
# The National Wellbeing Impacts of the Removal of Hydrogen Cyanamide

*A report prepared for New Zealand Kiwifruit Growers Incorporated*

NZKGI
NEW ZEALAND KIWIFRUIT GROWERS

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# Glossary

| | |
|---|---|
| **CBA** | Cost benefit analysis |
| **DALY** | Disability-adjusted life year |
| **DHB** | District Health Board |
| **EPA** | Environmental Protection Authority |
| **GHG** | Greenhouse gas |
| **GDP** | Gross Domestic Product |
| **HC** | Hydrogen Cyanamide |
| **LSF** | Living Standards Framework |
| **NPV** | Net present value |
| **NZIER** | New Zealand Institute of Economic Research |
| **NZKGI** | New Zealand Kiwifruit Growers Incorporated |
| **OGR** | Orchard gate returns |
| **PV** | Present value, the sum of a future stream of values expressed in present values |
| **QALY** | Quality adjusted life year |
| **TDB** | TDB Advisory Limited |
| **VSL** | Value of statistical life |
| **VSLy** | Value of statistical life year |

# Executive summary

This report adds an addendum (refer p.36 of this report) to the TDB Advisory report completed for NZKGI in September 2022. The addendum assesses the impacts of the EPA update report[1] that was released in December 2022 and the Sapere Social Impact Assessment[2] that was released in January 2023. This new information is considered by us to reinforce the conclusions of the initial TDB report.

New Zealand Kiwifruit Growers Incorporated (NZKGI) has requested TDB Advisory (TDB) to prepare a report assessing the impacts on national wellbeing of a ban on the use of Hydrogen Cyanamide (HC)[3]. The Environmental Protection Authority (EPA) has proposed that such a ban take effect within five years of a decision being made.[4] This report assesses - and quantifies in monetary terms where possible - the costs and benefits to national wellbeing of the proposed ban. We assess in particular whether the benefits likely to eventuate from the ban are proportionate to the risks that arise from the use of HC.

Our report expands the economic-cost analysis undertaken by NZIER and Sapere by considering and valuing where possible the broader impacts (costs and benefits) of the proposed ban on HC, including the impacts on human health and the environment, to assess whether the ban is likely to have an overall positive or negative impact on national wellbeing. To undertake this analysis, we use the New Zealand's Treasury's framework for wellbeing analysis: the Living Standards Framework 2021.

The purpose of this wellbeing analysis is to assess whether the potential health and environmental gains from the ban on HC use are sufficient to offset the expected economic, environmental and other costs. If they are, then national wellbeing will be enhanced, even with a lower level of measured GDP. However, if the benefits are not sufficient to offset the economic, environmental and other costs, then New Zealand as a whole is likely to be worse off from the ban. If the wellbeing gain does not justify the economic sacrifice, it also may mean that society will have to accept lower levels of other wellbeing enhancing activities or investments, such as fewer health services, fewer conservation programmes or less safe roads.

**Findings**

Our analysis indicates the wellbeing costs resulting from a ban on the use of HC that can be measured in monetary terms greatly outweigh the benefits that can be measured in monetary terms. The $1,561m 30-year present value of the expected costs of the ban compares to quantified benefits of just $8m.

The benefits that can be quantified in monetary terms include:

- the reduced risks to birds and terrestrial animals, with a 30-year present value (PV) of $5.3m;
- the reduced acute health risks to spray operators, with a PV of $0.6m; and
- the reduced risk of male infertility for spray operators, with a PV of $2.5m.

Costs expected from the proposed ban include:

- a reduction in kiwifruit harvest yields leading to a $100m per year reduction in GDP, with a PV of $1,537.2m;
- an increase in greenhouse gas emissions resulting from conversion of some kiwifruit orchards to dairy activities, with a PV of $15.7m;
- the wellbeing costs associated with involuntary unemployment in the kiwifruit industry, estimated as a one-off cost of $3.6m; and
- the mental health impacts associated with the financial stress of declining kiwifruit activity, estimated as a one-off cost of $4.8m.

There are a number of potential benefits of the ban that have not been able to be quantified due to a lack of relevant evidence. The most critical aspect relates

[1] https://www.epa.govt.nz/assets/FileAPI/hsno-ar/APP203974/APP203974_20221214.0-Update-Report.pdf

[2] https://www.epa.govt.nz/assets/FileAPI/hsno-ar/APP203974/APP203974_20230131_Social-Impact-Assessment.pdf

[3] Also commonly referred to by the brand name: Hi-Cane.

[4] https://www.epa.govt.nz/assets/FileAPI/hsno-ar/APP203974/APP203974_20210930_Application_report_hydrogen_cyanamide_reassessment.pdf .

to the assertion that HC is a potential cause of long-term illnesses such as cancers for the approximately 500 HC spray operators. The EPA, in its application report, has not quantified the harms to human health from the use of HC. Our own empirical investigation into the link between kiwifruit operations and risks of cancers as raised by the EPA found no evidence of a statistical correlation between cancer incidents and the prevalence of kiwifruit operations.

In the absence of a quantification of the link between kiwifruit operations and cancer incidence, we have conducted a reverse-engineering exercise to estimate the level of cancer risk required to provide a wellbeing benefit sufficient to justify a ban of HC use in New Zealand. Our central estimates indicate that an average of 35 new cancer registrations[5] would need to be averted each and every year in order to offset the estimated 30-year PV net costs of the ban of over $1.5b.

There is inevitably a degree of uncertainly around the above estimates. Analysis using Monte Carlo methods indicates a 95% confidence band for the estimated net monetary costs of between $931m and $2,857m. Taking a very conservative approach – ie, assuming that the net monetary costs of the ban are at the bottom of this range - the proposed ban would still need to prevent 20 cancer registration per year in order for a ban to be justified.

Such cancer rates amongst approximately 500 spray operators would imply cancer risks that are at least ten times the 0.5% cancer propensity of the average New Zealander. If the risks are that high, further actions to protect the health of spray operators would definitely be justified. However, it is not clear from the evidence presented by the EPA to date that spray operators face such high health risks. For example, in a recent exposure standard review of cyanamide WorkSafe noted “no studies were located regarding exposure and carcinogenicity potential in humans”[6].

The overall wellbeing costs and benefits of the ban are summarised in Table 1 below.

**Table 1: National Wellbeing Cost-Benefit Analysis of Hydrogen Cyanamide Ban**

| National Wellbeing Cost-Benefit Analysis of HiCane Ban in New Zealand | | | |
|---|---|---|---|
| **Quantifiable in monetary terms:** | | | |
| **Benefits ($m)** | | **Costs ($m)** | |
| **Financial impacts** | | | |
| | | Economic costs | -$1,537.2 |
| **Natural environment** | | | |
| Animal life benefits | $5.3 | Cost of increased GHG emissions | -$15.7 |
| **Human capability** | | | |
| Reduced acute incidents | $0.6 | Unemployment impact | -$3.6 |
| Reduced male infertility | $2.5 | Financial stress | -$4.8 |
| **Total** | | | |
| Total quantified benefits | $8.4 | Total quantified costs | -$1,561.3 |
| | | **Net monetary benefit (costs)** | -$1,552.9 |
| | | **Monetary benefit cost ratio** | 0.01 |
| **Not quantifiable in monetary terms:** | | | |
| **Unquantified benefits** | | | |
| Aqueous environment | | | |
| Soil environment | | | |
| Polinators | | | |
| Non-target plants | | | |
| Reduced incidence of cancer | | | |

[5] That is new cancer diagnoses.

[6] WorkSafe (September 2021).

**Recommendations**

Given the large scale of economic costs associated with the proposed ban, it would seem prudent for the EPA to invest in further investigations to verify the true scale of the health risk imposed by HC.

In the interim, we recommend that the scale of any regulatory change be proportional to the scale of the verified risk. A policy that has the potential of reducing GDP by $100m per year needs to yield comparable improvements in other forms of wellbeing for it to be in the best interests of the nation.

Better enforcement of the current regulatory standards and fostering improved orchard design and management practices would seem to be more appropriate responses given current knowledge about the scale of the problems associated with the use of HC.

Collecting more information, such as conducting New Zealand-based clinical, epidemiological and environmental studies, would provide a means of reducing the high level of uncertainty (and debate) about the true level of harm caused by HC. Such studies would delay decision making timeframes but would greatly reduce the potentially very high costs that a wrong or poorly informed decision might produce.

# 1 Introduction

## 1.1 Background

New Zealand Kiwifruit Growers Incorporated (NZKGI) has requested TDB Advisory (TDB) to prepare a report assessing the impacts on national wellbeing of a ban on the use of Hydrogen Cyanamide (HC). This report assesses - and quantifies in monetary terms where possible - the costs and benefits to national wellbeing of the proposed ban and considers whether the benefits likely to eventuate from the ban are proportionate to the risks that arise from the use of HC.

HC is the key active ingredient in a spray used by kiwifruit growers and other fruit growers to help buds form over winter and to raise the yield of export-quality fruit. HC helps to stimulate 'budbreak' and the production of flowers which go on to grow into kiwifruit and is a crucial tool in late winter to compensate for inadequate winter chill. Even in areas with sufficient winter chill, HC can be used to condense flowering and promote uniform budbreak, making labour and orchard management more efficient. At present, there are no known substitutes to HC that are as effective for kiwifruit growing and, despite continuing efforts and investment, finding an effective replacement for HC remains a challenge for the industry.

The Environmental Protection Authority (EPA)'s concerns about the use of HC revolve primarily around the potential health risks to workers from repeated exposure over time, with particular concerns that HC may be toxic to the reproductive system and thyroid. The EPA has proposed in its application report (the "application report")[7] that HC be reclassified as a suspected carcinogen and that a total ban on the substance be introduced in five years. This proposal is being consulted on and is due for consideration at a public hearing in March 2023.

There have been two studies undertaken in New Zealand in recent years of the economic costs arising from a ban of HC, one by Sapere[8] for the EPA in 2021 and one by the New Zealand Institute of Economic Research (NZIER)[9] for NZKGI in 2020. These two studies have generated reasonably similar estimates of the costs from a ban on the use of HC. The NZIER estimates that an inability to use HC would reduce orchard-gate returns (OGR) by $234m per year (with low-high estimates of $167m and $301m respectively). Sapere produced comparable estimates of $212m p.a. (with a range of $180m to $238m).

An assessment of the national wellbeing consequences of banning the use of HC, however, should account not just for the impacts on economic activity / GDP. As such, this report expands on the analysis of NZIER and Sapere by considering how banning the use of HC will impact on wellbeing in general. We expand the economic-cost analysis to consider and value the broader impacts (costs and benefits) of the proposed ban on HC use, particularly on human health and the environment, to assess whether the ban is likely to have an overall positive or negative impact on national wellbeing.

Such an expanded focus on wellbeing is consistent with the type of factors that are expected to be considered by the EPA in its decision-making. The reassessment of HC in New Zealand comes under the auspices of the Hazardous Substances and New Organisms Act 1996 (HSNO). Section 6 of that Act stipulates the need for the EPA to account for:

- the sustainability of all native and valued introduced flora and fauna;
- the intrinsic value of ecosystems;
- public health;
- the relationship of Māori and their culture and traditions with their ancestral lands, water, sites, waahi tapu, valued flora and fauna, and other taonga;
- the economic and related benefits and costs of using a particular hazardous substance or new organism; and
- New Zealand's international obligations.

In addition, Section 29 stipulates that in determining the positive and adverse effects of the substance, the EPA must take into account three broad criteria:

[7] https://www.epa.govt.nz/assets/FileAPI/hsno-ar/APP203974/APP203974_20210930_Application_report_hydrogen_cyanamide_reassessment.pdf .

[8] Davis and Barton (2021).

[9] Nixon (2020).

- any controls which may be imposed on the substance;
- all effects of the substance during the life cycle of that substance; and
- the likely effects of the substance being unavailable.

In addition, the EPA is expected to take into account the Hazardous Substances and New Organisms (Methodology) Order 1998 ("Methodology Order"), which - relevant to the wellbeing analysis presented here - requires the EPA to recognise risks, costs, benefits and other impacts associated with the substance or organism in an application which relate to the safeguarding of the life-supporting capacity of air, water, soil and ecosystems (Clause 9). Further, Clause 13 states that when evaluating the assessments of costs and benefits associated with the substance or organism in an application, the EPA must take into account:

- the costs and benefits associated with the application and whether the costs and benefits are monetary or non-monetary;
- the magnitude or expected value of the costs and benefits and the uncertainty bounds on the expected value; and
- the distributional effects of the costs and benefits over time and space and to groups in the community.

