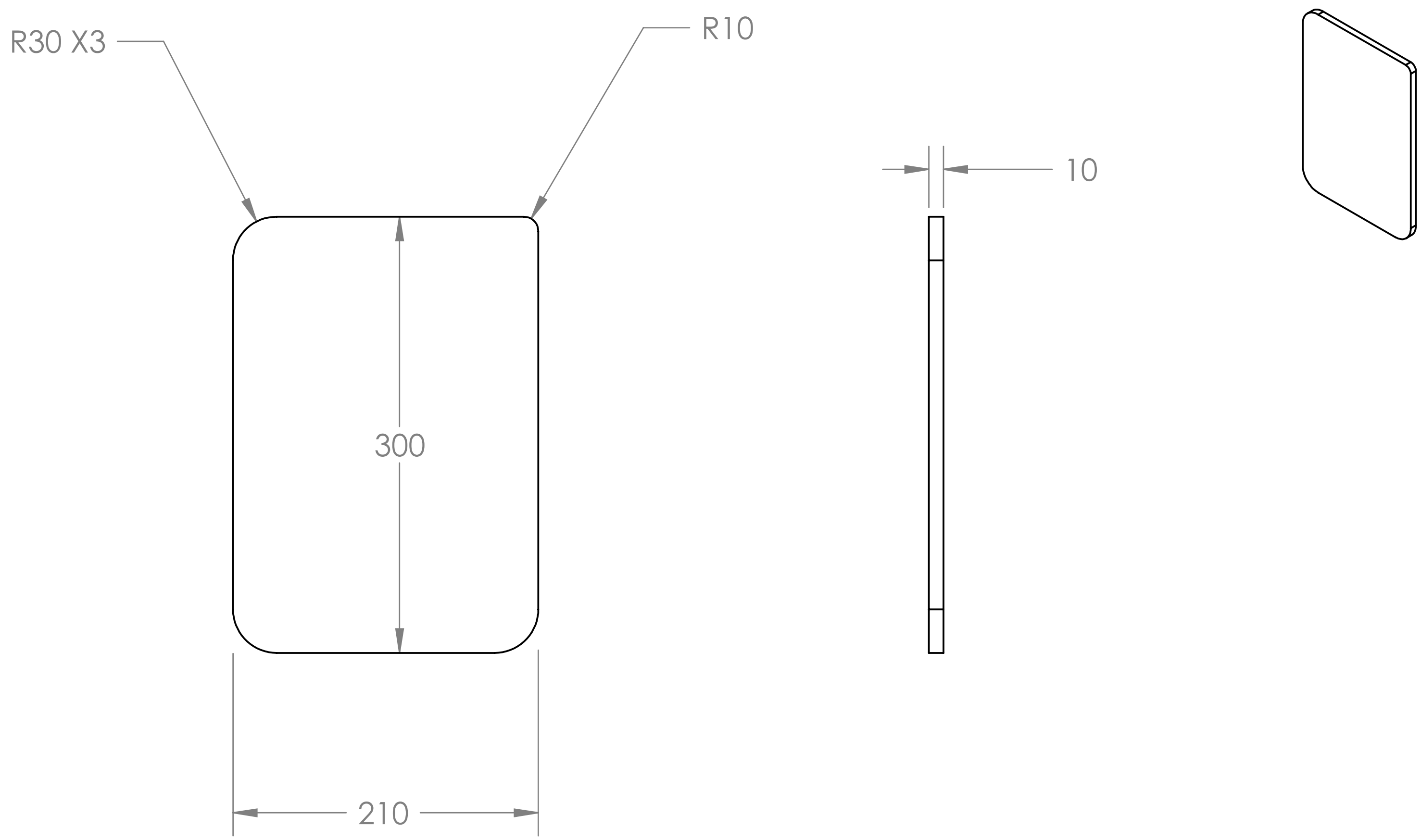
Build it Bigger

Large digesters like the one at the Berrybank Farm Piggery in Australia are fed by farm waste such as manure and discarded vegetables. They can provide power and heat for the farms and surrounding houses.

A biogas digester on a farm in Germany

Biogas digester facility powering 50,000 homes

Over 6,000 of the most advanced biogas digesters are used in Germany. Large facilities with many individual biogas digesters can provide power and heat to 50,000 homes or more using organic waste from farms.



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Q: How many tonnes of food does Australia waste in one year?

A: We waste 4 million tonnes of food every year. That’s enough to fill 450,000 rubbish trucks!

Q: Which item cannot be fed to a biogas digester?

A) meat scraps
B) banana peel
C) paper
D) grass

A:

C) Paper is made from wood. Anaerobic bacteria cannot digest the lignin contained in wood.

