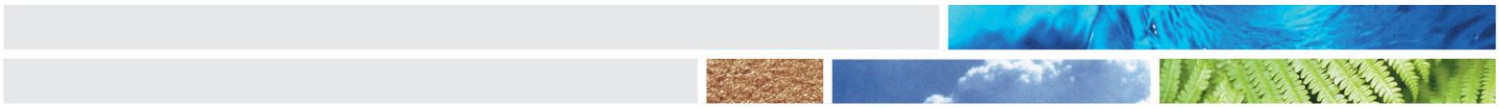
Environmental Protection Authority
Te Mana Rauhī Taiao

Appendices to the EPA advice on application ERMA200833 – the proposed release of *Clostridium magnum*

MARCH 2012



APPENDICES

New Zealand Government

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Appendix 1: Risk assessment of the proposed release of *C. magnum*

1. Scope

1.1. Application ERMA200833 from LanzaTech is for the release of *Clostridium magnum* – a bacterium new to New Zealand that can convert carbon-based gases to acetic acid.

1.2. LanzaTech has carried out research on *C. magnum* in their containment laboratory and now wishes to carry out activities outside of a containment facility. In order to carry out such activities they have applied for a release approval without controls under the Hazardous Substances and New Organisms (HSNO) Act.

1.3. The assessment of the potential risks, costs and benefits of the release of *C. magnum* was undertaken for five areas of impact: human health and safety, the environment, society and community, the relationship of Māori to the environment, and the market economy. *Clostridium magnum* was also assessed against the criteria of the minimum standards (section 36 of the HSNO Act).

1.4. *Clostridium magnum* (Schink 1984) is a bacterium that was originally isolated from mud. *Clostridium magnum* is a strict anaerobe so it dies when exposed to air. However, under certain conditions it can produce endospores (pages 5-6 of the application). Endospores are dormant forms of a bacterium formed during unfavourable conditions that can survive for long periods of time.

1.5. The applicant stated that their proposed activities will involve strains of *C. magnum* that have been in culture for many generations and noted that the ability to produce spores can be lost during continuous culturing (page 5-6 of the application). However, this risk assessment assumes that *C. magnum* may produce endospores.

1.6. While the initial activity using *C. magnum* is proposed to occur within an anaerobic vessel within a pilot plant, should the larger scale process be proven, the technology is intended to be commercialised (page 4 of the application). Therefore the risk assessment took into account that *C. magnum* may be grown and used anywhere in New Zealand.

1.7. The risk assessment also assumed that as this application is for a release without controls (rather than for an application where *C. magnum* will need to be totally contained within a facility); *C. magnum* may form self-sustaining populations in the New Zealand environment.

1.8. The risk assessment looked at the release of *C. magnum* in relation to the following three scenarios:

- Pre-commercialisation: development and running of a pilot plant (at a single site within New Zealand) - **Scenario 1 (pilot plant)**.
- Post commercialisation: limited adoption by industry at selected sites within New Zealand - **Scenario 2 (New Zealand implementation)**.
- Post commercialisation: large-scale adoption by industry worldwide - **Scenario 3 (worldwide implementation)**.

2. Identification and assessment of benefits

2.1. The possible benefits we identified from the release of *C. magnum* are outlined in Table 1 of this Appendix.

2.2. We considered that the following benefits would be significant:

- Gaining scientific knowledge from the operation of the plant(s), honing the process for commercialisation and intellectual property generation.
- Retaining international class scientific talent in New Zealand.
- Society and community beneficial effects from the development and use of sustainable 'green' technologies and greenhouse gas-capturing technologies.
- Providing growth and support opportunities for associated companies including enhancing the ability to form partnerships with carbon gas emitters and promoting increased international investment into research and development.

2.3. Given LanzaTech's prior successes we have assessed the likelihood of these benefits as **highly likely** to occur. The magnitude of the benefits has been assessed as **major** based on their significance to New Zealanders and New Zealand.

