SEA of the Draft Hydrogen Action Plan for Scotland

Environmental Report

November 2021

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Final report
Prepared by LUC
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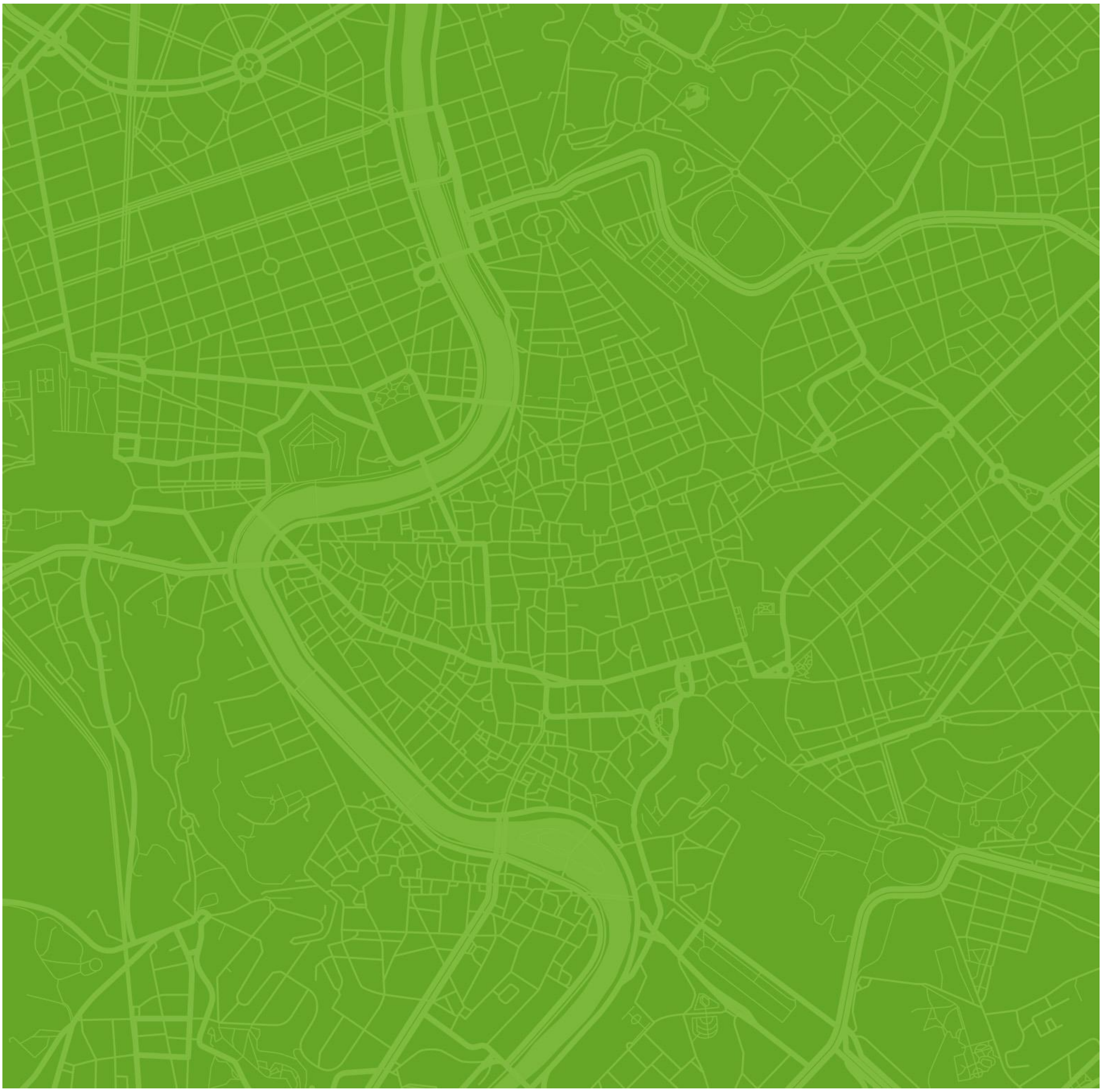

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Contents

Chapter 1
Non-Technical Summary

Introduction to the Draft Hydrogen Action Plan

1.1 The Scottish Government is currently preparing a Draft Hydrogen Action Plan which will detail the planned approach and the actions required to realise the objectives set out in the Hydrogen Policy Statement.

1.2 These themes are reflected through six action themes within the Draft Hydrogen Action Plan. These include:

- Scaling up hydrogen production in Scotland
- Facilitating the development of a domestic market
- Maximising the benefits of integrating hydrogen into our energy system
- Enabling the growth and transition of Scotland's supply chain and workforce
- Establishing and strengthening international partnerships and markets
- Strengthening research and innovation.

What is Strategic Environmental Assessment?

1.3 Strategic Environmental Assessment (SEA) is a way of considering the environment when preparing public plans, programmes and strategies. It identifies potential significant environmental effects and, where necessary, describes how these effects can be avoided or reduced. Through consultation, SEA also provides an opportunity for the public to express their views on proposed policies and their potential environmental impacts.

1.4 In this case, SEA is being used to assess the likely environmental effects of the Draft Hydrogen Action Plan.

How was the Strategic Environmental Assessment undertaken?

1.5 This SEA is an assessment of the likely significant environmental effects of the Draft Hydrogen Action Plan and the alternatives to it. The Environmental Report considers the environmental effects of the Draft Hydrogen Action Plan as they would influence activities across Scotland.

1.6 The assessment identifies positive and negative environmental effects and the significance of these; considers whether they would be temporary or permanent; and notes where they would arise in the short, medium or long term. It also distinguishes between effects arising directly from the Draft Hydrogen Action Plan and any 'secondary' effects, which would indirectly impact on the environment.

Which reasonable alternatives have been considered?

1.7 There are two types of alternative included within the SEA. Firstly, we consider alternatives based on variations in the extent of renewable or low-carbon hydrogen produced. Secondly, we consider alternatives that relate to the scale and spatial distribution of hydrogen production.

What are the key environmental challenges relevant to the Draft Hydrogen Action Plan?

1.8 Greenhouse gas (GHG) emissions are the key driver for climate change. Major contributors to the GHG emissions include the transport sector business, agriculture, energy supply and the residential sector. Key long-term climate change trends for Scotland are that weather may become more variable, typical summers will be hotter and drier, winter and autumn will be milder and wetter and sea levels will continue to rise. Climate change can also give rise to indirect impacts arising from mitigation and adaptation measures. Some of the key climate change risks for Scotland are flood risk; exposure to high temperatures; shortages in public water supply and for agriculture, energy production and industry; substantial risks to wildlife and natural ecosystems; and risks to domestic and international food production and trade.

1.9 Key pressures for biodiversity include land use intensification and modification, pollution, urban development, nutrient enrichment and over exploitation of natural resources. Climate change also poses a significant risk to biodiversity.

1.10 For population and human health, air pollution may have both short- and long-term health impacts. Transport is a significant contributor to poor air quality, especially in urban areas. Heating and cooling of homes accounts for a significant part of the GHG emissions, and fuel poverty remains an issue. Flooding can also pose significant environmental impacts and can affect people, communities and businesses.

1.11 Scotland's soils are considered to generally be in good health, however, there are a range of pressures on them. Issues such as climate change and loss of organic matter pose significant threats to Scottish soils, with both likely to affect soil function including loss of soil carbon. Changes in land use and land management are also some of the key pressures on soil. These include activities such as transport and development through road building, the expansion of urban areas, and agriculture and forestry practices.

1.12 Key pressures on the surface water environment include urbanisation, an increase in invasive non-native species, intensive agriculture/aquaculture and climate change. Rural and urban diffuse pollution remains a concern for water quality, particularly in relation to agriculture, forestry and urban development. The risk of flooding from rivers, surface waters and sea are also predicted to increase as a result of climate change.

1.13 Air pollution, despite recent reductions, is still identified as a concern especially in towns and cities. Some of the key contributors to air pollution are transport, energy generation and agriculture, which are also key contributors to climate change.

1.14 In terms of cultural heritage and historic environment, development poses a key pressure on these both directly in terms of damage to known and unknown features, and from potential impacts on setting. Other pressures include changing land use and land management, tourism/visitors, pollution and climate change.

1.15 Changes in landscape tend to occur over long periods of time, and gradual change as a result of development such as housing, and changes in farming and forestry practices can be difficult to determine. Climate change poses one of the key environmental challenges for Scottish landscapes due to changing temperatures and patterns of precipitation, weather events and sea level change.

1.16 Energy storage is likely to be an increasingly important part of the transition to delivering clean, affordable and secure supply of energy such as hydrogen. Infrastructure will play a key role in ensuring security of supply and decarbonising the energy system in the most cost-effective way. Hydrogen is a key opportunity as a fuel for heavy-duty transport, including for maritime and aviation sectors, offering longer range than electric only and it could also have an essential role in meeting the peaks in energy demand. Flooding, growing risks posed from heat, water scarcity and slope instability could prove to be significant risks for hydrogen economy. Therefore, the selection of the location of hydrogen production infrastructure needs to consider the potential for these extreme weather events and climatic risks to minimise future impacts on hydrogen production plants.

Which existing environmental protection objectives are relevant?

1.17 Environmental protection objectives which form the context for the assessment include international and national level policies and strategies that aim to reduce greenhouse emissions from energy production and encourage alternative technologies such as hydrogen production. Climatic objectives focus on achieving Scotland's GHG emissions to net zero by 2045. Objectives for biodiversity, fauna and flora are largely aimed at protecting habitats and species from damage and disturbance. Objectives for population and human health focus on setting out requirements for air quality, legislation against noise and vibration nuisance. Soil objectives seek to protect prime quality agricultural land and peatlands. Objectives for water aim to protect rivers, lochs, transitional waters, coastal waters and groundwater resources. Objectives for air aim to reduce pollution, and to reverse the effects of past emissions. Cultural heritage objectives are primarily focused on valued sites and features, including townscapes, buildings, archaeological sites, battlefields, wrecks and landscapes that have been recognised at the international, national and local levels. Landscape objectives reflect the importance of all landscapes and the need to help to improve those that have become degraded. Objectives for material assets seek to reduce the overall GHG emissions and make the best use of Scotland's resources and existing infrastructure.

Strategic Environmental Assessment findings

1.18 The environmental effects are considered as direct effects from the action themes and indirect effects.

Direct Effects

1.19 The draft HAP will have limited direct effects, and no significant adverse effects were identified in the assessment. Direct effects are only identified for a small number of SEA topics for some of the Action Themes.

1.20 Action Theme One aims to deliver a suitable context for private capital investment in hydrogen production by providing the necessary support framework. It is expected to have a minor negative effect in relation to soil, as this action may require additional development of facilities and lead to land take and soil compaction.

1.21 Action Theme Two aims to facilitate the development of a domestic hydrogen market, including in relation to heat, transport, and industrial decarbonisation. Minor positive effects are identified for climatic factors, as it is expected that the roll out of hydrogen ready boilers used for domestic heating would reduce GHG emissions in comparison to the current fossil fuel-based heating sources without carbon capture, and reduce air pollution.

1.22 No direct effects are identified for Action Theme Three which aims to integrate hydrogen into the energy system by identifying potential integration challenges, enabling knowledge sharing, exploring the use of hydrogen as an energy storage and exploring any required changes to the current energy market frameworks .

1.23 Action Theme Four aims to support the growth and transition of companies, and workforce skills development. Minor positive effects are identified in relation to population and human health as this Action Theme is likely to deliver training and employment opportunities within the hydrogen economy.

1.24 Action Theme Five aims to deliver international partnerships and markets. Minor negative effects are identified in relation to soil as Action Theme Five may require additional development of port and harbour facilities and lead to land take and soil compaction, as well as impacts on marine sediments from port expansion.

1.25 Action Theme six aims to ensure that there is ongoing research and development taking place along with the establishment of hydrogen production and the hydrogen economy in Scotland. Minor positive effects are identified in relation to population and human health, as this Action Theme is likely to deliver employment opportunities within research and development, supporting health and wellbeing.

1.26 The Draft Hydrogen Action Plan identifies potential Hydrogen Energy Hubs within Scotland. The development of the hydrogen energy hubs is expected to have positive effects on climatic factors by reducing greenhouse gas emissions. Reduced use of fossil fuels could have subsequent benefits for air quality. Overall improvements in air quality will reduce respiratory illness amongst the population and positive effects are identified in relation to population and human health.

1.27 The potential Hydrogen Energy Hubs will provide local jobs and training opportunities which will have positive effects on population and human health by supporting health and quality of life.

1.28 The deployment of hydrogen will have positive effects on material assets by improving the reliability, security and flexibility of energy supply, and where low carbon hydrogen is produced by reusing existing oil and gas infrastructure. However, upgrades to pipelines may have adverse effects on soil quality and biodiversity. Increased transportation of hydrogen by marine vessels may have detrimental effects on marine life and have negative effects on biodiversity. There will also be negative effects on water due to the significant quantities of water required to produce hydrogen,

1.29 Furthermore, hydrogen developments are likely to result in negative effects on the landscape and historic environment with potentially greater negative effects in less built-up locations such as Orkney and Shetland.

Indirect Effects

1.30 No significant adverse indirect effects are identified.

1.31 Indirect effects on biodiversity, fauna and flora relate to minor negative effects from land take for hydrogen production and storage facilities and negative impacts on the water environment from water abstraction. However minor positive effects will arise from improved air quality.

1.32 Indirect effects on population and human health include short term impacts from construction and operation of hydrogen production and storage facilities, and long term health benefits from improved air quality.

1.33 Indirect effects from soil relate to land take for construction for hydrogen production and storage facilities and transport.

1.34 Indirect effects on water could arise from the requirement for significant quantities of water leading to water shortages especially in spring and summer months.

1.35 Indirect effects on air include potential negative effects from air quality impacts arising from the storage of ammonia. This has negative impacts on human health and biodiversity. Energy requirements for compression and liquification of hydrogen could also contribute to negative effects on air quality. large-scale deployment of hydrogen, particularly in industry, shipping and heavy transport (including buses and heavy goods vehicles (HGVs) could contribute towards improvements in air quality if the hydrogen is combusted with fuel cells.

1.36 Indirect effects on climatic factors include negative effects from carbon embodied within building materials and energy requirements for construction activities, including transportation of materials and machinery. Leakage of hydrogen, which is a greenhouse gas, can also occur. However low carbon and renewable hydrogen will reduce greenhouse gas emissions compared to current emissions levels.

1.37 Minor negative effects on cultural heritage and the historic environment and landscape and geodiversity are likely from the construction of production and storage facilities, however these are likely to be local in effect.

1.38 Indirect effects on material assets include the development of hydrogen processing infrastructure, notably electrolysers for renewable hydrogen, hydrogen storage facilities, and facilities for producing fuel cells. Where hydrogen production makes use of existing oil and gas infrastructure, this represents an efficient use of existing resources.

1.39 Appropriate infrastructure to facilitate storage will enable more reliable and secure deployment of hydrogen, having positive effects on material assets.

1.40 The deployment of hydrogen fuel cells in vehicles will have positive effects on material assets by improving the resilience of the transport energy sector to the pressures on depleting non-renewable resources.

Cumulative, secondary and synergistic effects

1.41 Cumulative effects of the development of hydrogen facilities may negatively impact on biodiversity, flora and fauna as a result in habitat loss, however greater use of hydrogen and displacement of fossil fuels may provide benefits for biodiversity by enabling habitats to remain connected.

1.42 Development of hydrogen facilities and ancillary development such a renewable energy schemes may result more local job opportunities, local investment and opportunities to enhance skills having positive effects on population and human health by improving health and quality of life. Positive effects are further enhanced as the generation of zero or low carbon hydrogen fuel which may help to reduce fuel poverty across Scotland, particularly in areas close to hydrogen production. Hydrogen use displaces use of fossil fuels, and there are expected to be improvements to air quality benefitting the population. Furthermore, by reducing the use of fossil fuels, the future effects of climate change, such as the risk of extreme weather events will be reduced. Some negative effects on population and human health may arise due to construction related activities which could produce noise and dust. Depending on the fuel source of vehicles used to transport hydrogen, negative effects on health may arise due to release of carbon emissions and particulate matter.

1.43 The actions are identified as having potential cumulative mixed effects on soil. Actions promoting the development of hydrogen facilities and ancillary development may result in either positive or negative effects on soil, depending on whether they are sited on brownfield or greenfield land. Moreover, development of ancillary infrastructure, such as pipelines, will result in soil disturbance.

1.44 The production of hydrogen requires significant quantities of water which can be sourced either on land (freshwater) or from the sea. Over-abstraction for use in hydrogen facilities would have negative effects on the water environment and biodiversity, particularly during spring and summer months when water levels are lower. Extraction of water from the sea will need to undergo a desalination process which produces a brine by-product which is released back to the sea having negative effects on water quality. Further negative effects will arise as a result of construction activities relating to hydrogen development and its ancillary infrastructure, supporting renewable energy schemes and improvement of infrastructure.

1.45 Actions promoting the development of hydrogen facilities and ancillary development may result in both positive and negative effects on air quality. The use of hydrogen as a fuel will displace fossil fuels and help reduce emissions and pollutants associated with fossil fuels, having positive effects on air quality. Air pollution can also occur throughout the operational phases of hydrogen production, with negative effects. Actions promoting the development of hydrogen facilities and ancillary development may result in both positive and negative effects on climatic factors. The use of hydrogen as a fuel will displace fossil fuels and help reduce domestic, industrial and transport emissions associated with fossil fuels, having positive effects on the climate. However, the construction of hydrogen facilities and supporting infrastructure, including renewable energy, will result in carbon emissions during construction. Emissions can be released into the atmosphere during the lifecycle of hydrogen production.

1.46 Actions promoting the development of hydrogen facilities and ancillary development could result in direct negative effects on cultural heritage assets if the developments are sited close to these assets. However, the greater use of hydrogen and displacement of fossil fuels, may provide positive effects for cultural heritage by reducing the potential effects of climate change.

1.47 Actions promoting the development of hydrogen facilities and ancillary development may result in negative effects on the landscape, depending on where they are sited. Most hydrogen development is assumed to be on previously developed land associated with existing power stations, ports and oil and gas infrastructure. Hydrogen facilities on undeveloped land will have more significant negative effects. However, the greater use of hydrogen and displacement of fossil fuels, may provide positive effects for landscape by reducing the potential effects of climate change.

1.48 The production of large-scale hydrogen will help create a secure, reliable and flexible energy system which is resilient to future change with positive effects for material assets.

What measures could be put in place to avoid, reduce or manage the environmental effects of the Draft Hydrogen Action Plan?

1.49 No significant adverse effects are identified from the assessment. Consideration of mitigation is focused on opportunities to avoid, reduce or manage minor adverse effects. This includes managing direct effects on air, soil and the water environment.

What monitoring is proposed?

1.50 It is anticipated that indicators for unforeseen environmental effects could be linked to the indicators in the Environment Strategy Initial Monitoring Framework. Monitoring will be further considered and will be described in the Post Adoption Statement.

How can I comment on this Environmental Report?

1.51 The consultation on the Draft Hydrogen Action Plan will run for a 10 week period from 10th November to 19th January 2022. Comments on the Draft Hydrogen Action Plan and the Environmental Report can be submitted via the Scottish Government Citizen Space website. Request for hard copies of the Environmental Report can be made to: hydrogeneconomy@gov.scot

1.52 Consultation questions on the SEA Environmental Report are as follows:

1. Do you have any comments on the environmental baseline information referred to in the Environmental Report?
2. Are you aware of further information that could be used to inform the assessment findings?
3. What are your views on the assessment findings?
4. Are there other environmental effects arising from the Draft Hydrogen Action Plan?
5. What are your views on the alternatives considered?
6. What are the most significant environmental effects which should be taken into account as the Draft Hydrogen Action Plan is finalised?
7. How can the Draft Hydrogen Action Plan be enhanced to maximise positive environmental effects?
8. What do you think of the proposed approach to mitigation and monitoring proposed?

1.53 Following the consultation period, the consultation responses will be analysed and the Scottish Government will finalise and publish the Hydrogen Action Plan 2021-2026. After the Hydrogen Action Plan 2021-2026 is adopted a Post Adoption Statement will be produced. This Statement will set out how the SEA and the views received in the consultation processes have been taken into account.

Chapter 2
Introduction

Purpose of this Report

2.1 The Scottish Government is currently preparing a Draft Hydrogen Action Plan which will detail the planned approach and the actions required to realise the objectives set out in the Hydrogen Policy Statement[1].

2.2 LUC was appointed by the Scottish Government in February 2021 to undertake a Strategic Environmental Assessment (SEA) of the Draft Hydrogen Action Plan. The SEA of the Draft Hydrogen Action Plan presents an important opportunity to ensure that environmental considerations are brought to the forefront of the decision-making process and influence the outcome of the Draft Hydrogen Action Plan. Although the Draft Hydrogen Action Plan is driven by an environmental imperative, it is important to ensure that impacts on the wider environment are identified, evaluated and where possible avoided or minimised. Equally, there may be opportunities to enhance wider benefits delivered by the Draft Hydrogen Action Plan.

2.3 The purpose of this Environmental Report is to present the findings of the SEA process.

Key facts

2.4 Table 1.1 sets out the key facts for the Draft Hydrogen Action Plan.

Table 2.1: Key facts for the Draft Hydrogen Action Plan

Responsible Authority	Scottish Government
Title	Draft Hydrogen Action Plan
Subject	Hydrogen
Period Covered	2021 - 2026
Area covered by the policy	Scotland
What prompted the preparation of the policy?	The policy sets out the actions required to realise the policy objectives set out in the Hydrogen Policy Statement.

[1] Scottish Government (2020) Scottish Government Hydrogen Policy Statement [online] Available at: https://www.gov.scot/publications/scottish-government-hydrogen-policy-statement/ (accessed 09/02/2021)

Responsible Authority	Scottish Government
Purpose and/or objectives of the policy	The Hydrogen Action Plan provides further detail on the planned approach and proposed actions to implement the policy priorities in the Hydrogen Policy Statement. It sets out what the Scottish Government will do over the next five years to support the development of the hydrogen economy in Scotland, to support efforts to reduce greenhouse gas emissions from Scotland's energy system, industry, homes and transport, while ensuring a just transition.
Contact	hydrogeneconomy@gov.scot

Context for the Draft Hydrogen Action Plan

2.5 The Climate Change (Scotland) Act 2009[2] ("the 2009 Act") established the legal framework for emissions reductions by 2050. It set targets for the reduction in carbon emissions of 42% by 2020 and 80% by 2050, compared to the 1990 baseline. The Climate Change Plan (CCP) (2018) published by the Scottish Government, outlined policies and proposals to meet the emission targets as outlined in the 2009 Act, over the plan period of 2018 - 2032.

2.6 The Climate Change (Emissions Reduction Targets) (Scotland) Act 2019[3] amended the 2009 Act, including a commitment to achieve net zero emissions by 2045. Following the amendments to emissions reduction targets by the 2019 Act, the Scottish Government committed to updating the CCP.

2.7 The CCP update (CCPu) published in December 2020 promotes the deployment of hydrogen technologies which will provide opportunities to further decarbonise the energy sector in Scotland. The CCPu commits the Scottish Government to provide £180 million for an Emerging Energy Technologies Fund, supporting the development of hydrogen, Carbon Capture Utilisation and Storage (CCUS), and providing impetus to the development of Negative Emission Technologies (NETs).

2.8 The Scottish Government has also published a Hydrogen Policy Statement[4] in December 2020 which recognises the importance of hydrogen in the transition to Net Zero by 2045. The Hydrogen Policy Statement sets an ambition of generating 5GW of renewable and low-carbon hydrogen by 2030. This policy has been informed by the Scottish Hydrogen Assessment[5] and the Scottish Offshore Wind to Green Hydrogen Opportunity Assessment[6] and Deep Decarbonisation Pathways for Scottish Industries Research Report[7].

Hydrogen

2.9 Hydrogen can be produced in a number of different ways[8], each likely to result in different environmental effects:

- Grey hydrogen relies on natural gas stocks, and hence it cannot be classified as renewable energy.
- Blue or low-carbon hydrogen is also acquired from natural gas, however carbon dioxide is captured and stored.
- Green or renewable hydrogen is a result of electrolysis of water and can be fully green if production process is powered by renewable energy.
- The coupling of bioenergy with Carbon Capture and Storage technology offers the potential to manufacture hydrogen with negative carbon emissions.

2.10 There are also numerous other less common types including pink[9], yellow[10] and turquoise[11] hydrogen. However, for the purposes of this assessment, only renewable and low-carbon hydrogen are being considered.

2.11 Hydrogen technologies can be used for large scale energy storage, analogous to the presence of natural gas

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[2] The Climate Change (Scotland) Act 2009
[3] Climate Change (Emissions Reduction Targets) (Scotland) Act 2019
[4] Scottish Government (2020) Scottish Government Hydrogen Policy Statement [online] Available at: https://www.gov.scot/publications/scottish-government-hydrogen-policy-statement/ (accessed 09/02/2021)
[5] Scottish Government (2020) Scottish Hydrogen Assessment [online] Available at: https://www.gov.scot/publications/scottish-hydrogen-assessment-report/ (accessed 10/02/2021)
[6] Scottish Government (2020) Scottish Offshore Wind to Green Hydrogen Opportunity Assessment [online] Available at: https://www.gov.scot/publications/scottish-offshore-wind-green-hydrogen-opportunity-assessment/
[7] Element Energy (2020) Deep Decarbonisation pathways for Scottish Industries. Scottish Government. [online] Available at: https://www.gov.scot/publications/deep-decarbonisation-pathways-scottish-industries/ (accessed 18/3/2021)
[8] Hydrogen can also be produced using nuclear power; however this is not being taken forward as a method of hydrogen production in Scotland.
[9] Hydrogen generated through electrolysis powered by nuclear energy
[10] Hydrogen made through electrolysis using solar power
[11] Hydrogen produced from methane pyrolysis, uses methane as a feedstock but using heat from electricity.

across the existing energy system. This can help balance demand and supply on an hourly, daily or seasonal basis.

2.12 Deployment of hydrogen has the potential to play a significant role in decarbonising the transport system, electricity, heating and industries where heat demand means decarbonisation has been difficult to date. Use of hydrogen can deliver significant reductions in GHG emissions from electricity production, as in Scotland there is very significant potential for producing renewable hydrogen utilising onshore and offshore wind, tidal and hydro electricity. In the transport sector, hydrogen can help reduce emissions by offering an alternative to petrol and diesel fuels and has potential for use for bus fleets, HGV, rail, maritime and aviation. Within industries such as glass, cement, food and drink there is a scope to reduce emissions directly from manufacturing and production processes. Where current technology means that completely clean solutions are not available at current required capacity, there is a scope for utilising hydrogen and Carbon Capture and Storage technologies to minimise carbon emissions.

Scottish Government's Draft Hydrogen Action Plan

2.13 The Scottish Government has committed to developing a Hydrogen Action Plan. The Draft Hydrogen Action Plan provides further detail on the planned approach and proposed actions to implement the policy positions outlined in the Hydrogen Policy Statement[12].

2.14 The Draft Hydrogen Action Plan is structured around the six action themes.

2.15 These include:

- Scaling up hydrogen production in Scotland
- Facilitating the development of a domestic market
- Maximising the benefits of integrating hydrogen into our energy system
- Enabling the growth and transition of Scotland's supply chain and workforce
- Establishing and strengthening international partnerships and markets
- Strengthening research and innovation.

Strategic Environmental Assessment

2.16 The Environmental Assessment (Scotland) Act 2005 ('the 2005 Act')[13], is a means to judge the likely impact of the plan, programme or strategy on the environment and to seek ways to minimise adverse effects, if likely to be significant.

2.17 The SEA process comprises a number of stages:

- Pre-screening.
- Screening (preparation of a Screening Report).
- Scoping (preparation of a Scoping Report).
- Environmental Assessment (preparation of an Environmental Report).
- Main consultation on the Environmental Report.
- Preparation of a Post-adoption SEA Statement.
- Monitoring the significant environmental effects of implementing the Final Hydrogen Action Plan.

2.18 A Scoping report was prepared and submitted to the SEA Gateway in March 2021.

The UK Withdrawal from the European Union (Continuity) (Scotland) Act 2021[14]

2.19 Section 15 of the Continuity Act places a duty on responsible authorities to have due regard to the guiding principles on the environment when preparing a plan, programme or strategy requiring a SEA under the Environmental assessment (Scotland) Act 2005. Whilst not yet in force, nonetheless the guiding principles are set out below and will be taken into account in the preparation of the Environmental Report: The guiding principles as set out in Section 13 (1) of the Act are:

a. the principle that protecting the environment should be integrated into the making of policies,

b. the precautionary principle as it relates to the environment,

c. the principle that preventative action should be taken to avert environmental damage,

d. the principle that environmental damage should as a priority be rectified at source,

e. the principle that the polluter should pay.

2.20 The SEA process comprises a number of stages:

[12] Scottish Government (2020) Scottish Government Hydrogen Policy Statement [online] Available at: https://www.gov.scot/publications/scottish-government-hydrogen-policy-statement/ (accessed 09/02/2021)

[13] The Environmental Assessment (Scotland) Act 2005

[14] UK Withdrawal from the European Union (Continuity) (Scotland) Act 2021. Available at: https://www.legislation.gov.uk/asp/2021/4/enacted

- Pre-screening.
- Screening (preparation of a Screening Report).
- Scoping (preparation of a Scoping Report).
- Environmental Assessment (preparation of an Environmental Report).
- Main consultation on the Environmental Report and Draft Hydrogen Action Plan.
- Preparation of a Post-adoption SEA Statement.
- Monitoring the significant environmental effects of implementing the Draft Hydrogen Action Plan.

2.21 The Hydrogen Action Plan falls within section 5 (3) of the Environmental Assessment (Scotland) Act 2005 and can proceed directly to scoping stage.

Structure of the Environmental Report

2.22 This chapter has described the background to the Draft Hydrogen Action Plan and the requirement to undertake SEA. The report is structured into the following chapters, and bold highlights illustrate where these meet the requirements of the 2005 Act.

- Chapter 1: Includes the Non-Technical Summary of the Report.
- Chapter 2: Outlines the contents and main objectives of the Draft Hydrogen Action Plan 2021-2026 and its relationship with other qualifying plans and programmes.
- Chapter 3: Describes the approach to the assessment including the difficulties encountered.
- Chapter 4: Describes environmental policy context.
- Chapter 5: Describes the environmental baseline including key trends and environmental problems.
- Chapter 6: Describes the significant environmental effects expected from the Draft Hydrogen Action Plan 2021-2026.
- Chapter 7: Describes the significant environmental effects expected from the reasonable alternatives.
- Chapter 8: Describes the mitigation and enhancement measures proposed.
- Chapter 9: Describes the approach to monitoring.
- Chapter 10: Sets out conclusions and the next steps for the Draft Hydrogen Action Plan 2021-2026 and for the environmental assessment process.

2.23 The main body of the report is supported by **Appendix A** which presents the review of plans, programmes and environmental protection objectives of relevance to the Draft Hydrogen Action Plan,

Chapter 3
Approach to the Assessment

Requirement under the 2005 Act

3.1 The Draft Hydrogen Action Plan is considered to fall under Section 5(3) of the 2005 Act and as such, a SEA is required.

3.2 Schedule 3(6) of the 2005 Act requires the Environmental Report to consider "*The likely significant effects on the environment, including (a) on issues such as – (i) biodiversity; (ii) population; (iii) human health; (iv) fauna; (v) flora; (vi) soil; (vii) water; (viii) air; (ix) climatic factors; (x) material assets; (xi) cultural heritage including architectural and archaeological heritage; (xii) landscape; and (xiii) the inter-relationship between the issues referred to in heads (i)–(xii); (b) short, medium and long-term effects; (c) permanent and temporary effects; (d) positive and negative effects; and (e) secondary, cumulative and synergistic effects*".

Scoping of SEA Topics

3.3 In accordance with Schedule 2 of the 2005 Act, consideration has been given as to whether the environmental effects (both positive and negative) of the Draft Hydrogen Action Plan are likely to be significant.

3.4 Given the anticipated environmental effects of the proposed measures that could be set out in the Draft Hydrogen Action Plan, it is considered that all SEA topics required to be considered by the 2005 Act should be scoped into the SEA process. These are set out in **Table 3.1.**

Table 3.1: Proposed scoping in/out of SEA topics

SEA Topic	Scoped in
Biodiversity, flora and fauna	✓
Population and human health	✓
Soil	✓
Water	✓
Air	✓
Climatic factors	✓

SEA Topic	Scoped in
Cultural heritage and the historic environment	✓
Landscape and geodiversity	✓
Material assets	✓

Approach to Assessment

3.5 This is a strategic level assessment of a high-level Draft Hydrogen Action Plan and reflects the national perspective the Draft Hydrogen Action Plan will take. Specifically, the SEA takes the form of a baseline-led assessment which compares the potential impacts of the Draft Hydrogen Action Plan against the current environmental baseline and understanding of the environmental effects of hydrogen production in order to assess the significance of any environmental effects that could arise for each SEA topic.

3.6 Due to the nature of the Draft Hydrogen Action Plan, the approach has focused separately on the direct and indirect effects of the Action Plan. This reflects the role of the Action Plan in enabling future hydrogen development, but the limited scale of hydrogen production that is likely within the lifespan of the Action Plan itself.

3.7 The assessment identifies the actions and SEA topics for which direct environmental effects are identified. Not all actions have direct environmental effects. This is then followed by consideration of the indirect effects, including the impacts associated with supporting development that will be required for hydrogen production.

Consideration of Reasonable Alternatives

3.8 Part 14(2) of the 2005 Act requires that:

"The report shall identify, describe and evaluate the likely significant effects on the environment of implementing (a) the plan or programme; and (b) reasonable alternatives to the plan or programme, taking into account the objectives and the geographical scope of the Plan or Programme".

3.9 Therefore, the SEA must appraise not only the objectives and actions, but "reasonable alternatives" to these. This implies that alternatives that are not reasonable do not need to be subject to appraisal. It is important to note that when considering the scope of alternatives, the 2005 Act does not specify whether this means considering an alternative plan, programme, or strategy, or different alternatives within the plan, programme, or strategy itself that should be assessed. Part (b) of Regulation 14(2) above notes that reasonable alternatives will take into account the objectives of the plan, as well as its geographical scope. Therefore, alternatives that do not meet the objectives of national policy are unlikely to be reasonable.

Reasonable Alternatives

3.10 The role of hydrogen as part of future energy supply is established in the policy framework for achieving net zero emissions. The reasonable alternatives considered are anticipated to be based around the three future development scenarios for hydrogen in Scotland as set out in the Scottish Hydrogen Assessment[15] and a combination of these. These scenarios are based around different levels of hydrogen contribution to transport, domestic and commercial heat, industry and electric and export. The scenarios are:

- Hydrogen economy: Hydrogen is one of the main ways in which Scotland's energy system is decarbonised. A balanced mix of low-carbon and renewable hydrogen is used extensively across all sectors.
- Green Export: Scotland's vast renewable resources, particularly offshore wind, but also wave, tidal and onshore wind are used to produce renewable hydrogen. This serves a European export market and also provides hydrogen for domestic use, primarily in the transport sector
- Focused Hydrogen: Hydrogen plays a supporting role in decarbonising the energy system in sectors that are hard to decarbonise by other means. Hydrogen is produced near to where it is used.

3.11 The scenarios have different spatial effects and different impacts for the decarbonisation of different sectors such as transport, heat and energy. They are based around different scales of hydrogen production and different proportions of renewable and low-carbon hydrogen production.

3.12 In addition to the three scenarios, there are different environmental effects depending on the production process for hydrogen. The difference in environmental effects from the main alternatives of renewable or blue hydrogen are therefore also explored through the alternatives.

Defining the scope of the SEA of the Hydrogen Action Plan – dependencies for hydrogen production

3.13 Renewable hydrogen is produced solely from renewable energy sources and is dependent on renewable energy

[15] Arup and E4Tech (2020) Scottish Hydrogen Assessment. Scottish Government https://www.gov.scot/binaries/content/documents/govscot/publications/research-and-analysis/2020/12/scottish-hydrogen-assessment-report/documents/scottish-hydrogen-assessment/scottish-hydrogen-assessment/govscot%3Adocument/scottish-hydrogen-assessment.pdf

supply. Although policy documents such as the Offshore Wind Policy Statement refer to their relationship with hydrogen production, they are not currently influenced by the levels of hydrogen production that will be set out in the Draft Hydrogen Action Plan as this is an emerging document. The Offshore Wind Policy Statement (2020) sets out the potential for between 8GW and 11GW of offshore wind capacity by 2030. Although large scale renewable energy development is most significant to the large-scale production of hydrogen, all of the reasonable alternatives are reliant on renewable energy supply. However, consideration of the potential for the Draft Hydrogen Action Plan to stimulate renewable energy developments beyond that addressed within existing policy documents is outside of the scope of the SEA.

3.14 Production of hydrogen from biomass feedstock with carbon capture and storage is dependent on a sustainable supply of biomass, for which there are potential supply constraints, and is reliant on carbon capture and storage technology development. The production of hydrogen from biomass with carbon capture and storage is not identified as a likely significant contributor to hydrogen production in Scotland, due to the reliance on imported biomass. The environmental impacts of hydrogen produced from biomass would be reflected in the assessment, as the bioenergy production would be directly related to the hydrogen production.

3.15 Low-carbon hydrogen is dependent on supply of natural gas. Low-carbon hydrogen is dependent on synergy with the oil and gas industry and the use of oil and gas infrastructure for transport of hydrogen and CCS. The environmental impacts of natural gas production as an existing activity are considered outside of the scope of this assessment.

3.16 Low-carbon hydrogen is dependent on capturing, transporting and storing carbon that is currently an emerging technology with risks of imperfect carbon capture, energy penalties and leakage from the process.

3.17 Hydrogen production can take place both onshore and offshore and is reliant on water supply. In locations with a lack of freshwater, such as an offshore location, or onshore location with limited supply, desalinisation will be required. Water supply, and the environmental impacts of water extraction and desalinisation will be included in the scope of the assessment.

Likely significance of effects

3.18 Schedule 2 of the 2005 Act identifies criteria for determining the likely significance of effects on the environment (see Table 3.2) which will be reflected in the approach to assessment.