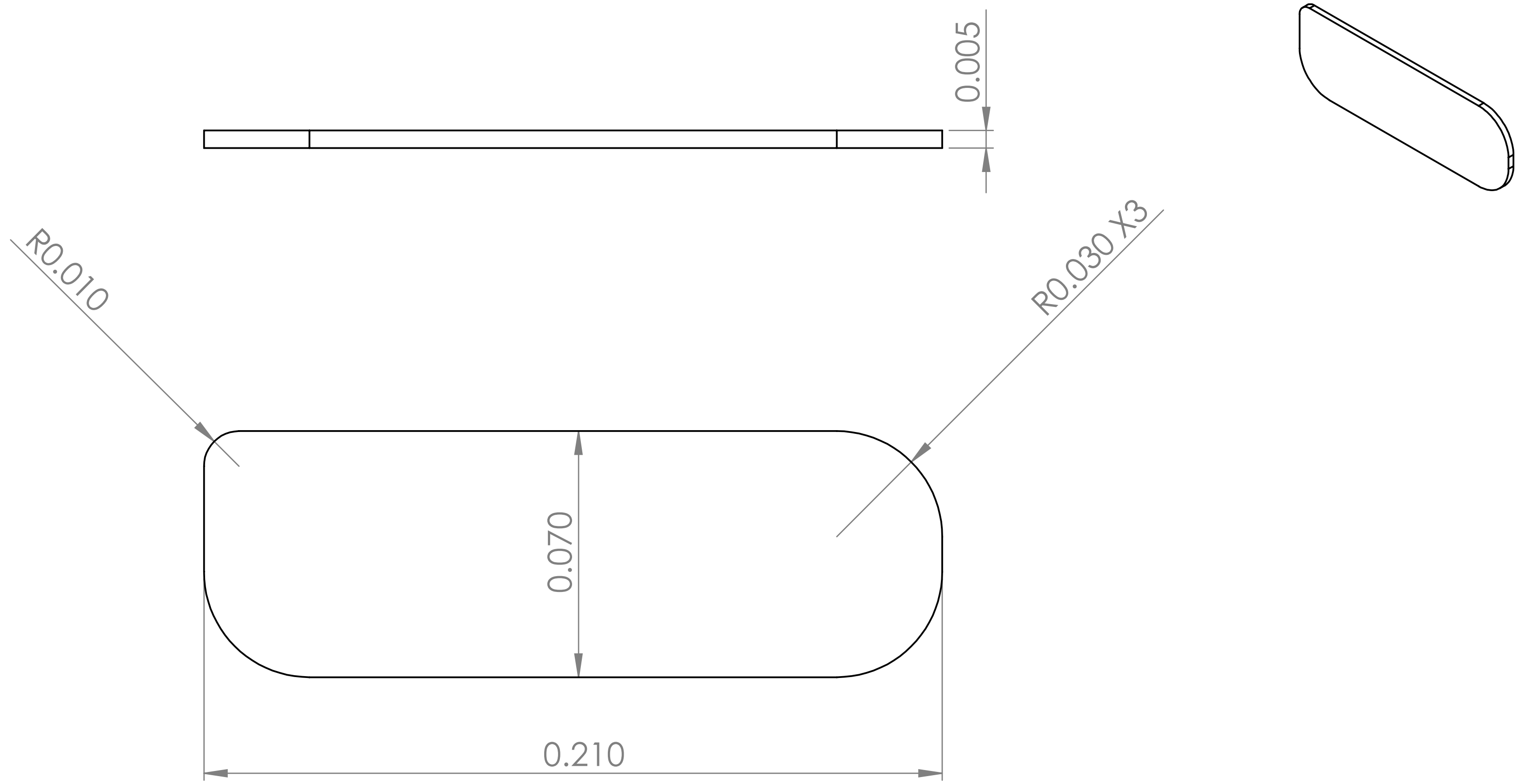
Q

- Is fertiliser from a biogas digester better
- than compost?

A: No. There is little nutrient difference between compost and fertiliser from the digester.

Q: Is it okay to waste food if a biogas digester can turn it into energy and fertiliser?

A: No! Energy is needed to grow, transport and process food. This energy is lost when food is wasted.



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		MATERIAL PLAIN CARBON STEEL	COMMENTS:			SIZE A · DWG. NO. Q&A Panel · REV A
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5 4 3 2 1