## 1.2 This report

In this report we assess and compare the national economic costs estimated by NZIER and Sapere from the removal of HC use with valuations of the potential benefits from the removal of HC use. Our purpose is to investigate whether the proposal to ban the use of HC is proportional to the potential risks from HC use. The purpose of this report is not to assess the EPA's arguments about HC causing harm to the health of sprayers and the environment. Rather, for the purpose of this report, we take the EPA's statements of facts as given and use standard economic approach to value the health, environmental and other impacts, as assessed by the EPA, in monetary terms so that they can then be assessed from an overall national welfare perspective.

Thus, the purpose of this report is to use standard economic methodology to measure where possible the potential benefits from banning HC (ie, the harms avoided) and compare these benefits to the measured costs to national wellbeing of the ban. We use monetary measures where possible to permit comparisons between the different costs and benefits. Where the costs and benefits cannot be measured in monetary terms, we assess the costs and benefits in qualitative terms.

It is normal for a regulatory body proposing a regulatory change to demonstrate that the national benefits of the change exceed the costs imposed by the proposed change (ie, that there are net benefits from the regulatory change). Demonstrating a net national benefit is not necessarily sufficient justification for a proposal as it is usually also expected that the recommendation is superior to alternative policy designs. It is not obvious to us that the EPA application report and its supporting documents have either clearly demonstrated that there is likely to be national net benefit as a result of banning the use of HC or that the proposal to ban its use is superior to other policy options.

There is no question that HC can cause harm to sprayers and the environment if the appropriate health and safety spraying protocols are not followed. A ban of its use would reduce risks resulting from any protocol failures. However, it should be noted that industry practices and protocols around the application of HC have strengthened since the early 2000s, with a resulting decline in reports of exposure incidents. The question then is whether the benefit of reducing these risks by a complete ban of HC's use is proportional to the potential harm caused and whether these benefits justify the costs that will accompany a ban.

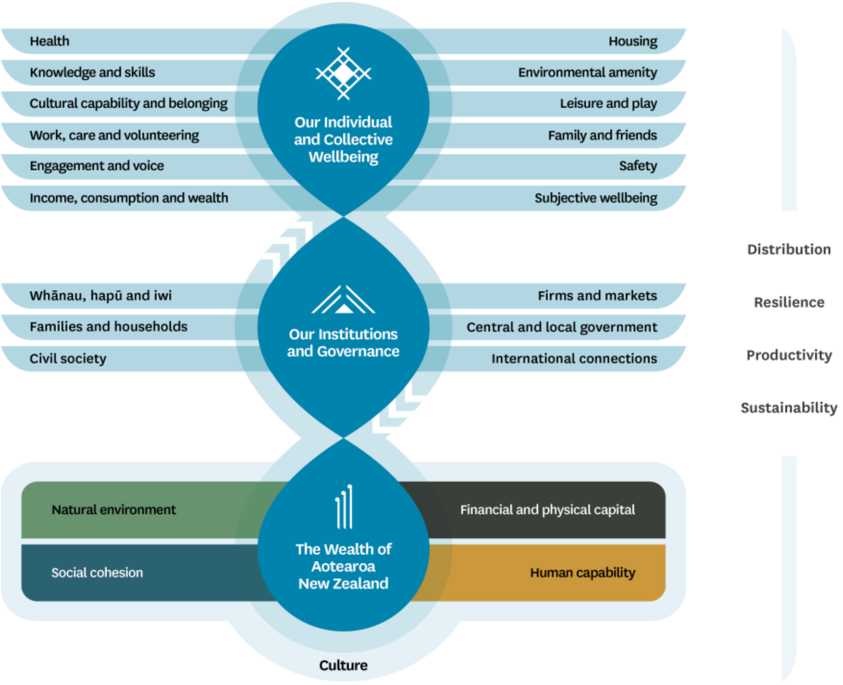
# 2 Framework for analysis

## 2.1 National wellbeing analysis

This report analyses the impact of the proposed ban of HC using a national wellbeing approach. National wellbeing analysis considers, as far as is feasible, the effects of a policy or project on society's overall wellbeing. A good national wellbeing analysis considers not just the monetary or financial effects on people of a project or policy but also the impacts on relevant non-market-values such as environmental, cultural, physical and mental-health values that affect wellbeing, even though these values are often difficult or impossible to quantify in monetary terms.

The New Zealand's Treasury's latest framework for wellbeing analysis is the Living Standards Framework 2021 (LSF). The framework is summarised in Figure 1 below.

**Figure 1: The Living Standards Framework 2021**




*Source: New Zealand Treasury*

The LSF includes a number of dimensions across three levels: individual and collective wellbeing; institutions and governance; and the wealth of Aotearoa New Zealand. The three levels and the dimensions within each are interconnected. The framework includes analytical prompts on the right-hand side, which act as key criteria to analyse wellbeing across the three levels of the framework. Further explanation of the LSF is provided in Appendix 2.

This report uses the Treasury's framework to analyse the costs and benefits to national wellbeing of the proposed ban of HC. To do so, we examine the costs and benefits as they impact on Level 3 of the LSF – the wealth of Aotearoa New Zealand. The four 'wealths' (referred to in this report as domains) can be thought of as stocks (rather than flows), that together contribute to individual and collective wellbeing of New Zealanders and their institutions. Changes in these domains flow through to wellbeing dimensions in other levels, often impacting on specific groups rather than uniformly across New Zealand.

Our focus in this report is on aggregate national impacts, but we note that kiwifruit orchards are geographically concentrated in the upper North Island, particularly in the Bay of Plenty, and that around 9% of class 1 kiwifruit production is Māori owned.

A ban of HC will have costs and benefits to national wellbeing within the following three domains:

- Financial and physical capital;
- Natural environment; and
- Human capability.

Sections 3, 4 and 5 of this report analyse the costs and benefits to each of the above three domains in turn. The fourth domain, social cohesion, is not considered to be materially impacted by the proposed ban.

In national wellbeing analysis, costs and benefits which are able to be quantified in monetary terms with a reasonable degree of precision are quantified, while those costs and benefits which are not able to be rigorously and reliably quantified in monetary terms are incorporated qualitatively. When undertaking national wellbeing analysis, the New Zealand Treasury encourages users to:

- focus on monetising key effects that have a good evidence base, rather than trying to monetise all effects;
- consider all effects, whether monetised or not; and

- leave effects as unmonetised or provide sensitivity analyses and ranges, when the evidence base is limited or the connection is tenuous and uncertain.

A ban on HC use could be considered an investment in natural and human capital that is aimed at improving environmental and human-health wellbeing. However, there are also potential trade-offs. The analysis undertaken by NZIER and Sapere indicates that this investment will come at the cost of kiwifruit earnings that will have negative impacts on wellbeing associated with income and consumption and with jobs and earnings. Such economic costs are justifiable if the benefits, say in health, are sufficient to offset these economic costs. For example, if people avoid illnesses due to a ban on a substance that would otherwise cause the illness, then people's enhanced health will reduce costs on society and allow the people to better participate in society.

The purpose of this CBA within the wellbeing framework is to assess whether the potential health and environmental gains from the ban on HC use are sufficient to offset the expected economic, environmental and other costs. If the benefits are big enough, then national wellbeing will be enhanced, even with a lower level of measured GDP. However, if the benefits are not sufficient to offset the economic, environmental and other costs then New Zealanders are worse off overall. In those circumstances, not only does the wellbeing gain fail to justify the wellbeing sacrifice, it is also likely to mean that society will not have sufficient funds to support other capital investments, such as in new hospitals, conservation programmes or roads, that society might highly value.

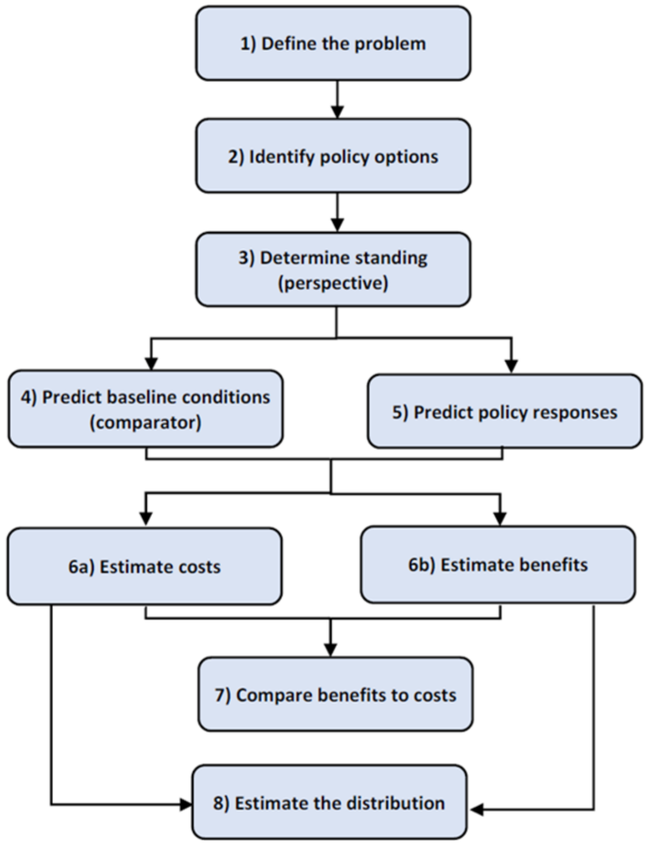
Section 6 of this report presents the overall costs and benefits of the ban, alongside a discussion of the four wellbeing criteria: distribution; resilience; productivity and sustainability. The specific modelling assumptions we make are discussed in detail within each section of the report.

## 2.2 Cost-benefit analysis

This report uses conventional CBA within the Treasury's national wellbeing framework. The aim of CBA is to assess the effects of a policy on overall national wellbeing. A CBA uses monetary values to measure the extent to which individuals are willing to exchange their income – which can be spent on other things – for the outcomes they will likely experience if a policy is implemented.

The component stages of CBA are presented in Figure 2 below. Of importance is the structured approach underpinning the CBA assessment process. Also notable is the reliance of the analysis on predictions and estimates. As a result of this latter feature, there is a further important aspect to CBA (that is not highlighted in Figure 2), which is the need for undertaking sensitivity tests to investigate the robustness of results and to identify critical areas of uncertainty.

**Figure 2: Component stages of CBA**




*Source: https://cdn1.sph.harvard.edu/wp-content/uploads/sites/2447/2019/05/BCA-Guidelines-May-2019.pdf.* [10]

[10] Robinson et al. (2019) .

A brief description of these eight stages of CBA and the implications for this assessment of the wellbeing effects of the ban of HC use is provided below.

**(1) Define the problem:** This component describes the nature of the problem that proposed policies aim to address. There is concern that the application of HC, while beneficial to the yield, management and quality of kiwifruit in New Zealand, could be harmful to spray operators and the environment. The EPA application report suggests that risks to other horticulture workers and neighbours, given the short life of HC, can be adequately managed by application protocols and orchard design. The CBA question is, therefore; do the benefits to society from removing the harms (via a ban on the use of HC) outweigh the economic and other costs. A critical issue remains to isolate the impacts of HC from other factors that potentially impose health or environmental risks.

**(2) Identify policy options:** this component defines the policy options being considered to address the observed problem. Although there are potentially a wide range of policy options available to the EPA with respect to the degree of regulation applied to the use of HC, the CBA here considers just two options:

- the status quo, whereby the application of HC can continue subject to the same regulations that have applied in New Zealand since 2006; and

- banning the use of HC in New Zealand. Although the EPA's proposal includes a five-year period before such a ban applied, for analytical simplicity, the calculations presented in this report do not account for any timing factors and simply compare the "state of the world" with and without the use of HC at the present day.

**(3) Determine who has standing (perspective)**: Standing refers to identifying whose benefits and costs will be counted in a CBA. Groups that are likely to either bear a cost or benefit from a ban of the use of HC include:

- kiwifruit-orchard owners, their employees and their families;

- spray operators;

- neighbours and others who could potentially be impacted by HC applications;

- businesses and individuals that supply services to the kiwifruit industry (eg, packhouses, transporters, agricultural services and Zespri shareholders);

- taxpayers/citizens who benefit from services funded by the additional GDP earned by the kiwifruit industry due to the application of HC;

- consumers of kiwifruit who might face quality, price and quantity impacts; and

- future generations whose wellbeing will be influenced by the current level, direction and quality of investment into the four capitals.

Although all of these groups have standing, the CBA presented here does not focus on the distribution of the impacts but presents from a whole-of-New Zealand wellbeing perspective.

**(4) Predict baseline conditions (the "counterfactual"):** Each policy option is typically compared to a "no-action" baseline that reflects predicted future conditions in the absence of the policy change.[11] Here, the baseline is the status quo, with the impact of banning the use of HC compared with the current regulatory environment for HC.

**(5) Predict policy responses:** This component of the CBA involves predicting the impacts of each option in comparison to the counterfactual. One challenge is ensuring that changes likely to occur under the baseline conditions are not inappropriately attributed to the policy; another is understanding the causal pathway that links the policy to the outcomes of concern. The goal is to represent the policy impacts as realistically as possible, taking into account real-world behaviour.