Table 3.2: Criteria for assessing the likely significant effects

SEA Assessment Criteria	Breakdown and Description
(a) the probability, duration, frequency and reversibility of the effects	<u>Probability</u> Low – Not likely to have an effect Medium High – Highly likely to have an effect <u>Duration</u> Short-term – 0-5 years Medium-term – 5- 10 years (up to the end of action plan period) Long-term – 10+ years (beyond the end of the action plan period) <u>Frequency</u> Continual; defined by number of occurrences; or intermittent <u>Reversibility</u> Whether the effect can be reversed (i.e., can the receptor return to baseline condition) without significant intervention

SEA Assessment Criteria	Breakdown and Description
(b) the cumulative nature of the effects	Where several options each have insignificant effects but together have a significant or combined effect. This includes synergistic effects, which is when effects interact to produce a total effect greater than the sum of the individual effects.
(c) the transboundary nature of the effects	Effects beyond Scotland's boundary.
(d) the risks to human health or the environment	Whether the impact of the effect would present a risk for people and the environment.
(e) the magnitude and spatial extent of the effects (geographical area and size of the population likely to be affected)	<u>Magnitude</u> High – High proportion of the receptor affected Medium Low – Low proportion of the receptor affected <u>Spatial extent</u> National/Transboundary – Effects on Scotland or England International – Effects extending to the UK or beyond
(f) the value and vulnerability of the area likely to be affected due to: (i) special natural characteristics or cultural heritage (ii) exceeded environmental quality standards or limit values (iii) intensive land-use	Impact of the effect on the value or condition of the existing area.
(g) the effects on areas or landscapes which have a recognised national, Community or international protection status	Impacts on areas with national, community or international protection.

Assessment of SEA topics

3.19 The appraisal is based around the SEA topic areas and takes a strategic view of environmental effects on each topic, reflecting the nature of the Draft Hydrogen Action Plan. Table 3.3 sets out the considerations in relation to each SEA topic. These have been used to inform the approach to the narrative assessment.

Table 3.3: SEA assessment scope for the Draft Hydrogen Action Plan

SEA Topic Area	SEA assessment scope
Climatic Factors	Climate change mitigation and adaptation. In particular the assessment for 'climatic factors' will reflect both the impacts for GHG emissions, and the impacts of climate change on coastal infrastructure, recognising the vulnerability of coastal locations to sea level rise and storm damage.
Biodiversity, flora and fauna	Terrestrial and aquatic habitats and species of international, national, regional or local importance, and habitat fragmentation.
Population and human health	Health, quality of life and living environment.
Soil	Loss of soil resources and reuse of vacant and derelict land.
Water	Quality and quantity of watercourses and waterbodies (surface water and groundwater) including coastal and estuarial waters and flood risk. taking into account climate change impacts on water supply.
Air	Air pollution, particularly changes in areas where air quality is a known issue.
Cultural heritage and the historic environment	Terrestrial and marine designated and undesignated heritage assets and the quality of the wider built environment.
Landscape and geodiversity	Designated and undesignated landscape and seascape, and geodiversity.
Material assets	Existing resources and development of new material assets.

3.20 The findings from the SEA of the Draft Hydrogen Action Plan are presented as a narrative for each component of the Draft Hydrogen Action Plan in the main body of the Environmental Report.

3.21 The narrative reflects the significance of the effect. In order to determine significance the text considers the following factors (see **Table 3.2**):

- The **magnitude** of the Draft Hydrogen Action Plan's effects, including the degree to which the plan sets a framework for projects, the degree to which it influences other plans and environmental problems relevant to the Draft Hydrogen Action Plan
- The **sensitivity** of the receiving environment, including the value and vulnerability of the area, exceeded environmental quality standards, and effects on designated areas or landscapes.
- The **effect characteristics**, including probability, duration, frequency, reversibility, cumulative effects, transboundary effects, risks to human health or the environment, and the magnitude and spatial extent of the effects.

3.22 The likely effects of the objectives and actions scoped into the assessment need to be determined and their significance assessed, which inevitably requires a series of judgments to be made.

Mitigation and monitoring proposals and opportunities for enhancement

3.23 A key part of the SEA process is the identification of mitigation for adverse effects and opportunities to enhance benefits, in addition to the development of proposals for monitoring post adoption. It is anticipated that existing initiatives such as the Scottish Government's Hydrogen Policy Statement and Climate Change Plan update may contribute to the delivery of the monitoring requirements identified in the SEA. Where possible, existing data sources, environmental indicators and monitoring programmes will be identified in the SEA.

3.24 Any recommendations for monitoring made in the SEA process are likely to focus on areas where the assessment identifies the potential for significant environmental effects, and the need to address data gaps. These are likely to be linked to the implementation of mitigation or enhancement measures where appropriate.

Difficulties encountered

3.25 The evidence base on the environmental impacts of hydrogen is incomplete, and there are key areas of uncertainty related to the future development of the hydrogen production technology in Scotland. This means that there is a level of uncertainty in the assessment findings. This particularly relates to the air quality impacts of hydrogen manufacture, storage, and deployment. The role of the regulatory framework is therefore important in addressing potential environmental effects.

3.26 The scale of water demand from hydrogen production balanced against the impact of climate change on water resource availability is also a key area of uncertainty, which will require to be closely addressed by the regulatory framework.

Chapter 4
Environmental Context

Relationships of plans, policies, programmes and strategies, and environmental protection objectives

Introduction

4.1 The Draft Hydrogen Action Plan is not being prepared in isolation and is greatly influenced by other plans, programmes and strategies (PPS), and by broader environmental objectives. The Draft Hydrogen Action Plan needs to be consistent with international and national guidance and strategic planning policies and should contribute to the goals of a wide range of other programmes and plans. It must also conform to environmental protection legislation and the environmental objectives established at the international, national and local level.

4.2 Schedule 3 of the 2005 Act requires:

- *(1) "An outline of the contents and main objectives of the plan or programme, and of its relationship (if any) with other qualifying plans and programmes.*
- *(5) The environmental protection objectives, established at international, Community or Member State level, which are relevant to the plan or programme and the way those objectives and any environmental considerations have been taken into account during its preparation"*.

4.3 **Chapter 1** has outlined the contents and main objectives of the Scottish Government's Draft Hydrogen Action Plan.

4.4 In order to establish a clear scope for the SEA it is necessary to review and develop an understanding of the environmental objectives contained within international and national plans and programmes that are of relevance to the Draft Hydrogen Action Plan. The review is not, and cannot be, exhaustive. Appendix A identifies the relationship that the PPS's have with the development of the Draft Hydrogen Action Plan, and also shows how the environmental objectives have been taken into account during the preparation of the SEA Framework. The following sections of this chapter provide an overview by SEA topic area of the overarching objectives considered most relevant in the context of the preparation of the Draft Hydrogen Action Plan.

Climatic Factors

4.5 Scotland's ambition on tackling climate change is set out in the *Climate Change (Scotland) Act 2009* ("the 2009 Act")[16]. Through this legislation, Scotland contributes to international (UN) efforts on climate change mitigation and adaptation. The 2009 Act creates the statutory framework for greenhouse gas (GHG) emissions reduction in Scotland and set targets for reduction in emissions of the seven Kyoto Protocol GHG by 80% by 2050, with an interim 2020 target of 42%, compared to the 1990/1995 baseline level.

4.6 *The Climate Change (Emissions Reduction Targets) (Scotland) Act 2019*[17], amends the *Climate Change (Scotland) Act 2009*, sets targets to reduce Scotland's emissions of all greenhouse gases to net-zero by 2045 at the latest, with interim targets for reductions of at least 56% by 2020, 75% by 2030, 90% by 2040.

4.7 The 2019 Act also requires that annual GHG emissions targets are set, by Order, for each year in the period 2021-2045. Following the initial phase of target-setting, the annual targets are set in nine-year batches.

4.8 *The Climate Change Plan*[18] set out a vision that by 2032 Scotland will have reduced its emissions by 66% relative to 1990 baseline. Specifically, the emissions from electricity production are expected to fall by 28% within that period, emissions from buildings by 33%, emissions from transport by 37%, emissions from industries by 21%, emissions from waste by 52%, and emissions from agriculture by 9%. In addition, land use, land use change and forestry should sequester 6.7 $MtC0_2e$ by 2032. However, following the introduction of the 2019 Act and the net-zero GHG emissions target for 2045, the Scottish Government has updated the *Climate Change Plan (CCPu)*[19].

4.9 The *update to the Climate Change Plan*[20] commits the Scottish government to provide £180 million for an Emerging Energy Technologies Fund, supporting the development of hydrogen and Negative Emission technologies (NETs).

4.10 *The Scottish Energy Strategy*[21] sets out priorities for the local and national energy sector in order to support Scotland's long term climate change targets. It identifies how low carbon electricity and hydrogen will contribute to a largely decarbonised energy system by 2050.

4.11 The *Scottish Climate Change Adaptation Programme* (the Adaptation Programme)[22] addresses the impacts identified for Scotland in the *UK Climate Change Risk Assessment* (CCRA).[23] The Adaptation Programme sets out Scottish Ministers' objectives in relation to adaptation to climate change, their proposals and policies for meeting these objectives, and the period within which these proposals and policies will be introduced. The Programme also sets out the arrangements for wider engagement in meeting these objectives.

4.12 The Scottish Government's *Hydrogen Policy Statement*[24] sets out a vision for Scotland to become a leading hydrogen nation in the production of reliable, competitive, and sustainable hydrogen. It recognises the importance of hydrogen in the transition to renewable energy. The policy statement:

- Confirms its support for the strategic growth of a hydrogen economy in Scotland, focusing on supporting the development of Scotland's hydrogen production capability to meet an ambition of at least 5GW of renewable and low-carbon hydrogen by 2030 and at least 25GW by 2045.

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[16] The Scottish Government (2009) Climate Change (Scotland) Act 2009 [online] Available at: http://www.legislation.gov.uk/asp/2009/12/contents(accessed 04/02/2021)

[17] Scottish Government (2019) The Climate Change (Emissions Reduction Targets) (Scotland) Act 2019 [online] Available at: http://www.legislation.gov.uk/asp/2019/15/enacted (accessed 04/02/2021)

[18] Scottish Government (2018) Climate Change Plan [online] Available at: https://www.gov.scot/publications/scottish-governments-climate-change-plan-third-report-proposals-policies-2018-9781788516488/ (accessed 04/02/2021)

[19] Scottish Government (2020) Securing a green recovery on a path to net zero: climate change plan 2018-2032 – update [Online] Available at: https://www.gov.scot/publications/securing-green-recovery-path-net-zero-update-climate-change-plan-20182032/ (access 05/02/2021)

[20] Ibid.

[21] Scottish Government (2017) Scottish Energy Strategy: The future of energy in Scotland(online) Available at: https://www.gov.scot/binaries/content/documents/govscot/publications/strategy-plan/2017/12/scottish-energy-strategy-future-energy-scotland-9781788515276/documents/00529523-pdf/00529523-pdf/govscot%3Adocument/00529523.pdf?forceDownload=true (accessed 18/3/2021)

[22] Scottish Government (2019) Climate Ready Scotland Scottish Climate Change Adaptation Programme 2019-2024 [online] Available at: https://www.gov.scot/publications/climate-ready-scotland-second-scottish-climate-change-adaptation-programme-2019-2024/ (accessed 04/02/2021)

[23] UK Government (2017) UK Climate Change Risk Assessment [online] Available at: https://www.gov.uk/government/publications/uk-climate-change-risk-assessment-2017(accessed 04/02/2021)

[24] Scottish Government (2020) Scottish Government Hydrogen Policy Statement [Online] Available at: https://www.gov.scot/publications/scottish-government-hydrogen-policy-statement/ (accessed on 05/02/2021)

- Commits £100 million funding towards the development of the hydrogen economy over the next five years (as it will be implemented through the Draft Hydrogen Action Plan which will be published in 2021).
- Confirms that both renewable and low-carbon hydrogen will play an increasingly important role in Scotland's energy transition to net zero in 2045 and the importance of establishing low-carbon hydrogen production at scale by the mid-2020s, linked to Carbon Capture and Storage (CCS).
- Sets out how Scotland's abundant natural resources, skills and supply chain offer the potential for large scale production of renewable hydrogen from offshore wind to be a key driver of the longer-term hydrogen economy in Scotland;
- Supports the demonstration, development and deployment of hydrogen and its emergent role in the sustainable decarbonisation of critical industry functions and processes, transport and heat in buildings;
- Commits to drive technological progress and advance innovation by unlocking public and private funds for innovation development, and support demonstration for key hydrogen technologies, such as fuel cells and electrolysers;
- Recognises the need for pace – the need to start now and grow quickly to capitalise on opportunities within the domestic and global hydrogen market;
- Commits to actively seek international collaboration in the development of Scotland's shared hydrogen economy and fully explore the hydrogen export potential;
- Supports the transition and growth of Scotland's existing supply chain, including in the development of skills and manufacturing capacity, that can play a significant role in the hydrogen economy both domestically and internationally;
- Commits to exploring the opportunities for negative carbon hydrogen, combining the potential to use bioenergy resources to produce hydrogen with CCS; and
- Commits to engage with the UK Government on the development of a UK policy and regulatory framework for hydrogen, business models, market mechanisms, carbon pricing, feed in tariffs, fuel economy standards, renewable fuel standards and zero emission vehicle mandates – all of which are important for raising market certainty and investor confidence.

4.13 The *Scottish Hydrogen Assessment*[25] informed the development of future Scottish decarbonisation policy, including the *Hydrogen Policy Statement*[26] and the Draft Hydrogen Action Plan. This assessment investigated how and where hydrogen may fit within the evolving energy system technically, geographically and economically. Key findings include:

- Renewable hydrogen is likely to feature in some capacity in Scotland's energy economy and its role will likely grow in the long term;
- Scotland could become a large-scale producer of renewable hydrogen for export, most likely for Europe;
- Hydrogen is an opportunity for rural areas and islands to harness their renewable energy sources;
- Low-carbon hydrogen could be an important part of Scotland's future in the short to medium term;
- There are low regret options for building hydrogen demand in the short to medium term, especially fleet vehicles. This can be led by buses, but also includes HGVs, non-electrified rail and water transport;
- Hydrogen is a good option for industrial applications;
- There are decisions to be made as to whether hydrogen should be used in the gas distribution network. Hydrogen is a potential option but there are other options, electrification, district heating and CCUS (for industry);
- Hydrogen production, either low-carbon or green, could bring significant economic value and jobs to Scotland particularly if more of the supply chain could be captured within Scotland; and
- There is a complex regulatory framework, and a lack of clarity of roles in some areas.

4.14 The Hydrogen Policy Statement and Draft Hydrogen Action Plan are also informed by the *Scottish Offshore Wind to Green Hydrogen Opportunity Assessment*[27]. The assessment concluded that:

[25] Scottish Government (2020) Scottish Hydrogen: Assessment Report [online] Available at: https://www.gov.scot/publications/scottish-hydrogen-assessment-report/ (accessed 05/02/2021)
[26] Scottish Government (2020) Scottish Government Hydrogen Policy Statement [Online] Available at: https://www.gov.scot/publications/scottish-government-hydrogen-policy-statement/ (accessed on 05/02/2021)

[27] Scottish Government (2020) Scottish Offshore Wind to Green Hydrogen Opportunity Assessment [online] Available at: https://www.gov.scot/publications/scottish-offshore-wind-green-hydrogen-opportunity-assessment/#:~:text=Summary%20of%20Key%20Findings,in%20our%20net%20zero%20transition.&text=Falling%20wind%20and%20electrolyser%20costs,and%20heat%20sectors%20by%202032. (accessed 05/02/2021)

- Scotland's abundant offshore wind can be used to produce renewable hydrogen and help abate emissions of historically challenging sectors such as heating, transport and industry;
- The production of renewable hydrogen from offshore wind can help overcome Scotland's grid constraints and unlock a massive clean power generation resource, creating a clean fuel for Scottish industry and households and a highly valuable commodity to supply rapidly growing UK and European markets;
- The primary export markets for Scottish renewable hydrogen are expected to be in Northern Europe (Germany, the Netherlands and Belgium). Strong competition to supply these markets is expected to come from renewable hydrogen produced from solar energy in Southern Europe and North Africa;
- It is predicted that falling wind and electrolyser costs will enable renewable hydrogen production to be cost-competitive in the key transport and heat sectors by 2032. Strategic investment in hydrogen transportation and storage is essential to unlocking the economic opportunity for Scotland;
- Scotland has extensive port and pipeline infrastructure that can be repurposed for hydrogen export to the rest of UK and to Europe;
- There is considerable hydrogen supply chain overlap with elements of parallel sectors, most notably, the oil and gas, offshore wind and subsea engineering sectors. Scotland already has a mature hydrocarbon supply chain which is engaged in supporting renewable hydrogen;
- There are gaps in the Scottish supply chain in the areas of design, manufacture and maintenance of hydrogen production, storage and transportation systems. Support, including apprenticeships, will be needed to develop indigenous skills and capabilities in these areas; and
- The development of renewable hydrogen from offshore wind has the potential to create high value jobs, a significant proportion which are likely to be in remote, rural/coastal communities located close to offshore wind resources.

4.15 *Deep decarbonisation pathways for Scottish industries*[28] research report explores pathways to deeply cut emissions from Scotland's industrial subsectors by improving energy efficiency, replacing fossil fuels with hydrogen, electricity or in limited cases bioenergy, and implementing carbon capture, utilisation and storage. It explores the rate of emissions savings for each pathway and the relative costs.

4.16 The *Heat in Buildings Strategy*[29] supports the path to net zero emissions heating in Scotland. This includes energy efficiency, low and zero emissions heating, using existing technologies of heat pumps and heat networks and hydrogen for heat.

4.17 At the Paris Climate Conference (COP 21) in December 2015, 195 countries adopted the first ever universal, legally binding global climate deal. The *Paris Agreement* is a bridge between today's policies and climate-neutrality before the end of the century. The agreement sets out a global action plan to put the world on track to avoid dangerous climate change by limiting global warming to well below 2ºC[30]. The deal also states that countries should aim for the even more ambitious target of 1.5ºC[31]. A number of other agreements were reached on key issues such as mitigation through reducing emissions, adaptation and loss and damage[32]. The Agreement entered into force on 4th November 2016[33].

4.18 Scotland's contribution to the Paris Agreement: Indicative Nationally Determined Contribution[34] draws together Scotland's ambitious policy framework and commitments to climate change action. This indicative Nationally Determined Contribution (iNDC) sets out Scotland's approach to tackling climate change, including a distinct framework of statutory emissions reduction targets, and a focus on the necessity and opportunities of a just transition to net-zero emissions that creates green jobs, tackles inequalities and nurtures wellbeing. In this, Scotland recognises climate change as a human rights issue and action on climate change to be fundamentally important to the future prosperity of Scotland's people and the planet.

[28] Element Energy (2020) Deep Decarbonisation pathways for Scottish Industries. Scottish Government. [online] Available at: https://www.gov.scot/publications/deep-decarbonisation-pathways-scottish-industries/ (accessed 18/3/2021)
[29] Scottish Government (2021) Heat in Buildings Strategy: Achieving Net Zero Emissions in Scotland's Building [online] Available at: https://www.gov.scot/publications/heat-buildings-strategy-achieving-net-zero-emissions-scotlands-buildings/
[30] UNFCC (2016) The Paris Agreement [online] Available at: http://unfccc.int/paris_agreement/items/9485.php (accessed 04/02/2021)
[31] Ibid.
[32] Ibid.
[33] Ibid.
[34] Scottish Government (2021) Scotland's contribution to the Paris Agreement: indicative Nationally Determined Contribution. [online] Available at: https://www.gov.scot/publications/scotlands-contribution-paris-agreement-indicative-ndc/

4.19 The UK Hydrogen Strategy[35] is the first of its kind and outlines:

- how the UK will rapidly and significantly scale up production and lay the foundations for a low carbon hydrogen economy by 2030.
- how government will support innovation and stimulate investment in the 2020s to scale up low carbon hydrogen.

4.20 The Strategy details how the UK government will look to capture the economic benefits of growing the UK hydrogen economy, supporting innovation and stimulating investment to develop the supply chains and skills needed and create jobs and export opportunities for the UK.

4.21 It also sets out a twin-track approach to supporting both electrolytic 'green' and carbon capture (CCUS) - enabled 'low-carbon' hydrogen production, alongside other potential production routes, which will enable the rapid growth of the sector while bringing down costs. The strategy also outlines a comprehensive roadmap for the development of the wider hydrogen economy over the 2020s to deliver the 2030 5GW ambition.

4.22 The 2021 *IPCC Assessment Report*[36] is the sixth in a series of reports which assess scientific, technical, and socio-economic information concerning climate change. The Working Group I contribution to the Sixth Assessment Report addresses the most up-to-date physical understanding of the climate system and climate change, bringing together the latest advances in climate science, and combining multiple lines of evidence from paleoclimate, observations, process understanding, and global and regional climate simulations.

4.23 A total of 234 scientists from 66 countries contributed to the first of three working group reports. Working group 1 (WGI) published The Physical Science Basis of Climate Change. The report's authors built on more than 14,000 scientific papers to produce the report, which was then approved by 195 governments. According to the report, it is only possible to avoid warming of 1.5 °C or 2 °C if massive and immediate cuts in greenhouse gas emissions are made.

Biodiversity, Flora and Fauna

4.24 Environmental protection objectives for biodiversity, flora and fauna are largely aimed at protecting habitats and species from damage and disturbance; principally through the identification and conservation of areas of particular value. The policies define a hierarchy of protection and include a range of international conventions, including the development of the *Aichi Targets for 2020*[37] and the *Convention on Biological Diversity*[38].

4.25 Special Areas of Conservation (SACs) and Special Protection Areas (SPAs), were developed under the European Commission 'Habitats Directive' (Directive 92/43/EEC)[39] and the 'Birds Directive' (Directive 79/409/EEC)[40]. SACs are strictly protected sites designated under the Directive 92/43/EEC (the 'Habitats Directive') and form a European network of important, high quality conservation sites. The Conservation (Natural Habitats, &c.) (EU Exit) (Scotland) (Amendment) Regulations 2019 amended the Conservation (Natural Habitats, &c.) Regulations 1994 to ensure these designations continue to operate effectively following the UK's withdrawal from the EU. (The 1994 Regulations as amended therefore maintains the statutory protection these areas and species are provided). The majority of SPAs and SACs are also underpinned by SSSI legislation[41].

4.26 The designation of European protected species and identification of species and habitats as being the most threatened and requiring conservation action in the UK also demonstrates the prioritisation of conservation ambitions at European and national levels. *UK Biodiversity Action Plan,*[42] succeeded by the *UK Post 2010 Biodiversity Framework*[43] is a response to Article 6 of the Biodiversity Convention. It is a national strategy for the conservation of biological diversity, the sustainable use of biological resources and to contribute to

[35] HM Government (2021) UK Hydrogen Strategy [pdf] Available online: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1011283/UK-Hydrogen-Strategy_web.pdf
[36] IPCC (2021) IPCC Sixth Assessment Report [pdf] Available at: https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Full_Report.pdf
[37] Convention on Biological Diversity (2011) Aichi Biodiversity Targets [online] Available at: https://www.cbd.int/sp/targets/default.shtml (accessed 04/02/2021)
[38] Convention on Biological Diversity (1993) Text of the CBD [online] Available at: https://www.cbd.int/convention/text/ (accessed 04/02/2021)
[39] European Commission, The Habitats Directive [online] Available at: http://ec.europa.eu/environment/nature/legislation/habitatsdirective/index_en.htm (accessed 04/02/2021)
[40] European Commission, The Birds Directive [online] Available at: http://ec.europa.eu/environment/nature/legislation/birdsdirective/index_en.htm (accessed 04/02/2021)
[41] Scottish Government (undated) Natura 2000 [online] Available at: https://www.gov.scot/policies/biodiversity/natura-2000/ (accessed 04/02/2021)
[42] UK Government (1994) Biodiversity: The UK Action Plan [online] Available at: http://data.jncc.gov.uk/data/cb0ef1c9-2325-4d17-9f87-a5c84fe400bd/UKBAP-BiodiversityActionPlan-1994.pdf (accessed 04/02/2021)
[43] JNCC and Defra on behalf of the Four Countries' Biodiversity Group (2012) UK Post-2010 Biodiversity Framework [online] Available at: https://hub.jncc.gov.uk/assets/587024ff-864f-4d1d-a669-f38cb448abdc#UK-Post2010-Biodiversity-Framework-2012.pdf (accessed 04/02/2021)

the conservation of global biodiversity through all appropriate mechanisms.

4.27 The *2020 Challenge for Scotland's Biodiversity*[44] is Scotland's response to the 20 Aichi Targets set by the United Nations Convention on Biological Diversity, and the *European Union's Biodiversity Strategy for 2020*[45]. The 2020 Challenge supplements the 2004 *Scottish Biodiversity Strategy*[46] and focuses on the importance of healthy ecosystems and an outcome that *"Scotland's ecosystems are restored to good ecological health so that they provide robust ecosystem services and build on our natural capital".*

4.28 Beyond site and species designations there are also longer-term aspirations for enhancing biodiversity, improving landscape-scale ecological networks and addressing the impacts of climate change on the natural environment.

Population and Human Health

4.29 Many existing environmental protection objectives are relevant to population and human health, either directly or indirectly. For example, the *Air Quality Standards (Scotland) Regulations 2010*[47], the *Air Quality (Scotland) Regulations 2000*[48], the *Air Quality (Scotland) Amendment Regulations 2002*[49] and the *Air Quality (Scotland) Amendment Regulations 2016*[50] help set out current objectives and requirements for air quality with clear relevance for human health. Protection is also afforded through existing legislation against noise and vibration nuisance at the both the European level through the *Environmental Noise Directive (2002/49/EC)*[51] and the national level through regulations such as the *Environmental Noise (Scotland) Regulations 2006*[52].

4.30 The *Pollution Prevention and Control (Scotland) Regulations 2012*[53] (PPC Regulations) also seek to provide protection for human health. The PPC Regulations introduce a consistent and integrated approach to environmental protection to ensure that industrial activities that may have a significant impact on the environment are strictly regulated. The regulations were designed to eliminate or minimise emissions to air, water and land and extended pollution controls to previously unregulated sectors.

4.31 *Cleaner Air for Scotland 2 – Towards a Better Place for Everyone*[54] sets out the Scottish Government's air quality policy framework for the next five years. The document is shaped around ten general themes which arose from the Cleaner Air for Scotland review.

4.32 *Just Transition Commission: A National Mission for a fairer, greener Scotland*[55] started work in early 2019, with a remit to provide practical and affordable recommendations to Scottish Ministers. The report sets out some of the key challenges that need to be addressed to deliver a just transition in Scotland. It recommends practical steps that could be taken. Finally, the report looks ahead to the future of just transition in Scotland and consider what arrangements may be needed to maintain momentum behind this agenda.

4.33 *Just Transition: A Fairer, Greener Scotland – Scottish Government response to the report of the Just Transition Commission*[56] sets out a long-term vision for just transition

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[44] Scottish Government (2013) 2020 Challenge for Scotland's Biodiversity – A Strategy for the conservation and enhancement of biodiversity in Scotland [online] Available at: https://www.gov.scot/publications/2020-challenge-scotlands-biodiversity-strategy-conservation-enhancement-biodiversity-scotland/ (accessed 04/02/2021)

[45]European Commission (2011) Our life insurance, our natural capital: an EU biodiversity strategy to 2020 [online] Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52011DC0244&from=EN

[46] Scottish Government (2004) Scottish Biodiversity Strategy – It's in your hands [online] Available at: https://www.gov.scot/publications/scotlands-biodiversity---its-in-your-hands/ (accessed 04/02/2021)

[47] The Air Quality Standards (Scotland) Regulations 2010 [online] Available at: http://www.legislation.gov.uk/ssi/2010/204/contents/made (accessed 04/02/2021)

[48] Scottish Government (2000) The Air Quality (Scotland) Regulations 2000 [online] Available at: http://www.legislation.gov.uk/ssi/2000/97/made (accessed 04/02/2021)

[49] Scottish Government (2002) The Air Quality (Scotland) Amendment Regulations 2002 [online] Available at: http://www.legislation.gov.uk/ssi/2002/297/introduction/made (accessed 04/02/2021)

[50] The Air Quality (Scotland) Amendment Regulations 2016 [online] Available at: http://www.legislation.gov.uk/sdsi/2016/9780111030837/contents (accessed 04/02/2021)

[51] Environmental Noise Directive 2002/49/EC [online] Available at: http://ec.europa.eu/environment/noise/directive_en.htm (accessed 04/02/2021)

[52] Environmental Noise (Scotland) Regulations 2006 [online] Available at: http://www.legislation.gov.uk/ssi/2006/465/made (accessed 04/02/2021)

[53] The Pollution and Prevention Control (Scotland) Regulations 2012 [online] Available at: http://www.legislation.gov.uk/ssi/2012/360/contents/made(accessed 04/02/2021)

[54] Scottish Government (2021) Cleaner Air for Scotland – Towards a Better Place for Everyone [online] Available at: https://www.gov.scot/binaries/content/documents/govscot/publications/strategy-plan/2021/07/cleaner-air-scotland-2-towards-better-place-everyone/documents/cleaner-air-scotland-2-towards-better-place-everyone/cleaner-air-scotland-2-towards-better-place-everyone/govscot%3Adocument/cleaner-air-scotland-2-towards-better-place-everyone.pdf (accessed 01/10/2021)

[55] Scottish Government (2021) Just Transition Commission: A National Mission for a fairer, greener Scotland [online] Available at: https://www.gov.scot/publications/transition-commission-national-mission-fairer-greener-scotland/

[56] Scottish Government (2021) Just Transition - A Fairer, Greener Scotland: Scottish Government response [online] Available at:

and provides details on the National Just Transition Planning Framework. It also outlines how Government will be held accountable on the delivery of just transition.

Soil and Geology

4.34 The importance of soil as a resource is recognised internationally through the *European Commission's Thematic Strategy for Soil Protection*[57]. Nationally, the protection of prime quality agricultural land and peatlands is set out in the *Scottish Soil Framework*[58], *Scotland's National Peatland Plan*[59] and the *Scottish Government's Draft Peatland and Energy Policy Statement*[60].

4.35 Geological sites receive protection through the designation of geological Sites of Special Scientific Interest (SSSIs) at the national level and at the international recognition through establishment of a network of Geoparks.[61]

Water

4.36 The condition of all Scottish water bodies is implemented by the Water Environment and Water Services (Scotland) Act 2003 as amended by the Environment (EU Exit) (Scotland) (Amendment etc.) Regulations 2019 and reflecting the original Water Framework Directive requirements, as part of retained EU Law. The legislation governs objectives for rivers, lochs, transitional waters, coastal waters and groundwater resources. The Water Framework Directive requires assessment of both chemical and ecological status, alongside the requirement to consider the status of biodiversity as an indicator in determining water quality. The Water Environment (Controlled Activities) (Scotland) Regulations 2011, The Water Environment (River Basin Management Planning: Further Provision) (Scotland) Regulations 2013, and The Pollution Prevention and Control (Scotland) Regulations 2012 were all amended by the Environment (EU Exit) (Scotland) (Amendment etc.) Regulations 2019 to ensure they retained effect post the UKs exist from the EU. These regulations collectively aim to improve the overall condition of water bodies and control pollution relating to industry discharges.

4.37 Objectives relating to the condition of all water bodies are set through the *Water Framework Directive*[62], which governs objectives for rivers, lochs, transitional waters, coastal waters and groundwater resources. The Water Framework Directive sets out the requirement for an assessment of both chemical and ecological status, alongside the requirement to consider the status of biodiversity as an indicator in determining water quality. The Environment (EU Exit) (Scotland) (Amendment etc.) Regulations 2019[63] amend the Water Environment and Water Services (Scotland) Act 2003, The Water Environment (Controlled Activities) (Scotland) Regulations 2011, The Water Environment (River Basin Management Planning: Further Provision) (Scotland) Regulations 2013, and The Pollution Prevention and Control (Scotland) Regulations 2012. These regulations aim to improve the overall condition of water bodies and control pollution relating to industry discharges.

4.38 The *Flood Risk Management (Scotland) Act 2009*[64] provides for the management of flood risk and translates the *EU Floods Directive*[65] into the national context. The Directive mandates the creation of Flood Risk Management Plans (FRMPs) for all inland and coastal areas at risk of flooding, integrating their development and employment with existing RBMPs.

4.39 *Scotland's National Marine Plan*[66] covers the management of both Scottish inshore waters (out to 12 nautical miles) and offshore waters (12 to 200 nautical miles). The plan provides direction to a wide range of marine decisions and consents made by public bodies and seeks to promote development that is compatible with the protection and enhancement of the marine environment.

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https://www.gov.scot/publications/transition-fairer-greener-scotland/documents/ (accessed 14/10/2021)

[57] European Commission (2015) Soil, The Soil Thematic Strategy [online] Available at: http://ec.europa.eu/environment/soil/three_en.htm (accessed 04/02/2021)

[58] The Scottish Government (2009) The Scottish Soil Framework [online] Available at: https://www.gov.scot/publications/scottish-soil-framework/ (accessed 04/02/2021)

[59] SNH (2015) Scotland's National Peatland Plan, Working for our Future [online] Available at: https://www.nature.scot/scotlands-national-peatland-plan-working-our-future (accessed 04/02/2021)

[60] The Scottish Government (2017) Draft Peatland and Energy Policy Statement [online] Available at: http://www.gov.scot/Resource/0050/00502389.pdf (accessed 04/02/2021)

[61] SNH (undated) Geoparks [online] Available at: https://www.nature.scot/professional-advice/safeguarding-protected-areas-and-species/protected-areas/international-designations/geopark (accessed 04/02/2021)

[62] European Commission (2000) The Water Framework Directive [online] Available at: http://eur-lex.europa.eu/resource.html?uri=cellar:5c835afb-2ec6-4577-bdf8-756d3d694eeb.0004.02/DOC_1&format=PDF (accessed 04/02/2021)

[63] https://www.legislation.gov.uk/ssi/2019/26/made

[64] The Flood Risk Management (Scotland) Act 2009 [online] Available at: http://www.legislation.gov.uk/asp/2009/6/contents (accessed 04/02/2021)

[65] European Commission, Directive 2007/60/EC of 23 October 2007 on the Assessment and Management of Flood Risks [online] Available at: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32007L0060&from=EN (accessed 04/02/2021)

[66] Scottish Government (2015) Scotland's National Marine Plan [online] Available at: https://www.gov.scot/publications/scotlands-national-marine-plan/ (accessed 04/02/2021)

Air

4.40 Scotland's air quality environmental protection objectives are largely derived from the *EC Air Quality Directive* (2008/50/EC)[67] and the *4th Air Quality Daughter Directive* (2004/107/EC)[68], via the *Air Quality Standards (Scotland) Regulations 2010*[69] which transpose these Directives into the Scottish context. The Scottish Government will ensure that EU standards and principles relating to emissions of air pollutants continue to apply in Scotland following the UK's exit from the EU.

4.41 The Air Quality (Amendment etc.) (EU Exit) (No. 1) Regulations 2018 contain amendments to directly applicable EU legislation. The Air Quality (Amendments) (EU Exit) (No. 2) Regulations 2018 contain amendments to EU-derived domestic legislation. There are also domestic objectives as part of the Local Air Quality Management system set under the *Environment Act 1995*[70] and associated regulations[71]. Scotland's *PPC Regulations* (2012)[72] allow for the regulation and monitoring of certain industrial activities that can generate airborne pollution. Together, they set a requirement for monitoring air quality with a particular focus on areas where air pollution is concentrated and seek to identify the sources.

4.42 These objectives are largely aimed at reducing air emissions that are potentially harmful to human health and the environment, and together they set out the requirement for monitoring with a particular focus on areas where air pollution is concentrated.

4.43 Air Quality Strategy for England, Scotland, Wales and Northern Ireland[73] sets out long term air quality objectives and policy options to further improve air quality in the UK. The strategy focuses on tackling the key air pollutants to air in the UK which include Particulate Matter (PM-PM10 and PM2.5), oxides of nitrogen (NOx), Ozone, sulphur dioxide, polycyclic aromatics hydrocarbons (PAHs), benzene, 1,3 – butadiene, carbon monoxide, lead and ammonia. It sets out specific national objectives that consider European Directive limits and target values for protecting human health.

4.44 *Cleaner Air for Scotland 2 - Towards a Better Place for Everyone*[74] is the Scottish Governments new air quality strategy setting out how the Scottish Government will continue to deliver air quality improvements over the next five years. It supports Scotland's vision of having the best air quality in Europe. The actions set out in this strategy are built on the work of an independently-led review of Cleaner Air for Scotland completed in 2019.

4.45 The *Delivery Plan* for Cleaner Air for Scotland 2[75] is structured around 10 priorities which reflect the 10 high level themes from the independently led review of Cleaner Air for Scotland completed in 2019. These are:

1. Health
2. Integrated Policy
3. Placemaking
4. Data
5. Behaviour Change
6. Industrial Emissions Regulation
7. Tackling Non-Transport Emissions Sources
8. Transport
9. Governance, Accountability and Delivery
10. Further Progress Review

4.46 The delivery plan builds on the consultation exercise undertaken to inform CAFS 2, with its development continuing

[67] The European Parliament and the Council of the European Union (2008) Directive 2008/50/EC of the European Parliament and of the Council on ambient air quality and cleaner air for Europe [online] Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008L0050&from=en (accessed 04/02/2021)

[68] The European Parliament and the Council of European Union (2004) Directive 2004/107/EC of the European Parliament and of the Council relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air [online] Available at: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2005:023:0003:0016:EN:PDF (accessed 04/02/2021)

[69] The Air Quality Standards (Scotland) Regulations 2010 [online] Available at: http://www.legislation.gov.uk/ssi/2010/204/pdfs/ssi_20100204_en.pdf (accessed 04/02/2021)

[70] Environment Act 1995, c.25 [online] Available at: http://www.legislation.gov.uk/ukpga/1995/25/introduction (accessed 04/02/2021)

[71] Scottish Government (2016) Local Air Quality Management policy guidance [online] Available at: https://www.gov.scot/binaries/content/documents/govscot/publications/advice-and-guidance/2018/03/local-air-quality-management-policy-guidance-scotland/documents/00507617-pdf/00507617-pdf/govscot%3Adocument/00507617.pdf (accessed 04/02/2021)

[72] Scottish Parliament, The Pollution Prevention and Control (Scotland) Regulations 2012 [online] Available at: http://www.legislation.gov.uk/sdsi/2012/9780111018408/pdfs/sdsi_9780111018408_en.pdf (accessed 04/02/2021)

[73] DEFRA, Scottish Executive, Welsh Assembly Government and DENI (2007) The Air Quality Strategy for England, Scotland, Wales and Northern Ireland [online] Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/69336/pb12654-air-quality-strategy-vol1-070712.pdf (accessed 04/02/2021)

Chapter 1 [74] Scottish Government (2021) Cleaner Air for Scotland 2: delivery plan [online] Available at: https://www.gov.scot/publications/cleaner-air-scotland-2-delivery-plan/

[75] Scottish Government (2021) Cleaner Air for Scotland 2: delivery plan [online] Available at: https://www.gov.scot/publications/cleaner-air-scotland-2-delivery-plan/

to engage with a range of partners. The Plan outlines the Scottish governments priorities, outcomes and actions as well as delivery timescales. It encompasses actions being led or supported by the Scottish Environment Protection Agency (SEPA), Transport Scotland, NatureScot, Local Authorities and Health Protection Scotland.

