A sustainable sewerage system for Glenorchy

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1 Introduction

Communities wanting sustainable sewerage options need to recover the nutrients from their waste streams in a way that meets public health needs, while using a minimum amount of energy and water. Essentially a sewerage system must cater for all well beings of the governing Act: social, cultural and economic, without impacting on the environment.

If the only consideration were the chemical (nutrients and water) and pathogen components of the sewage, then the most sustainable system would be that which: used no water, needed no energy, recycled all nutrients and killed all the pathogens (such a technology is called the Beacon). There is thus a continuum between the technology perfection inherent in the Beacon and direct discharge of raw sewage (the absence of technology).

Bringing the community's well beings into consideration implies a location on this continuum at which these well beings are optimised. In addition, as the cultural and economic elements of a community change over time then this optimisation question also involves consideration of changes over time.

The approach taken here to make sense of this complexity is to utilize the existing organizational forms, in particular: a community's location and size, regulatory institutions and commerce, and embed their behaviour patterns within the information realm. In the information realm each entity can be considered a semi-autonomous unit with interconnections to other units. As we can understand the behaviour characteristics of each entity by observation, then the focus can move towards the interconnections between the participants.

From the sustainability perspective of this work, the performance of the current suite of technologies were found wanting. In particular, nutrient recycling is very difficult and needs substantial energy, while water use as a transfer mechanism for faecal wastes needs to be questioned. The reason for the 'gap' in the available technologies was attributed to the industry in general – there is little incentive for commerce to improve and/or manufacture more sustainable technologies if councils are pushing conventional sewerage systems onto un-sewered communities.

However, small communities can form an important component of change in the industry. Particularly as:

- There is little risk for councils of allowing forward looking individuals within a small community to choose sustainable technologies – the risk of technology failure lies with the individual, rather than the community, the council, or the environment.
- The role of the primary adopter in effecting social change is widely acknowledged in the social sciences and this attribute can be used by councils to encourage the development of more sustainable technologies for our waste streams. With such a high value in effecting change, primary adopters need to be nurtured. Mechanisms by which this can occur within a

community sewerage system by using the economic system are shown to be possible (Chapman, 2015b).

- The change to sustainable technologies in the industry can be incremental and not inconsistent with a community reticulation system; as everyone will generate greywater for which a community reticulation system is reasonable. Using a community reticulation system means a council's requirement for monitoring water discharges is satisfied as there is a single discharge point. Individual variability reduces to volumes and chemical characteristics of the water that is being transported. The 'space' for acknowledging an individual's contribution to sustainability is not extinguished with a communal reticulation system.

As Glenorchy has very strong sustainability aspirations and is currently un-sewered, it can contribute to change in the industry by creating 'space' for primary adopters in those locations that are suitable. Creating space for these people then generates information signals that motivate commerce to manufacture technologies that enable nutrient recycling with minimum energy and water use. However, this potential is lost when a 'conventional' sewerage system is 'imposed' over the whole community, as it stifles the creativity inherent in the variability between different locations and individual preferences.

2 Background

In related work I argued that to begin to make sense of the Nature: human use of Nature complexity it is convenient to divide the full complexity into two: a **Nature** Information processing Structure using the fundamental laws and processes (Chapman, 2013), and **human** complexity (Chapman, 2014a). The boundary between these two is where our technologies are created and can be made creative in a number of different ways (Chapman, 2014c). The notion of an optimum technology for a community can be asked and answered.

In diagrammatic form, this optimum technology (X) would be located at the intersection of the three semi-autonomous organisational forms (called *Structures*) that facilitate human functioning, as in Figure 1:

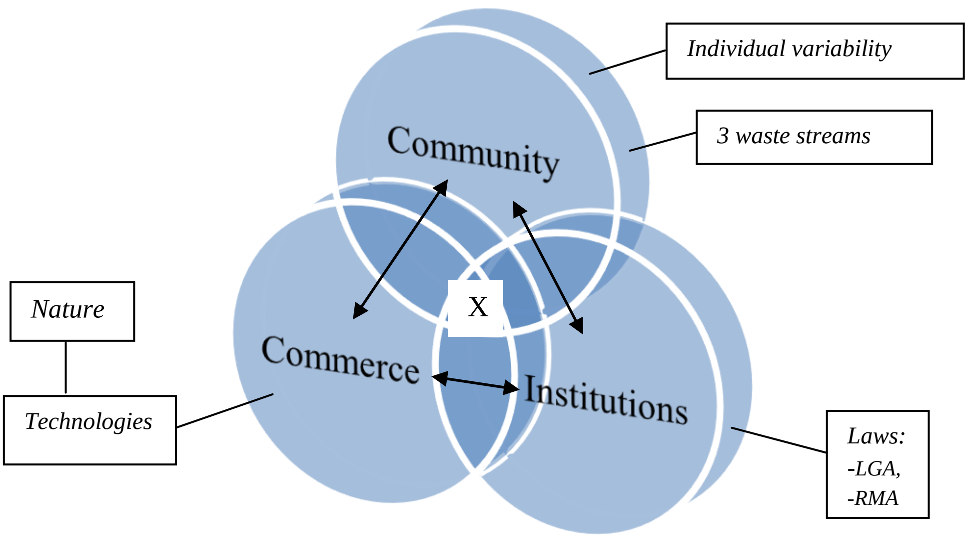

Figure 1 – Separating the human parts of the planet's complexity while retaining the system's interconnections (possible in the information world) enables a separate assessment of each part which then combines with the other parts to enable identification of an optimum technology (X) for the community. This optimum is a mix of available technologies (Nature within a technology that is manufactured by commerce), institutional requirements and the community's economic well being.

This paper takes this background and applies it to a small community of a few hundred people who have very strong sustainability aspirations.

Two particularly useful concepts from this background: the notion of a Beacon and interconnections between the Structures, are repeated below.

2.1 Nature's special Structure – The Beacon

In the context of our waste streams it is possible to define a hypothetical technology that: used no water, needed no energy, recycled all nutrients and killed all pathogens. This is a special state of Nature that occurs when sustainability criteria are applied **before** Nature is formulated for a particular technology. This is called the Beacon in Chapman (2013) & (2015d) as it has two components: a position in information space (all the sustainability zeros) and a guiding beam that can cut through the murky messiness of human functioning. The 'cut through' element of the guiding beam arises because the zeros are quantitative (and consequently measurable) meaning a pass/ fail test is unavoidable, unarguable and unable to be affected by politics.

This Beacon can be used by all parts in Figure 1. This is in contrast to commerce's use of Nature's Structure where Nature is formulated for a particular technology.

The Beacon is a useful mechanism by which the performance of **all** technologies (current and possible) can be judged. But also as the Beacon fully meets the purpose of the Resource Management Act 1991 (RMA), in the case of sewerage it is a very useful tool for councils because of its explicit perfection.

2.2 Interconnections between the Structures

The optimum technology for the community (X in Figure 1) would need all of the following:

- Commerce to produce the most sustainable possible technology; and
- The governing institutions to encourage/allow its use; and
- The community to be aware of its existence.

If the technologies are available and within the public dialogue, then the optimum for the community involves choosing from the suite of technologies those that best meet their needs (which include environmental consequences).

In contrast, if such a technology is **not** available then the information flow needs to encourage its development.

It becomes apparent that each of these semi-autonomous organisational forms needs some external criteria by which their particular performance is measured. Sub-optimal behaviour by any of the participants in Figure 1 will prevent the optimum (X) from being achieved. Mechanisms to achieve this external critique play an important role in optimising the development of technologies over time. The Beacon can serve this role as it is external to all human functioning (Figure 2).