2.4. In conclusion the benefits have been assessed as **high**.

Table 1: Identification of potential benefits

Potential benefit	Scenario 1: Pilot plant (at a single site in New Zealand)	Scenario 2: Limited adoption (at specific industrial sites within New Zealand)	Scenario 3: Large-scale adoption (at industrial sites worldwide)
• Gain in scientific knowledge from the operation of the plant(s), honing the process for commercialisation and intellectual property generation • Retain international class scientific talent • Wider society and community beneficial effects from the development and use of green technologies and greenhouse gas-capturing technologies	See section 2 of the advice. Many New Zealanders see scientific research (such as into green technologies) as a way to fulfil their personal self-development as well as a way of contributing to making New Zealand a better place to live in. So even if the technology is ultimately unsuccessful there is value to New Zealand and New Zealanders in allowing such activities to occur in New Zealand (Rankin, 2011). LanzaTech has previous successes including an existing pilot plant which produces ethanol from waste gases (Anon, 2010). LanzaTech also has collaborations to build demonstration plants overseas (see below). Given LanzaTech's prior successes we have assessed the likelihood of these benefits for all three scenarios as **highly likely**. The magnitude of the benefits has been assessed as **major** based on their significance to New Zealand and New Zealanders. In conclusion the benefits have been assessed as **high**.		

Potential benefit	Scenario 1: Pilot plant (at a single site in New Zealand)	Scenario 2: Limited adoption (at specific industrial sites within New Zealand)	Scenario 3: Large-scale adoption (at industrial sites worldwide)
• Provide growth and support opportunities for associated companies • Enhance ability to form partnerships with carbon gas emitters • Encourage increased international investment into research and development	LanzaTech has been successive in attracting international investors and contracts such as a US $55.8 new investment publicised in January 2012 (Lanzatech, 2012). LanzaTech has gained numerous awards and accolades including in 2011 being named Platts Global Energy's "Sustainable Technology Innovation of the Year"[1] (former OPEC energy ministers, national regulators, former heads of major energy companies and leading academics and legislators are among the past and current judges of these awards) (see http://lanzatech.co.nz/media/media-releases). LanzaTech has previous successes including an existing pilot plant which produces ethanol from waste gases (Anon, 2010) and has been successful in forming collaborations such as building a demonstration plant in Shanghai to use the off gases from a steel mill to produce ethanol (Lanzatech, 2011). Given LanzaTech's prior successes, we have assessed the likelihood of these benefits for all three scenarios as **highly likely**. The magnitude of the benefits has been assessed as **major** based on their significance to New Zealanders and New Zealand. In conclusion the benefits have been assessed as **high**.		

[1] see http://geaweb.platts.com/Home.aspx

Potential benefit	Scenario 1: Pilot plant (at a single site in New Zealand)	Scenario 2: Limited adoption (at specific industrial sites within New Zealand)	Scenario 3: Large-scale adoption (at industrial sites worldwide)
Reduced greenhouse gases through less carbon emissions with consequential: • environmental and human health beneficial effects • production of commercial quantities of acetic acid so that New Zealand industries do not need to import acetic acid/New Zealand could become an exporter of acetic acid	Due to the limited nature of pilot plants, we do not consider that there would be a significant reduction in New Zealand's carbon gas emissions for this scenario. For example, if it is assumed that a pilot plant may reduce carbon emissions by 50-100 tonnes per annum (LanzaTech, pers. coms), this is equivalent to removing 17-34 cars off the road or the planting of 1.5-3 hectares of radiata pine in the Auckland region (worked out using figures obtained from the Ministry for the Environment (2011), the Ministry of Transport (2011) and the Climate Change (Forestry Sector) Regulations 2008). While this may not be significant in a New Zealand-wide context (with New Zealand's carbon dioxide emissions being 35,231,500 metric tons CO_2 equivalent in 2007 (Ministry for the Environment, 2009)), a reduction would be proof of the potential value of this technology.	We recognise the potential reduction in carbon emissions (and production of acetic acid) from the commercial implementation of a technology based on *C. magnum*. As the magnitude of benefits would depend upon which facilities adopt the technology, their level of carbon-based gas emissions and the level of reduction in carbon-based gas emissions/production of acetic acid seen after the use of this technology, at this stage would be too speculative for us to make an assessment.	We recognise the potential reduction in carbon emissions (and production of acetic acid) from the commercial implementation of a technology based on *C. magnum*. This benefit would be worldwide. As the magnitude of benefits would depend upon which facilities adopt the technology, their level of carbon-based gas emissions and the level of reduction in carbon-based gas emissions/ production of acetic acid seen after the use of this technology at this stage would be too speculative for us to make an assessment