Cultural Heritage and the Historic Environment

4.47 Existing cultural heritage objectives are set out in legislation including the Historic Environment (Amendment) Scotland Act 2011[76], Ancient Monuments and Archaeological Areas Act 1979 (as amended) [77] and Planning (Listed Buildings and Conservation Areas) (Scotland) Act 1997[78]. These objectives are focused primarily on the protection of valued sites and features, including townscapes (i.e., places, buildings and open spaces), buildings, archaeological sites, battlefields, wrecks and landscapes that have been recognised at the international, national and local levels through a hierarchy of designations.

4.48 Policies such as National Planning Framework (NPF3)[79] and Scottish Planning Policy (SPP)[80] aim to improve the quality of our settlements and built environment with a national level focus. These are complemented by the Historic Environment Strategy for Scotland (2014)[81] and the Historic Environment Scotland Policy Statement[82] which provide an overarching framework for historic environment policy in Scotland. Together, they emphasise the importance of preserving recognised sites, avoiding negative impacts on them and their wider setting, and contributing to their enhancement where appropriate. These key objectives also extend to taking into accounting of, and avoiding damage to or loss of, currently unknown archaeology.

Landscape and geodiversity

4.49 Environmental protection objectives reflect the importance of all landscapes and also the need to help to improve those that have become degraded. The *European Landscape Convention*[83] lays the foundation for these objectives[84].

4.50 The establishment of key national programmes including the National Scenic Areas Programme[85] demonstrate a continuing commitment to protect the special qualities of nationally important landscapes and seascapes. The protection and enhancement of Scotland's landscapes are set out at the national level in SPP and are also referenced in relation to several national developments and under a natural, resilient place in NPF3.

4.51 NatureScot Natural Heritage Futures[86] sets out guidelines for sustainable management and use of Scotland's nature and landscapes until 2025. It aims to ensure utilisation of an integrated approach to work with Scotland's nature and land and provides the basis for stakeholders' engagement. It consists of 21 documents that cover the whole of Scotland, as each of the areas has its own identity and distinct issues.

4.52 NatureScot Landscape Policy Framework[87] sets out to safeguard and enhance the distinct identity, the diverse character and the special qualities of Scotland's landscapes to ensure that in the future they will contribute to the quality of life. Its main priorities include promotion of the debate on Scotland's future landscapes, description of Scotland's

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[76] The Historic Environment (Amendment) Scotland Act 2011 [online] Available at: http://www.legislation.gov.uk/asp/2011/3/contents/enacted (accessed 04/02/2021)
[77] Ancient Monuments and Archaeological Areas Act 1979 (as amended) [online] Available at: http://www.legislation.gov.uk/ukpga/1979/46/pdfs/ukpga_19790046_en.pdf (accessed 04/02/2021)
[78] Planning (Listed Buildings and Conservation Areas) (Scotland) Act 1997 [online] Available at: http://www.legislation.gov.uk/ukpga/1997/9/contents (accessed 04/02/2021)
[79] The Scottish Government (2014) National Planning Framework 3 [online] Available at: http://www.gov.scot/Publications/2014/06/3539/0 (accessed 04/02/2021)
[80] The Scottish Government (2014) Scottish Planning Policy [online] Available at: http://www.gov.scot/Publications/2014/06/5823 (accessed 04/02/2021)
[81] Historic Environment Scotland (2014) Our Place in Time: The Historic Environment Strategy for Scotland [online] Available at: http://www.gov.scot/Resource/0044/00445046.pdf (accessed 04/02/2021)
[82] Historic Environment Scotland (2019) Historic Environment Scotland Policy Statement [online] Available at: https://www.historicenvironment.scot/advice-and-support/planning-and-guidance/legislation-and-guidance/historic-environment-scotland-policy-statement/ (accessed 04/02/2021)
[83] Council of Europe (2015) European Landscape Convention, ETS No. 176 [online] Available at: http://www.coe.int/en/web/conventions/full-list/-/conventions/treaty/176 (accessed 04/02/2021)
[84] EU exit has no direct impact on the European Landscape Convention, https://www.nature.scot/professional-advice/landscape/framework-landscape-policy/european-landscape-convention
[85] SNH (undated) National Scenic Areas [online] Available at: https://www.nature.scot/professional-advice/safeguarding-protected-areas-and-species/protected-areas/national-designations/national-scenic-areas (accessed04/02/2021)
[86] Scottish Natural Heritage (2002) Natural Heritage Futures: An Overview [online] Available at: https://www.nls.uk/e-monographs/2020/216666894.23.pdf (accessed 04/02/2021)
[87] Scottish Natural Heritage (2010) SNH's Landscape Policy Framework [online] Available at: https://www.nature.scot/sites/default/files/2019-10/Landscape%20Policy%20Framework%20-%20Policy%20Statement%20No.05-01.pdf (accessed 04/02/2021)

landscape resources, monitoring of change in Scotland's landscape, landscape planning and management and action for Scotland's special landscapes.

4.53 NatureScot has undertaken research to identify areas which are viewed as wildland[88]. This is based on four attributes: perceived naturalness of land cover; ruggedness of the terrain; remoteness from public roads or ferries; and lack of buildings, roads, pylons and modern artefacts. Areas with stronger wildland characteristics are more commonly found in the north and west, particularly areas of higher ground, although additional areas of wildland are present in other areas of Scotland[89].

Material Assets

4.54 While existing policies relating to energy, transportation and land use are wide-ranging, they largely share the aims of contributing to core planning objectives and supporting sustainable development, reducing GHG emissions, and making the best use of Scotland's resources and existing infrastructure.

4.55 There is a wealth of existing protection objectives and policy at the national and international levels relating to these broad topic areas. These include existing and forthcoming energy policy and climate change commitments in addition to current objectives and commitments set out in relevant policies.

4.56 The National Planning Framework 3 (NPF3)[90] is a long-term strategy for Scotland that identifies national developments and other strategically important development opportunities in Scotland. It sets out a vision for Scotland to be a successful and sustainable, low carbon, natural and resilient and a connected place. This is reflected in the Fourth National Planning Framework Position Statement[91]. *Scottish Planning Policy (SPP)*[92] sets out national planning policies. It promotes the consistency in application of policies across Scotland and it relates to the preparation of development plans, the design of development, and the determination of planning applications and appeals. Scotland's fourth National Planning Framework is currently in preparation.

4.57 Scotland's National Transport Strategy 2[93] considers the whole transport system including walking, wheeling, cycling, travelling by bus, train, ferry, car, lorry and aeroplanes. It supports the switch to low emission vehicles such as those powered by hydrogen fuel cells, and supports low carbon public transport including rail, busses and ferries. The Strategy sets out the strategic framework within which future decisions on investment will be made.

4.58 The Infrastructure Investment Plan 2015[94] sets out priorities for investment and a long-term strategy for the development of public infrastructure in Scotland. It sets out why the Scottish Government invests, how it invests and what it plans to invest in.

4.59 Getting the Best from Our Land: A Land Use Strategy for Scotland 2021-2026[95] builds on the framework set out in 2011 in Scotland's first Land Use Strategy from 2011. The overall aim of this strategy is to continue use Scotland's land with long term objectives in mind and in a well-integrated and sustainable manner. In addition, this strategy focuses on the five-year period (2021 – 2026) and represents a programme of action supported by a suite of policies and proposals.

4.60 Energy Efficient Scotland: Route Map[96] focuses on improving the energy efficiency of Scotland's existing buildings and supporting the deployment of low carbon heat options to achieve the targets of the Climate Change Plan 2018.

4.61 The Scottish Energy Strategy: The future of energy in Scotland[97] guides energy related decisions of the Scottish Government. It directly builds on the Heat Policy Statement of 2015, and it continues to focus on energy and electricity. However, this strategy takes a whole-system view and also includes heat and transport sectors. This is supported by

[88] SNH (undated) Landscape Policy: Mountains [online] Available at: https://www.nature.scot/professional-advice/landscape/landscape-policy-and-guidance/landscape-policy-wild-land (accessed 04/02/2021)
[89] Ibid
[90] Scottish Government (2014) National Planning Framework 3 [online] Available at: http://www.gov.scot/Publications/2014/06/3539/0 (accessed 10/02/2021)
[91] Scottish Government (2020) Scotland's Fourth National Planning Framework Position Statement [online] Available at: https://www.gov.scot/publications/scotlands-fourth-national-planning-framework-position-statement/documents/ (accessed 28/10/2021)
[92] Scottish Government (2016) Scottish Planning Policy [online] Available at: http://www.gov.scot/Publications/2014/06/5823 (accessed 10/02/2021)
[93] Scottish Government (2020) National Transport Strategy 2, Protecting our Climate and Improving Lives [online] Available at: https://www.transport.gov.scot/media/47052/national-transport-strategy.pdf(accessed 10/02/2021)
[94] Scottish Government (2015) Infrastructure Investment Plan [online] Available at: https://www.gov.scot/publications/infrastructure-investment-plan-2015/ (accessed 10/02/2021)
[95] Scottish Government (2021) Land use - getting the best from our land: strategy 2021 to 2026 [online] Available at: https://www.gov.scot/publications/scotlands-third-land-use-strategy-2021-2026-getting-best-land/
[96] Scottish Government (2018) Energy Efficient Scotland: route map [online] Available at: https://www.gov.scot/publications/energy-efficient-scotland-route-map/ (accessed 10/02/2021)
[97] Scottish Government (2017) Scottish Energy Strategy: The future of energy in Scotland [online] Available at: https://www.gov.scot/publications/scottish-energy-strategy-future-energy-scotland-9781788515276/ (accessed 10/02/2021)

Scotland's Energy Strategy Position Statement[98] which sets out key priorities for the short to medium-term, including the development of a hydrogen economy.

4.62 Heat Policy Statement[99] - A key objective of the statement is to support heat decarbonisation of homes and buildings in Scotland, including the scaling up and acceleration of existing work with the aim to reduce emissions from heating our homes and buildings to levels compatible with net zero by 2045, in line with advice from the Committee on Climate Change and the targets in the 2019 Act.

4.63 Heat in Buildings Strategy: Achieving Net Zero Emissions in Scotland's Buildings[100] builds on the Heat Policy Statement[101] and sets out how the ambition for net zero by 2045 will be achieved, in relation to heating buildings. Key targets include reducing emissions from buildings by 68% by 2030 (compared to 2020), increasing the deployment of heat networks, and requiring 22% of heat in buildings to be supplied by renewable sources by 2030.

4.64 Making Things Last: A Circular Economy Strategy for Scotland[102] sets out priorities for moving towards a more circular economy with a long-term ambition. It articulates Scotland's aspirations and proposes a number of actions to take over the short to medium term and creates conditions for long term change. This strategy builds on the Zero Waste Plan (2010)[103] and the Safeguarding Scotland's Resources (2013)[104]

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[98] Scottish Government (2021) Scotland's Energy Strategy Position Statement [online] Available at: https://www.gov.scot/binaries/content/documents/govscot/publications/strategy-plan/2021/03/scotlands-energy-strategy-position-statement/documents/scotlands-energy-strategy-position-statement/scotlands-energy-strategy-position-statement/govscot%3Adocument/scotlands-energy-strategy-position-statement.pdf [Accessed 17/3/2021]
[99] Scottish Government (2015) Heat Policy Statement [online] Available at: https://www.gov.scot/binaries/content/documents/govscot/publications/speech-statement/2015/06/heat-policy-statement-towards-decarbonising-heat-maximising-opportunities-scotland/documents/00478997-pdf/00478997-pdf/govscot%3Adocument/00478997.pdf (accessed 10/02/2021)
[100] https://www.gov.scot/publications/heat-buildings-strategy-achieving-net-zero-emissions-scotlands-buildings/documents/
[101] Scottish Government (2015) Heat Policy Statement [online] Available at: https://www.gov.scot/binaries/content/documents/govscot/publications/speech-statement/2015/06/heat-policy-statement-towards-decarbonising-heat-maximising-opportunities-scotland/documents/00478997-pdf/00478997-pdf/govscot%3Adocument/00478997.pdf (accessed 10/02/2021)
[102] Scottish Government (2016) Making Things Last: A Circular Economy Strategy for Scotland [online] Available at: 5 http://www.gov.scot/Resource/0049/00494471.pdf (accessed 12/02/2021)
[103] Scottish Government (2010) Zero Waste Plan [online] Available at: https://www.gov.scot/publications/scotlands-zero-waste-plan/ (accessed12/02/2021)
[104] Scottish Government (2013) Safeguarding Scotland's Resources: blueprint for a more resource efficient and circular economy [online] Available at: https://www.gov.scot/publications/safeguarding-scotlands-resources-blueprint-more-resource-efficient-circular-economy/ (accessed 12/02/2021)

Chapter 5
Environmental Baseline

Introduction

5.1 Schedule 3 of the 2005 Act requires information to be provided on:

> (2) The relevant aspects of the current state of the environment and the likely evolution thereof without implementation of the plan or programme.
>
> (3) The environmental characteristics of areas likely to be significantly affected.
>
> (4) Any existing environmental problems which are relevant to the plan or programme including, in particular, those relating to any areas of a particular environmental importance, such as areas designated pursuant to Council Directives 79/409/EEC on the conservation of wild birds and Council Directive 92/43/EEC on the conservation of natural habitats and of wild flora and fauna (as last amended by Council Directive 97/62/EC).

5.2 The Draft Hydrogen Action Plan has been assessed against this baseline to provide an indication of the type and significance of any environmental effects that could arise.

Environmental effects of hydrogen manufacturing, storage, transportation and deployment

5.3 In order to provide context for the environmental effects of hydrogen, the following paragraphs provide baseline information in relation to hydrogen manufacturing, storage, transportation and deployment. This is followed by baseline information for each of the SEA topics.

Manufacturing

5.4 Whilst hydrogen is considered to be a clean fuel, manufacturing hydrogen can be energy intensive. There are several types of hydrogen including grey hydrogen[105]; low-carbon hydrogen; renewable hydrogen[106]; and numerous

[105] Hydrogen produced from fossil fuels without carbon capture.

[106] Hydrogen produced from renewable energy sources such as wind energy or solar power.

other less common types including pink[107], and turquoise[108] hydrogen. However, for the purposes of this assessment, only renewable and low-carbon hydrogen are being considered. Furthermore, the focus of renewable hydrogen in the assessment is on using renewable wind energy, due to the abundance of the wind resource in Scotland.

5.5 Low-carbon hydrogen is produced when natural gas is split into hydrogen and CO_2 via Steam Methane Reforming (SMR) or Autothermal Reforming (ATR), with the majority of the CO_2 captured and stored through Carbon Capture Utilisation and Storage (CCUS). Production of low-carbon hydrogen is more expensive and requires more energy than grey hydrogen as there is an additional need to capture CO_2. The process is expected to get cheaper with mass deployment and increased CCUS. Low-carbon hydrogen has advantages in certain locations and regions, primarily due to the potential to store CO_2 in geological formations and presence of existing pipeline infrastructure. For this reason, Scotland, with its close proximity and links with the oil and gas industry in the North Sea is well placed for the manufacturing of low-carbon hydrogen.

5.6 CCUS is applied in either pre- or post-combustion phase. One of the most common and verified method for capturing carbon is to scrub the synthetic gas or stack discharge with an amine-based solvent. The carbon dioxide is adsorbed in the solvent, with a subsequent separation process of the carbon dioxide and the solvent, which is then recycled back to the scrubber. However, this process is not 100% efficient, and the solvent can degrade through oxidation, thermal degradation, chemical reactions or be lost through evaporation or carry-over with the cleaned flue gas. Some of the most common degradation products include ammonia, nitrosamines, nitramines, amides, aldehydes and volatile acids, with ammonia being the principal by product. Amine solvents used for CCUS have associated health effects and there is still some uncertainty as to how much risk to human health these pose. It is also understood that the highest risk associated with amine degradation happens during the post-combustion CCUS[109].

5.7 Renewable hydrogen is produced by splitting water (H_2O) by electrolysis. This process involves passing an electrical current through an electrolyser to split water into hydrogen and oxygen. There is no carbon involved in the process, and oxygen formed during the process is released into the atmosphere with no adverse effects. The electrical current is provided via renewable energy sources such as wind turbines. Scotland's extensive renewable energy resources make it well placed for the production of renewable hydrogen. Renewable hydrogen production is also expensive relative to its alternatives. Production costs are expected to reduce due to technological advancements and economies of scale driven by increasing production volumes.

Storage

5.8 The storage of hydrogen is challenging, being the lightest molecule, hydrogen gas has a very low density, and 1kg of hydrogen occupies 11m^3 at room temperature and atmospheric pressure. For the hydrogen storage to be economically viable, its storage density must be increased[110].

5.9 Large-scale storage of hydrogen is fundamental for a potential future of hydrogen economy[111]. There currently are four ways of storing hydrogen including geological storage, compressed hydrogen, liquified hydrogen and materials-based storage[112].

5.10 Storage of gaseous hydrogen in salt caverns is already used on an industrial scale, this approach is not applicable in all regions due to varied geological conditions[113]. Pure hydrogen is stored in salt caverns as a substance used in chemical and petrochemical industry. Such storage already exists in Teeside in the UK and two caverns in Texas in the USA[114].

[107] Hydrogen generated through electrolysis powered by nuclear energy
[108] Hydrogen produced from methane pyrolysis, uses methane as a feedstock but using heat from electricity.
[109] Air Quality consultants (2021) The Potential Wider Environmental Effects of Industrial Decarbonisation. [online] Available at: https://www.aqconsultants.co.uk/CMSPages/GetFile.aspx?guid=3912973e-c8f8-4334-b0f8-10823d2eb5d7 (accessed 31/08/2021)
[110] Andersson, J., Grönkvist S., (2019) Large-scale storage of hydrogen. International Journal of Hydrogen Energy. Vol. 44, Issue 23. [online] Available at: https://reader.elsevier.com/reader/sd/pii/S0360319919310195?token=DEBC997ED8406C9E6FBB2AFCAAC1F5115E7B085B0D442816B8274B784F1EC3F60EE2F00EFB7BE3B1028B18EEADC1EBFA&originRegion=eu-west-1&originCreation=20210423142222 (accessed 19/08/2021)
[111] Andersson, J., Grönkvist S., (2019) Large-scale storage of hydrogen. International Journal of Hydrogen Energy. Vol. 44, Issue 23. [online] Available at: https://reader.elsevier.com/reader/sd/pii/S0360319919310195?token=DEBC997ED8406C9E6FBB2AFCAAC1F5115E7B085B0D442816B8274B784F1EC3F60EE2F00EFB7BE3B1028B18EEADC1EBFA&originRegion=eu-west-1&originCreation=20210423142222 (accessed 19/08/2021)
[112] Willige, A., (2020) 4 ways of storing hydrogen from renewable energy. Spectra. [online] Available at: https://spectra.mhi.com/4-ways-of-storing-hydrogen-from-renewable-energy (accessed 19/08/2021)
[113] Andersson, J., Grönkvist S., (2019) Large-scale storage of hydrogen. International Journal of Hydrogen Energy. Vol. 44, Issue 23. [online] Available at: https://reader.elsevier.com/reader/sd/pii/S0360319919310195?token=DEBC997ED8406C9E6FBB2AFCAAC1F5115E7B085B0D442816B8274B784F1EC3F60EE2F00EFB7BE3B1028B18EEADC1EBFA&originRegion=eu-west-1&originCreation=20210423142222 (accessed 19/08/2021)
[114] Lankof, L., Polański, K., Ślizowski, J., Tomaszewska, B., (2016) Possibility of Energy Storage in Salt Caverns. AGH Drilling Oil Gas. Vol. 33. Issue (2). [online] Available at:

5.11 The storage of pure hydrogen can be achieved in the gas or liquid phase. A compressed hydrogen gas storage system has two main components: the storage compartments and the compressors needed to achieve the storage pressure. Due to reasons of material properties and operating costs, large amounts of gaseous hydrogen are usually not stored at pressures exceeding 100 bar in aboveground vessels and 200 bar in underground storages. However, some sources identify that in certain conditions for smaller volumes hydrogen can be stored in higher pressures up to 700 bar[115]. As the storage pressures are limited, so are the achievable hydrogen storage densities: at 100 bar and 20 C, the density of hydrogen gas is approximately 7.8 kg/m^3. The low hydrogen density leads to large storage specific volumes, and, thus, high investment costs. However, a lower storage pressure demands less compression work and, thus, operating costs[116].

5.12 Liquified hydrogen can be stored in dewars or tanks, however it requires cryogenic temperatures of -252.8°C. As liquified hydrogen has a higher density (0.070 kg/L) compared to compressed hydrogen gas (0.030 kg/L) at 700 bar, liquid hydrogen tanks can store more hydrogen than their gaseous equivalent. However, due to the low temperatures required for storage, the energy demand for hydrogen liquefaction is high consuming 30% of the heating value of the hydrogen being liquefied[117]. This is in comparison to the 5-20% heating value for hydrogen gas compressed at 700 bar[118]. Additionally, some liquified hydrogen will be lost through evaporation, or "boil off", particularly when using small tanks with large surface-to-volume ratios[119].

5.13 Another way to store hydrogen is to produce ammonia. Ammonia produced by harvesting of renewable energy sources is carbon-free, has no direct GHG effect, and can be synthesized with an entirely carbon-free process from renewable power sources. There is an established and reliable existing infrastructure for both ammonia storage and distribution[120]. Ammonia could be considered preferable to liquid hydrogen as it is easier to store and transport, with temperature requirements of -33°C which are considerable higher than those required for liquified hydrogen. However, ammonia poses additional risks to air quality, human health and biodiversity.

5.14 Hydrogen can also be stored utilising Liquid Organic Hydrogen Carriers (LOHC) which are organic compounds that absorb or release hydrogen through chemical reactions, and therefore they can be used as storage media for hydrogen. This method makes use of existing infrastructure for liquid fuels and offers a way of on-board generation of electric energy in mobile applications[121].

Transportation

5.15 The existing natural gas network has the potential to transport and distribute hydrogen provided the injected fraction remains below 20% by volume, although estimates vary[122]. Additionally, there also is a project H100 underway that will demonstrate the safe, secure and reliable distribution of 100% hydrogen in gas network[123]. Scotland currently has 12,805 km of pipelines[124].The key limiting factors for using existing gas pipelines are gas quality standard and equipment compliance, pipeline integrity (failure, fire, and explosion) and end-user safety.

5.16 Other modes of transportation include via the road in cryogenic liquid tanker trucks or gaseous tube trailers, and also via rail or barge. Transport distance is an important consideration in the delivery of hydrogen; pipelines tend to be

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https://www.researchgate.net/publication/304245727_Possibility_of_Energy_Storage_in_Salt_Caverns (accessed 19/08/2021)

[115] Lloyd's Register (2017) Hydrogen – Safety Consideration and Future Regulations. [online] Available at: https://www.fch.europa.eu/sites/default/files/3.%20Joseph%20Morelos%20-%20H2Safety.pdf (accessed 19/08/2021)

[116] Andersson, J., Grönkvist S., (2019) Large-scale storage of hydrogen. International Journal of Hydrogen Energy. Vol. 44, Issue 23. [online] Available at: https://reader.elsevier.com/reader/sd/pii/S0360319919310195?token=DEBC997ED8406C9E6FBB2AFCAAC1F5115E7B085B0D442816B8274B784F1EC3F60EE2F00EFB7BE3B1028B18EEADC1EBFA&originRegion=eu-west-1&originCreation=20210423142222 (accessed 19/08/2021)

[117] Florida Solar Energy Center (undated) Hydrogen Basics – Liquid Storage. [online] Available at: http://www.fsec.ucf.edu/en/consumer/hydrogen/basics/storage-liquid.htm (accessed 19/08/2021)

[118] Rivard, E., Trudeau, M. and Zaghib, K., 2019. Hydrogen Storage for Mobility: A Review. Materials, 12(12).

[119] https://www.energy.gov/eere/fuelcells/liquid-hydrogen-delivery (accessed 19/08/2021)

[120] Valera-Medina, A., Xiao, H., Owne-Jones, M., David, W.I.F., Bowen, P.J. (2018) Ammonia for power. Progress in Energy and Combustion Science. [online] Available at: https://www.sciencedirect.com/science/article/pii/S0360128517302320 (accessed 19/08/2021)

[121] G. Sievi, D. Geburtig, T. Skeledzik, A. Bösmann, P. Preuster, O. Brummel, F. Waidhas, M. A. Montero, P. Khanipour, I. Katsounaros, J. Libuda, K. Mayrhofer and P. Wasserscheid (2019) Towards an efficient Liquid Organic Hydrogen Carrier fuel cell concept. Energy Environ. Sci. [online] Available at: https://ri.conicet.gov.ar/bitstream/handle/11336/109995/CONICET_Digital_Nro.c7125f7c-a350-4777-81ef-9dec98c22ccf_A.pdf?sequence=2&isAllowed=y (accessed 14/10/2021)

[122] Intergovernmental Panel on Climate Change (2018) Working Group 3 Chapter 7: Energy Systems. [online] Available at: https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_chapter7.pdf (accessed 19/08/2021)

[123] SGN Natural Gas (undated) H100 NIA [online] Available at: https://www.sgn.co.uk/about-us/future-of-gas/hydrogen/hydrogen-100 (accessed 14/10/2021)

[124] Scottish Government (2011) Scotland's Marine Atlas: Information for The National Marine Plan. [online] Available at: https://www.gov.scot/publications/scotlands-marine-atlas-information-national-marine-plan/pages/51/ (accessed 19/08/2021)

used over shorter delivery distances and at high flow rates, while batch delivery of liquid hydrogen for long distances[125]. Batch delivery of liquid hydrogen is more economical as liquid tanker trucks can hold much larger quantities of hydrogen than gaseous tube trailers[126]. Hydrogen transport by shipping is not yet widely established. However, there are projects underway that are looking at long distance transportation via pipeline within the UK and to Europe and a European Hydrogen Backbone in the longer term. Such approach could reduce transport emissions in the longer term[127].

Deployment

5.17 The deployment of hydrogen can provide a clean alternative to fossil fuels which can be utilised within the transport and industrial sectors. In addition, hydrogen can be used as an energy source for residential and other buildings and providing cleaner heating[128]. However, the Committee on Climate Change has suggested that although hydrogen energy system will be inevitable in energy transition to net-zero in the UK it will only be essential in specific sectors where electrification of the current systems is not possible, such as long-distance freight, shipping and heavy industry[129]**.** It is in these sectors where hydrogen offers the greatest potential to reduce emissions that would otherwise be difficult to address

5.18 Ammonia can be used directly as a marine fuel and is easier to store and transport due to higher temperature requirements compared to liquified hydrogen. It is expected that hydrogen derived ammonia, instead of pure hydrogen, will play a pivotal role in the shipping industry in the future. It is anticipated that the industry will adopt one or the other as a fuel source, but unlikely to be both. To facilitate this shift from fossil fuels, appropriate infrastructure will be required. It is uncertain if port infrastructure will be developed first, followed by marine vessels capable of being powered by hydrogen/ammonia, or if the port infrastructure will follow development of new vessels.

5.19 Hydrogen power can also be deployed in the transport sector via vehicles powered by fuel cells. Fuel cells are similar to batteries, however they generate electricity through an electrochemical reaction. A fuel cell consists of two electrodes, a negative (anode) and a positive (cathode), and an electrolyte membrane[130]. A catalyst splits the hydrogen molecules into electrons and protons at the anode site. The protons pass through the electrolyte membrane, while the electrons generate an electric current and excess heat by going through a circuit. The protons, electrons, and oxygen combine to produce water molecules at the cathode[131]. The electricity produced is then used to power the vehicle, with only water molecules produced as a by-product. Whilst fuel cells are primarily used for vehicles, (particularly larger vehicles less suited to battery propulsion) they can be manufactured to scale to provide energy (or back up power sources) for industrial applications.

5.20 In terms of air quality, fuel cell combustion is the cleanest combustion of hydrogen that is available. However, if hydrogen is combusted in different applications there is the potential for nitrogen oxides (NO_x) pollution. Therefore, it is important to understand the NO_x emissions from hydrogen combustion with a process and compare them to the amount of fossil fuel being displaced, and also consider whether a low-carbon alternative would reduce NO_x to a greater extent[132]. This is particularly important for difficult to decarbonise industries, buildings and transportation so that most effective solutions can be implemented.

Climatic Factors

Overview of Baseline

5.21 In October 2018, the Intergovernmental Panel on Climate Change published a report which predicts that the impacts and costs of global warming 1.5ºC above pre-industrial levels will be far greater than expected. It also highlights that the impacts will be much worse if global warming reaches 2ºC or more. Urgency for action is required as the report predicts such level of global warming can be reached within the next 11 years, and most certainly within 20

[125] Intergovernmental Panel on Climate Change (2018) Working Group 3 Chapter 7: Energy Systems. [online] Available at: https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_chapter7.pdf (accessed 19/08/2021)
[126] U.S. Department of Energy (undated) Liquid Hydrogen Delivery. [online] Available at: https://www.energy.gov/eere/fuelcells/liquid-hydrogen-delivery (accessed 19/08/2021)
[127] Gas for Climate (2021) Extending the European Hydrogen Backbone: A European Hydrogen Infrastructure Vision Covering 21 Countries [online] Available at: https://gasforclimate2050.eu/wp-content/uploads/2021/06/European-Hydrogen-Backbone_April-2021_V3.pdf (accessed 14/10/2021)
[128] Acar, C., Dincer, I. (2019) Review and evaluation of hydrogen production options for better environment. J. Clean. Prod. 218, 835 – 848. Available at: https://hydrogenfuelsystems.com.au/wp-content/uploads/2019/03/Review_and_evaluation_of_hydrogen_produc.pdf (accessed 19/08/2021)
[129] Evans, S. (2020) In-depth: Hydrogen 'required' to meet UK net-zero goal, says National Grid. Carbon Brief. [online] Available at: https://www.carbonbrief.org/in-depth-hydrogen-required-to-meet-uk-net-zero-goal-says-national-grid (accessed 19/08/2021)
[130] U.S. Department of Energy (undated) Fuel Cells. [online] Available at: https://www.energy.gov/eere/fuelcells/fuel-cells (accessed 19/08/2021)
[131] Fuell Cell & Hydrogen Energy Association (undated) Fuel Cell Basics. [online] Available at: https://www.fchea.org/fuelcells (accessed 19/08/2021)
[132] Committee on Climate Change (2018) Hydrogen in a low-carbon economy. [online] Available at: https://www.theccc.org.uk/wp-content/uploads/2018/11/Hydrogen-in-a-low-carbon-economy.pdf (accessed 20/08/2021)

years without major reductions in CO_2 emissions. The Scottish government has recognised a climate emergency and is acting accordingly.

5.22 In 2018, Scotland's total emissions of the seven GHG were estimated to be 41.6 $MtCO_2e$, an increase in source emissions of 1.5% from 2017[133]. The main contributors to this increase between 2017 and 2018 was a rise in Energy Supply emissions (0.8$MtCO_2e$, 13.4%) and it was driven almost entirely by increased emissions from power stations. A 45.4% reduction in estimated GHG emissions between 1990 and 2018 was also reported[134]. Decreases in emissions were from energy supply, land use, land use change and forestry, waste management, and business emissions (such as manufacturing). The largest factor slowing the overall reduction is transport (excluding international), as this sector was the largest contributor in 2018 with 12.9$MtCO_2e$, and it has only reduced emissions by 4.9% since 1990[135].

5.23 Land use, land use change and forestry (LULUCF) play a crucial role in removing CO_2 from the atmosphere by serving as a carbon stock in a form of forestland, cropland, grassland, wetlands, settlements and harvested wood products and rewetting soils and gaining soils organic matter. Climate change poses significant risks to peatlands, as with the warming climate half of the carbon currently stored in Scottish blanket bogs will be at risk of loss and additional emissions. This may significantly hamper efforts to meet emission reduction targets. LULUCF not only stores carbon, but it also has the ability to sequester it by forestry and grassland. Land changes for examples from a grassland to cropland or settlement lead to carbon losses and emissions[136].

5.24 In towns and cities, urban woodlands, forests and trees not only improve the general public realm but also deliver cooling, shade, better air quality and absorb CO_2 emissions.

Evolution of Baseline – Pressure, Trends and Key Points

Greenhouse Gas Emissions

5.25 In Scotland, greenhouse gas (GHG) emissions are the key driver for climate change. Major contributors to the GHG emissions include transport sector (excluding international aviation and shipping) (12.0 million tonnes of carbon dioxide equivalent (MtCO2e) – 25.1% of Scotland's total GHG emissions), business (7.9$MtCO_2e$), agriculture (7.5$MtCO_2e$), energy supply (6.4$MtCO_2e$) and the residential sector (6.2$MtCO_2e$). Aviation and shipping contributed a further 1.9$MTCO_2e$. Minor contributions were recorded for public sector buildings, waste management and industrial processes[137]. 70.2% of Scotland's GHG emissions in 2019 were in the form of carbon dioxide (CO_2). During 2019, CO_2 was the main greenhouse gas emitted or removed in most sectors, with the exceptions of the Agriculture, LULUCF and Waste Management sectors. Methane (followed by CO_2 and nitrous oxide) was the main gas emitted by the agriculture sector and almost all emissions emitted by the waste management sector were in the form of methane[138].

Transport

5.26 Transport emissions, including Scotland's share of international aviation and shipping, accounted for 35.6% (14.8 $MtCO_2e$) of Scotland's total emissions in 2018, a decrease of 1.1% on the previous year.[139] Road transport is by far the largest source of these emissions, accounting for 68% of all transport emissions. In 2018, cars alone accounted for nearly half of Scotland's transport sector emissions (39.3%) alongside HGVs (12.6%). International aviation and shipping emissions contributed around 31% of total transport emissions.[140]

5.27 2019 is the second year in a row that emissions have decreased in Scotland. They were 2.5% lower than in 2018, and 11.3% lower than in 1990[141]. These reductions are mainly due to improved car efficiency for given car classes and have been driven by EU standards and implemented by the UK[142]. However, emissions in 2019 are likely to have been impacted by the pandemic.

5.28 Road transport accounted for 10 $MtCO_2e$ in 2018. Car emissions were 5.8 $MtCO_2e$, which was a 1.3% decrease from 2017, and 0.5% above the 1990 baseline. Between 2017 and

[133] Scottish Government (2020) Scottish Greenhouse Gas Emissions 2018. [pdf] Available at: https://www.gov.scot/publications/scottish-greenhouse-gas-emissions-2018/ [Accessed on 04/02/2021]
[134] Ibid.
[135] Ibid.
[136] Committee on Climate Change (2013) Factsheet: Land Use, Land Use Change and Forestry [online] Available at: https://www.theccc.org.uk/wp-content/uploads/2013/03/LULUCF.pdf (accessed 04/02/2021)
[137] Scottish Government (2021) *Scottish Greenhouse Gas statistics: 1990-2019* [online] Available at: https://www.gov.scot/publications/scottish-greenhouse-gas-statistics-1990-2019/
[138] Ibid
[139] Transport Scotland (2020) Carbon Account for Transport No. 12: 2020 Edition [online] Available at: https://www.transport.gov.scot/media/48199/sct07209535161.pdf (accessed 01/02/2021)
[140] ibid
[141] Ibid.
[142] Committee on Climate change (2020) Reducing emissions in Scotland Progress Report to Parliament [online] Available at: https://www.theccc.org.uk/wp-content/uploads/2020/10/Reducing-emissions-in-Scotland-Progress-Report-to-Parliament-FINAL.pdf (accessed 03/02/2021)

2018 car kilometres increased by 0.6%.[143]. Emissions from shipping and aviation were 2.30 $MtCO_2e$ (15.5%) and 2.23 $MtCO_2e$ (15.1%) respectively, rail emissions were 0.16 $MtCO_2e$ (1.1%).[144].

5.29 Newly registered cars are becoming more efficient in terms of carbon dioxide emissions, with average CO_2 emissions in Scotland for new car registrations falling by 15% over the last ten years and decreasing by 2% compared to the previous year[145].

5.30 There has been a nine-fold increase in the uptake of ultra-low carbon vehicles between 2014 and 2018[146], and an 80% increase in new registrations in 2019 compared to 2018[147], however this currently represents a relatively small proportion of new car registrations. More than 98% of road vehicles in Scotland ran on petrol (50%) or diesel (48%) in 2019.[148] As of 2019, there were 56,722 kilometres of public road in Scotland. While road vehicles have become more fuel efficient, this has largely been offset by an increase in kilometres driven. Since 2011, vehicle kilometres have increased by 11% over the past nine years and road transport emissions by 7.5% over the same period[149].

5.31 Passenger journeys on Scotrail services decreased by 1.4% to 96.4 million in the 2019-20 financial year, an increase of 26% since 2008-09. The total route length of the railway network in Scotland is 2,758km which is serviced by 359 stations. Of this total, 893km are electrified. Bus use is generally higher in urban areas compared to rural, however, bus passenger journeys have generally been falling in the long-term[150].

5.32 A reported 29.4 million air terminal passengers travelled through Scottish airports in 2019, down 2% compared to the previous year, and 28% higher than 2009. Over the longer term, passenger numbers have generally been increasing. Edinburgh Airport had the highest number of terminal passengers in 2019, though Glasgow's share has decreased in the last 2 years. A number of smaller airports are also run by Local Authorities in Scotland, such as Oban Airport, and some of these provide connections to more remote areas[151].

