



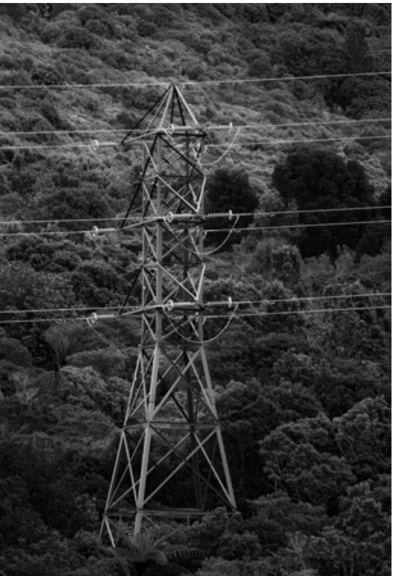

Wider than freshwater

How non-freshwater related activity can indirectly influence and have impact on freshwater outcomes

June 2024









Wider than freshwater

How non-freshwater-related activity can indirectly influence and have an impact on freshwater outcomes

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Foreword

In recent years significant effort has been invested in developing national and regional policy to improve freshwater outcomes. The National Policy Statement for Freshwater Management (NPSFM) is an example of this. Much good work has been completed and much more will continue to be done. Yet freshwater issues are only one of the many challenges that both national and regional policy seek to influence.

Significant government effort is also being made to address issues such as housing affordability, greenhouse gas emissions and climate change, indigenous biodiversity, and social challenges such as income inequality and improving health outcomes. Such challenges are complex, and there is an understandable and natural tendency for policy efforts to focus on each subject area narrowly. While each is important, this narrow focus risks policy efforts becoming siloed within organisations or subject areas. This may result in policies across different subject areas being at best uncoordinated, and at worst directly conflicting with each other.

Increasingly, such policy challenges are not only seen as complex in their own right, but as inter-related and affecting each other. Action in one policy area is not independent of impacts in another. Recognising such interconnectedness and incorporating it into policy development will be an increasingly necessary skill in the future.

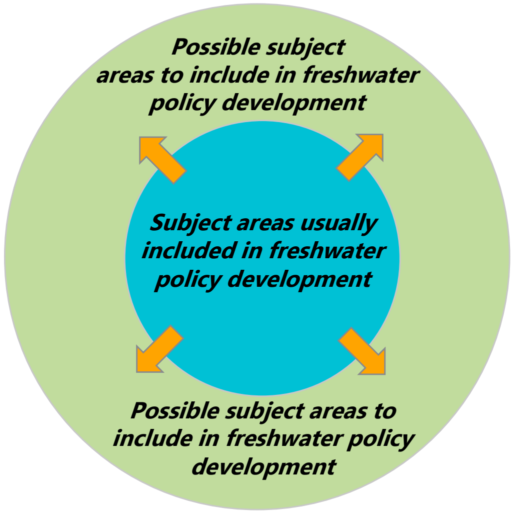
This guidance document recognises such interconnectedness. It draws on a systems-thinking approach and seeks to provide initial steps towards understanding the complexity of how some of these 'other' issues are related to, and affect, freshwater outcomes. The document is intended to support freshwater policy discussions and the people involved in/with them. While the primary audience is policy professionals, we believe this will be useful to anyone with an active involvement or interest in the development of freshwater policy and action.

That said, it should be stressed that this is not a guide on how to develop policy. At the time of writing, resource management reform is underway. This guidance does not provide detail on, or answers to, exactly what policies should be written and where. Rather, it is intended as a tool to support *discussing freshwater issues in a more interconnected way with other policy areas*. It is intended to help expand the subject areas that are discussed or included in freshwater policy development.

Within systems science there is a widely held view that it is not possible to 'solve' complex issues. Complex systems are dynamic and we will never know everything about them. They will, therefore, always surprise us. Instead, our aim should be to navigate complexity as best we can. We take this view. As one participant noted during the interviews that informed this document:

'recognising complexity is one thing; embracing complexity is the next thing'.

This work has omissions. Not everything can be included, and our collective understanding of how the subject areas discussed here are connected will continue to evolve. In the meantime, this document can help people take early or continuing steps to build their understanding of the many issues relating to freshwater management. For some, we hope this helps them recognise the complexity of achieving freshwater outcomes; for others, we hope this is a pragmatic tool to support them taking steps towards embracing such complexity and acting on it.



1. Background to this work

Since 2011 successive New Zealand governments have introduced and subsequently amended the National Policy Statement for Freshwater Management (NPSFM), a policy that instructs regional councils and unitary authorities to set enforceable and measurable water quantity and quality limits across all freshwater bodies. Five iterations of the NPSFM have been published since 2011, filling a gap in national freshwater policy direction that had been present since the establishment of the Resource Management Act in 1991.

Despite this resurgence of central government policy direction in freshwater, regional councils and unitary authorities have experienced difficulties implementing these policies in practice, including aligning local plans with updated versions of the NPSFM and with other national standards and objectives (Kirk et al. 2020). For example, along with implementing the NPSFM and National Environmental Standards for Freshwater (NESFM), regional councils and unitary authorities also have a responsibility to implement national direction on plantation forestry, urban development, highly productive land, coastal areas, renewable electricity generation, air quality and drinking-water, and indigenous biodiversity. These policies and standards are developed by different government ministries, not always with explicit consideration of the interactions between them. As a result local authorities have struggled to manage the competing demands of multiple national directives, with the potential for ineffective policies and provisions, and unintended policy consequences.

These tensions highlight an urgent need to integrate responses to a range of environmental, social, and economic issues. To support this integration, this document maps a broad array of influences on freshwater quality and quantity that are relevant when setting policy affecting freshwater.

The general goals of this guide are to:

1. **highlight to policy makers the inter-related areas related to freshwater, and the impact they may have on freshwater outcomes**
2. **suggest some 'leverage points' (or places to take action) in addition to those traditionally included in freshwater discussions, to help achieve freshwater outcomes.**

2. How to use this document

In this document we do not outline *how* to develop freshwater policy. We seek to highlight *what other policy areas* affect freshwater outcomes and therefore would be useful to *include in or align with freshwater policy*. It is structured with this in mind, demonstrating interconnectivity at a high level and supporting this with visualisations.

Each area discussed is highly complex in its own right. Other expertise and sources of information are available to help understand each of these in detail. We do not seek to summarise all such knowledge here: we simply seek to highlight the *generalised or generalisable interconnections* between these areas. This is intended as a complementary companion to the detailed knowledge and expertise that exist in both freshwater and the other areas discussed.

This report is structured so that each section can be read relatively independently. Yet, we recommend a complete read of the document as these individual areas are interconnected. This allows specific areas to be read or revisited independently and used as a prompt to guide potential policy alignment. In each section we also present leverage points for achieving freshwater outcomes. These are not explicit recommendations or suggestions for policy responses. They are intended to be thought-provoking in the pursuit of improved policy alignment. The leverage points are graded as lower, medium, and higher leverage (read: impact)

We have grouped major sections of the guidance with coloured tabs. Some important sections of this guide are:

- an overview of the systems-thinking approach used (section 4)
- an overview of all the inter-related issues (section 5)
- those issues that are specific and proximal to freshwater (section 6)
- those issues that are broad and underlying (section 7).

We identified connections between freshwater policy and other policy domains through interviews. Although we interviewed people with expertise in te ao Māori (the Māori world view) and mātauranga Māori (Māori knowledge), we acknowledge that our systems analysis does not capture a strong te ao Māori perspective. The way Māori conceptualise the connections between wai (water) and other areas of importance will differ from non-Māori approaches. We recognise that to attempt to align the concepts of te ao Māori with the approach used in this guidance may compromise, or not fully represent, te ao Māori perspectives.

What this document can do is assist co-development of policy with Māori by supporting more systemic and interconnected thinking by policy makers.

3. The approach taken in this work

We developed the insights presented in this document using a systems-thinking approach. After the authors identified key areas of interest, 11 subject matter experts from those areas were interviewed. We then synthesised what we heard using systems-thinking methods, producing causal diagrams to demonstrate interconnections. For ease of reading we have not included citations relating to expert elicited perspectives.

3.1 What is systems thinking?

Systems thinking is a general term that recognises that the world that we live in is a dynamic, interconnected place of cause and effect. Policy is usually developed in response to some kind of challenge(s). Such challenges can be thought of as undesirable trend(s) (e.g. a declining level of something or an increasing level of something). Systems thinking is a good way of understanding the causes behind such trends in order to try to change them (e.g. by identifying the actions needed to change the trend in a more desirable direction). While there are many methods or disciplines that may be considered systems thinking, this work is guided by the discipline of system dynamics.[1]

Systems thinking provides a conceptual framework and set of tools to help clarify patterns of interconnectedness at a high level (Senge 2006).[2] It deliberately seeks to simplify the complex *detail* of specific areas in order to help build an understanding of the complex *inter-relationships of influence* between areas. In short, it seeks to understand how elements combine, rather than breaking them apart and looking at them in isolation.

Doing this helps us understand how various interacting factors that generate the trends or 'behaviour' we are trying to understand and then change. Once these interconnections are articulated, we can better understand which parts of a system are having the most influence on behaviour, allowing us to identify the areas of greatest influence, which helps inform where to intervene.

The main qualitative systems-thinking tool used in this guidance is the causal diagram. A description of the fundamentals relating to how a causal diagram operates is provided in section 4 and Appendix 1. There we explain the key feature of systems thinking and causal diagrams: the concept of *circular causality* instead of linear *causality* (see Figure 3-1). In our diagrams this takes the form of either *reinforcing or balancing feedback loops*. Feedback loops are the basic building blocks of causal diagrams.

(To fully understand the causal diagrams presented in the remainder of this report, unfamiliar readers should acquaint themselves with the contents of section 4 and Appendix 1.)

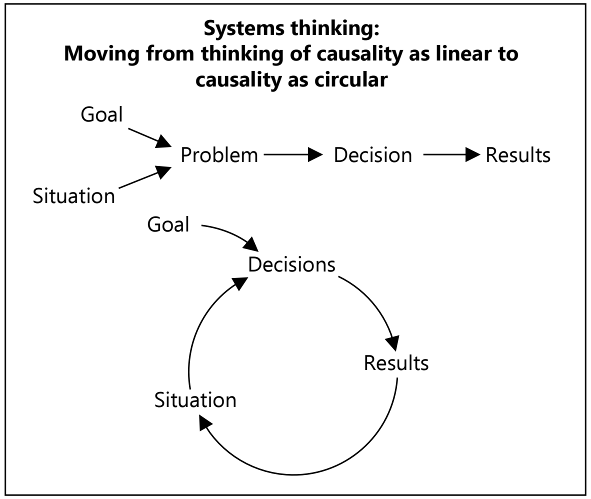


Figure 3-1. From linear to circular causality.

[1] System dynamics originated from the Sloan School of Management at the Massachusetts Institute of Technology, Cambridge, Massachusetts, in the late 1960s.

[2] For a detailed introduction to the concepts of systems thinking, the reader is referred to *The Fifth Discipline – The art and practice of the learning organisation* (2nd ed.) by Peter Senge (2006) as an accessible introduction.

3.2 Data gathering

As noted earlier, in this work we don't focus on the detail of freshwater policy development. Rather, we seek to highlight *how other policy areas outside of freshwater are broadly inter-related and influence it*. This helps to build understanding and highlight insights.

Among the authors we have deep specialist knowledge in freshwater policy and environmental management. This knowledge was supplemented by other specialists with expertise in:

- climate change and greenhouse gas (GHG) emissions
- energy generation and use
- transitioning to a low carbon energy future
- biodiversity and biosecurity
- green infrastructure and nature-based solutions to climate change and urban issues
- freshwater policy development, particularly with a focus on governance and community involvement
- freshwater management perspectives
- freshwater and terrestrial ecology.

The subject matter experts were asked to identify macro trends they thought might be related or linked to freshwater management, including those not yet on people's 'radar'. The focus on trends was a deliberate tactic, aligned with a systems-thinking approach that seeks to understand trends over time and the inter-related factors causing them.

3.3 Grouping influences and identifying leverage areas

We analysed the data gathered in the interviews and identified potential causal elements and inter-relationships. We then summarised these insights into two broad sections, which have informed the structure of this document.

1. ***Inter-related freshwater issues or factors that are specific and proximal (near) each other:*** these are most of the areas *usually included* in freshwater policy discussions, as well as many that are not. They were able to be drawn in a causal diagram, which highlights their interconnectedness, giving insights into what to factor into policy development.
2. ***Inter-related freshwater issues or factors that are broad and underlying many of the specific factors:*** these are *often not included* in freshwater policy discussions. They were not able to be drawn in a causal diagram, but these issues, trends or factors should be considered when discussing the proximal factors identified in the causal diagrams.[3]

These two sections are presented separately but are interconnected and should be considered together, where possible. Note that the issues and inter-relationships described here are general. While the strength of influences will vary depending on the local context, the general relationships described are expected to hold true.

This guidance suggests that the greater number of issues influencing freshwater are included in policy discussions, the better the final policy and outcomes. The rationale for this is based on the concept of leverage within a system (see section 4.5). When considering this kind of leverage, it is important to bear in mind that the most proximal (nearest) subject areas are *not necessarily the most powerful* for making change. Decision-makers and policy practitioners should be aware of this in order to have the greatest impact.

[3] The system diagram is a visual tool that relies on connecting written nodes or factors with arrows of influence. Because many of the broad and underlying issues, trends or factors affect so many of the factors in the diagram, any attempt to represent them would have made the diagram messy and confusing, limiting its use.

4. Thinking systemically – some basics

This section outlines a few basic principles for helping to understand systems. (See Appendix 1 for more details on how to read a causal diagram.)

4.1 View challenges as trends over time and as a prompt for understanding causality

Often the challenges we are trying to deal with are viewed as discrete events, like a large number of something or a low number of something. However, in order to better understand a *system* causing an issue, think of that challenge as a *behaviour over time* that a system produces. For example, instead of a large number of something, perhaps it is an *increasing* number of something. Or instead of a low number of something, a *decreasing* level of something. Or a *persistent* level of something despite efforts to change it (either up or down). (see Figure 4-1)

Behaviour over time helps us understand *how* something is changing over time (i.e. a trend). That trend can then be used to help articulate the causal structure and interaction of factors that help explain *why* that trend occurs.

Articulating causal structure can range from simple to complicated, yet the broad general behaviour of a system can often be summarised by quite simple feedback loops. Remember: systems thinking seeks to understand how elements combine, rather than separating them and analysing them in isolation.

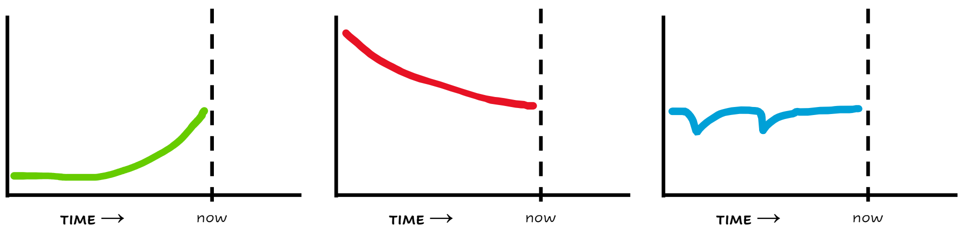


Figure 4-1. View challenges as trends over time.

4.2 The bathtub analogy

A useful analogy used in systems thinking is the *bathtub analogy*. This helps to conceptualise important parts of the challenge you are focusing on: where do things build up or erode? Or, where do things accumulate or decrease?

In our metaphorical bathtub, the level of the bathtub is the level of something you are interested in. This level can build up or decline. A bathtub (sometimes called *stock*) might be anything you are interested in – the number of people, quality of water, level of morale, etc.

The level in the bathtub can only increase through more inflow (the *tap* over the metaphorical bathtub), and only decline through more outflow (the *drain*). This applies to whatever you are interested in (see Figure 4-2).

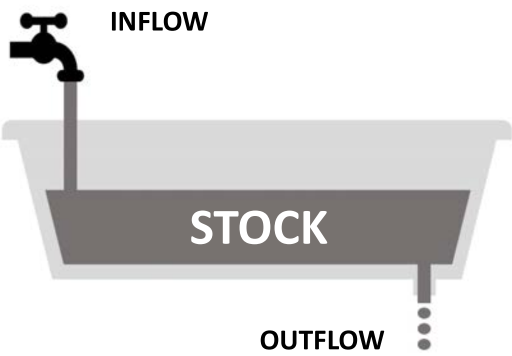


Figure 4-2. The bathtub analogy – conceptualising accumulation and decrease

The inclusion of a conceptual bathtub in a causal diagram allows a greater level of insight to understand whether a change in a key variable (*bathtub*) is due to a change in *inflow* (tap) or a change in *outflow* (drain).

We have used a bathtub to represent several important variables in this guidance.

4.3 Feedback loops

Feedback loops are the basic building blocks of causal diagrams and are used to represent circular causality. There are two types: reinforcing and balancing (Figure 4-3).

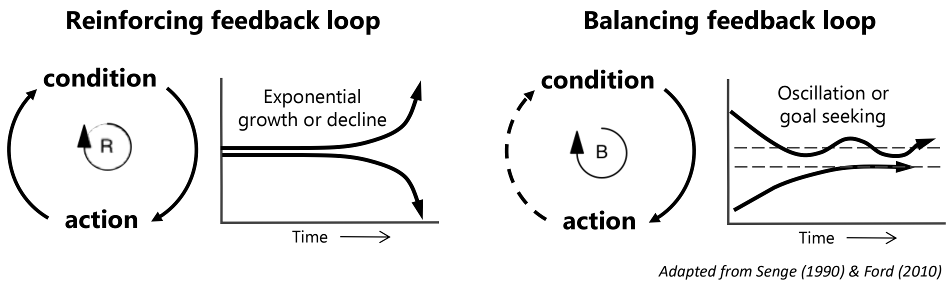


Figure 4-3. The two types of feedback loops.

In a *reinforcing feedback loop*, influence transfers around the loop and back to the original factor in the *same* direction. That is, if something goes up, it will continue to go up, or vice versa. This *reinforces* the direction of the original influence, and any change will build and amplify. Reinforcing loops can operate in both upward or downward directions. Reinforcing feedback loops drive growth or decline in a system.

For example, (untouched) money in the bank will earn compounding interest and grow, or rust will expose more metal to corrosion and thus create more rust.

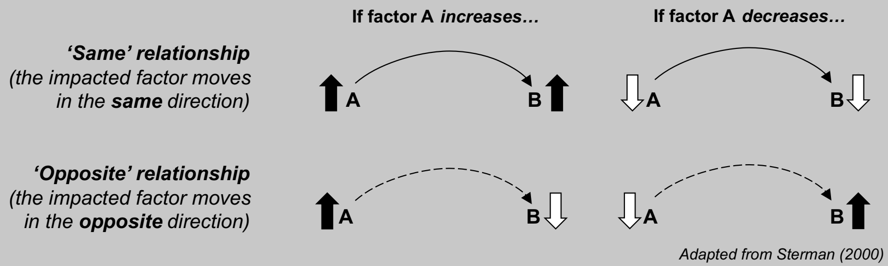
In a *balancing feedback loop*, influence transfers around the loop and back on the original factor in the *opposite* direction. That is, if a factor goes up it will prompt action that will cause it to go down again, or vice versa. This *balances* the direction of the original influence. Balancing feedback loops create control, restraint or resistance in a system.

For example, a thermostat connected to a heater will turn it on if the room is cold. The heater will heat the room then turn itself off. The room will then cool until the thermostat turns on again, and the cycle begins over again.

A note on how arrows are labelled in causal diagrams

Causal diagrams (and feedback loops) are made up of variables connected by arrows representing causal influence. There are two kinds of causal influence.

- *Same influences* are when change in the direction in one variable leads to a change in the *same* direction in the next variable (i.e. if A goes up, then B goes up, or vice versa). Same influences are shown as arrows with a solid line.
- *Opposite influences* are when change in the direction in one variable leads to a change in the *opposite* direction in the next variable (i.e. if A goes up, then B goes down, or vice versa). Opposite influences are shown as arrows with a dashed line.



- *Delays* are where there is a delay between cause and effect; for example, change occurs in variable A, but it takes time to present in variable B. These are represented by short double lines across an arrow. In causal diagrams *delays are relative* (i.e. the time taken to present is longer relative to others shown in the diagram).

4.4 (Mis)understanding exponential growth

The concept of exponential growth is not always understood, yet it is critical to a good understanding of systems. Why is this? *Because a simple, constant system structure can produce dynamic behaviour (i.e. behaviour that changes over time).* When behaviours or trends change, this is often attributed to something changing within 'the system', yet this need not be the case. Many behaviours will change when everything has been operating in a constant and consistent manner the entire time. Exponential growth is one such behaviour.

Exponential growth describes when the absolute amount of something consistently doubles over a repeating timeframe (the doubling time). For example, algae in a Petri dish double every 2 hours, or house prices double every 7 years, or a city's population doubles every 30 years.

The doubling time is determined by the *growth rate (i.e. the percentage growth rate, e.g. 5% per year):* the higher the *growth rate*, the shorter the *doubling time*.

The often misunderstood characteristic of exponential growth, however, is that a *constant (i.e. flat over time) growth rate* will always lead to *exponential growth in the absolute amount* of something (over time) (see Figure 4-4).

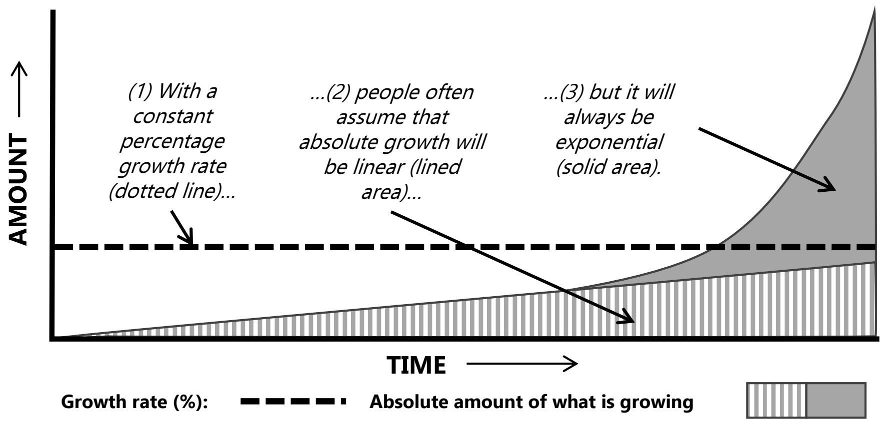


Figure 4-4. How a constant growth rate leads to exponential growth.

The first key insight here is that, in the longer term, *any* constant growth rate will *always* lead to exponential growth in the absolute amount of something. Because this is not always understood, when exponential growth *does* occur it can come as a surprise. It is often assumed that something 'changed' in the system to cause it. In fact there was no change: all causal influences remained constant.