Potential benefit	Scenario 1: Pilot plant (at a single site in New Zealand)	Scenario 2: Limited adoption (at specific industrial sites within New Zealand)	Scenario 3: Large-scale adoption (at industrial sites worldwide)
Approval would be consistent with the New Zealand Government's strategies of reducing greenhouse gas emissions	Of the 2007 New Zealand greenhouse gas (GHG) emissions, 47% was from carbon dioxide (35,231.5 gigagrams = 35,231,500 metric tons) of carbon dioxide equivalent (CO_2-e)). The largest GHG emission source is from agriculture (48% in 2007), with other sources including the energy (43%), industrial processes (6%) and waste (2%) sectors (Ministry for the Environment, 2009). Even though most of our greenhouse emissions are from agriculture, as some of the CO_2 emissions are from industry, New Zealand may directly benefit from technologies that could reduce CO_2 emissions as well as indirectly through a reduction in other countries' CO_2 emissions. The New Zealand Government has announced national targets for reducing New Zealand's GHG (Ministry for the Environment, 2009). While the Emissions Trading Scheme is the Government's principal policy response to climate change, there are other strategies or initiatives in place. For example a independent advisory group (called the Green Advisory Group) has been set up by the Government to look into green growth topics including greater development and adoption of new technologies including clean technologies (e.g. technologies, products or devices aimed at reducing GHG emissions and other pollutants) in New Zealand's productive sectors (Green Growth Advisory Group, 2011). The development of technologies that use microorganisms to convert carbon-based waste gases into valuable products is consistent with the Government's strategy of reducing New Zealand's GHG emissions.		

3. Identification and assessment of adverse effects

3.1. We identified and then assessed the following possible adverse effects from the release of *C. magnum*:

- *Clostridium magnum* causes disease in humans, plants or animals.
- *Clostridium magnum* displaces native species within their natural habitat, causes significant deterioration of natural habitats or causes significant adverse effect to New Zealand's inherent genetic diversity.

Assessment of *C. magnum*'s ability to cause disease

3.2. We note that while most members of the genus *Clostridium* are saprobes (i.e. they live on dead or decaying organic matter), there are a few members that can cause diseases such as *Clostridium perfringens* (Todar, 2011; Vos et al, 2009). After reviewing the known biological charactertistics, there is no evidence that *C. magnum* will cause disease in humans, plants and animals or will become a vector for human, plant or animal diseases.

Assessment of *C. magnum*'s ability to displace native species within their natural habitat, cause significant deterioration of natural habitats or cause significant adverse effect to New Zealand's inherent genetic diversity

3.3. The distribution of bacteria in the environment is the subject of on-going research. It has been proposed that a bacterial species will either exhibit biogeography (it is only found at specific locations and therefore limited in distribution) or will not (it is ubiquitous i.e. unlimited in distribution) (Finlay, 2002; Fenchel, 2003).

3.4. Examples of organisms that show biogeography are plant pathogenic bacteria which are highly evolved to a host species and exhibit the same biogeography as the host, or bacteria of 'rare biospheres', such as those that live in very specific but limited habitats e.g. thermal vents (Patterson, 2009).

3.5. Bacteria responsible for the general decay of organic material are likely to be ubiquitous as they are easily dispersed and readily find suitable habitats in which to grow (Geddes, 2009). As a saprobe, *C. magnum* is likely to be ubiquitous; although it must be treated as a new organism under the HSNO Act as it has not be isolated in New Zealand. Other closely related *Clostridium* species have been found in New Zealand e.g. *C. autoethanogenum* (page 5 of the application) .

3.6. The composition of microbial populations can be influenced by a number of factors. For example in soil, the composition of microbial populations can fluctuate depending upon the temperature, soil texture and structure, pH, salinity, moisture levels, which plants are grown in the soil, and the presence or absence of suitable resources (Turbé et al, 2010). So although ubiquitous microorganisms may be detected everywhere (Griffin, 2007), they will only be metabolically "active" if the appropriate environmental conditions prevail.

3.7. In many cases it is the presence of a suitable substrate which is quickly colonised and utilised so that the microbe might only be metabolically active while an ephemeral island of opportunity (the substrate) exists. As Garrett (1951) notes, with reference to soil fungi, that in a particular environment there is an assemblage of species observed that can quickly utilise an ephemeral substrate rather than an ecosystem.

3.8. Therefore *C. magnum* would be only metabolically active when the substrate that it utilises is available (i.e. it would be effectively absent when the substrate is absent). We also note that the colonisation of a substrate by *C. magnum* would be through a chance encounter with that substrate rather than it actively seeking that substrate. Therefore we consider that should *C. magnum* (as a bacterium or an endospore) reach an anaerobic niche, it is unlikely to displace other organisms present, cause significant deterioration of natural habitats or cause significant adverse effect to New Zealand's inherent genetic diversity.

