Learn Chemistry

Chemistry of Energy

Student Guide

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National HE STEM Programme

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Student Introduction

'The Chemistry of Energy' is a group case study which will guide you through some of the key chemical aspects of power generation, the distribution of energy and the relationship between science and policy. You will work in groups as a scientific advisory team to a number of ministries in the government of Northland. Please read the emails that you receive from government ministers and the accompanying attachments for more details on what you need to do.

Emails and News Stories

Throughout this problem you will be presented with a number of messages in the form of emails. These emails include important information on what you need to do for each part of the problem. Read them carefully and in your groups decide how best to respond.

You will also see a number of news stories relevant to the problem. These stories will provide some additional background information to the problem and will also contain some information that you will need to consider when preparing your solutions to the problem.

Learning Outcomes and Pre-session Preparation

The resource includes a list of relevant intended learning outcomes from each session. This acts as a check list for what you should be able to do after tackling the part of the problem covered in that session. The assessments for each part of the problem is aligned to these lists so please make sure you demonstrate the competencies listed in your assessed work.

The pre-session preparation should guide your research before each session. It is worth remembering that the information presented in the problem is meant to be a starting point, you will need to do further research to fully prepare for each session.

Assessment

This resource makes use of a range of different types of assessment based on the general theme of science communication in the workplace. Communicating your understanding to a range of different audience types in a number of different ways is a very important skill to have. This resource aims to give you the opportunity to develop a range of communication skills and to make key decisions based on your scientific understanding of various concepts combined with an understanding of related political and economic factors.

Facilitation

You will be guided through the problem solving process by a facilitator (or tutor). Although your facilitator can provide advice on problem solving strategies, the facilitator will not freely give information about the problem away (for example, they won't tell you which proposal they would back in the first part of the problem). Your facilitator will help you by encouraging discussion amongst the group and (if needed) focussing this discussion.

Dear Scientific advisory team,

I want to welcome you to your new role as scientific consultants to the Northland government. I am looking forward to working with you on the development of a plan to develop sustainable energy technologies which will ensure the long term security of our nation's energy supplies. I have given included some data about our current power generating facilities as well as some facts about transport habits and carbon footprint that you may need to refer to during this task.

Best wishes,

Robert Davies (Northland Science Minister)

Welcome to Northland

Northland is a small North-Western European nation with a population of around 5 million. Northland is a member state of the European Union and its economic and political structures are similar to those of other nations in the region.

Data on Northland (provided by the Northland office of statistics)

Location: North-Western Europe

Population: around 5 million (density about 60 per km2) – major population centres are in the south of the nation.

Political Unions: Member state of the European Union, NATO and UN member

Political/Economic Structure: Parliamentary democracy. Nation divided into constituencies with a political representative elected in each (similar to those of other EU member states in the region).

Current energy resources:

- Declining offshore oil and gas
- 2 nuclear power stations that the government wishes to decommission
- 2 coal and 1 gas power plant where the government has expressed an interest in to install carbon capture and storage
- Around 1.5 GW of 1st generation hydro-electric schemes
- Considerable potential for wind, wave and tidal renewables in far north of country

Other relevant factors:

- New N-S power lines planned
- Renewables have peak output in summer
    - Long hours sunshine, steady winds
- High per capita fuel consumption for transport and winter heating

Carbon Footprint

- Current Carbon Footprint 55.4 million tonnes CO_2
    - Transport :14.4 MT
    - Built environment 22 MT
    - Power generation 16.6 MT, from total 10,600 MW installed capacity

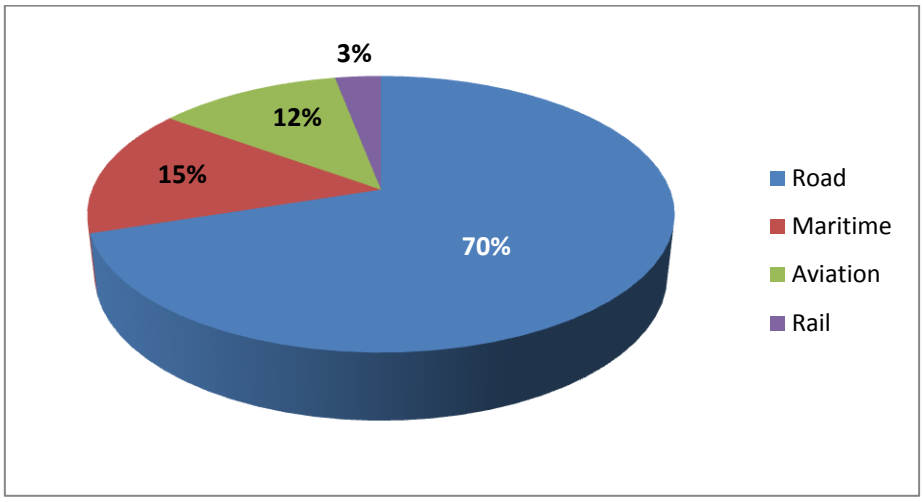
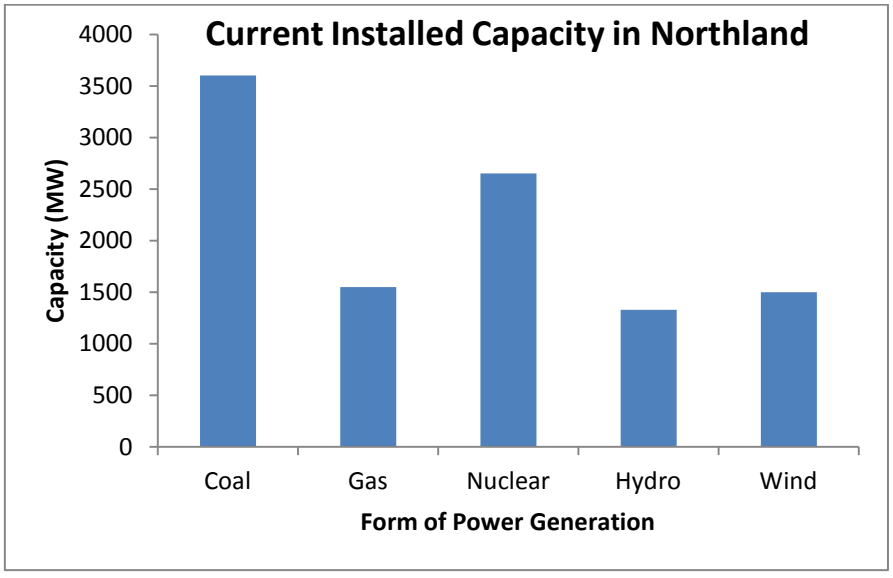


Figure 1 Contributions to carbon footprint from transport

- Other contributions to carbon footprint:
  - Built environment 22 MT
  - Power generation 16.6 MT, from total 10,600 MW installed capacity

Breakdown of installed capacity:

- 3600 MW Coal
- 1550 MW Gas
- 2652 MW Nuclear
- 1330 MW Hydro
- 1500 MW Wind



Information on Commuting in Northland:

- Average one way commute of 30 minutes.
- 25% of workforce have commutes of 45 minutes or more.
- 80% of urban workforce commute by car.
- 85% of rural workforce commute by car.

- The entire Northland rail network is run by a publically owned body (NorthRail). The government is in the advanced stages of planning the privatization of NorthRail which is hoped will provide an injection of cash to help modernize the nation's aging rail network. The entire network is currently operated entirely by diesel trains.
- Under 5% of all car owners own electric cars

Part 1: Building for a Sustainable Northland (Power Generation)

Session 1 (90-120 minutes)

Pre-Session Preparation

You should be prepared to discuss the following topics in this session:

- All of the technologies and processes referred to in part one of the problem: photovoltaic cells, wind power, biorefineries, nuclear power, carbon capture technology and bastnäsite mining and processing.