To ensure the robustness of the predicted policy responses, this report explicitly identifies the assumptions underpinning the calculations used and presents the evidence justifying the choice of assumptions. As noted above, the nature of CBAs means the numbers underpinning the calculations can never be fully justified. For this reason, the sensitivity of the results has been tested based on the assumption decisions, using Monte Carlo analysis techniques (see Section 7 *Risk analysis*).

[11] Other counterfactuals may at times be used.

**(6) Estimate costs and benefits:** Costs include both the direct and indirect/consequential costs associated with policy implementation. For example, there are costs imposed on parties complying with the ban on HC use, there are impacts on third parties, there may be unintended side effects, and so on.

In this study, three types of costs arising from the proposed ban on HC use are quantified:

- financial costs associated with the decline in GDP resulting from lower kiwifruit yields reducing export earnings;
- environmental costs associated with a higher level of greenhouse gas (GHG) emissions; and
- human impacts in terms of costs associated with people coping with financial distress and/or periods of involuntary unemployment.

The potential benefits of the ban on HC-use relate to benefits to human health and to some aspects of the natural environment. These benefits include direct and indirect impacts and costs that are avoided. According to the EPA, the potential human health benefits relate to the avoided acute illnesses from episodes of excessive exposure to HC, as well as to the avoided potential longer-term health costs related to thyroid disorders, male infertility and increased risks of cancer.[12]

Our valuation of the health impacts of the ban is based on conventional value of statistical life (VSL) concepts.[13] Although it might be considered inappropriate to place dollar values on a human life, a VSL approach is often used in CBAs that inform government policy as the value reflects the potential opportunity cost associated with spending money to protect lives. The opportunity cost arises because the government, as well as the nation as a whole, faces budget constraints, which mean that spending to mitigate risks in one area limits the amount available to mitigate other potential risks. The current VSL estimate used by the New Zealand Treasury in its CBAx model is $4.56m. The implication of this value is that incurring more costs than $4.56m in order to avoid one death is unlikely to produce a net benefit to the country as the commitment of resources means the resources are unavailable to reduce risks in other areas.

We utilise disability-adjusted life year (DALY) concepts to measure potential health impacts. A DALY has both a health intensity and a time dimension. To illustrate, a health issue that is considered to reduce someone's health and functionality by 50% for an entire year might be considered to have experienced a 0.5 DALY health impact. However, an affliction of the same intensity, but lasting only half a year would have a 0.25 DALY measurement (0.5 disability quotient x 0.5 years = 0.25 DALY).

From an environmental perspective, in addition to the GHG effects noted above, explicit estimates are made in this report of the value of the potential increases in birdlife and reductions in the risks to terrestrial animals from the proposed ban on HC use. No explicit valuation of the potential impacts on bees, soil and aqueous habitats is made in this report because of a lack of information on the potential impacts that banning HC might have on these organisms and habitats (in part due to the rapid breakdown of HC meaning that there is no bioaccumulation) and due to a lack of information on the monetary value of the potential impacts.

**(7) Compare benefits to costs:** As part of the process of comparing costs and benefits, future-year impacts are discounted to reflect society's time preference and the opportunity costs of investments made in different periods. This discounting reflects the general social desire to receive benefits early and to defer costs. The monetary values of benefits and costs should be discounted at the same rate.

This CBA has been conducted over a thirty-year time period. Although this analytical time period may seem long from an economic or orchard-management perspective, we have chosen a thirty-year time period in order to incorporate potentially long-acting implications for health and the environment. Costs and benefits are allocated to individual years, but results are reported in present value terms according to the following formula:

$$PV = \sum_{n=1}^{30} FV_n \frac{1}{(1+\delta)^n}$$

where the present value (PV) is the sum of future values (FV) in each period (n) discounted by the discount rate (δ).

Present values are used to account for the opportunity cost of devoting resources to the policy or project of interest. As recommended by the Treasury,

[12] See EPA Science Memo (2021), Appendix C, p29.

[13] Office of Best Practice Regulation (August 2019) .

the central discount rate used is 5%.[14] The present value formulation, using a 5% discount rate, means that \$100 in one year's time has a present value of \$100/1.05 = \$95.24. For \$100 two years into the future its present value would be $\$100/(1.05)^2$ = \$100/1.1025 = \$90.70. The choice of a 5% discount rate is varied in our risk analysis where discount rates are allowed to range from 3% to 8% (see section *7 Risk analysis*).

Unless explicitly noted, all values in this report are in constant 2021 prices.

**(8) Estimate the distribution of impacts:** Cost-benefit techniques are not ideally suited for exploring distribution impacts. This is because of the indirect nature of social interactions; who ultimately bears the cost or benefits the most from a policy can often be different from the policy's direct incidence. For example, some businesses might be able to pass on cost increases to customers, others might not be able to.

While a purpose of CBA is to generate objective measures of the net contribution of an intervention to national wellbeing, the discipline associated with the CBA process is as important as the measurement. As the Treasury notes, "CBA is often rejected on the grounds that some benefits are hard to measure. While that is often true, a CBA is about organising in a logical and methodical way whatever information is available".[15]

[14] See https://www.treasury.govt.nz/information-and-services/state-sector-leadership/investment-management/plan-investment-choices/cost-benefit-analysis-including-public-sector-discount-rates/treasurys-cbax-tool .

[15] The Treasury (2015).

# 3 Financial and physical capital

As noted above, there have been two studies undertaken in recent years of the economic costs arising from a ban of HC, one by Sapere[16] for the EPA and one by the NZIER[17] for NZKGI. These two studies have generated reasonably similar estimates of the costs from a ban of HC. The NZIER estimates that an inability to use HC would reduce orchard-gate returns (OGR) by $234m per year (with low-high estimates of $167m and $301m respectively). Sapere produced comparable estimates of $212m p.a. (with a range of $180m to $238m).

We consider that, in general, there is close accordance in these two sets of estimates of the economic consequences of banning HC. Given this general agreement, we do not see any useful purpose in re-estimating these economic costs. To avoid any unnecessary debate, we base our calculations on the slightly lower estimates provided by Sapere. In addition, as this cost-benefit analysis (CBA) has primarily a national focus, we use the Sapere estimate that HC's ban will likely reduce national GDP by $100m per year.

We focus on the GDP impact estimates rather than orchard-gate returns (OGR) as the focus of CBA is national wellbeing. If our focus was simply on the wellbeing of orchardists, then OGR would be an appropriate summary measure of financial and economic wellbeing impacts. With a broader national wellbeing perspective, GDP is a more appropriate measure of economic impacts. In this report we rely on the Sapere calculations that GDP implications are 45% of OGR impacts.[18]

Over a 30-year period and using the Treasury recommended 5% discount rate, this cost has a present value of $1,537m.

**Table 2: Financial impacts ($m, NPV)**

| $m | 30 year present value |
|---|---|
| Costs | |
| Economic costs | -$1,537.2 |
| Benefits | |
| | $0.0 |
| Quantified net benefits (costs) | -$1,537.2 |

[16] Davis and Barton (2021) *op cit.*

[17] Nixon (2020) *op cit.*

[18] The contribution to GDP is lower than the OGR, as OGR is a revenue concept, while GDP is a value-added concept, thus the contribution to GDP is approximately the OGR less intermediate consumption – the purchases of goods and services used in the production process.

# 4 Natural environment

## 4.1 Introduction

Following the analysis of the impact of the ban on financial and physical capital in Section 3 above, this section analyses the impacts on the natural environment. The natural environment domain is defined in the LSF as all aspects of the natural environment which support life and human activity, whether valued for spiritual, cultural or economic reasons.

This section of the report discusses the environmental impacts of the proposed removal of HC use. The impacts include those on flora and fauna, greenhouse gas (GHG) emissions and other effects.

## 4.2 Flora and fauna

The application of HC can potentially have adverse consequences for proximate fauna and flora. The EPA's application report notes chronic risks to birds as well as to the aquatic environment, non-target plants, pollinators, and non-target terrestrial animals from HC use on orchards. The EPA is particularly concerned about the potential impact on birds, with the application report stating (p4):

> *Acute risks to birds were determined to be above the level of concern and cannot be mitigated even with the prescribed, modified, and additional controls.*

In this section of the report we present estimates of the value of reducing risks to birds and terrestrial animals such as dogs. The EPA's application report notes that risks to non-birdlife can be mitigated through the use of buffer zones, restrictions on application rate and timing, and prohibiting application when bees are present (p4). However, the banning of HC will also reduce these risks and this risk reduction will have wellbeing benefits for society. No explicit valuation of potential impacts to bees, soil and aqueous habitats is made because of a lack of information on the potential impact that banning HC might have on these organisms and on the social value of the potentially impacted organisms. The implication is that the value of the benefits to the environment from the removal of HC are likely to be underestimated in this report. Given the speedy breakdown of hydrogen cyanamide and its lack of bioaccumulation, we consider it unlikely that the value of these missing factors will be sufficiently large as to materially alter our findings.

### Birds

As noted above, the beneficial impact on birds of banning HC was particularly highlighted by the EPA. Although the potential exposure of birds during the time when HC is applied has been questioned and is the subject of an upcoming investigation, the importance of native birds to New Zealanders is not something that should be ignored or undervalued.[19] Consistent with our approach to other issues, our aim is to generously value the potential impact that a ban of HC might have on bird life so as not to risk underestimating any net benefits of the proposed ban. Our focus is on native birds.

We base our estimates of the potential impact of HC on birdlife on Rate et al, 2007.[20] We note that the bird study conducted by Rate et al was based on observations over summer months (November to January) and was not focussed on assessing impacts of HC on birdlife. However, their results provide a benchmark for assessing the potential impact of organic practices on the propensity of bird life on kiwifruit orchards. Differences in bird sightings between organic and non-organic orchards is likely to provide an upper bound estimate of the potential positive benefit for birds that might result from banning the use of HC.

Rate et al found 3.7 native birds in an average five-minute bird count on organic orchards compared with 2.3 on non-organic orchards. The Rate et al results imply that there is a 63% higher chance of observing native birds on organic kiwifruit orchards than on non-certified organic kiwifruit orchards.

The formula we use for valuing the premium for bird life is:

> Bird value = area kiwifruit orchard density x area population x individual willingness to pay for bird conservation x organic orchard bird volume premium (ie 0.63)

[19] An early draft of "Bird Use of Kiwifruit Orchards Around the Time of Hydrogen Cyanamide application", Wildlands Contract Report 6373d prepared for Zespri Ltd, (version viewed dated 7 September 2022) indicated that although bird life can be present at the time of HC application, kiwifruit orchards do not appear to be hosts to bird species of conservation concern. The report did not appear to provide clear insights into the potential impacts of HC on bird life as it could not distinguish between the impacts of HC applications and changes in fruit availability.

[20] Rate et al. (2007).

Kiwifruit orchard density is calculated as the area (ha) planted in kiwifruit as a percent of each region's total area. The actual kiwifruit density and area population data used is the same as presented in Table 4 on page 21 below.

The willingness to pay for native bird conservation is sourced from Kaval and Roskruge (2009), which found a $96 willingness to pay for bird conservation from the analysis of a phone survey of 200 Waikato residents.[21] Here we have inflated this figure, using the CPI, to a 2021 value of $119.

The result of these calculations is an indicative estimate of the native bird value of banning HC use of $296,000 per year, with a 30-year present value of $4.55m (using a 5% discount rate).

We consider this to be a generous valuation as the estimate:

- takes no account of site-specific factors that might have independently increased the estimated organic orchard native bird premium;
- applies the willingness to pay result to the entire population in kiwifruit regions rather than potentially more plausibly applying it to the number of households; and it
- implicitly assumes that all of the bird-count differences are attributable to the use of HC.

### Other non-target terrestrial vertebrates

The EPA's application report seems to accept that spray operations that comply with WorkSafe and industry guidelines should have minimal impacts on non-target terrestrial vertebrates. However, a complete ban on the use of HC would mitigate risks of non-compliance and unavoidable accidental animal exposures. For example, dogs are known to be susceptible to poisoning from HC. We are not aware of any data about the frequency or outcome of dogs being poisoned by HC, but there is anecdotal evidence of occurrences of unintended dog fatalities or near fatalities.

The banning of HC will reduce risks for dogs and other animals. To value this reduced risk we have assumed that the absence of HC will reduce terrestrial vertebrate fatalities (other than birds) by 5 each year, with an average value of $10,000 per saved animal.[22] We regard these values as conservative in the sense that they are likely to err on the side of overstating the number of possible incidents and individual animal values and thus overestimate the net social benefits of banning HC. The estimated net impact is a benefit from banning HC of $50,000 per year, with a 30- year present value of $0.769m (using a 5% discount rate).