One of the reasons this is important is that exponential growth will result from dominant reinforcing loops. This is a powerful systems-thinking insight.

A second key insight is to recognise that *nothing grows forever in isolation*. While growth might be experienced for a time (even a very long time), all reinforcing loops will eventually be constrained by other balancing loops.

The 'rule of 70'

The 'rule of 70' is a simple calculation to roughly *estimate the amount of time it will take a quantity of something to double*, based on a constant growth rate.

For example, if you have $1,000 in the bank earning a rate of interest of 3.5% per year, simply divide 70 by 3.5 to determine the years it will take to double to $2,000. In this case, 70/3.5 = 20, so it would take 20 years for $1,000 to grow to $2,000 at a 3.5.% interest rate (assuming no taxes or withdrawals). In another 20 years $4,000, and 20 years after that $8,000, etc.

Similarly, if you know the doubling time and want to roughly *calculate the rate of growth that caused it*, 70 can also be divided by the doubling time to determine the growth rate. Using the same example, if you know that your money has doubled over 20 years, but are not sure of the interest rate (growth rate), then this can be roughly determined by dividing 70 by the doubling time. In this case, 70/20 = 3.5. Therefore 3.5% per year interest rate.

Therefore the rule of 70 can be used:

To determine the doubling time: 70 / growth rate = doubling time

To determine the growth rate: 70 / doubling time = growth rate

4.5 Understanding and utilising leverage areas within systems

The previous two subsections outlined some basics of thinking systemically: thinking in terms of trends over time and correctly understanding the impact of exponential growth. Having gained such insights, how does one apply them? This subsection introduces the reader to the concept of leverage points, or some guidance on where to intervene or take action.

In systems thinking people often talk about understanding problems from a 'deeper' level. The further 'down' or 'within' a system one is able to operate, the increasing 'leverage' one is able to apply to alter or influence the problem.

The deeper one operates the more one becomes aware of mindsets and values which have helped establish the system, or help hold it in place.

Three systems thinking frameworks that introduce the concept of leverage are shown in Figure 4-5. While all differ in subtle ways, they all share the feature of increasing leverage when operating at a deeper and more values-based level.

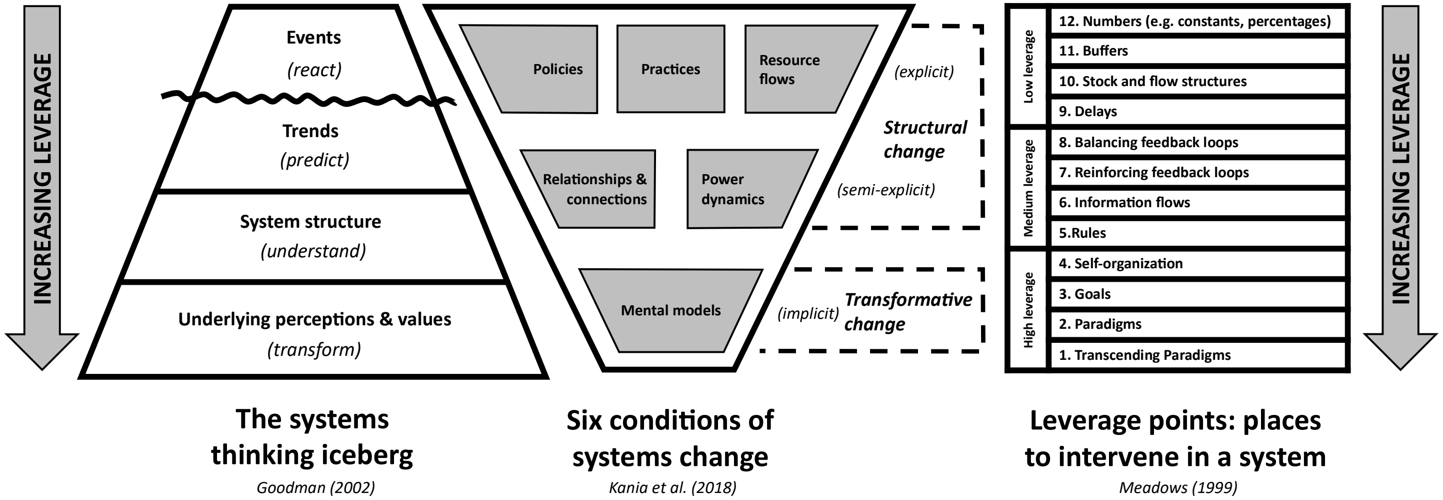


Figure 4-5. Where to intervene in a system – a tradition of understanding the relative leverage of action.

Goodman (2002) talks about a systems 'iceberg' where:

- only issues (or 'events') appear above the surface
- below the surface, thinking in 'trends' shows patterns of behaviour.

This helps to understand the structure of causal influences, which in turn helps to understand the 'underlying perceptions and values' that enable it.

This iceberg analogy also draws heavily on Peter Senge's The Fifth Discipline (1990, 2006).

Kania et al. (2018) articulate six conditions of systems change over three layers:

- 'Policies', 'practices' and 'resource flows' are explicit and obvious, yet lower leverage.
- 'Relationships and connections' and 'power dynamics' are semi-explicit and medium leverage.
- 'Mental models', or deeply held values and assumptions about how the world does or should work, are implicit and the least obvious, yet are higher leverage areas to intervene.

Donnella Meadows' described 12 leverage points: Places to intervene in a system (1999). Shown here in three layers:

- numbers (constants, parameters, rates); buffers; stock and flow structures; and delays. Lower leverage.
- balancing and reinforcing feedback loops; information flows (including knowledge); and rules. Medium leverage.
- a system's ability to self-organise; the goal of the system; the paradigms of those who created or maintain it; and the ability to transcend paradigms. Higher leverage.

An important observation often made about leverage points is that those that are obvious or near the problem are often lower leverage. Lower leverage points also often have a high financial cost to deploy. This may be because they are a physical or infrastructural intervention, or require a large financial subsidy.

Deeper and more powerful leverage points, on the other hand, tend not to have such a high financial cost to deploy but often require significant expenditure of social or political capital to change assumptions or mindsets.

The often inverse relationship between the cost of an intervention and its leverage is not intuitive. It is actually *counterintuitive* (Meadows 2008). Therefore, when looking for powerful leverage points, look beyond the most obvious or easily identified.

Identifying strong leverage points can be challenging. Donella Meadows described her motivation to list places to intervene in a system below:

> *I have come up with no quick or easy formulas for finding leverage points in complex and dynamic systems. Give me a few months or years and I'll figure it out. And I know from bitter experience that, because they are so counterintuitive, when I do discover a system's leverage points, hardly anybody will believe me. Very frustrating – especially for those of us who yearn not just to understand complex systems, but to make the world work better.* (Meadows 2008, p. 146)

Causal relationships are discussed throughout this document, so some reflections on the relative leverage of different interventions are provided. Three broad leverage levels are described: lower, medium, and higher (see Table 4-1). Specific reflections on leverage levels are presented throughout this document (see Table 4-2).

Table 4-1. Three relative levels of leverage used in this guidance

Description	Relative leverage
Tweak the system – fundamental structure (and goal) remain Change the relative rate or number of things, or increase the buffers related to things in the system, which often present as 'supply'-related buffers or refinements. Adjust delays within the system so that things may happen sooner or later, but the same structure remains.	**Lower leverage**
Change the rules of the system Actively intervene to strengthen (or weaken) important balancing or reinforcing feedback loops. Improve or create new information flows that adjust or evolve system structure. Seek to evolve important relationships between actors in a system and the power dynamics that exist between them.	**Medium leverage**
Change the goal of the system Enable the system to self-organise, or change the goals inherently built into the system. Change the mindsets or mental models that have created the existing system.	**Higher leverage**

Table 4-2. Reflections on leverage throughout this guidance

Possible areas of leverage		
#	Example description of a lower leverage area or intervention	**Lower leverage**
#	Example description of a medium leverage area or intervention	**Medium leverage**
#	Example description of a higher leverage area or intervention	**Higher leverage**

5. An overview of related freshwater issues

Specific and proximal influences tend to be physical factors (or related attitudes and beliefs. These are captured in a causal diagram (Figure 5-1) and in the companion visualisation (Figure 5-2).

Don't feel pressure to examine it in detail here, it is shown to give an indication of the complexity of the causal relationships affecting freshwater. It is explained in detail in section 6, where we work through the structure step by step, so that it gradually becomes clear. A large version of the diagram is shown in Figure 6-20 (centre pages 28-29).

In the diagrams and visualisations freshwater is often abbreviated to FW. Loops are labelled (e.g. B1 or R1) for reference and discussion in the text

The *shaded* areas in Figure 5-1 are those influences usually included in freshwater policy discussions; for example: freshwater quality, quantity and ecosystem health; human recreational use; farm intensity and water use; nitrogen in soils (fertiliser and leaching); mitigations to reduce contaminant pathways to freshwater; and municipal water use.

Areas *not shaded* are not usually included in freshwater discussions. We suggest that including or coordinating with these policy areas will strengthen freshwater policy.

Broad and underlying influences are social or non-physical in nature and affect many of the proximal influences. These have not been captured in the causal diagram and they are described in section 7. A summary of these is provided in Table 5-1.

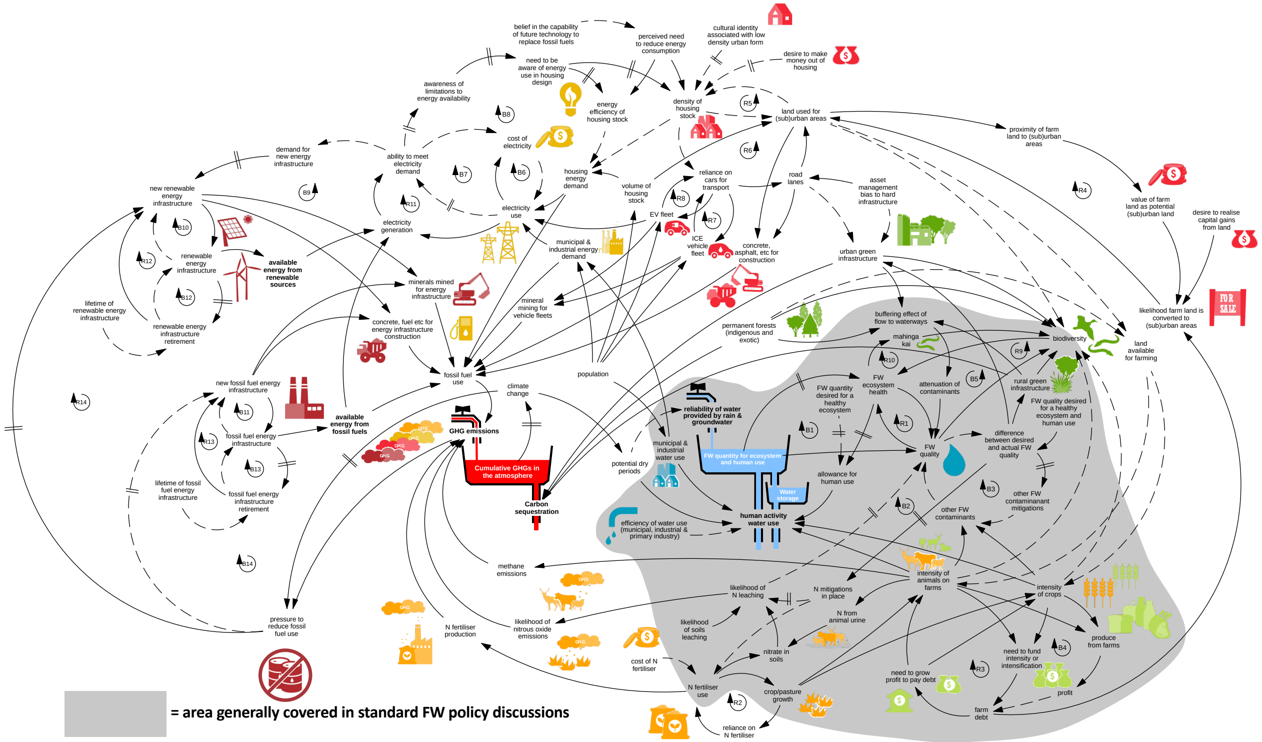


Figure 5-1. Specific and proximal influences on freshwater in a causal diagram (with regular freshwater policy subjects shaded).

Table 5-1. Broad and underlying influences (not shown on the causal diagram)

- Appropriateness of policy design processes and institutions
- Trust in science and policy
- Length of political and funding cycles
- Willingness to give away decision-making power
- Importance and measurement of non-financial returns
- Ecological literacy, time spent in nature, and mental health and wellbeing
- Social justice and (in)equality
- Climate resilience on farms and greater appreciation of climate change as a risk
- A low(er) energy future and the 'net energy' equation

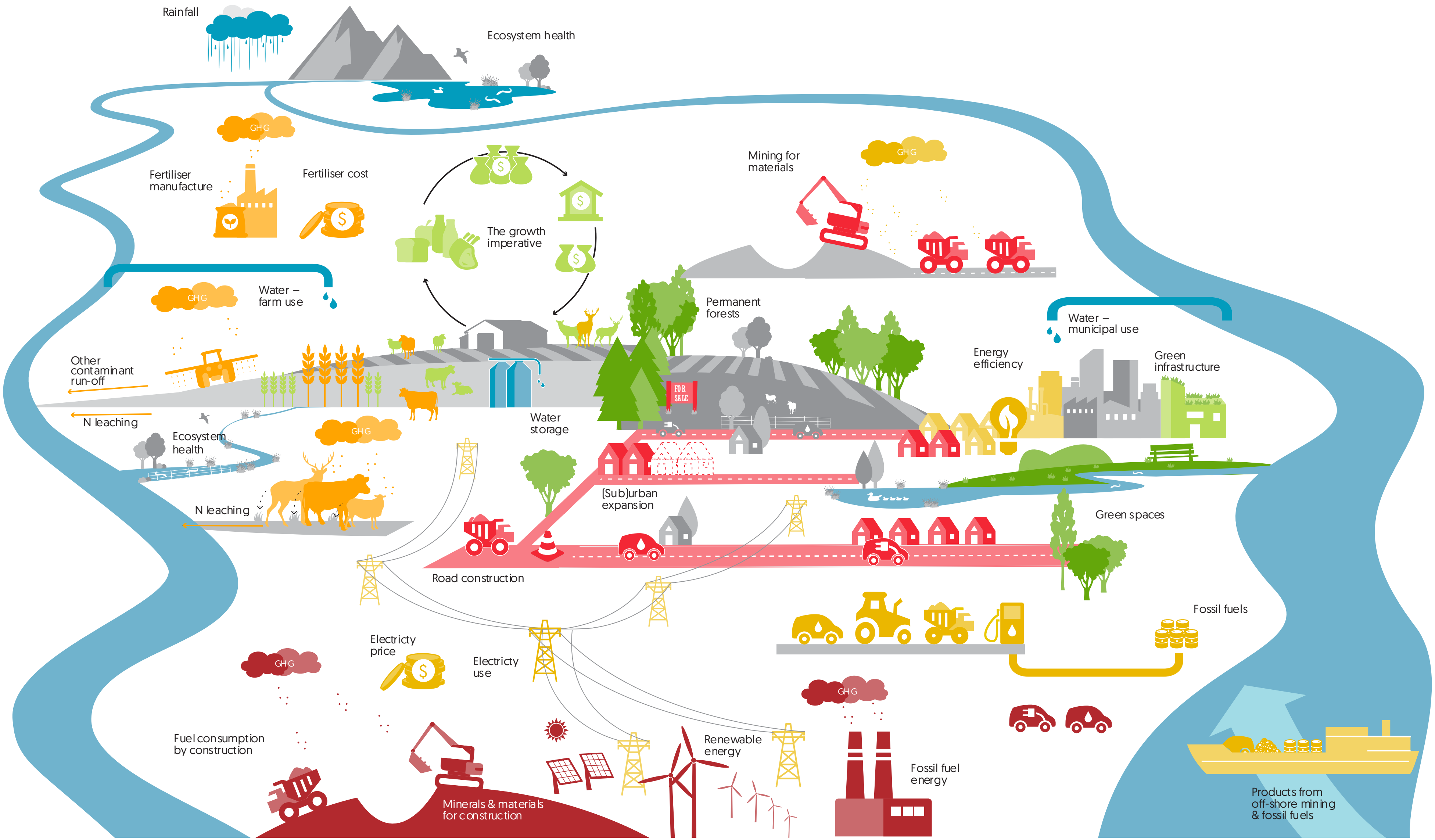


Figure 5-2. Specific and proximal influences in a visualisation.

6. Related freshwater issues – specific and proximal

This section outlines a range of *specific and proximal* issues influencing freshwater quality and quantity, and ecosystem health. These issues are captured in a series of causal diagrams that draw heavily on the bathtub analogy and circular causality described in section 4 and Appendix 1. When factors from the figures in this report are referred to, they are given in single quotation marks (e.g. 'population').

6.1 Freshwater quality and quantity, and ecosystem health

The physical factors at the core of freshwater management and policy are freshwater ecosystem health, freshwater quality, and freshwater quantity.

6.1.1 Representing freshwater quantity

Firstly, the 'FW quantity for ecosystem and human use' is shown as a *bathtub*; this represents a conceptual amount of water (see Figure 6-1, right). The *inflow* to this conceptual *bathtub* (the 'tap' in) is what increases this water. This is labelled the 'reliability of water provided by rain & groundwater'. This simplification of the water cycle indicates that this comes from a reliable and consistent flow of water in the water cycle, primarily from rainfall but also from groundwater flow (which is itself recharged by rainfall somewhere else).

The *outflow* from this *bathtub* (the 'drain' out) represents water used by humans directly and indirectly, both for municipal use (human consumption and industrial processes) and for agriculture. This is labelled 'human activity water use'.

The 'FW quantity for ecosystem and human use' (the amount in the *bathtub*) is influenced by both the *inflow* and the *outflow*.

Secondly, the 'FW quantity for ecosystem and human use' influences the 'FW ecosystem health', which in turn influences the 'allowance for human use'. This loop represents the constant tension between the extent to which the quantity of available freshwater is in line (or not) with the desired (or required) amount of freshwater for a healthy ecosystem, and therefore how much freshwater can be extracted for human use without affecting ecosystem health. This is represented as a balancing loop (B1) (Figure 6-2).

Note: Remember that the double lines across the arrows indicate a *relative delay* (not a stop).

'FW ecosystem health' is a conceptual factor representing appropriate amounts of freshwater of sufficient quality and supporting (and being supported by) healthy biological communities.

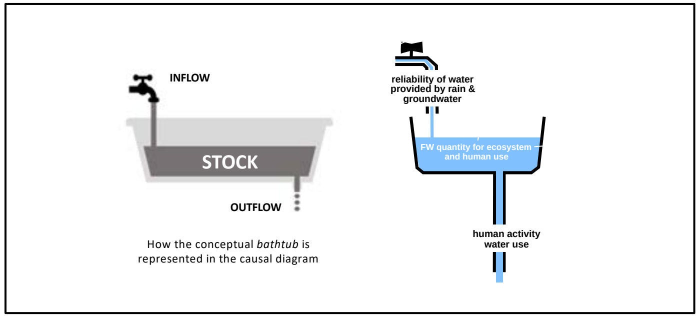


Figure 6-1. Representing freshwater quantity as a 'bathtub'

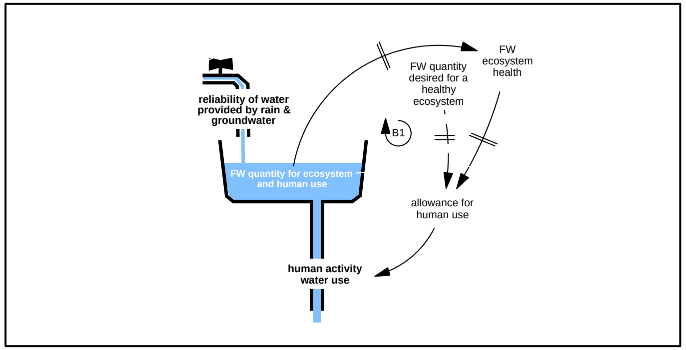


Figure 6-2. The balancing loop controlling human water use

6.1.2 Linking freshwater quantity and quality, and ecosystem health

The factors of freshwater quantity and quality and of ecosystem health are all interconnected (Figure 6-3).

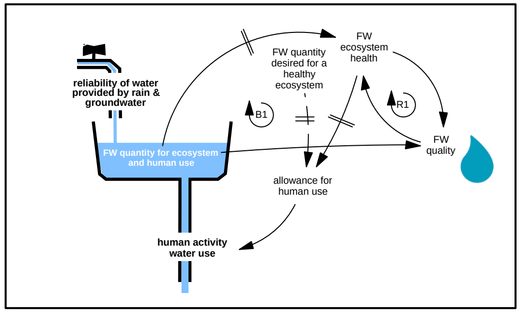


Figure 6-3. Freshwater quantity and quality, and ecosystem health

In addition to the link between the amount of freshwater and ecosystem health (B1), ecosystem health and freshwater quality are also linked (R1) in a way that can spiral in either direction: if freshwater quality declines, so too will ecosystem health, which in turn may put further pressure on freshwater quality (through related factors of ecosystem health and its effect on freshwater quality); or if freshwater quality is improved, then so too is ecosystem health, and again, in turn, freshwater quality. R1 is a reinforcing loop.

There is a similar relationship between freshwater quantity and freshwater quality: the more water there is in a waterway, the better the quality. This of course assumes an 'all other things being equal' perspective, where, for instance, the same amount of other contaminants is assumed. This should also be considered at an annual (or longer) time interval. For example, there may be an intense weather event with lots of rain, which causes erosion and sedimentation in the short term, but all things being equal, more water in the cycle reduces pollution concentration (and increases quality).

All of these factors are constantly influencing each other, and their individual and collective levels will be an aggregate of all these influences, plus the others described in subsequent sections.

Background nutrient losses that occur naturally are not included in this diagram.

6.1.3 FW ecosystem health supports mahinga kai

A stable level of 'FW ecosystem health' is required to support 'mahinga kai' or traditional food-gathering locations. This is simplified as a *same* influence between 'FW ecosystem health' and 'mahinga kai'. (See Collier et al. 2017) (Figure 6-4).

6.1.4 Municipal, industrial, and primary industry water use

The amount of 'human activity water use' is driven by the amount of municipal, industrial and primary industry water use. The level of the 'population' influences 'municipal & industrial water use'. While primary industry use is represented by two factors: 'intensity of animals on farm' and 'intensity of crops'.

All are *same* relationships: if one increases so does the other (and vice versa) (Figure 6-5).