Intended Learning Outcomes

Scientific:

By the end of this part of the problem you should be able to:

- Demonstrate an understanding of scientific principle of a number of sustainable power generation technologies
- Compare and contrast the relative merits of a number of different sustainable energy technologies.
- Evaluate the potential output of a number of new power generation technologies and decide which is most suitable for a small EU nation.
- Justify the chosen approach based on considerations of the future energy demands of the nation and the impact on the nation's carbon footprint.
- Consider the financial implications of the introduction of a number of power generation technologies.
- Calculate the anticipated power output from a number of different technologies by making reasonable approximations.

Transferable:

By the end of this part of the problem you should be able to:

- Work in a team on the peer-review of a number of funding applications.
- Plan and prepare detailed responses to possible questions that may be asked on a given scientific concept (i.e. one of these sustainable approaches to power generation in this case).
- Perform literature searches on active area of research in order to gain a greater understanding of fundamental scientific concepts are applied to current research
- Work in groups to produce written summaries of scientific research suitable for a range of different audiences
- Prepare for an interview (or in this case a press conference) based on the communication of a scientific concept to a specified audience type (the media in this case)

To: scienceteam@northlandgreens.org.nld

From: scienceminister@northland.gov.nld

Sent with high priority!

Subject: Review of grant proposals

Dear team,

I hope you had a chance to look through the data that I sent you. We recently put out a tender for a project to develop sustainable (i.e. using a fuel which is abundant enough to generate power for at least 1000 years) power generating facilities. Please take a look at the summaries of the most suitable proposals that we have received and write a one page summary of the proposal you feel is most worthy of investment which includes figures on the impact it will have on our dependence on non-renewables and our C footprint. The chosen approach must be clean, efficient, conform to our definition of sustainable (outlined above) and must be achievable with a realistic budget.

Please make sure you include the following points in your report:

- Describe the scientific basis of your chosen proposal
- A description of the potential this project has to meet the nation's energy demands (include any values you can calculate on how much energy this approach could produce) and the effect it will have on our dependence on non-renewables. Will it have an impact on our carbon footprint?
- The financial implications of this project – how much will it cost? What will get back in return?
- How does your chosen proposal compare to the other options?

Best wishes,

Robert Davies (Northland Science Minister)

Hint:

The discussion questions should help focus your discussion and the facilitation session. You may find it useful to consider the answers to these questions when planning your one page summary. Please note that the proposals and the discussion questions should act as a starting point – your research should go beyond these points.

The Proposals

Applicant 1 - Northland Maglev PLC

Title: Mining Bastnäsite in Northland

A recent geological survey has discovered potentially large quantities of the mineral bastnäsite (along with associated monazite) in the hills of Northland. We propose further analysis of this site followed by the establishment of a mining operation that would allow us to recover the mineral.

This development would be hugely significant for the renewable energy resources of Northland, the nation's dependence of Chinese sources of bastnäsite would be broken. By extracting bastnäsite on a large scale we could then press ahead with the second part of our project as detailed below:

- Wind power is constrained by environmental objections to the appearance of conventional wind turbines and suffers from intermittent output in variable wind conditions – including being unable to function when the wind is too strong!
- There is potential for a new design of wind turbine that addresses most of these problems – the Maglev device. We see this as the basis of a new wind power industry in Northland
- The MagLev wind turbine uses frictionless magnetic levitation: the vertically oriented blades of the wind turbine are magnetically suspended (using permanent Nd magnets) above its base
- Similar permanent magnets are used in the generator assembly as well as in the bearing
- The supply of sufficient quantities of these magnets will of course be crucial to the project, but we do not believe this will be a major problem

Discussion Questions

- What are bastnäsite and monazite?
- Why would a new source of bastnäsite and monazite be valuable to the economy of Northland?
- Why is the processing of these minerals considered to be difficult?
- What is the connection between the mining operation and the potential application in the novel magnetic turbine? What physical property is being exploited here and what is its origin?
- What complications are caused by the presence of monazite as well in the minerals?
- How would technology helping the mine also potentially help the nuclear industry?
- How does bastnäsite impact on the production of renewable and clean energy? Why does this process present a dilemma for environmental activists?
- How much power would be generated per m^2 for the onshore and offshore wind farms?
- How big would the offshore wind farm need to be to generate 10 % of Northland's total energy requirement?

Applicant 2: Northland Nuclear Limited

Title: New generation uranium fission reactors for Northland

Project Abstract:

In spite of a number of isolated safety incidents involving nuclear fission processes, nuclear remains the safest and most economically viable way to plan for a sustainable future for the nation. Nuclear power is an effective, sustainable power source and when compared to other nations in the area we underuse nuclear and rely too much on fossil fuels (see comparison of the energy mix in France and Northland below) Northland has relied on nuclear facilities to deliver over 2.5 GW of power since the mid twentieth century. As these first generation power stations are decommissioned we need to be ready to bring a new generation of once through nuclear fission facilities online in order to ensure that the energy demands of the nation are met.

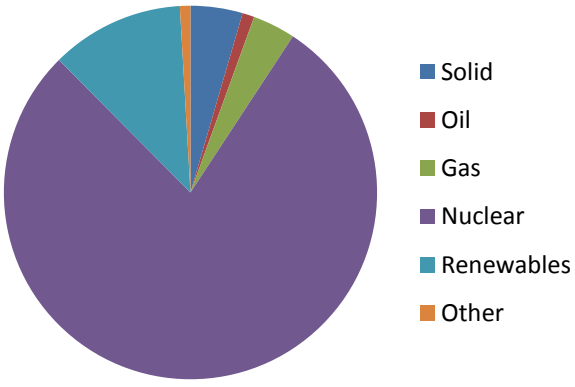
In order to make Northland self-sufficient in nuclear power, we plan to establish a facility which is capable of recovering uranium from the oceans. By opening the first industrial scale oceanic uranium recovery plant, the government of Northland will be sending a strong message out to the rest of the world that our nation is committed to the development of innovative solutions to the problem of ensuring a sustainable energy supply.

Northland currently relies entirely on imported Uranium for use in our nuclear facilities, by extracting uranium from our own coastal waters we would be able to reduce costs and possibly work towards becoming a net exporter of both uranium and the energy produced. Northland has coastal waters of 9000 cubic miles; initial findings have shown that these waters have a uranium concentration of 3.3 ppb by mass.

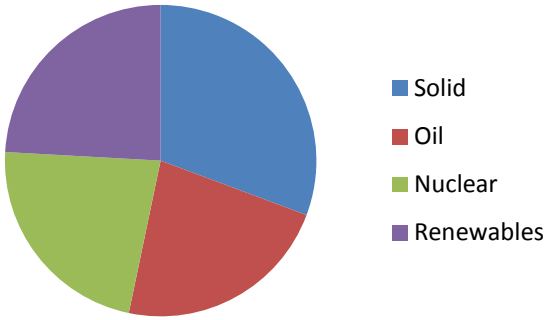
We plan on developing an approach based on that employed by the Takanobu Sugo group at the Japan Atomic Energy Research Institute (JAERI).The Japanese group has described an approach which uses an adsorbent which selectively soaks up uranium from sea water. This adsorbent is essentially a nonwoven fabric of polyethylene with amidoxime groups attached by graft polymerisation. It is the amidoxime groups which are responsible for recovery of uranium.[1]

The first stage of the project will see us take control of two existing nuclear sites and overseeing their decommissioning, the same land will be reused for the new generation sites.

We are confident this project will give Northland the energy security it needs in a time of global shortages of non-renewables.