Biogas Digester

F.A.Q. Education

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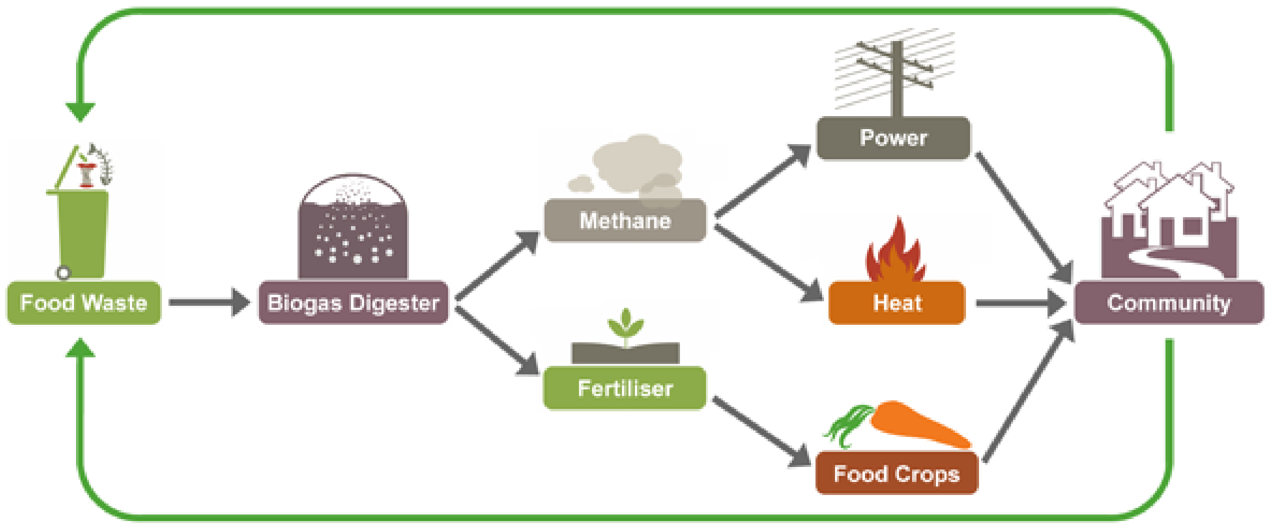
Biogas / F.A.Q



Biogas digesters represent a beautiful concept derived from nature. This technology has been around for many years in developing countries such as India and parts of Africa and South America. Today, developed countries such as the United States, the United Kingdom, Germany, Sweden and Australia are constantly

Solar Charge Station

Solar Pavilion

Solar Thermal

Swift Wind Turbine

UGE Wind Turbine

Building

Learning Centre

Van Raay Centre

Ecohouse

Water

Food

Aquaponics

Solar Cooking

Transport

EV Resources

Electric Vehicle

EV Solar Charge Station

improving this technology for use in their local communities.

The biogas digester can help us become a more environmentally friendly society. Today's society wastes a great deal of the food it produces. This waste can be attributed to individuals, farms, supermarkets, and businesses. Biogas digesters provide a great way of dealing with potentially harmful organic materials, including food waste, and turning them into valuable new resources. Using food waste, this technology has the potential to provide base-load power to large communities without contributing to climate change.

Common Wheelie Bin Full of Food

Compact Fluorescent Light Globe

A biogas digester takes in YOUR food scraps, grass clippings, and any other type of organic material and decomposes it through a natural process. This process is known as anaerobic digestion and it is similar to what happens in a cow's stomach. The outputs of this process are methane and fertiliser. Methane is a gas that can be used to cook food, heat our homes, and produce electricity sustainably. The fertiliser is a nutrient rich liquid that can replace expensive chemical fertilisers and can be used to grow more food. The food scraps can be placed in the biogas digester and continue this sustainable cycle for generations to come.

The biogas digester is a great technology. It helps communities become more efficient and contributes to our fight against today's environmental issues. If implemented successfully, a biogas digester can power a whole community out of their own organic waste. For more information on food waste, how the biogas digester works, energy production and real life applications of these technologies please click on the icons above.

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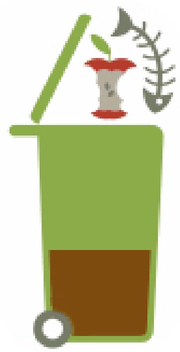
Food Waste

Home

World wide, approximately 4.4 billion tonnes of food are produced every year. Out of this number about 1.3 billion tonnes are wasted. In Australia, things are no better;

> Australians throw away up to 20% of the food they purchase.
>
> Up to 40% of every household rubbish bin is food waste.
>
> Each year Australia produces enough food waste to fill 450,000 rubbish trucks.
>
> Each year Australia produces enough food waste to fill the MCG a little over 4 times.



According to foodwise.com.au, Australians are throwing out an average of 4 million tonnes of food every year. Households in Australia are now spending a total of $5.2 billion on food that they do not eat, according to recent research by the Australia Institute. Currently, Australians rank among the people who waste the most food worldwide.

Solar Charge Station

Solar Pavilion

Solar Thermal

Swift Wind Turbine

UGE Wind Turbine

Building
Learning Centre

Van Raay Centre

Ecohouse

Water

Food
Aquaponics

Solar Cooking

Transport
EV Resources

Electric Vehicle

EV Solar Charge Station

Food waste is created because of regulations, production of too much food, consumer expectations, serving portions and lack of storage. In Australia, about 20% to 40% of fresh fruit and vegetables is thrown out before they reach our shops. Food waste isn't something that only happens in our homes. This happens in our restaurants, supermarkets, business and farmlands, where product that is not purchased goes to waste. Our wasteful society not only harms our economy, but also our environment.

Food Waste in the Queen Victoria Market, Melbourne, Australia

Landfills

Common Landfill

Food waste that isn't recycled or already being composted will likely end up in one of Australia's landfills. In these landfills food will break down naturally and will pollute soil and ground water resources. The natural decomposition of food also releases methane. Methane is a greenhouse gas 25 times more harmful than carbon dioxide per unit mass. Methane contributes to climate change by trapping the sun's heat within our atmosphere. Landfills also create thriving environment for pests, they smell and look bad, and they are a threat to human health.