5.33 Scotland's marine areas and coastal waters are utilised by a wide range of vessels and service a variety of industries. Ports and harbours are located all around the Scottish coastline. In addition to being an important means of distributing goods, the shipping sector also helps deliver lifeline ferry services which are vital to island communities. In 2019, 67 million tonnes of freight were handled by ports, accounting for roughly one quarter of Scotland's total freight tonnage. A total of 8.7 million passengers travelled on ferry routes within Scotland in 2019. Larger ports such as Cairnryan support ferry services between Scotland and Northern Ireland, with a further 1.8 million passengers travelling to Northern Ireland in 2018. The Forth (25 million tonnes), Clyde (9 million tonnes) and Glensanda (7 million tonnes) ports accounted for the highest freight traffic in 2019[152].

Energy use and storage

5.34 Energy storage is likely to be an increasingly important part of the transition to delivering clean, affordable and secure supplies of energy[153]. For example, the continued development of battery storage technologies and hydrogen fuel cells for vehicle use in the transport sector. The energy sector has seen large reductions in emissions from 22.7 $MtCO_2e$ in 1990 down to 6.4 $MtCO_2e$ in 2019 (71.8%)[154]. These reductions are mainly due to the complete cessation of coal use in electricity generation and reductions in emissions from power stations. Between 2018 and 2019 Energy Supply emissions decreased by 0.4 $MtCO_2e$ (6.1 per cent decrease). This decrease was driven by a decrease in CO_2 emissions from power stations[155].

5.35 Heating makes up approximately half of Scotland's energy consumption (50.3%) compared to transport (24.5%)

[143] Transport Scotland (2020) Carbon Account for Transport No. 12: 2020 Edition [online] Available at: https://www.transport.gov.scot/media/48199/sct07209535161.pdf
[144] Transport Scotland (2020) Carbon Account for Transport No. 12: 2020 Edition [online] Available at: https://www.transport.gov.scot/media/48199/sct07209535161.pdf (accessed 01/02/2021)
[145] Transport Scotland (2021) Scottish Transport Statistics No. 39 2020 edition [pdf] Available at: https://www.transport.gov.scot/media/49874/scottish-transport-statistics-2020-may-2021.pdf (accessed 30/08/2021)
[146] Transport Scotland (2018) Scottish Transport Statistics No. 37 2018 Edition [online] Available at: https://www.transport.gov.scot/publication/scottish-transport-statistics-no-37-2018-edition/chapter-4-road-network/ 9accessed 05/02/2021)
[147] Transport Scotland (2021) Scottish Transport Statistics No. 39 2020 edition [pdf] Available at: https://www.transport.gov.scot/media/49874/scottish-transport-statistics-2020-may-2021.pdf (accessed 30/08/2021)
[148] Transport Scotland (2021) Scottish Transport Statistics No. 39 2020 edition [pdf] Available at: https://www.transport.gov.scot/media/49874/scottish-transport-statistics-2020-may-2021.pdf (accessed 30/08/2021)
[149] Ibid
[150] Ibid
[151] Ibid
[152] ibid
[153] ClimateXChange (2016) Energy Storage in Scotland - Summary of reports on thermal and electrical energy storage [online] Available at: https://www.climatexchange.org.uk/media/1391/summary_energy_storage.pdf (accessed 01/02/2021)
[154] Scottish Government (2021) Scottish Greenhouse Gas Emissions 2019 [online] Available at: https://www.gov.scot/publications/scottish-greenhouse-gas-statistics-1990-2019/documents/ (accessed 30/08/2021)
[155] Ibid

and electricity (21.1%) making up approximately a quarter each[156]. A breakdown of electricity and heat consumption by sector shows that three-fifths of is accounted for by the industrial and commercial sectors and two-fifths consumed domestically. Energy consumption in industry makes up approximately a third of all Scottish consumption (48.0 TWh) and has decreased by 24.1% from the 2005-07 baseline, and 3.5% down on 2017[157]. Energy consumption in the domestic sector is next largest at 43.6 TWh, having decreased 17.2% from 2005-07. This may reflect improvements in energy efficiency in the domestic building stock in this time. Conversely, consumption in the commercial sector rose by 11.9% from the baseline to 17.1 TWh in 2018[158].

5.36 Provisional figures for 2018 indicate that 21.1% of total Scottish energy consumption came from renewable sources; the highest level to date, increasing from 19.2% in 2017. Renewable energy generated increased by almost 2,300 GWh between 2017 and 2018. This includes over 1,500 GWh extra renewable electricity generated thanks to an additional 1.0 GW installed capacity between 2017 and 2018, mainly from onshore and offshore wind. In 2019, the equivalent of 90.1% of gross electricity consumption was from renewable sources, rising from 76.7% in 2018. Much of this increase is due to wind; in this period there was an almost 1.0 GW increase in wind capacity.[159].

5.37 In 2020, 71% of all renewable electricity generated in Scotland was from wind[160]. Hydro is Scotland's second highest source of renewable generation, while solar capacity has increased rapidly in the first half of this decade[161]. Bioenergy and energy from waste accounts for 8.3% and whilst the current capacity of wave and tidal is considered to be relatively small, technology is developing[162].

5.38 As Scotland's energy mix changes over the next few years, the electricity transmission network (grid) that supports the balance between energy generation and demand will change significantly. Infrastructure will play a key role in ensuring security of supply and decarbonising our energy systems in the most cost effective, affordable way[163].

Business

5.39 Business was the second largest emitting sector in 2019 with 7.9 $MtCO_2e$, following the transport sector. This sector has seen a 4.6 $MtCO_2e$ (36.7 per cent) reduction in emissions between 1990 and 2019, much of this decrease is linked to a decline in emissions from manufacturing and the iron and steel industry in the 1990s. There has been a further smaller decrease between 2008 and 2009 (1.0 $MtCO_2e$ decrease) reflecting the recession. Between 2018 and 2019 there was a relatively large 0.6 $MtCO_2e$ decrease in business emissions[164]. However, there is significant potential for this sector to decrease its emissions if circular economy and hydrogen solutions are implemented, especially across difficult to decarbonise business sectors, specifically transport, electricity, heating and other industries that require heat for the production process.

Effects of climate change

5.40 The extent of the effects of climate change will vary by location and projections indicate that climate change trends observed over the last century will continue and intensify over the coming decades. Key long-term climate change trends for Scotland are that weather may become more variable, typical summers will be hotter and drier, winter and autumn will be milder and wetter and sea levels will continue to rise[165] and this will have an impact on coastal landscapes. Increases in summer heat waves, extreme temperatures and drought, as well as an increase in the frequency and intensity of extreme precipitation events, are also expected[166]. Urban areas in particular will be exposed to extreme heat conditions.

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156 Scottish Government (2020) Annual Compendium of Scottish Energy Statistics 2020 [pdf] Available at: https://www.gov.scot/binaries/content/documents/govscot/publications/statistics/2019/05/annual-compendium-of-scottish-energy-statistics/documents/annual-compendium-december-2020/annual-compendium-december-2020/govscot%3Adocument/ACSES%2B2020%2B-%2BDecember.pdf?forceDownload=true (accessed 30/08/2021)
157 Ibid
158 Ibid
159 Ibid.
160 Scottish Government (2021) Energy Statistics for Scotland Q4 2020 Figures [pdf] Available at: https://www.gov.scot/binaries/content/documents/govscot/publications/statistics/2018/10/quarterly-energy-statistics-bulletins/documents/energy-statistics-summary---march-2021/energy-statistics-summary---march-2021/govscot:document/Scotland+Energy+Statistics+Q4+2020.pdf (accessed 30/08/2021)
161 Scottish Renewables (2019) Statistics [online] Available at: https://www.scottishrenewables.com/our-industry/statistics
162 Ibid
163 DECC (2015) Towards a Smart Energy System [online] Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/486362/Towards_a_smart_energy_system.pdf (accessed 01/02/2021)
164 Scottish Government (2021) Scottish Greenhouse Gas Emissions 2019 [online] Available at: https://www.gov.scot/publications/scottish-greenhouse-gas-statistics-1990-2019/documents/ (accessed 30/08/2021)
165 Adaptation Scotland (2018) Climate trends and projections [online] Available at: https://www.adaptationscotland.org.uk/why-adapt/climate-trends-and-projections (accessed 04/02/2021)
166 ibid

5.41 Climate change has been identified as a primary pressure on many of the SEA topic areas (i.e., soil, water, biodiversity, cultural heritage and the historic environment). These pressures and predicted impacts have been discussed further under the individual SEA topics. The complex interaction between air quality and climate change has also been considered under the SEA topic of "Air Quality".

5.42 Climate change can also give rise to indirect impacts arising from mitigation and adaptation measures. For example, renewable energy is crucial to meeting Scotland's emissions reduction targets. However, individual technologies can have negative environmental impacts such as localised visual effects, changes in landscape and land use, and impacts on biodiversity, water. and air quality, amongst others.

Flood Risk

5.43 It is predicted that the greatest direct climate change-related threats for the UK are large increases in flood risk, exposure to high temperatures and heat waves; shortages in the public water supply and for agriculture, energy production and industry; substantial risks to UK wildlife and natural ecosystems, risks to domestic and international food production and trade[167]. New and emerging pests and diseases, and invasive non-native species affecting people, plants and animals has also been noted as a research priority[168].

5.44 Coastal flood risk is a key issue related to the threats from sea level rise and changes in storminess, and there are specific threats to coastal infrastructure as a result of future erosion.

Carbon Stores and Sinks

5.45 Scotland's soils and peatlands are the biggest terrestrial store of carbon with peatlands alone holding around 3,000 megatonnes of carbon[169]; 60 times more than carbon stored by trees and other vegetation[170]. Inshore and offshore waters also store a significant resource of low-carbon carbon, with an estimated 18 million tonnes of organic carbon stored in the top 10 cm of sediments across Scotland's seas[171]. Stocks of carbon within the habitats and surface sediments of offshore Marine Protected Areas are estimated at 9.4 Mt organic carbon and 47.8 Mt inorganic carbon[172].

Biodiversity, Flora and Fauna

Overview of Baseline

5.46 Biodiversity is commonly used as a measure of the health of an ecosystem and helps to provide the ecosystems services that are the basis of life including the regulation of air and water, soil formation, nutrient cycling, flood regulation and pollination, amongst many others[173].

5.47 As of 2021, Scotland's protected areas included 243 SACs[174], 153 SPAs[175], 51 Ramsar sites and 2 Biosphere reserves[176], amongst other internationally designated sites. There are further national level designations such as 1,422 SSSIs[177], 245 Marine Protected Areas[178] (which include some of the above listed sites and cover 37% of our seas), and two National Parks. In December 2020, a further four new MPAs in Scottish waters were designated, alongside 12 Special Protection Areas[179].

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167 Committee on Climate Change (2017) UK Climate Change Risk Assessment 2017. Available at: https://www.theccc.org.uk/uk-climate-change-risk-assessment-2017/ (accessed 04/02/2021)

168 ibid

169 SNH [2019] Managing nature for carbon capture [online] Available at: https://www.nature.scot/professional-advice/land-and-sea-management/carbon-management/managing-nature-carbon-capture (accessed 04/02/2021)

170 ibid

171 SNH (2014) SNH Commissioned Report 761 – Assessment of carbon budgets and potential blue carbon stores in Scotland's coastal and marine environment. Available at: https://www.nature.scot/snh-commissioned-report-761-assessment-carbon-budgets-and-potential-blue-carbon-stores-scotlands (accessed 04/02/2021)

172 SNH (2017) SNH Commissioned Report No. 957: Assessment of Blue Carbon Resources in Scotland's Inshore Marine Protected Area Network. Available at: https://www.nature.scot/snh-commissioned-report-957-assessment-blue-carbon-resources-scotlands-inshore-marine-protected-area (accessed 04/02/2021)

173 SNH (undated) Ecosystem approach [online] Available at: https://www.nature.scot/scotlands-biodiversity/scottish-biodiversity-strategy/ecosystem-approach#:~:text=The%20Convention%20on%20Biological%20Diversity,management%20that%20may%20affect%2C%20or (accessed 04/02/2021)

174 SNH (undated) Special Areas of Conservation [online] Available at: https://www.nature.scot/professional-advice/safeguarding-protected-areas-and-species/protected-areas/international-designations/natura-sites/special-areas-conservation-sacs (accessed 30/08/2021)

175 SNH (undated) Special Protection Areas [online] Available at: https://www.nature.scot/professional-advice/safeguarding-protected-areas-and-species/protected-areas/international-designations/natura-sites/special-protection-areas-spas (accessed 30/08/2021)

176 SNH (undated) Biosphere Reserves [online] Available at: https://www.nature.scot/professional-advice/safeguarding-protected-areas-and-species/protected-areas/international-designations/biosphere-reserve (accessed 30/08/2021)

177 SNH (undated) Sites of Special Scientific Interest [online] Available at: https://www.nature.scot/professional-advice/safeguarding-protected-areas-and-species/protected-areas/national-designations/sites-special-scientific-interest (accessed 30/08/2021)

178 Scottish Government (2021) Marine environment [online] Available at: https://www.gov.scot/policies/marine-environment/marine-protected-areas/ (accessed 30/08/2021)

179 NatureScot (2021) Special Protection Areas (SPAs) [online] Available at: https://www.nature.scot/professional-advice/protected-areas-and-species/protected-areas/international-designations/european-sites/special-protection-areas-spas (accessed 30/08/2021)

5.48 The UK Biodiversity Action Plan[180] identified 39 priority habitats and 197 priority species either occurring, or known to have occurred until recently, in Scotland. By March 2020, the proportion of nationally protected nature sites reported as being in a "favourable" condition decreased by 0.1 from 78.9% in 2019 to 78.8%[181]. Despite this decrease, this represents a 2.8% percentage point increase since the current protocols were established in 2007[182].

Evolution of Baseline – Pressure, Trends and Key Points

5.49 Biodiversity loss has been well documented over the last 50 years, and today there is a range of pressures with the potential to impact on Scotland's wildlife and biodiversity. Key issues such as land use intensification and modification, and pollution have been noted[183].

5.50 Climate change in particular has the potential to greatly impact on biodiversity on a global scale[184]. The predicted effects of climate change and the potential for associated impacts on biodiversity, flora and fauna are well documented, with evidence already showing the wide-ranging effects that a changing climate can have on flora and fauna species and their habitats[185]. Indirect impacts may also arise through climate change adaptation and the action taken in sectors such as renewable energy (e.g., onshore and offshore wind, solar, hydro-power, hydrogen etc.), agriculture, forestry, planning, water and coastal management in the face of a changing climate[186].

5.51 Habitat change, due mainly to increased and more intensive land management, urban development, pollution, nutrient enrichment, and over exploitation of natural resources such as water are other known pressures.

Population and Human Health

Overview of Baseline

5.52 The estimated population of Scotland in 2020 was 5.46 million, this has increased by 0.05% (2,700 people) in the past year, the slowest since mid-2003. This was mainly due to higher numbers of deaths and lower levels of net migration[187]. Projections forecast that the population will continue to rise to around 5.5 million in 2028, continuing to increase to around 5.57 million in 2043[188]. Life expectancy has increased over the past three decades; however, this has slowed in recent years[189].

5.53 Approximately 71% of Scotland's people live in urban areas, which accounts for just 2% of Scotland's land surface[190]. Most of the population and industry is concentrated in highly urbanised areas in the Central Belt and on the East Coast, and primarily in four key city regions (Aberdeen, Dundee, Edinburgh, and Glasgow) and several smaller cities and towns (e.g., Ayr, Inverness, Perth and Stirling). Around 12.4% of the population live in small towns of less than 10,000 people; of these, around 70% are located within a 30-minute drive of large urban settlements, with the other 30% located more remotely[191].

5.54 The Scottish Index of Multiple Deprivation ranks small areas (data zones) in Scotland from the most deprived to the least deprived. It analyses data from several indicators across the domains of income, employment, health, education, skills and training, housing, geographic access and crime. Key findings from the 2020 Index show that 14 areas have been consistently among the 5% most deprived in Scotland since the 2004 Index. Of these, nine were in Glasgow City with the remainder located in Inverclyde, Renfrewshire, Highland, North Lanarkshire and North Ayrshire. Six council areas now have a larger share of the 20% most deprived data zones in

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180 UK Government (1994) Biodiversity: The UK Action Plan [online] Available at: http://data.jncc.gov.uk/data/cb0ef1c9-2325-4d17-9f87-a5c84fe400bd/UKBAP-BiodiversityActionPlan-1994.pdf (accessed 04/02/2021)

181 SNH (2020) The Proportion of Scotland's Protected Sites in Favourable Condition 2020: An Official Statistics Publication for Scotland [online] Available at: https://www.nature.scot/information-hub/official-statistics/official-statistics-protected-sites (accessed 04/02/2021)

182 Ibid

183 SNH (undated) Key pressures on biodiversity [online] Available at: https://www.nature.scot/scotlands-biodiversity/key-pressures-biodiversity (accessed 04/02/2021)

184 Convention on Biological Diversity (undated) Climate Change and Biodiversity – Introduction [online] Available at: http://www.cbd.int/climate/intro.shtml (accessed 04/02/2021)

185 SNH (undated) Climate change impacts in Scotland [online] Available at: https://www.nature.scot/climate-change/climate-change-impacts-scotland (accessed 04/02/2021)

186 JNCC (2010) Biodiversity and Climate Change – a summary of impacts in the UK [online] Available at: https://hub.jncc.gov.uk/assets/e2d77481-dcb2-4fb3-8fff-d8b1c0cfc97f (accessed 04/02/2021)

187 National Records of Scotland (2021) Mid-2020 Population Estimates, Scotland [pdf] Available at: https://www.nrscotland.gov.uk/files//statistics/population-estimates/mid-20/mid-year-pop-est-20-report.pdf (accessed 30/08/2021)

188 Ibid

189 Ibid

190 Scotland's Environment (2014) Scotland's State of the Environment Report 2014 – 7 People and the environment [online] Available at: https://www.environment.gov.scot/media/1170/state-of-environment-report-2014.pdf (accessed 04/02/2021)

191 ibid

Scotland compared to 2016, with the largest increases observed in Aberdeen City, North Lanarkshire, Moray, East Lothian, Highland and North Ayrshire[192].

5.55 Heating and cooling homes and businesses accounts for approximately half of Scotland's GHG emissions. Challenging weather, poor energy efficiency and reduced heating options (especially in rural areas) can make fuel bills unaffordable, resulting in fuel poverty[193]. In 2019, the estimated rate of fuel poverty remained similar to the previous year at approximately 24.6% or around 613,000 fuel poor households, and 12.4% or 311,000 households were living in extreme fuel poverty[194]. This compares to the 25.0% or 619,000 fuel poor households in 2018, with 11.3% or 279,000 households living in extreme fuel poverty[195].

Evolution of Baseline – Pressure, Trends and Key Points

5.56 Air quality is important for both short and long-term human health. In general, healthy people may not suffer from any serious health effects from exposure to the levels of pollution commonly experienced in urban environments. However, continual exposure can cause harm over the long term, and those with pre-existing health conditions such as heart disease, lung conditions, and asthma can be adversely impacted by exposure to air pollutants[196]. Research has shown that air pollution is one of the largest environmental risks to public health in the UK, reducing average life expectancy and often contributing to premature deaths[197]. Activities that generate air pollutants have been considered under the topic of Air Quality.

5.57 Transport is a significant contributor to poor air quality in urban areas[198] and emissions from transport have only declined by 4.9% since 1990[199]. Approximately 66% of all journeys in Scotland are reported to be made by car, which is an increase of 7.7% over 5 years[200]. Due to several common sources, most notably road traffic in urban areas, there is also a close relationship between air quality and environmental noise[201].

5.58 Flooding can have significant environmental impacts and can also affect people, communities and businesses[202]. When floods occur, they disrupt day-to-day lives, and their impacts can be long lasting. Climate change is expected to increase the risk of flooding in coming years, and it also brings additional risks to human health posed by changes to air quality and rising temperatures[203].

5.59 The potential risks and benefits of climate change on population and health will not be evenly spread. For example, pockets of dense urban development will be more at risk of surface water flooding and summer heat stress. In addition, the effects to human health from climate change may have the greatest impact on vulnerable people. Negative health effects are likely to be disproportionately severe in areas of high deprivation because of the reduced ability of individuals and communities in these areas to prepare, respond and recover[204].

Soil and Geology

Overview of Baseline

5.60 Soil is a non-renewable resource and is fundamentally one of Scotland's most important assets[205]. There is an intrinsic relationship between soil health and other environmental topics; biodiversity, water and air quality in

[192] Scottish Government (2020) Introducing - The Scottish Index of Multiple Deprivation 2020 [online] Available at: https://www.gov.scot/publications/scottish-index-multiple-deprivation-2020/ (accessed 04/02/2021)

[193] Scottish Government (undated) Home energy and fuel poverty [online] Available at: https://www.gov.scot/policies/home-energy-and-fuel-poverty/ (accessed 12/02/2021)

[194] Scottish Government (2020) Scottish house condition survey: 2019 key findings [online] Available at: https://www.gov.scot/publications/scottish-house-condition-survey-2019-key-findings/pages/6/ (accessed 04/02/2021)

[195] ibid

[196] Scotland's Environment (2016) Air quality and health [online] Available at: https://www.environment.gov.scot/our-environment/air/air-quality-and-health/ (accessed 04/02/2021)

[197] Scottish Government (2019) Cleaner Air for Scotland strategy: independent review [pdf] Available at: https://www.gov.scot/publications/cleaner-air-scotland-strategy-independent-review/pages/6/ (accessed 04/02/2021)

[198] Scotland's Environment (2016) Air quality [online] Available at: https://www.environment.gov.scot/our-environment/air/air-quality/ (accessed 04/02/2021)

[199] Scottish Government (2020) Scottish Greenhouse Gas Emissions 2018. [pdf] Available at: https://www.gov.scot/publications/scottish-greenhouse-gas-emissions-2018/ (accessed on 04/02/2021)

[200] Transport Scotland (2019) Scottish Transport Statistics [pdf] Available at: https://www.transport.gov.scot/media/47196/scottish-transport-statistics-2019.pdf (accessed 30/08/2021)

[201] Scottish Government (2019) Cleaner Air for Scotland strategy: independent review [pdf] Available at: https://www.gov.scot/publications/cleaner-air-scotland-strategy-independent-review/pages/6/ (accessed 04/02/2021)

[202] Committee on Climate Change (2017) UK Climate Change Risk Assessment 2017 Evidence Report [online] Available at: https://www.theccc.org.uk/uk-climate-change-risk-assessment-2017/ (accessed 04/02/2021)

[203] Ibid.

[204] The Scottish Parliament (2012) SPICe Briefing: Climate Change and Health in Scotland [online] Available at: http://www.parliament.scot/ResearchBriefingsAndFactsheets/S4/SB_12-26rev.pdf (accessed 04/02/2021)

[205] Scotland's Soils – part of Scotland's Environment (2017) State of Scotland's soils – State of Scotland's Soil Report 2011 [online] Available at: http://soils.environment.gov.scot/soils-in-scotland/state-of-scotlands-soils/ (accessed 04/02/2021)

particular. For example, soil erosion is one of the main contributors to diffuse water pollution[206].

5.61 Soils can play two significant roles with regards to carbon. It is estimated that Scotland's soils contain over 3 billion tonnes of historic carbon, 60 times the amount of carbon held in trees and plants, making up over 53% of the UK's soil carbon[207]. Soil has also capacity to continue removing atmospheric carbon dioxide through additional sequestration. It is estimated that the loss of just 1% of soil carbon as carbon dioxide would triple Scotland's annual GHG emissions[208].

5.62 Degraded soil can act as a net carbon emitter, soils in good condition protect the carbon store and depending on the vegetation cover can continue to sequester carbon. Land use change and management practices, and new development such as onshore wind farms can impact significantly on soil carbon stores and sequestration.

Evolution of Baseline – Pressure, Trends and Key Points

5.63 While Scotland's soils are considered to generally be in good health, there are a range of pressures on them. Climate change and loss of organic matter pose significant threats to Scottish soils, with both likely to affect soil function, including loss of soil carbon. The loss of valued soils in particular has the potential for national impacts which will be difficult to reverse. In the case of climate change, these impacts have the potential to be felt on a global scale[209]. As such, the management and use of these resources can affect the amount of CO_2 that is held or released. Peatlands in good condition remove CO_2 from the atmosphere and store carbon in the soil. Conversely, degraded peatlands may emit more CO_2 than they remove and become a net source of greenhouse gases[210].

5.64 Changes in land use and land management practices are also a key pressure on soil. These include activities such as transport and development, including road building, development of renewable technologies, and the expansion of agriculture and forestry[211]. At present, there is uncertainty and a lack of quantitative information regarding threats to soil functions and ecosystem services, particularly in relation to the extent of soil sealing, changes in soil biodiversity, and compaction of soils[212]. Estimates of soil sealing suggest figures of approximately 1000 hectares a year[213]. Soil contamination can also arise from many causes, including atmospheric deposition, agriculture and forestry operations, mining and historic land contamination, and can impact on soil function and biodiversity[214]. Climate change also impacts on soil through erosion, land instability and increased risk of compaction and degradation of high carbon soils such as peat.

Water

Overview of Baseline

5.65 Scotland's water provides a wide range of benefits that support our health and prosperity, such as the provision of drinking water and as a resource for use in agriculture and industry[215]. It can also be used as an energy source through hydro-power schemes, tidal and wave energy, and hydrogen technologies. These water resources also support a rich diversity of habitats and species, attract tourism, promote recreation and provide for the sustainable growth of the economy[216]. Scotland's groundwater is a valuable asset for many, particularly rural communities where it provides most of the private drinking water (75%)[217]. Around 80% of Scotland's groundwater is in good condition, although there are particular regions with widespread problems; for example, in the Central

206 SEPA (undated) Soil [online] Available at: http://www.sepa.org.uk/environment/land/soil/#effect (accessed 04/02/2021)

207 Scotland's Soils – part of Scotland's Environment (2017) State of Scotland's soils – State of Scotland's Soil Report 2011 [online] Available at: http://soils.environment.gov.scot/soils-in-scotland/state-of-scotlands-soils/ (accessed 04/02/2021)

208 ibid

209 ibid

210 Scotland's Environment (2019) Peatland Restoration [online] Available at: https://soils.environment.gov.scot/resources/peatland-restoration/ (accessed 04/02/2021)

211 Scotland's Environment (2011) Soils [online] Available at: https://www.environment.gov.scot/media/1213/land-soils.pdf (accessed 04/02/2021)

212 European Commission (2016) JRC Technical Reports - Soil threats in Europe - Status, methods, drivers and effects on ecosystem services [online] Available at: http://esdac.jrc.ec.europa.eu/public_path/shared_folder/doc_pub/EUR27607.pdf (accessed 04/02/2021)

213 SEPA (2011) The State of Scotland's Soil [online] Available at: https://www.sepa.org.uk/media/138741/state-of-soil-report-final.pdf (accessed 04/02/2021)

214 SEPA (2019) Guidance on consideration of soil in Strategy Environmental Assessment [online] Available at: https://www.sepa.org.uk/media/162986/lups-sea-gu2-consideration-of-soil-in-sea.pdf (accessed 04/02/2021)

215 Scotland's Environment (undated) Scotland's Freshwater [online] Available at: https://www.environment.gov.scot/our-environment/water/scotland-s-freshwater/ (accessed 04/02/2021)

216 Scotland's Environment (2014) Scotland's State of the Environment Report 2014 [online] Available at: https://www.environment.gov.scot/media/1170/state-of-environment-report-2014.pdf (accessed 04/02/2021)

217 Scotland's Environment (2011) Groundwater [online] Available at: https://www.environment.gov.scot/media/1230/water-groundwater.pdf (accessed 04/02/2021)

Belt[218]. Agriculture and the legacy of industrial activity are the main causes of regional-scale groundwater problems, whereas inadequate construction of private water supplies and inappropriate management of wastes can create localised problems[219].

5.66 Flooding can have significant and long-lasting impacts on people, communities, and businesses. Flood Risk Management Strategies[220] co-ordinate action to tackle flooding in Scotland, setting out the national direction for flood risk management and helping target investment and coordinate action across public bodies. Flood maps have also been produced which help to show where areas are likely to be at risk of flooding from rivers, seas and surface water[221].

Evolution of Baseline – Pressure, Trends and Key Points

5.67 Key pressures on the surface water environment include urbanisation, an increase in invasive non-native species, intensive agriculture/aquaculture and climate change. Rural and urban diffuse pollution remains a concern for water quality, particularly in relation to agriculture, forestry, and urban development[222].

5.68 Airborne pollution, particularly associated with vehicle emissions can impact upon water bodies. Heightened nitrogen concentrations can cause the acidification and eutrophication of water bodies. Eutrophication occurs when the concentrations of otherwise limiting nutrients increase, allowing aquatic plants and algae to grow unchecked and depleting oxygen levels.

5.69 Scottish Water carries out extensive monitoring of their supply zones, and SEPA carries out river monitoring and uses predictive tools to give early warning of possible water scarcity. During dry periods, when the water environment comes under pressure, SEPA is required to balance the need for sustainable water use whilst protecting the environment. Areas with little water storage will be affected by short dry periods. Areas which more frequently experience water storage may have greater water storage capacity. Equally, if an area rarely has dry periods, it may have less storage and be more vulnerable. [223]

5.70 The predicted effects of climate change such as increased temperatures and changes to rainfall patterns could affect flows in rivers and impact on water resource availability[224]. This could be further exacerbated if water is extracted for use in the electrolysis process for hydrogen. A changing climate is also expected to have ecological impacts, such as warmer sea temperatures and an increasing risk of non-native species spreading and becoming established in water environments[225].

5.71 The risk of flooding from rivers, surface waters and sea is predicted to increase. This can damage material assets, pose risks to population and human health through the spread of infectious diseases and also lead to a loss of habitats, resulting from erosion.

5.72 The development and operation of new infrastructure has the potential to negatively impact on water quality, either during construction or via pollution run-off. New structures on land can also affect the capacity of flood plains or flood defences.

Air

Overview of Baseline

5.73 As discussed in 'Population and Human Health', air pollution can result in adverse impacts on human health and can significantly affect many aspects of quality of life. Air pollution can also cause adverse effects in the wider environment. For example, it can increase nutrient levels in water bodies and soil and contribute to acidification, both of which can impact on plant and animal life, as well as damage the fabric of buildings and monuments.

5.74 The quality of the air around us is affected by the pollutants released into the atmosphere through human activities, such as transport, industry and agriculture as well as pollutants arising from natural sources. The main air pollutants

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218 ibid

219 ibid

220 SEPA (undated) Flood Risk Management Strategies [online] Available at: http://apps.sepa.org.uk/FRMStrategies/ (accessed 04/02/2021)

221 SEPA (undated) Flood maps [online] Available at: http://www.sepa.org.uk/environment/water/flooding/flood-maps/ (accessed 04/02/2021)

222 SEPA (2015) The river basin management plan for the Scotland river basin district: 2015–2027 [online] Available at: https://www.sepa.org.uk/media/163445/the-river-basin-management-plan-for-the-scotland-river-basin-district-2015-2027.pdf (accessed 04/02/2021)

223 SEPA (2020) Scotland's National Water Scarcity Plan [online] Available at: www.sepa.org.uk/media/219302/scotlands-national-water-scarcity-plan.pdf (accessed 28/10/21)

224 Scotland's Environment (2014) Scotland's State of the Environment Report 2014 [online] Available at: https://www.environment.gov.scot/media/1170/state-of-environment-report-2014.pdf (accessed 04/02/2021)

225 SEPA (2015) The river basin management plan for the Scotland river basin district: 2015–2027 [online] Available at: https://www.sepa.org.uk/media/163445/the-river-basin-management-plan-for-the-scotland-river-basin-district-2015-2027.pdf (accessed 04/02/2021)

are nitrogen oxides (NO_x), particulate matter (PM_x), sulphur dioxide (SO_2), ammonia (NH_3), volatile organic compounds (VOCs), and ozone (O_3). Sulphur dioxide, oxides of nitrogen, particulates, and low-level ozone are generally considered to be of most importance in relation to human health and the environment[226].

Evolution of Baseline – Pressure, Trends and Key Points

5.75 Air quality in Scotland has improved considerably over the last few decades. Between 1990 and 2018 there were decreases of 84% for carbon monoxide (CO), 73% for nitrogen oxides (NOx), 64% for non-methane volatile organic compounds, 62% for fine particulate matter (PM10) and 96% for SO2[227]. However, air pollution is still estimated to reduce the life expectancy of every person in the UK by an average of 7–8 months[228] and there are some areas of towns and cities where air quality has been identified as a concern.

5.76 Section 83(1) of the *Environmental Act 1995*[229] sets out a requirement that where air quality objectives are not being met or are unlikely to be met within the relevant period, Local Authorities must designate an Air Quality Management Area (AQMA). In Scotland, 36 AQMAs are currently declared, with 14 of Scotland's 32 Local Authorities having declared at least one. The majority of these are in urban areas as a result of NO_x alone or in combination with PM_{10} levels, and primarily as a result of traffic emissions[230].

5.77 Air pollution often originates from the same activities that contribute to climate change; notably transport, agriculture and energy generation. Transport is the most significant source contributing to poor air quality in urban areas.[231] While measures such as using alternative fuels sources and encouraging active travel can help improve air quality in addition to reducing GHG emissions, some measures aimed at reducing the impacts of climate change can also have a negative impact on air quality. For example, while emissions from well operated and well-maintained modern biomass boilers are generally lower than the coal equivalent, the burning of biomass feedstock does emit air pollutants such as particulates.[232] Likewise, adverse effects on air quality are possible during the hydrogen to energy process due to the release of particulate emissions, toxic dust and smoke[233].

5.78 Cleaner air provides multiple benefits and actions taken, such as a shift towards low or zero emissions transport and energy sources, should provide mutual benefits for both air quality and climate change.[234]

5.79 The Covid-19 pandemic has led to short term air quality improvements especially in urban areas mainly due to the reduction in private and public transport use. Evidence suggests that due to the pandemic, air pollution of NO_2 and NO_x across 7 sites in Scotland has on average decreased by -55% and -61% respectively[235]. However, such results have been gained by implementing very strict measures.

5.80 Private and public transport declined by approximately 90% between 14th to 19th of April 2020 in comparison to the same period the previous last year. In the same time period active travel such as cycling has increased by 50%[236]. With the easing of lockdown restrictions, private vehicles have returned on the roads, however bus and rail services still experience significant drops in demand (rail: -70%, bus: - 55% for the week of 17 – 23 of August).

226 Scotland's Environment (2014) Scotland's State of the Environment Report 2014 [online] Available at: https://www.environment.gov.scot/media/1170/state-of-environment-report-2014.pdf (accessed 04/02/2021)

227 National Atmospheric Emissions Inventory (2020) Air Pollutant Inventories for England, Scotland, Wales, and Northern Ireland: 1990-2018 [pdf] Available at: https://uk-air.defra.gov.uk/assets/documents/reports/cat09/2010220959_DA_Air_Pollutant_Inventories_1990-2018_v1.2.pdf (accessed 30/08/2021)

228 Scottish Air Quality (undated) Air Quality in Scotland – About Air quality [online] Available at: http://www.scottishairquality.scot/air-quality/ (accessed 04/02/2021)

229 Environment Act 1995, c.25 [online] Available at: http://www.legislation.gov.uk/ukpga/1995/25/introduction (accessed 04/02/2021)

230 Air Quality in Scotland (2021) Air Quality Management Areas [online] Available at: http://www.scottishairquality.scot/laqm/aqma (accessed 30/08/2021)

231 Scotland's Environment (2016) Air quality [online] Available at: https://www.environment.gov.scot/our-environment/air/air-quality/ (accessed 04/02/2021)

232 ibid

233 Australian Government (2019) Australia's National Hydrogen Strategy [online] Available at: https://www.industry.gov.au/data-and-publications/australias-national-hydrogen-strategy#:~:text=Australia's%20National%20Hydrogen%20Strategy%20sets,a%20major%20player%20by%202030.&text=It%20includes%20a%20set%20of,governments%2C%20industry%20and%20the%20community. (accessed 08/02/2021)

234 Scottish Government (2015) Cleaner air for Scotland: the road to a healthier future [online] Available at: http://www.gov.scot/Publications/2015/11/5671 (accessed 04/02/2021)

235 Ricardo Energy and Environment (2020) COVID-19 lockdown effects on air quality. [online] Available at: http://www.scottishairquality.scot/assets/documents//COVID19_lockdown_effects_on_air_quality.html (accessed 04/02/2021)

236 Transport Scotland (2020) COVID-19 Transport Trend Data 14 – 19 April 2020 [online] Available at: https://www.transport.gov.scot/publication/covid-19-transport-trend-data-14-19-april-2020/ (accessed 04/02/2021)

Cultural Heritage and the Historic Environment

Overview of Baseline

5.81 Scotland's many and varied historical sites are unique and irreplaceable. These sites and features are regarded as making a valuable contribution to our quality of life, cultural identity, education and economy. While these assets are distributed widely throughout Scotland, there are clusters of sites in and around our settlements and also around our coastlines.

5.82 Some parts of Scotland's historic environment are protected through a process of designation. The process aims to identify parts of the historic environment for their significance and enhance their protection. As of 2016, it is estimated that around 5-10% of the historic environment is designated[237]. Designated assets currently include World Heritage Sites, Listed Buildings, Scheduled Monuments, Conservation Areas, Designed Gardens and Landscapes, Historic Marine Protected Areas, Scheduled Wrecks and Nationally Important Battlefields[238]. However, whilst most of the historic environment is undesignated (90-95%), these known but undesignated assets provide important contextual information which helps us better understand designated sites[239].

Evolution of Baseline – Pressure, Trends and Key Points

5.83 Development is a key pressure on the historic environment and cultural heritage, both directly in terms of damage to known and unknown features, and the potential for impacts on setting. Other known pressures include changing land use and land management, tourism/visitors, pollution and climate change.

5.84 It is projected that Scotland will become warmer and wetter as a result of climate change, resulting in the increased weathering of stone, rotting timbers and corrosion of metals. Rising sea levels and increased storm events may increase coastal erosion, endangering our historic landscapes, structures, buildings and archaeology in the coastal zone. Some of Scotland's unique and special sites, such as Skara Brae in Orkney, are at most risk[240].