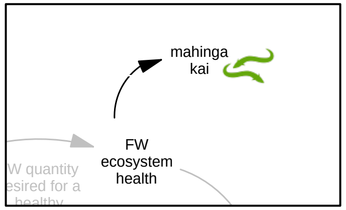


Figure 6-4. FW ecosystem health supports mahinga kai

The efficiency of water use is represented by a single factor 'efficiency of water use (municipal, industrial & primary industry'. This has an opposite relationship with water use. If the efficiency of use increases, then the volume of use reduces, all other things being equal.

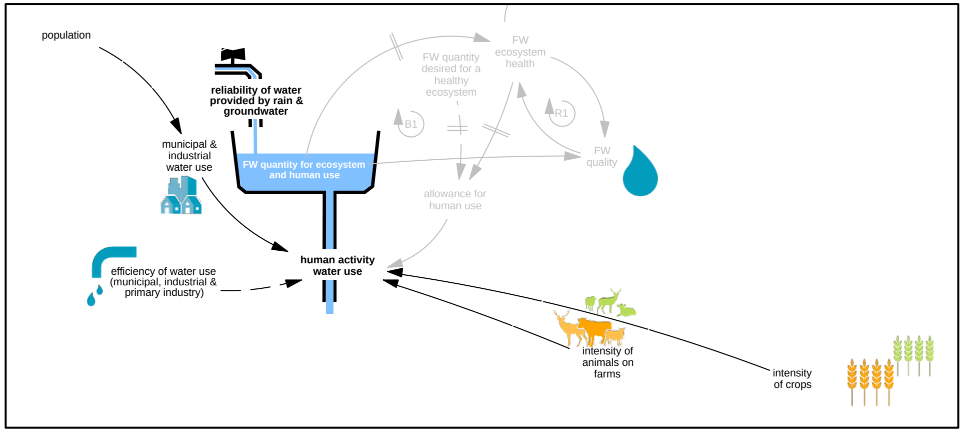


Figure 6-5. Municipal, industrial and primary industry water use

6.1.5 Water storage for primary industries

Water storage for primary industries is often included in discussions relating to freshwater issues, particularly in relation to water allocation challenges in a climate-affected future (e.g. MPI 2021). This is shown as an additional bathtub specifically for water storage in the causal diagram (Figure 6-6).

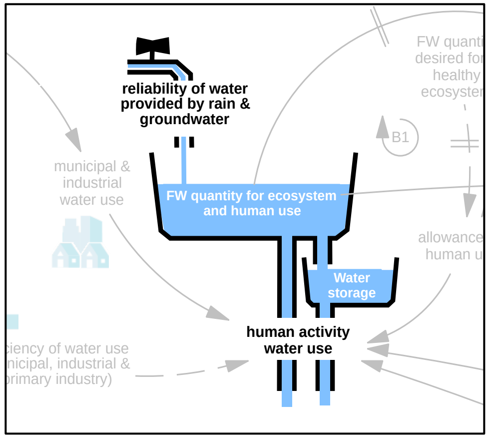


Figure 6-6. The impact of water storage.

This is because, at a conceptual level, creating man-made water storage simply creates another bathtub, which is topped up during times of plenty (e.g. harvesting water during high flow). The water for ‘human activity water use’ then comes from either ‘FW quantity for ecosystem and human use’ or ‘Water storage’.

This obviously depends on the characteristics of the specific situation, and these can only be demonstrated here at a conceptual level. While water storage may be useful in some instances, it doesn’t change any other characteristics or features of the system within which it operates. For example, if a farm production system is highly water dependent, creating water storage is unlikely to change that: water may be more efficiently used, but the farm system is still likely to be highly water dependent.

In a future affected by climate change, the inflow to the bathtub may decrease, making the outflow of the bathtub a greater percentage of the amount of water. Although water storage may increase the total amount of water available at a point in time, it is also likely to reinforce a systemic dependence on stored or augmented water. This potentially reduces the system’s resilience if the demand (outflow) is greater than the reliability of water (inflow) (i.e. the capacity is fully utilised).

Therefore, in terms of the places to intervene, in a system outlined earlier (Meadows 1999), water storage only increases the temporary buffer of water that is available. As a general rule it is therefore considered a relatively lower leverage intervention. The reader is referred to a Waikato Regional Council technical document (#2021/28), *Adapting to Drought in the Waikato*, where this tension and leverage point are explored (Connolly et al. 2021).

Some participants noted that water storage can also have ecological impacts (e.g. through flooding land and changing the balance of ecosystem services the flooded area originally provided), as well as potentially affecting freshwater quality. These impacts are noted, but are difficult to generalise so have not been represented in the diagram.

Possible areas of leverage		
1	*Water storage policies* These only increase the temporary buffer of water available for use, so they may not change the fundamental water-dependent characteristics of the farm system.	**Lower leverage**
2	*Interventions that improve the efficiency of water use (e.g. irrigation type) or required water (e.g. lower-water-use cultivars)* These only improve or reduce the water use or absorption rate. Changes in rates of water use retain the same general farm system. Efficiencies may even encourage *higher* water use in the longer term due to the increased efficiency (a.k.a. Jevon’s Paradox). Therefore they are considered lower leverage at a wider systemic level.	**Lower leverage**
3	*Encourage shift to rain-fed agriculture* This recognises the future needs for farm systems that thrive in a rain-fed environment while still producing food and fibre.	**Medium leverage**

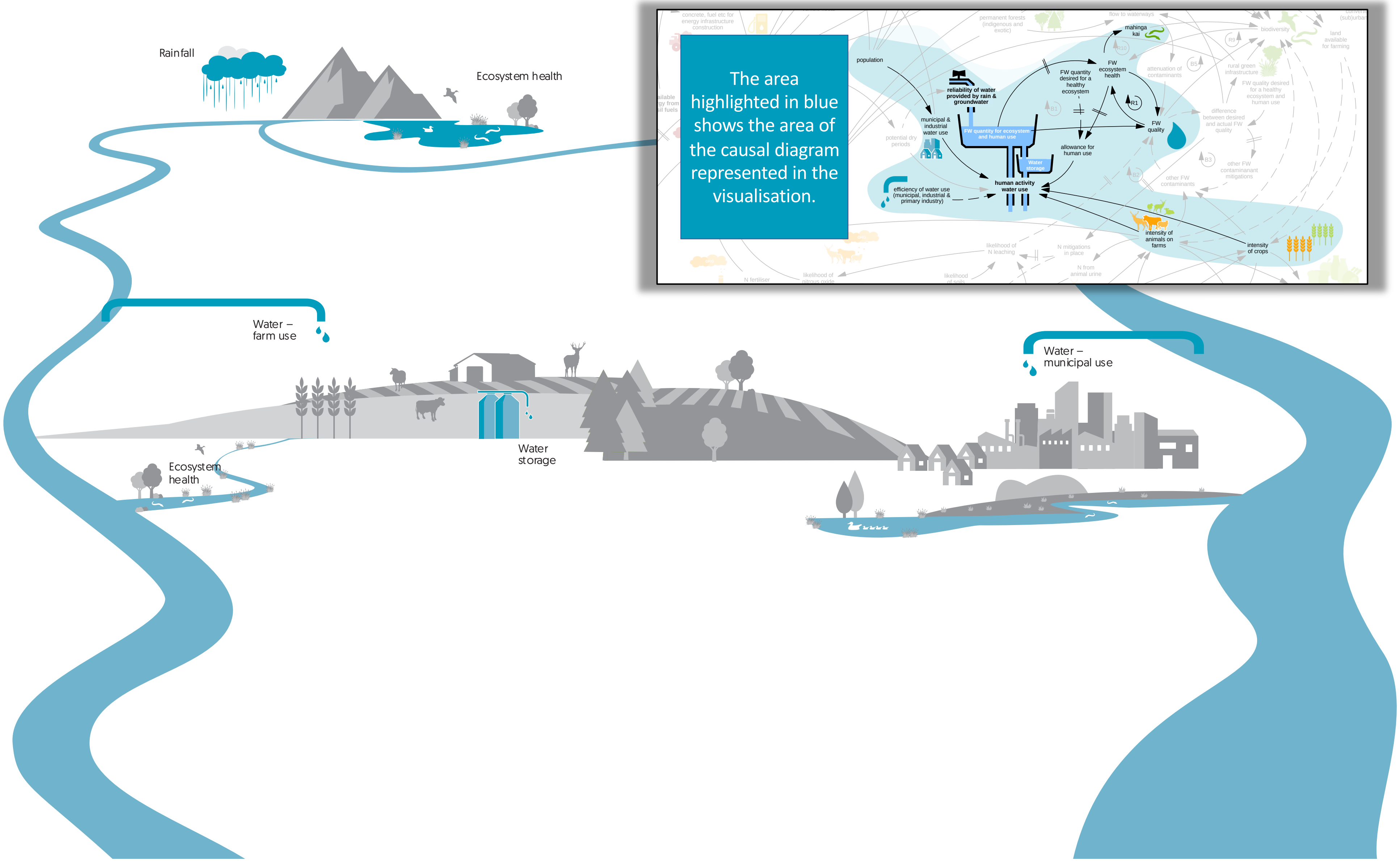


Figure 6-7. How freshwater quality, quantity, ecosystem health and water storage are related.

6.2 Diffuse contaminants

Freshwater contaminants arise from *point sources* or *diffuse sources*. *Point source* contaminants enter waterways from a clearly defined point (e.g. a pipe from a water treatment plant or factory). *Diffuse* contaminants have no clear infrastructure pathway, like nutrient run-off from farmland or erosion from hills.

Industrial discharges are often in the form of *point source* contaminants, and are more readily monitored and managed by consents. Agricultural land-use losses tend to be in the form of *diffuse* contaminants and are more challenging, both to model and to manage. Urban losses are often a mixture of both point and diffuse losses. This report focuses on diffuse contaminants.

6.2.1 Summarising diffuse freshwater contaminants, sources, and responses

Freshwater quality is influenced by many diffuse contaminants; e.g. nitrogen, sediment, phosphorus, and *E. coli*. Those with similar drivers/behaviours are grouped in the causal diagram (Figure 6-8) as:

- nitrogen (N, often as nitrate-N): nitrate-N is carried through soil in water (leaching) and can take months, years or decades to present in waterways
- other FW contaminants (sediment, phosphorous, *E. coli*): these tend to flow to waterways via overland flow paths, so present relatively quickly.

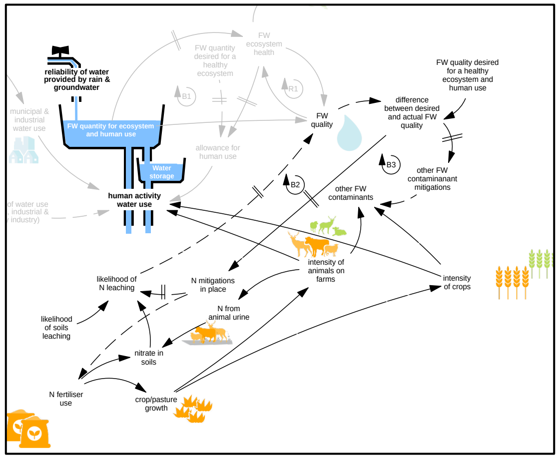


Figure 6-8. Diffuse freshwater contaminants, sources, and responses.

The level of 'other FW contaminants' is influenced by the intensity of animals and crops on farms. This is shown with *same* arrows from both of those factors. The level of 'Nitrate in soils' is influenced by two factors:

- the 'intensity of animals on farm', which influences the amount of 'N from animal urine', which in turn influences the amount of 'Nitrate in soils'
- the amount of 'N fertiliser use', which supports 'crop/pasture growth', which in turn supports the intensity of both animals and crops on farms.

Both groups are influenced by mitigations to reduce their impacts. These are influenced by how in line freshwater quality is with societal expectations (which may evolve over time). These influences form balancing feedback loops (B2 & B3).

In balancing loop B2, an increased 'likelihood of N leaching' over time leads to reduced 'FW quality' (note the arrow delay mark). Reduced FW quality then increases the 'difference between desired and actual FW quality'. Over time, these increases likely to lead to more 'N mitigations in place', reducing the 'likelihood of N leaching'.

In balancing loop B3, an increase in 'other FW contaminants' leads to reduced 'FW quality'. Most contaminants (other than N) will present quickly as changes in 'FW quality' (so no delay). Reduced 'FW quality' will increase the 'difference between desired and actual FW quality', over time this may prompt 'other freshwater contaminant mitigations", which in turn reduces the level of 'other FW contaminants'.

Possible areas of leverage		
4	*Minimise the difference between desired and actual water quality* Lowering contaminants or the intensity of farm activities reduces the strength of these loops. So does lowering desired water quality objectives (although this is not suggested as an intervention). We note that this area is where a lot of effort in freshwater policy development is already targeted .	**Medium leverage**

6.2.2 Representing GHG emissions and atmospheric accumulation

Greenhouse gases (GHGs) in the atmosphere are also shown in the causal diagram as a bathtub (Figure 6-9). This critically important issue will be part of most public policy in the coming decades.

The level of this metaphorical bathtub represents the 'Cumulative GHGs in the atmosphere', or the concentration of CO_2-equivalent gases in the atmosphere. This is the main driver of climate change.

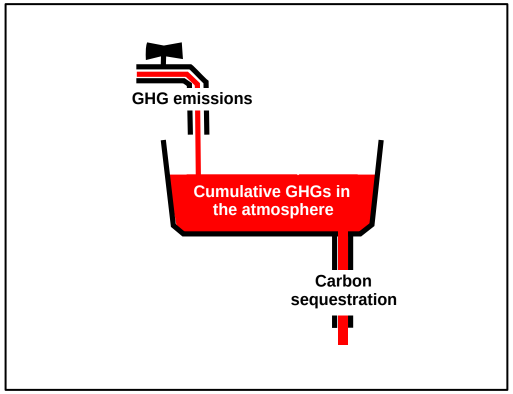


Figure 6-9. Representing GHGs as a bathtub.

The inflow (the tap) to the bathtub represents 'GHG emissions' that are released into the air. This includes carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and other CO_2-equivalent gases.

The outflow (the drain) from the bathtub represents 'Carbon sequestration' – the processes by which carbon is sequestered from the atmosphere and absorbed into oceans, trees and plants, as well as the technology that removes carbon from the atmosphere.

The main way carbon sequestration is interpreted in this work is through plant and tree growth absorbing carbon into plants, trees and soils.

6.2.3 GHG emissions from nitrogen fertiliser and animals

The sources of N and other freshwater contaminants was described earlier. This section outlines the drivers and impacts of N fertiliser use on GHG emissions, as well as GHG emissions that come from animals on farms.

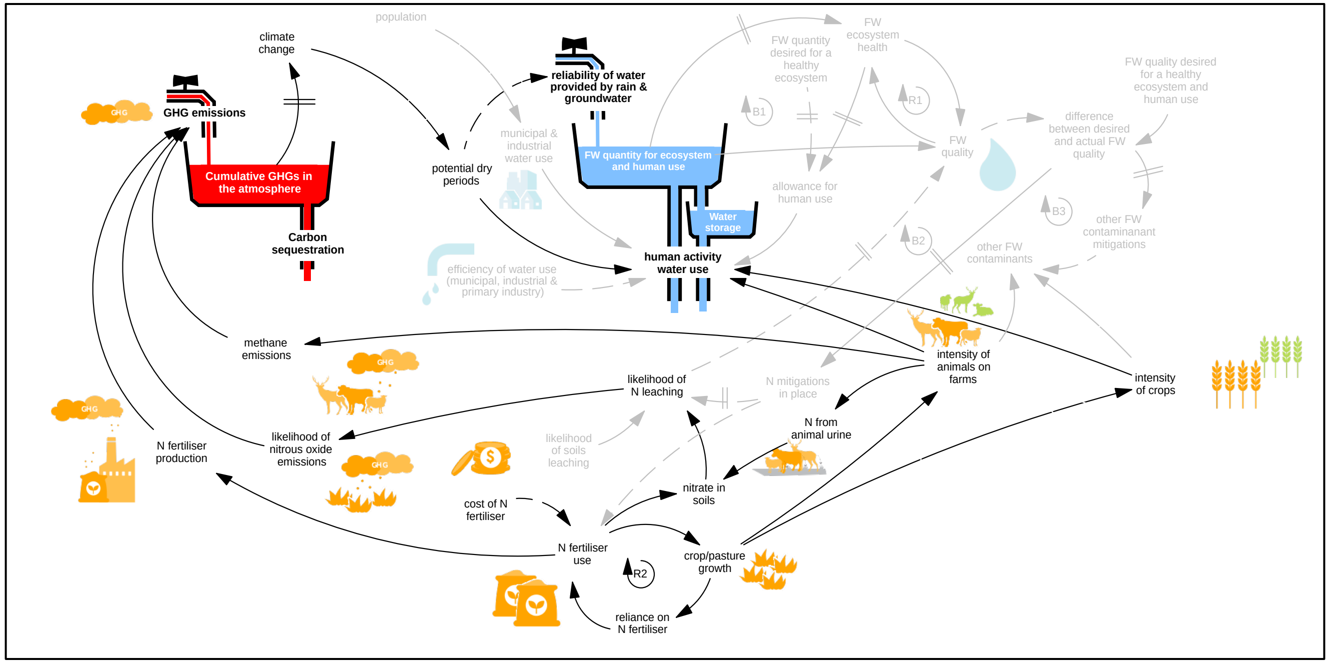


Figure 6-10. GHG emissions from nitrogen fertiliser and animals.

'N fertiliser use' forms a reinforcing feedback loop (R2) with 'crop/pasture growth' and 'reliance on N fertiliser': the more it is used, the more growth occurs and the greater reliance there is on N fertiliser. The strength of this loop is heavily influenced by the 'cost of N fertiliser': the lower the cost, the more likely it is to be used (see Figure 6-10).

This reinforcing loop is a known relationship in freshwater management, and pasture growth itself is usually at least implicit, and often included, in the freshwater policy discussion, especially in modelling. Managing N fertiliser is usually included in the freshwater policy discussion.

In addition to freshwater quality, 'N fertiliser use' also produces GHG emissions via several pathways. Firstly, the process of making synthetic N fertiliser requires an industrial process that emits GHGs. Secondly, the use of N fertiliser increases the likelihood of N leaching from soils, which also increases the 'likelihood of nitrous oxide emissions', another GHG. Therefore, the volume of N fertiliser use is not only linked to freshwater quality policy discussions, but also to GHG emissions ones.

In addition to N fertiliser use, the 'intensity of animals on farms' is related to the amount of 'methane emissions'. The 'intensity of animals on farms' is supported by the level of 'crop/pasture growth' enabled by 'N fertiliser use'. Methane is a powerful GHG that features highly in New Zealand's GHG emissions profile (MfE (2022).

Possible areas of leverage		
5	*Reduce the strength of the fertiliser dependence reinforcing loop (R2).* Fertiliser use is a key driver of intensification. Reducing fertiliser dependence could be achieved in multiple ways; for example, by heavily restricting the use of nitrogen fertiliser (through price or a cap), or exploring profitable but lower nitrogen-dependent crops. This would also help reduce GHG emissions.	**Medium leverage**

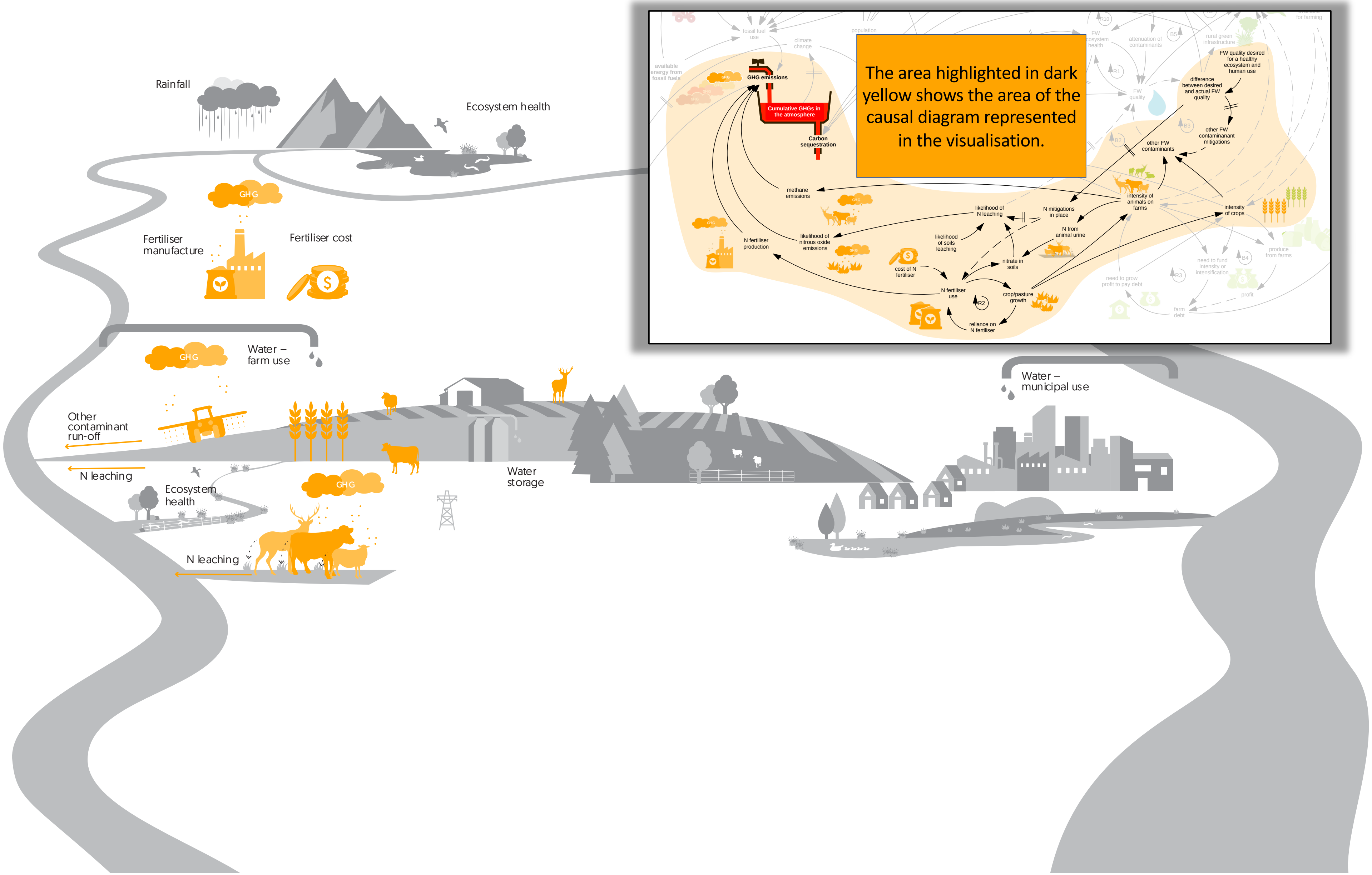


Figure 6-11. Diffuse contaminants.