2004 Domestic Production of Energy in France[2]

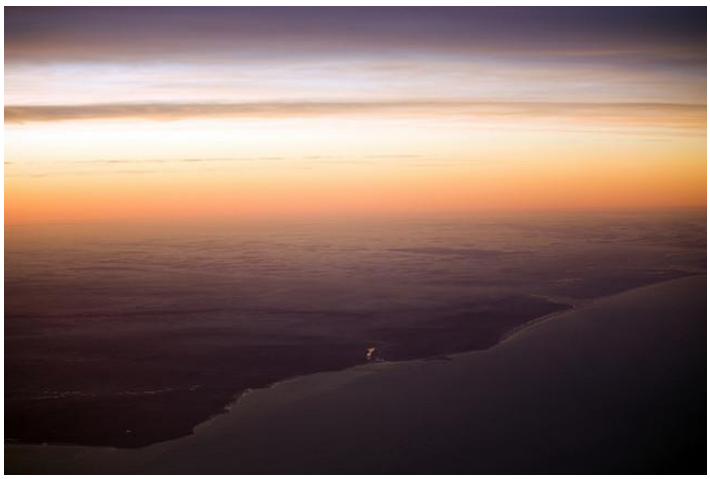


2010 Domestic Production of Energy in Northland

1 http://escholarship.org/uc/item/12h981cf.pdf
2 http://ec.europa.eu/energy/energy_policy/doc/factsheets/mix/mix_fr_en.pdf

Executive Summary:

- The World's oceans contain around 4.5 billion tons of Uranium, new recovery technologies can be used to extract this Uranium and processing this material in new generation nuclear facilities provide an effectively sustainable supply of energy
- We propose the extraction of Uranium from the Western Sea. This will be used to run a new generation of fast breeder nuclear reactors
- In spite of the recent incident in Japan, nuclear remains amongst the safest power generation technology
- The Northland coastal waters contain a volume of approximately 9,000 cubic miles.
- We propose to develop new facilities on the sites the two existing nuclear facilities located on Northland's west coast.
- We will engage in public consultation on the decommissioning of the existing facilities



Comment from Science Minister:

The PM is fascinated by the concept of using an adsorbent to extract Uranium. How does it work? Will this really work on a large scale?

Discussion Questions:

- Describe the process of nuclear fission.
- Have there been any other projects comparable to this proposal?
- What issues are involved in the shutdown of a nuclear power station?
- Given his background in chemistry, the prime minister will be fascinated by the Uranium extraction process. Will the process described by the Japanese group work on a large scale? How does it work?
- Based on the values quoted in the proposal, how energy per person, per day could be generated if this approach was sustainable?

Applicant 3: Northland Power

Title: Sustainable solid fuel for Northland

Project Abstract:

The current power generation strategy of Northland makes heavy use of coal-fired power stations (current installed capacity: 3600 MW). This is partly due to our nation's once abundant reserves of coal; of which approximately 1.4 Gt remain. We believe that coal will continue to play an important part in any future power generation strategy. Many renewable sources of power are very expensive to harness, the technologies aren't advanced enough to make a major impact or are simply incapable of generating sufficient energy to meet the growing needs of the population of Northland.

We need to change the way we think about coal power and use this resource much more efficiently and effectively. The energy equivalent value of one ton of coal is 8000 kWh (or 29.3 GJ); if we were to use our coal reserve responsibly, we could potentially meet a significant amount of the nation's energy requirements over a long enough period of time to consider this approach to be sustainable.

In order to address concerns about the environmental impact of continued fossil fuel combustion we propose the construction of new generation power stations which will use carbon capture and storage technology which will significantly reduce emissions of CO_2 minimising the impact of this approach on the nation's carbon footprint.

We argue that coal plays an important part in the power generation strategy of the nation alongside renewable approaches.

Executive Summary:

- Fossil fuels will continue to provide a vital contribution to the nation's energy mix for the foreseeable future – 'renewable' energy sources alone will not meet the nation's energy needs!
- Northland has coal reserves of around 1.4 Gt
- A new generation of coal based power stations utilising carbon capture and storage will be developed

- By working in parallel with other approaches to change Northland's energy usage profile, we can use our existing fossil fuel resources in a sustainable manner providing energy for the next 1000 years
- See: Carbonate chemistry for sequestering fossil carbon and Greenhouse Gas Mitigation Policy

Discussion Questions:

- How does this technology work? Will carbon emissions be completely eliminated?
- How much energy does the carbon capture process use?
- What is the energy equivalent value per person per day of this process?
- The coal fired power stations in Northland produce about 12.3 Mt of CO_2 each year. How much coal must they be burning to produce this? They produce about 14 TWh of electricity a year. Given the energy of combustion of coal, what does that say about the efficiency of these plants?
- How long would the current reserves of fossil fuel last at this rate of consumption?

Applicant 4: Photocell PLC

Title: The development of a sustainable solar farming sector in Northland

This project will follow the example of ambitious schemes such as Bavaria Solarpark in Germany as well as smaller scale schemes such as the Rhosygilwen solar park in Wales. Northland can no longer afford to ignore the potential of solar cells as a solution to large scale power generation. If Northland persists with its dependence on non-renewable energy resources, it is likely that the nation will be entirely dependent on energy imported from other nations by the middle of the century. Given the constant concerns about security of supply and fluctuating energy prices, it makes sense for us to invest in our future now that we have the opportunity. Solar power is a totally clean energy source; we could eliminate a significant quantity of our CO_2 emissions if we were to invest in a large scale solar solution.

The sun provides 1000 W of power at midday on a clear day (see Figure 1 for the variation of average solar intensity throughout the year as recorded by Northland University). The key aspect of our proposal is the creation of a 50 hectare solar park which will make use of 15 % efficient photovoltaic cells fitted to solar trackers.

The project is based on the development of a large scale solar park for power generation but also includes two other vital sub-projects. We aim to make thermal panels commercially viable solutions to all households in Northland. With a government subsidy, it is likely that we could encourage mass take up of solar heating schemes amongst the population of Northland. If we covered all south facing roofs with thermal panels we could significantly reduce the drain that these properties currently place on the national grid due to heating.

The third aspect of this project is based on the establishment of a research and development plant in collaboration with Northland University's Centre for Sustainable Energy. The aim is to develop a world leading site in the field of solar cell research. We aim to pursue research into the development of highly efficient, low cost solar cells based on both silicon semiconductor and dye sensitised technologies.

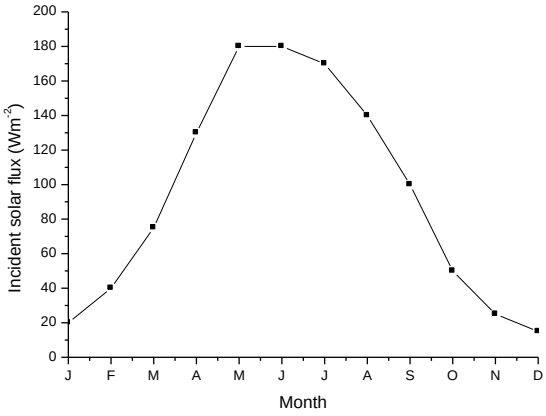


Figure 1. The variation of average solar intensity at Northland University throughout the year

Executive Summary

- We propose an ambitious plan to substantially reduce the dependence of Northland on non-renewable forms of energy.
- Our plan is based on three main components:
    - The installation of subsidised solar panels on south facing roofing of residential and business properties to provide hot water. This will be used to help reduce the drain on the national grid by individual properties.
    - Solar farming – we propose the development of a number of solar farms on suitable south facing land. This has the potential to produce a significant amount of power.
    - The final aspect of our plan involves the establishment of a large scale research and development plant which will investigate the development of photovoltaic cells with greater efficiency than currently possible.