5.85 Increased rainfall will mean that historic buildings and assets will be wetter for longer periods of time, and as such may result in the penetration of water, dampness, condensation and fungus growth, ground instability and structural collapse. This can potentially have damaging effects on the fabric of buildings and the health of those using it. This threat will grow in the future, given the future predictions of the likely effects of global warming and climate change for the remainder of this century.

Landscape

Overview of Baseline

5.86 Rich in diversity, Scotland's landscapes are internationally renowned. Scotland's distinctive landscapes are a significant part of the country's natural and cultural heritage and make a significant contribution to both the country's economic performance and the well-being of its people. Scotland's landscapes play a key role in attracting tourism, affording opportunities for business and providing the setting for outdoor recreation.

5.87 There are currently two National Parks (Loch Lomond and The Trossachs, and the Cairngorms) and 40 National Scenic Areas in Scotland. Over 13% of Scotland's land area has been classified as a National Scenic Area[241]. Designations such as Local Landscape Areas, Special Landscape Areas, Regional Scenic Areas and Areas of Great Landscape Value have also been established at a regional and local level by many local authorities[242]. These areas of important nature or landscape value have been designated locally for conservation purposes and are afforded protection from inappropriate development[243]. 42 wild land areas are also recognised as nationally important in Scotland reflecting landscapes with minimal human influence.

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[237] Historic Environment Scotland (2016) Scotland's Historic Environment Audit: Summary Report 2016 [online] Available at: https://www.historicenvironment.scot/archives-and-research/publications/publication/?publicationId=bac8296b-fcd4-4fdf-8617-ab9e009235db (accessed 04/02/2021)

[238] Scotland's Environment (undated) Historic Environment [online] Available at: https://www.environment.gov.scot/our-environment/people-and-the-environment/historic-environment/ (accessed 04/02/2021)

[239] ibid

[240] Scotland's Environment (2014) Scotland's State of the Environment Report 2014 [online] Available at: https://www.environment.gov.scot/media/1170/state-of-environment-report-2014.pdf (accessed 04/02/2021)

[241] NatureScot (undated) National Scenic Areas [online] Available at: https://www.nature.scot/professional-advice/safeguarding-protected-areas-and-species/protected-areas/national-designations/national-scenic-areas (accessed 12/02/2021)

[242] NatureScot (undated) Local Designations [online] Available at: https://www.nature.scot/professional-advice/safeguarding-protected-areas-and-species/protected-areas/local-designations (accessed 04/02/2021)

[243] Ibid

Evolution of Baseline – Pressure, Trends and Key Points

5.88 Scotland's landscapes are constantly changing and evolving in response to both natural processes and the changing demands of society. Changes in landscape tend to occur over long periods of time, and gradual change, as a result of development such as housing and renewable energy can be difficult to determine[244].

5.89 Climate change is expected to lead to extensive landscape change across Scotland and is viewed as an increasing pressure on landscape, not only as a result of direct effects but also as a result of indirect impacts.[245] Direct impacts are likely as a result of changing temperatures and patterns of precipitation, weather events and sea level change[246]. Other commitments to adapting to the predicted effects of climate change, for example, the development of renewable energy (such as wind farms, hydro-power schemes, solar power and hydrogen technologies) is seen by many as a pressure on both visual amenity and the character of many rural landscapes. The construction of new transport infrastructure and working towards a national target for increasing forest cover in Scotland also has the potential to affect our landscapes and seascapes.

5.90 The greatest changes are likely to be seen in areas of highest population, such as lowland and coastal areas. Mitigation and adaptation measures are expected to have a greater influence on both Scotland's landscapes and the quality of life than that of the direct effects of climate change[247]. The coast and foreshore are under many pressures particularly from climate change, rising sea level and coastal erosion.

Material Assets

Baseline Overview

5.91 Energy, waste, and transportation infrastructure, forestry and land managed for agriculture are material assets. Scotland's natural resources are also material assets. Mineral resources and aggregates are used for purposes such as fuel (e.g., coal), and construction (e.g. sand, gravel and rock). However, the quantity of these resources is finite and once they are used up, they cannot be replaced.

Energy

5.92 Heating makes up approximately half of Scotland's energy consumption (50.3%) with transport (24.5%) and electricity (22.1%) making up approximately a quarter each[248]. A breakdown by sector of non-transport energy consumption shows that 59.9% is accounted for by industrial and commercial sectors, with 40.1% consumed domestically[249]. Domestic consumption of electricity and heat dropped by 17.2%% in 2018, compared to the 2005-2007 baseline. Energy consumption in transport increased slightly in 2018 by 0.7%. It is estimated that industrial energy consumption has dropped by 24.1% but commercial consumption rose by 11.9% compared to the 2005-2007 baseline[250].

5.93 It is estimated that 21.1% of Scotland's total energy consumption in 2018 came from renewable sources; the highest level to date and an increase from 19.2% in 2017. This is attributed to an increase in installed capacity for renewable electricity and heat between 2017-2018. In 2019, provisional figures indicate that the equivalent of 90.1% of gross electricity consumption was from reviewable sources, rising from 76.7% in 2018. Much of this increase is due to increase in wind capacity[251].

5.94 There have been significant changes to the electricity generation mix in recent years with the vast majority of the electricity that Scotland generated from low carbon sources, 88.3% in 2017, compared to 50.1% in 2010[252]. In turn, fossil fuel generation is at its lowest level, with just 10.5% of all electricity generated from oil and gas, compared to 48.4% in 2010[253].

5.95 In 2020, 71% of all renewable electricity generated in Scotland was from wind. Hydro is Scotland's second highest source of renewable generation (15.8%). The remaining 8.4% was produced by other renewable energy technologies. Solar capacity has increased rapidly in the first half of this decade. Bioenergy and energy from waste accounts for 8.1% and whilst the current capacity of wave and tidal is considered to

[244] Scotland's Environment (2014) Landscape [online] Available at: https://www.environment.gov.scot/media/1196/land-landscape.pdf (accessed 04/02/2021)

[245] Scottish Natural Heritage (2019) Landscape: Climate change [online] Available at: https://www.nature.scot/professional-advice/landscape/landscape-policy-and-guidance/landscape-climate-change (accessed 04/02/2021)

[246] Scotland's Environment (2014) Landscape [online] Available at: https://www.environment.gov.scot/media/1196/land-landscape.pdf (accessed 04/02/2021)

[247] SNH (undated) Landscape: climate change. Available at: https://www.nature.scot/professional-advice/landscape/landscape-policy-and-guidance/landscape-climate-change (accessed 04/02/2021)

[248] Scottish Government (2020) Annual Compendium of Scottish Energy Statistics December 2020 Update [online] Available online: https://www.gov.scot/publications/annual-compendium-of-scottish-energy-statistics/ (accessed 08/02/2021)

[249] ibid

[250] ibid

[251] ibid

[252] ibid

[253] ibid

be relatively small, technology is developing[254] and Scotland benefits from significant resource potential in these areas. At a domestic level, Scotland is reliant on gas as the primary heating fuel for homes, with 80% of Scotland's 2.5 million dwellings using gas[255]. However, almost 20% of Scottish domestic consumers live in an off-gas grid area, with the highest proportion of off-grid properties found in the Highlands and Argyll and Bute[256].

5.96 In 2019, the equivalent of 6.5% of non-renewable heat demand was met by renewable sources, an increase from 6.2% in 2018. A rise in the generation of renewable heat by biomethane is attributed to this increase. Thermal energy from waste and heat pumps make up 7% and 8%, respectively, of renewable heat output[257].

5.97 As Scotland's energy mix changes over the next few years, the electricity transmission network (grid) that supports the balance between energy generation and demand will change significantly. For example, as a result of the increased electrification of the transport and heat network. Infrastructure will play a key role in ensuring security of supply and decarbonising our energy systems in the most cost effective, affordable way[258].

5.98 Since 2000, Scottish renewables have displaced an estimated 124 million tonnes of CO_2[259], assuming that the same amount of electricity generation would have been generated by fossil fuels[260] In 2007 alone, Scottish renewable electricity displaced an estimated 11.6 million tonnes of CO_2[261].

Hydrogen

5.99 The use of hydrogen in Scotland may further contribute towards reduced GHG emissions. The Scottish Hydrogen Assessment[262] identifies 38 existing hydrogen projects in Scotland. Grangemouth is an industrial cluster and refinery that represents a potential high demand for hydrogen. It currently produces its own 'grey' hydrogen through steam methane reforming and has potential to switch to low-carbon or renewable hydrogen. Mossmoran chemical plant also produces grey hydrogen.

5.100 Aberdeen has been described as the 'Hydrogen Model Region'[263], paving the way as an early adopter of hydrogen buses. The Hydrogen Bus Project currently has a fleet of ten buses powered by renewable hydrogen, with an additional 15 to be added to the fleet[264], which are serviced by a refuelling station in Kittybrewster. In addition, the proposed Acorn Carbon Capture Utilisation and Storage (CCUS) project located at the St Fergus Gas Terminal near Aberdeen includes a low-carbon hydrogen production plant producing hydrogen from natural gas landed at St Fergus, coupled with a CCUS facility that will capture the CO_2 from hydrogen production, as well as other sources, and transport it for storage in the North Sea.

5.101 The Orkney Islands have made significant progress in the production of renewable hydrogen, with the Shetland and Outer Hebrides starting to follow suit. The Surf 'n' Turf project in Orkney delivered a 500 kilowatt (kW) renewable hydrogen production facility on the Isle of Eday. The hydrogen is produced using tidal power from deployed turbines at the European Marine Energy Centre (EMEC), along with 900 kW community wind generation. Once fully commissioned 50 tonnes of hydrogen will be produced annually for local buildings and transported to Kirkwall for heat and power of harbour buildings, the marina, vessels and a refuelling station for road vehicles.

Evolution of Baseline – Pressure, Trends and Key Points

5.102 As Scotland's energy mix changes over the next few years, the electricity transmission network (grid) that supports the balance between energy generation and demand will change significantly. For example, as a result of the increased electrification of the transport and heat network. Infrastructure will play a key role in ensuring security of supply and decarbonising our energy systems in the most cost effective,

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[254] ibid

[255] Infrastructure Commission for Scotland (2020) Key findings report [online] Available at: https://infrastructurecommission.scot/page/key-findings-report (accessed 12/02/2021)

[256] Ibid.

[257] Scottish Government (2020) Annual Compendium of Scottish Energy Statistics December 2020 Update [online] Available online: https://www.gov.scot/publications/annual-compendium-of-scottish-energy-statistics/ (accessed 08/02/2021)

[258] DECC (2015) Towards a Smart Energy System [online] Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/486362/Towards_a_smart_energy_system.pdf (accessed 08/02/2021)

[259] Across the GB system

[260] Scottish Government (2019) Annual Compendium of Scottish Energy Statistics May 2019 Update [online] Available online: https://www.gov.scot/publications/annual-compendium-of-scottish-energy-statistics/ (accessed 08/02/2021)

[261] ibid

[262] Scottish Government (2020) Scottish Hydrogen Assessment [online] Available at: https://www.gov.scot/binaries/content/documents/govscot/publications/research-and-analysis/2020/12/scottish-hydrogen-assessment-report/documents/scottish-hydrogen-assessment/scottish-hydrogen-assessment/govscot%3Adocument/scottish-hydrogen-assessment.pdf (accessed 15/02/2021)

[263] ibid

[264] Electrive (2019) Aberdeen orders another 15 hydrogen buses [online] Available at: https://www.electrive.com/2019/07/24/aberdeen-orders-another-15-hydrogen-buses/ (accessed 14/10/2021)

affordable way[265]. Energy storage is likely to be an increasingly important part of the transition to delivering clean, affordable and secure supplies of energy[266] and to support the integration of increasing volumes of renewables into the energy system and address intermittencies. For example, the continued development of battery storage technologies and hydrogen fuel cells for vehicle use in the transport sector.

5.103 Hydrogen is a key opportunity for heavy-duty transport, maritime and aviation uses, offering longer range than electric only. However, a comprehensive hydrogen refuelling network will be required to support this. Hydrogen fuel cells are an opportunity for the rail network; however electrification is a key alternative, and hydrogen may play a more limited role, facilitating the transition in areas which are harder to electrify in the short term[267].

5.104 Hydrogen could be a future key opportunity for, for example, Scotland's only cement plant at Dunbar, and also for all other difficult to decarbonise industries through fuel switching technologies and utilising hydrogen as feedstock for chemical processes[268].

5.105 Hydrogen could have an essential role in meeting the peaks in energy demand in the Scotch Whisky subsector which heat pumps would find hard to meet. In 2018, the whisky industry alone accounted for 1.3% of Scotland's territorial GHG emissions and current research indicates that this sector may be a key opportunity for hydrogen in Scotland's future. Hydrogen technology for Scottish distilleries is still in research and development and not yet at commercial scale. There are many small-scale projects starting up currently, with a recent government fund kick starting at least seven in Scotland assessing the feasibility of various hydrogen-technologies.

5.106 Flooding poses the greatest long-term climate related risk to infrastructure performance, however, growing risks posed from heat, water scarcity and slope instability caused by severe weather could also prove significant[269]. Therefore, selection of the location of hydrogen production infrastructure needs to consider the potential for these extreme weather events and climatic risks in order to minimise their potential future impacts on hydrogen production plants.

[265] DECC (2015) Towards a Smart Energy System [online] Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/486362/Towards_a_smart_energy_system.pdf (accessed 10/02/2021)
[266] ClimateXChange (2016) Energy Storage in Scotland - Summary of reports on thermal and electrical energy storage [online] Available at: https://www.climatexchange.org.uk/media/1391/summary_energy_storage.pdf (accessed 10/02/2021)
[267] Arup (undated) Hydrogen Transport – Fuelling the Future [online] https://www.arup.com/-/media/arup/files/publications/h/hydrogen-transport-fuelling-the-future-arup.pdf (accessed 23/08/2021)
[268] Scottish Government (2020) Deep Decarbonisation Pathways for Scottish Industries: A Study for the Scottish Government [online] Available at: https://www.gov.scot/binaries/content/documents/govscot/publications/research-and-analysis/2020/12/deep-decarbonisation-pathways-scottish-industries/documents/deep-decarbonisation-pathways-scottish-industries-study-scottish-government-final-report/deep-decarbonisation-pathways-scottish-industries-study-scottish-government-final-report/govscot%3Adocument/deep-decarbonisation-pathways-scottish-industries-study-scottish-government-final-report.pdf (accessed 14/02/2021)
[269] Committee on Climate Change (2017) UK Climate Change Risk Assessment 2017 Evidence Report – Summary for Scotland [online]: https://www.theccc.org.uk/wp-content/uploads/2016/07/UK-CCRA-2017-Scotland-National-Summary.pdf (accessed 10/02/2021)

Chapter 6
Strategic Environmental Assessment findings

Introduction

6.1 This chapter of the Environmental Report sets out the assessment findings and the significant environmental effects of the Draft Hydrogen Action Plan. The findings are grouped as direct or indirect effects. These are effects arising directly from the Draft Hydrogen Action Plan and any 'secondary' effects, which would indirectly impact on the environment.

6.2 As outlined in Chapter 2 of this Environmental report, the Draft Hydrogen Action Plan is framed around six action themes with associated actions.

Direct effects

6.3 The following paragraphs present the assessment of the direct effects of the six Action Themes that constitute the draft Hydrogen Action Plan (HAP). The overall aim of the draft HAP is to take supportive action to enable a hydrogen production capability of 5GW by 2030, to encourage domestic demand for hydrogen and to develop Scotland's supply chain, workforce and export potential. The draft HAP sets out actions for the period of 5 years between 2021 to 2026 and recognises the need to create the necessary regulatory framework and context to encourage future private investments in the technology. Due to the short-term nature of the actions within the draft HAP, direct impacts are limited as they reflect actions such as creating guidelines, establishing relationships and assessing workforce requirements for this new sector. For each Action Theme, any direct effects are highlighted in relation the relevant SEA topic. This is followed by a separate section which sets out indirect effects arising as a consequence of the actions in the draft HAP.

6.4 The draft Hydrogen Action Plan does not directly influence renewable energy development, which is not included within the scope the assessment of direct and indirect effects, however the delivery of the ambitions of the draft HAP is reliant on the delivery of these energy sources.

Action Theme One: Scaling up hydrogen production in Scotland

6.5 This action aims to deliver a suitable context for private capital investment in hydrogen production by providing the necessary support framework consisting of:

- Hydrogen development fund;
- Policy, planning, regulation and licensing support for hydrogen production, and required renewable energy.
- Provision of sufficient water resources; and
- Support decarbonisation of unabated hydrogen production.

6.6 A robust regulatory environment will help to avoid direct adverse environmental effects across all of the SEA topic areas in the future. It will be particularly relevant to the following SEA topic areas where the production and use of hydrogen has particular potential impacts:

- Hydrogen combustion in fuel cells will have positive effects on air quality, however if hydrogen is combusted in an alternative way it may lead to emissions;
- Both low-carbon and renewable hydrogen will require water for their production process, however renewable hydrogen will require significantly larger quantities of water for the electrolysis process;
- Low-carbon hydrogen will lead to fugitive hydrogen and some carbon emissions as the current technology does not capture 100% of the emissions; and
- There is still uncertainty in relation to the health and safety of domestic use of hydrogen for heating purposes.

6.7 For Action Theme One, direct effects have only been identified for **soil**.

Soil

6.8 **Minor negative effects** are identified in relation to direct effects on soil arising from Action Theme One. This action may require additional development of facilities and lead to land take and soil compaction. There is the potential to mitigate for the negative effects at this stage of the action plan by selecting brownfield land for the necessary developments.

Action Theme Two: Facilitating the development of a domestic market.

6.9 This action aims to facilitate the development of a domestic hydrogen market, including in relation to heat, transport, and industrial decarbonisation.

6.10 This Action Theme lists actions required to enable the uptake of hydrogen across the domestic market. This includes funding for the development of Regional Hydrogen Hubs, hydrogen blending, hydrogen ready boilers, and hydrogen applied in industrial heating. Within the transport section, actions including supporting innovation, training, education and knowledge sharing, providing refuelling infrastructure, forecasting hydrogen demand, providing funding support, developing standards and regulations, and supporting the transport technology supply chain. It is not expected that direct effects will arise from hydrogen ready boilers within the timeframes of this draft HAP. However, some direct and tangible results may be delivered by the uptake of hydrogen by industry and transport. It is assumed that these results will be delivered in the final years of this draft HAP.

6.11 For Action Theme Two, direct effects have only been identified for Air and Climatic factors.

Air

6.12 Hydrogen ready boilers will produce lower carbon heat, however current research indicates that burning of hydrogen may lead to NO_x emissions having negative effects on the overall air quality[270]. Burning hydrogen has similar or lower NO_x emissions to those emitted when using methane fuel[271].

6.13 The speed of conversion of hydrogen boilers, and scale of roll out is **uncertain**, as are the associated air pollution emissions impacts compared to natural gas boilers. Therefore, assuming a limited level of installation of hydrogen boilers they would continue to contribute to negative effects on air quality, however this would be **neutral** compared to the baseline of natural gas boilers.

Climatic factors

6.14 Direct effects are identified for climatic factors, as it is expected that the rollout of hydrogen ready boilers used for domestic heating, using renewable hydrogen or low-carbon hydrogen with carbon capture would reduce GHG emissions in comparison to the current fossil fuel-based heating sources without carbon capture. Due to the likely scale of hydrogen boilers and timescale of implementation, a **minor positive effect** is identified.

Action Theme Three: Maximising the benefits of integrating hydrogen into our energy system.

6.15 This Action Theme aims to integrate hydrogen into the energy system by identifying potential integration challenges, enabling knowledge sharing, exploring the use of hydrogen as an energy storage and exploring any required changes to the current energy market frameworks to ensure efficient

[270] Air Quality Expert Group (2020) Impacts of Net Zero pathways on future air quality in the UK. Available at: https://uk-air.defra.gov.uk/assets/documents/reports/cat09/2006240802_Impacts_of_Net_Zero_pathways_on_future_air_quality_in_the_UK.pdf
[271] Ibid.

integration. It also seeks to provide financial support for the establishment of hydrogen transport and distribution infrastructure to support ambitions to become an exported of hydrogen to the rest of the UK and Europe.

6.16 No direct effects are identified arising from Action Theme Three.

Action Theme Four: Enabling the growth and transition of Scotland's supply chain and workforce

6.17 This Action Theme aims to support the growth and transition of companies, and workforce skills development. This will underpin the hydrogen economy by establishing the stable and secure production of affordable large-scale hydrogen.

6.18 It will largely involve working with agencies and industry to build support for the Scottish Hydrogen Supply Chain and assess the workforce demand. It includes actions to establish the skills required to underpin Scotland's energy transition, such as promoting training programmes for specialist skills and funding to encourage knowledge sharing between academia and enterprises. For example, the new National Energy Skills Accelerator (NESA) being established in Aberdeen. The development of an online tool will encourage the development of hydrogen projects by providing information on upcoming projects and supply chain.

6.19 Direct effects are identified in relation to population and human health, soil and material assets.

Population and human health

6.20 **Minor positive effects** are identified in relation to population and human health as this Action Theme is likely to deliver training and employment opportunities related to the hydrogen economy, supporting health and wellbeing. This includes roles relating to research and innovation and the supply chain. Providing training and employment opportunities in more remote areas, such as where some of the hydrogen hubs will be delivered, is crucial in addressing unemployment and depopulation. Provision of more hydrogen related jobs may encourage more younger people to remain in these areas, contributing to the local economy, and supporting health and wellbeing.

Soil

6.21 Training required to stimulate research and innovation may require additional facilities. It is assumed that development for training will be associated with this Action Theme. It is assumed that most training related development will be on brownfield land in areas where hydrogen is likely to be produced. **Negligible negative effects** are expected on soil in the form of soil sealing and loss of soil carbon.

Material assets

6.22 Training facilities will require materials, energy and equipment necessary for the construction phase of the development. This is likely to small scale of this development and **negligible negative effects** are expected in relation to material assets arising from Action Theme Four.

Action Theme Five: Establishing and strengthening international partnerships and markets

6.23 This action aims to deliver international partnerships and markets. It will largely involve publishing a Hydrogen Export Plan, developing a Hydrogen Outreach Programme, supporting international trade and investment, and strengthening international relationships. In addition, it includes actions to work with ports and harbours to provide adequate hydrogen infrastructure.

6.24 Direct effects are identified in relation to soil.

Soil

6.25 **Minor negative effects** are identified in relation to direct effects on soil arising from Action Theme Five. This action may require additional development of port and harbour facilities and lead to land take and soil compaction, as well as impacts on marine sediments from port expansion. There is the potential to mitigate for the negative effects at this stage of the action plan by selecting brownfield land for the necessary developments.

Action Theme Six: Strengthening research and innovation

6.26 This Action Theme aims to ensure that there is ongoing research and development taking place along with the establishment of hydrogen production and the hydrogen economy in Scotland. Research and development activities will enable innovation and collaboration.

6.27 Direct effects will relate to new employment opportunities within research and development and construction of necessary facilities.

6.28 For Action Theme Six, direct effects have been identified for the following SEA topics:

- Population and human health;
- Soil;
- Material assets.

Population and human health

6.29 **Minor positive effects** are identified in relation to population and human health as this Action Theme is likely to deliver employment opportunities within research and development, supporting health and wellbeing. However, it is likely to be of smaller scale with research and innovation facilities dispersed across the country. It is assumed that the majority of the research activities will take place within the next 20 years to ensure the most effective implementation of the hydrogen economy.

Soil

6.30 Research and development activities may require additional facilities, and therefore it is assumed that minor development will be linked with this Action Theme. However, it is assumed that most of the developments are going to be delivered on previously developed land in areas where hydrogen production is expected, therefore **negligible negative effects** are expected on soil in a form of soil sealing and loss of soil carbon.

Material assets

6.31 Research and development facilities will require materials, energy and equipment necessary for the construction phase of the development and due to the anticipated scale of development **negligible negative effects** are expected in relation to material assets arising from Action Theme Six.

Hydrogen Energy Hubs

6.32 The Draft Hydrogen Action Plan identifies potential Hydrogen Energy Hubs within Scotland. Four of these (Orkney, Aberdeen & North East, Grangemouth, and Western Isles) are producing hydrogen, whilst those located in (Shetland, Cromarty Firth, Dundee, Fife, Glasgow and Argyle/Islands, and Ayrshire) currently have plans to produce hydrogen in the future. The environmental effects are identified at a regional scale.

Grangemouth

6.33 The Draft Hydrogen Action Plan identifies the potential of industrial clusters such as Grangemouth, which currently produces hydrogen at a large-scale, to become hubs of low-carbon hydrogen production.

6.34 The development of a potential Hydrogen Energy Hub at Grangemouth will create low-carbon hydrogen by utilising SMR technology. Low-carbon hydrogen promotes the continued use of natural gas, which could have adverse effects on climatic factors. However, the carbon emissions are proposed to be captured and transported for offshore storage. This would reduce the amount of carbon released to the atmosphere. Furthermore, the utilisation of hydrogen power for industrial use at Grangemouth as well as more widely in transport and heating, could have **positive effects** on **climatic factors** by displacing the use of traditional fossil fuels.

6.35 Some negative effects may arise in relation to climatic factors from the leakage of carbon during storage and transportation, however this is expected to be minimal. Likewise, the increased energy required for storage, transport and CCUS, and increased commuting of workers may result in carbon emissions. Overall, compared to the current baseline the positive effects for climatic factors are judged to outweigh the negatives.

6.36 Reduced direct use of fossil fuels could have subsequent benefits for air quality due to the greater uptake of hydrogen. Combustion of natural gas to produce low-carbon hydrogen has fewer air quality impacts than other fossil fuels, but still emits air pollutants. Minor negative effects may arise in relation to air quality during transportation of hydrogen, or people travelling to/from work, depending on the fuel source used. Furthermore, emissions released during extraction of natural gas, or ammonia released during hydrogen storage will also have adverse effects on air quality, but this is expected to be minimal. Compared to the baseline air quality emissions from Grangemouth, overall minor **positive effects** are expected in relation to **air quality.**

6.37 Associated benefits linked to air quality and climatic factors are also expected in relation to population and human health. Overall improvements in air quality will reduce adverse health outcomes amongst the population. Additionally, deployment of hydrogen will reduce the effects of climate change, minimising risk associated with extreme weather events. Furthermore, the expansion of hydrogen production in Grangemouth will provide local job and training opportunities which could benefit the population through supporting health and quality of life. Therefore, minor **positive effects** are identified in relation to **population and human health.**

6.38 Although the construction of the hydrogen hub will require materials, impacting on finite resources, the deployment of hydrogen is likely to have minor **positive effects** on **material assets** by improving the reliability, security and flexibility of energy supply, and by reusing existing oil and gas infrastructure.

6.39 As the potential Hydrogen Energy Hub at Grangemouth will likely be sited on brownfield land impacts on soil quality and biodiversity will be limited. However, any pipeline works for captured carbon may have adverse effects on soil quality and biodiversity, although the effects would be managed through the planning system. Overall, minor **mixed effects** are expected in relation to **soil**. Increased transport of hydrogen by ship in the Firth of Forth may have detrimental effects on marine life including European sites. Minor **negative effects** are therefore expected on **biodiversity**.

6.40 Use of brownfield land is likely to minimise adverse effects in relation to the **landscape** and **cultural heritage and the historic environment** and negligible adverse effects are identified.

6.41 There could be minor **negative effects** on **water** due to the significant quantities which are required to produce hydrogen. All areas of Scotland are anticipated to experience reduced summer rainfall under future climate projections. This could result in water shortages if taken from on land, or potential pollution of the marine environment due to the salty pulp generated as part of the desalination process.

Aberdeen and North East

6.42 The Draft Hydrogen Action Plan identifies Aberdeen and North East as a potential Hydrogen Energy Hub. This area will be producing renewable hydrogen, including at St. Fergus and Peterhead taking advantage of the nearby windfarms. The Acorn project in Aberdeen will produce low-carbon hydrogen with CCUS. Low-carbon hydrogen promotes the continued use of natural gas, having negative effects on climatic factors. However, the carbon emissions will be captured and stored. Therefore, compared to fossil fuels or hydrogen without CCUS, there will be a reduction in the amount of carbon released to the atmosphere.

6.43 In addition, the deployment of hydrogen power for industrial or transport uses will have positive effects on climatic factors by displacing the use of traditional fossil fuels. However, transport of hydrogen may have some negative effects depending on how it is transported. Pipelines are likely to have limited effects, but transport via marine vessel or vehicles may have negative effects depending on the fuel source. Marine transportation is currently diesel powered and unlikely to switch to lower carbon sources of fuel in a short timeframe.

6.44 Small scale leakage of carbon during storage and transportation is likely to have minor negative effects in relation to climate change. Likewise, the increased energy required for storage, transport and CCUS, and increased commuting of workers may result in more carbon emissions. Overall, compared to the baseline, the minor **positive effects** for the **climate** are judged to outweigh the negatives.

6.45 Subsequent benefits for air quality are likely to arise due to the greater uptake of hydrogen and reduced use of fossil fuels. Some minor negative effects may arise from transportation of hydrogen, transport of workers, extraction of natural gas, and release of ammonia during storage. However, this is expected to be minimal. Overall, **minor positive effects** are expected in relation to **air quality.**

6.46 Changes in the distribution of air pollution emissions as a result of hydrogen production and use may reduce adverse health outcomes amongst the population. However, the air quality impacts depend on the deployment of hydrogen and its use in transport or industry. Furthermore, hydrogen use is likely to reduce the effects of climate change, minimising risk associated with extreme weather events. Additionally, the creation of the potential Hydrogen Energy Hub may provide local job and training opportunities which would benefit the population through supporting health and wellbeing. Uptake of hydrogen as a domestic fuel (hydrogen boilers) in the north east may also help reduce fuel poverty. Therefore, minor **positive effects** are identified in relation to **population and human health.**

6.47 The deployment of hydrogen is likely to have minor **positive effects** on **material assets** by improving the reliability, security and flexibility of energy supply, and by reusing old oil and gas infrastructure.

6.48 Hydrogen development in the north-east will likely be sited on brownfield land and make use of existing oil and gas infrastructure. Impacts on soil quality and biodiversity are likely to be limited. However, any upgrades required to the pipelines and port infrastructure may have adverse effects on soil quality and biodiversity, although the effects would be managed through the planning system. Use of brownfield land will have negligible **positive effects** in relation to **soil**, the **landscape** and **cultural heritage.**

6.49 There could be minor **negative effects** on **water** due to the large quantities which are required for hydrogen production. All areas of Scotland are anticipated to experience reduced summer rainfall under future climate projections. This could result in water shortages if taken from on land, or potential pollution of the marine environment due to the salty pulp generated as part of the desalination process. Furthermore, upgrades to port infrastructure at Peterhead may have further negative effects on the marine environment.

Shetland & Orkney

6.50 Shetland and Orkney are also identified as potential hydrogen hubs. Both island groups have some of the best wind conditions in Europe and can produce onshore and offshore wind through both small-scale community owned and commercial scale renewable schemes. This renewable energy could be used to produce renewable hydrogen via electrolysis.

6.51 Renewable hydrogen is produced at Orkney as a result of the abundant renewable energy sources on the island. Shetland, which does not currently produce hydrogen would be primarily focused on producing renewable hydrogen, taking advantage of the nearby windfarms. It is currently planned to produce local wind-powered hydrogen by 2025. There is also potential for low-carbon hydrogen production at Shetland considering the remaining oil and gas resources. However, the key aims for Shetland are to produce renewable hydrogen for export at an industrial scale using offshore wind power, transform dependency from fossil fuels to affordable renewable energy, and enabling the oil and gas sector to transition to net zero by 2030.

6.52 Renewable hydrogen production will result in no direct carbon emissions, as electricity from renewable energy powers the process. Therefore, the deployment of hydrogen could reduce reliance on fossil fuels, having minor **positive effects** on **climatic factors**. Some emissions may leak during transportation and storage, but this is expected to be minimal.

6.53 Positive effects on climate factors are further enhanced by the uptake of hydrogen for industrial or transport uses. However, transport of hydrogen may have negative effects depending on how it is transported. Pipelines are likely to have limited effects, but transport via marine vessel or vehicles may have negative effects depending on the fuel source. Marine transportation is diesel powered and unlikely to switch to renewable sources of fuel in a short timeframe. Overall, compared to the baseline, the minor **positive effects** for the **climate** are judged to outweigh the negatives.

6.54 Use of hydrogen will have minor **positive effects** on **air quality**. Minor negative effects may arise from transportation of hydrogen, extraction of natural gas, and release of ammonia during storage. Overall compared to the baseline, positive effects are judged to outweigh the negative effects.

6.55 Changes in the distribution of air pollution emissions as a result of hydrogen production and use may reduce respiratory illness amongst the population. However, the air quality impacts depend on the deployment of hydrogen and its use in transport or industry. Improvements to air quality and climatic factors will have subsequent minor **positive effects** for **population and human health**, by reducing adverse health outcomes. Hydrogen use could also reduce the effects of climate change, minimising risk associated with extreme weather events and will reduce fuel poverty. Additionally, new jobs associated with the hydrogen facilities are likely to have positive effects on the population through supporting health and wellbeing. The deployment of hydrogen is also likely to have minor **positive effects** on **material assets** by improving the reliability, security and flexibility of energy supply, and by reusing old oil and gas infrastructure in the case of low-carbon hydrogen.

6.56 Hydrogen development will likely be sited on brownfield land, and where possible make use of existing oil and gas infrastructure. Impacts on soil quality and biodiversity are likely to be limited, having neutral effects. However, any upgrades required to the pipelines and port infrastructure may have adverse effects on soil quality and biodiversity, although the effects would be managed through the planning system. Overall, minor **mixed effects** are expected in relation to **soil** and **biodiversity**. Furthermore, such developments are likely to result in minor **negative effects** on the **landscape** and **historic environment.**

6.57 Large quantities of water are likely to be required to produce both renewable and low-carbon hydrogen. This could result in water shortages if taken from on land, as 9 kg (9L) of water is consumed for every kilogram of hydrogen produced[272], or potential pollution of the marine environment due to the salty pulp generated as part of the desalination process. All areas of Scotland are anticipated to experience reduced summer rainfall under future climate projections. Therefore, minor **negative effects** are expected in relation to **water**. Furthermore, upgrades to port infrastructure at Shetland and Orkney may have further negative effects on the marine environment.

Cromarty Firth, Dundee & Fife

6.58 The potential Hydrogen Energy Hubs proposed in Cromarty Firth, Dundee and Fife will all produce renewable hydrogen from onshore and offshore renewable energy. The renewable hydrogen produced would initially provide zero carbon energy for homes in Fife, the transport sector in Dundee, and industry (distilleries) near Cromarty Firth.

6.59 The Cromarty Distilleries Project aims to have a 35MW electrolyser facility operational by the end of 2024, which would produce up to 14 tonnes of renewable hydrogen per day to meet the demands of local distilleries. Excess hydrogen production is expected to be distributed into the region for heat and transport, and potentially exported, further in the future.

6.60 The production of renewable hydrogen does not release any direct carbon emissions as electricity from renewable sources splits water into hydrogen and oxygen by electrolysis. This form of hydrogen is likely to have positive effects on climatic factors. It is expected that hydrogen will be transported via pipeline directly to homes and industry in Fife and the Cromarty Firth areas, respectively. Transportation for use in the transport sector in Dundee could be via tanks and there is greater risk of leakage during transportation or storage. However, emissions would be minimal and negative

[272] Beswick, R., Oliveira, A. and Yan, Y. (2021). Does the Green Hydrogen Economy Have a Water Problem?. ACS Energy Letters, [online] Available at: https://pubs.acs.org/doi/10.1021/acsenergylett.1c01375 (accessed 28/10/2021)

effects on the climate would be minor. Overall, the deployment of hydrogen is likely to reduce reliance on fossil fuels, having minor **positive effects** on **climatic factors** compared to the baseline.

6.61 Use of hydrogen as an energy source is likely to have minor **positive effects** on **air quality**, by displacing the use of fossil fuels. Minor negative effects may arise from transportation of hydrogen, commuters travelling to/from hydrogen facilities, and release of ammonia during storage. However, the positive effects are judged to outweigh the negative effects.

6.62 Improvements to air quality and climatic factors may have subsequent minor **positive effects** for **population and human health**, by reducing adverse health outcomes. Changes in the distribution of air pollution emissions as a result of hydrogen production and use may reduce respiratory illness amongst the population. However, the air quality impacts depend on the deployment of hydrogen and its use in transport or industry. Hydrogen use could also reduce the effects of climate change, minimising risk associated with and frequency of extreme weather events. Provision of hydrogen directly to homes in Fife may also help reduce fuel poverty in the area. Additionally, new jobs associated with each of the hydrogen facilities and supporting renewable energy schemes could have positive effects on the population through supporting health and wellbeing.

6.63 The deployment of hydrogen is likely to have minor **positive effects** on **material assets** by improving the reliability, security and flexibility of energy supply. However, minor negative effects may arise as utilising renewable hydrogen is a less efficient way of delivering energy, compared to providing electricity straight from renewable developments to be used as electricity.

6.64 Hydrogen development will likely be sited on brownfield land in existing industrial areas. Therefore, impacts on soil quality and biodiversity and habitats will be minimised. However, any upgrades and installation of pipelines to transport hydrogen may result in soil disturbance, compaction and carbon loss. Associated negative effects may arise for biodiversity as a result of pipeline work, both on land and offshore to offshore wind farms. Overall, minor **mixed effects** are expected in relation to **soil** and **biodiversity**. Furthermore, such developments are likely to result in minor **negative effects** on the **landscape** and **historic environment**.

6.65 Large quantities of water are likely to be required to produce both renewable and low-carbon hydrogen. This could result in water shortages if taken from on land. As Dundee, Fife and Cromarty Firth will each produce renewable hydrogen either entirely or partially, by offshore wind, a significant proportion of water used is likely to be fresh water. This will potentially impact on the fresh water and groundwater availability for other sectors and uses in the area. Therefore, minor **negative effects** are expected in relation to **water**. This could have associated negative effects for biodiversity, flora and fauna with impacts on European sites.