Conclusion

3.9. We did not identify adverse effects from the release of *C. magnum*.

3.10. The Department of Conservation and the Ministry of Agriculture and Forestry did not raise any concerns with the release of *C. magnum.*

Assessment against the minimum standards

3.11. Any organism being assessed for release must pass the five minimum standards as stated in the HSNO Act.

3.12. The minimum standards require the decision makers to consider:

- If *C. magnum* is likely to cause any significant adverse effects on human health and safety.
- If *C. magnum* is likely to cause disease, be parasitic or become a vector for human, animal or plant disease.
- If *C. magnum* is likely to cause any significant displacement of any native species within its native habitat.
- If *C. magnum* is likely to cause any significant deterioration of natural habitats.
- If *C. magnum* is likely to cause any significant adverse effect to New Zealand's inherent genetic diversity.

Is *C. magnum* likely to cause any significant adverse effects on human health and safety or cause disease, be parasitic or become a vector for human, animal or plant disease?

3.13. For the reasons discussed in section 3.2 of this Appendix, we do not consider that *C. magnum* will cause any significant adverse effects on human health and safety, or cause disease, be parasitic or become a vector for human, animal or plant disease.

Is *C. magnum* likely to displace native species within their natural habitat, cause significant deterioration of natural habitats or cause significant adverse effect to New Zealand's inherent genetic diversity?

3.14. For the reasons discussed in sections 3.3-3.8 of this Appendix, we do not think that it is likely that *C. magnum* will displace native species within their natural habitat, cause significant deterioration of natural habitats or cause significant adverse effect to New Zealand's inherent genetic diversity.

Conclusion

3.15. We consider that *C. magnum* passes the minimum standards.

Appendix 2: Summary of the main themes raised in submissions

Three submissions were received. One submission opposed of the proposed release of *C. magnum*. The key points from the submissions are summarised below.

Environment

Potential effects, concerns or issues raised	Illustrative quote	Response
C. magnum may cause significant biogeochemical changes. The wider impact of such effects is unknown. We don't know a lot about the anaerobic environments.	"*The bacterium Clostridium magnum is an organism with metabolic capabilities that are the basis of its value in the developing technology of exhaust gas carbon capture. These same capabilities give it the potential to effect significant biogeochemical changes within any anaerobic environment into which it might be introduced. The wider impact of such effects is unknown and could be major. Anaerobic environments in deep soil and unstirred aquatic environments are large, little investigated and very little understood*." (Cliff Mason #102510)	Potential adverse effects is addressed in in Appendix 1.
The strains used should be restricted to non-sporulating laboratory strains.	"*However, while the strains used in the LanzaTech method may be compromised in their ability to be survive outside of strictly anaerobic environments, the designation of the species as approved for release will render the same approval for sporulating forms that may be introduced by other parties in the future*." (Cliff Mason #102510) "*It is thus necessary for there to be controls placed on any approval for wider employment of the bacterium*	As this is an application for release, we have conducted the risk assessment based on the effects that *C. magnum* would have once it is in the environment. Restricting an approval to non-sporulating laboratory strains of *C. magnum* is a mechanism for reducing the persistence of *C. magnum* in the environment. Under section 27A of the HSNO Act, the decision makers can approve a new organism at any taxonomic classification that they think fit. Therefore only specific strains of an organism can be

Potential effects, concerns or issues raised	Illustrative quote	Response
	outside of containment laboratories. These controls should specify that the organism should be non-sporulating……." (Cliff Mason #102510)	approved. However, there is no evidence that *C. magnum* will have adverse effects on the environment or human health and safety (Appendix 1), and whether *C. magnum* can or cannot produce spores does not change this assessment. We note that it has been shown that in the laboratory, spore production can be restored in other bacterial strains which had lost the ability to produce spores (Sastalla et al, 2010). Therefore we do not recommend that *C. magnum* is limited to non-sporulating laboratory strains.
Controls should be imposed so that the organism is contained.	"*These controls should specify ….. that there should be strict accountability for the containment and ultimate destruction of the organisms in any industrial application. They represent a biohazard which, while of unknown proportions, is effectively the same as a radiation of other physical hazard for which similar controls would be universally accepted as necessary in routine operations. Unfortunately, even with well established and understood precautions in the use of physically dangerous materials and processes, accidents have happened. It is liklyn that the same will occur even with containment and other precautions in use of a biohazardous agent but this does not lessen the justification for such precautions*." (Cliff Mason #102510)	As this application is for the release of *C. magnum*, we have conducted the risk assessment on this basis and looked at the effects that *C. magnum* could have once it is in the environment. Imposing containment requirements is a mechanism to prevent the exposure of *C. magnum* to humans, animals, plants and other microorganisms. Section 38B of the HSNO Act allows controls to be imposed (i.e. the application be treated as a conditional release application) with the agreement of the applicant. However, there is no evidence that *C. magnum* will have adverse effects on the environment or human health and safety (Appendix 1). Therefore we do not recommend that controls be imposed to limit the exposure of *C. magnum* to the environment or humans.