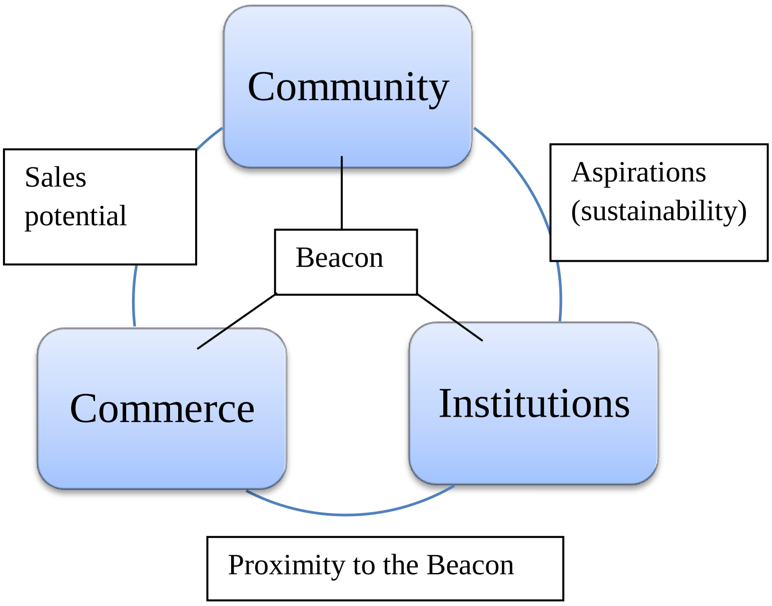

Figure 2 – The interconnections between the Structures. Where the Beacon arises from applying the sustainability zeros to the assemblage of FL&P that describe the system and consequently is outside of all social organisational forms.

It becomes apparent that this optimum technology will also need the **information** flows between the participating Structures to be consistent with the best possible technology. The community needs to know what is the best possible; commerce needs to know that the community desires the best possible and the institutions need to act in a manner that does not impede knowledge of best possible.

3 Two level decision structure for optimisation

Consider beginning with the planet and Nature's special Structure (Section 2.1 above). This is a useful starting point as Nature was doing Nature's thing long before humans existed on this planet. Being a carrier of what is possible if the sustainability zeros are applied to Nature outside of all human structures, then using the Beacon begins without influence from human messiness.

It follows that using the Beacon in the first optimisation consideration (Figure 3), means that the proximity of the available technologies to the beacon is similarly assessed against a standard that is outside of human systems. If the current technologies are found wanting then the task becomes the mechanisms to motivate commerce to search for better technologies. If it were a decision tree that contains branches, then each branch would require a decision before moving on to the next branch. This decision tree (or more particularly resolving deeper level constraints before moving to the next constraint) is a component of the journey into information space that is necessary to find the optimum technology.

For a community's waste issues, it is sufficient if the **system** optimisation is broken into only two parts – the first being the comparison to the Beacon, while the second is the whole suite of *techniques* available to enable the community to make the best decision. With the available technologies rated against the beacon then the optimisation task for the community reduces to mechanisms for considering meeting their needs and well beings from either:

- the suite of current technologies if they pass the first optimisation consideration, or

- if the available technologies are found wanting, then create 'space' for new technologies so that they can be used when they arrive and give commerce signals to produce these better technologies.