Argyle/Islands, Glasgow & Western Isles

6.66 It is assumed that the potential Hydrogen Energy Hubs on the Western Isles and Argyle/Islands, and in Glasgow will each produce renewable hydrogen from renewable energy developments (e.g., onshore and offshore wind, solar tidal energy, wave energy etc.). The hydrogen plant in Glasgow would be powered by Whitelee Wind Farm and would provide low carbon energy for transport and industry in the area. Hydrogen produced on the islands would likely provide a low-carbon energy source for domestic use and transport.

6.67 As renewable hydrogen does not result in carbon emissions, minor **positive effects** are expected in relation to **climatic factors.** It is expected that hydrogen will be transported via pipeline and vehicles or marine vessels (particularly between islands). Transportation of hydrogen via vehicles or marine vessels could have negative effects on carbon emissions, depending on the fuel source used. Marine vessels are powered by fossil fuels and unlikely to have a lower carbon alternative in the short term. However, emissions would be minimal and negative effects on the climate would be minor. Overall, the deployment of hydrogen is likely to reduce reliance on fossil fuels, having minor **positive effects** on **climatic factors.**

6.68 Use of hydrogen as an energy source could have minor **positive effects** on **air quality**, by displacing the use of fossil fuels. The combustion of hydrogen as a fuel can have air quality impacts through the release of NOx. Minor negative effects may arise from transportation and storage of hydrogen, and commuters travelling to/from hydrogen facilities and other supporting renewable energy developments.

6.69 Improvements to air quality will have subsequent minor **positive effects** for **population and human health**. Furthermore, reducing the effects of climate change through uptake of hydrogen, will minimise the risk of extreme weather events such as drought or storms. Additionally, new jobs associated with each of the hydrogen facilities and supporting renewable energy schemes may have positive effects on the population through supporting health and wellbeing.

6.70 The deployment of hydrogen is likely to have minor **positive effects** on **material assets** by improving the reliability, security and flexibility of energy supply. However, minor negative effects may arise as utilising renewable hydrogen is a less efficient way of delivering energy, compared to providing electricity straight from renewable developments.

6.71 Hydrogen facilities could be sited on greenfield land, and subsequently have minor **negative effects** on **soil** quality and **biodiversity** habitats. If sited on brownfield land, negative effects would be reduced. Furthermore, the installation of pipelines to transport hydrogen or the development of any renewable energy schemes on land will also result in soil disturbance, compaction and carbon loss. Associated negative effects may arise for biodiversity as a result of such development. In addition, renewable energy developments to support such developments are likely to result in minor **negative effects** on the **landscape** and **historic environment**, particularly as a result of cumulative developments.

6.72 Large quantities of water are required to produce renewable hydrogen. If this water is sourced from watercourses or waterbodies on land, this could result in water shortages in spring and summer. If it is sourced from the sea, it will need to be desalinated. The by-products of this process could have negative effects on the marine environment. All areas of Scotland are anticipated to experience reduced summer rainfall under future climate projections. Therefore, minor **negative effects** are identified in relation to **water**. This could have associated adverse effects on marine biodiversity including European sites.

Ayrshire

6.73 It is assumed that the potential Hydrogen Energy Hub in Ayrshire will produce renewable hydrogen. This area has extensive renewable energy resources, notably onshore wind. The hydrogen would be either produced on site, or elsewhere via a power purchase agreement (PPA). Hydrogen produced would likely provide a low-carbon energy source for domestic use, industry and/or transport.

6.74 As renewable hydrogen does not result in carbon emissions, minor **positive effects** are expected in relation to **climatic factors**. It is expected that hydrogen will be transported via pipeline and vehicles. Transportation of hydrogen via vehicles could have negative effects on carbon emissions, depending on the fuel source used. However, emissions would be minimal and negative effects on the climate would be minor. Overall, the deployment of hydrogen could reduce reliance on fossil fuels, having minor **positive effects** on **climatic factors.**

6.75 The displacement of fossil fuels may have minor **positive effects** on **air quality**. Minor negative effects may arise from transportation and storage of hydrogen, and commuters travelling to/from hydrogen facilities and other supporting renewable energy developments. The combustion of hydrogen as a fuel can have air quality impacts through the release of NO_x. However, it is likely to bring about improvements to air quality which will have associated minor **positive effects** for **population and human health.** Furthermore, reducing the effects of climate change through uptake of hydrogen, will minimise the risk of extreme weather events such as drought or storms. Additionally, new jobs associated with each of the hydrogen facilities and supporting renewable energy schemes may have positive effects on the population through providing employment and supporting health and wellbeing.

6.76 The deployment of hydrogen could have minor **positive effects** on **material assets** by improving the reliability, security and flexibility of energy supply. However, minor negative effects may arise as utilising renewable hydrogen is a less efficient way of delivering energy, compared to providing electricity straight from renewable developments.

6.77 Hydrogen facilities would likely be sited on brownfield land at Hunterston Port area, and subsequently effects on soil quality and biodiversity would be minimised compared to if on greenfield land. Furthermore, the installation of pipelines to transport hydrogen (if required) or the development of any renewable energy schemes on land will also result in soil disturbance, compaction and carbon loss. Associated negative effects may arise for biodiversity as a result of such development. Overall, minor **mixed effects** are expected in relation to **soil** and **biodiversity**.

6.78 In addition, renewable energy developments to support such developments are likely to result in minor **negative effects** on the **landscape** and **historic environment**, particularly as a result of cumulative developments. However, development of hydrogen facility on previously developed land at Hunterston would have negligible effects on landscape character and the historic environment.

6.79 Large quantities of water are required to produce renewable hydrogen. If this water is sourced from watercourses or waterbodies on land, this could result in water shortages in spring and summer. All areas of Scotland are anticipated to experience reduced summer rainfall under future climate projections. If it is sourced from the sea, it will need to be desalinated. The by-products of this process could have negative effects on the marine environment. Therefore, minor **negative effects** are expected in relation to **water**.

Indirect effects

6.80 The overall aim of the Draft Hydrogen Action Plan is to enable hydrogen production and the hydrogen economy in Scotland.

6.81 Building on the 'Environmental baseline' chapter, indirect effects are considered in relation to each SEA topic.

6.82 The text firstly describes generic effects on each SEA topic in relation to manufacturing, hydrogen storage, hydrogen transportation and hydrogen deployment for heating, transport fuel, industry and energy storage, then draws out environmental effects specific to the Action Themes of the draft HAP.

Biodiversity, flora and fauna

Manufacturing

6.83 Renewable hydrogen production needs substantial quantities of water. In offshore locations, or coastal locations with limited freshwater supply, the desalination process is required which results in a by-product, a very concentrated brine, which normally is released to the sea having negative effects on the marine ecosystems. Brine comprises of about 5% salt and often includes toxins and heavy metals. It is somewhat saltier than sea water and therefore can cut levels of oxygen in the sea near desalination plants having adverse effects on shellfish and other creatures living on the seabed, with additional negative indirect impacts on other species up the food chain[273].

6.84 Low-carbon hydrogen production plants are assumed to be mainly delivered on previously developed land in areas where oil and gas industry is currently located. Therefore, no significant effects on biodiversity, flora and fauna are identified.

Storage

6.85 Hydrogen storage in the form of high-pressure storage dewars will have negative effects on biodiversity, especially during the construction phase as the facilities will require additional land. Considering that there is a limit to how much hydrogen can be condensed, the volumes of hydrogen produced are likely to be substantial. Moreover, in order to ensure that hydrogen is available in strategic locations, it will be necessary to construct storage facilities across the country making hydrogen available for different uses. This may result in additional land take having permanent **negative effects** on biodiversity limiting space for habitats and species.

Transportation

6.86 Transportation of hydrogen in pipelines, particularly if existing oil and gas infrastructure is used, is likely to have negligible effects on biodiversity. However, transportation via road may negatively impact on biodiversity if fossil fuel powered vehicles are used for transportation. It is assumed that over time all vehicles would be powered by low carbon hydrogen or electricity leading to an overall reduction of the GHG from transportation (see **Air** for more details).

Deployment

6.87 No indirect effects are identified in relation to biodiversity. However changing water and air quality as a result of reduced emissions will have a positive impact on biodiversity in the long term (see **Air** and **Water**).

Themes

6.88 The indirect effects of Action Theme One relate broadly to all of the issues described above. Furthermore, indirect effects of Action Theme One highlight the need for the regulatory, planning and consent framework to consider the longer term biodiversity impacts from water abstraction and desalinisation, as relevant to both renewable and low-carbon hydrogen production. The indirect effects of Action Theme Two relate broadly to all of the issues described above.

6.89 The indirect effects of Action Theme Three include broader benefits across Scotland from increased efficiency of the energy system, reducing overall additional energy production demand, and associated land take and biodiversity, flora and fauna impacts from additional new development. In addition, this also supports lower emissions overall, reducing climate change impacts and associated effects on flora and fauna. These effects are minor positive but widespread across Scotland.

6.90 The indirect effects of Action Theme Four relate broadly to all of the issues described above. There is scope for **enhancement** of Action Theme Four, through ensuring that skills and training to support the supply chain and online tools to support hydrogen development focus on understanding the direct and indirect environmental effects of hydrogen use and deployment on biodiversity, flora and fauna. It should also mitigate against potential adverse effects by encouraging training and guidance on best practice techniques.

6.91 The indirect effects of Action Theme Five include the export and wider use of hydrogen in other countries. This will result in indirect positive effects on air quality, and as a consequence benefit for biodiversity which is negatively impacted by poor air quality.

6.92 There is scope for **enhancement** of Action Theme Six, through ensuring that research and innovation also focuses on understanding the direct and indirect environmental effects of hydrogen use and deployment on biodiversity, flora and fauna.

[273] Doyle, A., (2019) Too much salt: water desalination plants harm environment: U.N. Reuters. [online] Available at: https://www.reuters.com/article/us-environment-brine-idUSKCN1P81PX (accessed 20/08/2021)

Population and human health

Manufacturing

6.93 The construction and operation of hydrogen production facilities, including electrolysers, and storage facilities could have adverse effects on population and human health. Construction activities relating to each component of the hydrogen facility could result in short term noise and dust pollution which may affect nearby residents, having adverse effects on their quality of life. These effects would be limited to the construction phases and managed through planning mechanisms. These activities will also support employment in the sector, supporting health and wellbeing through the transition to a low carbon economy.

Storage

6.94 The buoyancy of hydrogen and its very high diffusivity must be recognised and effectively harnessed through informed design in order to reduce the risk from fire and explosion, particularly during storage. Hydrogen escaping from pressurised systems moves rapidly upwards and, in appropriately designed installations, away from sources of ignition to be quickly dispersed into a safe area. In contrast, petrol and LPG releases tend to remain near the point of release for some considerable time and may spread or roll along the floor some considerable distance until eventually dispersed or ignited[274]. Therefore, if storage facilities are appropriately designed negligible effects should be expected on population and human health.

Transportation

6.95 Transportation of hydrogen in pipelines is likely to have negligible effects on population and human health. However, transportation via road in cryogenic and compression tankers could result in potential positive and negative effects on human health, depending on the fuel source for the vehicle transporting the hydrogen. Transport of hydrogen via road or marine vessels could have negative effects on air quality if these transportation modes are powered by fossil fuels, with associated impacts on human health. Conversely, transport powered by sustainable fuels could reduce air pollution, having positive impacts on population and human health.

Deployment

6.96 The deployment of hydrogen, particularly in the industrial and transport sectors can contribute towards long term improvements in air quality, having associated benefits for population and human health. Likewise, the displacement of fossil fuels will reduce contribution to climate change, may have additional positive effects on human health by minimising the frequency of extreme weather events such as drought, wildfires, and flooding.

6.97 However, as hydrogen is colourless, odourless and tasteless, there is a greater risk of leaks going undetected. Although hydrogen is non-toxic and non-carcinogenic, it can act as an asphyxiant, a substance that can cause unconsciousness or death by suffocation. Additives such as ethyl isobutyrate can be added to hydrogen gas to give it an odour which helps detect any leakages. This is similar to the process of adding mercaptan to natural gas. One of the most important hazardous qualities of hydrogen is its flammability which is frequently invisible, has a high temperature flame and it can form explosive mixtures with air[275]. However, it is also argued that hydrogen is not inherently more dangerous that other fuels, such as natural gas or gasoline, but its properties are unique and must be handled with appropriate care (see **Material Assets**). The safety of hydrogen needs to be assessed taking into account the particular circumstances in which it will be used[276]. Therefore, it is crucially important to ensure that the design of systems and processes prevents from any potential leaks.

6.98 Renewable and low-carbon hydrogen will lead to an overall reduction of GHG from energy production, and as a result will improve air and water quality and will benefit human health. However, increased demand for fresh water, required for electrolysis process may lead to water scarcity issues (see **Water**).

6.99 Hydrogen will continue to contribute to climate change through increasing the global warming potential of methane and tropospheric ozone. This will negatively impact on climatic factors and air quality (see **Climatic factors** and **Air**) enhancing climatic changes and leading to negative consequences for population and human health by further enhancing climatic changes[277].

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[274] Ricci, M., Newsholme, G., Bellay, P., Flynn, R. (2006) 'Hydrogen: too dangerous to base out future upon?' Symposium Series No. 151 [online] Available at: https://www.icheme.org/media/9792/xix-paper-04.pdf (accessed 19/08/2021)
[275] Ricci, M., Newsholme, G., Bellay, P., Flynn, R. (2006) 'Hydrogen: too dangerous to base out future upon?' Symposium Series No. 151 [online] Available at: https://www.icheme.org/media/9792/xix-paper-04.pdf (accessed 19/08/2021)
[276] Ricci, M., Newsholme, G., Bellay, P., Flynn, R. (2006) 'Hydrogen: too dangerous to base out future upon?' Symposium Series No. 151 [online] Available at: https://www.icheme.org/media/9792/xix-paper-04.pdf (accessed 19/08/2021)
[277] Department for Business, Energy & Industrial Strategy (2018) Hydrogen for heating: atmospheric impacts – a literature review. [online] Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/760538/Hydrogen_atmospheric_impact_report.pdf (accessed 20/08/2021)

Themes

6.100 The indirect effects in relation to Action Theme One relate broadly to the issues described above. Furthermore, indirect effects on Action Theme One highlight the need to ensure that regulatory, planning and consent framework considers human health and safety, as relevant for the distribution of both renewable and low-carbon hydrogen. It will be crucial for standards to ensure that installations are safe to use in domestic and industrial settings.

6.101 The indirect effects in relation to Action Theme Two relate broadly to the issues described above.

6.102 The indirect effects of Action Theme Three include broader benefits across Scotland from increased efficiency of the energy system, reducing overall additional production demand from other sources, and their associated impacts on population and human health. Hydrogen production is likely to lead to overall reductions in GHG emissions, reducing climate change impacts and improving the resilience of the population. Potential enhancement of Action Theme Three would include consideration of the cumulative effects of hydrogen production and distribution on population and human health.

6.103 The indirect effects of Action Theme Four broadly relate to the issues described above. In addition, there is scope for enhancement of Action Theme Four, through ensuring that skills and training to support the supply chain and online tools to support hydrogen development focus on understanding the direct and indirect environmental effects of hydrogen on population and human health.

6.104 The indirect effects from Action Theme Five include the future export and wider use of hydrogen in other countries resulting in indirect positive effects on air quality, and as a consequence benefits for the population. The type of hydrogen deployment will determine the precise impacts on population and human health, however there will be benefits from where hydrogen displaces more polluting fuels.

6.105 There is scope for enhancement of Action Theme Six, through ensuring that research and innovation also focuses on understanding the direct and indirect environmental effects of hydrogen use and deployment on population and human health, in the short and longer term beyond 2100. It will be crucially important to understand the potential impacts of long-term carbon storage underground and to have more certainty over whether hydrogen will be suitable as a domestic heating fuel.

Soil

6.106 Hydrogen is somewhat unusual among trace gases in that, although its life cycle has been heavily influenced by human activities, its mixing ratios in the northern hemisphere are lower than those in the southern hemisphere. This phenomenon is caused by the main sink for hydrogen, surface uptake by soils, which accounts for 80% of the total loss of hydrogen from the atmosphere. The majority of the sink is therefore occurring over the continental land masses in the northern hemisphere[278]. Soil resources also act as an important sink for carbon.

Manufacturing

6.107 There is potential for hydrogen and carbon stored in soils to be lost during the manufacturing process for hydrogen production, including associated manufacturing needs such as for fuel cells. Both carbon and hydrogen stored in soils may be released due to disturbance of soils and/or land take when constructing hydrogen production facilities.

6.108 Any required developments at sea for the production or transportation of hydrogen may have negative consequences on marine sediments and lead to habitat degradation.

6.109 It is assumed that low-carbon hydrogen will mainly reuse existing infrastructure from the oil and gas industry. There may be a need for additional facilities, however, these are assumed to be delivered within the vicinity of the gas and oil industry, in co-location with sources of demand and therefore on brownfield and already developed land. There is the potential for disturbance to soils and land take for the purposes of carbon and hydrogen storage, that would lead to negative effects.

Storage

6.110 The development of storage facilities for hydrogen and captured carbon, both above and below ground, and associated hydrogen infrastructure (e.g., factories for fuel cell production) could also result in land take and disturbance to soils.

Transportation

6.111 Any upgrades to or construction of new pipelines for transportation purposes may have associated impacts on soil quality through disturbance and excavation. These would likely be short term in nature, occurring predominantly in the construction phases, and would be managed through planning mechanisms such as EIA.

[278] Derwent, R., Simmonds, P., O'Doherty, S., Manning, A., Collins, W., Johnson, C., Sanderson, M., Stevenson, D. (undated) Global environmental Impacts of Hydrogen Economy. [online] Available at: https://www.geos.ed.ac.uk/~dstevens/Presentations/Papers/derwent_ijhr06.pdf (accessed 19/08/2021)

Deployment

6.112 Effects on soil arising from the deployment of hydrogen will primarily relate to infrastructure improvements for manufacturing, storage and transport of hydrogen. However, additional infrastructure to support hydrogen may be required at its end location (e.g., industrial sites, fuelling stations, fuel cells). This may involve additional land take with permanent negative effects on soil. Although fuel cells intended for vehicles will have no effect on soils, larger fuel cells for industrial purposes may result in loss of land. Once the appropriate infrastructure is in place, deployment of hydrogen will likely have negligible effects on soil resources.

6.113 Both types of hydrogen will require supporting infrastructure and pipelines. Any upgrades to pipelines or construction of new pipelines will lead to soil disturbances and excavation. Over the operational phase of the development, maintenance and safety works may be required resulting in potential negative effects on soils from excavation activities.

Themes

6.114 The indirect effects in relation to Action Theme One and Two relate broadly to the issues described above. Furthermore, the indirect effects of Action Theme One highlight the need to ensure that the regulatory, planning and consent framework considers soil impacts from both renewable and low-carbon hydrogen developments and supporting infrastructure. This includes hydrogen production facilities, hydrogen and carbon storage which all have the potential for negative effects on soil. The key enhancement opportunity for Action Theme One is to consider the cumulative effects of extensive hydrogen developments and supporting infrastructure on soil.

6.115 The indirect effects in relation to Action Theme Two relate broadly to the issues described above.

6.116 The indirect effects of Action Theme Three include broader benefits across Scotland from increased efficiency of the energy system, reducing overall additional energy production demand, and associated impacts on soil. Hydrogen production is likely to lead to overall reductions in GHG emissions, reducing future climate change impacts.

6.117 There is scope for enhancement of Action Theme Four, through ensuring that skills and training to support the supply chain and online tools to support hydrogen development focus on understanding the direct and indirect environmental effects of hydrogen use and deployment on soil. Training and all elements of the supply chain should aim to mitigate against potential adverse effects by encouraging training in relation to minimising effects on soil and promoting guidance on best practice techniques.

6.118 The indirect effects from Action Theme Five include the export and wider use of hydrogen in other countries resulting in indirect effects on soil quality. Negative impacts on soil such as soil compaction arise from hydrogen storage facilities and distribution network.

6.119 There is also scope for enhancement of Action Theme Six, through ensuring that research and innovation focuses on understanding the direct and indirect environmental effects of hydrogen use and deployment on soil in the long term, especially considering that there is likely to be an increased amount of hydrogen in the atmosphere from fugitive emissions and how this would impact on the hydrogen cycle and hydrogen's main sink, the soil.

Water

Manufacturing

6.120 Large scale production of renewable hydrogen requires significant quantities of water. It is suggested that some of the electrolysis process from offshore wind renewable energy may take place at sea; and hence, this will require water desalination and additional energy to carry out the process. Overall, the desalination process could have negative effect on water quality and marine ecosystems (see **Biodiversity**).

6.121 Onshore electrolysis processes carried out on land, will utilise freshwater from rivers and lochs. This may lead to water shortages especially in spring and summer months, as 9 kg (9L) of water is consumed for every kilogram of hydrogen produced[279]. Water shortage issues may be further exacerbated by the changing climate and unpredictable weather conditions such as droughts. This may lead to water pressure conflicts between different uses such as hydrogen production, agriculture and domestic use, and will have ecological impacts if it exacerbates low flow conditions. This will lead to raised levels of pollution and increased temperature variability. These impacts could be most pronounced in areas most sensitive to the impacts of climate change on water availability and supply.

6.122 There is a significant amount of uncertainty in relation to water requirements for the low-carbon hydrogen production. Most resources assume that low-carbon hydrogen requires significantly less water than renewable hydrogen. However, there are studies that indicate that water consumption of the

[279] Beswick, R., Oliveira, A. and Yan, Y. (2021). Does the Green Hydrogen Economy Have a Water Problem?. ACS Energy Letters, [online] Available at: https://pubs.acs.org/doi/10.1021/acsenergylett.1c01375 (accessed 28/10/2021)

low-carbon hydrogen production process may be comparable with that of renewable hydrogen[280] [281] or only slightly less.

Storage, Transportation and Deployment

6.123 The storage and transportation of hydrogen will have negligible effects on water. Likewise, deployment of hydrogen is unlikely to have adverse effects on water quality, however water will be released from fuel cells as a by-product.

Themes

6.124 The indirect effects in relation to Action Theme One relate broadly to the issues described above. Furthermore, the indirect effects of Action Theme One highlight the need to ensure that the regulatory, planning and consent framework considers the potential impacts on sea and fresh water from both renewable and low-carbon hydrogen developments and supporting infrastructure. Water quantity and quality may be compromised because of the large-scale renewable hydrogen production. Therefore, there is a key opportunity for enhancement of Action Theme One, for the regulatory framework to consider the cumulative effects of extensive hydrogen development and supporting infrastructure on water. The regulatory framework should identify strategic locations for the onshore renewable hydrogen facilities which would be in the vicinity of freshwater supply without increasing the pressure on other water uses in the area. In terms of the offshore desalination processes, there is a need for regulations relating to the release of the brine. In order to reduce the potential adverse effects brine could for example be diluted before the release.

6.125 The indirect effects in relation to Action Theme Two relate broadly to the issues described above.

6.126 The indirect effects of Action Theme Three include broader benefits across Scotland from increased efficiency of the energy system, reducing overall additional energy production demand, however, it is likely to have negative effects on water. Hydrogen production is likely to lead to overall reductions in GHG emissions, reducing future climate change impacts and reduce the risk of unpredictable and extreme weather events.

6.127 There is scope for enhancement of Action Theme Four, through ensuring that skills and training to support the supply chain and online tools to support hydrogen development focus on understanding the direct and indirect environmental effects of hydrogen use and deployment on the water environment. Training and all elements of the supply chain should aim to mitigate against potential adverse effects by encouraging training and guidance on best practice techniques, particularly as large quantities of water will be used to produce hydrogen.

6.128 The indirect effects from Action Theme Five relate to the export and wider use of hydrogen in other countries, international collaboration on research, innovation and projects. The export and use of hydrogen could result in indirect effects on water. It is expected that renewable hydrogen will have more negative impacts on water through greater water abstraction and desalination processes, nevertheless, low-carbon hydrogen will still require some water for the production. These effects are mainly going to be experienced in Scotland, whereas the benefits of the hydrogen will be harnessed abroad.

6.129 The key enhancement opportunity for Action Theme Six includes ensuring that research and innovation focuses on understanding the direct and indirect environmental effects of hydrogen use and deployment on water. In particular, it should focus on optimising the desalination process and gaining an understanding of how the brine can be disposed of in the most environmentally friendly manner.

Air

Manufacturing

6.130 The manufacturing of hydrogen is unlikely to worsen air quality in Scotland. Through delivering carbon reductions from energy production air quality should improve over time. However, different types of hydrogen will have varied potential impacts. For low-carbon hydrogen, there are minor negative risks to air quality from the extraction of natural gas for the purposes of this process and then accordingly from carbon capture and storage. Even though in this technological setting, CO_2 emissions would be captured during the hydrogen production and then accordingly transported and stored, it is suggested that leakage of carbon could happen at multiple stages of the process.

6.131 In the case of renewable hydrogen, major risks to air quality are reduced, as this process will rely on renewable energy for the production process. However, fully renewable hydrogen energy systems will require significant wind energy capacity. This may result in temporary minor adverse effects on air quality arising during the construction phases of wind farm developments.

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[280] Noussan, M., Raimondi, P. P., Scita, R., Hafner, M. (2021) The Role of Green and Blue Hydrogen in the Energy Transition – A technological and Geopolitical Perspective. Sustainability. [online] Available at: https://www.mdpi.com/2071-1050/13/1/298 (accessed 08/09/2021)

[281] Hopcroft, T., Papadamou, A. (2021) The water industry in a hydrogen economy. PA Energy and Utility Experts. [online] Available at: https://www.paconsulting.com/newsroom/expert-opinion/the-water-report-the-water-industry-in-a-hydrogen-economy-12-july-2021/ (accessed 08/09/2021)

Storage

6.132 Hydrogen can be stored in various forms including compressed hydrogen gas, liquified hydrogen, and by turning the hydrogen into ammonia. The latter, in particular, poses risks to air quality if any ammonia is leaked, with associated negative impacts on human health and biodiversity. Additionally, energy requirements to facilitate the compression and liquification of hydrogen could contribute to negative effects on air quality, depending on the source of energy to enable storage processing.

Transportation

6.133 Any upgrades to or construction of new pipelines for transportation purposes may have associated impacts on air quality, although these would likely be short term in nature and managed through planning mechanisms such as EIA.

6.134 Transportation of hydrogen is largely via pipelines, ship or via the road in cryogenic/compression tankers in short to medium time scales. As previously mentioned, there are projects to explore hydrogen pipeline connections between Scotland and the rest of the UK and Europe in the longer term. Whilst transport via pipeline would have limited effects on air quality, transportation via road or marine vessels could result in adverse effects on air quality. This is largely dependent on the fuel used to power these vehicles and vessels. For example, hydrogen being distributed via diesel powered transport will result in additional air pollution from nitrous oxides, hydrocarbons and particulate matter. However, if transportation utilises clean fuel such as hydrogen or other means (e.g., electricity) effects on air quality will be negligible. Therefore, investment in pipelines would have negative short-term effects on ecosystems, soil, water, however in the longer term they could deliver more significant benefits by improving air quality and reducing the demand for transport fuel.

Deployment

6.135 Large-scale deployment of hydrogen, particularly in industry, shipping and heavy transport (including buses and heavy goods vehicles (HGVs) could contribute towards improvements in air quality if the hydrogen is combusted with fuel cells. Emissions from hydrogen-powered vehicles and vessels, primarily through use of fuel cells, will displace and eliminate the release of nitrogen oxides (NO_x), hydrocarbons, and particulate matter which are usually associated with petrol and diesel fuelled transportation. Instead, only water will be released as a by-product. Similarly, pollutants and emissions derived from the combustion of fossil fuels during industrial processes will also be eliminated, having further positive effects on air quality.

6.136 Development and production of fuel cells may have associated effects on air quality due to air pollution released during the manufacturing process. If the hydrogen combustion uses different applications, there is the potential for NO_x emissions[282]. For example, partial deployment through the methane gas network would result in continued emissions of air pollutants, compared to a direct switch to alternative technologies. It is recognised that hydrogen is anticipated to play a role in bridging the gap in the transition to net zero.

6.137 CCS technology may be considered to be generally beneficial both in terms of air quality and climate change, however uncertainty over the potential increase in certain emissions through the use of CCS requires further evidence[283].

Themes

6.138 The indirect effects in relation to Action Theme One relate broadly to the issues described above. Furthermore, the indirect effects of Action Theme One highlight the need to ensure that the regulatory, planning and consent framework considers air quality impacts, in particular, from low-carbon hydrogen developments, supporting infrastructure and also hydrogen distribution. Air quality is not likely to be largely compromised because of the large-scale hydrogen production, however, air quality can be affected in short to medium time scales from construction activities. Therefore, the key enhancement opportunity for Action Theme One is to consider the cumulative effects of extensive hydrogen developments and supporting infrastructure on air quality.

6.139 The indirect effects in relation to Action Theme Two relate broadly to the issues described above.

6.140 The indirect effects of Action Theme Three include broader benefits across Scotland from increased efficiency of the energy system, reducing overall additional production demand, and associated impacts on air. Hydrogen production is likely to lead to overall reductions in GHG emissions, reducing future climate change impacts and improving the air quality.

6.141 The indirect effects of Action Theme Four relate broadly to the issues described above. There is scope for enhancement of Action Theme Four, through ensuring that skills and training to support the supply chain and online tools to support hydrogen development focus on understanding the direct and indirect environmental effects of hydrogen use and

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[282] Committee on Climate Change (2018) Hydrogen in a low-carbon economy. [online] Available at: https://www.theccc.org.uk/wp-content/uploads/2018/11/Hydrogen-in-a-low-carbon-economy.pdf (accessed 20/08/2021)

[283] European Environment Agency Technical Report No 14/2011 (2011) Air pollution impacts from carbon capture and storage (CCS) [online] Available at: https://www.eea.europa.eu/publications/carbon-capture-and-storage

deployment on air quality. The supply chain should mitigate against potential adverse effects on air quality by providing training and guidance on best practice techniques.

6.142 The indirect effects from Action Theme Five include the export and wider use of hydrogen in other countries resulting in indirect effects on air quality, which are largely going to be positive as hydrogen will help displace emissions from fossil fuels especially in difficult to decarbonise industries. Low-carbon hydrogen is likely to have more negative effects on air as it will continue relying on natural gas and will pose a risk of leakage. Hydrogen export will require a significant amount of transport activity, that will lead to increased emissions and will negatively impact air quality.

6.143 There is scope for enhancement of Action Theme Six, through ensuring that research and innovation focuses on understanding the direct and indirect environmental effects of hydrogen use and deployment on air. In particular, it could focus on minimising the risk of leakage during the hydrogen production, storage and distribution of carbon and hydrogen.

Climatic factors

6.144 Hydrogen (H_2) is an important, though little studied, trace component of the atmosphere. Currently, it is present at the mixing ratio of about 510 ppb and has both man-made and natural sources. Its atmospheric lifetime is about 2.5 years and there is a global burden of about 180 Tg in the atmosphere. Because hydrogen reacts with tropospheric hydroxyl radical, emissions of hydrogen to atmosphere perturb the distributions of methane and ozone, the second and third most important GHG after carbon dioxide[284]. Essentially, in the atmosphere, ozone and water vapour react with sunlight to produce hydroxyl radicals, or hydroxides (OH) (the primary methane sink). These important and powerful radicals react with and help remove, acting as sinks, other chemicals that were released into the atmosphere via natural and human process, primarily methane[285]. Methane is over 80 times more powerful, though shorter-lived GHG than CO_2[286].

6.145 Atmospheric H_2 affects global atmospheric chemistry in the same way as carbon oxides (CO). The net effect of adding H_2 to the atmosphere is to reduce hydroxide and thereby increase methane abundance. Thus, H_2, like CO, is an indirect greenhouse gas[287 288]. Moreover, other studies suggest that the emission of hydrogen to the troposphere also leads to changes in the global distribution of ozone, the third most important greenhouse gas. Emissions of hydrogen lead to increased burdens of ozone and increase global radiative forcing, meaning that more sunlight is captured in the atmosphere leading to warming of the planet. Hydrogen is accordingly an indirect radiatively active trace gas with a global warming potential of 5.8 over a 100-year time horizon[289]. Other issues linked to increased H_2 concentrations in the atmosphere include the potential of hydrogen to increase the amount of noctilucent clouds[290], that can potentially impact on the Earth's albedo[291] and mesospheric chemistry. Moreover, research suggests that H_2 is a microbial nutrient, and thus increased partial pressures of H_2 over natural soils might have unforeseen effects on microbial communities[292].

6.146 Over the last 25 years, the concentration of hydrogen has increased by 4%, however with the current understanding of the hydrogen cycle it is impossible to say why this has occurred. Current knowledge suggests that hydrogen may increase global warming potential of methane by 20-30% if

[284] Derwent, R., Simmonds, P., O'Doherty, S., Manning, A., Collins, W., Johnson, C., Sanderson, M., Stevenson, D. (undated) Global environmental Impacts of Hydrogen Economy. [online] Available at: https://www.geos.ed.ac.uk/~dstevens/Presentations/Papers/derwent_ijhr06.pdf (accessed 19/08/2021)
[285] Pearman, G., Prather, M. (2020) Don't rush into a hydrogen economy until we know all the risks to our climate. The Conversation. [online] Available at: https://theconversation.com/dont-rush-into-a-hydrogen-economy-until-we-know-all-the-risks-to-our-climate-140433 (accessed 19/08/2021)
[286] UNECE (2020) Methane management. [online] Available at: https://unece.org/sustainable-energy/methane-management (accessed 20/08/2021)
[287] Prather, M. (2003) An Environmental Experiment with H2? Science. 302(5645) [online] Available at: https://escholarship.org/content/qt2550z16n/qt2550z16n.pdf (accessed 19/08/2021)
[288] Pearman, G., Prather, M. (2020) Don't rush into a hydrogen economy until we know all the risks to our climate. The Conversation. [online] Available at: https://theconversation.com/dont-rush-into-a-hydrogen-economy-until-we-know-all-the-risks-to-our-climate-140433 (accessed 19/08/2021)
[289] Derwent, R., Simmonds, P., O'Doherty, S., Manning, A., Collins, W., Johnson, C., Sanderson, M., Stevenson, D. (undated) Global environmental Impacts of Hydrogen Economy. [online] Available at: https://www.geos.ed.ac.uk/~dstevens/Presentations/Papers/derwent_ijhr06.pdf (accessed 19/08/2021)
[290] Clouds of icy dust that form at high altitudes.
[291] Amount of sunlight that is reflected back to space.
[292] Tromp, T., Shia, R. S., Allen, M., Eiler, J. M., Yung, Y. L. (2003) Potential Environmental Impacts of a Hydrogen Economy on the Stratosphere. [online] Available at: https://www.researchgate.net/profile/Yuk-Yung-2/publication/10708531_Potential_Environmental_Impact_of_a_Hydrogen_Economy_on_the_Stratosphere/links/574cab2108aec988526a1dac/Potential-Environmental-Impact-of-a-Hydrogen-Economy-on-the-Stratosphere.pdf (accessed 19/08/2021)

leaked into the atmosphere[293] [294] [295]. This could be further exacerbated through the release of more hydrogen into the atmosphere associated with the uptake of hydrogen fuels. This highlights the importance of minimising hydrogen leakage during manufacture, transport, storage and use.

Manufacturing

6.147 The construction of both renewable and low carbon hydrogen production facilities will result in increased release of greenhouse gas emissions, arising from carbon embodied within building materials and energy requirements for construction activities, including transportation of materials and machinery. Depending on the type of hydrogen created, there may be additional requirements for electricity to enable hydrogen production. Whilst renewable hydrogen would be powered by renewable electricity sources, releasing no direct emissions, low-carbon hydrogen production (including the storage of CO2 in CCUS), will utilise non-renewable energy with associated release of greenhouse gas emissions.

6.148 Although low-carbon hydrogen production from fossil fuels can be partly decarbonised by CCUS, doing this leads to additional energy demand and extra costs. According to the International Energy Agency (IEA) Greenhouse Gas Research and Development Programme, CCUS rates are generally designed to be 85-90% efficient (i.e., 10-15% of the carbon emissions may not be captured). The IEA report suggested that while it should be technically possible to achieve capture rates of 99% using CCUS, doing so brings an additional efficiency penalty for the power plant, meaning additional energy will be required to produce the same amount of hydrogen. This in turn increases the amount of upstream fugitive emissions from the extraction and transportation of fossil fuels[296]. It is important to highlight that low-carbon hydrogen is not zero emissions and risks a lock-in of high carbon infrastructure and jobs[297], hence reliance on this technology can have long-term repercussions on achieving net-zero by 2045.

6.149 Moreover, low-carbon hydrogen production will have upstream methane emissions linked with the natural gas supply chain, which directly lead to increased radiative forcing and advancing climatic changes[298].

6.150 Leakage of hydrogen during the manufacturing process may have an impact on global warming. As suggested above, current levels of evidence suggest that investing in global-scale hydrogen production may worsen global warming by affecting chemical reactions in the atmosphere and urge further research before making any significant investments[299].

6.151 Additionally, increased emissions from construction of hydrogen production facilities arising from carbon embodied in building materials and energy requirements for construction activities, including transportation of materials and machinery are also expected.

Storage

6.152 Hydrogen storage facilities will need to be constructed, requiring a significant amount of carbon heavy materials for the construction process. Due to the small size of hydrogen atoms, it can diffuse though many materials considered to be impermeable to other gases. Under the scenario of a global hydrogen economy replacing the current fossil fuel economy, hydrogen leakage is estimated to produce a global climate impact of 0.6% of the current fossil fuel-based system (based on 1% leakage). If the leakage rate were 10%, then the global climate impact would be 6% of the current system[300].