Human health and safety

Potential effects, concerns or issues raised	Illustrative quote	Response
There could be a reduction in the harmful effects from pollution.	LanzaTech "*has the potential to assist to make large contributions in reducing the harmful effects from a range of polluting industries that would be of benefit to Maori and the Community at large*." (Clean Earth #102505)	Potential benefits are addressed in Appendix 1.

Relationship of Māori to the environment and the Treaty of Waitangi

Potential effects, concerns or issues raised	Illustrative quote	Response
The application does not carry a lot of information about relationship with Māori.	"*The application is very brief on the relationship of Maori*" (Clean Earth #102505)	In accordance with our consultation policy, we advised that the applicant did not need to consult about this application. We consider the information provided in the application to be appropriate. Should this application be approved we are aware that consultation at a local level will occur when facilities are developed.
The EPA should assist applicant to identify groups to consult with at plant site(s).	"*recommend the EPA assist the applicant to built robust knowledge of the availability of databases of the tangata whenua that have manawhenua status in the chosen area where the site may be established*." (Clean Earth #102505)	Should this application be approved, we are open to providing the applicant assistance in establishing a relationship with the tangata whenua at the plant site(s).
This project demonstrates the rationale that more R&D investment is needed in emerging low-carbon industry.	"*It demonstrates the rationale that has been touted by Maori and others that more R&D investment is needed in emerging low-carbon industry to secure our livelihood for the future pathway forward is worth pursuing*." (Clean Earth #102505)	Potential benefits are addressed in Appendix 1.

Society and community

Potential effects, concerns or issues raised	Illustrative quote	Response
Potential to create green technologies and clean tech products.	"*there is the potential to create technologies that will contribute a range of products that would move the global field posts towards clean tech products sooner*." (Clean Earth #102505)	Potential benefits are addressed in Appendix 1.
If the application is not approved LanzaTech could be forced to go overseas.	"*Not approving this application will be likely to drive New Zealand's leading clean-tech company off-shore causing irreparable damage to the sector in New Zealand. The damage will be caused not only by the loss of Lanzatech itself, and the associated opportunities for companies working with Lanzatech, but also the atmosphere it will set for related companies*." (NZBIO #102508)	Potential benefits are addressed in Appendix 1.
Provide growth and support opportunities for associated companies and New Zealand's high value clean tech sector. Continue to be a key part of New Zealand's ability to promote itself as being innovative and a technology leader. Increase confidence to invest in clean tech in New Zealand.	"*If this application is approved Lanzatech will be able to develop new processes and technologies in this country and can retain a strong New Zealand presence and identity as it grows. The company will be able to continue to provide growth and support opportunities for associated companies and New Zealand's high value clean tech sector in general. They will continue to be a key part of New Zealand's ability to promote itself as being innovative and a technology leader as well as being "a nice place to visit*"". (NZBIO #102508) "*Other companies will see the success that Lanzatech has achieved in New Zealand and have the confidence to invest in clean tech activity here*." (NZBIO #102508)	Potential benefits are addressed in Appendix 1.

Market economy

Potential effects, concerns or issues raised	Illustrative quote	Response
There may be benefits from high paying jobs and high margin exports.	"*Approving this application will make it possible for New Zealand to benefit from the huge international clean tech market. It will lead to high paying jobs and high margin products and services for export around the world.*" (NZBIO #102508)	Potential benefits are addressed in Appendix 1.

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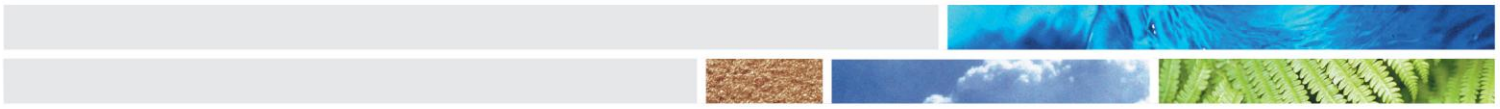

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