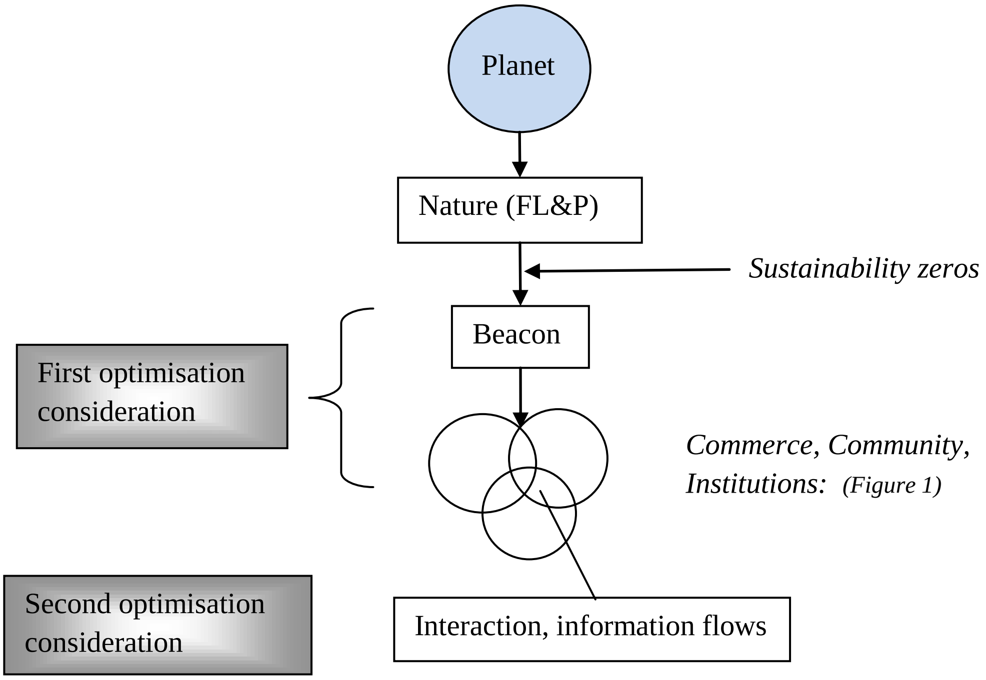

Figure 3 – A two level optimisation structure that enables the Beacon to serve a guiding role in the system optimisation.

4 The first optimisation consideration - is the incumbent technology(s) the most sustainable?

Rating current technologies by comparing their performance to the Beacon to identify possible gaps is not location specific; consequently it needs to occur as a society consideration rather than a community consideration.

The incumbent technology (flush toilet with all three waste streams mixed, and carried in sewers to a central treatment station) is an historical artefact that over the years has had numerous 'adaptations', none of which appear to have questioned the validity of previous 'adaptations'. An exception to this generalisation was the installation of separate sewers, as using the storm water system (the original 'sewer') caused treatment station overflows during rain events. This occurred because the decision to use a water-based **transfer** system preceded the treatment system (this historical artefact also explains why treatment stations are at the end of the pipe). See Benidickson (2007) for more detail of this history.

Consider scrutiny of the desirability of the incumbent technology, for which in the first instance, there is a need for a dispassionate appraisal of the flush toilet with non-flush toilets. If the flush toilet is the most sustainable possible technology then continue with a conventional sewer.

However, if it isn't the most sustainable then we would be well advised to begin developing better technologies; and what better place to begin this process than with a community which does not currently have a sewerage system. Resolving this question requires using the pre-technology boundary

with the comparison being as in Figure 4. The comparison can be done in detail (Chapman, 2014b) and include costs and pathogen control, but a superficial assessment would suggest such detail is not necessary to conclude that the flush-toilet is sub-optimum as:

- Flush toilets require a water flush therefore they fail the zero water criteria.
- The nutrients (particularly N) are primarily in the urine pointing to the desirability of urine collection technology's efficacy for nutrient recycling.
- Energy is required to move the flush water and supply oxygen for nitrification in this aqueous environment, so energy use would be reduced if water were not used to carry the toilet wastes. Particularly as diffusion requires no energy and can be used as an oxygen transfer mechanism if faeces remain in their solid form.