Transportation

6.153 Transport via pipeline requires the hydrogen to be pumped under pressure which requires energy inputs, which may have GHG emissions. There will also be emissions

[293] Pearman, G., Prather, M. (2020) Don't rush into a hydrogen economy until we know all the risks to our climate. The Conversation. [online] Available at: https://theconversation.com/dont-rush-into-a-hydrogen-economy-until-we-know-all-the-risks-to-our-climate-140433 (accessed 19/08/2021)
[294] Derwent, R. G., Stevenson, D. S., Utembe, S. R., Jenkin, M. E., Khan, A., H., Shallcross, D. E. (2020) Global modelling studies of hydrogen and its isotopomers using STOCHEM-CRI: Likely radiative forcing consequences of a future hydrogen economy. Int. J. Hyd. Enrg. 45 (15), 9211 – 9221. [online] Available at: https://www.sciencedirect.com/science/article/abs/pii/S0360319920302779 (accessed 19/08/2021)
[295] Tromp, T., Shia, R. S., Allen, M., Eiler, J. M., Yung, Y. L. (2003) Potential Environmental Impacts of a Hydrogen Economy on the Stratosphere. [online] Available at: https://www.researchgate.net/profile/Yuk-Yung-2/publication/10708531_Potential_Environmental_Impact_of_a_Hydrogen_Economy_on_the_Stratosphere/links/574cab2108aec988526a1dac/Potential-Environmental-Impact-of-a-Hydrogen-Economy-on-the-Stratosphere.pdf (accessed 19/08/2021)
[296] Childs, M. (2020) The role of hydrogen in our low-carbon transition. Friends of the Earth. [online] Available at: https://policy.friendsoftheearth.uk/insight/role-hydrogen-our-low-carbon-transition (accessed 19/08/2021)
[297] E3G report
[298] Alvarez, R. A. et. al (2018) Assessment of methane emissions from the U.S. oil and gas supply chain. Science. [online] Available at: https://www.science.org/lookup/doi/10.1126/science.aar7204 (accessed 02/09/2021)
[299] Pearman, G., Prather, M. (2020) Don't rush into a hydrogen economy until we know all the risks to our climate. The Conversation. [online] Available at: https://theconversation.com/dont-rush-into-a-hydrogen-economy-until-we-know-all-the-risks-to-our-climate-140433 (accessed 19/08/2021)
[300] Derwent, R., Simmonds, P., O'Doherty, S., Manning, A., Collins, W., Johnson, C., Sanderson, M., Stevenson, D. (undated) Global environmental Impacts of Hydrogen Economy. [online] Available at: https://www.geos.ed.ac.uk/~dstevens/Presentations/Papers/derwent_ijhr06.pdf (accessed 19/08/2021)

associated with upgrades to and/or construction of pipelines. Transport via road and water could potentially have greater impacts on climate change, depending on the fuel source used to power these modes of transport. For example, hydrogen being distributed via diesel powered transport will result in additional release of GHG emissions, including nitrous oxides, methane and carbon dioxide. However, if transportation utilises clean fuel such as hydrogen or other means (e.g., electricity) effects on air quality will be negligible. As with all other stages of hydrogen implementation, there is potential for hydrogen leakage during transportation.

6.154 There is the potential for hydrogen leakage during the distribution, transportation and storage processes. Hydrogen when leaked, acts as an indirect GHG by increasing global warming potential and negatively impacting the ozone layer[301]. There will also be the potential for additional emissions from transportation and distribution depending on the transport mode used.

Deployment

6.155 A hydrogen-based economy is likely to have greenhouse gas consequences and will not be free from climate perturbations[302]. If a global hydrogen economy replaced the current fossil fuel-based energy system leakage would still lead to significant emissions in comparison to the current system (as described in **Storage**). Therefore, careful attention must be given to reduce the leakage of hydrogen to a minimum from the manufacture, storage and utilisation of hydrogen if the full climate benefits are to be realised[303]. Careful environmental assessments are required for all of the technologies that are to be employed at each step from manufacture through to utilisation to ensure that overall environmental pollution is minimised[304].

6.156 Despite the potential for fugitive hydrogen emissions to contribute towards climate change, the large-scale deployment of hydrogen will provide a cleaner alternative to traditional fossil fuels. Hydrogen can be utilised within shipping, heavy transport (via fuel cells), and industrial sectors enabling displacement of the GHG emissions arising from the burning of fossil fuels conventionally used to power these sectors. Emissions from hydrogen-powered vehicles and vessels and industry will displace and eliminate the release of nitrogen oxides and carbon where solutions such as fuel cells are used. Furthermore, as hydrogen fuel cells are more powerful and energy efficient compared to fossil fuels, hydrogen use will be less than the equivalent power from fossil fuels.

6.157 For low-carbon hydrogen, there is the potential for emissions from CCUS, as not all carbon is captured. Studies suggest CCUS projects typically have a CO_2 capture rate of 90%[305,306] however with improved efficiency capture rates of up to 98% may be possible in the future[307]. Deployment of CCUS is associated with some uncertainties around the scale, technologies and economics of CCUS. However, the current UK carbon budget already includes the CCUS in its energy mix. It is anticipated that efficient large-scale CCUS will effectively capture emissions within the plant infrastructure, and this will be regulated, permitted and monitored.

Themes

6.158 The indirect effects in relation to Action Theme One relate broadly to the issues described above. Furthermore, the indirect effects of Action Theme One highlight the need to ensure that the regulatory, planning and consent framework considers impacts on the climatic factors, particularly in relation to hydrogen leakage during the production, storage and distribution processes. Fugitive emissions associated with large-scale production of hydrogen may have negative climatic impacts as it may exacerbate the global warming effects by extending the lifetime of methane in the atmosphere. Therefore, the key enhancement opportunity for Action Theme One is to consider the cumulative effects of extensive hydrogen developments and supporting infrastructure on

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[301] Department for Business, Energy & Industrial Strategy (2018) Hydrogen for heating: atmospheric impacts – a literature review. [online] Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/760538/Hydrogen_atmospheric_impact_report.pdf (accessed 20/08/2021)

[302] Pearman, G., Prather, M. (2020) Don't rush into a hydrogen economy until we know all the risks to our climate. The Conversation. [online] Available at: https://theconversation.com/dont-rush-into-a-hydrogen-economy-until-we-know-all-the-risks-to-our-climate-140433 (accessed 19/08/2021)

[303] Derwent, R., Simmonds, P., O'Doherty, S., Manning, A., Collins, W., Johnson, C., Sanderson, M., Stevenson, D. (undated) Global environmental Impacts of Hydrogen Economy. [online] Available at: https://www.geos.ed.ac.uk/~dstevens/Presentations/Papers/derwent_ijhr06.pdf (accessed 19/08/2021)

[304] Derwent, R., Simmonds, P., O'Doherty, S., Manning, A., Collins, W., Johnson, C., Sanderson, M., Stevenson, D. (undated) Global environmental Impacts of Hydrogen Economy. [online] Available at: https://www.geos.ed.ac.uk/~dstevens/Presentations/Papers/derwent_ijhr06.pdf (accessed 19/08/2021)

[305] Leung, D., Caramanna, G. and Maroto-Valer, M. (2014). An overview of current status of carbon dioxide capture and storage technologies. Renewable and Sustainable Energy Reviews, [online] Available at: https://www.sciencedirect.com/science/article/pii/S1364032114005450 (accessed 28/10/2021).

[306] Dods, M., Kim, E., Long, J. and Weston, S. (2021). Deep CCS: Moving Beyond 90% Carbon Dioxide Capture. Environmental Science & Technology, [online] Available at: https://pubs.acs.org/doi/10.1021/acs.est.0c07390 (accessed on 28/10/2021)

[307] Brandl, P., Bui, M., Hallett, J. and Mac Dowell, N. (2021). Beyond 90% capture: Possible, but at what cost?. International Journal of Greenhouse Gas Control, 105, p.103239.

climatic factors to ensure that all possible steps to minimise leakage are taken. However, this needs to be balanced against the carbon savings from the use of hydrogen over fossil fuels without carbon capture.

6.159 The indirect effects in relation to Action Theme Two relate broadly to the issues described above.

6.160 The indirect effects of Action Theme Three include broader benefits across Scotland from increased efficiency of the energy system, reducing overall additional production demand, and associated impacts on climatic factors. Hydrogen production is likely to lead to overall reductions in GHG emissions, reducing future climate change impacts.

6.161 The indirect effects of Action Theme Four broadly relate to the issues described above. There is scope for enhancement of this Action Theme, by ensuring that skills and training to support the supply chain focus on understanding the direct and indirect environmental effects of hydrogen use and deployment on the climate. The supply chain should mitigate against adverse effects on the climate by providing training and guidance on best practice techniques, particularly in the production, storage and transportation stages.

6.162 The indirect effects from Action Theme Five include the export and wider use of hydrogen in other countries resulting in indirect effects on climatic factors, which may be negative if the risks from leakage during manufacture, storage and transportation are not addressed through the regulatory framework.

6.163 There is scope for enhancement of Action Theme Six, through ensuring that research and innovation focus on understanding the direct and indirect environmental effects of hydrogen use and deployment on climatic factors. There is still considerable uncertainty on the subject of large-scale hydrogen production, storage and transportation and its potential impacts on global warming. One of the key areas that needs more investigation is the hydrogen cycle, which currently is poorly understood.

Cultural heritage and the historic environment

Manufacturing

6.164 Hydrogen production plants will require construction new infrastructure which could have negative impacts on heritage assets. This will include impacts on setting and direct impacts on land and marine historic environment features. However, these effects can be addressed through existing planning mechanisms.

Storage

6.165 Similarity, hydrogen storage may have negative impacts on cultural heritage and the historic environment as storage facilities may change the setting of the heritage sites. However, it is assumed that most of these facilities will be developed within the vicinity of existing industrial areas and reducing additional impacts.

Transportation

6.166 Hydrogen transportation via pipelines may have negative effects on historic assets during excavation. Any upgrades or new pipelines may cause adverse effects on historic buildings.

6.167 Road transport is not expected to have any adverse effects on historic environment.

Deployment

6.168 There is the potential for hydrogen to enable more sustainable forms of heating for historic assets reducing their overall carbon footprint.

Themes

6.169 The indirect effects in relation to Action Theme One relate broadly to the issues described above. Furthermore, the indirect effects of Action Theme One highlight the need to ensure that the regulatory, planning and consent framework considers impacts on the historic environment that including the setting of cultural heritage assets. Therefore, there is a key opportunity for enhancement of Action Theme One, for the regulatory, planning and consent framework to consider the cumulative effects of extensive hydrogen development and supporting infrastructure on cultural heritage and historic environment.

6.170 The indirect effects in relation to Action Theme Two relate broadly to the issues described above.

6.171 The indirect effects of Action Theme Three include broader benefits across Scotland from increased efficiency of the energy system, reducing overall additional production demand, and associated impacts on cultural heritage and historic environment. Hydrogen production is likely to lead to overall reductions in GHG emissions, reducing future climate change impacts.

6.172 The indirect effects of Action Theme Four broadly relate to the issues described above. This Action Theme could be enhanced by ensuring that training to support the supply chain consider the direct and indirect environmental effects of hydrogen on cultural heritage assets. It should also mitigate against potential adverse effects by encouraging training and guidance on best practice.

6.173 The indirect effects from Action Theme Five relate broadly to the issues describe above.

6.174 In relation to the indirect effects from Action Theme Six, it is assumed that existing planning mechanisms will help avoid adverse effects on cultural heritage and the historic environment. However, research and innovation should focus on understanding the direct and indirect environmental effects of hydrogen use and deployment on cultural heritage and the historic environment. There is uncertainty as to whether hydrogen used as heating would be suitable for historic buildings.

Landscape and geodiversity

Manufacturing

6.175 Hydrogen production will require additional facilities, however it is assumed that majority of them are going to be delivered on brownfield land or will form part of on or offshore production facilities.

6.176 Low-carbon hydrogen production involves CCUS, and the geological storage of carbon dioxide, typically using existing oil and gas infrastructure with some new development.

Storage

6.177 Hydrogen storage may negatively impact on landscape setting especially in more remote areas and less developed locations. However, it is assumed that pre-development planning mechanisms will offer viable mitigation.

Transportation

6.178 Hydrogen transportation is unlikely to have any effects on landscape and geodiversity, as existing oil and gas infrastructure is anticipated to be used where hydrogen or carbon is transported by pipeline.

Deployment

6.179 In terms of deployment, underground storage of energy in the form of hydrogen may have negative effects on geodiversity as the long-term effects of this activity are uncertain.

6.180 For other deployment uses, it is assumed that existing road infrastructure will be used or improved having no significant impact on landscape.

Themes

6.181 The indirect effects in relation to Action Theme One relate broadly to the issues described above.

6.182 The indirect effects in relation to Action Theme Two relate broadly to the issues described above.

6.183 The indirect effects of Action Theme Three include broader benefits across Scotland from increased efficiency of the energy system, reducing overall additional production demand, and associated positive impacts on landscape and geodiversity. Hydrogen production is likely to lead to overall reductions in GHG emissions, reducing future climate change impacts on the landscape.

6.184 The indirect effects of Action Theme Four broadly relate to the issues described above. This Action Theme could be enhanced by ensuring that training to support the supply chain consider the direct and indirect environmental effects of hydrogen production and deployment on the landscape. The supply chain should also mitigate against potential adverse effects by adhering to best practice guidance.

6.185 No indirect effects are identified in relation to Action Theme Five which includes the export and wider use of hydrogen in other countries.

6.186 In relation to the indirect effects from Action Theme Six, this could be enhanced by ensuring that research and innovation focuses on understanding the direct and indirect environmental effects of hydrogen use and deployment on landscape and geodiversity. There is still considerable uncertainty around large-scale hydrogen production, storage and transportation that need to be addressed to minimise any adverse effects. One of the key focus areas should investigate the potential long-term impacts of geological carbon storage beyond 2100.

Material assets

Manufacturing

6.187 To enable the large-scale production of hydrogen, there is a requirement to develop hydrogen processing infrastructure, notably electrolysers for renewable hydrogen, hydrogen storage facilities, and facilities for producing fuel cells.

6.188 Where hydrogen production makes use of existing oil and gas infrastructure, this represents an efficient use of existing resources.

6.189 The development of hydrogen technologies will have positive effects on material assets by improving the reliability and security of energy supply, as well as the resilience of the energy sector to the predicted pressures from climate change. This may result in associated benefits for climate change and population and human health.

Storage

6.190 As with the production of hydrogen, hydrogen storage facilities will be required to enable the large-scale rollout of hydrogen across the industrial and transport sectors. Appropriate infrastructure to facilitate storage in compression tanks, cryogenic tanks and salt caverns (including offshore) will enable more reliable and secure deployment of hydrogen, having positive effects on material assets.

Transportation

6.191 Upgrades will likely be required to the existing gas network and supporting infrastructure, to enable both the transportation of hydrogen and in the case of low-carbon hydrogen, transportation of CO_2 to be stored in geological formations as part of CCUS.

6.192 The existing natural gas network also has the potential to transport and distribute hydrogen provided the injected fraction remains below 20% by volume, although estimates vary[308]. Mixing of hydrogen and natural gas in the pipelines should also reduce the risk of fire or explosion. The Committee on Climate Change has argued switching the gas grid to 100% hydrogen could be impractical for zero carbon heat. In their view this is because the UK has an extensive natural gas grid, and it is unlikely that burning 100% hydrogen in domestic boilers would be the best approach[309]. Some of the key limiting factors for using existing gas pipelines are gas quality standard and equipment compliance, pipeline integrity (failure, fire, and explosion) and end-user safety, however more research is required. Where the pipelines are suitable and more frequent inspections can be undertaken, a higher fraction of hydrogen can be carried, although the lower volumetric energy density of hydrogen will reduce energy flow, unless gas pressure can be increased. If required, hydrogen separation is possible via a range of existing technologies[310].

6.193 For dedicated hydrogen delivery, transport distance is an important consideration; pipelines are favoured over shorter delivery distances and at high flow rates, while batch delivery of liquid hydrogen is favoured by long distances[311]. Therefore, there will be greater requirements for vehicles capable of transporting hydrogen in gaseous and liquid states.

Deployment

6.194 Estimates of the costs for refurbishing the gas grid for hydrogen deployment are uncertain, a study for the EU concludes that the costs of fully converting distribution networks and appliances for hydrogen are prohibitive[312]. Lastly, it is also suggested that hydrogen pipelines should be built around secure demand and supply; not around the question of how existing gas assets can be best kept functioning[313].

6.195 The deployment of hydrogen for some sectors will be very inefficient. It is estimated that if hydrogen was used for heating purposes it could require around 30 times more offshore wind farm capacity than currently available to produce enough renewable hydrogen to replace all gas boilers, as well as adding costs for consumers[314]. There is evidence to suggest that hydrogen for heating is not an effective solution for most of the country. Research from the London Energy Transformative Initiative (LETI) shows that hydrogen conversion, delivery and combustion has between a third and one sixth the efficiency of clean heat alternatives such as electrification and heat pumps[315].

6.196 The deployment of hydrogen fuel cells in vehicles will have positive effects on material assets by improving the resilience of the transport energy sector to the pressures on depleting non-renewable resources, whilst maintaining the flexibility of conventional cars in terms of comparable refuelling times. Hydrogen powered vehicles can be refuelled in less than 5 minutes whereas charge time for electric cars can currently require several hours[316]. Hydrogen also provides a viable alternative to fossil fuels for HGVs, where electrification is not an option. In addition, the improved efficiency and power compared with fossil fuels will have further positive effects. However, to ensure the successful

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[308] Intergovernmental Panel on Climate Change (2018) Working Group 3 Chapter 7: Energy Systems. [online] Available at: https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_chapter7.pdf (accessed 19/08/2021)

[309] Committee on Climate Chante (2018) Hydrogen in a credible option for the future. The UK must prepare for the key decisions on zero-carbon energy. [online] Available at: https://www.theccc.org.uk/2018/11/22/hydrogen-is-a-credible-option-for-the-future-the-uk-must-now-prepare-for-the-key-decisions-on-zero-carbon-energy/ (accessed 19/08/2021)

[310] Intergovernmental Panel on Climate Change (2018) Working Group 3 Chapter 7: Energy Systems. [online] Available at: https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_chapter7.pdf (accessed 19/08/2021)

[311] Intergovernmental Panel on Climate Change (2018) Working Group 3 Chapter 7: Energy Systems. [online] Available at: https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_chapter7.pdf (accessed 19/08/2021)

[312] E3G report

[313] Agora Energiewende (2021) No regret hydrogen infrastructure for Europe. [online] Available at: https://www.agora-energiewende.de/en/publications/no-regret-hydrogen/ (accessed 20/08/2021)

[314] E3G report

[315] London Energy Transformation Initiative (2021) Hydrogen A decarbonisation route for heat in buildings? [online] Available at: https://www.leti.london/hydrogen (accessed 20/08/2021)

[316] U.S. Department of Energy (2016) 5 things to know when filling up your fuel cell electricity vehicle. [online] Available at: https://www.energy.gov/eere/articles/5-things-know-when-filling-your-fuel-cell-electric-vehicle#:~:text=It%20takes%20roughly%20five%20minutes,same%20as%20a%20gasoline%20tank. (accessed 20/08/2021)

large-scale deployment, greater investment is needed in hydrogen refuelling technologies across Scotland.

Themes

6.197 The indirect effects in relation to Action Theme One relate broadly to the issues described above. Furthermore, the indirect effects of Action Theme One highlights the need to ensure that the regulatory, planning and consent framework considers impacts on the material assets. There is a key opportunity for enhancement of Action Theme One, for the regulatory, planning and consent framework to consider the cumulative effects of extensive hydrogen development and supporting infrastructure on material assets.

6.198 The indirect effects in relation to Action Theme Two relate broadly to the issues described above.

6.199 The indirect effects of Action Theme Three include broader benefits across Scotland from increased efficiency of the energy system, reducing overall additional production demand, and associated impacts on material assets. Hydrogen production is likely to lead to overall reductions in GHG emissions, reducing future climate change impacts.

6.200 The indirect effects of Action Theme Four include those outlined above. There is scope for enhancement of Action Theme Four, through ensuring that skills and training to support the supply chain and online tools to support hydrogen development focus on understanding the direct and indirect effects of hydrogen on material assets.

6.201 The indirect effects from Action Theme Five include the export and wider use of hydrogen in other countries resulting in indirect negative effects on materials assets, as a significant amount of infrastructure will be required for the export activities. Additional infrastructure will require carbon heavy materials and may lead to additional emissions.

6.202 In relation to the indirect effects from Action Theme Six, this can be enhanced through ensuring that research and innovation also focuses on understanding the direct and indirect environmental effects of hydrogen use and deployment on material assets. This could include optimising the use of existing oil and gas infrastructure that can be reused for the needs of low-carbon hydrogen production and optimising the quantity of new resources used.

Cumulative, secondary and synergistic effects

6.203 The following paragraphs set out the potential cumulative effects likely to arise from the Draft Hydrogen Action Plan.

Biodiversity, flora and fauna

6.204 The actions set out within the Draft Hydrogen Action Plan are identified as having potential adverse indirect effects on biodiversity, flora and fauna. Actions promoting the development of hydrogen facilities may result in habitat loss as a result of land take. Greater use of hydrogen and displacement of fossil fuels may provide benefits for biodiversity. By reducing the potential effects of climate change, habitats are less likely to be affected by a changing climate (e.g., drought, wildfires etc.). This will enable habitats to remain connected allowing species movement.

Population and Human Health

6.205 The actions set out within the Draft Hydrogen Action Plan are identified as having mainly positive effects on population and human health. Actions promoting the development of hydrogen facilities and ancillary development may result more local job opportunities, local investment and opportunities to enhance skills through education and training. This will have positive effects on population and human health.

6.206 Positive effects are further enhanced as the generation of low carbon hydrogen fuel may help reduce fuel poverty across Scotland, particularly in areas close to hydrogen production. Furthermore, as hydrogen use displaces use of fossil fuels, there are expected to be improvements to air quality which could benefit the population by reducing adverse health outcomes. This is especially the case if hydrogen is taken up by the industrial and transport sectors, displacing more polluting fuels.

6.207 Furthermore, by reducing the use of fossil fuels, the future effects of climate change, such as extreme weather events will be reduced. This will have additional positive effects on human health, although the effects would be experienced over a longer timescale.

6.208 However, some negative effects on the population and human health may arise due to construction related activities which could produce noise and dust. This is likely to be localised and short-term in nature. In many instances, adverse impacts may be mitigated through a combination of planning mechanisms and on-site management measures.

6.209 Furthermore, depending on the fuel source of vehicles used to transport hydrogen, negative effects on health may arise due to release of carbon emissions and particulate matter.

Soil

6.210 The actions set out within the Draft Hydrogen Action Plan are identified as having potential mixed effects on soil. Actions promoting the development of hydrogen facilities and ancillary development may result in either positive or negative effects on soil, depending on whether they are sited on brownfield or greenfield land. Most hydrogen development is assumed to be on previously developed land associated with existing power stations, ports and oil and gas infrastructure, and therefore will have positive effects on soil quality. However, development of ancillary infrastructure, such as pipelines, will result in soil disturbance.

Water

6.211 The Draft Hydrogen Action Plan sets out actions which promote the development of renewable and low-carbon hydrogen production facilities. The production of hydrogen requires significant quantities of water which can be sourced either on land (freshwater) or from the sea. Over abstraction for use in hydrogen facilities will have negative effects on the water environment and its biodiversity, particularly during spring and summer months when water levels are lower.

6.212 Extraction of water from the sea will need to undergo a desalination process which produces a brine by-product which is released back to the sea. This could have further negative effects on water quality by changing the salinity in localised areas.

6.213 Further negative effects will arise as a result of construction activities relating to hydrogen development and its ancillary infrastructure, supporting renewable energy schemes and improvement of infrastructure. This is likely to be localised and short-term in nature. In many instances, adverse impacts may be mitigated through a combination of planning mechanisms and on-site management measures.

Air

6.214 The actions set out within the Hydrogen Action Plan are identified as having potential mixed effects on air quality. Actions promoting the development of hydrogen facilities and ancillary development may result in both positive and negative effects on air quality. The use of hydrogen as a fuel will displace fossil fuels and help reduce emissions and pollutants associated with fossil fuels, having positive effects on air quality. This is further enhanced by the development of supporting renewable energy schemes.

6.215 Development of hydrogen production facilities and infrastructure could result in negative effects on air quality during construction. This is likely to be localised and short-term in nature. In many instances, adverse impacts may be mitigated through a combination of planning mechanisms and on-site management measures.

6.216 Pollution into the air can occur throughout the operational phases of hydrogen production. In terms of low-carbon hydrogen, leakage of natural gas can occur. Furthermore, carbon may be leaked when being transported to be stored in geological formations via CCUS. Release of ammonia during hydrogen storage will have further negative effects on air quality. Furthermore, negative effects may arise from the transportation associated with hydrogen development, including workers commuting, and transportation of hydrogen. Most hydrogen that is not transported via pipeline may be transported via marine vessels and lorries. Both these forms of transport are primarily fuelled by fossil fuels, and therefore the mass transport of hydrogen will result in transport related air pollution unless renewable fuels are used.

Climatic Factors

6.217 The actions set out within the Draft Hydrogen Action Plan are identified as having potential mixed effects on climatic factors. Actions promoting the development of hydrogen facilities and ancillary development may result in both positive and negative effects on climatic factors. The use of hydrogen as a fuel will displace fossil fuels and help reduce domestic, industrial and transport emissions associated with fossil fuels, having positive effects on the climate. This is further enhanced by the increased development of renewable energy schemes to support hydrogen development. However, the construction of hydrogen facilities and supporting infrastructure, will result in carbon emissions during construction which would have negative effects on the climate.

6.218 Emissions can be released into the atmosphere during the lifecycle of hydrogen production. In terms of low-carbon hydrogen, natural gas can leak into the atmosphere during extraction. Furthermore, carbon emissions may be leaked when being transported to be stored in geological formations via CCUS. Furthermore, negative effects may arise from the transportation associated with hydrogen development, including workers commuting, transportation of hydrogen and transportation of carbon emissions to be stored in geological formations. Most hydrogen that is not transported via pipeline will be transported via marine vessels and lorries. Both these forms of transport are currently primarily fuelled by fossil fuels, and therefore the mass transport of hydrogen will result in the release of carbon emissions.

Cultural Heritage and the Historic Environment

6.219 The actions set out within the Hydrogen Action Plan are identified as having potential indirect negative effects on the historic environment. Actions promoting the development of hydrogen facilities and ancillary development will result in direct negative effects on cultural heritage assets if the developments are sited on these assets. Such development could also have negative effects on the setting of these assets, depending on where they are sited. Most low-carbon hydrogen development is assumed to be on previously developed land associated with existing power stations, ports and oil and gas infrastructure. Such areas are already industrial in nature and the addition of hydrogen facilities would be unlikely to cause significant adverse effects on the setting of heritage assets.

6.220 The greater use of hydrogen and displacement of fossil fuels may provide positive effects for cultural heritage. By reducing the potential effects of climate change, cultural heritage assets are less likely to be affected by a changing climate (e.g., storms and flooding etc.). This will help preserve these assets longer.

Landscape and Geodiversity

6.221 The actions set out within the Hydrogen Action Plan are identified as having potential indirect negative effects on the landscape. Actions promoting the development of hydrogen facilities and ancillary development may result in negative effects on the landscape, depending on where they are sited. Most hydrogen development is assumed to be on previously developed land associated with existing power stations, ports and oil and gas infrastructure. Such areas are already industrial in nature and the addition of hydrogen facilities is unlikely to cause significant adverse effects on the landscape. Hydrogen facilities on undeveloped land will have more significant negative effects.

6.222 However, the greater use of hydrogen and displacement of fossil fuels, may provide positive effects for landscape. By reducing the potential effects of climate change, the landscape is less likely to be affected by a changing climate (e.g., storms, flooding, drought etc.). This will help preserve the landscape and prevent the spread of invasive and non-native species.

Material Assets

6.223 The actions set out within the Hydrogen Action Plan are identified as having mainly positive effects on material assets. The production of large-scale hydrogen will help create a secure, reliable and flexible energy system which is resilient to future change. Furthermore, the development of hydrogen infrastructure is a valuable asset to the Scottish economy. Therefore, significant positive effects are expected in relation to material assets.

6.224 These positive effects are further enhanced as renewable hydrogen will need to be supported by renewable energy schemes which themselves will further contribute towards improving the energy network in Scotland.

6.225 However, negative effects will also arise from the production and use of hydrogen. Compared to renewable energy itself, renewable hydrogen is a less efficient way of delivering energy. However, it is recognised that hydrogen is often more suitable for industrial processes and use and some modes of transport than electricity.

Chapter 7
Reasonable alternative assessment findings

7.1 Part 14(2) of the 2005 Act requires that:

"The report shall identify, describe and evaluate the likely significant effects on the environment of implementing (a) the plan or programme; and (b) reasonable alternatives to the plan or programme, taking into account the objectives and the geographical scope of the Plan or Programme".

7.2 Therefore, the SEA must appraise not only the objectives and actions, but "reasonable alternatives" to these.

7.3 As outlined in the approach to the assessment, the reasonable alternatives explore the different environmental effects from:

- A greater focus on renewable hydrogen production (but including an element of low-carbon hydrogen production)
- A greater focus on low-carbon hydrogen production (but including an element of renewable hydrogen production)

7.4 Three future development scenarios for hydrogen as set out in the Scottish Hydrogen Assessment:

- Hydrogen economy (production from both renewable and low-carbon sources roughly in equal parts)
- Green export (large scale production of hydrogen from renewable energy sources)
- Focused hydrogen (small scale renewable or low-carbon hydrogen for the harder to decarbonise industries)

7.5 The assessment of the reasonable alternatives focuses on indirect effects only, reflecting the scope of environmental effects from the draft Hydrogen Action Plan and the limited direct environmental effects anticipated within the timeframe of the document.

The assessment of the reasonable alternatives includes consideration of the indirect effects of renewable energy development to support renewable hydrogen production, reflecting potential environmental effects associated with different scales of hydrogen production, which are assumed to require additional renewable energy development to that already reflected in current policy and planning.

Biodiversity, flora and fauna

Green hydrogen production - biodiversity, flora and fauna impacts

7.6 A focus on the alternative of renewable hydrogen production may require additional renewable energy capacity to power the hydrolysis process. This could result in indirect environmental effects on biodiversity, flora and fauna as a consequence of impacts on marine and terrestrial habitats and species from the production of renewable energy to support renewable hydrogen production. Given the scale of development that is likely to be required, this could be a potentially significant negative effect. It is uncertain whether a greater proportion of renewable hydrogen production will take place offshore or onshore. Offshore production is assumed to be more reliant on desalinisation of seawater, with biodiversity, flora and fauna impacts arising from the additional renewable energy requirement of this and a result of the disposal of brine. Where renewable hydrogen production uses freshwater, there are potential negative biodiversity implications from the abstraction of water and changing flow levels impacting on key habitats and species, potentially exacerbated by the impacts of climate change. These effects are likely to be widespread and occur over the long term. Onshore wind development for hydrogen production will also have impacts relating to habitat loss and fragmentation resulting from wind farm construction. There could be improvements to air quality from the use of hydrogen as a fuel for transport with positive effects for biodiversity, flora and fauna.

7.7 Overall, the potential for **significant negative** indirect environmental effects are identified. However, it is assumed that the development of the regulatory framework would be in step with the scaling up of renewable hydrogen production, and with the assumption of this in place, a **minor negative** effect is identified.

Low-carbon hydrogen production - biodiversity, flora and fauna impacts

7.8 Low-carbon hydrogen production also utilises water, although less is required than for renewable hydrogen. Production of hydrogen may be on or offshore and could use either freshwater or desalinised sea water. Given the lower water requirements for low-carbon hydrogen less significant environmental effects on biodiversity, flora and fauna from water abstraction and desalinisation are likely.

7.9 Low-carbon hydrogen also depends on CCUS technology which is likely to result in environmental effects. These include emissions of air pollutants which could negatively impact on biodiversity, fauna and flora. However, there are potential net air quality benefits over the baseline from the use of cleaner fuel for in a range of applications. However, in light of the potential scale of hydrogen production overall and potential impacts on the water environment, **significant negative** indirect environmental effects are identified. As for renewable hydrogen, it is assumed that the development of the regulatory framework would be in step with the scaling up of low-carbon hydrogen production, and with the assumption of this in place, a **minor negative** effect is identified.

Hydrogen economy- biodiversity, flora and fauna impacts

7.10 A hydrogen economy focuses on large scale hydrogen production from both renewable and low-carbon sources. This results in negative effects on biodiversity, flora and fauna as outlined in relation to renewable and low-carbon hydrogen production. This approach also supports the rapid displacement of fossil fuels with consequent improvements in air quality, bringing benefits for biodiversity. It also supports the more rapid decarbonisation of the economy which reduces GHG emissions and the impacts of climate change, with potential biodiversity benefits. However, the **significant negative** environmental effects of large-scale hydrogen production are assumed to outweigh these positive effects.

7.11 Therefore, using the same assumptions as previously for the regulatory framework, **significant negative** effects would be assumed to be reduced to overall **minor negative** effects.

Green export - biodiversity, flora and fauna impacts

7.12 This alternative focuses on large scale production of renewable hydrogen for export. This will lead to the potential negative effects of renewable hydrogen production on biodiversity, flora and fauna arising from large scale renewable energy development and associated hydrogen production. The provision of renewable hydrogen for export supports GHG emissions reductions in other countries, with wider indirect positive effects for biodiversity from improved air quality where hydrogen is used for transport. However, it is assumed that if Scotland does not produce renewable hydrogen for export, this market demand would be fulfilled by other countries with strategic wind and water resources. Therefore, it is assumed that other countries would continue to meet their climate change commitments and no additional benefits to biodiversity, flora and fauna are achieved from this alternative. Therefore, using the same assumptions as previously for the regulatory framework, **significant negative** effects from large scale renewable hydrogen production would be assumed to be reduced to overall **minor negative** effects.

Focused hydrogen- biodiversity, flora and fauna impacts

7.13 Under the alternative of a focused hydrogen economy, the environmental effects of hydrogen production are smaller in scale, due to smaller scale development of hydrogen production related infrastructure. This alternative assumes the use of other technologies to reduce GHG emissions without the widespread use of hydrogen, therefore impacts of climate change on biodiversity, flora and fauna are assumed to be similar and not increased under this alternative. The scale of focused hydrogen production is unknown, however assuming a focused level of production in key locations **minor negative** environmental effects are identified. Assuming that the development of the regulatory framework would be in step with the development of hydrogen production, the environmental effects are assumed to be **minor to negligible negative**.

Population and human health

Green hydrogen production- population and human health impacts

7.14 In relation to the alternative where the majority of hydrogen produced will be renewable the potential indirect environmental effects on population and human health arising from the production of renewable energy to support renewable hydrogen production are potentially mixed. Positive effects could include improved air quality due to the use of hydrogen for transport that will consequently lead to improved human health, although emissions of NO_x will occur from some uses. Negative effects expected from renewable hydrogen arise from the desalination process and its impact on water quality that consequently may negatively impact on population and human health, ecosystems on which humans rely on and food security. Onshore hydrogen production will rely on freshwater, potentially constraining the availability of water for agriculture and domestic use (see **Water**). This is likely to have even more significant negative impacts in long term scales. Onshore renewable energy production will involve land take potentially constraining the availability of land for agricultural production. This may also generate employment and support health and wellbeing through improving quality of life.

7.15 Overall mixed (**significant negative and minor positive)** indirect environmental effects are identified. However, it is assumed that the development of the regulatory framework would be in step with the scaling up of renewable hydrogen production, and with the assumption of this in place, a mixed (**minor negative and minor positive)** effect is identified.

Low-carbon hydrogen production - population and human health impacts

7.16 Low-carbon hydrogen production also requires water for the production process, although water demand is significantly lower than that of renewable hydrogen. Within this reasonable alternative, renewable hydrogen only accounts for a small proportion of hydrogen produced. Renewable energy production may be on or offshore and therefore renewable hydrogen production requires either freshwater or desalinised sea water depending on the location. As mentioned, the overall water requirements for low-carbon hydrogen are less than for renewable hydrogen, and therefore, smaller scale environmental effects on population and human health from water abstraction and desalinisation than for renewable hydrogen are expected. Low-carbon hydrogen production prolongs the reliance on fossil fuels. It has a greater potential for leakage of both hydrogen and captured carbon and therefore may still result in net emissions if rolled out at large scale.

7.17 However, considering the scale of low-carbon hydrogen production overall **significant negative** indirect environmental effects are identified for this alternative. As for renewable hydrogen, it is assumed that the development of the regulatory framework would be in step with the scaling up of low-carbon hydrogen production, and with the assumption of this in place, a **minor negative** effect is identified.

Hydrogen economy- population and human health impacts

7.18 A hydrogen economy focuses on large scale hydrogen production from both renewable and low-carbon sources roughly in equal parts. This results in mixed effects (significant negative and minor positive) on population and human health as outlined in relation to renewable and low-carbon hydrogen production. It is assumed that this approach will enable rapid displacement of fossil fuels with air quality benefits from transport, or mixed effects from other applications, and consequently mixed effects for population and human health. It also supports the more rapid decarbonisation of the economy which reduces GHG emissions and the impacts of climate change, with potential benefits for population. However, there is uncertainty in relation to the potential negative impacts of the CCUS technologies and leakage of hydrogen. Therefore, despite the range of positive effects, it is expected that hydrogen economy has **significant negative** effects.

7.19 However, if regulatory framework addresses all the issues listed above, **significant negative** effects would be assumed to be reduced to overall **minor negative** effects.

Green export- population and human health impacts

7.20 The focus of renewable export is for the large-scale production of renewable hydrogen for export to mainland Europe and the wider UK. This will lead to the potential negative effects of renewable hydrogen production on population and human health arising from large scale renewable energy development and associated hydrogen production. It is assumed that under this alternative, the production will need to ensure sufficient scale of production for the domestic use and for export. This accordingly will require even more renewable energy to be delivered both on and offshore.

7.21 This supports employment in the hydrogen and renewable energy sectors, with positive effects on human health and wellbeing.

7.22 The provision of renewable hydrogen for export supports GHG emissions reductions in other countries, with wider indirect positive effects for population and human health. However, it is assumed that if Scotland does not produce renewable hydrogen for export, this market demand would be fulfilled by other countries with strategic wind and water resources. Therefore, it is assumed that other countries would continue to meet their climate change commitments and no additional benefits to population and human health are achieved from this alternative. Therefore, using the same assumptions as previously for the regulatory framework, **significant negative** effects from large scale renewable hydrogen production would be assumed to be reduced to overall **minor negative** effects.