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kevinthoule on Flickr

Discussion Questions:

- What is a reasonable value for the average value of the solar power per m^2 in Northland? You may assume that the intensity of sunlight in Northland is approximately the same as it is in Northern England.
- What is the potential total power output of this facility?
- What is the operating principle of silicon based photovoltaic cells? What is the typical efficiency these cells?
- Why are researchers having difficulty creating photovoltaic cells with efficiencies higher than around 40%?

Applicant 5: Northland Biomass

Title: Northland Biomass Refinery

Project Abstract:

This project will transform the global perception of Northland from a small nation dependent on environmentally unfriendly industrial activities powered by non-renewable energy supplies into a dynamic nation willing to embrace new technologies in order to guarantee a sustainable future.

This project will develop two biorefinery complexes which will process locally grown biomass such as rye-grass into a range of bio based products (such as chemical resources and materials such as plastics) and bioenergy (such as fuel, heat and power).

This processing method is will generate a number of high-value products (as described above). These refineries will generate electricity and process heat by making use of combined heat and power technology – this will generate enough power to run the refinery (thus reducing the refineries dependence on externally generated electricity) and may produce enough to contribute to Northland's national grid system. The biofuel generated by this refinery has the potential to act as a petroleum substitute which could be used to relieve the dependence of the nation's transport infrastructure on fossil fuels.

The biorefinery concept is well suited to Northland due to the abundant supply of feedstock which can be harvested without disruption to the land use pattern in the nation. This project will be highly valuable to the nation as it will aid in the economic and social regeneration of rural communities in Northland by producing a diversified farming industry.

We aim to harmonise our plans with those of the EU biorefinery project with the eventual aim of allowing our sites to become demonstration plants for the EU project. In order to apply for membership of the EU project we will require a commitment from the Northland government.

Executive Summary

- We proposal to develop two biorefinery complexes which will produce valuable chemical feedstocks and will generate electrical energy used to power the facility and to be distributed back in to the grid.
- We aim to get some financial and technical support from the EU biorefinery project with the eventual aim of opening our plants as demonstration sites for the biorefinery project.

Discussion Questions:

- What is the potential total power output of this facility? Assume that Northland has about 1.35 million hectares of woodland and plans to add another 0.65 million hectares. The incremental woodland will add around 1 million tonnes of wood biomass fuels per year as well as absorbing CO_2. How much energy might we get from this?
- Give details of some of the chemical processes that occur in similar biorefinery facilities.

To: scienceteam@northland.gov.nld

From: scienceminister@northland.gov.nld

Sent with high priority

Subject: Press conference

Dear team,

Thanks for agreeing to take a look through these proposals. We need you to do one more thing related to this. It is very important that we make a positive impact when we announce these plans to the press so I would like to invite you along to the press conference as subject experts. Please make sure you know the background of your chosen project so you can deal with any tricky questions!

Please note that journalists are often very keen on asking questions based on the following points:

- The cost of the project and the potential return.
- Environmental impact – Particularly pollution and Carbon footprint.
- What is the scientific basis of the project?
- Journalists may also ask how this is linked to other hot topics in the news. Please take a look through the latest news in the Northland Gazette.

Best wishes,

Robert Davies (Northland Science Minister)

The Press Conference

A press conference is another way of communicating scientific ideas; the one page summary that you have prepared will form the basis of this conference. A typical press conference will start with a short address from the presenters (usually up to 5 minutes long) which summarises the message that they hope to get across. This is followed by a longer period of questioning from the audience (members of the press).

It is important to remember these points:

- This is not a standard oral presentation, the majority of the time you will be answering questions. Although you will be given a few minutes (usually no more than 5 minutes) at the start of your press conference to outline your decision, you do not need to prepare a PowerPoint presentation.
- Communicate your responses at an appropriate level, the audience (members of the press) won't be experts on these technologies so it won't be much use to simply quote findings direct from a research paper!
- The fact that you don't know how the press conference will unfold beforehand makes this a more challenging scenario than a normal oral presentation. You could possibly ask some friends to help you practice by reading through your summary and asking some general questions.

- The discussion questions should be used as a starting for preparing for the press conference.
- Critically evaluate your decision (and one-page summary) and compile a list of possible questions. Put yourselves in the shoes of the press. Some of the things that you may want to think (depending on your decision) about include:
- What are the key advantages of your chosen proposal? What does it offer that the other proposals lacked?
- What is the impact on the economy and environment of Northland? Is your chosen proposal sustainable?
- Can you support your decision with numbers which demonstrate why your chosen proposal is the most suitable option?

Hint:

Once again you may find it useful to look back at the discussion questions when planning for the press conference.

Assessment

- Your group must hand in a one page report on one of the proposals.
- You must thoroughly research your chosen proposal and be prepared to be questioned on it at a press conference in the next session.
- When you are not presenting, you will be a member of the press in the audience. Make sure you have questions prepared for the other groups – **questioning will be student led!**

Group reflection

Review your progress in this session and think about what remains to be done. Construct a brief plan of action – the plan should include a list of the tasks that each group member is expected to do and a timescale for each of these tasks to be done. Remember to include enough time to proof read each other's work before submission. You should briefly present this plan to your tutor before the end of the session.

Session 2 (90-120 minutes)

Pre-Session Preparation

You should be prepared to discuss the following topics in this session:

- Your chosen proposal (from session 1) so that you can answer a range of questions on this subject (you will need to thoroughly research the background of this proposal).

Intended Learning Outcomes

Transferable:

By the end of this part of the problem you should be able to:

- Verbally communicate scientific ideas with an audience of peers and to respond to a range of questions on the ideas presented
- Act as ambassadors of science in the community by helping the public gain a deeper understanding of scientific concepts which are often miscommunicated by the media

Scientific

By the end of this part of the problem you should be able to:

- Describe the relative advantages and disadvantages of a number of different approaches to power generation based on scientific considerations.

Integrative Exercise - Whose Fault is it?

Intended Learning Outcomes

Scientific:

By the end of this part of the problem you should be able to:

- Compare two approaches to sustainable power generation and decide what the most suitable option is by calculating the energy output of each in a given situation.
- Explain what a kilowatt hour is and show how it can be converted into other energy units.
- Make realistic approximations when calculating the energy output of various technologies (e.g. how does cloud cover affect photovoltaic cells?).
- Explain the concepts which give rise to the efficiency limits of photovoltaic cells.

Transferable:

By the end of this part of the problem you should be able to:

- Work in a group to evaluate two scientific options.
- Work in groups to produce a short written report based on the evaluation of two approaches to sustainable power generation.

To: scienceteam@northland.gov.nld

From: scienceminister@northland.gov.nld

Sent with high priority

Subject: Northland fault line

Dear team,

The PM needs us to do a feasibility study to make sure his feasibility study is going to find the right answers. OK, where to start? How efficient are PV cells these days? Could we produce a 100% efficient cell? Do we get enough sun, I know we have long summer hours of daylight but does that compensate for our dark winters? And how much energy do they produce – what on earth are kilowatt hours? Can you compare the PV option (i.e. dedicating the Northland Fault Line to solar farms) with the energy we could generate from planting a biomass crop like wood fuel or oil seed rape along the fault line? Please send a short report (around 500 words) addressing the following points and anything else raised in the forwarded email below:

Best wishes,
Robert Davies (Northland Science Minister)

To: scienceminister@northland.gov.nld

From: pm@northland.gov.nld

I've just had a meeting with a Californian state government advisor on renewable energy policy. They've done some amazing things over there; the latest photo-voltaic devices that they are using are really efficient. If we could adapt their idea to meet our needs we could cover all or more of Northland's energy if we just had a large enough area of south-facing slope. One of my advisors has suggested that we would look into using the Northland Fault Line as it's a south-facing ridge about 100 miles long and roughly 200 metres high right across the width of central Northland. I want to announce a major feasibility study into the Northland Fault Photo-voltaic Scheme at the Party Conference next month. It's just the kind of imaginative plan that will enthuse the Party and the Voters. But I want to check it out before I announce the study – I don't want it to come back with the wrong results. So can you check out the idea over the next week or so? What might such a scheme cost, and how much energy could we generate? Could we store the energy we make in the summer for use in our long dark winters? And can you come up with a response to any likely problems – just make sure we can actually get enough PV cells and that sort of thing? Of course the Greens will just want to plant trees on the ridge and absorb CO_2 but that's not really high-tech is it? Mind you, we could harvest them for biomass! I'm sure I saw an article about a new process in Chemistry World recently, can you check that out as well?