6.3 Farming and the growth imperative

The types of primary industry land use that occur in a location are usually part of the freshwater policy discussion. So, too, are the drivers of those land uses, like profit and debt burden, these are also included in regular freshwater policy discussion. However, that information is not always available to inform such discussions, particularly about farm debt burden.

Figure 6-12 describes these influences and how they are influenced by, and in turn influence, the intensity of primary industry land use. There are two loops. Both operate either via 'intensity of animals on farm' or 'intensity of crops'.

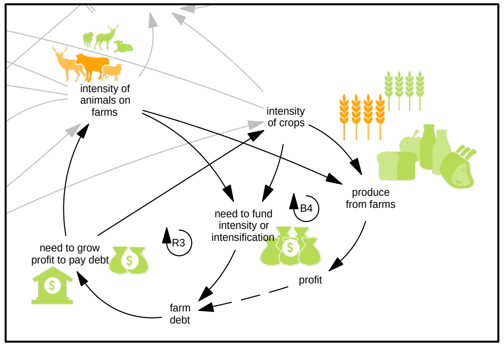


Figure 6-12. Farming and the growth imperative.

In both of the loops in Figure 6-12 it is assumed that most farms are carrying debt. This may not apply to all farms, and to those that it does apply this will be to varying levels.

The first loop is the balancing loop (B4) of farm produce and profits. Here, the intensity of both animals and crops supports the amount of 'produce from farms', which in turn supports the financial profit. The term 'profit' has been used as a simplification of revenues minus costs incurred in the business of farming. The greater the farm profits, the greater the likelihood that farm debt will be reduced. Less debt means less 'need to grow profit to pay debt', reducing the need for further intensification of animals or crops on farms.

The second loop is a reinforcing loop (R3) describing the costs of farm intensification and the need to fund them. Here, any increase in intensification increases the 'need to fund intensity or intensification', which (if funded by debt) leads to an increase in 'farm debt'. The same influences from this point remain in the loop, but they influence in the reverse direction: increased 'farm debt' increases the 'need to grow profit to pay debt', which increases the likelihood of further intensification of animals or crops.

These two loops are constantly in tension, and the resulting impacts will be a combination of the combined strength of both, influenced by which is the more dominant. Note that intensification of farming will also lead to intensification of supporting industries (e.g. new infrastructure and processing facilities). This may contribute to higher energy and resource use, probably including water use outside of irrigation. For simplicity this has not been shown on the causal diagram. Similarly, consumer preferences have an impact on produce from farms, but space also constrains this from being shown in the causal diagram.

Possible areas of leverage		
6	*Seek to adapt the business of farming and other primary industry land uses (including finance) to be less reliant on debt and the need for growth* This might involve reimagining farming so that it is less focused on financial metrics of success and implementing policies and approaches to support this shift. This may also help sustain primary industry land use in the longer term, without that land use needing to be reliant on growth or increased intensificiation of activity.	**Higher leverage**
7	*Rules that limit the intensification of farm land* These can constrain the loops relating to farm profit and debt, effectively capping the ability to increase borrowing through intensification and increase profit through increased production. Note that this may be a common intervention, but it does not remove the growth imperative. Farmers may either change to less-intensive farming types (the intent of the intervention), or convert to suburban land if they are near an urban area (not the intent of the intervention).	**Medium leverage**

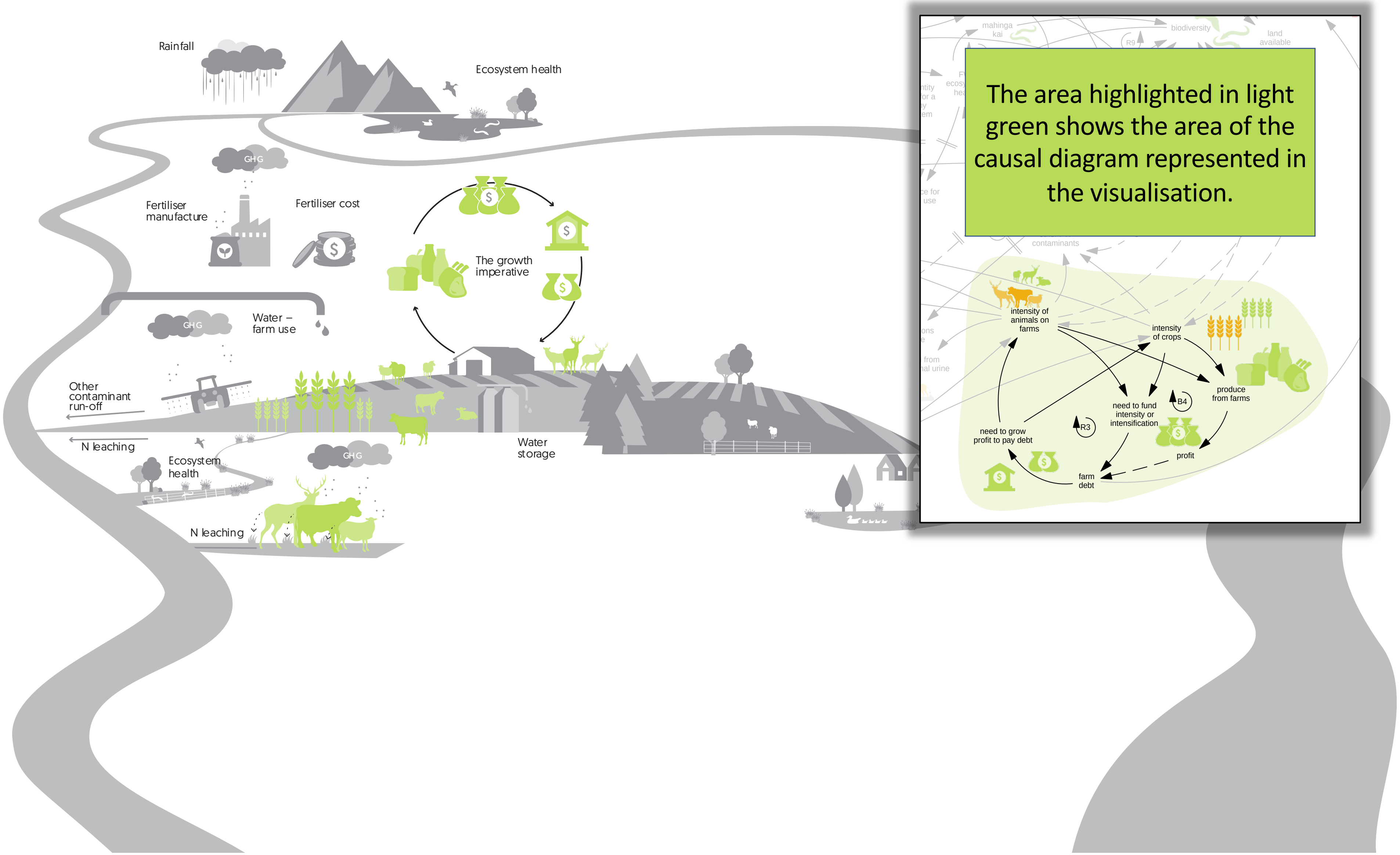


Figure 6-13. Farming and the growth imperative.

6.4 Urban form and urban expansion

The urban and rural contexts of freshwater policy development are often dealt with separately. While the interventions required for each may be different, urban form has an influence on rural form, which may be an indirect influence on freshwater outcomes.

6.4.1 Sustained pressure on rural land from urban expansion

Urban areas expand at the expense of rural areas. As urban areas expand (shown as 'land used for (sub)urban area'), the 'proximity of farm land to (sub)urban areas' is increased, which increases the likely 'value of farm land as potential (sub)urban land'. This increases the 'likelihood farm land is converted to (sub)urban area', often resulting in urban sprawl and an increase in 'land used for (sub)urban area'. This forms a reinforcing loop (R4) that continues to operate and underpin urban sprawl. This is shown in Figure 6-14.

This loop is influenced by several factors. High levels of 'farm debt' and/or a 'likelihood of realising capital from land' (top left in figure) may increase the 'likelihood farm land is converted to (sub)urban area' to realise cash for both these drivers. Population levels and the volume of housing required may also increase pressure on 'land used for (sub)urban area'.

This pressure from urban form on rural land use means there is less 'land available for farming', which means there is increased pressure to intensify animals and crops on farms to compensate. Farm intensity is an important influence on freshwater quality.

The influence of urban sprawl on rural farm land is considered a medium leverage influence because it is weakening this specific feedback loop. However, although this influence is indirect, once converted, urban land is rarely converted back to rural use so it is unlikely to be reversed.

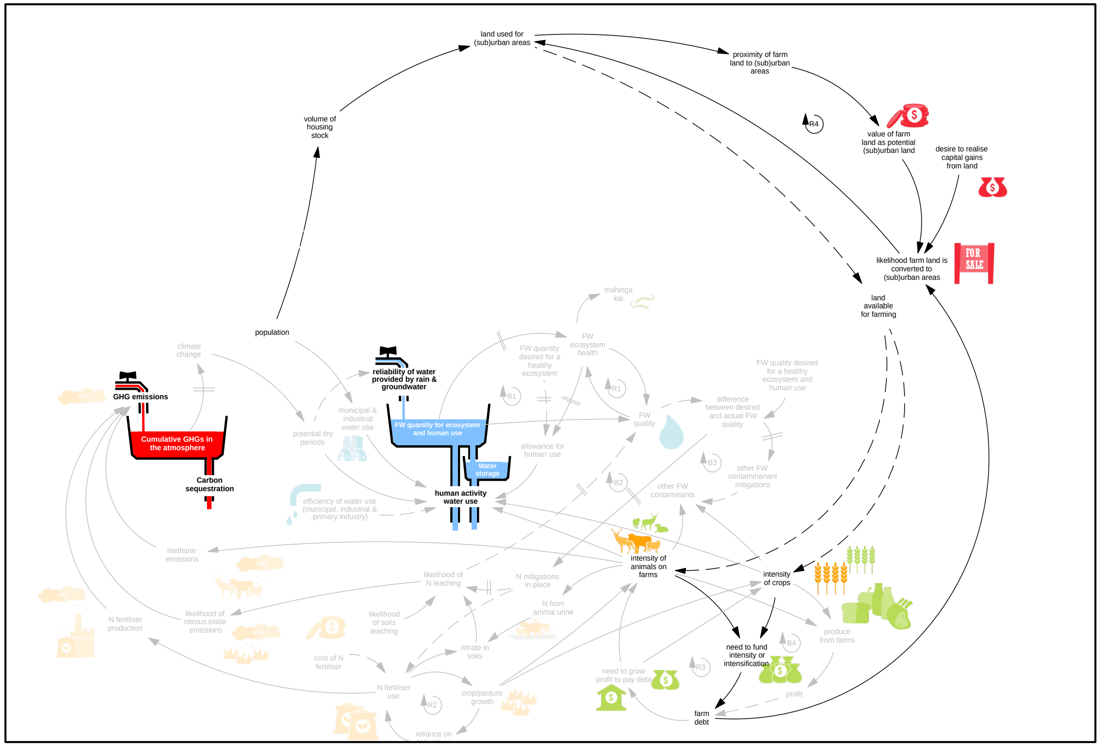


Figure 6-14. Sustained pressure on rural land from urban expansion.

Possible areas of leverage		
8	*Reduce urban sprawl* Most of New Zealand's towns and cities are historically based around our best/richest soils. Urban sprawl has covered (and continues to cover) much of this land, moving rural activity to other areas and perhaps lower-quality soils. Therefore, policy/regulation that reduces urban sprawl will, in the longer term, reduce the strength of the pattern of where rural land is converted to (sub)urban land, thus retaining rural land for farming and reducing the need to intensify farming activities to compensate. See also leverage area 9.	**Medium leverage**

6.4.2 (Sub)urban area and its relationship with cars

This section describes influences on (sub)urban form, primarily from the dominance of cars (private motor vehicles) (Figure 6-15).

The 'density of housing stock' determines the 'land used for (sub)urban area'. The lower the density, the more land used; concomitantly, the more land used, the lower the density. Therefore these two factors form a reinforcing loop (R5) (with two opposite relationships).

Transport infrastructure has an influence on the 'density of housing stock' and the amount of 'land used for (sub)urban area'.

The traditional dominance of cars for transport is included in a reinforcing feedback loop (R6). The traditional dominance of a lower 'density of housing stock' increases the 'reliance on cars for transport' (our dominant transport mode). This further encourages the building of more/bigger roads (shown in the diagram as 'road lanes'), which leads to more 'land used for (sub)urban area' and a continued lower 'density of housing stock'.

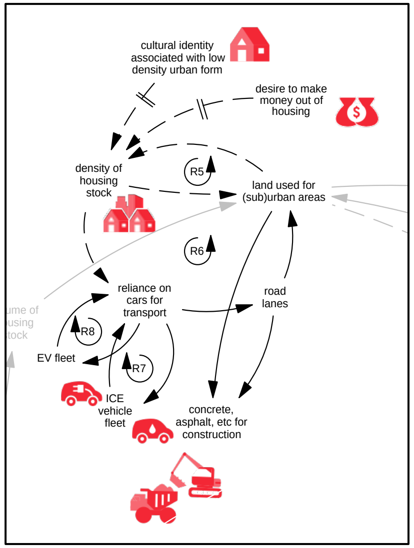


Figure 6-15. The nature of urban form and its relationship with cars.

It is a moot point whether low-density housing originally encouraged the dominance of cars for transport or vice versa. What is important is to recognise that these two influences together have created the dominant urban form we have.

With the dominance of cars the amount of 'road lanes' and 'land used for (sub)urban area' contribute to the amount of 'concrete, asphalt, etc. for construction'.

The *types* of cars are also important. Two types are identified: the 'ICE vehicle fleet' (ICE = internal combustion engine) and the 'EV fleet' (EV = electric vehicle). Both of these form reinforcing loops with 'reliance on cars for transport'. The more cars there are (regardless of their fuel), the greater reliance we have on cars for transportation, and vice versa. This differentiation of fuel type in cars has little bearing on the nature of (sub)urban form, but it is important when discussing fossil fuel use and GHG emissions (sections 6.6 and 6.7).

Some interviewees noted the strong cultural identities associated with lower-density urban form (e.g. detached suburban housing) and viewing housing as the main pathway to wealth generation; 'cultural identity associated with low density urban form' and 'desire to make money out of housing' capture these. Both have delayed and opposite effects on the 'density of housing stock'. In other words, the culture that desires detached suburban homes and views housing as an investment influences the density of urban form, car use, and urban sprawl. Changes in this culture would have an impact but would take time.

This culture also affects freshwater in several ways. Reduced farmland may increase farming intensity (as shown in the causal diagram), while new (sub)urban areas may change water flows, reduce soil ecosystem services such as filtration, and affect the groundwater. Such impacts are context specific so are *not* shown in the diagram.

In summary, this area seeks to demonstrate that the volume and form of urban areas can be an important influence on freshwater quality. Policies that seek to change the dominant culture of preferring lower-density housing and reducing the reliance on private cars for transport should be viewed as high-leverage policy areas for freshwater issues.

Possible areas of leverage		
9	*Seek to change the dominant culture of building wealth out of (mostly suburban) housing.* Over time this would mean a move away from suburban and lower-density forms of housing, reducing reliance on private cars for transport.	**Higher leverage**

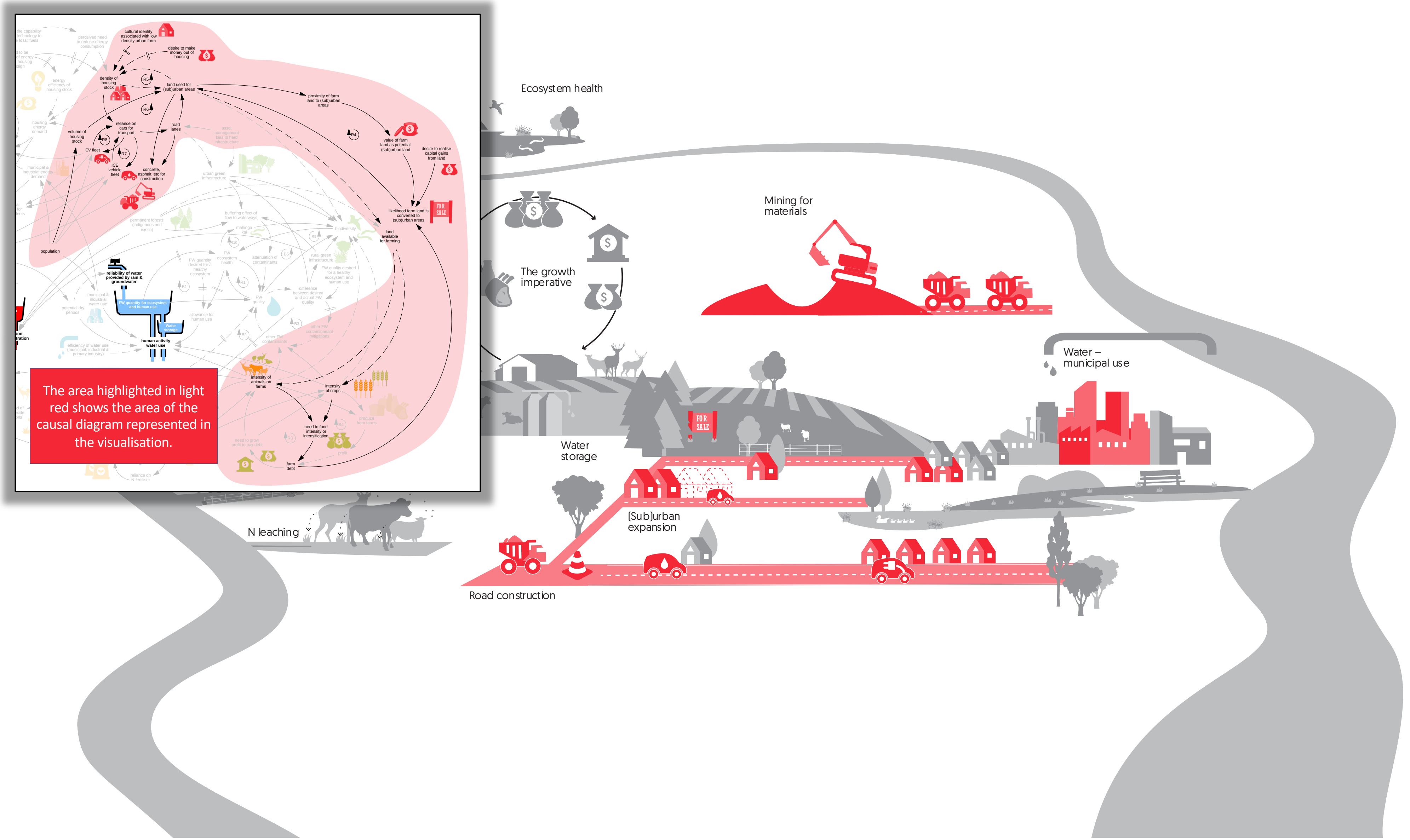


Figure 6-16. Urban form and urban expansion.

6.5 Green infrastructure and biodiversity

6.5.1 Green infrastructure

The use of green infrastructure is recognised as having an important role to play in managing and mitigating freshwater issues (Figure 6-17). In urban areas this includes things like street trees, drainage swales, and green roofs; and in rural areas things like wetlands, sand dunes, and riparian strips. These play an important role in providing a 'buffering effect of flow to waterways', which helps the 'attenuation of contaminants' and thus has an influence on freshwater quality ('FW quality'). The buffering effects and attenuation of contaminants are often included in freshwater policy discussions and are therefore included in the shaded area in the diagram.

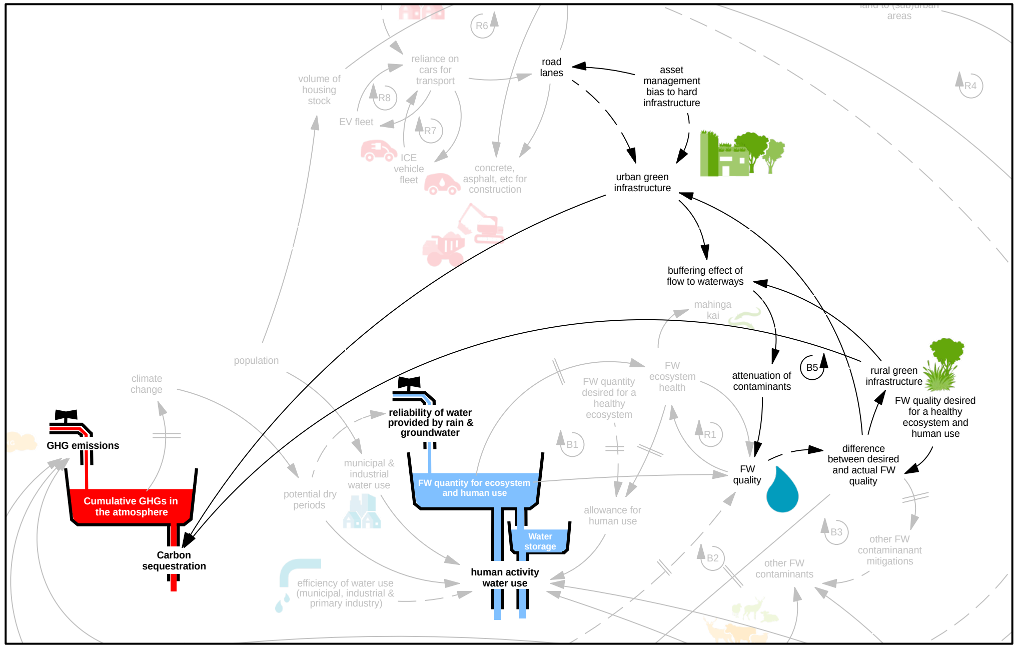


Figure 6-17. Green infrastructure.

While prevalent in rural discussions about freshwater, widespread discussions relating to 'urban green infrastructure', such as street trees, are not usually a major part of the freshwater discussion. Drivers of or influences on these factors are discussed here, as are their influences on other factors (outside those noted above).

An important influence on green infrastructure is the dominance of a mindset that prefers *hard* infrastructure to *green* infrastructure, particularly in urban areas. This is captured in the diagram as an 'asset management bias to hard infrastructure', which reduces the likelihood of green infrastructure. Two ways that such a bias presents itself are a preference for building hard infrastructure due to the traditional dominance of that approach, and a focus in asset management on assets that depreciate financially and the associated need to fund/pay for such depreciation.

Because many green assets (e.g. trees, riparian strips, plants in wetlands) grow, they don't depreciate, and actually appreciate in value (at least until they mature). This can be challenging to accommodate in an asset management system designed to estimate how much things *depreciate and decay*, and how much maintenance and replacement funding they need.