## 4.3 GHG emissions

In the 2021 TDB Advisory report for Zespri, TDB noted that the financial distress caused by a ban on the use of HC could lead to 15 to 30% of kiwifruit orchardists becoming unprofitable and potentially exiting the industry.[23] With the future profitability of kiwifruit operation lower than otherwise, a proportion of the land currently planted in kiwifruit is likely to be re-purposed. Two potential alternatives are a move to organic kiwifruit or to avocados. However, the viability of such transitions has been questioned by submitters.[24] So, at least to some degree, an HC ban is likely to encourage some shift into dairy farming. As dairy is a major source of greenhouse gas (GHG) emissions in New Zealand[25], the ban of HC could well instigate higher levels of emissions with resulting environmental harms. Although the NZIER noted that climate change might increase the kiwifruit industry's reliance on HC (as frosts become less reliable), no allowance was made for a potential contribution to climate change from banning the use of HC.

Our central estimates of the potential social cost from an increase in GHG emissions are based on the following assumptions:

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[21] Kaval and Roskruge (2009).

[22] See for example https://www.stuff.co.nz/national/124843744/puppy-prices-as-high-as-6000-while-wait-times-reach-two-years, which indicates that prices for puppies advertised on TradeMe typically ranged from $2,000 to $4,000 in 2021, with the highest asking price being $6,500 for a cavoodle.

[23] TDB Advisory Ltd (2021).

[24] For example, in https://www.epa.govt.nz/assets/FileAPI/hsno-ar/APP203974/APP203974_20220304_SUBMISSION127907_Te_Puke_Fruit_Growers_Association_Redacted.pdf it is argued that the avocado sector is already grappling with over supply issues and in https://www.epa.govt.nz/assets/FileAPI/hsno-ar/APP203974/APP203974_20220309_SUBMISSION127868_Apata_Suppliers_Entity_Limited_Redacted.pdf where it is argued that an influx into organic kiwifruit will critically dilute the price premium available to existing organic growers.

[25] See for example: https://niwa.co.nz/education-and-training/schools/students/climate-change/agriculture .

- 1,325 hectares of land in the upper North Island transfers from kiwifruit to dairy production as a result of a ban in the use of HC. This represents 10% of the land currently planted in kiwifruit;

- average GHG emissions will be 13,464 kg of $CO_2$ equivalent per hectare, the central estimate obtained by Ledgard and Falconer (2015) for dairy operations in the Bay of Plenty;[26] and

- the social cost of carbon is taken to be $76.50, the spot price for one tonne of CO2 equivalent as at 22 June 2022.[27]

The orchard GHG emissions were estimated in 2010 to be around 575g $CO_2$ equivalent per tray equivalent[28], which we estimate translates to around 4 tonnes per hectare. However, Zespri estimates that the carbon footprint for kiwifruit orchards declined by 20% in the decade to 2019[29]. We therefore make the simplifying assumption that the conversion of land use from kiwifruit to dairy will increase GHG emissions by 10 tonnes of $CO_2$ equivalent per hectare.

The net impact is a potential additional annual cost of around $1.0m (= 1,325ha x 10t$CO_{2e}$ x $76.50). Over a 30-year period this cost to national wellbeing has a present value of $15.7m (calculated using a 5% discount rate).

## 4.4 Other environmental impacts

It is difficult to assess, given the available evidence, which other organisms would benefit from a ban on the use of HC, and to what degree. The EPA's application report concluded (p4)[30]:

> *Risks to the aquatic environment, non-target plants, pollinators, and non-target arthropods as well as chronic risks to birds were determined to be above the level of concern. Risks to these receptors can be mitigated through the use of buffer zones, restrictions on application rate and timing, and prohibiting application when bees are present.*

Although there may be scientific evidence of potential environmental risks from HC, it is less clear what the magnitude of the risks is. For example, the EPA Science Memo[31] notes that although risks were identified for threatened and non-threatened earthworms, it is highly unlikely that threatened earthworm species will be present in agricultural fields as they prefer habitat with a rich organic layer and risks are likely limited to non-threatened species. (p16). The Science Memo's environmental risk conclusion was (p17):

> *Overall, based on the information available, risks to the environment can be mitigated with proposed controls in some areas (aquatic environment, soil environment at lower rates, terrestrial invertebrates off-field) but risks cannot be fully excluded from some other areas with controls (birds, soil environment at higher rates, terrestrial invertebrates in-field).*

Given the lack of evidence on the magnitude of the risks, valuation of the potential benefits is problematic. With little hard information, we are left in the position of treating these potential environmental impacts as unquantified benefits of the ban.

## 4.5 Overall impacts on the natural environment

This section has analysed the impact of the ban on the natural environment domain. Overall we find the ban is likely to result in:

- a benefit to the natural environment from a reduction in potential harm to birds and non-target terrestrial animals of around $0.35m p.a. or $5.3m in NPV terms;

- unquantified benefits resulting from reduced risks to the aquatic environment, non-target plants and pollinators; and

[26] See Table 11 on p24 in https://www.mpi.govt.nz/dmsdocument/28329-total-greenhouse-gas-emissions-from-farm-systems-with-increasing-use-of-supplementary-feeds-across-different-regions-of-new-zealand .

[27] See https://www.carbonnews.co.nz/tag.asp?tag=Carbon+prices .

[28] Mithraratne et al. (2010).

[29] See https://www.zespri.com/en-NZ/sustainability-carbon-footprint#:~:text=The%20carbon%20footprint%20of%20our%20kiwifruit&text=In%202019%2C%20we%20assessed%20the,than%20for%20the%202009%20crop.

[30] https://www.epa.govt.nz/assets/FileAPI/hsno-ar/APP203974/APP203974_20210930_Application_report_hydrogen_cyanamide_reassessment.pdf .

[31] https://www.epa.govt.nz/assets/FileAPI/hsno-ar/APP203974/APP203974_20210920.1_Appendix_B_Science_memo.pdf .

- costs associated with a potential increase in GHG emissions as land moves from lower emission kiwifruit orchards to higher emission dairy uses of around $1m p.a. or $15.7m in NPV terms.

Table 3 below summarises our assessment of the costs and benefits to the environment arising from the ban, which can be quantified in monetary terms.

**Table 3: Natural environment impacts ($m, NPV)**

| $m | 30 year present value |
|---|---|
| Costs | |
| Cost of increased GHG emissions | -$15.7 |
| Benefits | |
| Animal life benefits | $5.3 |
| Quantified net benefits (costs) | -$10.4 |
| **Unquantified benefits** | |
| Aqueous environment | |
| Soil environment | |
| Polinators | |
| Non-target plants | |

The net costs to the environment of the ban that can be quantified in monetary terms sum to around $10.4m in NPV terms.

# 5 Human capability

## 5.1 Introduction

A key aspect behind the EPA proposal to ban HC is the EPA's assessment that:

> *Risks to operators using hydrogen cyanamide were determined to be above the level of concern, and risks could not be mitigated even with the prescribed, modified, and additional controls, or considering the lowest current label application rates. Overall, without further refinements, the risks are above the level of concern for operators.*[32]

The evidence that underpins this assessment is likely to be the subject of debate at the forthcoming EPA hearing on the reassessment of HC.[33] As noted in Section 1.2 above, our role is not to debate the scientific evidence. Rather, we take the EPA's statements of fact as given and use standard economic approach to value the human capability and other impacts, as assessed by the EPA, in monetary terms so that they can then be assessed from an overall national welfare perspective.

## 5.2 Short-term health benefits

The potential adverse short-term health impacts for operators come from excessive dermal exposure to HC or from drinking HC. Such exposure is potentially fatal, but very unlikely to occur under existing spray application standards. The typical impacts of excessive exposure include nausea and vomiting, headaches, contact dermatitis and erythema.

There have been a number of exposure incidents to HC in New Zealand over the years, with an average of 4.4 HC-related referrals to the National Poisons Centre per annum in the period from 2006 to 2019.[34] Prior to 2006, HC-related referrals typically averaged 10 per year, so there seems to have been a notable improvement in the effectiveness of HC safety procedures since 2006. Full details are not available on the severity of the incidents, but there have been no recorded fatalities. It is generally recognised that HC is typically fully excreted from the human body (via urination) within a number of days, with no accumulation of HC in human tissue. Exposure to HC is commonly described as producing acute short-term health impacts (like nausea and headaches) but not cumulative chronic impacts.

In our valuation of the potential costs associated with incidents of acute exposure to HC, we adopt a purposely conservative approach, taking care not to understate the risks of individual exposures. We would rather err on the side of valuing more cases than the evidence suggests is typical than undervaluing them. We therefore assume that there are ten exposure incidents per year (ie, more than double the typical number reported to the National Poison Centre each year since 2006) and that each incident has a 7-day disability impact on the affected person.[35] The implication of this is a total 70-day disability impact each year: ie, 0.19165 disability-adjusted life years (DALYs) (= 70 ÷ 365.25). With a value of statistical life (VSL) of $4.56m (see Treasury CBAx[36]), and a VSL year of $195,000[37], a 0.19165 DALY implies a potential annual cost to the nation from acute exposures to HC of $37,372. Over a 30-year period, using a 5%

[32] https://www.epa.govt.nz/assets/FileAPI/hsno-ar/APP203974/APP203974_20210930_Application_report_hydrogen_cyanamide_reassessment.pdf , p3.

[33] See for example the submissions prepared by AlzChem Trostberg GmbH (https://www.epa.govt.nz/assets/FileAPI/hsno-ar/APP203974/APP203974_20220330_SUBMISSION127856_AlzChem_Trostberg_GmbH_Redacted.pdf), and Zespri (https://www.epa.govt.nz/assets/FileAPI/hsno-ar/APP203974/APP203974_20220414_SUBMISSION127842_Zespri_Redacted.pdf).

[34] NZKGI/Zespri (2020).

[35] The seven-day recovery assumption is based on a conversation with a sprayer grower who had an incident with HC 20 years ago as a result from a gap in his protective clothing (he noted this event was prior to the introduction of cabins and AI nozzles). He stated that it was an unpleasant experience (warm sensation, breathless, thumping chest and temples), but that he was fully recovered in 2 days.

[36] https://www.treasury.govt.nz/information-and-services/state-sector-leadership/investment-management/plan-investment-choices/cost-benefit-analysis-including-public-sector-discount-rates/treasurys-cbax-tool .

[37] The Treasury CBAx model recommends a value of $59,897 for the value of a quality adjusted life year. This seems to us to be a low figure to be consistent with a VSL of $4.56m. For example, the Office of Best Practice Regulation in Australia equates a figure of $A217,000 as being the single year value of life consistent with an Australian VSL of $A5.08m. Reverse engineering this Australian VSL/VSLy relationship and applying it to a New Zealand VSL of $4.56m suggests that a single year value of $195,000 is more appropriate than $59,897 for New Zealand. Our approach inflates the health benefits of an HC ban compared with using the lower CBAx VSLY figure. See Office of Best Practice Regulation. 2020. 'Best Practice Regulation Guidance Note: Value of Statistical Life'. Department of the Prime Minister and Cabinet, Australian Government. https://pmc.gov.au/resource-centre/regulation/best-practice-regulation-guidance-note-value-statistical-life .

discount rate this implies a present value cost of $0.57m to the nation from acute exposures to HC.

## 5.3 Longer-term health benefits

Although HC breaks down and is excreted rapidly from the body, the EPA's reassessment raised concerns about the effects of long-term health impacts of exposure to HC, with international laboratory tests on mice, rats and dogs suggesting that long-term exposure to HC could potentially raise risks of thyroid conditions, male infertility and cancer risks. Again, the veracity and applicability of these laboratory tests will be the subject of debate at upcoming hearings on the HC reassessment, but out of an abundance of caution, for the purpose of this CBA we have assumed HC does pose these risks. The exposure levels faced by spray operators in New Zealand conditions will also be the focus of forthcoming scientific studies during the 2022 HC spraying season.[38]

Our aim here was to estimate the value of the long-term health impacts based on the evidence provided by the EPA. The EPA's application report, however, provides no quantitative estimates of the human harm (eg, numbers of deaths or disabilities per annum) caused by the use of HC.

It is beyond the scope of this study to establish the true relationship between health outcomes and long-term exposure to HC in New Zealand. Given the absence of quantitative estimates in the EPA's application report we found it necessary to investigate the circumstantial evidence for an association between health outcomes, in particular in relation to cancers and disorders associated with the thyroid and male genitalia. If there is a causal link between long-term HC exposure and these conditions one would expect to be able to observe a correlation between these conditions and the prevalence of kiwifruit orchards. Finding such a link would not be sufficient to verify that there was real-world support for the laboratory evidence underpinning the EPA's HC reassessment recommendations, but its absence would question the materiality of potential health impacts from long-term exposure to HC.

However, we were not able to find any statistical link between the prevalence of kiwifruit orchards and either new cancer registrations or cancer deaths either in general or specifically related to thyroid or male genitalia. We present a description of our analytical approach and an example of the estimation results in Appendix 1 to this report.