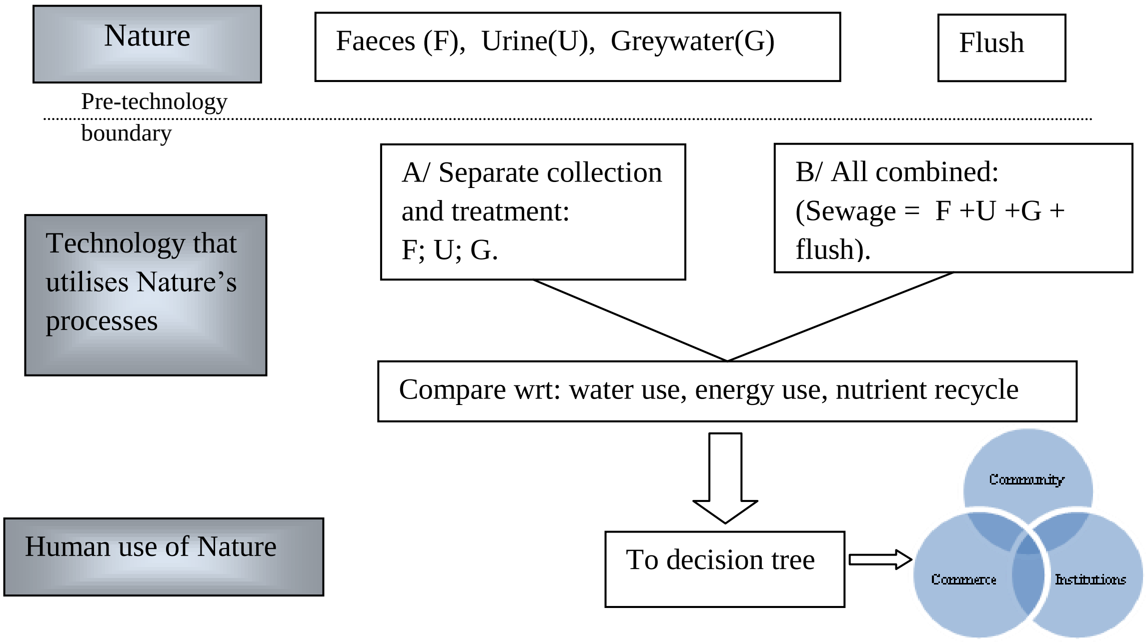

Figure 4 – Using the pre-technology information boundary to get data on the value, from within a sustainability context, of the separate treatment of each waste stream as compared with a conventional sewerage system. The sustainability context in this case being water use, energy use and nutrient recycle potential.

Beginning with sustainability aspirations in the comparison of Figure 4 means that the result of the comparison test determines whether the flush toilet can be a part of the continuing path towards sustainability. However, the flush toilet fails on all of the relevant sustainability criteria: water use, energy use and nutrient recycling potential. Even the detail does not provide support for the flush toilet. Consider the increased energy requirement for the planet when a conventional treatment station converts nitrates and ammonia into elemental N (requiring energy), while somewhere else in the world a company uses more energy to convert elemental N into nitrates for fertiliser. Linking the nitrates (and P & K) in our faeces and urine to fertiliser for food growing is easily the least energy consuming and consequently the more sustainable.

An equally compelling argument can be made for pathogen control strategies, for which toilets with long retention times enable strategies that require less chemicals and energy. These time-based pathogen control strategies become economically viable with the small annual volumes of faeces; but these are only small volumes if the water flush is eliminated. In comparison, time in a conventional

sewerage system is very expensive due to the large volumes involved – most of which arise from the greywater and the toilet flush. A more in depth discussion of the separate treatment question is contained in Chapman (2014b).

Indeed, sewerage systems are "*not especially clever, nor logical, nor completely effective – and it is not necessarily what would be done today if these same countries had the chance to start again*" (Feachem, Bradley, Garelick, & Mara, 1983, p. 64).

5 Industry constraint

With a failure to pass the first optimisation consideration, the behaviour of each of the system participants (commerce, institutions and communities) needs consideration.

To begin addressing this constraint, gather some more information:

- Are non-flush toilets available – yes?
- Are urine collection systems available – yes but not in NZ.
- Are they part of the industry dialogue? – No!!

As preferable technologies are available, but not widely used, then the constraint is **not** primarily a technological one, but rather is best viewed as an **industry** constraint; necessitating consideration of how the industry can begin to move towards sustainable technologies. Particularly, as the purpose of the industry's governing act necessitates sustainability considerations and that the flush toilet fails to pass the first optimisation consideration. This industry consideration needs to include the information flows between the industry participants.

The decision tree of Figure 4 can be in the form of:

- If the preferred technology is available but not suitable, then initiate improvements. In this case the detail is in **how** to initiate improvements and **what** needs improving.
- If there are cultural limits to adoption of the preferred technology then deal with this issue. This presumably would involve social change theories, such as the role of the primary adopter.

Resolving these industry constraints will necessitate a mix of:

- Information flows, and
- Technology design, and
- Cultural changes.