Because of this, efforts to alter the asset management system to accommodate and value assets that appreciate, such as green infrastructure, are viewed as a high-leverage way to influence freshwater outcomes. This particularly relates to asset management systems of public organisations.

Two additional influences relating to green infrastructure are noted. Green infrastructure can also support increased biodiversity, which will be explored in the following section (0); and a sustained difference between desired and actual freshwater quality (i.e. ongoing freshwater quality issues) has the ability to encourage greater use of green infrastructure.

Because of these and the other influences outlined above, the development of green infrastructure (in both urban and rural areas) is seen as a medium-leverage way to influence freshwater quality outcomes.

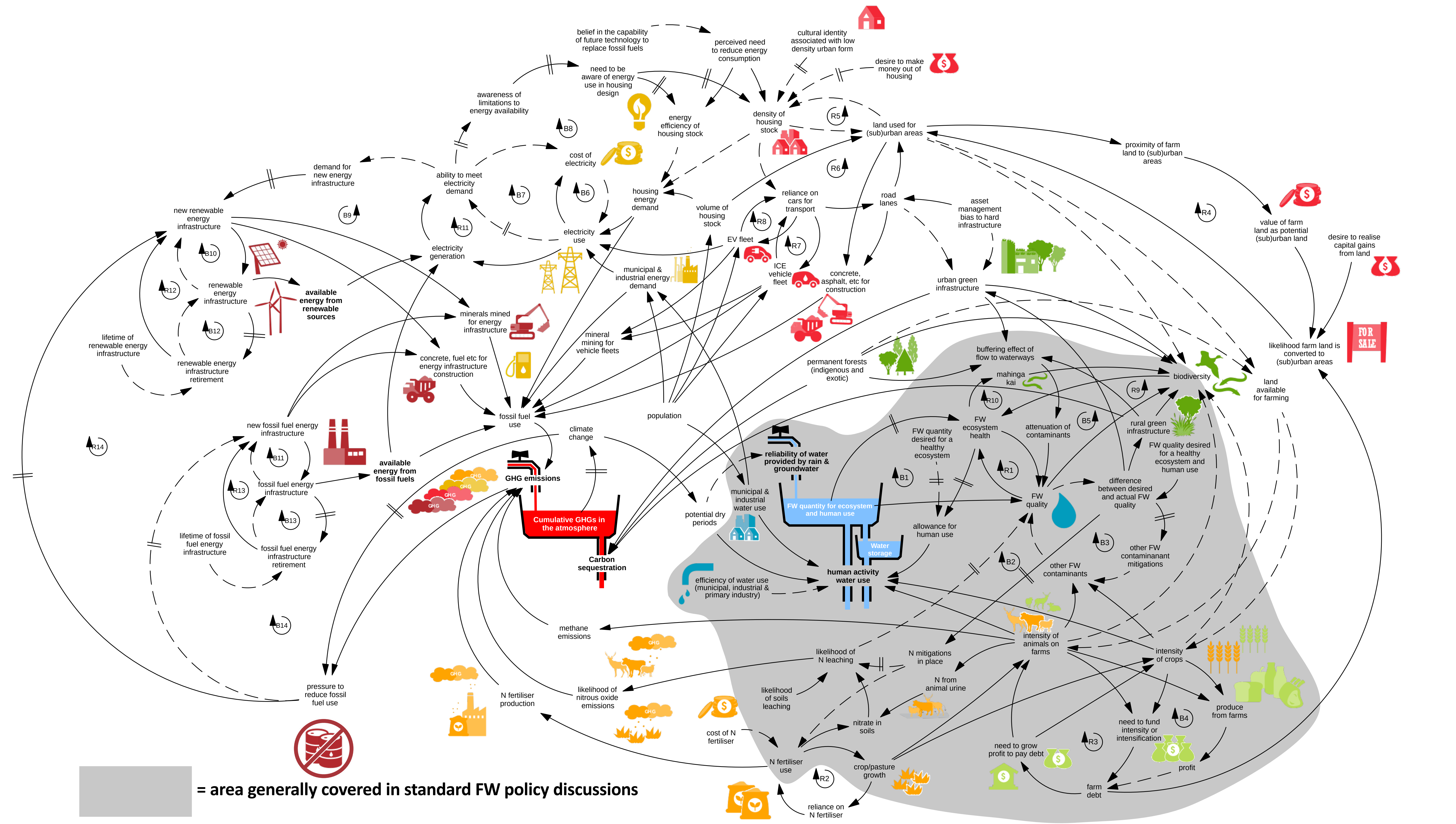


Figure 6-20. Specific and proximal influences on freshwater in a causal diagram (with regular freshwater policy subjects shaded). Full sized.

This is a larger version of the overarching diagram referred to in section 5. It is included in the middle of the document due to its size.

6.5.2 More than just freshwater biodiversity

Maintaining healthy biodiversity (both indigenous and non-invasive exotic) is an important part of environmental policy discussions (Figure 6-18).

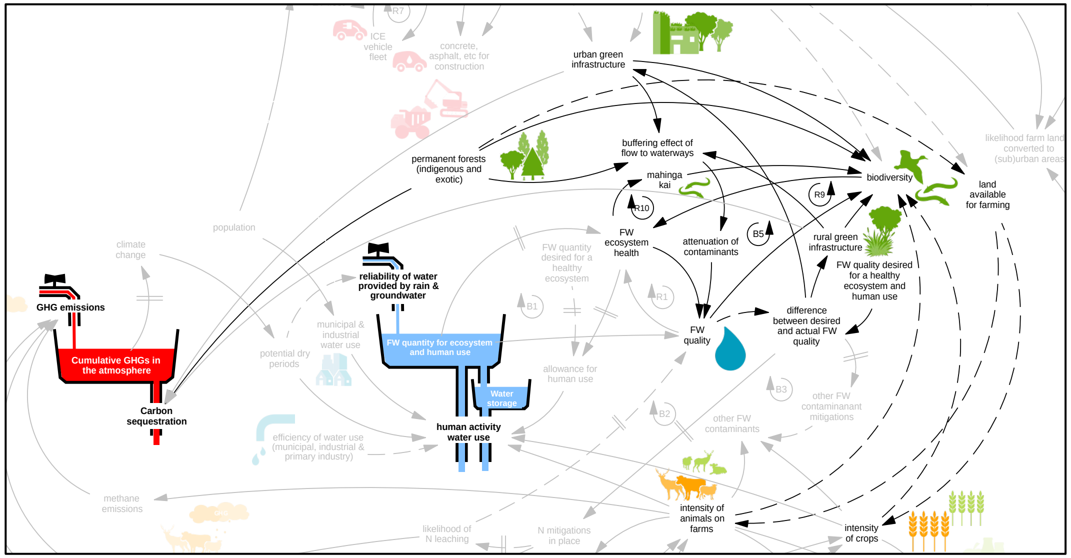


Figure 6-18. Influences on and from biodiversity.

Biodiversity is often dealt with in separate policy discussions, such as those on threats from pest species. While some elements are incorporated into freshwater policy discussions (e.g. macroinvertebrates as a measure of stream and river health), expanding our understanding of the relationships between freshwater and biodiversity policy could help strengthen freshwater outcomes.

Healthy biodiversity forms a broader reinforcing loop with freshwater quality and freshwater ecosystem health, both directly (R9) and via mahinga kai (R10). Generally , the better the health of each, the better the health of the others. This relates to both flora and fauna, indigenous and non-invasive exotic.

However, the major opposite impacts on biodiversity include things already discussed above. In general, the greater the intensity of animals and crops (especially monoculture crops) on farms, and the greater the 'land used for (sub)urban area', the less healthy biodiversity tends to be. At the same time, the more 'urban green infrastructure' and 'permanent forests (indigenous and exotic)', the more likely there will be healthy biodiversity. Note, however, that indigenous forests generally contribute more to biodiversity than exotic forests.

Policies that target these areas have already been discussed: reducing urban sprawl, limiting intensification of animals and crops on farms, and increasing green infrastructure and indigenous forests can support healthy biodiversity, which can have a positive impact on freshwater outcomes.

Possible areas of leverage		
10	*Encourge green infrastructure in rural and urban areas* This will help reduce the bias towards hard infrastructure and help buffer flows to waterways.	**Medium leverage**
11	*Seek to change the focus of asset management to include assets that appreciate, such as green infrastructure* This would mean a shift of mindset in how green assets are viewed in council accounting systems.	**Higher leverage**
12	*Take actions that reduce urban sprawl, limit intensification of animals and crops on farms, and/or increase green infrastructure and forests* These can all support healthy biodiversity, which can have a positive impact on freshwater outcomes. As most of these are actions in feedback loops, they are considered medium leverage, although multiple cumulative actions would increase their impact.	**Medium leverage**
13	*Encourage ways of farming that recognise the role of ecosystems within their farm systems and seek to live in balance with it.* This involves a change in mindset to encompass a more reciprocal relationship with the natural world upon which we depend.	**Higher leverage**

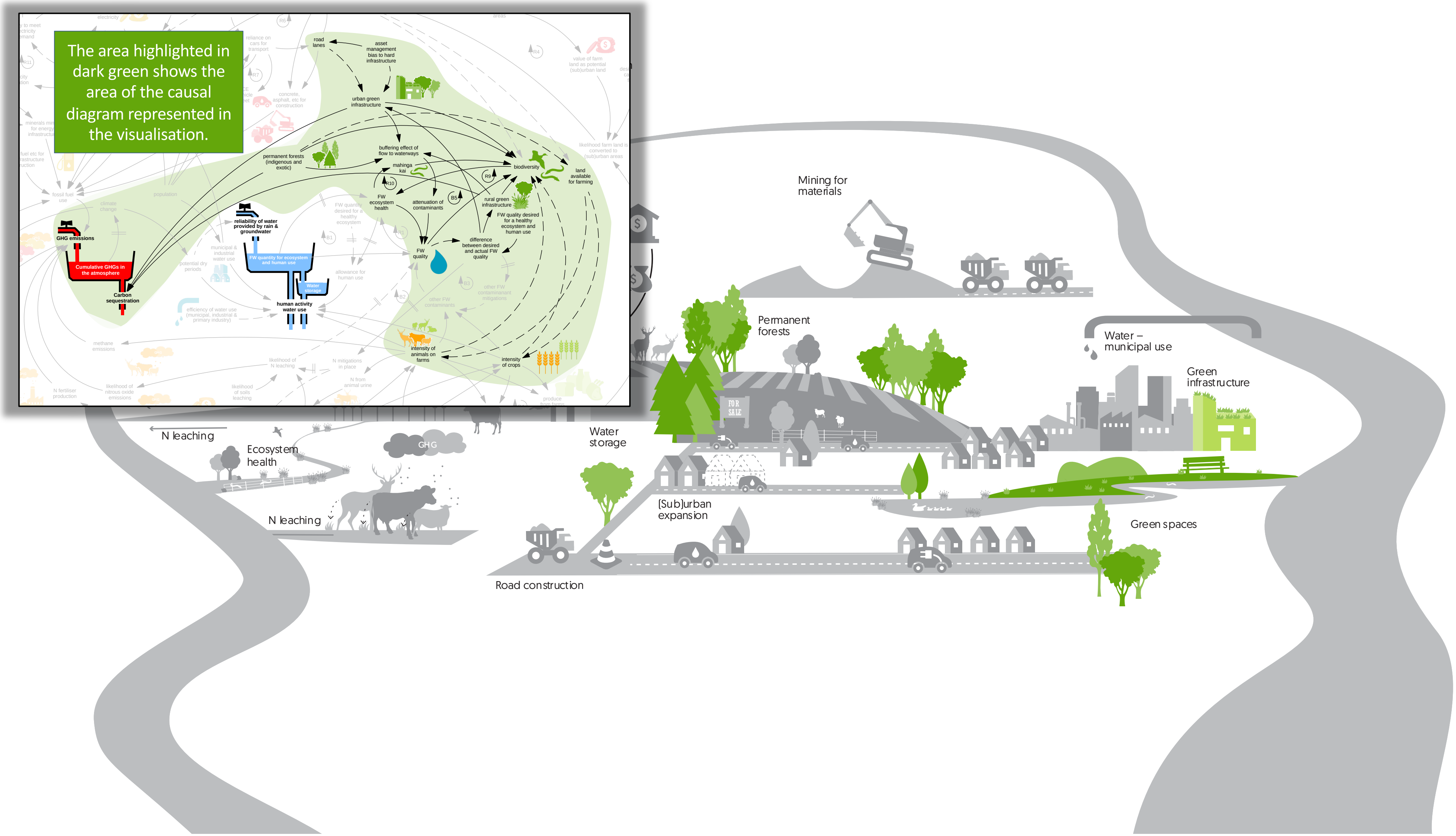


Figure 6-19. Green infrastructure and biodiversity.

6.6 Electricity and fuel – demand implications

Electricity (generated by both fossil fuels and renewables) and the combustion of fossil fuels (mostly for fuel in transport and industrial processes) are the two general types of energy use (demand) represented in this causal diagram (Figure 6-21). Causal influences relating to these factors are described in this section.

6.6.1 Electricity and fossil fuel demand from vehicles

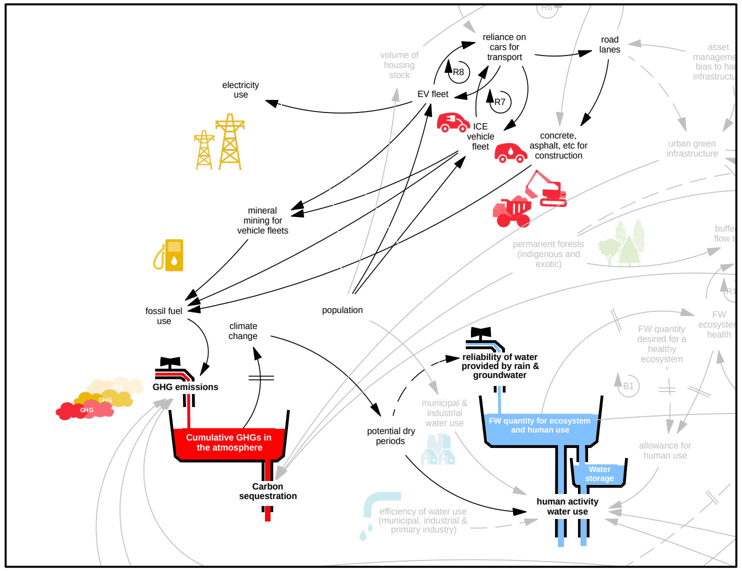


Figure 6-21. Electricity and fossil fuel demand from vehicles.

The larger the 'ICE vehicle fleet' the greater the 'fossil fuel use', while the greater the 'EV fleet', the greater the 'electricity use'. The greater *both* of these types of vehicle fleets, the greater the 'reliance on cars for transport' (reinforcing loops R7 & R8) and 'road lanes', thus the greater the amount of 'concrete, asphalt, etc for construction'. Such construction generally requires fossil fuel for power, as heavy electric construction equipment is not widely available. Both ICE and EV fleets are also influenced by the level of population.

In addition, *both* ICE vehicles and EV vehicles need to be manufactured from minerals and materials that are dependent on fossil fuel machinery and processes to be mined. This is represented as *same* influences from both of these fleets ('ICE vehicle fleet' and 'EV fleet') to the factor 'mineral mining for vehicle fleets', which then influences 'fossil fuel use'.

The use of fossil fuels releases 'GHG emissions', which continue to add to the bathtub of 'Cumulative GHG in the atmosphere'. Over time this contributes to additional 'climate change', continuing to reinforce 'potential dry periods' and reducing the 'reliability of water provided by rain & groundwater'. Hence this has a longer-term, yet direct, influence on freshwater outcomes.

6.6.2 Electricity and fossil fuel demand from housing and industry

Housing services are powered by a mixture of both fossil fuels and electricity. For example, a house may be heated by electricity and use an electric stove/oven, or it may be heated by natural gas heating and use a gas stove/oven. Or a mixture of the two. Therefore, housing energy demand has a *same* influence on both fossil fuel use and electricity use Figure 6-22).

While the relative split of that demand across energy sources depends on the technologies used in the home, it is the influences on housing energy demand that will determine the volume of energy used from either source. There are three of these. The 'volume of housing stock' has a *same* influence on 'housing energy demand': the *more* houses there are, the *more* the energy demand. Both the 'density of housing stock' and the 'energy efficiency of housing stock' have an *opposite* influence on 'housing energy demand': the *greater* the energy efficiency (e.g. insulation) and density (i.e. closer together and often smaller size) of housing, the *lower* the energy demand.

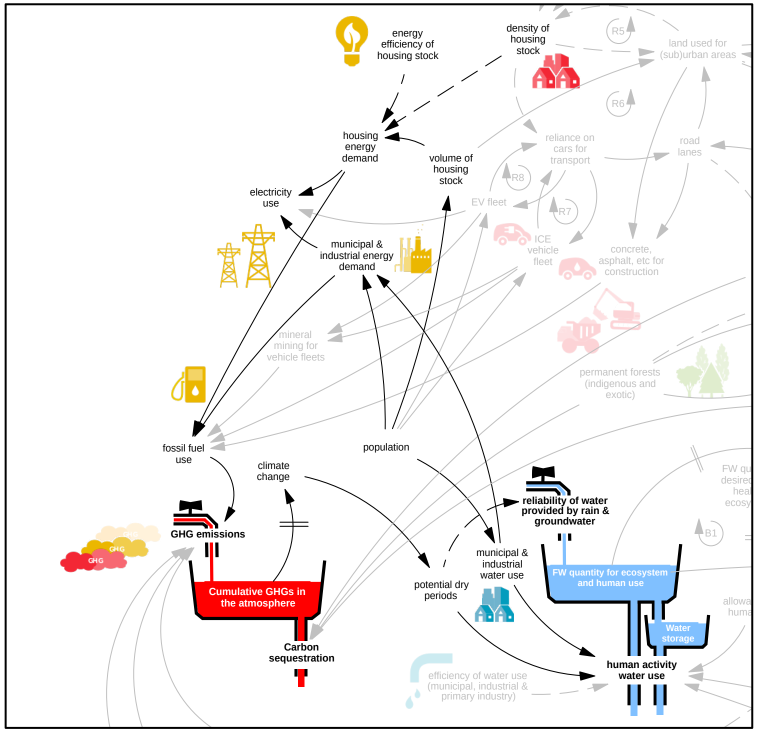


Figure 6-22. Electricity and fossil fuel demand from housing.

Again, the use of fossil fuels releases 'GHG emissions' that contribute to 'climate change', which in the longer term continues to reinforce the challenges relating to the 'reliability of water provided by rain & groundwater'. Hence this is a long-term but direct influence on freshwater outcomes.

'Municipal & industrial water use' also influences 'municipal & industrial energy demand', which contributes to 'electricity use'. Note that this is a highly aggregated representation of the many types of municipal and industrial electricity use (linked via water use), which is also influenced by 'population'.

6.6.3 Electricity use and the longer-term influence of meeting electricity demand on housing form

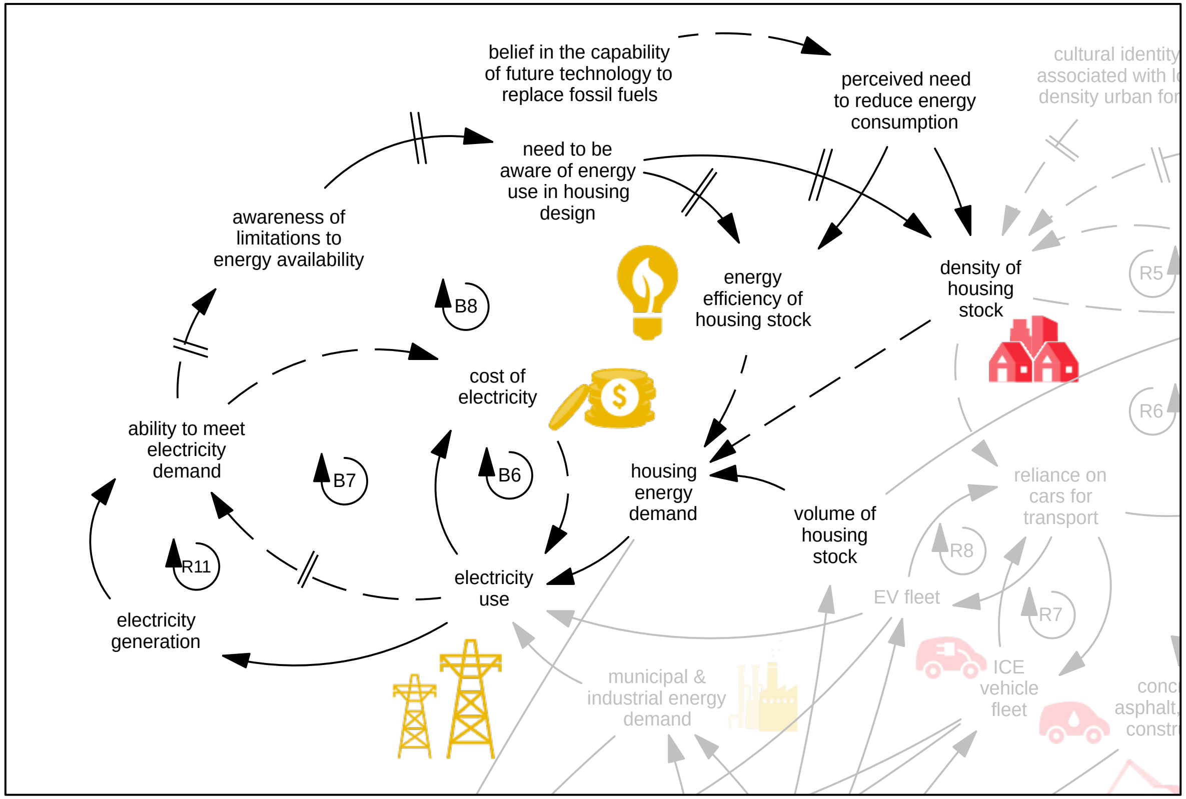


Figure 6-23. Electricity use and the longer-term influence of meeting electricity demand on housing form.

When describing this area there are several sets of influences relating to electricity use that require explanation (Figure 6-23).

There is a balancing loop between 'electricity use' and 'cost of electricity'. If 'electricity use' goes up, there is more demand and so 'cost of electricity' goes up. In turn this has the effect of affecting and reducing 'electricity use'. This creates a balancing loop (B6). This can also work in the reverse direction: lower prices increase use, which then increases price.

There are also multiple loops between electricity use and generation.

Firstly, assuming static energy generation, the greater the 'electricity use', the lower the 'ability to meet electricity demand' and the greater the 'cost of electricity', which will probably reduce 'electricity use'. This is labelled as loop B7.

Secondly, there is a reinforcing loop that include additional energy generation: the greater the 'electricity use', the greater the 'electricity generation' to meet that demand. This increases the 'ability to meet electricity demand', which can reduce the 'cost of electricity', can encourage additional 'electricity use' (R11). This can operate in an upwards or downwards direction.