Information for Team

Insolation data for Northland Fault

	Average Incident W/m^2	Daily Flux	Average daylight	Hours
Jan		20		7
Feb		40		9
Mar		75		11
Apr		130		14
May		180		16
Jun		175		17
Jul		170		17
Aug		140		15
Sep		90		13
Oct		50		10.5
Nov		20		8
Dec		15		7

Oil Seed Rape Planting Northland

Current Planting 35,000 hectares, which produces 124 kilotonnes Oil

Estimated yield biodiesel from Rape Oil 94%

Energy Yield from Biodiesel 37.2 MJ/kg

Forestry Biomass Planting: Northland has about 1.35 million hectares of woodland and plans to add another 0.65 million hectares. The incremental woodland will add around 1 million tonnes of wood biomass fuels per year as well as absorbing CO_2. Fuel wood has around 42% of the calorific value of coal (which is around 32.15 MJ/kg).

Forestry CO_2 uptake. Currently 3.316154 million acres of Forest in Northland. Absorbs around 10 million tonnes CO_2 pa.

Group reflection

Review your progress in this session and think about what remains to be done. Construct a brief plan of action – the plan should include a list of the tasks that each group member is expected to do and a timescale for each of these tasks to be done. Remember to include enough time to proof read each other's work before submission. You should briefly present this plan to your tutor before the end of the session.

Part 2: Lost in Transmission (Energy Conservation)

Session 3 (90-120 minutes)

Pre-Session Preparation

You should be prepared to discuss the following topics in this session:

- The five research funding applications based on new conductor wire technology produced by academics at northland University
- Energy losses during transmission and skin effect
- The physical properties (including electrical conductivities) of a range of different materials

Intended Learning Outcomes

Scientific:

By the end of this part of the problem you should be able to:

- Explain the electrical properties of a range of different types of materials based in terms of the structure of the material and an appropriate description of bonding (e.g. band theory)
- Explain how electrical power is transmitted by Grid type systems
- Decide on the suitability of a range of materials for a specific purpose (the transmission of power over long distances) based on an evaluation of a range of physical properties
- Make a decision on which material to use for a new generation of conductor wires based on a range of factors (including efficiency, safety and security) and compare the chosen approach to the other options.
- Evaluate the potential losses during transmission of power during transmission
- Explain the 'skin effect' phenomenon and minimise the impact of this phenomenon in conductor wires (or cables) through choice of an appropriate material

Transferrable:

By the end of this part of the problem you should be able to:

- Work within a group to critically evaluate a number of different scientific funding applications
- Create a short presentation which justifies a decision to back a scientific proposal.

Government Stalls on Interconnector

Story from the Northland Gazette

The Northland government has come under increased pressure to underline its plans for the North-South interconnector which will allow power to be transferred from a new tidal power station due to be commissioned in 2013. The new power station will provide 10 GW of installed capacity. The interconnector is an integral part of the government vision to use the plant to power the heavily populated regions in the central region of Northland.

The controversial plan to build the interconnector through hundreds of miles of National Park has polarised opinion within the coalition government as some members of the Democratic party keen to see the plans pushed through whereas members of the Liberal party are keen to find an efficient alternative that won't blight the landscape of the nation.

Dear team,

Please read through the following research funding applications that were presented to the minister for industry and energy by academics at Northland University. For more background information, please read through the forwarded emails below.

We need a solution that both links our large reserves of renewable energy to the main electric grid system 300 miles away and reduces the financial and environmental costs of imported copper cables and the increasing problem of cable theft?

Our coalition partners (the greens) are unlikely to back our original plans to use pylons which are double the normal height. They have already asked us to look into burying power cables or using new technology which would allow smaller pylons and/or wires.

Prepare a short presentation (around 3 slides) for the industry and energy minister which details the potential of one or more of the projects in this area.

Best wishes,

Robert

Northland Science Minister

To ministerindustryenergy@northland.gov.nld:

From: pm@northland.gov.nld

How are we doing with the North-South interconnector project? Are we ready to move to detailed planning approval yet? I know that you're in discussions with the Greens, but they are our coalition partners so they'll have to fall into line eventually. Don't let them mess you around and delay the project unduly. I have every faith in your energetic (ho ho) approach on this one!

To ministerindustryenergy@northland.gov.nld:

From ministerenviron@northlandgreens.org.nld

Jo,

My party are finding it very difficult to support this interconnector project. The existing lines are bad enough but you want to double the height of this power line cutting across over 250 miles of some of the most beautiful scenery in Northland. We understand that we need to transmit the power from the new tidal scheme but why on earth do the pylons need to be so big? Can't you bury power cables? Isn't there any new technology out there to make the wires and/or the pylons smaller? Frankly, you'd better come up with a story about this if you want to have any chance at all of convincing my party

To: ministerenviron@northlandgreens.org.nld

From: ministerindustryenergy@northland.gov.nld

Jan,

Thanks for your helpful e-mail outlining the concerns of your party. We always try to work closely with our coalition partners and to that end I have asked some of my top people to produce an outline report explaining the key issues by the end of the week after next. I hope you find this useful in both explaining things to and persuading your colleagues

To: ministerindustryenergy@northland.gov.nld:

From: ceo@northlandpowertrans.co.nld

Dear Minister,

I know we have spoken about this before, but I really must repeat that the Northland N-S interconnector is crucial for our industry's and your government's plans regarding renewables. The fact is that our largest source of renewables is 250 miles away up on the north coast and we have to get the power down here. We might have 16 GW of capacity up there and we'll have to transmit it at 750KV or we'll waste huge amounts just heating the conductor wire! We'll need multiple lines to carry that AC current (Google skin effect if you want the technical stuff) and at that voltage we've got to keep it high off the ground. Sorry, but there is no alternative to our interconnector project.

To: ceo@northlandpowertrans.co.nld

From: ministerindustryenergy@northland.gov.nld:

Remind me again why we can't bury the cables?

To: ministerindustryenergy@northland.gov.nld:

From: ceo@northlandpowertrans.co.nld

Well basically the cost is so much greater. It's not just that you have to dig a trench; it's also that the cable (by the way we call them wires when they are above the ground, but cables when they are buried) itself is so much more expensive. Most underground power cables have a triple or quadruple insulated structure, with some bits being at high potential, some at earth (the outer insulator) but often you need to put ionic salts at low potential in between those layers to reduce the chance of water getting into micropores in the insulator. And of course metal is so expensive these days – hence all the thefts of copper cable that are causing such problems on the railways. Ideally we need something really cheap to carry current underground. Sadly, the cheapest electrical conductor is actually metallic sodium! Try burying that in our damp soil…'

To: ministerindustryenergy@northland.gov.nld:

From: chiefstaff.industryenergy@northland.gov.nld:

Time to go over to Northland University; you are looking at some research funding applications this afternoon.