It is not our purpose to dismiss the potential for significant longer-term human health impacts for HC operators just because we have been unable to identify the scale of such impacts. But we are not prepared to estimate the potential value of such impacts without any obvious source of evidence on the number of people likely to be affected in such ways. Instead, the approach we have taken, in regard to the longer-term health impacts, is to estimate all the quantifiable costs and benefits and then calculate the minimum size that longer-term health impacts would need to be in order to ensure that the benefits from banning HC exceed the identified costs.

Therefore, we first present the estimates of all other quantifiable costs and benefits, undertake an analysis of the likely distribution of the true values of these costs and benefits and finally present estimates of the scale of serious health impacts required to justify the proposed ban on use of HC. This analysis is presented in Section *8 Reverse engineering of required reduction in cancer risks*.

## 5.4 Other human-health benefits

The EPA's application report notes evidence from historical laboratory-based small-sample tests of dogs that extensive exposure to HC could result in fertility issues for men. Our purpose once again is to assess the potential scale of the wellbeing cost of fertility issues, not to dispute the underpinning evidence. Once again, however, no evidence is presented by the EPA that demonstrates the incidence of fertility issues resulting from exposure to HC by spray operators, as such, it is not possible for us to place a monetary value on the risk.

Our approach, therefore, is first to estimate the prevalence of male fertility that is proportional to both national rates of male fertility issues and the relative presence of kiwifruit orchards within regions. This provides an estimate of the likely prevalence of male fertility issues associated with kiwifruit orchards, but independent of any potential impact from exposure to HC. We then apply an HC-exposure risk factor to account for a potential impact.

According to the Institute for Health Metrics and Evaluation, male infertility imposed a health impact of 2.1 DALYs per 100,000 people nationally in New

[38] Initial results from the Air Matters 2022 investigation sponsored by Zespri Ltd, "Exposure study on kiwifruit orchard workers spraying hydrogen cyanamide in the Bay of Plenty, New Zealand to assess the level of systemic exposure" (version viewed dated 15 September 2022) are that the measurements of spray operator exposures were appreciably lower than the model outputs underlying the EPA assessment application. Depending on the EPA comparator, the EPA modelling assumptions are significantly greater than the Air Matters exposure measurements.

Zealand in 2019.[39] Applying this DALY impact to the DHB populations in DHB areas with kiwifruit orchards that are potentially applying HC implies male infertility is imposing an annual impact in total of 46.6 DALYs in these seven DHB areas (see Table 4**)**. Total male infertility in these areas would translate to an annual social cost of around $9.1m (46.6 DALYs @ a VSLy of $0.195m p.a.). This would have a 30-year present value of around $139.5m (using a 5% discount rate). However, assuming that all male infertility issues in these areas is due to HC seems extreme and unrealistic.

In Table 4 we present calculations of the costs of male infertility that are proportional to the density of kiwifruit orchards in the seven DHB areas. This would imply an annual wellbeing cost associated with kiwifruit orchards of $16,120. In our calculations we use a conservative approach and assume that the risk associated with kiwifruit orchards is ten times this proportional estimate. This would imply an annual cost of $161,200, with a 30-year present value of $2.49m.

**Table 4: Annual cost estimates of excess cases of male infertility proportional to kiwifruit orchard density**

| DHB area | DHB population | DHB Infertility DALYs | Kiwifruit orchard density | Estimated impact associated with kiwifruit density | Estimated economic value |
|---|---|---|---|---|---|
| | A | B | C | D | E |
| | (2019) | (@ 2.1 DALY per 100,000) | | (DALY = B x C) | ($m = D x 0.19165) |
| Northland | 185,100 | 3.9 | 0.00037 | 0.00144 | 0.00028 |
| Waitemata | 599,300 | 12.6 | 0.00138 | 0.01737 | 0.00333 |
| Counties Manukau | 552,500 | 11.6 | 0.00028 | 0.00330 | 0.00063 |
| Waikato | 415,500 | 8.7 | 0.00026 | 0.00225 | 0.00043 |
| Bay of Plenty | 247,700 | 5.2 | 0.01108 | 0.05763 | 0.01104 |
| Tairawhiti | 48,300 | 1.0 | 0.00042 | 0.00043 | 0.00008 |
| Hawke's Bay | 169,500 | 3.6 | 0.00016 | 0.00057 | 0.00011 |
| Total | 2,217,900 | 46.6 | 0.00181 | 0.08412 | 0.01612 |

*Kiwifruit orchard densities are calculated as the proportion of region area planted in kiwifruit

## 5.5 Costs to human capability

There are other material impacts on wellbeing that would be expected to arise if the use of HC was banned. In particular, we note:

- the stress on growers whose businesses are no longer viable and who face increased financial pressures and bankruptcy. As noted above, in the 2021 TDB Advisory report for Zespri, the financial distress caused by a ban on the use of HC could lead to 15 to 30% of kiwifruit orchardists becoming unprofitable and potentially exiting the industry;[40] and

- the increased unemployment. Such unemployment would be likely to be transitional rather than permanent given the labour shortages in the economy. But unemployment nevertheless raises material wellbeing costs for those affected.

Affected people are likely to recover from the adverse impacts noted above: their financial concerns are likely to abate and other employment opportunities will arise (though perhaps in other locations). But this does not mean that individuals would not have preferred to avoid these involuntary costs. In the two subsections below we value the costs of involuntary unemployment and the potential mental anguish associated with financial distress and/or involuntary unemployment.

### Involuntary unemployment costs

To value the wellbeing costs of involuntary unemployment, we utilise the method proposed by Patterson et al (2019).[41] The cost of unemployment for the average individual is calculated as the difference between the unemployment benefit and the minimum wage. The underlying assumptions are a 37.5 hour working week for on average 52.14 weeks per year, so that the wellbeing cost of a full year of involuntary unemployment for an individual would be calculated as:

$$CU_{annual} = (MW_{hour} - UB_{week}/37.5) \cdot 37.5 \cdot 52.14$$

Using the adult minimum wage of $21.20 per hour[42] and the jobseeker weekly benefit for a single person aged 20 to 24 in 2022 of $274.37[43] this formula implies

[39] See https://vizhub.healthdata.org/gbd-compare/.

[40] TDB Advisory (2021), op cit.

[41] Patterson et al. (2019).

[42] See https://www.employment.govt.nz/hours-and-wages/pay/minimum-wage/ .

[43] See https://www.workandincome.govt.nz/products/benefit-rates/benefit-rates-april-2022.html .

a wellbeing cost of $27,145.65 for an individual spending an entire year involuntarily unemployed. Our central estimates assume that 525 workers (15% of a 3,500 workforce) spend on average 3 months in involuntary unemployment as a result of the ban on the use of HC[44], which generates a one-off wellbeing cost of $3.56m as a result of the unemployment expected to follow a ban in the use of HC.

### Mental-health impacts

For a number of people associated with the kiwifruit industry, the uncertainty associated with the prospect of a ban on HC use could raise anxiety levels, perhaps to the point of mental health issues for some. We value the scale of potential mental health consequences by assuming that raised anxiety levels are sufficient to induce clinical depression for 175 people associated with the kiwifruit industry (5% of a 3,500 workforce)[45]. We assume that this depression responds to treatment and that affected people are on average fully recovered in six months. We use clinical information from the Institute for Clinical Research and Health Policy Studies, Tufts Medical Center[46] that indicates that depression that is responsive to treatment has a 28% average detrimental impact on peoples' health. Using the same central estimate for the value of statistical life year (VSLy) of $195,000 used elsewhere in this report implies a one-off mental health wellbeing cost of $4.77m (= no of people x average health impact x average number of years impacted x VSLy = 175 x 0.28 x 0.5 x 195,000).

## 5.6 Overall impacts on human capability

This section has analysed the impact of the proposed ban on the human capability domain. Overall, we find the ban is likely to result in:

- a benefit to the health of HC spray operators from reduced acute (but non-fatal) dermal poisoning incidents with a value of around $0.04m p.a. (or around $0.6m NPV) in monetary terms;
- a benefit to spray operators from reduced risk of male infertility of around $0.16m p.a. (or $2.5m NPV) in monetary terms;
- one-off costs associated with a temporary increase in unemployment of around $3.56m; and
- temporary costs of increased mental health issues for members of the kiwifruit industry associated with the financial stress caused by the fall out of an HC ban of $4.8m.

Table 5 below summarises the costs and benefits (that can be quantified in monetary terms) - to human capability arising from the ban.

**Table 5: Human capability impacts ($m, NPV)**

| $m | 30 year present value |
|---|---|
| Costs | |
| Unemployment impact | -$3.6 |
| Financial stress | -$4.8 |
| Benefits | |
| Reduced acute incidents | $0.6 |
| Reduced male infertility | $2.5 |
| Quantified net benefits (costs) | -$5.3 |
| **Unquantified benefits** | |
| Reduced incidence of cancer | |

The net costs to human capability arising from the ban that can be quantified in monetary terms sum to around $5.3m in NPV terms.

Our attempts to identify and therefore quantify the cancer risk faced by HC spray operators was unsuccessful, so this potential benefit remains unquantified. We present reverse engineered estimates of the level of cancer risk that would need to be mitigated by the proposed HC ban in order to justify the residual costs from our overall analysis in Section 8 of this report.

[44] TDB Advisory, op cit. p 4.

[45] We consider that this approach produces conservative estimates of the potential costs as it accounts for mental-health impacts only for those meeting a particular diagnosis status and ignores the potential continuum of people experiencing different levels of anxiety.

[46] See https://cevr.tuftsmedicalcenter.org/databases/cea-registry .

# 6 Overall costs and benefits

The outcome of our national wellbeing assessment of the costs and benefits of the proposed ban on HC use is presented in Table 6 below. We present separately the costs and benefits that can be quantified in monetary terms and those that, given the available information, we have not been able to quantify in monetary terms.

**Table 6: National wellbeing impacts of removing HC, $m NPV (30 year)**

| National Wellbeing Cost-Benefit Analysis of HiCane Ban in New Zealand | | | |
|---|---|---|---|
| **Quantifiable in monetary terms:** | | | |
| **Benefits ($m)** | | **Costs ($m)** | |
| **Financial impacts** | | | |
| | | Economic costs | -$1,537.2 |
| **Natural environment** | | | |
| Animal life benefits | $5.3 | Cost of increased GHG emissions | -$15.7 |
| **Human capability** | | | |
| Reduced acute incidents | $0.6 | Unemployment impact | -$3.6 |
| Reduced male infertility | $2.5 | Financial stress | -$4.8 |
| **Total** | | | |
| Total quantified benefits | $8.4 | Total quantified costs | -$1,561.3 |
| | | **Net monetary benefit (costs)** | -$1,552.9 |
| | | **Monetary benefit cost ratio** | 0.01 |
| **Not quantifiable in monetary terms:** | | | |
| **Unquantified benefits** | | | |
| Aqueous environment | | | |
| Soil environment | | | |
| Polinators | | | |
| Non-target plants | | | |
| Reduced incidence of cancer | | | |

The estimates indicate that the costs to society of the ban on the use of HC that can be measured in monetary terms are likely to well exceed the benefits of the ban that can be measured in monetary terms. Even using generous valuations for the wellbeing benefits, the benefits that can be quantified in monetary terms appear to be at best less than 1% of the expected costs that a ban on HC is likely to impose on society.

Our quantitative assessment does not include the potential for reduced incidence of cancer or the potential environmental benefits for the aquatic environment, non-target plants and pollinators., The calculations presented in Table 6 suggest that these benefits would need to have a value greater than $100m p.a. or $1.5b in NPV terms for the ban to result in a net improvement in overall national wellbeing. As we present in Section *8 Reverse engineering of required reduction in cancer risks*, HC would need to be responsible for at least a ten-fold increase in the risk of HC spray operators getting cancer compared with the typical New Zealander for the potential benefits from banning HC to approach the expected wellbeing costs expected from such a ban.

The net costs to society that can be valued in monetary terms that are expected to arise from the ban are material and are not notional in nature. Over a 30-year period, using a 5% discount rate, the present value of the estimated net monetary costs arising from the ban is around $1.553 bn. Such losses would have very real consequences for New Zealanders. They are, for example, equivalent to 22 excess deaths per year ($100m p.a. divided by a VSL of $4.56m). Put in other ways, $100m each year is equivalent to:

- 513 disability-adjusted life years (valued at $195,000 per DALY); or[47]

- 19,231 hospital patient nights (valued at the CBAx assumption of $5,200 per night); or

- 974 full time hospital nurses (valued at 1,800 hours per year at the CBAx assumed $57 per hour).

On the whole it seems that regulatory changes in 2006, as well as industry responses, have resulted in improvements in HC application practices. However, as noted in the description of current practices in the EPA's application report (pp. 17 to 20) there is still potential for further improvements in spray operator compliance and to orchard design and practices. Banning HC will solve these problems, but at a high national cost and, as indicated by the numbers presented in this report, at a cost that appears disproportionate to the size of the problems posed by HC.