However, the question for Glenorchy is how it can position itself to facilitate the needed transition to more sustainable technologies for our waste streams; particularly as these sustainability sentiments are so deeply held within the community. These sustainability aspirations arise in part because Glenorchy is so dominated by Nature that people with these sentiments are drawn to the area. In a 2001 questionnaire 77% of respondents wanted an "environmentally friendly sewerage system" and in a repeat of that planning process in 2015, sustainability was the most strongly supported goal for the long-term vision.

6 Applying the optimisation procedures to Glenorchy

To summarise Glenorchy's information space within which the waste issue needs to be optimised:

- Resident's sentiments are strongly oriented to sustainability.
- We have specific locations within the town that have discharge issues.
- Nutrients (nitrogen) are the main discharge concern.
- These concerns are likely to deepen in the future, necessitating future upgrades of any technology.
- Technology development is needed to enable cost-effective nutrient recycling.
- Industry dialogue is information poor in terms of the most sustainable technologies.

Then a part of the optimisation question for Glenorchy is how it can facilitate movement of the **industry** towards the more sustainable technologies that the community desires. Movement requires time so there is a time component to this industry change.

For Glenorchy, time necessitates either waiting for better technologies, or creating space so that when they arrive that can be incorporated.

The issue in Glenorchy is spatially and temporally complex:

- Geographical variation arising from some immediate discharge issues – particularly the commerce area and Humboldt Park.
- Time that is necessary to develop (and commercialise) the more sustainable technologies that the community desires.
- Cultural change needed to move away from the flush toilet and the space to adopt non-flush toilets when they arrive.

To which we need to add all the other areas of complexity discussed in this series of papers; particularly the difference between the 3 waste streams, and the nutrient recycle potential of each technology.

Given this spatial and temporal complexity, then the optimisation question for Glenorchy can be rephrased as: how to achieve a decreasing nutrient load to receiving water **over time**, while maintaining the economic well being of the community **and generating useful information signals for commerce to action**. This level of complexity is not suited to a *one size fits all* approach.

The need for a decreasing nutrient load however, is an issue amenable to mass balance laws. As mass originates from each atom, this starting point enables us to trace the atom's path from the nutrients needed to grow the food we eat, through the technology chosen to deal with our faeces and urine, and back to the planet's nutrient cycles. The optimisation question consequently begins without any distortion arising from an 'expected' technology solution and can be formulated with the community's sustainability aspirations as a primary constraint. In addition, as an atoms 'path' through the body determines whether it appears in the faeces, urine or greywater (such as skin cells or body exudates that are washed off), then this starting point also includes the difference between the 3 waste streams and individual variability.

In effect, optimisation of waste disposal systems for small communities currently using on-site systems needs to begin with technologies that are *clever, logical and effective* – these communities ***have** the chance to start again* and avoid the inefficiencies of the incumbent water-based transfer

system (where the italics are words from Feachem et.al's 1983 summary that **do not** have the constraints of conventional sewerage systems).

If *clever, logical and effective* technologies are **not** available then the first optimisation consideration is finding mechanisms to create them. This is Glenorchy's current state.

Logical technologies will be consistent with the evidence from the mass balance approach (discussed above) as energy (thermodynamics) also links to atoms – be it the static/dynamic energy flows needed to move mass (read water), or the thermal energy needed to nullify the decreased microbial performance in a cold climate.

However, *logic* can also be applied to each component of a conventional sewerage system by using mass balance laws (and microbial kinetics). This is convenient as each of the components can then be considered separately in the information space of Glenorchy's optimisation:

- Reticulation – All residents require disposal of their greywater which is the greatest *volume* of sewage. Reticulation is unaffected by nutrient loading (although it may be affected by carbon if it is in a solid form and requires minimum water velocities to prevent blockage) and largely unaffected by volumes (assuming distance affects capital cost more than pipe size). A reticulation system satisfies the council requirement for monitoring discharges, as a single discharge point can be engineered.
- Treatment – this is *directly affected* by pathogens, BOD_5 (carbon) and nitrogen concentrations and indirectly affected by volumes. The costs (capital and running) are consequently affected by any technology choice that a household may (or may not) make.
- Disposal – Land disposal is directly affected by *volumes* and indirectly by BOD_5 and N.