It is important to note that the direction of this loop will be influenced by either or both of 'electricity use' and/or 'electricity generation'. For example, if electricity generation were constrained or reduced, this would lead to a lower 'ability to meet electricity demand', increase the 'cost of electricity', and lower 'electricity use'.

Having highlighted the important influence the 'ability to meet electricity demand' has on electricity use, its longer-term influence on housing form is described next.

The 'ability to meet electricity demand' has a delayed *opposite* influence on people's 'awareness of limitations to energy availability'. That is, the better the ability to meet electricity demand, the less aware people will be that energy is a constrained resource; and the lower the ability to meet electricity demand, the more aware people are that energy is a constrained resource.

This 'awareness of limitations to energy availability' then has a delayed *same* influence on the 'need to be aware of energy use in housing design'. If people perceive energy to be limited, then over time people will be more aware that greater energy efficiency needs to be designed into housing. This factor then has delayed *same* influences on both the 'energy efficiency of housing stock' and the 'density of housing stock', as both of these are ways of addressing energy efficiency.

Related to this area is the factor called 'belief in the capability of future technology to replace fossil fuels'. This represents the level of confidence within society that technology will be developed that can replace fossil-fuel-dependent energy sources. The *greater* this belief, the *lower* the 'perceived need to reduce energy consumption', which in turn has a *same* influence on both energy efficiency and housing density.

Possible areas of leverage		
14	*Encourage denser urban form that is less dependent on private vehicles and the roads associated with them* This will reduce the land used for (sub)urban areas and the associated converson of high quality agricultural land near urban areas. Such policies will also have the benefit of reducing the strength of feedback relating to electricity use and GHG emissions, which, in the longer-term, will reduce GHG emissions from fossil fuels.	**Medium leverage**

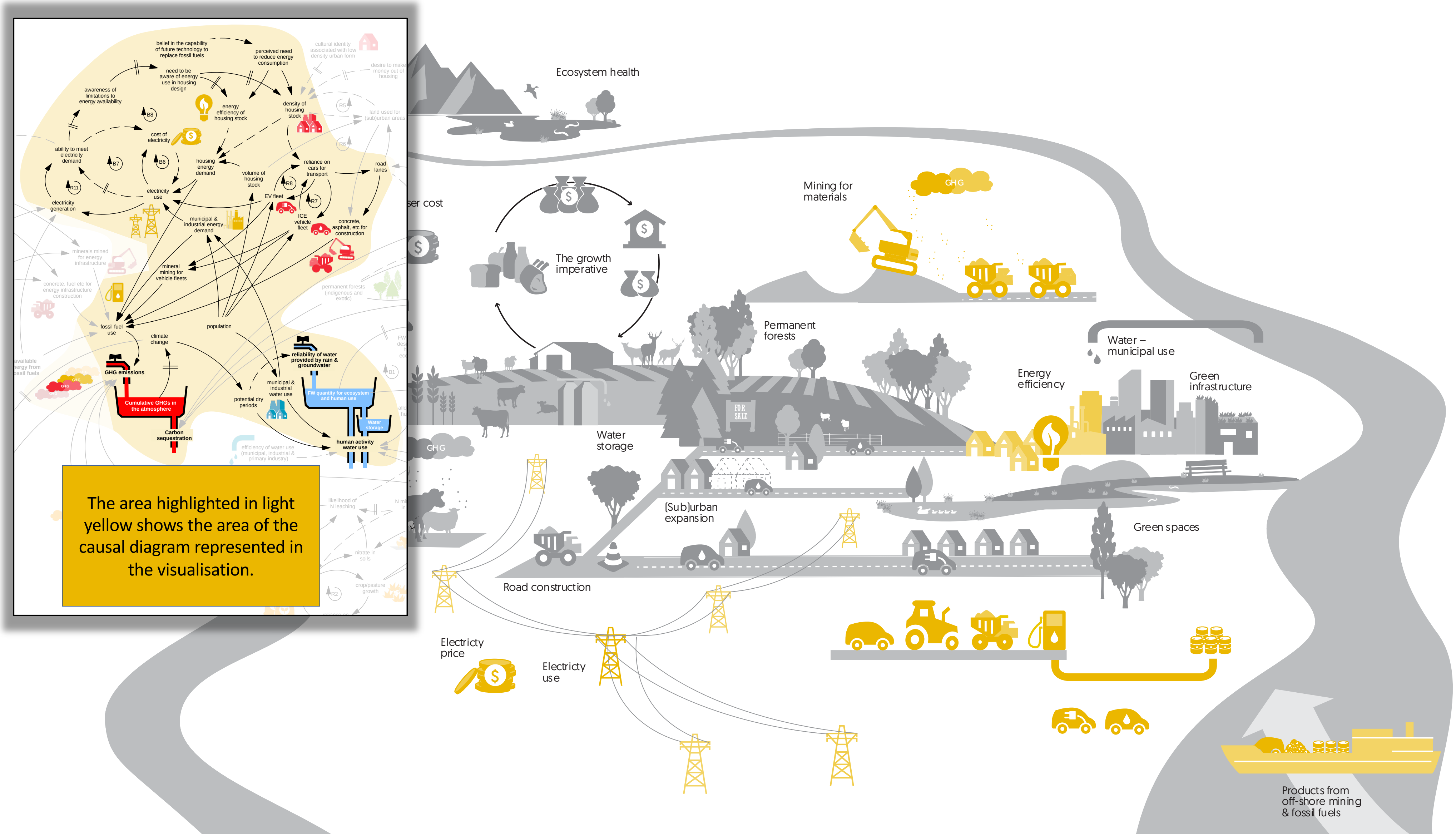


Figure 6-24. Electricity and fuel – demand implications.

6.7 Energy generation and the dependence of all electricity on fossil fuels

It is important to note that New Zealand's electricity has a huge amount of hydro generation, which is obviously linked to water, but its use is not consumptive, because water passes *through* hydro assets. For simplicity, this use of water by hydro dams has not been represented in the causal diagrams.

6.7.1 Energy generation – renewable and fossil fuels

Note: This diagram assumes that all new energy infrastructure built is renewable (primarily wind and solar).

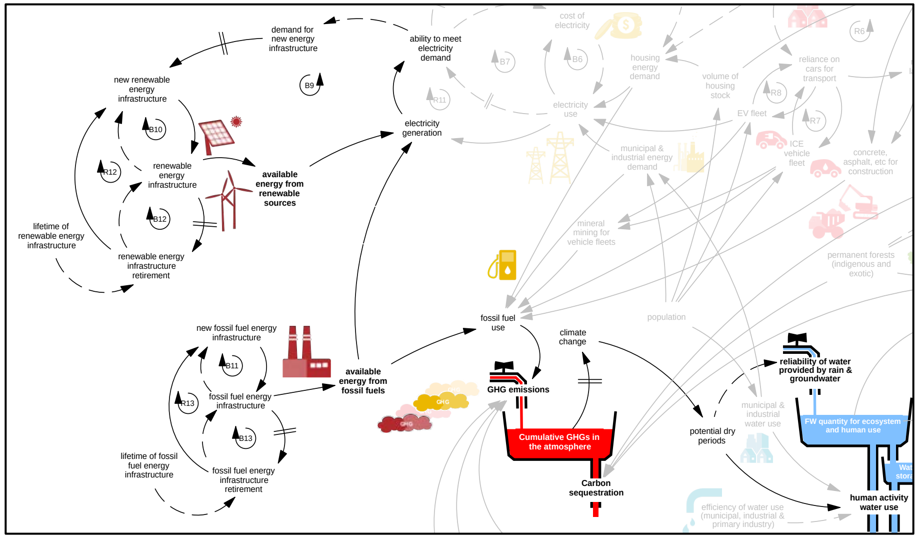


Figure 6-25. Energy generation – renewable and fossil fuels.

Firstly, there is a balancing loop in new energy infrastructure. Less 'ability to meet electricity demand' increases 'demand for new energy infrastructure', and over time this increases the 'new renewable energy infrastructure'. More new infrastructure increases the volume of existing infrastructure, which increases the 'available energy from renewable sources', and thus 'electricity generation' and 'ability to meet electricity demand'. This eases demand for new infrastructure, creating a balancing loop (B10). (See Figure 6-25).

The volume of energy infrastructure (renewable or fossil fuel-generated) supports the available energy for use (represented by the two nodes 'available energy from renewable sources' and 'available energy from fossil fuels').

Both types of energy generation have three main factors:

- new renewable or new fossil fuel energy infrastructure (the amount of new infrastructure built and commissioned)
- renewable or fossil fuel energy infrastructure (the total volume of energy infrastructure)
- renewable or fossil fuel energy infrastructure retirement (the volume of energy infrastructure that is retired).

These form similar feedback loops across the two types of energy. Firstly, the greater the volume of new infrastructure of either type, the greater the total volume of that type of energy infrastructure (*same* relationship); and the greater the volume of either type of energy infrastructure the lower the need for new infrastructure of that type (*opposite* relationship). These create balancing loops between new and existing infrastructure (B10 for renewables & B11 for fossil fuels).

Secondly, the greater the total volume of either type of energy infrastructure, the greater the *eventual* volume of retired infrastructure of that type; i.e. after their useful life (*same* relationship with a delay (e.g. decades)); and the greater the volume of retired infrastructure, the lower the volume of existing energy infrastructure (*opposite* relationship) (B12 for renewables & B13 for fossil fuels).

The lifetime of both renewable and fossil fuel energy infrastructure also has an influence here. The longer the lifetime of infrastructure, the longer the delay before it is retired.

Finally, the more infrastructure there is, the more is eventually retired and the more that needs replacing (or vice versa). This creates reinforcing loops (R12 & R13). Although most of the fossil fuel infrastructure creating fossil fuels used in New Zealand, is overseas, this pressure still exists.

6.7.2 The fossil fuel dependence of all energy infrastructure

Both types of energy infrastructure require fossil fuels during construction. These are shown respectively as 'minerals mined for energy infrastructure' and 'concrete, fuel etc for energy infrastructure construction' (see Figure 6-26).

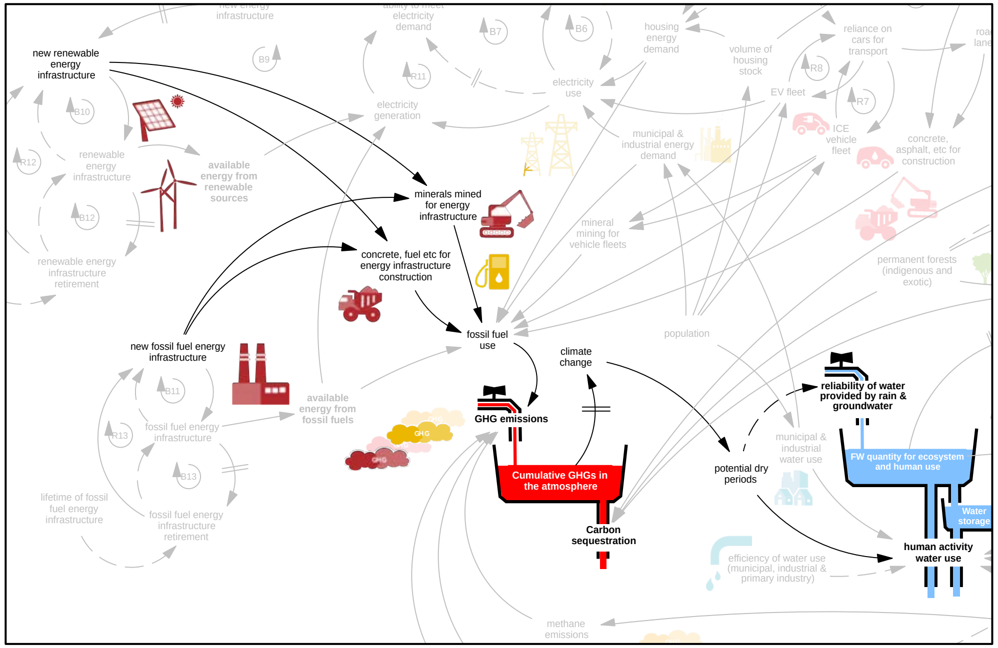


Figure 6-26. The fossil fuel dependence of all energy infrastructure.

Therefore, any new infrastructure will result in 'fossil fuel use', increasing 'GHG emissions'. This is an under-appreciated fact: while the energy created *by* renewable energy infrastructure is *low in GHG emissions*, the energy required *to build* the infrastructure still produces GHG emissions.

6.7.3 The counterintuitive impact of increasing renewable energy to reduce GHG emissions

Sustained 'GHG emissions' and the impacts of 'climate change' will increase the 'pressure to reduce fossil fuel use' and 'GHG emissions' (see Figure 6-27).

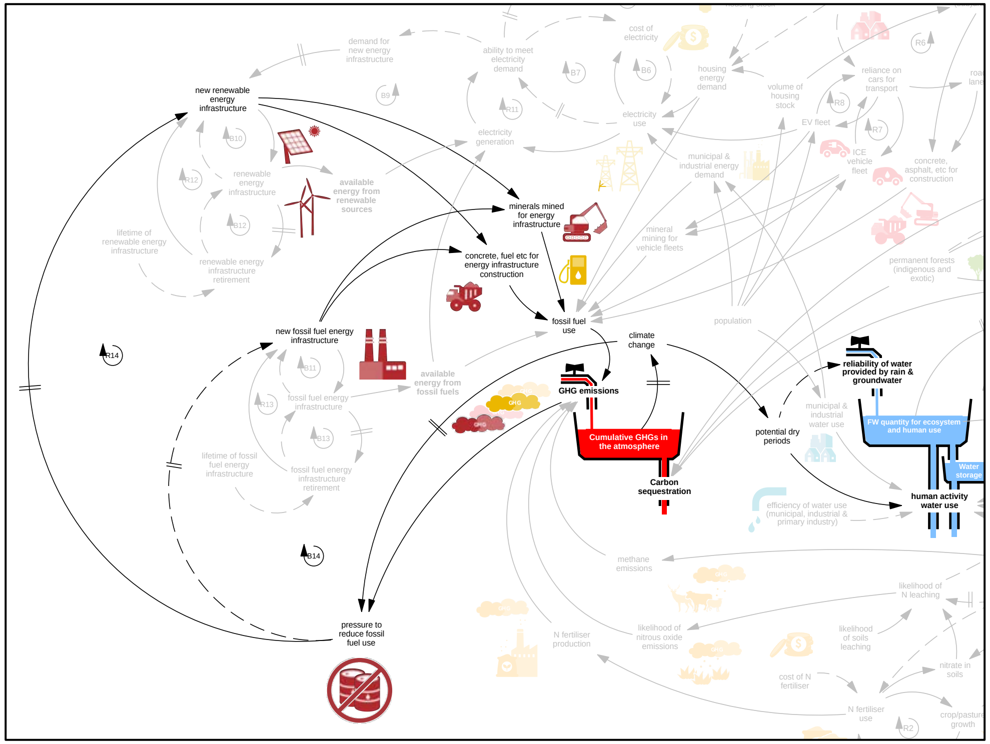


Figure 6-27. The counterintuitive impact of increasing renewable energy to reduce GHG emissions.

This will lead (and has led) to pressure to *reduce or eliminate* the creation of 'new fossil fuel energy infrastructure'. This will reduce fossil fuel use in the construction of fossil fuel infrastructure and reduce 'GHG emissions'. This forms the balancing loop B14

At the same time, this will lead (and has led) to the demand that new energy infrastructure be renewable. Yet, *counterintuitively*, all new renewable energy infrastructure built, assuming energy demand continues to grow, will still *sustain or increase* 'fossil fuel use' and 'GHG emissions'. This is because of the fossil fuel use required in their construction. (See reinforcing loop R14)

The key insight here is that *even renewable energy is not GHG-emissions neutral*. Therefore we need to reduce demand *as well as* switch to renewables.

Possible areas of leverage		
15	*Switch current fossil-fuel-based energy consumption for renewable energy equivalents* Renewable energy equivalents will still incur some GHG emissions (e.g. in their manufacturing), and so will be lower leverage for reducing GHG emissions unless combined with reducing overall energy demand.	**Lower leverage**

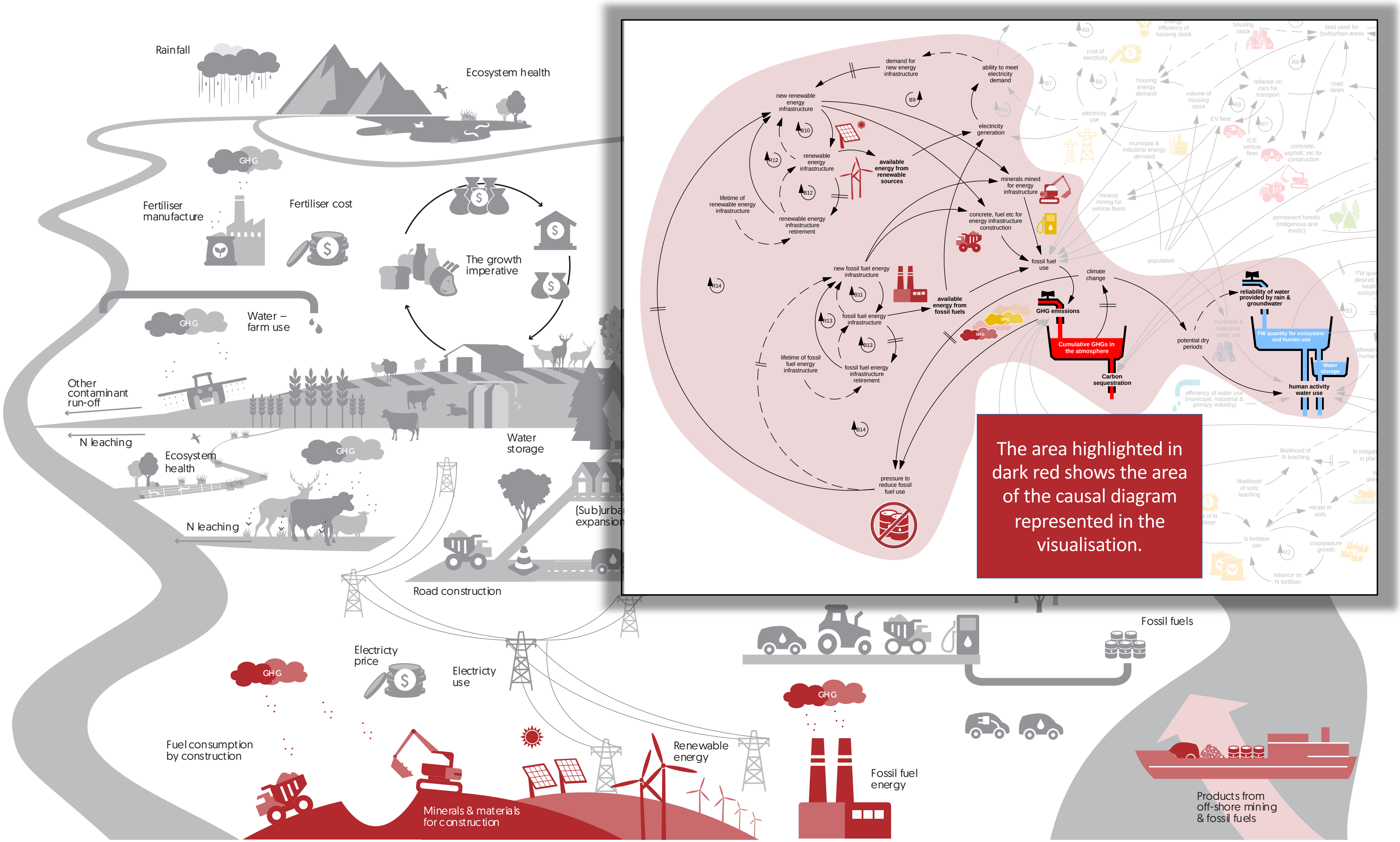


Figure 6-28. Energy generation and the dependence of all electricity on fossil fuels.

7. Related freshwater issues – broad and underlying

This section will cover general issues and trends that affect a range of issues relating to freshwater. These include:

- the appropriateness of policy design processes and institutions
- trust in science and policy, the length of political and funding cycles, and willingness to give away decision-making power
- the importance and measurement of non-financial returns
- ecological literacy, time spent in nature, and mental health and wellbeing
- social justice and (in)equality
- climate resilience on farms and greater appreciation of climate change as a risk
- a low(er) energy future and the 'net energy' equation.

As noted earlier, these issues have not been included in the causal diagram. This is because they are unlikely to fit in any one particular part of that diagram and are more likely to be an influence on many factors across it. Not appearing on the causal diagram does not mean the issues and potential intervention areas discussed below are lower leverage. Indeed, some are very higher leverage and are considered to have impact across outcomes wider than freshwater.

7.1 Appropriateness of policy design processes and central/local government

This issue relates to the appropriateness and coordination of central and local government. This may be considered both vertically and horizontally: vertical refers to central versus local government; horizontal refers to divisions and delegations within and between these organisations.

Vertical considerations may be 'What issues are dealt with at central government and local government?' and 'Are these appropriately coordinated?' Horizontal considerations may be 'Are policies and action coordinated across departments/institutions?' and 'Are they coherent and complementary, or do they conflict and compete?'

For example, one issue highlighted in the interviews was the fact that there had been a huge throughput of National Policy Statements (NPS's) since 2011, across successive governments, yet these were not always coordinated or coherent. As noted in the causal diagram earlier, (sub)urban form is one impact on freshwater outcomes that is not always considered: the NPS's related to urban form and freshwater are not coordinated or consistent with each other. If these two policy statements are not consistent, what do councils choose to follow in their planning and regulation? Will these plans then be subject to litigation for failing to achieve mutually inconsistent standards? This increases the chance they will conflict and lead to sub-optimal outcomes in both areas.

The high turnover and longer-term inconsistency of policy and science staff in central government institutions was noted as an issue in interviews, but was also a challenge at many local authorities.

Another issue highlighted by an interviewee was that the submission process for both local and central government is no longer fit for purpose: it is highly resource intensive and perceived as having no impact.

How might this be improved? It was observed that caucusing (collective discussion and agreement) occurs at the central government level to coordinate government policy, yet this is dominated by ministerial dynamics and politics. Might there be an opportunity to develop mechanisms that allow caucusing across government ministries and departments? Indeed, might there be an opportunity for such caucusing to extend more widely than central and local government to include affected industries and communities, and even to attempt to represent the affected environments or future generations in caucusing and decision-making?

Another tension highlighted was that between localised and centralised decision-making. This has presented in New Zealand across various governments as an alternating appetite for developing freshwater policy, and perhaps more importantly *action*, at a very local or geographical level (often catchment scale), and more centralised regulation of activities that affect freshwater. Interviewees observed that a lack of coordination between central and local government is affecting successful freshwater policy development and implementation.