Environmental Initiatives

The Environmental Protection Act (1970) created eleven principles for environmental protection. One of these principles established an order for waste management. Through this, EPA is looking to reduce the amount of waste created in Victoria by making a structure where avoidance is the most preferable practice, followed by reusing, recycling, recovery of energy, treatment, containment and disposal into landfills being the least preferable option. Through the biogas digester we can apply two of these most desirable methods for disposal, which are recovery of energy and recycling food. Placing our food scraps into a biogas digester will not solve our nation wide food waste problem, but it can be a potential start. By recycling our food scraps in biogas digesters, we can reduce our impact on landfills and climate change, help our economy and produce sustainable green energy to cook, and power our homes in a carbon neutral way.

For more information on the topics of food waste, landfills or other related issues please visit the CERES Sustainability Hub or:

http://www.lovefoodhatewaste.nsw.gov.au/love-food/environmental-impacts.aspx

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How Biogas Digesters Work

Home

Basics

Biogas digesters use a relatively simple technology. They take in organic waste, use bacteria to break it down, and produce methane in a process called anaerobic digestion. The decomposed waste can be used as a natural fertiliser and the methane can be burned as a fuel for heating or to produce electricity.

Inputs

The biogas digester can make use of almost any organic material that can rot. In general, everything from lawn cuttings to leftover sandwiches and vegetables can be processed. While meat and fish can be used, small digesters may have issues with pests and extreme odours. The most noticeable exception is wood because the

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Solar Pavilion

Solar Thermal

Swift Wind Turbine

UGE Wind Turbine

Building

Learning Centre

Van Raay Centre

Ecohouse

Water

Food

Aquaponics

Solar Cooking

Transport

EV Resources

Electric Vehicle

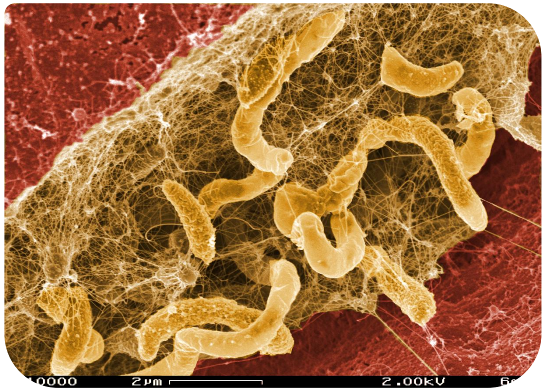
EV Solar Charge Station

bacteria have trouble digesting lignin.

Rotting Food Waste

Digestion

The digestion process is done in the absence of air and is comprised of four stages: hydrolysis, acidogenesis, acetogenesis, and methanogenesis. Three types of bacteria sequentially break down the waste into hydrogen and acetic acid (vitamin C). This allows the fourth stage bacteria to feed and produce methane and carbon dioxide as by-products.



Anaerobic Bacteria

For the bacteria, an ideal environment is defined by two factors, the temperature and the acidity [pH]. There are three temperature ranges: low (20-25 °C), medium (35-40 °C), and high (55-60 °C). The CERES digester and most other small digesters run in the medium temperature range, while large digesters often run in the high temperature range. Methane production is reduced when operating in the low temperature range so it is avoided when possible. The pH range is usually from 6.5 to 8. However, in some specialised digesters with multiple tanks, one tank can be at a lower pH to optimise the third stage of the digestion.

Just as food needs to stay in an animal's stomach for a period of time, the waste needs to stay in the biogas digester for a period of time for the anaerobic digestion to occur. This time span is called the hydraulic retention time and it can range from 15 days for high temperatures to over 100 days for lower temperatures.

Outputs

Biogas is usually comprised of 60% to 70% methane, the useful flammable gas, the rest being mostly carbon dioxide. Similar to natural gas, biogas can be used in stoves, heaters, or generators to produce electricity.