Enforcement of regulatory standards and fostering orchard design and practices may be more appropriately scaled responses to the remaining problems associated with the use of HC. If the EPA continues to have material concerns about the health and environmental consequences of HC use, from a wellbeing perspective there would appear to be real-option value to the EPA waiting and devoting more resources to collecting more robust evidence of the problems arising from the use of HC in New Zealand.

At this stage it does not appear that the evidence provided by the EPA is sufficient to justify the costs that would result from banning HC. Collecting more information, such as conducting New Zealand-based epidemiological and environmental studies would provide a means of reducing the high level of uncertainty (and debate) about the true level of harm caused by HC. Such studies would delay decision-making timeframes but would greatly reduce the potentially very high costs of regret that a wrong or poorly informed decision might produce.

In particular, given the lack of quantitative evidence on the human harms arising from the use of HC in New Zealand, a priority area for future research would be to undertake population studies in order to better quantify the long-term health risks for HC spray operators.

[47] This can mean a variety of health outcomes. It could mean, for example, 382 bedridden patients for an entire year. It is also equivalent to 19,932 HC spray operators each spending seven days every year recovering from an acute exposure to HC.

# 7 Risk analysis

Given the inevitable uncertainties around the estimates presented in this report we supplement our analysis using Monte Carlo risk-analysis techniques to test the robustness of our conclusion that the costs of banning HC use that can quantified in monetary terms are likely to well exceed the benefits that can be quantified in monetary terms.

Monte Carlo simulation techniques provide a method for investigating the interactions between multiple areas of uncertainty. A Monte Carlo simulation uses statistical sampling and probability distributions to simulate the effects of uncertain variables on model outcomes. It provides a systematic assessment of the combined effects of multiple sources of risk.

The approach adopted here is to simulate 20,000 observations for each varied component assuming random inputs into a Beta distribution.[48] The assumed distribution takes into account prior information about the potential distribution and can also constrain the distribution to avoid impossible outcomes, like negative costs.

The strength of the Monte Carlo simulation is that it allows a wide range of combinations between the different components (for example, one simulation could effectively assume that some costs are low, but others are high). Twenty thousand simulations were found to be sufficient to ensure that results were stable between different samplings.

Monte Carlo analysis also allows us to present a graphical (histogram) presentation of the distribution of cost estimates and to provide 95% confidence intervals for the cost estimates.

The key assumptions underpinning the Monte Carlo analysis undertaken here are presented in Table 7 below. The central values used are the same as those used in the central analysis presented above. The Beta value summarises the skewness of distribution assumed, with a higher Beta value signifying more room provided for values above the central assumption.

Points to note are:

- the values for the size of the reduction in GDP associated with the removal of HC come from the Sapere report;
- the low/high assumptions for conversions from kiwifruit to dairy are based on zero and 30% of land currently planted in kiwifruit;
- the range of GHG emissions are based on the high/low estimates from Ledgard and Falconer (2015)[49] less a range of estimates emissions on kiwifruit orchards benchmarked from Mithraratne et al (2010)[50];
- the low value for the social cost of carbon reflects the pre-2020 spot price for carbon. The high value of $310 is based on the Pindyck (2016)[51] survey of experts estimating the long-term expected social cost of carbon;

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[48] A Beta distribution is selected as it provides scope to constrain the distribution outcomes within plausible bounds (established by the A and B terms) and to allow skewed distributions (established by the relative size of the α and β terms).

In practice each alpha term has been set to 1 and then the beta value (which sets the distribution skewness) is adjusted to ensure that the resulting distribution mean matches the values used in the central calculations. The resulting distributions are bound by plausible constraints but also utilise available information about the likely distribution.

For example, if the average price of a milkshake is $10, prices below zero and over $50 may be excluded as impossible or implausible. But as the average price is $10, observations of $8 to $12 would be expected to be more likely than observations of $38-$42. So, in this example, A would be set to 0, B to 50, and with α set to 1, a value of 5 would be chosen for β, as this is the value that will generate a sample average of 10.

For the Monte Carlo analysis of the cost estimates of the proposed EPA amendments, the following assumptions have been made:

- α = 1.
- β = adjusted to ensure that the distribution average equals the central estimate.
- A = lower bound of distribution (if not constrained by a zero lower bound, assumed to be lower than the low sensitivity test value by a proportion that is 25% of the gap between the sensitivity low value and the central estimate).
- B = upper bound (typically assumed to be greater than the high sensitivity test value by a proportion that is 25% of the gap between the sensitivity high value and the central estimate).

[49] Ledgard and Falconer (2015).

[50] Mithraratne et al. (2010).

[51] Pindyck (2016).

- the high/low values for the DALYs associated with male fertility are the associated high/low figures that accompanied the central figure used from the Institute for Health Metrics and Evaluation;

- the mental health impact alternative assumptions relate to CEA Registry assessments of DALY depression impacts for patients in remission (the 10% low impact) or treatment resistant depression (TRD) patients who do not respond to two sequential courses of anti-depressant medication (the 64% high impact); and

- the other values represent our judgements. We have deliberately included a wide band for these values to reflect the degree of uncertainty around the central estimates.

### Table 7: Key assumptions underpinning the Monte Carlo analysis

| Variable | Unit | Low | Central | High | Beta (skewness) |
|---|---|---|---|---|---|
| **General** | | | | | |
| Value of statistical life (VSL) | $m | $3.36 | $4.56 | $6.45 | 1.57 |
| Value of statistical life year (VSLy) | $m | $0.14 | $0.19 | $0.28 | 1.57 |
| Discount rate | % | 2% | 5% | 8% | 1.00 |
| Kiwifruit orchard density | % of DHB land area | 0.09% | 0.18% | 0.36% | 2.00 |
| DHB population in 2019 | 7 kiwifruit HC use areas | 1,996,110 | 2,217,900 | 2,439,690 | 1.00 |
| **Costs** | | | | | |
| Financial | | | | | |
| Value of reduction in GDP from removal of HC | $m | $85 | $100 | $113 | 0.87 |
| Environmental | | | | | |
| Land converting from kiwifruit to livestock | Ha | 0 | 1,325 | 3,974 | 2.50 |
| GHG emissions | Kg CO2-eq/ha | 8,992 | 13,366 | 17,657 | 0.98 |
| Social cost of carbon | $NZ/tonne CO2-eq | $25.00 | $76.50 | $310.00 | 4.53 |
| Human | | | | | |
| *Involuntary unemployment* | | | | | |
| Fiwifruit labour force | Count | 3,000 | 3,500 | 5,000 | 3.00 |
| Proportion with employment disruption | % | 5% | 15% | 30% | 1.50 |
| Individual cost of involuntary unemployment | $ | $20,000 | $27,146 | $50,000 | 3.20 |
| Period unemployed | Months | 1 | 3 | 6 | 1.50 |
| *Mental health* | | | | | |
| Individual health impact | % health reduction | 10% | 28% | 64% | 2.00 |
| Proportion of growers impacted | % | 1% | 5% | 15% | 2.50 |
| Period of depression | Months | 1 | 6 | 12 | 1.20 |
| **Benefits** | | | | | |
| Environmental | | | | | |
| *Animal deaths* | | | | | |
| Number per year | | 1 | 5 | 20 | 3.75 |
| Animal value | $ | $2,000 | $10,000 | $20,000 | 1.25 |
| *Bird sightings* | | | | | |
| Organic orchard native bird premium | % | 30% | 63% | 200% | 4.13 |
| Willingness to pay for bird conservation | $ | $40 | $119 | $500 | 4.82 |
| Human | | | | | |
| *Acute incidents* | | | | | |
| Number per year | | 5 | 10 | 20 | 2.00 |
| Recovery period | days | 3 | 7 | 14 | 1.75 |
| *Male infertility* | | | | | |
| DALY | per 100,000 | 0.81 | 2.10 | 4.89 | 2.16 |
| Impact factor | Multiple of orchard densit | 1 | 10 | 20 | 1.11 |

The distribution of the estimates for the 30-year present values of net monetary benefits are presented in Table 8 and Figure 3. The key result is that, based on the assumptions underlying the analysis, the probability of the monetary benefits exceeding the monetary costs from a ban of HC is zero, with the high point of the 95% confidence range still implying a net national cost of -$931m over a thirty-year period.

If this was a proposal to spend public money, results of this magnitude would make it very difficult to secure funding. Being a regulatory decision, it can be easier to ignore the costs to society that might result from the decision. Although the resulting societal costs might not be as transparent as those associated with a spending proposal, the societal impacts will be just as harmful.

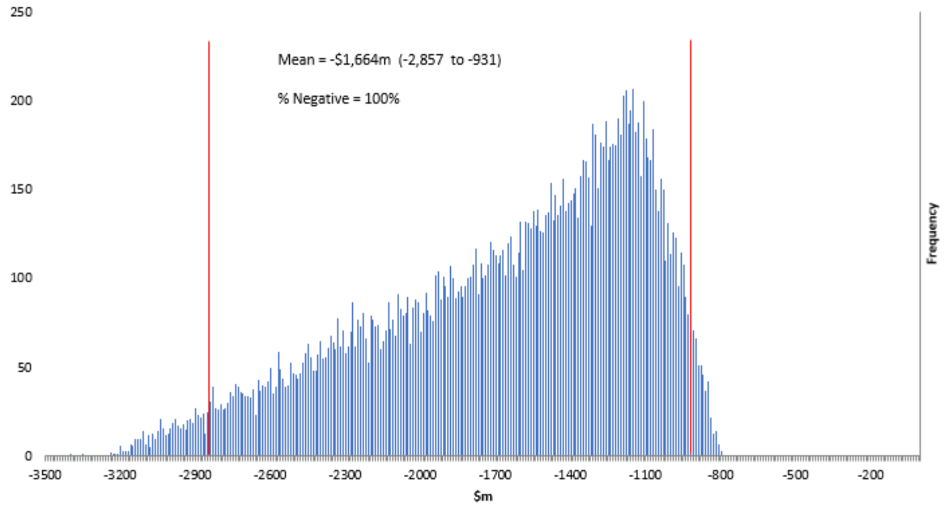
**Table 8: 95% confidence intervals from Monte Carlo analysis, $m p.a.**

| | Central | Low | High |
|---|---|---|---|
| **Costs** | | | |
| Financial | | | |
| GDP reduction | $100 | $82 | $116 |
| Environmental | | | |
| Increased GHG emissions | $1.4 | $0.0 | $6.1 |
| Human costs | | | |
| Involuntary unemployment1 | $3.5 | $0.3 | $12.0 |
| Mental health1 | $4.9 | $0.0 | $25.1 |
| **Benefits** | | | |
| Financial | | | |
| | | | |
| Environmental | | | |
| Reduced non-target animal harm | $0.4 | $0.0 | $1.5 |
| Human costs | | | |
| Elimination of risk of acute incidents | $0.04 | $0.01 | $0.11 |
| Reduced risk of male infertility | $0.18 | $0.00 | $0.73 |
| Present value of net benefit (costs)2 | -$1,664 | -$2,857 | -$931 |

1. One-off temporary transition costs

2. 30-year present value

**Figure 3: Distribution of estimates for 30-year present values of net monetary benefits/costs, $m p.a.**



# 8 Reverse engineering of required reduction in cancer risks

Our quantified analysis suggests that the costs of a ban on the use of HC that can be measured in monetary terms are likely to considerably exceed the value of the benefits that can be measured in monetary terms. The central estimate is that the quantified projected benefits are estimated to be less than 1% of the quantified costs. Over a 30-year period, the net costs are estimated to have a present value of $1,553m (calculated using a 5% discount rate). As noted, there is considerable uncertainty associated with the quantification of the estimated costs and benefits. To reflect this uncertainty, Monte Carlo risk analysis was undertaken, yet could not yield one positive outcome out of the 20,000 iterations undertaken. The 95% confidence range of the present value of net cost estimates ranged from $931m to $2,857m.

However, a number of potential benefits that are expected to come from a ban of HC have not been quantified. Some of these relate to factors such as environmental impacts on water, soil, bees, plants and mammals. In general, these were not factors that appear critical to the focus of the EPA's concerns about the use of HC, based on the EPA's application report.

Thus, although the quantification of these factors is likely to reduce the measured gap between costs and benefits, one would not expect this be sufficient to drastically change the implications of the analysis presented here.

However, a key area of concern of the EPA relates to the potential long-term health risks for spray operators. As the EPA states:

> *Risks to operators using hydrogen cyanamide were determined to be above the level of concern, and risks could not be mitigated even with the prescribed, modified, and additional controls, or considering the lowest current label application rates. Overall, without further refinements, the risks are above the level of concern for operators.*[52]

Our attempts to generate mechanisms for quantifying this risk did not provide us with sufficient evidence to quantify the value of these health risks. This does not mean that such risks do not exist, but it does suggest that it would be prudent for further information to be collected and further analysis undertaken before finalising any decision about banning the use of HC.