If a trend towards more localisation continues, it is likely to challenge people's long-held understanding of the role of local government. This is especially in relation to whether local government is there to enforce regulations, or to nurture environments where groups may, at least in part, hold themselves accountable for achieving environmental outcomes.

It is likely that this area may require significant further investment (in both research and active support) in the coming years. The length of political and funding cycles also has an impact here. This is discussed further in section 7.2.

Possible areas of leverage		
16	*Increase consistency of science and policy staff in government institutions, as well as the ability to contract relevant external advice and support* This will be institution-dependent, and may relate to both employment opportunities and ensuring that science and policy skills and insights are valued and appreciated. This is one way of helping to retain knowledge and coordinate policy across institutions in the longer term.	**Medium leverage**
17	*Coordinate NPS's so that they are both collectively consistent and not conflicting* While they may seek to achieve different goals, identifying the interactions between NPS areas, where they overlap , where they complement and conflict, and internally resolving these tensions will support their co-ordination and implementation..	**Medium leverage**

7.2 Trust in science and policy, length of political and funding cycles, and willingness to give away decision-making power

These three things are grouped here as they are all loosely (but not entirely) related to the operation of local and central government.

Interviewees noted that there is declining trust in science and scientists, as well as in politicians and the political process. Both are highly problematic for engendering support in science-based policy outcomes.

Some interviewees noted that declining trust in science partly relates to the historically specific nature of scientific advice and support, such as modelling, and how this is not necessarily appropriate for dealing with the multi-faceted problems that modern policy needed to address. Some noted that there is a greater awareness that scientific support needs to come with caveats relating to the limited nature of its focus; others noted that the inability of scientific advice and support to deliver results for multi-faceted policy challenges is partly what has undermined people's faith in it.

It was also noted that decline of trust in science and the political process reflects a worldwide trend, the causes of which may only be speculated. Yet this decrease in trust for science and politicians could be considered in conjunction with the increasing trend of challenging the economic status quo (see section 7.3, and the increasing levels of inequality the world is experiencing (see section 7.5), as such trends have emerged from a society where trust and confidence in science has been paramount.

Some interviewees noted that the length of funding and political cycles is a challenge. Three-year electoral cycles are short relative to the length of time required to deal with most of the issues being addressed. This does not always allow for consistency of elected representatives at the governance table, and it can also contribute to policy and action being taken to address issues being 're-litigated' every 3 years in popular debate during elections. In effect, it was considered that such short election cycles do not allow sufficient periods of time to commit to, undertake, and evaluate the success of action.

Interviewees also noted that it was a challenge for decision-makers (either elected or managerial) to give away (or devolve) decision-making power on important issues. It was noted earlier (section 7.1) that some experts consider that the submission process is no longer fit or purpose, and this is a related tension. Involving community perspectives in decision-making often requires some decision-making power to be given up, yet this can be difficult to do for people charged with responsibility. In part this may be contributing to the inadequacy of such mechanisms as the submission process.

Possible areas of leverage		
18	*Lengthen the political cycles (a)* This would help reduce changes in focus of freshwater policy for political gain, which arguably has caused some misalignment in activity and desired outcomes.	**Medium leverage**
19	*Lengthen the political cycles (b)* This would help create greater certainty relating to the actions that need to be undertaken within a cycle, providing those who need to do them greater certainty within which to operate.	**Medium leverage**
20	*Appreciate and fund the longer-term requirements of freshwater mitigation interventions beyond capital expenditure (e.g. to include maintenance)* This will help to ensure their success and will be important if many policy changes are to be enduring. Without ongoing support, initial changes may revert as soon as the policy incentive expires.	**Medium leverage**

7.3 Importance and measurement of non-financial returns

The continued dominance of narrow financial returns and metrics in policy development and decision-making was noted by several participants. They also anticipated an increase in the importance of appreciating and measuring non-financial returns on investments and activities.

This aligned with other comments relating to a very active discussion on the nature of our current economic system(s) and a need to reform them so that they are fit for purpose. This is partly related to the trend of growing inequality noted in section 7.5

Participants observed that there is a growing appreciation that 'economic' value includes non-financial returns, meaning there is a greater appreciation of ecosystem services. There was also the suggestion that more localised economies may play an important role in New Zealand in the future (i.e. more localised supply chains and less dependence on international ones), while recognising that exports will remain an important part of New Zealand's economy.

These observations reflect larger political debates about the role of economics and economies at a global scale. The underlying assumption that economic growth (representing collective economic activity) is the default path to better social and environmental outcomes is being actively challenged.

For example, there is growing awareness and acceptance of such concepts as:

- for richer countries economic growth is no longer a prerequisite to achieve prosperity (Jackson (2016)
- viewing the role of society as being to ensure the natural world has the capabilities to flourish and humans to live lives they deem valuable (The Treasury 2021; O'Connell et al. 2018; Stiglitz et al. 2009)
- the main measure of economic success should be how well societies achieve the provision of societal foundations (minimums) within ecological limits (maximums) (Raworth 2017; Rockström et al. 2009).

Possible areas of leverage		
21	*Recognising alternative measures of success such as wellbeing indicators, rather than the traditional (and limited) economic and financial metrics such as GDP* These are measures that seek to change the rules of the systems and therefore its structure, and are considered medium leverage.	**Medium leverage**
22	*Seek to change the goal of the economic system to one that seeks to achieve wellbeing,* Seeking to change the goal of the economic system is a very deep leverage point. Currently the goal is on growth in the volume of economic activity, and assuming this produces wellbeing, rather than actually focussing on wellbeing.	**Higher leverage**

7.4 Ecological literacy, time spent in nature, and mental health and wellbeing

This issue describes the interconnectedness of people's ecological literacy (or awareness and connection with nature), the time they spend in nature, and the positive mental health and wellbeing impacts this has.

One interviewee believed that there is increasing trend of ecological literacy and a movement to reclaim familiarity and living in balance with indigenous biodiversity in New Zealand. However it was also noted that this is starting from a very low level, due to the disconnect with indigenous flora and fauna that was the result of a century and a half of colonialisation, and the dominance of European influence after the Treaty of Waitangi. During this time, the replacement of indigenous species with introduced species, usually to underpin primary industry land uses, came to dominate New Zealand's landscape.

As a result of this disconnection most people in New Zealand have extinction of experience: they don't have living memory of a landscape dominated by indigenous flora and fauna.

A growing trend to change this extinction of experience was noted; for example, riparian plantings with indigenous species, which in the longer term would lay the foundations for regeneration of other, larger species such as trees. However, the large time delay inherent in this was noted: larger indigenous trees take 18–20 years before they begin reproducing, so the timeframe for noticing significant changes in indigenous biodiversity is many decades.

Related to this increasing trend is the reinforcing relationship between several factors. Time spent in the outdoors among flora and fauna helps to reconnect people with nature and restore ecological literacy, as well as an appreciation that human activity is part of the environment, not separate from it. It was noted that such reconnection can also happen in urban environments if appropriately planned for, such as urban re-wilding creating spaces where people can reconnect with flora and fauna.

The very positive physical, mental health, and wellbeing benefits of regularly being in or connected to nature were noted, as was the suggestion that supporting such trends could actively affect these outcomes.

Possible areas of leverage		
23	*Incorporate (re)wilding into urban and rural areas* This enables people to have increased interaction and connection with nature.	**Medium leverage**
24	*Increase the public's ecological literacy* Consider opportunities that actively or passively enable or support people to increase their ecological literacy. This will help reclaim familiarity and living in balance with indigenous biodiversity.	**Medium leverage**
25	*Help people recognise that they are part of nature not separate from it* Similar to leverage point 13, this involves a change in mindset to acknolwedge our relationship with and dependence on the natural world.	**Higher leverage**

7.5 Social justice and inequality

A number of issues relating to social justice, social tensions, and inequality within society were touched upon by multiple participants. This presented in a range of ways. At a macro level it was noted that the international climate change literature is showing a strong recognition of growing social inequality in the world, along with the expectation that this will be exacerbated by climate change. There is also an increasing recognition that effective action on climate change and social inequality are intimately linked, and that actions that achieve the former will have to appropriately seek to resolve the latter in order to be effective.

Several points were noted that are specific to New Zealand. The average age of farmers is quite high and farming assets continue to increase in cost, requiring more significant debt to finance, which means it is becoming harder for individuals/families to acquire assets for the first time. In farming this is likely to result in a mixture of increased corporatisation as well as novel business structures. For example, sharemilking has become a more common form of asset ownership, but other forms of business structure might evolve in the future.

Possible areas of leverage		
26	*Support the involvement of under-resourced interests in the development of policy* This may help achieve successful freshwater policy by introducing broader perspectives and ideas through e.g. funding under-resourced/-represented groups to participate.	**Medium leverage**
27	*Seek to incorporate under-represented groups in the procurement process* Where policy requires funded or procured services to occur, consider options for procurement practices that actively seek to incorporate under-represented groups in the procurement process.	**Medium leverage**

There is also greater awareness that entrenched inequality of Māori and Pasifika, relative to Pākehā, is growing, and greater recognition that incorporating targeted action to address such inequities will be necessary for future socio-economic wellbeing to be maintained or achieved. If being aware of the impacts of inequality is incorporated into freshwater policy discussions, this will help make them have more impact in the longer term.

7.6 Climate change as a risk, and greater appreciation of climate resilience on farms

Another trend that several participants highlighted is the increasing awareness that climate change is a very real risk to society in terms of social and economic prosperity, and that there is a greater appreciation of the need for climate resilience on farms and in the landscape more generally.

This trend highlights the need to consider how multiple policy factors are related to each other, and how they might be considered together when considering policy in one of those areas. This is exactly what has been attempted in the causal diagram described earlier. It also reinforces the need to consider climate- and emissions-related issues alongside freshwater issues, and not separately from them.

This implies the need for greater coordination of activity across policy and other activities of (local and central) government. This has already been touched on in leverage area 17, which talked about coordinating NPS's. A more general leverage point is highlighted below.

Possible areas of leverage		
28	*Encourage coordination of local and central government activities* Increased coordination across multiple subject matter areas, particularly with a climate change related lens may also help to address freshwater concerns in an integrated way.	**Medium leverage**

7.7 A low(er) energy future

The fossil fuel dependence of all forms of energy generation was described in section 6.7.

Fossil fuels are a finite resource, and our ability to practically extract them will eventually be practically exhausted. Even though fossil fuel consumption is still growing, we will see demand fall in the future as fossils fuels become more expensive and we switch to alternatives with lower marginal costs.

These transitions may be sped up by policies, and some are currently actively trying to reduce fossil fuel use. So we can expect to see fossil fuel use decline.

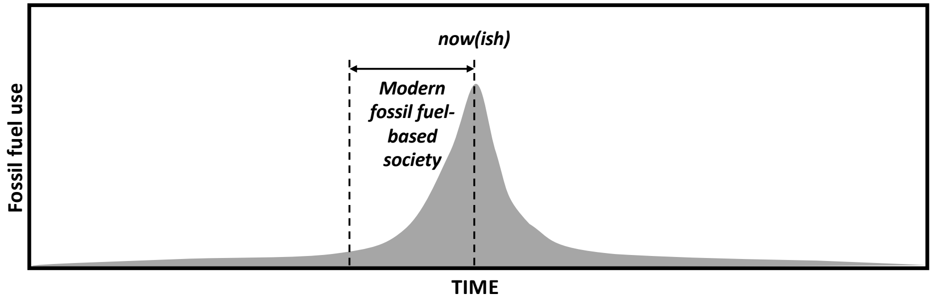


Figure 7-1. A conceptual representation of fossil fuel use over time.

However, if all types of energy generation are dependent on fossil fuels (i.e. fossil fuels are not substitutable in the production of renewable energy infrastructure, see section 6.7) and fossil fuels will be used far less in the future, it follows that where fossil fuel use is constrained, energy generation will also be constrained.

A conceptual representation of the utilisation of fossil fuels over time is shown in Figure 7-1. Yet our modern society has also been able to develop over the last several hundred years by tapping into previously unknown reserves of fossil fuels.

It therefore holds that, even in a future with predominantly renewable energy generation, our society will probably need to return to operating in an energy environment where the *amount of energy available is far lower than today.*

Generally, the volume of economic production in society is dependent on energy use. Even with more efficient energy use, continued growth in consumption may mean more energy is required. Economic discussions about *post-growth* economics are related to this challenge.

Possible areas of leverage		
29	*Treat electricity as a limited and precious resource, and help people view electricity as a limited resource* This will encourage both lower energy farming practices and higher-density and higher-energy-efficiency housing. Over time such increased housing density will reduce the land used for (sub)urban area and the associated converson of high quality agricultural land near urban areas.	**Medium leverage**
30	*Reduce energy demand by shifting to lower energy lifestyles and farming practices* This is because there is a need to reduce overall energy demand as well as shift to renewable energy sources.	**Medium leverage**

8. Summary

The number of challenges facing modern policy development are only increasing and becoming more interconnected. The world has more humans on it than it has ever had, we are hitting environmental limits and thresholds, and subjects that previously operated independently (or at least appeared to) are conflicting with each other more and more. At the same time, our natural and understandable tendency to focus attention in specialist areas can lead to policy development that is siloed and itself contributes to conflicting policy.

In this guidance document we encourage those involved with freshwater policy to take a wider perspective on the issues and challenges that would be useful to include or align with freshwater policy. We have sought to highlight the non-linear nature of the relationships and influences that are operating in relation to freshwater. A key insight is that sometimes these align and sometimes they conflict. We have tried to do this in an accessible and visual way, and by providing perspectives on possible areas of leverage to include in or align with policy discussions (summarised here in Table 8-1). These insights are intended to complement the highly detailed and specialised knowledge that exists with both professionals in freshwater and the other areas discussed. This is not intended to imply that there a single 'solutions' that can be taken to address freshwater outcomes. To achieve desired outcomes, parallel pathways of action will likely be needed.

We hope this document is useful. If the connections drawn and explained are already being considered in freshwater policy – fantastic. If not, we hope this guidance encourages those discussions to broaden.

If readers find the approach taken, or any of the interconnections drawn in this document, confronting or challenging, then it has also served one of its purposes. If so, may this guidance act as an opportunity or prompt to explore a different way of understanding interconnection and complexity.

This guidance has necessarily had to be limited: it has limitations. Regardless, we believe it provides useful insights and introduces readers to an interconnected way of viewing policy issues more systemically that will only become increasingly necessary in the future.

Pass it on, discuss it, use it.

May this help people not only recognise complexity, but embrace it.

Table 8-1. Summary of possible areas of leverage – higher to lower

#	Description	H/M/L
6	*Seek to adapt the business of farming and other primary industry land uses (including finance) to be less reliant on debt and the need for growth* This might involve reimagining farming so that it is less focused on financial metrics of success and implementing policies and approaches to support this shift. This may also help sustain primary industry land use in the longer term, without that land use needing to be reliant on growth or increased intensificiation of activity.	**Higher leverage**
9	*Seek to change the dominant culture of building wealth out of (mostly suburban) housing.* Over time this would mean a move away from suburban and lower-density forms of housing, reducing reliance on private cars for transport.	**Higher leverage**
11	*Seek to change the focus of asset management to include assets that appreciate, such as green infrastructure* This would mean a shift of mindset in how green assets are viewed in council accounting systems.	**Higher leverage**
13	*Encourage ways of farming that recognise the role of ecosystems within their farm systems and seek to live in balance with it.* This involves a change in mindset to encompass a more reciprocal relationship with the natural world upon which we depend.	**Higher leverage**
22	*Seek to change the goal of the economic system to one that seeks to achieve wellbeing,* Seeking to change the goal of the economic system is a very deep leverage point. Currently the goal is on growth in the volume of economic activity, and assuming this produces wellbeing, rather than actually focussing on wellbeing.	**Higher leverage**
25	*Help people recognise that they are part of nature not separate from it* Similar to leverage point 13, this involves a change in mindset to acknolwedge our relationship with and dependence on the natural world.	**Higher leverage**
3	*Encourage shift to rain-fed agriculture* This recognises the future needs for farm systems that thrive in a rain-fed environment while still producing food and fibre.	**Medium leverage**
4	*Minimise the difference between desired and actual water quality* Lowering contaminants or the intensity of farm activities reduces the strength of these loops. So does lowering desired water quality objectives (although this is not suggested as an intervention). We note that this area is where a lot of effort in freshwater policy development is already targeted .	**Medium leverage**
5	*Reduce fertiliser dependence* Fertiliser use is a key driver of intensification. Reducing fertiliser dependence could be achieved in multiple ways; for example, by heavily restricting the use of nitrogen fertiliser (through price or a cap), or exploring profitable but lower nitrogen-dependent crops. This would also help reduce GHG emissions.	**Medium leverage**
7	*Rules that limit the intensification of farm land* These can constrain the loops relating to farm profit and debt, effectively capping the ability to increase borrowing through intensification and increase profit through increased production. Note that this may be a common intervention, but it does not remove the growth imperative. Farmers may either change to less-intensive farming types (the intent of the intervention), or convert to suburban land if they are near an urban area (not the intent of the intervention).	**Medium leverage**
8	*Reduce urban sprawl* Most of New Zealand's towns and cities are historically based around our best/richest soils. Urban sprawl has covered (and continues to cover) much of this land, moving rural activity to other areas and perhaps lower-quality soils. Therefore, policy/regulation that reduces urban sprawl will, in the longer term, reduce the strength of the pattern of where rural land is converted to (sub)urban land, thus retaining rural land for farming and reducing the need to intensify farming activities to compensate. See also leverage area 9.	**Medium leverage**
10	*Encourge green infrastructure in rural and urban areas* This will help reduce the bias towards hard infrastructure and help buffer flows to waterways.	**Medium leverage**
12	*Take actions that reduce urban sprawl, limit intensification of animals and crops on farms, and/or increase green infrastructure and forests* These can all support healthy biodiversity, which can have a positive impact on freshwater outcomes. As most of these are actions in feedback loops, they are considered medium leverage, although multiple cumulative actions would increase their impact.	**Medium leverage**
14	*Encourage denser urban form that is less dependent on private vehicles and the roads associated with them* This will reduce the land used for (sub)urban areas and the associated converson of high quality agricultural land near urban areas. Such policies will also have the benefit of reducing the strength of feedback relating to electricity use and GHG emissions, which, in the longer-term, will reduce GHG emissions from fossil fuels.	**Medium leverage**

#	Description	H/M/L
16	*Increase consistency of science and policy staff in government institutions, as well as the ability to contract relevant external advice and support* This will be institution-dependent, and may relate to both employment opportunities and ensuring that science and policy skills and insights are valued and appreciated. This is one way of helping to retain knowledge and coordinate policy across institutions in the longer term.	**Medium leverage**
17	*Coordinate NPS's so that they are both collectively consistent and not conflicting* While they may seek to achieve different goals, identifying the interactions between NPS areas, where they overlap , where they complement and conflict, and internally resolving these tensions will support their co-ordination and implementation..	**Medium leverage**
18	*Lengthen the political cycles (a)* This would help reduce changes in focus of freshwater policy for political gain, which arguably has caused some misalignment in activity and desired outcomes.	**Medium leverage**
19	*Lengthen the political cycles (b)* This would help create greater certainty relating to the actions that need to be undertaken within a cycle, providing those who need to do them greater certainty within which to operate.	**Medium leverage**
20	*Appreciate and fund the longer-term requirements of freshwater mitigation interventions beyond capital expenditure (e.g. to include maintenance)* This will help to ensure their success and will be important if many policy changes are to be enduring. Without ongoing support, initial changes may revert as soon as the policy incentive expires.	**Medium leverage**
21	*Recognising alternative measures of success such as wellbeing indicators, rather than the traditional (and limited) economic and financial metrics such as GDP* These are measures that seek to change the rules of the systems and therefore its structure, and are considered medium leverage.	**Medium leverage**
23	*Incorporate (re)wilding into urban and rural areas* This enables people to have increased interaction and connection with nature.	**Medium leverage**
24	*Increase the public's ecological literacy* Consider opportunities that actively or passively enable or support people to increase their ecological literacy. This will help reclaim familiarity and living in balance with indigenous biodiversity.	**Medium leverage**
26	*Support the involvement of under-resourced interests in the development of policy* This may help achieve successful freshwater policy by introducing broader perspectives and ideas through e.g. funding under-resourced/-represented groups to participate.	**Medium leverage**
27	*Seek to incorporate under-represented groups in the procurement process* Where policy requires funded or procured services to occur, consider options for procurement practices that actively seek to incorporate under-represented groups in the procurement process.	**Medium leverage**
28	*Encourage coordination of local and central government activities* Increased coordination across multiple subject matter areas, particularly with a climate change related lens may also help to address freshwater concerns in an integrated way.	**Medium leverage**
29	*Treat electricity as a limited and precious resource, and help people view electricity as a limited resource* This will encourage both lower energy farming practices and higher-density and higher-energy-efficiency housing. Over time such increased housing density will reduce the land used for (sub)urban area and the associated converson of high quality agricultural land near urban areas.	**Medium leverage**
30	*Reduce energy demand by shifting to lower energy lifestyles and farming practices* This is because there is a need to reduce overall energy demand as well as shift to renewable energy sources.	**Medium leverage**
1	*Water storage policies* These only increase the temporary buffer of water available for use, so they may not change the fundamental water-dependent characteristics of the farm system.	**Lower leverage**
2	*Interventions that improve the efficiency of water use (e.g. irrigation type) or required water (e.g. lower-water-use cultivars)* These only improve or reduce the water use or absorption rate. Changes in rates of water use retain the same general farm system. Efficiencies may even encourage higher water use in the longer term due to the increased efficiency (a.k.a. Jevon's Paradox). Therefore they are considered lower leverage at a wider systemic level.	**Lower leverage**
15	*Switch current fossil-fuel-based energy consumption for renewable energy equivalents* Renewable energy equivalents will still incur some GHG emissions (e.g. in their manufacturing), and so will be lower leverage for reducing GHG emissions unless combined with reducing overall energy demand.	**Lower leverage**

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Appendix 1. How to read a causal diagram

This appendix provides a guide to the symbols and terms used in a causal diagram. This is an extended explanation of the basic concepts outlined in section 4. It provides useful guidance to understanding the approach used in the causal diagram described in this guidance.

At the core of a causal diagram is the desire to visually articulate the relationships between factors that best explain the behaviour of the system you are trying to understand. The behaviour of a system is described as some kind of 'behaviour over time' (like a trend on a graph). This visual articulation of relationships is known as 'system structure'.

The following subsections outline important fundamental elements of system structure. These are:

- feedback loops
- how relationships/influences are correctly annotated
- the use of the 'goal/gap' structure (as this can explain how different loops dominate in a system at different times)
- understanding how influences can have different effects if they are flowing 'upstream' or 'downstream'.