Effective technologies, in addition to ones based only on logic, will kill all pathogens and recycle nutrients without using water or needing energy – they will satisfy the sustainable zeros. While *clever* technologies will not only be *logical* and *effective* but also consistent with the community's vision – the community will emphasise with the system.

6.1 The limit to effecting sustainability in Glenorchy

The 'gap' preventing Glenorchy from choosing the most sustainable system is the available technologies – which is argued to be an industry issue, in part because the information flows are not supportive of their development. Therefore the dominant considerations for Glenorchy's optimisation question are:

- To create space for sustainable technologies so they can be used when they arrive; and
- How to generate (and use) the flow of information to nurture the development of more sustainable technologies; particularly as the industry appears to have difficulty with this.

The spatial and temporal variability in Glenorchy can play a role here. In particular, the need to fit the spatial variability inherent in the current on-site discharge systems with the need to decrease nutrient loadings to receiving waters over time. This spatial variability is best considered as separate issues:

- The immediate issues: the commercial area and Humboldt Park. The immediacy of these issues necessitates choosing from the incumbent technologies for a solution.
- However, the areas **not** in immediate need of an upgrade have much more flexibility in the technologies they choose, and can wait for technology development. These areas can be used to generate information signals for the industry.

- Consider creating space for nutrient recycling technologies within the sewerage system as greywater disposal is required by all residents. This satisfies the regulatory requirement for monitoring discharges.

A ‘solution’ to this is beyond the length of this paper, but the essential elements necessary for a solution are preserved in this suggested framework. In particular, the spatial variability inherent in the current on-site system is not lost and there is ‘space’ for residents to choose more sustainable technologies in the future.

The information signals to the industry are also more complex than this paper can cover but in the information realm it is only necessary for the information to have ‘space’; it is a human function as to what notice is taken of this information. Councils (and commerce) can ignore this information but this would be counter to the intent of their governing act.

However as a participant in the full complexity, a community can hold their council to ensuring that the information space is not distorted *against* the sustainable technologies that their governing act requires. Mass balance laws in particular are outside of all human constructions and consequently also outside any exercise of power that attempts to distort the information landscape against the more sustainable technologies.

Mechanisms that Glenorchy can choose to help move the industry towards sustainable technologies include:

- Incentive to reduce water volumes.
- Acknowledge dwellings which recycle nutrients (and reduce load on the community treatment system).
- Send commerce signals: “if you manufacture a product that captures nutrients cost effectively I would consider purchasing one”.
- Use the economic system as an information carrier.
- Fully explore the possibilities inherent in considering the components of the system (reticulation, treatment and disposal) separately within the sustainability context that the community desires.

7 Conclusion

With small communities we have a chance to do something which retains the creative potential that lies at the boundary between science, commerce, and our institutions exercising our laws.

The lack of effective technologies that enable nutrient recycling while minimising water and energy use, is argued to be an ‘industry’ problem as the incumbent technology (centralised sewerage system) is so far away from *what is possible*. This is a deeper level question for which it is argued that small communities who do not have a sewerage system have the potential to choose a different path; but this potential is lost with a one-size-fits-all approach, or by ‘imposing’ a sub-optimal technology on the community.

The Glenorchy community has strong sustainability aspirations. These aspirations, when combined with the observation that better technologies are possible (and will need time to be developed), means that the spatial variability that exists within the current on-site systems can be usefully linked with social theories of change to generate ‘information signals’ that are accessible to commerce. When commerce produces better technologies (in part motivated by these signals) then these can be used by

the community to meet their sustainability aspirations. Our behaviour patterns can form a component of the information flow, with the added advantage that this 'signal' is not filtered through our bureaucracy.

The signals to commerce and our governing institutions are particularly important in view of the evidence of the industry failing to move towards sustainable technologies.

We can begin the optimisation question for a small community with the sustainability purpose of the governing act and use information lumping techniques (each semi-autonomous social organisational form) and navigation aids (such as the fist optimisation consideration of Figure 3) to identify technologies that are *clever, effective and logical*.

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