To: chiefstaff.industryenergy@northland.gov.nld:

From: ministerindustryenergy@northland.gov.nld:

OK, on my way. Do you suppose there's any chance that this group will come up with anything useful or relevant?

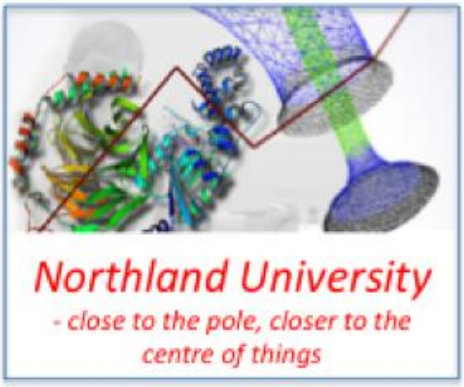
To: ministerindustryenergy@northland.gov.nld:

From: chiefstaff.industryenergy@northland.gov.nld:

Could be. You were at the School of Architecture before, but this lot are physical scientists, and their research has been rated as 'world-leading'. Don't let them bog you down in technicalities, though – just ask the odd 'so what' question every now and then until you've got it clear what they can actually do.

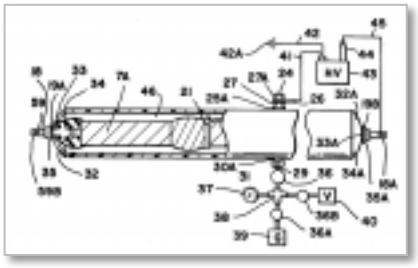
The Task:

- Look through the research funding applications from ‘Northland University’
- Consider the problem and discuss the grid approach to power transmission.
- Compare the relative strengths and weaknesses of each of the described approaches.
- Do any of the approaches described in these funding applications look like they might be relevant to the problems facing the Minister of Energy in Northland as it struggles to link its large reserves of renewable energy to the main electric grid system 300 miles away?
- Could any of these approaches potentially reduce the financial and environmental costs of imported copper cables and the increasing problem of cable theft?
- What is the skin effect? Is it relevant to any of these approaches?
- Create a short (around 3 slides) presentation for the minister detailing the potential of one or more of the projects in this area (use the above bullet points as a guide to what should be included). Include a description of what is shown in the slides in the ‘Notes’ section beneath the slides.



Research Funding Application

Gas Pressurised cable and conduit system



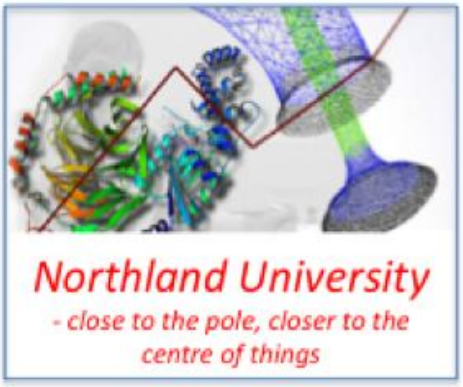
The chemical engineering department at Northland works on cable and electrical system safety in offshore oil platforms. Typical problems are in power transformers, and situations where there is a danger of chemical or fire hazards near electrical equipment.

We have used our own hazard extreme electrical testing unit plant (HEETUP) for many years. We wish to upgrade this plant by installing much more robust electric cabling conduits. We have developed a way of pressurising sulphur hexafluoride to form an insulating layer around metal conductors. Sulphur hexafluoride is both chemically inert and a high dielectric insulator. We have designed a system for producing gas pressurised SF_6 cables, which comprises taping machines for surrounding the conductor with a continuous insulating spacer and uses through taping machines for applying a conducting shielding material which partially covers the spacer. The insulated and shielded cable is continued on in the same production line into conduit, which is laid out horizontal in long lengths or is extruded loose-fit over the cable. The cable is then subjected to vacuum while in the conduit.

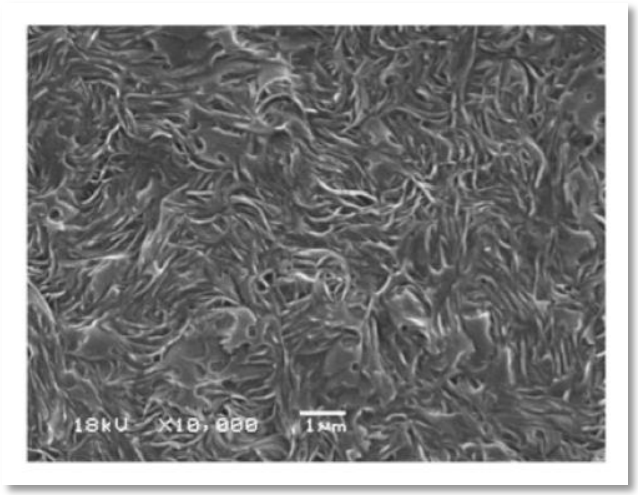
Experimental sections of cable using this technology have shown extreme resistance to fire, electrical breakdown and chemical hazard. At temperatures up to 1000C and under severe reactive conditions (oxidants, acids, alkalis) the central current carrying core is still protected by the insulating layer.

While we would like initial funding to upgrade our HEETUP system we would like to apply for ‘follow-up’ funding to investigate other applications. We feel that there could be potential for extending this cable technology to other applications, in the oil refining, chemical, and electrical industries.

Research Funding Application



New polyethylene blend materials



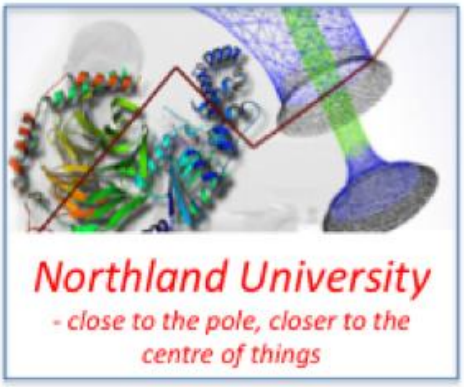
We have produced a novel polyethylene material by blending linear and branched polyethylene (LPE / BPE) as potential replacement materials for chemically crosslinked polyethylene (XLPE).

XLPE is a form of crosslinked polyethylene It is formed into tubing, and is used predominantly in hydronic radiant heating systems, domestic water piping and insulating applications.

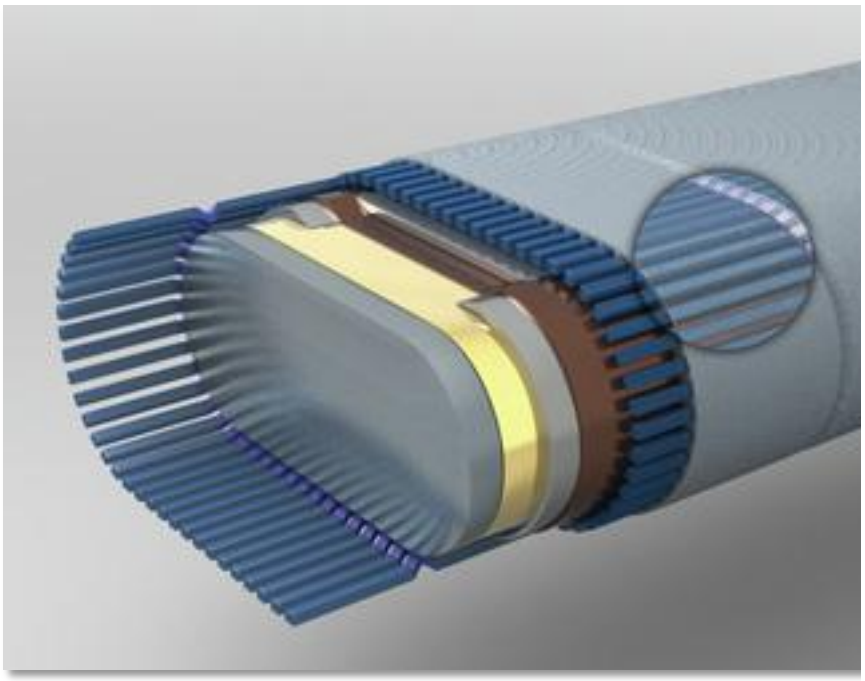
Our blends contain BPE in virgin and crosslinked states and also blended with 20wt% LPE. We have analysed the thin film AC ramp breakdown behaviour of blends as a function of temperature up to 97 C. In addition we have carried out dynamic mechanical analysis. In concert, these data show that with appropriate control the blended thermoplastic material outperforms XLPE under conventional operating conditions and may even be suitable for higher temperature operation than XLPE.