Below we present calculations that estimate the type of health impacts that would need to be obviated in order to justify the estimated costs associated with a ban of the use of HC in New Zealand. We model this based on ten scenarios of different rates of eroding health, from a 1% to a 10% permanent annual deterioration in health status. Of course, these scenarios are unrealistic from the perspective of any individual. Our focus is simply to provide a mechanism for estimating the pace and frequency of detrimental health impacts that would be required to justify a policy that has an economic cost in the range of $100m per year.

Table 9 presents estimates of the health impacts and their associated wellbeing costs. The left-hand column presents the assumed annual percentage reduction in health status. The second column presents the sum of implied quality adjusted life years (QALYs) lost under each scenario over a fifty-year period. Thus, for example, under the first scenario with a 1% per year health reduction, someone beginning with perfect health would by year 50 have a health quality that is 50% of what it would otherwise have been.[53] This translates into a 12.8 year reduction in quality adjusted life years. A 2% annual health reduction would imply that health status reaches zero by year 50, hence the assumption given in column 3 of a 50 year life expectancy. In the third scenario, with a 3% annual health deterioration, the health status equals zero in year 33. The QALY loss calculation of 33.8 equals 16.8 years of deteriorated life in the first 33 years plus the 17 years of life lost due to a premature death. The most extreme scenario adopted here is a 10% annual health reduction, which implies a rapidly declining health and death within 10 years.

[52] https://www.epa.govt.nz/assets/FileAPI/hsno-ar/APP203974/APP203974_20210930_Application_report_hydrogen_cyanamide_reassessment.pdf , p3.

[53] A fifty-year time horizon is used as Statistics New Zealand life tables indicate that around fifty years is the average future life expectancy of New Zealanders, given the current age distribution and life expectations.

**Table 9: Valuation of individual health deterioration scenarios over a 50 year time horizon**

| Health deterioration rate | Per person QALY loss | Life expectancy | Present value of per person QALY loss (5% discount rate) |
|---|---|---|---|
| % per year | | Years | $m |
| 1 | 12.8 | >50 | $0.55 |
| 2 | 25.5 | 50 | $1.10 |
| 3 | 33.8 | 33 | $1.55 |
| 4 | 38.0 | 25 | $1.87 |
| 5 | 40.5 | 20 | $2.10 |
| 6 | 42.2 | 16 | $2.28 |
| 7 | 43.4 | 14 | $2.41 |
| 8 | 44.2 | 12 | $2.52 |
| 9 | 44.9 | 11 | $2.61 |
| 10 | 45.5 | 10 | $2.68 |

The present value calculations of the associated QALY loss (presented in the fourth column in Table 9) are calculated based on a value of statistical life year of $195,000 and using a 5% discount rate. Thus, taking the first scenario, a 1% decline in health in the first year is valued at $1,950. The 2% loss in the second year is double this value (ie, $3,900) but when the deterioration in one year's time is discounted by 5% would imply a present value of $3,714. The sum of these discounted health costs over the 50-year period is $550,000, the number presented at the top of the fourth column. The present value of these scenarios ranges up to $2.68m per individual for those impacted by a 10% annual health deterioration rate.

The next step is to estimate the number of new cancer cases required each year under each scenario that would imply a social cost (in terms of the lost value of quality adjusted life years) that would be considered sufficient to justify the type of economic costs expected to result from banning the use of HC. These estimates are presented in Table 10 for the central estimated net present cost of quantified aspects expected from banning the use of HC (ie, $1,553m), as well as the values at the extremes of the 95 percent confidence interval of the Monte Carlo analysis results (ie, $931m and $2,857m respectively).

The case-number estimates are reverse engineered to estimate the number of new cancer cases each year that would need to be prevented to ensure that the present value of the health benefits over a 30-year period is equivalent to the expected net monetary wellbeing costs over the same period. To interpret, the central cost-benefit calculations estimate a monetary net present value of $1,553m, excluding longer-term health implications for spray operators.

If the type of illness that spray operators are susceptible from HC exposure is expected to have a health impact equivalent to a 1% per year health deterioration, then a ban on HC would need to reduce the number of new cases by 125 each year for the ban to enhance wellbeing. The number of required case preventions declines with the seriousness of expected health impacts (a 2% annual health deterioration halves the required annual case reduction to 63, but beyond 5%, increased health severity has little further impact on reducing the number of new cases).

Even if one is pessimistic about the longer-term health impacts of HC on spray operators and also optimistic about the potential costs of banning HC, Table 10 suggests that HC would need to be currently responsible for at least 20 new and probably terminal cancer cases each and every year for the ban to be wellbeing enhancing.

**Table 10: Annual new cancer cases required to justify HC ban**

| Health deterioration rate | Low | Central | High |
|---|---|---|---|
| % per year | (PV = -$931m) | (PV = -$1,553m) | (PV = -$2,857m) |
| 1 | 75 | 125 | 231 |
| 2 | 37 | 63 | 115 |
| 3 | 28 | 46 | 85 |
| 4 | 24 | 40 | 75 |
| 5 | 22 | 38 | 69 |
| 6 | 22 | 36 | 67 |
| 7 | 21 | 35 | 65 |
| 8 | 21 | 35 | 64 |
| 9 | 20 | 34 | 63 |
| 10 | 20 | 34 | 62 |

We understand that there are 472 spray operators associated with the application of HC on kiwifruit orchards in 2022.[54] If there were 35 new cancer cases each year as a result of spray operator exposure to HC (ie based on the central estimates) this would imply 7.4% of spray operators with a history of HC use would need to get cancer on average each year. Even using the low net cost estimates (ie 20 new cases per year), 4.4% of spray operators would need to get cancer on average each year. To put this in context, 0.5% of the national population is diagnosed with a form of cancer each year. This implies that exposure to HC (and HC alone) would need to result in a susceptibility to cancer for spray operators that is at least ten times greater than is typical for New Zealanders in order to justify banning the use of HC.

If the risks of cancers for HC spray operators are ten times the national average, then this would seem to be valid grounds for stricter controls on the use of HC. However, it would seem that more information about such a relationship is required. For example, the EPA evidence is based on laboratory tests on animals undertaken a number of decades ago that implied that thyroid and male genital issues are the likely cancer pathway. In 2019 there were 16 new thyroid cancer diagnosis and 6 new testicular cancer cases throughout the Bay of Plenty[55]. For the ban to be justified, HC would need to be responsible for all such cancers in the Bay of Plenty. However, as noted in Section 5 and Appendix 1, we have not identified any evidence of higher rates of thyroid and testicular cancer in the Bay of Plenty than elsewhere in the country.

Overall, it would seem that more information about the longer-term health risk imposed by exposure to HC is required.

[54] From personal communications with Zespri.

[55] New Zealand Cancer Registry, see https://www.health.govt.nz/nz-health-statistics/health-statistics-and-data-sets/cancer-data-and-stats .

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## Appendix 1: Investigation of correlation between kiwifruit orchards and cancer incidence

This Appendix investigates the correlation between kiwifruit orchards and the incidence of cancer.

Data was sourced from the Ministry of Health both on mortality and new cancer registrations.[56] Models were estimated of the form:

$$Y_{d,t} = \alpha + \beta K + \sum \gamma_i C_{i,d,t} + \sum \rho_t T_t + \sum \delta_d D_d + \mu$$

whereby the variable of interest, $Y$, either deaths from a certain cause or new registrations of a form of cancer, in DHB $d$ and year $t$, is regressed against a panel of data related to:

$K$, the propensity of kiwifruit planting in the area;

$C$, certain control variables, which included ethnicities, age and sex variables;

$T$, year control dummy variables, and

$D$, DHB control dummy variables.

The terms $\alpha, \beta, \gamma, \rho, \delta$ refer to the to-be-estimated coefficients and $\mu$ to the estimation residual.

The unit of analysis was District Health Board (DHB) areas, with the dependent variables, $Y$, and the control variables, $C$, expressed as proportions of the DHB area populations. The dummy variables were binary (0,1) variables controlling for years (2013-2019 for the cancer registrations and 2015-2019 for deaths) and for DHB areas. The critical variable of interest is $K$, which measures the proportion of DHB areas planted in kiwifruit where there is some potential for HC use: ie, Northland, Waitemata, Counties-Manukau, Waikato, Bay of Plenty, Tairawhiti and Hawkes Bay. These DHB areas are therefore omitted from the DHB dummy variable list, which included the remaining 12 DHB areas.[57]

The specific dependent variables investigated were:

- New cancer registrations of:
  - Testicular cancer (expressed as a proportion of the male population in each DHB area);
  - Males with thyroid cancers (proportion of DHB male population);
  - Thyroid cancers (both sexes, proportion of DHB total population);
  - Males with any form of cancer (proportion of DHB male population); and
  - All forms of cancer (both sexes, proportion of DHB total population).
- Mortalities from:
  - Male genital neoplasms (proportion of DHB male population);
  - Thyroidal neoplasms (both sexes, proportion of DHB total population);
  - Thyroidal disorders (both sexes, proportion of DHB total population); and
  - Any form of neoplasms (both sexes, proportion of DHB total population).

Estimation was conducted using PcGive[58] but was generally quite unsuccessful. All equations, except one, had evidence of structural problems, particularly failed

[56] Mortality data was sourced from https://www.health.govt.nz/publication/mortality-web-tool and new cancer registrations data was sourced from https://www.health.govt.nz/nz-health-statistics/health-statistics-and-data-sets/cancer-data-and-stats .

[57] Panel regression analysis also requires the omission of one dummy variable to ensure that there is not perfect collinearity between the dummy variables and the constant, $\alpha$. In our estimation the omitted variables were for the Auckland DHB and for the year 2019. These are therefore the points of reference for the estimated equations.

[58] Doornik and Hendry (2007).

normality and RESET tests, probably resulting from omitted variables, and so potentially biasing parameter estimates. The variable of primary interest, the proportion of DHB areas planted in kiwifruit, was invariably not found to have a statistically significant relationship with the dependent variables. That is, the analysis indicated no relationship between the health outcomes and the prevalence of kiwifruit plantings in the region. Indeed, of the nine equations estimated, five returned negative point estimates for the kiwifruit coefficient (new registrations of testicular, male thyroid and total thyroid cancers and for deaths associated with thyroidal neoplasms and disorders). However, all of these results should be discounted as all estimates cannot be statistically distinguished from zero.

In Table 11, we report in full the one estimated equation in which no clear structural problems were evident. The table presents estimates of the potential excess cancer deaths associated with kiwifruit orchard densities. As with the other estimated equations, the coefficient for kiwifruit orchard density is not statistically significant, with the standard error (0.01564) being ten times as large as the estimated coefficient (0.00146).

### Table 11: Estimation results investigating relationship between deaths from neoplasms and kiwifruit orchard densities

**Dependent variable: Deaths from neoplasms**

**Form: Proportion of DHB population**

| | Coefficient | Standard error | T-statistic |
|---|---|---|---|
| Constant | -0.00772 | 0.01167 | -0.662 |
| Proportion of DHB land area: | | | |
| Planted in kiwifruit | 0.00146 | 0.01564 | 0.093 |
| Proportion of DHB population: | | | |
| Died from all causes | 0.21939 | 0.02497 | 8.790 * |
| Male | 0.00807 | 0.02654 | 0.304 |
| European | 0.00460 | 0.00265 | 1.740 |
| Maori | 0.00224 | 0.00211 | 1.060 |
| Pacific People | 0.00460 | 0.00260 | 1.770 |
| Asian | 0.00203 | 0.00336 | 0.603 |
| Year dummy variables | | | |
| 2015 | 0.00036 | 0.00017 | 2.140 * |
| 2016 | 0.00036 | 0.00014 | 2.560 * |
| 2017 | 0.00015 | 0.00011 | 1.380 |
| 2018 | 0.00011 | 0.00006 | 1.820 |
| DHB dummy variables | | | |
| Lakes | -0.00002 | 0.00009 | -0.228 |
| Taranaki | -0.00026 | 0.00018 | -1.460 |
| Whanganui | 0.00095 | 0.00039 | 2.480 |
| MidCentral | -0.00059 | 0.00017 | -3.390 * |
| Hutt Valley | 0.00018 | 0.00013 | 1.410 |
| Capital and Coast | -0.00045 | 0.00022 | -2.010 * |
| Wairarapa | -0.00025 | 0.00017 | -1.490 |
| Nelson Marlborough | -0.00022 | 0.00015 | -1.500 |
| West Coast | -0.00010 | 0.00045 | -0.219 |
| Canterbury | -0.00031 | 0.00025 | -1.260 |
| South Canterbury | -0.00039 | 0.00018 | -2.160 * |
| Southern | -0.00029 | 0.00016 | -1.780 |

| | | | |
|---|---|---|---|
| **sigma** | 0.000155746 | **RSS** | 1.84352E-06 |
| **R2** | 0.988219 | **F(23,76) =** | 277.2 [0.000]** |
| **log-likelihood** | 748.556 | **DW** | 2.35 |
| **no. of observations** | 100 | **no. of parameters** | 24 |
| **mean(DNP)** | 0.00257586 | **var(DNP)** | 1.56487E-06 |

Normality test: Chi^2(2) = 5.5726 [0.0616]
Hetero test: F(30,45) = 1.3552 [0.1747]
RESET test: F(1,75) = 0.72685 [0.3966]

* denotes 95% statistical significance ** denotes 99% statistical significance

In Table 12 the estimation is repeated with the removal of the kiwifruit intensity variable (but with the addition of dummy variables for regions missing in Table 11, such as Northland, Bay of Plenty etc). When this is done, all location dummy variables are not statistically significant, with the death rate from all causes being the only variable robustly associated with deaths from neoplasms. This implies that there is no evidence, once one corrects for a region's overall death rate (which will reflect the region's age distribution and general state of health), that there are any regions in NZ where people are more susceptible to dying from cancer than any other region.