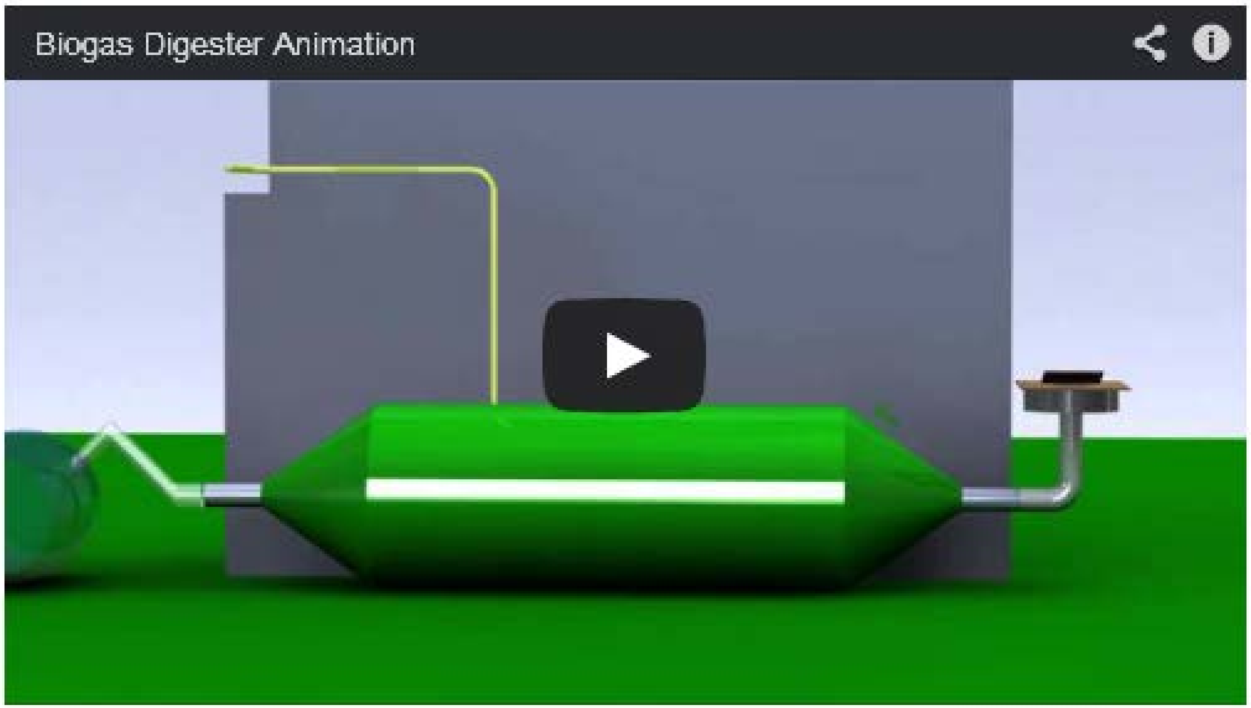
The liquid, or effluent, that comes out of the digester can be used to replace chemical fertiliser. The key components of this effluent that allow it to be used as a soil replenishing

Organic Fertiliser

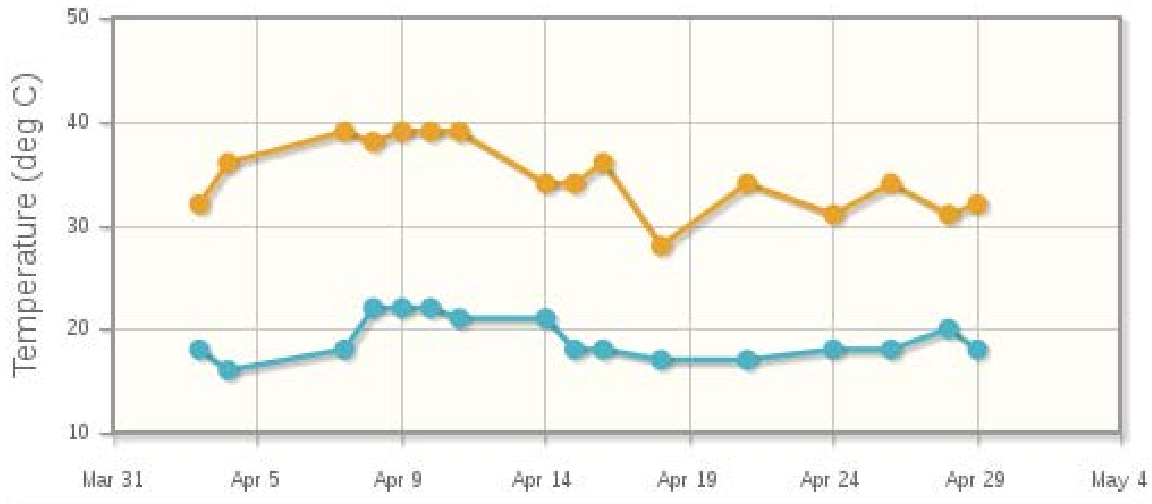
source are Nitrogen, Phosphorous, and Potassium. These are the main three minerals stripped from the ground during farming. In chemical fertiliser, the nutrients are obtained by mining for mineral rich rock or natural gas and then chemically processed. Both the mining and processing are harmful to the environment as well as costly, thus natural fertiliser from the digester has clear advantages.