It is recommended that readers familiarises themselves with these concepts to better understand the causal diagram in this report.

The final subsection outlines different ways that causal diagrams can be used.

1. Feedback loops – the basic building blocks of a causal diagram

Systems thinking is especially interested in identifying loops of causality – called *feedback loops*. There are two types of feedback loops, *reinforcing and balancing* (Senge 1990). The two types of feedback loop are described in Figure A1-1.

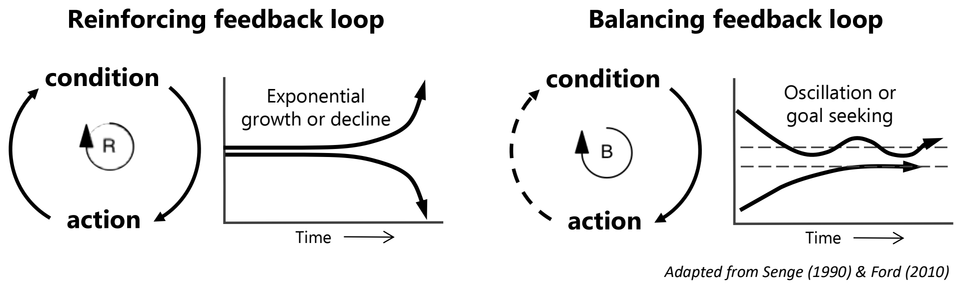


Figure A1-1. The two types of feedback loop.

In a *reinforcing feedback loop*, the direction of influence provided by one factor to another will transfer around the loop and influence the originating factor in the *same* direction. This has the effect of *reinforcing* the direction of the original influence, and any change will build on itself and amplify – resulting in either growth or decline. For example, (assuming no withdrawals) money in a bank account will earn interest, which in turn increases the amount of money in the account, which in turn enables it to earn more interest. When viewed over time this will present as consistent and compounding growth.

Reinforcing loops are what drive growth or decline within a system.

In a *balancing feedback loop*, the direction of influence provided by one factor to another will transfer around the loop through that one factor (or series of factors) and influence the originating factor in the *opposite* direction. This has the effect of *balancing* out the direction of the original influence. For example, a thermostat connected to a heater will turn on if the room is cold; this will heat the room to the desired temperature, at which point the thermostat turns the heater off, then the room will begin to cool until a point when the thermostat turns on again, at which point the cycle begins over again. This will present as an oscillating trend over time.

Balancing loops are what create control, restraint or resistance within a system.

Feedback loops can be made up of more than two variables and can be drawn together to form a causal diagram. How these interact provides insight into how a wider system operates.

2. Labelling factors

An important concept within causal diagrams is the concept of accumulation (or decrease; that is, where do things build up (or decrease)? The simple analogy of a bathtub is often used to describe this (see also section 4.2.

In causal diagrams, this concept of accumulation is captured by describing variables in such a way that their name implies that they can increase or decrease. This means they should be described as nouns, have a clear sense of direction, and have a normal sense of direction that is positive. Examples to demonstrate this are shown in Figure A1-2.

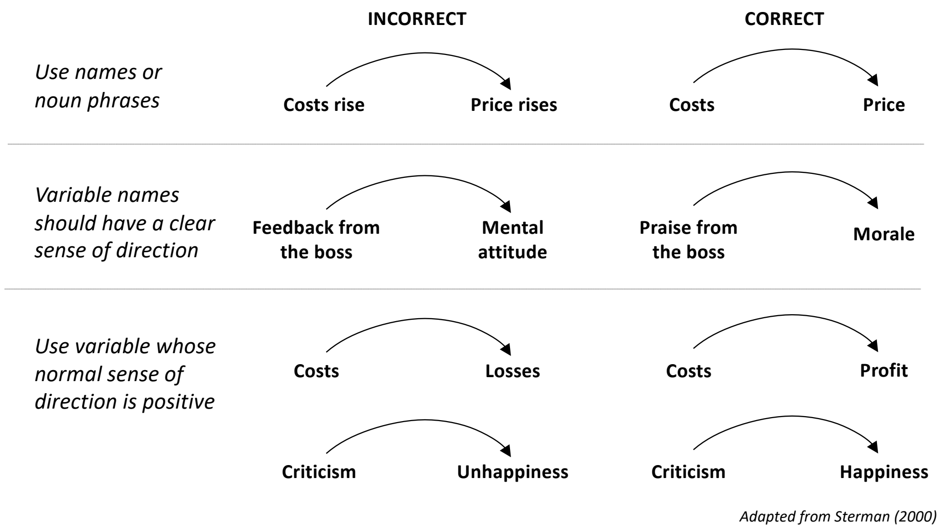


Figure A1-2. Labelling variables.

3. Labelling causal relationship arrows

Factors in causal diagrams are connected (and made into feedback loops) by arrows. These indicate that one factor has a causal relationship with the next. *Same* arrows are drawn with a solid line, while *opposite* arrows are drawn with a dashed line. These terms correspond to the direction of change that any change in the first variable will have on the second variable.

For example, if a directional change in one variable leads to a directional change in the next variable in the *same direction*, it is a *same relationship* (i.e. if A goes up and B goes up, or vice versa). Conversely, if the second variable changes in the *opposite direction*, it is an *opposite relationship* (i.e. if A goes up and B goes down, or vice versa). See Figure A1-3 for a visual description.

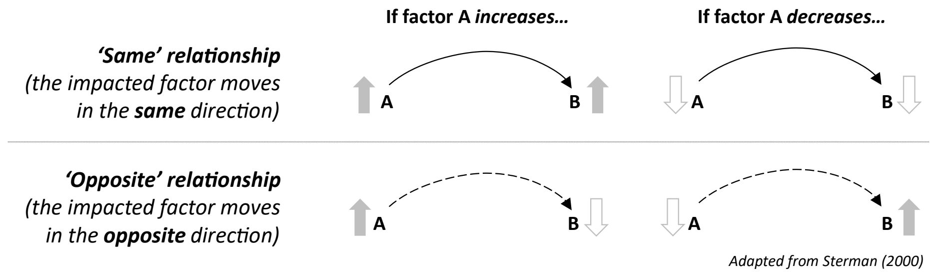


Figure A1-3. How arrows are labelled in causal diagrams

If there is a notable conceptual *delay* in an influence presenting in the second variable compared to other influences described in the causal diagram, this is annotated as a *double line crossing the arrow*. An example of this is shown in Figure A1-4. Delays are conceptual only and are not quantified.

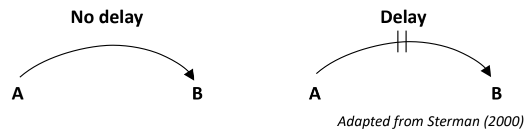


Figure A1-4. How delays are annotated on arrows

4. Goals and gaps – the changing dominance of individual loops

Understanding that multiple loops are operating within a system is the first useful insight of systems thinking. A further useful insight is understanding that not all loops may operate at the same strength all the time. Different loops can dominate the dynamics of a system at different times.

For example, a system might be dominated by a period of growth (a reinforcing loop), but when some kind of physical limit is approached (e.g. the available space in a pond for algae to grow) a balancing loop will start to dominate, therefore dominating and slowing the rate of growth.

One useful mechanism for gaining insight into the strength of a balancing loop is the *'goal/gap' structure*. This is a structure that combines both a *desired level* of something (a 'goal'), with an *actual level* of something. The *difference between these variables* is the 'gap' between the desired and actual levels.

The higher the desired level and the lower the actual level, the greater the 'gap' or difference and the greater the strength of the influence this gap passes on.

The lower the desired level and the higher the actual level, the lower the 'gap' or difference and therefore the weaker the strength of the influence this gap passes on.

The 'goal/gap' mechanism features in multiple places in the causal diagram in this report. A conceptual example is shown in Figure A1-5, which shows the act of filling a glass of water.

Initially, while the gap/difference between the desired and actual water level is high, the tap will be opened more and the strength of the water flow is higher. As the desired level of water is approached, the gap/difference reduces, so the tap is closed further, weakening the flow of water (you don't want the water to overflow the glass), until it is fully closed when the water level reaches the desired amount (Senge 1990).

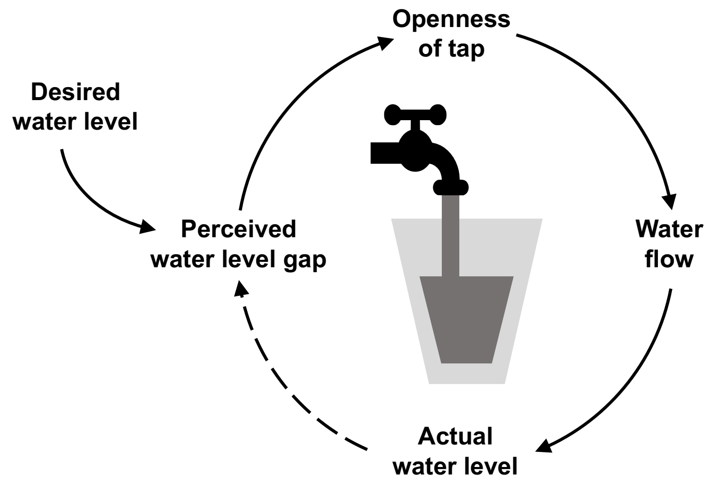


Figure A1-5. 'Goal/gap' structure in a causal diagram – pouring a glass of water

5. Stock and flow notation (bathtubs and flows)

The bulk of the causal diagrams described in this report are made up of variables and arrows, as described above. Such variables usually form the bulk of causal diagrams. However, in some places selected variables are described in a slightly more involved way – they are shown as a *bathtub* which represents *stock and flow notation*. This provides a slightly more nuanced level of insight into the behaviour of the system (see figure A1-6).

The metaphorical bathtub (or stock) might be anything that we are interested in – number of people, quality of water, level of morale, etc. Bathtubs/stocks can only increase through more inflow (the tap into the bathtub), and only decrease through more outflow (the drain out of the bathtub).

In this report, the use of bathtub (stock and flow) notation has been included for the variables of freshwater quantity and the accumulation of GHGs in the atmosphere.

While the conceptual bathtub has been used to reinforce the analogy in this report, in other reports simple boxes and arrows may be used to represent the same thing (Figure A1-6).

Figure A1-6. Stocks and flows – the more advanced notations used in system dynamics.

Both basic causal diagrams (with simple variables only) and more complicated stock and flow diagrams (with bathtubs or boxes and flow arrows) explain the same type of behaviour.

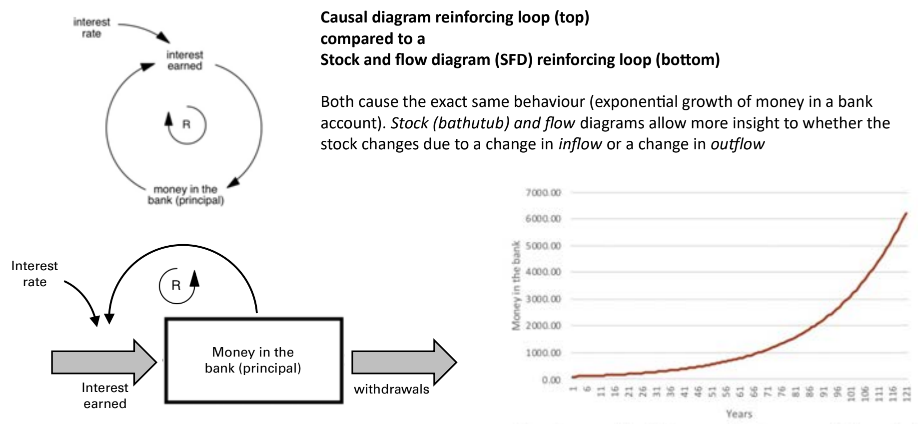


Figure A1-7. Comparison of reinforcing loops: causal diagrams (causal-loop diagrams) vs. stock and flow diagrams.

Yet the inclusion of bathtubs (stocks and flows) within a causal diagram allows a greater level of insight to understand whether a change in a key variable (bathtub/stock) is due to a change in *inflow* or a change in *outflow* (see Figure A1-7 for an example).

Stocks and flows are the language of simulation modelling in system dynamics. If any of these diagrams were to be expanded or developed into quantitative simulation modelling, then full stock and flow formulation would need to be used. This spectrum of quantitative rigour within the tools of system dynamics is explained later.

6. How influence operates differently upstream and downstream of a change in flow

When a diagram is made up partly of variables and arrows of influence, as well as stock (bathtub) and flow notation (as the causal diagrams in this report are), then the flows themselves often form pathways of influence within feedback loops. When this occurs, the influence can be either *same* or *opposite*, depending on which way along the flow the influence is travelling.

The flow structure and the variable/arrow influence structure are compared below in Figure A1-8. Where flow forms part of notable feedback loops that are discussed in this report, the influence direction has also been noted.

When a flow forms part of a feedback loop and the influence is travelling *with the flow* (i.e. downstream), then that is a *same* influence. That is, if the flow were to increase (or decrease), then the stock *to which it is flowing* would also increase (or decrease), all other things being equal.

When a flow forms part of a feedback loop and the influence is travelling *against the flow* (i.e. upstream), then that is an *opposite* influence. That is, if the flow were to increase (or decrease), then the stock *from which it is flowing* would decrease (or increase), all other things being equal.

7. How causal diagrams can be used

This section briefly outlines how causal diagrams themselves fit within a spectrum of quantitative rigour in the discipline of system dynamics, and how they may be used in conjunction with other methodological approaches.

The tools of system dynamics themselves exist on a spectrum of quantitative rigour. These are shown in Figure A1-9, which highlights how these varying tools can demonstrate the same system, each being able to demonstrate the complexity of that system, yet to differing levels of quantitative rigour or robustness.

This spectrum is also intended to highlight that causal diagrams are not the only possible output from the use of system dynamics tools.

Causal diagrams exist at the conceptual (low quantitative rigour) end of this spectrum. These can range from using the simple dynamics of a single feedback loop to demonstrate a type of behaviour, to multiple loop systems (as in this report), which can demonstrate the high level of complexity of a system.

The next step up in quantitative rigour are stock and flow diagrams (SFDs). While some components of the causal diagram within this report use stock (bathtub) and flow notation, these diagrams are not considered complete of 'full' SFD. This is because SFDs usually contain multiple stocks of interest, not just the focal variables. Although not all factors need to be stocks, their architecture tends to represent a greater level of mathematical functionality (although this may not actually be computed).

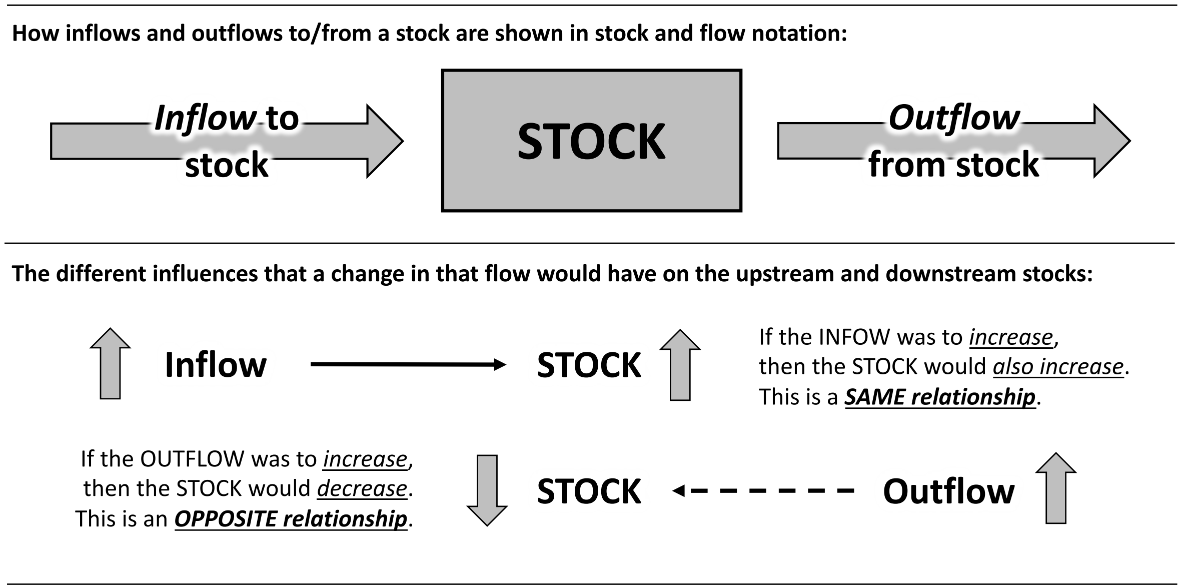


Figure A1-8. How inflows and outflows have different influences on a stock.

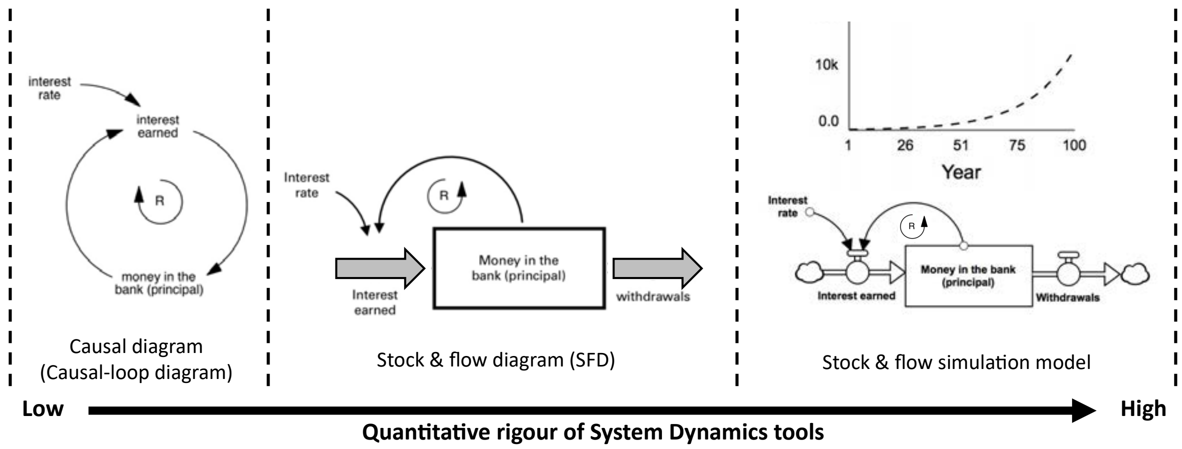


Figure A1-9. System dynamics tools exist on a spectrum: causal diagrams (or causal loop diagrams), stock and flow diagrams, and simulation modelling.

This is because SFDs tend to be qualitative representations of the actual functions and equations that would be represented in a stock and flow model.

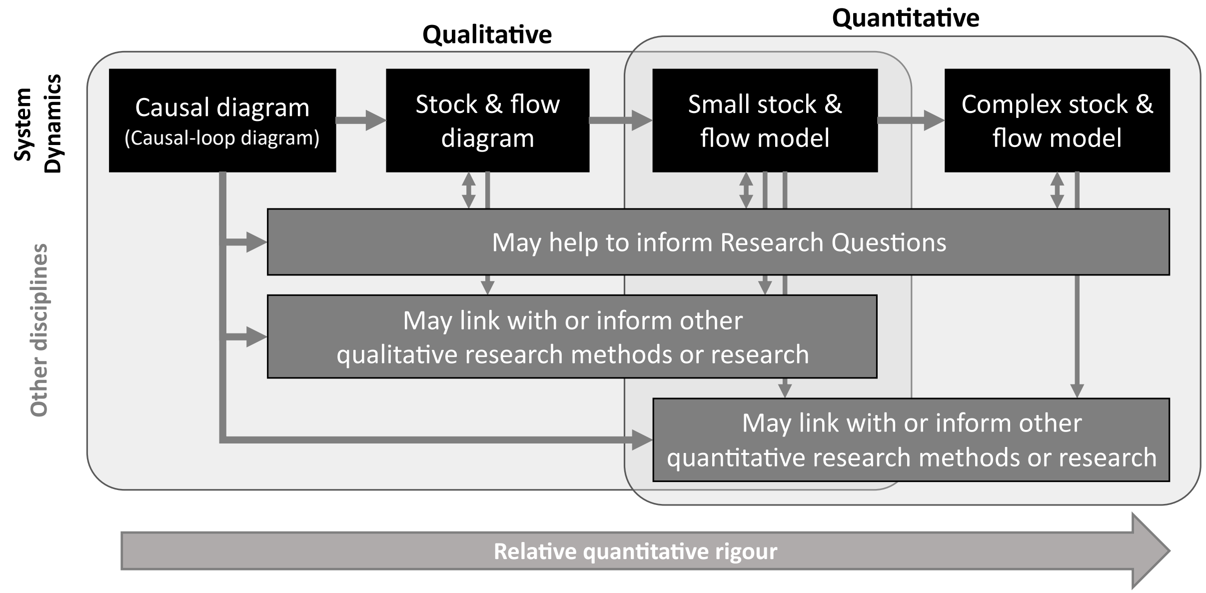
Computer simulation modelling (based on the stock and flow formulation) is the next step in quantitative rigour, turning stock and flow diagrams into simulation models. There is huge variability in the types of simulation models that can be developed, with some people advocating that large system insights can be gained from using small-scale models (Meadows 2008), and others demonstrating the utility of large-scale and highly complex simulation models (Sterman 2000).

8. How causal diagrams link with other methodological approaches

Causal diagrams can also link with or inform other methodological approaches within a wider research project (see Figure A-10).

The series of black boxes across the top of the diagram in Figure A-10 represent the increasing quantitative rigour of the system dynamics tools. The grey boxes in the lower part of the diagram represent the research questions that may be generated during research, as well as the different qualitative and quantitative methods that may be employed within the research. All of these may be informed by a causal diagram or something more rigorous (e.g. a small stock & flow model).

For example, a causal diagram may provide insight into the nature of relationships within the system, which may inform how a research question is framed.



Note: There is an overlap of the qualitative and quantitative areas of application because they are not mutually exclusive. For example, some quantitative relationships in models and their calculations may be informed by research or data, while others may be informed or assumed via some form of participatory process.

Figure A1.10. How causal diagramming can link with other research methodologies.

It may also inform *who* might be involved (researchers or research subjects). The nature of the relationships elicited throughout the causal diagramming process could also inform other qualitative or quantitative research methods that may be used.

The point of explaining this is to highlight that more precise numerical measures tend to give systems theorists the opportunity to specify more precise relationships and thus add layers of quantitative rigour to their models. Yet highly complex systems need not only be represented with tools of high quantitative rigour: these can also be articulated with qualitative tools, as in this guidance. In fact, in complex worlds, qualitative methods are more likely to capture complexity and make it available for analysis. Systems thinking and causal mapping may be used as a decision-support tool that enables a more holistic view of inter-relationships that may otherwise be missed or excluded from reductionist analyses (Senge 2006).

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