Overall, our estimation results find no evidence of a statistically significant link between the use of HC and long-term illnesses and heightened cancer risks. In addition, our analysis finds no evidence of any links along the transmission paths underpinning the EPA recommendations: ie, thyroidal and male genitalia cancers.

### Table 12: Result of simplified model excluding kiwifruit variable

| **Dependent variable: Deaths from neoplasms** | | | |
|---|---|---|---|
| **Form: Proportion of DHB population** | | | |
| | **Coefficient** | **Standard error** | **T-statistic** |
| Constant | 0.00422 | 0.02056 | 0.205 |
| Proportion of DHB population: | | | |
| Died from all causes | 0.21728 | 0.04774 | 4.550 * |
| Male | -0.00823 | 0.04311 | -0.191 |
| European | 0.00000 | 0.00534 | 0.000 |
| Maori | -0.00278 | 0.00447 | -0.623 |
| Pacific People | 0.00093 | 0.01491 | 0.063 |
| Asian | 0.00067 | 0.00353 | 0.191 |
| Year dummy variables | | | |
| 2015 | 0.00003 | 0.00023 | 0.138 |
| 2016 | 0.00010 | 0.00018 | 0.567 |
| 2017 | -0.00002 | 0.00014 | -0.170 |
| 2018 | 0.00003 | 0.00007 | 0.392 |
| DHB dummy variables | | | |
| Northland | 0.00167 | 0.00134 | 1.240 |
| Waitakere | 0.00035 | 0.00050 | 0.691 |
| Counties Manukau | 0.00031 | 0.00168 | 0.184 |
| Waikato | 0.00103 | 0.00106 | 0.976 |
| Lakes | 0.00137 | 0.00138 | 0.994 |
| Bay of Plenty | 0.00114 | 0.00119 | 0.961 |
| Taranaki | 0.00163 | 0.00216 | 0.755 |
| Whanganui | 0.00126 | 0.00144 | 0.878 |
| MidCentral | 0.00091 | 0.00096 | 0.945 |
| Hutt Valley | 0.00234 | 0.00131 | 1.790 |
| Capital and Coast | 0.00051 | 0.00104 | 0.488 |
| Wairarapa | 0.00113 | 0.00061 | 1.850 |
| Nelson Marlborough | 0.00014 | 0.00063 | 0.216 |
| West Coast | 0.00098 | 0.00125 | 0.791 |
| Canterbury | 0.00080 | 0.00153 | 0.524 |
| South Canterbury | 0.00119 | 0.00204 | 0.584 |
| Southern | 0.00053 | 0.00150 | 0.357 |

| | | | |
|---|---|---|---|
| **sigma** | 0.000151647 | **RSS** | 1.60978E-06 |
| **$R^2$** | 0.989713 | **F(23,76) =** | 232.2 [0.000]** |
| **log-likelihood** | 755.335 | **DW** | 2.62 |
| **no. of observations** | 100 | **no. of parameters** | 30 |
| **mean(DNP)** | 0.00257586 | **var(DNP)** | 1.56487E-06 |

Normality test: $Chi^2(2)$ = 4.7427 [0.0934]

Hetero test: F(35,34) = 1.2493 [0.2590]

RESET test: F(1,69) = 0.57182 [0.4521]

## Appendix 2: Living Standards Framework

The current New Zealand government standard for assessing the wellbeing impacts of a policy is the Treasury's Living Standards Framework (LSF). The 2021 LSF has three levels alongside a series of analytical prompts for consideration at each level.

**Level 1: Individual and collective wellbeing**

This level captures resources and aspects of our lives that are considered important to wellbeing at the individual, family, whānau and community level. The 12 domains are:

- Health
- Knowledge and skills
- Cultural capability and belonging
- Work, care and volunteering
- Engagement and voice
- Income, consumption and wealth
- Housing
- Environmental amenity
- Leisure and play
- Family and friends
- Safety
- Subjective wellbeing

**Level 2: Institutions and governance**

This level captures the role that political, economic, social and cultural institutions play in facilitating the wellbeing of individuals and collectives. Schools for example play a role in the wellbeing of children, as do marae in the wellbeing of tangata whenua. This level includes:

- Whanau, hapu and iwi
- Families and households
- Civil society
- Firms and markets
- Central and local government
- International connections

**Level 3: The wealth of Aotearoa**

This level captures the wealth of Aotearoa New Zealand. New Zealand's national wealth is captured under four areas:

- **Natural environment:** All aspects of the natural environment which support life and human activity, whether valued for spiritual, cultural or economic reasons
- **Human capability:** Peoples' knowledge and physical and mental health
- **Social cohesion:** The willingness of diverse individuals and groups to trust and cooperate with each other in the interests of all, supported by shared intercultural norms and values
- **Financial and physical capital:** Tangible human-made assets, intangible knowledge-based assets (e.g., research and development, software and databases, arts and literature) and financial assets minus liabilities

Rather than falling under one of the three levels, culture is considered to play a role in all elements of the 2021 LSF.

**Analytical prompts**

The LSF includes four key criteria for consideration when analysing the impact of a policy on the three levels of wellbeing above. These are:

1. **Distribution:** How is our aggregate wealth and wellbeing distributed across time, place and groups of people?
2. **Resilience:** Do individuals, collectives, institutions, organisations and the environment have an ability to adapt to or absorb stresses and shocks?
3. **Productivity:** How effectively is our wealth being used to generate wellbeing and things of economic value?
4. **Sustainability:** How well are we safeguarding our national wealth for the benefit of future generations?

Each of these prompts is considered important in understanding trends in wellbeing, as well as the potential impacts of policy.

# Addendum: Update to the TDB National Wellbeing Impacts of the Removal of Hydrogen Cyanamide

7 February 2023

The Environmental Protection Authority (EPA) released an update report with respect to its proposed reassessment of Hydrogen Cyanamide (HC) in December 2022[59]. In addition, Sapere released a social impact assessment (SIA) commissioned by the EPA in January 2023[60]. This addendum provides our assessment of the implications of this new information for the results presented in the TDB Advisory report: The National Wellbeing Impacts of the Removal of Hydrogen Cyanamide, September 2022.

We consider the key changes presented in the EPA update to be:

- A 43% increase in the estimated economic costs of banning the use of HC, with the expected reduction in GDP increasing from $100 million to $143 million per year[61].
- The removal by the EPA of cancer risks for spray operators from exposure to HC as a basis for any reassessment of HC use in New Zealand.
- Heightened perceptions of risks from HC exposure for non-threatened earthworm and collembola soil organisms.
- Heightened perceptions of risks of long-term reproduction toxicity from HC exposure for non-threatened bird species.
- An extension of the proposed phase out period for HC from five to ten years after the reassessment decision is accepted.

The Sapere SIA provided a qualitative assessment, based on interviews with individuals, on the mental health and wellbeing effects that could potentially manifest if the use of HC was faded out.

On balance we consider these changes reinforce the conclusions of the TDB report. The TDB report was based on the previous estimates made by Sapere that a ban on HC use would reduce GDP by $100 million per year. TDB estimated that in addition to these economic costs, there were also likely to be wellbeing costs associated with climate change, unemployment and financial distress. In total, annual wellbeing costs of $101.6 million were expected to result from the removal of HC use in New Zealand. Our analysis accounted for wellbeing benefits related to reduced health risks for spray operators and environmental benefits resulting from the removal of HC, with annual wellbeing benefits valued at $600,000. The net result was an estimated net annual wellbeing cost of $101 million, with a benefit-cost ratio of 0.006.

Using Sapere's updated estimates of the economic consequences of banning the use of HC, but retaining our estimates of other wellbeing costs and benefits, would yield an annual net wellbeing cost of $144 million with a benefit-cost ratio of 0.004.

We consider that this updated net wellbeing estimate already adequately accounts for the heightened risk to birds identified in the EPA update report. This is because we consider that our original estimates already included generous methods for valuing the potential for harm to birds from HC exposure. Our estimates of the potential harm to birdlife essentially assumed that HC use was the sole reason for all difference in bird populations between standard and organic orchards. Further this difference in birdlife observations was valued based on evidence of people's willingness to pay for native bird conservation in Waikato. That is, our valuation was based on generous assumptions of both the volume and price dimensions of the risks to bird life.

The September 2022 TDB national wellbeing report did not quantify potential wellbeing benefits resulting from reduced cancer risks for spray operators currently exposed to HC or the value of risks to soil organisms. This lack of quantification reflected our inability to obtain evidence of a statistical correlation between cancer incidents and the prevalence of kiwifruit operations and the lack of any evidence of carcinogenic risks provided in the earlier EPA reports. This

[59] Environmental Protection Authority, 'Update Report: Reassessment of Hydrogen Cyanamide', December 2022, https://www.epa.govt.nz/assets/FileAPI/hsno-ar/APP203974/APP203974_20221214.0-Update-Report.pdf.

[60] Davies P, Barton B and O'Hare J (2023), 'EPA reassessment of hydrogen cyanamide: A social impact assessment', Sapere report for the Environmental Protection Authority, https://www.epa.govt.nz/assets/FileAPI/hsno-ar/APP203974/APP203974_20230131_Social-Impact-Assessment.pdf.

[61] Davies P and Barton B (2022) 'Economic aspects of EPA reassessment of Hydrogen Cyanamide: Response to submissions' Sapere report for the Environmental Protection Authority, also included as Appendix C of Environmental Protection Authority, 'Update Report: Reassessment of Hydrogen Cyanamide', December 2022, https://www.epa.govt.nz/assets/FileAPI/hsno-ar/APP203974/APP203974_20221214.0-Update-Report.pdf.

lack of statistical evidence is perhaps consistent with the EPA decision to downgrade the potential cancer risk for spray operators in their update report.

We consider the downgrading of this potential health risk considerably weakens the national wellbeing case to ban the use of HC. In our September report we conducted a reverse engineering exercise to provide an estimate of the level of reduced cancer risk that would be required to provide a national wellbeing justification for banning the use of HC. This essentially required exposure to HC to result in a ten-fold increase in risk of cancers for spray operators compared with the typical New Zealander. The EPA update instead removes increased cancer risks from HC exposure as a reason for the proposed ban of HC. This reinforces the quantified estimates of the net wellbeing costs of the proposed ban presented in the 2022 TDB report. As stated above, incorporating the Sapere economic cost update implies that a ban on the use of HC is likely to yield just $600,000 of wellbeing benefits but at a wellbeing cost to the nation of $144.6m each year. This implies a benefit-cost ratio of 0.004. A policy should in general only be adopted if it is expected to yield a benefit-cost ratio of at least 1.0 or higher.

An implication of removing cancer risk as a basis for justifying a ban of HC is that the risk to soil organisms identified by the EPA in its update report would need to be expected to enhance national wellbeing by an amount that is worth in excess of $100 million, and perhaps close to $150 million, each year to New Zealanders in order to tip the scale in favour of a ban in HC. This might be the case if the risks from HC exposure put at risk the total earthworm and collembola (springtail) population throughout large areas of New Zealand, but it seems less likely if risks are confined to the areas where HC spraying takes place. There is also a time dimension given that HC spraying is conducted just once a year with HC breaking down within days of spray.

Finally, we do not consider the proposed increase in phase out period, from five to ten years, to have any material impact on the wellbeing assessment. The uncertainty associated with the proposed ban is already likely to be delaying and diverting investment activities away from the kiwifruit industry. A ten-year phase out, potentially provides more time for a viable alternative to HC to be developed, but the long-term viability of the industry will not be clear to industry participants until an actual alternative is identified, is proven to be a robust alternative, and it has, in its own turn, passed through all regulatory hurdles. In the meantime, uncertainty will continue in the industry, investment will be restrained and otherwise viable opportunities will be missed.