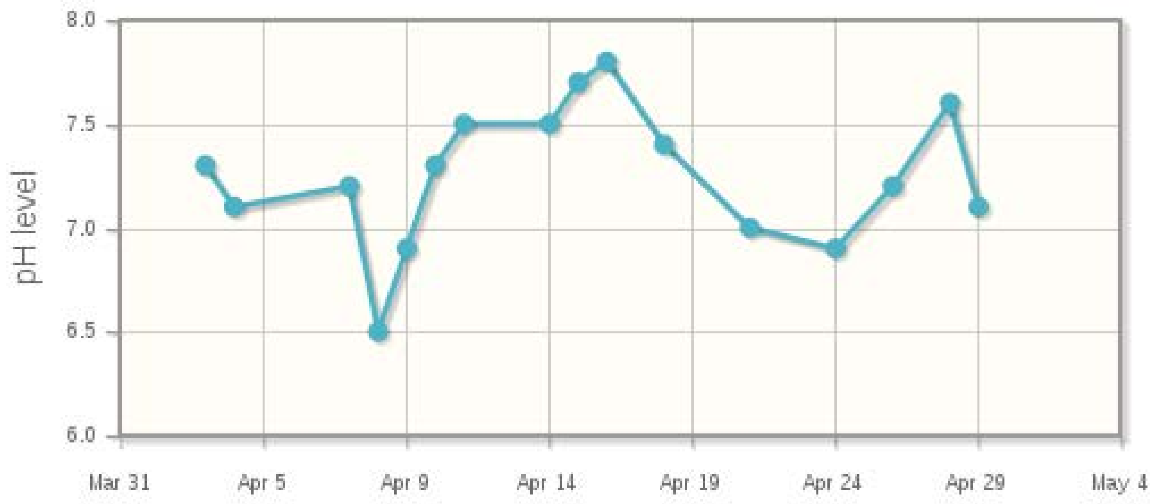
The CERES Biogas Digester

The biogas digester at CERES is a 90L plug-flow biogas digester with an estimated maximum daily gas production of 50L. It can store 450L of gas for burning and the burner attached can consume that gas at a rate of 7.2L per minute. When operating in the optimal temperature range of 30-35 °C and the optimal pH range of 6.8 to 8.5, the CERES digester can be fed 3.6L of diluted biomass (slurry) every day. The slurry is half waste - half water by volume and the hydraulic retention time is about 40 days.



Due to the importance of keeping the bacteria within proper temperature and pH ranges, the CERES biogas digester is monitored daily and adjusted when needed. Below you will find typical data for temperature and acidity in April.





For more information on how biogas digesters work please visit the CERES Sustainability Hub
Further information information available at:

http://www.swea.co.uk/downloads/Biogas_Brochure.pdf

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Energy from Biogas

Home

One of the products of a digester is a mix of methane and carbon dioxide. Methane is a flammable gas which stores its energy in chemical bonds. When methane burns, these bonds are broken and the energy is released. Carbon dioxide does not have stored energy and dilutes or thins out the methane. Because these two gases are produced together through a biological process, the mix is called biogas. The average amount of biogas made for every kilogram of waste put into the biogas digester is half a cubic metre, enough to power a light globe for about 90 hours.

Compact Fluorescent Light Globe

How much do YOU waste?

See what you could do with your waste!

Fill in how much organic waste you throw away every week and click 'Calculate'.

kg/week Calculate

Details

Gas Stove Burner

Biogas only contains 60 to 70 percent methane, the rest being mostly carbon dioxide. If incorrect digestion occurs, nitrogen and hydrogen sulphide can also be produced which can affect the burning properties. This composition makes the average energy of a cubic metre of biogas lower than that of methane. In order to use biogas similarly to methane, it can either be used in larger quantities or purified. One kilogram of waste is enough to run a single burner gas stove for one hour.

Biogas can be turned into electricity by running it through a generator. However, 65% of the energy is lost in the conversion process. These generators are usually large power plants that provide for thousands of homes. Some use the excess heat from electricity generation to warm the fermenter and provide an optimal environment for the bacteria. Other generators create steam from the excess heat and distribute it through pipes to heat the local community. The facilities that produce fertiliser pellets even use some excess heat to dry the solid digester output.

For more information on energy from biogas please visit the CERES Sustainability Hub or:

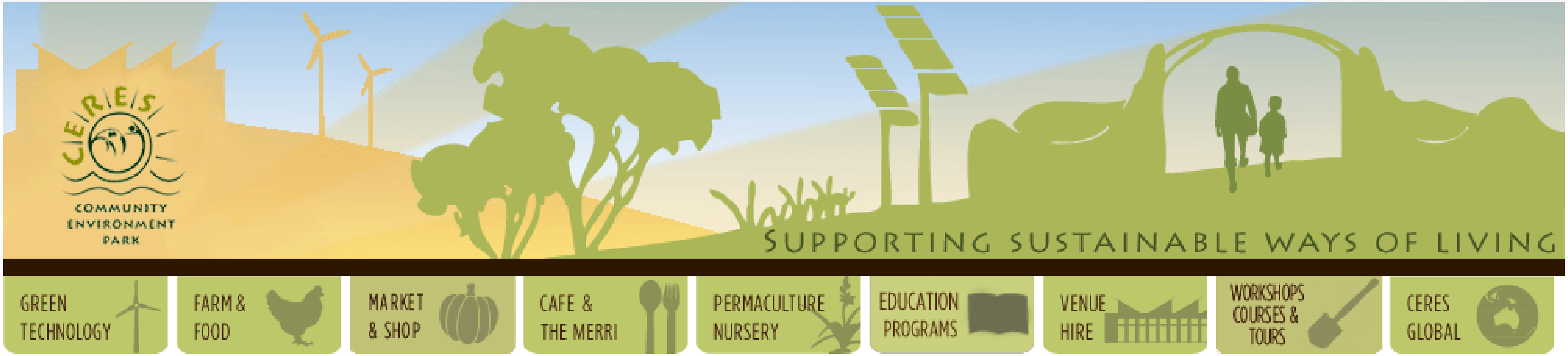
http://hypertextbook.com/facts/2002/JanyTran.shtml