Our lamellar crystal distribution and uniform distribution of impurities means that electrical tree growth can be greatly retarded. Developing this material does require more funding. We plan to carry out extensive mechanical creep testing and model cable trials. The effects on mechanical and electrical properties of longer term annealing, possible ageing at higher temperatures and of recrystallization following high temperature short circuit transients would require more research.

Research Funding Application



Lightweight electrical cabling

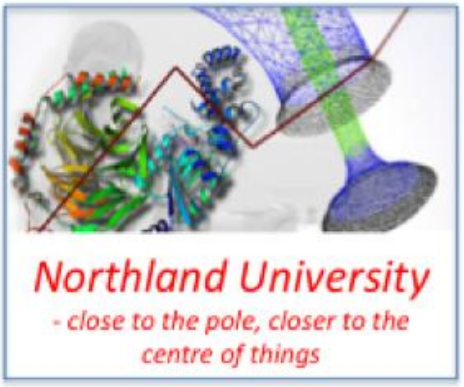


We are working on a new form of electrical cabling with world leading weight for weight conductivity. The key feature of the technology is the light-weight core which exploits metals with extremely mobile isolated 2s or 3s electrons. We believe this cable could be a third of the price of copper cabling which it could replace in many applications.

In many applications, it is not the resistance of the cable per se that is important, but rather its impulse tolerance (how much electricity you can briefly put through it without damage). Our cable is capable of surviving electrical impulses 700% more intense than the tolerance of an equivalent copper wire. Uniquely the core metal can still conduct electricity even if an overload causes it to melt, and defects are effectively self-healing. The cable is made using a single microfluidic continuous casting ("MCC") process and can be produced in a wide range of lengths and diameters. It incorporates unique safety bulkheads, which are the subject of a national patent.

Copper prices, although historically high, do not reflect the true cost of primary copper production, which includes billions of dollars annually in environmental damage, health costs and human suffering. Each ton of copper extracted produces five tons of CO_2, one ton of SO_2, global warming, acid rain, NO_x, arsenic, antimony, lead, mercury, zinc and other forms of air and water pollution.

We would like to apply for funding to support extensive field trials of this unique material.



Research Funding Application

Aluminum Core Power Line

Most power transmission lines are based on steel cores that support the aluminum conductors. Many of the existing transmission lines were designed and installed years ago and are now thermally constrained, which affects the amount of power that can be transmitted before performance is impacted. Due to a phenomenon called skin effect, the current capacity of a cable is not proportional to cross section, for the larger sizes. Some installations bundle multiple wires together to increase capacity, however this can be a problem in areas with strong prevailing winds.

We have developed a power line with aluminum rather than steel cores. Each core includes aluminum oxide fibers, which impart very high strength to weight ratio. The resulting cable weighs half as much and is able to continuously handle 210 degrees Celsius (and in an emergency 240 degrees Celsius), with considerably less sag than traditional conductors. This means that the power transmission capacity of a line can be greatly increased. Technically, the ceramic fibers are continuously oriented in the direction of the wire and are fully embedded within high-purity aluminum.

We would like to apply for funding to trial this power line in some field trials in Northland.

Research Funding Application

Northland University
- close to the pole, closer to the centre of things

Very high conductivity of layered lead zirconate titanates

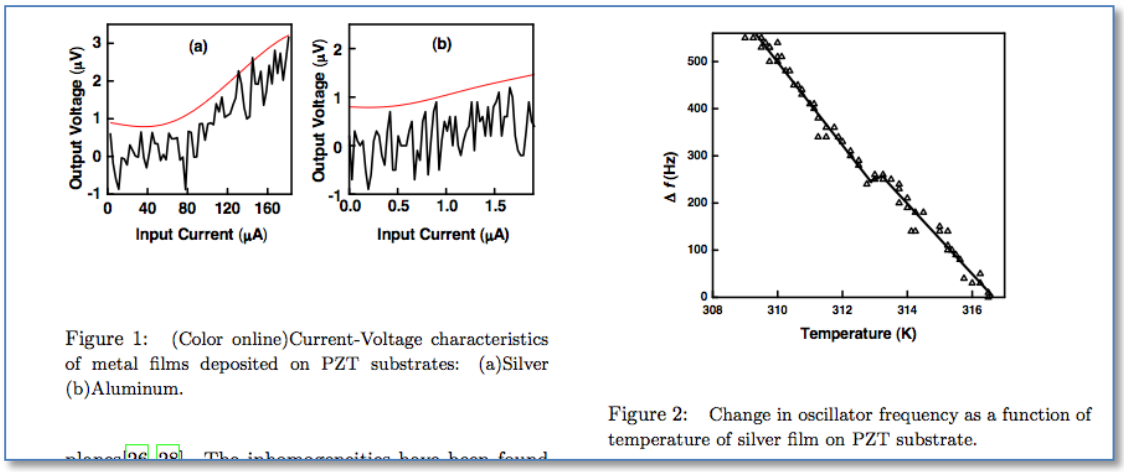


Figure 1: (Color online)Current-Voltage characteristics of metal films deposited on PZT substrates: (a)Silver (b)Aluminum.

Figure 2: Change in oscillator frequency as a function of temperature of silver film on PZT substrate.

We report extremely high conductivity in composite layers of either aluminum or sliver deposited on a substrate of lead titanate zirconate (LTZ). The samples used for current-voltage measurements were (i) thin strips 2 cm × 2 mm cut off from commercial LTZ discs 0.3 mm thick and with an average grain size 1 μm which were supplied in the poled state and with 0.1 mm silver coating on both faces and (ii) the same type of strips with the original silver coating removed and 4000A aluminum deposited by vacuum evaporation. The Curie temperature of the material was 360^0C as specified in the manufacturer's data sheet.

Measurements were carried out at room temperature using a four-probe arrangement with the sample placed inside a double permalloy magnetic shield, the residual magnetic field inside the enclosure being less than 10^{-5} tesla. The output voltage, which was of the order of microvolts, was measured using a home-built instrumentation amplifier based on an Analog Devices AD620 chip. Data were recorded in an Agilent 54622A digital storage oscilloscope by using a sawtooth current excitation at a frequency of 20 Hz from a function generator. It was found that scanning near this rate yielded the most consistent and reproducible data, least affected by fluctuations and noise.

The experimental results reported here strongly suggest the presence of very high conductivity near room temperature in the interface between a metal film and a LTZ substrate. We interpret the data in terms of the experimentally-observed inhomogeneous charge patterns in high-temperature superconductors.

Group reflection

Review your progress in this session and think about what remains to be done. Construct a brief plan of action – the plan should include a list of the tasks that each group member is expected to do and a timescale for each of these tasks to be done. Remember to include enough time to proof read each other's work before submission. You should briefly present this plan to your tutor before the end of the session.