http://www.adelaide.edu.au/biogas/anaerobic_digestion/Syringe_Protocol.pdf

http://www.clarke-energy.com/gas-type/biogas/

http://large.stanford.edu/courses/2010/ph240/pydipati2

http://www.valorgas.soton.ac.uk/Pub_docs/JyU%20SS%202011/CB%204.pdf



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Biogas Digester Examples

Home

In our Community

Biogas digesters are used on the community level right here in Australia. Eighty thousand tonnes of food waste, enough to fill 9,000 rubbish trucks, are collected from food manufacturers, supermarkets, restaurants, and households in the Sydney suburb of Camellia every year. This food waste is being used sustainably instead of being sent to landfills. The gas produced by the digesters is used to generate green electricity for 3,600 homes. For more information on this facility, visit earthpower.com.au.

Collecting Food Waste

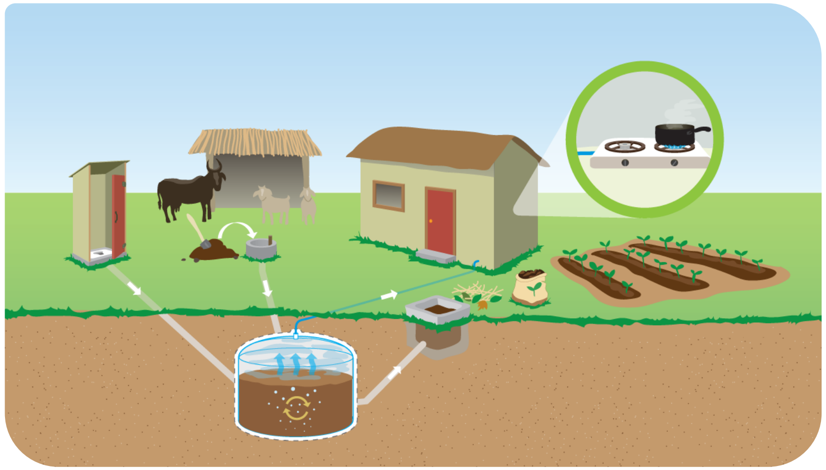
Food waste from households and businesses can be collected by Councils and private companies. Some Councils in the United Kingdom provide a special food waste bin besides rubbish and recycling. The food waste is collected on a weekly basis and taken to a local biogas digester. Also in the U.K, a waste management company works with local businesses to collect their food waste and bring it to biogas digesters on a nearby farm.

Food waste can also be collected with an in-sink food waste disposer. The ground food waste mixes with water and then moves through the sewers to a wastewater treatment plant. In the United States, over 1000 wastewater treatment plants produce biogas. Most of these plants use the biogas for process and building heating but ten per cent of them use the gas to generate electric power. In Australia, electricity is generated with biogas by similar wastewater treatment plants like the Werribee Sewage Plant in Victoria.

Wastewater Treatment Facility

At Home

Biogas digesters are also used around the world in homes, on farms, and on industrial sites. Millions of homes in India and China use small biogas digesters. Most of these digesters are located in farming areas and run on human waste, manure, and unused crops. The decomposed waste is used as an agricultural fertiliser. The gas is used for cooking and lighting and is able to provide most of a family's energy needs. The gas replaces wood as a fuel in these developing countries, reducing the amount of deforestation. Unlike wood, biogas burns cleanly without producing smoke. This makes it more environmentally friendly and less likely to cause health problems for the residents. The use of a biogas digester also reduces health risks by removing human waste from the home as effectively as a sewer system.



Rural Biogas Digester

On Farms

Many middle and large-scale biogas digesters that are fed with waste produced on farms. Examples can be found in the United Kingdom, China and Australia. Discarded vegetables, dairy manufacturing waste, manure, and grass silage are a few examples of the types of waste fed into these digesters. The large amount of gas created can be inserted into the national gas grid or used to generate electricity and heat. Megawatts of power can be used locally or sold back to the power company.

Industrially

Biogas Digester Facility

Some of the most advanced biogas digesters in the world are being used in Germany. One biogas plant is capable of producing 20 megawatts of power. This is enough to provide power to 50,000 homes. The plant is mainly fed with farm waste like crop silage. In Germany, there are over 6,000 large agricultural biogas digesters. These digesters contribute to a large portion of the 1,500 million tons of biomass digested each year in the European Union.

For more examples of biogas digesters please visit or:

http://www.lovefoodhatewaste.nsw.gov.au/love-food/environmental-impacts.aspx

http://www.afgc.org.au/sustainability/waste.html

http://www.abs.gov.au/ausstats/abs@.nsf/Lookup/by%20Subject/1370.0~2010~Chapter~Waste%20and%

http://www.abs.gov.au/ausstats/abs@.nsf/Lookup/by%20Subject/1370.0~2010~Chapter~Landfill%20(6.6.

http://foodwise.com.au/food-waste/food-waste-an-overview/

https://www.lunchalot.com/foodwaste.html

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Alternative Energy Technologies and the Australian Curriculum of Science

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Biogas Digester

Year 2

Science as a Human Endeavour

The Use and Influence of Science

ACSHE035 - People use science in their daily lives to care for the environment and living things

identifying the ways humans manage and protect resources, suchas reducing waste and caring for water supplies

Solar Charge Station

Solar Pavilion

Solar Thermal

Swift Wind Turbine

UGE Wind Turbine

Building

Learning Centre

Van Raay Centre

Ecohouse

Water

Food

Aquaponics

Solar Cooking

Transport

EV Resources

Electric Vehicle

EV Solar Charge Station

Year 6

Science as a Human Endeavour

Physical Sciences

ACSSU219 - Energy from a variety of sources can be used to generate electricity

considering whether an energy source is sustainable

Nature and Development of Science

ACSHE099 - Important contributions to the advancement of science have been made by people from a range of cultures

investigating how people from different cultures have used sustainable sources of energy, for example water and solar power

Use and Influence of Science

AACSHE100 - Scientific understandings, discoveries and inventions are used to solve problems that directly affect peoples' lives

investigating how electrical energy is generated in Australia and around the world

ACSHE220 - Scientific knowledge is used to inform personal and community decisions

considering how personal and community choices influence our use of sustainable sources of energy

Year 7

Science as a Human Endeavour

Nature and Development of Science

Workshops

ACSHE120 - Science and technology contribute to finding solutions to a range of contemporary issues; these solutions may impact on other areas of society and involve ethical considerations

considering how human activity in the community can have positive and negative effects on the sustainability of ecosystems

Year 8

Science as a Human Endeavour

Use and Influence of Science

ACSHE135 - Science and technology contribute to finding solutions to a range of contemporary issues; these solutions may impact on other areas of society and involve ethical considerations

investigating requirements and the design of systems for collecting and recycling household waste

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Biogas Digester F.A.Q.

Home

Can the biogas be used the same way as natural gas in a dual fire system?

Yes. Biogas and Natural Gas are both mainly composed of methane. In order for biogas to be used like natural gas, it has to go through "upgrades" to remove C02 and other impurities.

Is the fertiliser from the biogas digester more effective than compost?

Some of the fertiliser produced has been calculated to contain almost 3 times more nitrogen than compost. Although not all of the fertiliser produced is more effective, the process of attaining it is. This fertiliser is cost-effective and environmentally friendly since it is created from waste. Without the need for harmful chemicals, this fertiliser is also rich in nutrients.

Financial Savings

A biogas digester is a long term investment. It takes an upfront cost but returns money over time in the form of reduced waste removal costs, as well as profits from selling fertiliser and methane. In any country where there is a carbon tax, it can reduce a company's carbon foot print, reducing their taxes. The exact values of savings

Solar Charge Station

Solar Pavilion

Solar Thermal

Swift Wind Turbine

UGE Wind Turbine

Building
Learning Centre

Van Raay Centre

Ecohouse

Water

Food
Aquaponics

Solar Cooking

Transport
EV Resources

Electric Vehicle

EV Solar Charge Station

depends on the size of the digester implemented, the local cost of waste removal, and the regional prices for fertiliser and energy.

Is the technology preeminent enough?

Yes, the technology is here and well developed. Biogas plants have been constructed in Germany, Sweden, and various parts of Europe as well as in the United States and here in Australia. An Australian Biogas Plant in the suburb of Camellia in Sydney is capable of generating enough energy to power 3600 houses.

Can you use it on a small scale? How?

Yes. Biogas digesters have been used by individuals homes in countries like India and China for many years. They are fed with human waste, manure, and unused crops and they provide most of a family's energy needs.

How big can a biogas digester get?

In Germany, there are huge biogas digester facilities that have any individual digesters. One facility has 40 digesters that can each power up to 1,250 houses. That's a total of 50,000 houses powered by one facility.

Can biogas be stored and used for heating?

The biogas can be used in combined heat and power plants to provide heat for the local area. However, biogas is difficult to compress, which makes it difficult to store. That means that it is much more efficient to use it immediately.

What are the benefits of using Biogas Digesters?

1. It uses organic waste to produce different forms of energy such as electricity, heat and cooking gas.
2. It turns waste into high-quality organic fertiliser
3. It benefits the environment by capturing methane which otherwise would be produced in landfills and would exit into our atmosphere.
4. It protects soils and water resources.
5. It lessens our dependence on landfills for disposing of waste.