Part 3: Environmental Impact & Societal Issues

Session 4 (90-120 minutes)

Pre-Session Preparation

You should be prepared to discuss the following topics in this session:

- The emission of carbon dioxide due to the existing means of power generation (outlined in the 'Welcome to Northland' information) and the new approaches referred to in part 1 of the problem (i.e. Biofuel, Photovoltaic cells, Nuclear, Wind power and Fossil fuel combustion with carbon capture)
- Other sources of carbon dioxide emission associated with power generation by the means listed above. This includes emissions due to transport of fuel and emissions due to other associated processes (e.g. Fuel processing)
- The impact of carbon dioxide emissions in the context of the greenhouse effect

Intended Learning Outcomes

Scientific:

By the end of this part of the problem you should be able to:

- Use a spreadsheet to model the energy needs of a nation over a 12 year period and determine the carbon footprint of the nation over the same period
- Use the a spreadsheet model to compare the environmental impact and energy output of different approaches to power generation
- Write a set of meaningful conclusions based on the output from a spreadsheet model.

Transferable:

By the end of this part of the problem you should be able to:

- Work effectively in a group on a data processing task.
- Use a spreadsheet model in Microsoft Excel.
- Write a short report based on the outcomes calculated by a spreadsheet model.

To: scienceteam@northland.gov.nld

From: scienceminister@northland.gov.nld

Sent with high priority

Subject: 12-year projection

Dear Team,

Thank you for selecting a suitable sustainable solution for our nation's future energy needs. It is now important for us to predict the short term impact of this project in terms of the nation's total energy output and our carbon footprint. We need to be able to back up our decision with some numbers!

Please find a spreadsheet model attached to this email. You should be able to use this model to calculate the nation's estimated carbon emissions and energy output for the 2011-2022 period. Please use your selected form of power generation (as presented to the press recently) as a starting point, work out how much power it will deliver, how much CO_2 it will produce and what the impact of phasing some existing forms of power generation (e.g. the existing nuclear power facilities) will be on these numbers.

It is important that we take action that will allow us to reduce the carbon footprint of the nation while still producing enough energy to meet the nation's needs. Summarise your findings in a one to two page report which includes figures (include the spreadsheet as an appendix).

Provide a comparison of the impact of your chosen approach with the other proposals that were made (i.e. the other four proposals that were discussed in session 1). It would be useful these figures backed up our decision to invest in your chosen technology.

Best wishes,

Robert Davies (Northland Science Minister)

Group reflection

Review your progress in this session and think about what remains to be done. Construct a brief plan of action – the plan should include a list of the tasks that each group member is expected to do and a timescale for each of these tasks to be done. Remember to include enough time to proof read each other's work before submission. You should briefly present this plan to your tutor before the end of the session.

Session 5 (90-120 minutes)

Pre-Session Preparation

You should be prepared to discuss the following topics in this session:

- The mechanism of global warming including both the physical basis of the phenomenon and the actual impact on average global surface temperature
- The impact of transport and heating to the carbon footprint of nation

Intended Learning Outcomes

Scientific:

By the end of this part of the problem you should be able to:

- Calculate the energy consumed by transport and heating sectors and compare these values with the electricity sector
- Decide how much installed capacity is required to match the energy demands of various sectors
- Determine how the required amount of installed capacity would have to vary if a programme of rail electrification and/or introduction of electric vehicles was pursued.
- Use the a spreadsheet model to evaluate a number of potential solutions to a nation's future energy needs
- Describe the absorption of infrared radiation by greenhouse gases and explain why this phenomenon leads to a global average surface temperature higher than that predicted by a simple black-body model of the atmosphere.
- Describe measures that can be taken to minimise global warming.

Transferable:

By the end of this part of the problem you should be able to:

- Work effectively in a group on a data processing task.
- Use a spreadsheet model in Microsoft Excel.
- Write a short report based on the outcomes calculated by a spreadsheet model.
- Research an area of scientific interest for the general public (i.e. global warming) and write a report in a way that is accessible for a defined audience type (i.e. a chemistry graduate)

Part i

Government Announces Ambitious Transport Plans

Story from the Northland Gazette

The Government last night unveiled its ambitious plans to end the nation's dependence on diesel transport. The government plans to make a major investment which will allow recharging points for electric vehicles to be fitted across the nation. The government has also announced the electrification of two mainline rail routes. It is hoped that this will keep the government on target for its goal of producing 80% of the nation's energy needs from renewable sources.

To: scienceteam@northland.gov.nld

From: scienceminister@northland.gov.nld

Sent with high priority

Subject: Northland Energy Balance

Dear team,

There has been some confusion in the press about our policy of trying to achieve 80% of our energy from renewables. Some commentators are accusing us of only including electricity in that figure and ignoring transport and Built environment (heating). Before we put out a statement clarifying things can you do a quick estimate for us?

I'm sure that electricity is in fact much the largest sector, but can you quickly calculate the energy requirements of the heating and transport sectors? As chemists, you should be able to work back from the carbon dioxide emissions of each sector to get the energy consumption. Can you compare these sectors with the electricity sector so we can see what the implications might be if, for example, we moved much of our transport to electric vehicles or trains?

Use these figures:

Current Carbon Footprint 55.4 million tonnes CO_2

- *Transport :14.4 MT*
- *Built environment 22 MT*
- *Power generation 16.6 MT, from total 10,600 MW installed capacity*

to calculate the energy consumed in the transport and built environment sectors of Northland

The 'Northland Carbon template' spreadsheet has some data which should enable to go from tonnes of CO_2 emitted to tonnes of diesel fuel, gasoline or natural gas used. You should be able to use heats of combustion to calculate the energy consumption of these sectors

Convert the energy figure from Joules to Terawatt-hours so you can make a direct comparison with the electricity figures. How much extra generating capacity would Northland require to move a significant amount of transport or built environment to zero-carbon renewables?

Please submit an updated version of your report from last week which includes these figures.

Best wishes,

Robert Davies (Northland Science Minister)

Part (ii)

To: scienceteam@northland.gov.nld

From: scienceminister@northland.gov.nld

Sent with high priority

Subject: Warming mechanism

Dear Team,

The Prime Minister has requested a report on the mechanism of global warming. Recent statements from members of the opposition have demonstrated increasing scepticism about the science behind global warming and a general lack of enthusiasm in investment in renewables. The PM feels that we have to do something to inform both the public and the politicians.

As a trained chemist, the PM understands that CO_2 absorbs photons of energy and stops them from radiating out into space. The PM feels that climatologists have confused the public with their computer models and attempts to measure baseline temperature changes.

The PM believes that these models are trying to calculate how quickly we had to reduce carbon production and not whether it was important to do so! The PM said that 'the thermodynamics is settled, the models are just trying to establish the kinetics', but I'm not entirely sure what he meant by this!

Is it possible to calculate how much energy is emitted by the Earth at frequencies that are absorbed by CO_2. If we could determine this (and the amount of CO_2 in the atmosphere) we should be able to determine how much radiation has been absorbed by the CO_2 shouldn't we?

Please prepare a short report (no more than 600 words) on this process and include any relevant calculations. There are a few other points that you should include in your report: Is it possible to measure the infrared spectrum of the atmosphere somehow and see this absorption? And what happened to the energy? Did it go down to the ground or stay in the atmosphere? What can we do to minimise this warming effect?

Best wishes,

Robert Davies (Northland Science Minister)

Group reflection

Review your progress in this session and think about what remains to be done. Construct a brief plan of action – the plan should include a list of the tasks that each group member is expected to do and a timescale for each of these tasks to be done. Remember to include enough time to proof read each other's work before submission. You should briefly present this plan to your tutor before the end of the session.