Focused hydrogen- population and human health impacts

7.23 Under the alternative of a focused hydrogen economy, the environmental effects of hydrogen production are smaller in scale, due to significantly smaller scale development of hydrogen production related infrastructure. This alternative assumes the use of other technologies, such as electrification, to reduce GHG emissions without transition to hydrogen. There could be localised impacts on air quality depending on the fuel being displaced, and these may be positive overall. The scale of focused hydrogen production is uncertain, however assuming a focused level of production in key locations **minor negative** environmental effects are identified. Assuming that the development of the regulatory framework would be in step with the development of hydrogen production, the environmental effects are assumed to be **minor to negligible negative**.

Soil

Green hydrogen production – soil impacts

7.24 In relation to the alternative where majority of hydrogen produced will be renewable the potential indirect environmental effects on soil arising from the production of renewable energy to support renewable hydrogen production are potentially significant negative. Large scale renewable hydrogen production will require large scale on and offshore renewable energy production. Onshore wind farms, in particular, will have negative effects on soil, such as loss of soil carbon during the construction phase of the development and soil disturbance. Freshwater demand for the onshore renewable hydrogen production may also compromise soil quality and lead to soil erosion and the potential release of soil carbon in the long term. Moreover, hydrogen production facilities, hydrogen and carbon storage and pipelines will have negative effects on soil.

7.25 Overall, **significant negative** indirect environmental effects are identified. However, it is assumed that the development of the regulatory framework would be in step with the scaling up of renewable hydrogen production, and with the assumption of this in place, a **minor negative** effect is identified.

Low-carbon hydrogen production – soil impacts

7.26 Low-carbon hydrogen production will require significantly less land than renewable hydrogen. Moreover, much of existing oil and gas infrastructure can be reused and most of additional facilities can be delivered on already developed land, having negligible effect on soil. Within this reasonable alternative, renewable hydrogen will only account for a small proportion of hydrogen produced. Renewable energy production for renewable hydrogen may be on or offshore. Onshore energy production will involve land take and will lead to soil carbon loss and soil disturbance, especially during construction phases. Pipelines will be required for both hydrogen types and will lead to soil disturbance. Larger quantities of low-carbon hydrogen will also require a greater number of captured carbon storage facilities and some additional construction and pipelines. However there is also likely to be considerable reuse or repurposing of existing oil and gas infrastructure, limiting the extent of negative impacts on soil.

7.27 However, in light of the potential scale of hydrogen production and the fact that low-carbon hydrogen will account for majority of the production, an overall minor negative indirect environmental effect is identified. It is assumed that the development of the regulatory framework would be in step with the scaling up of low-carbon hydrogen production. However, even with this assumption, a **minor negative** effect is identified.

Hydrogen economy – soil impacts

7.28 A hydrogen economy focuses on large scale hydrogen production from both renewable and low-carbon sources roughly in equal parts. This results in negative effects on soil as outlined in relation to renewable and low-carbon hydrogen production. It is assumed that this approach will enable rapid displacement of fossil fuels with air quality benefits, and consequently benefits for soil. It also supports the more rapid decarbonisation of the economy which reduces GHG emissions and the impacts of climate change, with potential longer-term benefits for soil. Slowing climate change would help limit the impacts of extreme weather events such as droughts, flooding, etc. that could otherwise have negative impact on soil. Despite these positive effects, it is expected that the hydrogen economy alternative would have significant negative effects on soil.

7.29 However, if the regulatory framework addresses all the issues listed above, **significant negative** effects would be assumed to be reduced to overall **minor negative** effects.

Green export – soil impacts

7.30 The focus of renewable export is for the large-scale production of renewable hydrogen for export to mainland Europe and the rest of the UK. This will lead to the potential negative effects of renewable hydrogen production on soil arising from large scale renewable energy development and associated hydrogen production. It is assumed that under this alternative, the production will need to ensure sufficient scale of production for the domestic use and for export. This accordingly will require even more renewable energy to be delivered on and offshore in comparison to the renewable alternative. Onshore energy production, in particular, is likely to have negative effects on soil.

7.31 The provision of renewable hydrogen for export supports GHG emissions reductions in Scotland and also in other countries. However, it is assumed that if Scotland does not produce renewable hydrogen for export, this market demand would be fulfilled by other countries with strategic wind and water resources. Therefore, it is assumed that other countries would continue to meet their climate change commitments and no additional benefits to soil are achieved from this alternative. Therefore, using the same assumptions as previously for the regulatory framework, **significant negative** effects from large scale renewable hydrogen production would be assumed to be reduced to overall **minor negative** effects.

Focused hydrogen – soil impacts

7.32 Under the alternative of a focused hydrogen economy, the environmental effects of hydrogen production are smaller in scale, due to significantly smaller scale development of hydrogen production related infrastructure. This alternative assumes the use of other technologies, such as electrification, to reduce GHG emissions from many applications without transition to hydrogen. The scale of focused hydrogen production is uncertain, however assuming a focused level of production in key locations minor negative environmental effects in relation to soil are identified. Assuming that the development of the regulatory framework would be in step with the development of hydrogen production, the environmental effects are assumed to be **minor to negligible negative**.

Water

Green hydrogen production – water impacts

7.33 In relation to the alternative where majority of hydrogen produced will be renewable the potential indirect environmental effects on water arising from the production of renewable energy are expected to be significant negative. Large scale renewable hydrogen production will require large quantities of water for the electrolysis process. Offshore production would involve desalination process which could have negative effects on sea water quality and the marine ecosystem. Onshore production will require freshwater abstraction which could lead to water shortages and potential impacts on habitats and species, particularly where climate change increases the risk of drought conditions.

7.34 Overall, **significant negative** indirect environmental effects are identified. Water will be essential to the renewable hydrogen production and hydrogen uses significant quantities changes in water availability due to climate change may result in increased demand for water. It is assumed that even if the regulatory framework is in step with the scaling up of the renewable hydrogen production, the effects are still likely to remain **significant negative**.

Low-carbon hydrogen production – water impacts

7.35 Low-carbon hydrogen production will require less water than renewable hydrogen. However, assuming that within this reasonable alternative, renewable hydrogen will account for a small proportion of hydrogen produced, there would still be a demand for some water for the electrolysis process.

7.36 However, in light of the potential scale of hydrogen production and the fact that low-carbon hydrogen would account for majority of the production, overall minor negative indirect environmental effects are identified. As for renewable hydrogen, it is assumed that the development of the regulatory framework would be in step with the scaling up of low-carbon hydrogen production. It is also assumed that since renewable hydrogen will be of more limited extent, strategic and water rich locations would be chosen for its production. With this assumption, there is the potential for a **minor negative** effect.

Hydrogen economy – water impacts

7.37 A hydrogen economy focuses on large scale hydrogen production from both renewable and low-carbon sources roughly in equal parts. This results in significant negative effects on water as outlined in relation to renewable and low-carbon hydrogen production. It is assumed that this approach would enable rapid displacement of fossil fuels. It also supports the more rapid decarbonisation of the economy which reduces GHG emissions and the impacts of climate change. Despite the range of positive effects, it is expected that the hydrogen economy alternative has significant negative effects on water, as it would require significant amounts of sea and freshwater for the production process.

7.38 It is expected that even if the regulatory framework addresses all the issues listed above, **significant negative** effects would be identified.

Green export – water impacts

7.39 The focus of renewable export is for the large-scale production of renewable hydrogen for export to mainland Europe. This will lead to the potential negative effects of renewable hydrogen production on water arising from desalination process and freshwater abstraction associated with hydrogen production.

7.40 The provision of renewable hydrogen for export supports GHG emissions reductions in Scotland and also in other countries. However, it is assumed that if Scotland does not produce renewable hydrogen for export, this market demand would be fulfilled by other countries with strategic wind, solar and water resources. Therefore, it is assumed that other countries would continue to meet their climate change commitments.

7.41 However, it is expected that even with the regulatory framework in place, **significant negative** effects are identified.

Focused hydrogen – water impacts

7.42 Under the alternative of a focused hydrogen economy, the environmental effects of hydrogen production are smaller in scale, due to significantly smaller scale development of hydrogen production related infrastructure. This alternative assumes the use of other technologies, such as electrification, to reduce GHG emissions without transition to hydrogen. The scale of focused hydrogen production is uncertain, however assuming a focused level of production in key locations minor negative environmental effects are identified in relation to water. Assuming that the development of the regulatory framework would be in step with the development of hydrogen production, the environmental effects are assumed to be **minor to negligible negative**.

Air quality

Green hydrogen production – air quality impacts

7.43 In relation to the alternative where the majority of hydrogen produced is renewable the potential indirect environmental effects on air quality arising from the production of renewable energy are expected to be minor positive. Large scale renewable hydrogen production will displace emissions from traditional fossil fuels leading to an overall improvement in air quality depending on whether the hydrogen is used in fuel cells or other applications which emit NO_x. There will also be additional air quality impacts from storage (including storage as ammonia) and transportation. Low-carbon hydrogen will account for a small proportion of the hydrogen production and is likely to have negative effects on air quality due to the emissions associated with the combustion of natural gas. However, these emissions are likely to displace air quality impacts from other fossil fuel sources.

7.44 Overall, **minor positive** indirect environmental effects are identified, as it is expected that the use of hydrogen will displace existing more polluting alternatives.

Low-carbon hydrogen production – air quality impacts

7.45 Low-carbon hydrogen production is associated with having minor negative effects on air quality from the combustion of natural gas. Low-carbon hydrogen production is likely to have greater air quality impacts than renewable hydrogen production, although emissions from low-carbon hydrogen production is an area of uncertainty. Deployment of hydrogen may have positive or negative effects on air quality depending on the application as fuel cells or through direct combustion.

7.46 However, these emissions are likely to displace air quality impacts from other fossil fuel sources. There is uncertainty over the balance between overall air quality improvements and air quality impacts and therefore **mixed** (minor negative and minor positive) indirect environmental effects are identified.

Hydrogen economy – air quality impacts

7.47 A hydrogen economy focuses on large scale hydrogen production from both renewable and low-carbon sources roughly in equal parts. This results in **mixed** effects (minor negative and minor positive) on air as outlined in relation to renewable and low-carbon hydrogen production. It is assumed that this approach will enable rapid displacement of fossil fuels leading to overall improvements in air quality, although there will be emissions of NO_x from some applications of hydrogen. Despite the range of positive effects, it is expected that hydrogen economy has negative effects on air, especially from low-carbon hydrogen production, and hydrogen distribution activities. Assuming that the development of the regulatory framework would be in step with the development of hydrogen production, some of these effects may be addressed, however overall mixed effects are still identified.

Green export– air quality impacts

7.48 The focus of renewable export is for the large-scale production of renewable hydrogen for export to mainland Europe and the rest of the UK. This will lead to the potential indirect positive effects on air quality; however, these will be mainly experienced in countries importing the hydrogen. Some negative effects on air are likely to arise from the production process in Scotland. However, considering that only renewable hydrogen will be produced, the expected air quality issues should be short lived and occur only during the construction phase of the development. There is scope for hydrogen leakage during the production, storage and distribution. However, it is assumed that regulatory framework will address these issues. The provision of renewable hydrogen for export supports air quality improvements from the deployment of cleaner fuel in the recipient countries.

7.49 No additional benefits to air quality in Scotland are achieved from this alternative. Therefore, **neutral effects** are identified.

Focused hydrogen– air quality impacts

7.50 Under the alternative of a focused hydrogen economy, the environmental effects of hydrogen production are smaller in scale, due to significantly smaller scale development of hydrogen production related infrastructure. This alternative assumes the use of other technologies, such as electrification, to reduce GHG emissions without transition to hydrogen. The scale of focused hydrogen production is uncertain, however assuming a focused level of production in key locations for difficult to decarbonise industries, and assuming associated air quality benefits, minor positive environmental effects are identified. It is also assumed that strategic industries would be selected for the implementation of hydrogen into the processes to harness the most benefits as opposed to other technologies available.

7.51 Assuming that the development of the regulatory framework would be in step with the development of hydrogen production, the environmental effects are assumed to be **minor to negligible positive**.

Climatic factors

Green hydrogen production – climatic factors impacts

7.52 Within the renewable reasonable alternative, it is assumed that majority of hydrogen produced will be renewable and it is expected this will have significant positive effects on climatic factors. This alternative will largely displace emissions from traditional fossil fuels. However, even for renewable hydrogen, there is a scope for leakage especially during storage and distribution. Therefore, minor negative effects can arise. Low-carbon hydrogen, which will only account for a small proportion of the entire production under this alternative, is likely to have minor negative effects due to net carbon emissions. There will also be a significant amount of carbon embedded in the materials used for the construction phase of the developments. However, the production of low carbon hydrogen will displace current fossil fuel use without carbon capture, leading to **significant positive effects** overall on climatic factors.

7.53 It is assumed that the regulatory framework for the development of hydrogen production, storage and distribution and carbon capture technologies will be prepared in step with the hydrogen developments, reducing emissions from these processes.

Low-carbon hydrogen production – climatic factors impacts

7.54 Low-carbon hydrogen production is associated with the potential for hydrogen and carbon leakage from CCUS storage having negative effects on climatic factors, although there is a high degree of uncertainty over the scale of this effect. Studies suggest CCUS projects typically have a CO_2 capture rate of 90%[317,318] however with improved efficiency capture rates of up to 98% may be possible in the future[319] Furthermore, the production and processing of methane for low-carbon hydrogen production results in carbon emissions, including from fugitive emissions and flaring. These effects will be ongoing throughout the lifetime of low-carbon hydrogen production and relative to the scale of low-carbon hydrogen production.

7.55 However, the production of low carbon hydrogen will displace current fossil fuel use without carbon capture, leading to **significant positive effects** overall on climatic factors.

[317] Leung, D., Caramanna, G. and Maroto-Valer, M. (2014). An overview of current status of carbon dioxide capture and storage technologies. Renewable and Sustainable Energy Reviews, [online] Available at: https://www.sciencedirect.com/science/article/pii/S1364032114005450 (accessed 28/10/2021).
[318] Dods, M., Kim, E., Long, J. and Weston, S. (2021). Deep CCS: Moving Beyond 90% Carbon Dioxide Capture. Environmental Science & Technology, [online] Available at: https://pubs.acs.org/doi/10.1021/acs.est.0c07390 (accessed on 28/10/2021)
[319] Brandl, P., Bui, M., Hallett, J. and Mac Dowell, N. (2021). Beyond 90% capture: Possible, but at what cost?. International Journal of Greenhouse Gas Control, 105, p.103239.

7.56 It is assumed that the regulatory framework for the development of hydrogen production, storage and distribution and carbon capture technologies will be prepared in step with the hydrogen developments, reducing emissions from these processes. The regulatory framework for oil and gas production is already established, therefore the levels of emissions associated with these processes would remain as present.

Hydrogen economy – climatic factors impacts

7.57 A hydrogen economy focuses on large scale hydrogen production from both renewable and low-carbon sources roughly in equal parts. This results in both minor negative and significant positive effects on climatic factors as outlined in relation to renewable and low-carbon hydrogen production. It is assumed that this approach will enable rapid displacement of fossil fuels, leading to reduced GHG emissions in the case of renewable hydrogen.

7.58 However, the production of low carbon hydrogen will displace current fossil fuel use without carbon capture, leading to **significant positive effects** overall on climatic factors.

Green export – climatic factors impacts

7.59 The focus of renewable export is for the large-scale production of renewable hydrogen for export to mainland Europe. This will lead to the potential indirect positive effects on climatic factors, as renewable hydrogen will help displace emissions from fossil fuel-based energy sources in the recipient countries. However, there will be negative effects on climatic factors within Scotland arising from the potential for hydrogen leakage and its consequences on global warming.

7.60 It is assumed that if Scotland does not produce renewable hydrogen for export, this market demand would be fulfilled by other countries with strategic wind and water resources. Therefore, it is assumed that other countries would continue to meet their climate change commitments and source renewable hydrogen from other locations, and no additional benefits to climatic factors are achieved from this alternative. Therefore, this alternative has **minor negative effects** on Scotland's greenhouse gas emissions from production related emissions.

Focused hydrogen – climatic factors impacts

7.61 Under the focused hydrogen economy alternative, the environmental effects of hydrogen production are smaller in scale, due to substantially smaller scale of hydrogen developments and related infrastructure. This alternative assumes the use of other technologies, such as electrification, to reduce GHG emissions without transition to hydrogen. The scale of focused hydrogen production is uncertain, however assuming production in key locations which are most challenging to decarbonise, it is assumed that low carbon hydrogen will displace current fossil fuel use without carbon capture. Assuming that the development of the regulatory framework would be in step with the development of hydrogen production, the environmental effects are assumed to be **minor positive**.

Cultural heritage and the historic environment

Green hydrogen production – cultural heritage and the historic environment impacts

7.62 In relation to the alternative where majority of hydrogen produced will be renewable the potential indirect environmental effects on cultural heritage arising from the production of renewable energy are expected to be minor negative. Considering the large scale of the renewable energy production required, it is expected that some on and offshore windfarms may negatively impact on historic assets or their setting. It is assumed that adverse effects will be addressed through existing planning mechanisms, however a **minor negative** effect is still expected.

Low-carbon hydrogen production – cultural heritage and the historic environment impacts

7.63 Low-carbon hydrogen production is less likely to lead to negative effects on cultural heritage and historic environment as it is assumed that majority of the required facilities will be delivered either on already developed land or will reuse existing oil and gas infrastructure. Therefore, a **neutral** effect is identified.

Hydrogen economy – cultural heritage and the historic environment impacts

7.64 A hydrogen economy focuses on large scale hydrogen production from both renewable and low-carbon sources roughly in equal parts. This results in minor negative effects on cultural heritage and the historic environment as outlined in relation to renewable and low-carbon hydrogen production. It is assumed that this approach will enable rapid displacement of fossil fuels, leading to reduced GHG emissions. Due to the impacts from renewable energy production and hydrogen storage it is expected that the hydrogen economy alternative will have **minor negative effects**.

7.65 However, if the regulatory framework addresses all of the issues listed above and in particular in relation to the developments impacting on the setting of historic environment features, a remaining **minor negative** effect is likely to remain.

Green export – cultural heritage and the historic environment impacts

7.66 The focus of renewable export is for the large-scale production of renewable hydrogen for export to mainland Europe. This will lead to the potential significant negative effects of renewable hydrogen production on cultural heritage and the historic environment. This is because the scale of hydrogen production will be larger than in the renewable hydrogen production alternative, therefore having larger impacts.

7.67 This reasonable alternative will require renewable energy to satisfy the domestic demand and the energy required for the hydrogen production for export.

7.68 The provision of renewable hydrogen for export supports GHG emissions reductions in other countries. However, it is assumed that if Scotland does not produce renewable hydrogen for export, this market demand would be fulfilled by other countries with strategic wind, solar and water resources. Therefore, it is assumed that other countries would continue to meet their climate change commitments and no additional benefits to cultural heritage and historic environment are achieved from this alternative. Therefore, using the same assumptions as previously for the regulatory framework, **significant negative** effects from large scale renewable hydrogen production would be assumed to be reduced to overall **minor negative** effects.

Focused hydrogen – cultural heritage and the historic environment impacts

7.69 Under the alternative of a focused hydrogen economy, the environmental effects of hydrogen production are smaller in scale, due to significantly smaller scale development of hydrogen production related infrastructure. This alternative assumes the use of other technologies, such as electrification, to reduce GHG emissions without transition to hydrogen. The scale of focused hydrogen production is uncertain, however assuming a focused level of production in key locations for hard to decarbonise industries, minor negative environmental effects are identified. Assuming that the development of the regulatory framework would be in step with the development of hydrogen production, the environmental effects are assumed to be **minor to negligible** negative.

Landscape and geodiversity

Green hydrogen production – landscape and geodiversity impacts

7.70 In relation to the renewable alternative, the potential indirect environmental effects on landscape and geodiversity arising from the production of renewable energy are expected to be significant negative. Considering the scale of the renewable energy production required, it is expected that some on and offshore windfarms may negatively impact on landscapes and their setting. It is assumed that adverse effects will be addressed through existing planning mechanisms and that the regulatory framework will be prepared in step with the renewable hydrogen developments, considering the scale of renewable energy developments needed, **significant negative** effects are still identified.

Low-carbon hydrogen production – landscape and geodiversity impacts

7.71 Low-carbon hydrogen production is less likely to lead to negative effects on landscape and geodiversity as it is assumed that majority of the required facilities will be delivered either on already developed land or will reuse existing oil and gas infrastructure. Renewable hydrogen will only account for a small proportion of the developments, and negative effects are identified in relation to it. However, overall, a **minor negative** effect is identified.

Hydrogen economy – landscape and geodiversity impacts

7.72 A hydrogen economy focuses on large scale hydrogen production from both renewable and low-carbon sources roughly in equal parts. This results in mixed effects (significant negative and minor positive) on landscape and geodiversity as outlined in relation to renewable and low-carbon hydrogen production. It is assumed that this approach will enable rapid displacement of fossil fuels, leading to reduced GHG emissions in the case of renewable hydrogen. It is expected that the hydrogen economy alternative will have mixed effects.

7.73 Even if the regulatory framework addresses all the issues listed above and in particular in relation to the development's encroachment on protected and unique landscapes, **mixed effects** would be assumed to remain.

Green export – landscape and geodiversity impacts

7.74 The focus of renewable export is for the large-scale production of renewable hydrogen for export to mainland Europe. This will lead to the potential significant negative effects of renewable hydrogen production on landscape and geodiversity. This is because the scale of the hydrogen production will be larger than in the renewable alternative, therefore having more significant adverse effects.

7.75 This reasonable alternative will require renewable energy to satisfy the domestic demand hydrogen demand and export demand.

7.76 Therefore, using the same assumptions as for the renewable hydrogen production alternative, it is assumed that adverse effects will be minimised through existing planning mechanisms and that the regulatory framework will be prepared in step with the renewable hydrogen developments, however considering the scale of renewable energy developments needed, significant negative effects are still identified.

Focused hydrogen – landscape and geodiversity impacts

7.77 Under the alternative of a focused hydrogen economy, the environmental effects of hydrogen production are smaller in scale, due to the significantly smaller scale development of hydrogen production related infrastructure. This alternative assumes the use of other technologies, such as electrification, to reduce GHG emissions without transition to hydrogen. The scale of focused hydrogen production is uncertain, however assuming a focused level of production in key locations **minor negative environmental** effects are identified. Assuming that the development of the regulatory framework would be in step with the development of hydrogen production, the environmental effects are assumed to be **minor to negligible** negative.

Material Assets

Green hydrogen production – material assets impacts

7.78 Renewable hydrogen production will require a significant number of new wind farms, supporting facilities and infrastructure. Only some of the materials required will be recycled, and a significant amount of energy will be required for construction and for maintenance. However, this will increase the overall renewable energy capacity, with positive effects on renewable energy infrastructure. As such there will be **mixed** (minor positive and minor negative effects) on material assets.

7.79 It is assumed that the regulatory framework will be developed in step with the renewable hydrogen developments, and this may offer a scope for potential reductions in materials required. However, it is expected that the effect will remain **mixed**.

Low-carbon hydrogen production – material assets impacts

7.80 Low-carbon hydrogen production will require significantly fewer material assets than renewable hydrogen for the construction of the required infrastructure. However, low-carbon hydrogen will require continued extraction of natural gas. Moreover, assuming that within this reasonable alternative, renewable hydrogen will only account for a small proportion of hydrogen produced, there will still be a demand for some new materials for additional wind farms.

7.81 However, in light of the potential scale of hydrogen production and the fact that low-carbon hydrogen will account for the majority of the production, overall minor negative indirect environmental effects are identified. As for renewable hydrogen, it is assumed that the development of the regulatory framework would be in step with the scaling up of low-carbon hydrogen production. It is also assumed that since renewable hydrogen will be lesser, renewable hydrogen production facilities will be located strategically within the vicinity of wind farms.

7.82 Due to the increased demand for materials and improvements to hydrogen production infrastructure, it is expected that this alternative will have **mixed** (minor positive and minor negative effects) effect on material assets.

Hydrogen economy– material assets impacts

7.83 A hydrogen economy focuses on large scale hydrogen production from both renewable and low-carbon sources roughly in equal parts. This results in the mixed negative effects on material assets as outlined in relation to renewable and low-carbon hydrogen production.

7.84 This will increase the overall renewable energy capacity, with positive effects on renewable energy infrastructure. As such there will be **mixed** (minor positive and minor negative effects) on material assets.

7.85 It is assumed that the regulatory framework will be developed in step with the hydrogen developments, and this may offer a scope for potential reductions in materials required. However, it is expected that the effect will remain **mixed**.

Green export– material assets impacts

7.86 The focus of renewable export is for the large-scale production of renewable hydrogen for export to mainland Europe. This will lead to the potential negative effects of renewable hydrogen production on material assets considering the scale of additional renewable energy that will need to be produced. It is because the scale of the hydrogen production will be larger than in the renewable alternative, therefore having larger impacts.

7.87 This reasonable alternative will require renewable energy to satisfy the domestic demand and the energy required for the hydrogen production for export. This requires development of significant renewable energy resources, and associated demands on materials, and enhancement to the renewable hydrogen production infrastructure. This results in both minor negative and minor positive effects.

7.88 The provision of renewable hydrogen for export supports GHG emissions reductions in other countries. However, it is assumed that if Scotland does not produce renewable hydrogen for export, this market demand would be fulfilled by other countries with strategic wind and water resources. Therefore, it is assumed that similar demands would be made on material assets in other countries producing hydrogen and no additional benefits to resource consumption from material assets are achieved from this alternative. Despite using the same assumptions as previously for the regulatory framework, **mixed** effects are still identified.

Focused hydrogen– material assets impacts

7.89 Under the alternative of a focused hydrogen economy, the environmental effects of hydrogen production are smaller in scale, due to significantly smaller scale development of hydrogen production related infrastructure. This alternative assumes the use of other technologies, such as electrification, to reduce GHG emissions without transition to hydrogen. The scale of focused hydrogen production is uncertain, however assuming a focused level of production in key locations with associated resource use and infrastructure enhancement, minor to negligible mixed effects (minor negative and minor positive) are identified.

Chapter 8
Mitigation and enhancement

Introduction

8.1 The 2005 Act states that *'the measures envisaged to prevent, reduce and as fully as possible offset any significant adverse effects on the environment of implementing the plan or programme'* are outlined within the Environmental Report. These measures are often referred to as mitigation measures. The following text summarises the mitigation measures identified from the assessment.

8.2 This assessment has identified no Actions judged likely to result in direct significant adverse effects. However, the assessment has identified negative indirect effects. This section therefore focuses on ways in which minor adverse effects could be reduced or avoided, or where there is potential to enhance benefits and it focuses on minimising the negative indirect effects.

8.3 Scottish Government is delivering a Hydrogen Action Plan to encourage and guide hydrogen generation, distribution and utilisation in Scotland. Mitigation and enhancement measures will inform development and implementation of the Action Plan.

Mitigation

8.4 The following actions are required to address minor adverse effects or avoid the potential for such effects to occur.

8.5 Considering that the focus of this Action Plan is short-term, and it therefore provides a limited number of actions that would lead to tangible developments taking place during the 2021-2026 timeframe, there are only a few mitigation opportunities that could address the direct effects. These include:

- In terms of adverse effects on soil, developments of hydrogen infrastructure or supporting infrastructure should avoid being constructed on greenfield land. Where such developments need to be delivered on greenfield sites, soil restoration measures need to be taken.
- Minimise leakage from heating boilers when hydrogen is used and that any potential emissions from NO_x are minimised through effective technology solutions.

Similarly, more work is required to ensure that existing and new pipelines will prevent hydrogen leakage.

- Ensure adequate regulation for desalination facilities to avoid environmental impacts.
- Ensure adequate regulation and monitoring for water abstraction for onshore electrolysis, allowing sufficient acknowledgement of impacts of water scarcity from climate change.

Enhancement

8.6 The identified areas for enhancement relate primarily to research and innovation to address knowledge gaps, and development of the regulatory, planning and consent framework to consider cumulative effects from hydrogen development.

- Ensure that research and innovation focuses on understanding the direct and indirect environmental effects of hydrogen use and deployment on biodiversity, flora and fauna.
- Ensure the regulatory, planning and consent framework considers the consideration of the cumulative effects of hydrogen production and distribution on population and human health.
- Ensure that research and innovation focuses on understanding the direct and indirect environmental effects of hydrogen use and deployment on population and human health, especially in the longer term.
- Ensure the regulatory, planning and consent framework considers the cumulative effects of extensive hydrogen developments and supporting infrastructure on soil.
- Ensure that research and innovation focuses on understanding the direct and indirect environmental effects of hydrogen use and deployment on soil in the long term.
- Ensure the regulatory, planning and consent framework considers the cumulative effects of extensive hydrogen development and supporting infrastructure on water, including supply and disposal of brine from desalinisation.
- Ensure that research and innovation focuses on understanding the direct and indirect environmental effects of hydrogen use and deployment on water. In particular, it should focus on optimising the desalination process and gaining an understanding of how the brine can be disposed of to minimise environmental effects.
- Ensure that research and innovation focuses on understanding the cumulative effects of extensive hydrogen developments, supporting infrastructure, hydrogen use and deployment on air quality.
- Ensure the regulatory, planning and consent framework considers the cumulative effects of extensive hydrogen developments and supporting infrastructure on climatic factors
- Ensure that research and innovation focuses on understanding required processes to minimise leakage of hydrogen at all stages of production, distribution and deployment.
- Provide training and guidance on best practice techniques, particularly in the production, storage and transportation stages.
- Ensure that research and innovation focus on understanding the direct and indirect environmental effects of hydrogen use and deployment on climatic factors. There is still a lot of uncertainty on the subject of large-scale hydrogen production, storage and transportation and its potential impacts on global warming. One of the key areas that needs more investigation is the hydrogen cycle, which currently is poorly understood.
- Ensure the regulatory, planning and consent framework to consider the cumulative effects of extensive hydrogen development and supporting infrastructure on cultural heritage and historic environment.
- Ensure the regulatory, planning and consent framework to consider the cumulative effects of extensive hydrogen development and supporting infrastructure on landscape and geodiversity.
- Ensure that research and innovation focus on understanding the direct and indirect effects of hydrogen on material assets.

Chapter 9
Monitoring

9.1 Monitoring significant environmental effects is a statutory requirement within the 2005 Act. Monitoring seeks to ensure that plans avoid generating unforeseen adverse environmental effects and enables the responsible authority to undertake appropriate remedial action.

9.2 Proposals for monitoring the draft HAP are in development and will be addressed and further outlined within the post-adoption statement at the end of the SEA process.

9.3 At this stage it is anticipated that monitoring for unforeseen environmental effects could be linked to the indicators in the Environment Strategy Initial Monitoring Framework[320], relevant indicators include:

- Composite biodiversity indicator
- Air pollutant emissions
- Freshwater condition
- Marine environmental quality
- Greenhouse gas emissions
- Scotland's carbon footprint

9.4 Indicators for soil health as part of the Environment Strategy are under development.

9.5 Indicators for landscape and geodiversity and cultural heritage and the historic environment will require to be identified.

[320] Scottish Government (2021) Environment Strategy: Initial monitoring framework. [Online] Available at: https://www.gov.scot/publications/environment-strategy-scotland-initial-monitoring-framework/documents/

Chapter 10
Conclusions and next steps

Conclusions

10.1 The preferred approach to the Draft Hydrogen Action Plan does not differentiate between a greater focus on renewable or low-carbon hydrogen production, therefore the environmental effects from large scale deployment of both technologies are assumed.

10.2 The preferred approach to the Draft Hydrogen Action Plan, as set out through the six action themes reflects a combination of the three future development scenarios for hydrogen.

Next steps

10.3 The consultation on the Draft Hydrogen Action Plan will run for an 10 week period from 10th November to 19th January 2022. Comments on the Draft Hydrogen Action Plan and the Environmental Report can be submitted via the Scottish Government Citizen Space website . Requests for hard copies of the Environmental Report can be made to hydrogeneconomy@gov.scot.

10.4 Consultation questions on the SEA Environmental Report are as follows:

a. Do you have any comments on the environmental baseline information referred to in the Environmental Report?

b. Are you aware of further information that could be used to inform the assessment findings?

c. What are your views on the assessment findings?

d. Are there other environmental effects arising from the Draft Hydrogen Action Plan?

e. What are your views on the alternatives considered?

f. What are the most significant environmental effects which should be taken into account as the Draft Hydrogen Action Plan is finalised?

g. How can the Draft Hydrogen Action Plan be enhanced to maximise positive environmental effects?

h. What do you think of the proposed approach to mitigation and monitoring proposed?

10.5 Following the consultation period, the consultation responses will be analysed and the Scottish Government will finalise and publish the Hydrogen Action Plan 2021-2026. After the Hydrogen Action Plan 2021-2026 is adopted a Post Adoption Statement will be produced. This Statement will set out how the SEA and the views received in the consultation processes have been taken into account.

Appendix A

Plans, policies and strategies

Note: The Scottish Government has committed to alignment between Scots and EU law as a result of EU exit. Although the statutory governance arrangements are not yet in place, European legislation is included in the tables below.

General

Source	Key objectives	Implications/ Comments
International		
Aarhus Convention (1998)	To develop a number of rights of the public with regard to the environment. Local authorities should provide for: ■ The right of everyone to receive environmental information ■ The right to participate from an early stage in environmental decision making ■ The right to challenge in a court of law public decisions that have been made without respecting the two rights above or environmental law in general	Ensure that the public are involved and consulted at all relevant stages of SEA production.
Johannesburg Declaration on Sustainable Development (2002)	Commitment to building a humane, equitable and caring global society aware of the need for human dignity for all. Areas of focus include: ■ Sustainable consumption and production patterns. ■ Accelerate shift towards sustainable consumption and production – 10-year framework of programmed of action. ■ Reverse trend in loss of natural resources. ■ Renewable energy and energy efficiency. ■ Urgently and substantially increase Global share of renewable energy. ■ Significantly reduce the rate of biodiversity loss by 2010.	The SEA should reflect objectives to support reduction in emissions of greenhouse gases, promote renewable energy and energy efficiency.
European		
EU Public Participation Directive	Provides a legal framework for community involvement by requiring public participation in decision-making and regulation, including through access to information and consultation.	Ensure that the public are involved and consulted at all relevant stages of drawing up certain plans and programmes relating to the environment.

Source	Key objectives	Implications/ Comments
Directive 2003/35/EC on providing for public participation in respect of the drawing up of certain plans and programmes relating to the environment and amending with regard to public participation and access to justice Council Directives 85/337/EEC and 96/61/EC		
SEA Directive 2001 Directive 2001/42/EC on the assessment of the effects of certain plans and programmes on the environment	The key objective of the SEA Directive is to provide for a high level of protection of the environment and contribute to the integration of environmental considerations into the preparation and adoption of plans and programmes with a view to promoting sustainable development.	Requirements of the SEA Directive must be met in Strategic Environmental Assessments.
National (Legislation)		
Town and Country Planning (Scotland) Act 1997 (as amended)	The Town and Country Planning (Scotland) Act governs the use and development of land within Scotland. The 1997 Act forms the basis of the Scottish planning system. It sets out the roles of Scottish Ministers and designates local authorities as 'planning authorities' with a responsibility for producing local development plans and handling most aspects of development management and enforcement. All planning applications in Scotland are required to be determined against the Town and Country Planning (Scotland) Ac 1997.	The SEA should be mindful of the requirements set out in the 1997 Act.
Planning etc. (Scotland) Act 2006	The Planning etc. (Scotland) Act 2006 formed a central part of the reform of the Scottish planning system. One of its key effects was the creation of Strategic Development Planning Authorities, which comprise several local planning authorities and are charged with producing long-term development plans.	The SEA should be mindful of the requirements set out in the Planning etc. (Scotland) Act 2006
Town and Country Planning (Development Management Procedure) (Scotland)	Sets out provisions for granting planning permission in accordance with the Town and Country Planning (Scotland) Act 1997.	The SEA should be mindful of the requirements of the Town and Country Planning (Development Management Procedure) Scotland Regulations

Source	Key objectives	Implications/ Comments
Regulations 2008 (as amended)		
Town and Country Planning (Environmental Impact Assessment) (Scotland) Regulations 2011	Sets out criteria for determining whether an Environmental Impact Assessment would be required for developments.	The SEA should reflect the objectives **to minimise the potential environmental impacts of development**
Planning (Scotland) Bill	An Act of the Scottish Parliament to make provision about how land is developed and used. The Bill is part of a wider planning system reform responding to an independent review of planning, which includes changes to secondary legislation made under existing powers as well as non-legislative changes. Some of the key aspects of the Bill are its provisions in relation to the system of development plans; the opportunities for community engagement in planning; the effective performance of planning authorities' functions; and a new way to fund infrastructure development.	The SEA should be mindful of the requirements proposed by the Planning (Scotland) Bill.
Electricity Act 1989	Establishes a licensing regime for generation, transmission, distribution and supply, and sets out the statutory duties of the regulator. The Act gives powers to Scottish Ministers for the determination of applications for electricity infrastructure including applications to construct, extend and operate onshore electricity generating stations exceeding 50 megawatts capacity; applications to vary existing consents which were granted under section 36; and applications for overhead lines.	The SEA should be mindful of the requirements of the Act.
National (policies, Plans, Programmes and Strategies)		
National Planning Framework 3 (the Scottish Government, 2014)	The National Planning Framework 3 sets out the Scottish Government's spatial development/investment priorities over the next 20-30 years. It is a long-term strategy to promote environmental sustainability, equality in opportunity, technological progress and human well-being and health. Key outcomes of the framework are as follows: ■ Creating sustainable places ■ Reducing carbon emissions and adapting to climate change	The SEA should reflect the objectives to make Scotland a **successful, sustainable** place; a **low carbon** place; a **natural, resilient** place; and, a **connected** place.

Source	Key objectives	Implications/ Comments
	▪ Protecting and enhancing Scotland's natural cultural assets as well as facilitating their sustainable use ▪ Supporting better transport and digital connectivity	
Scottish Planning Policy (The Scottish Government, 2014)	The purpose of the Scottish Planning Policy is to set out national planning policies on how to address land use matters across the country. It is non-statutory, however, it is in line with the Town and Country Planning (Scotland) ▪ Creating sustainable places ▪ Reducing carbon emissions and adapting to climate change ▪ Protecting and enhancing Scotland's natural cultural assets as well as facilitating their sustainable use ▪ Supporting better transport and digital connectivity	The SEA should reflect the objectives to make Scotland a **successful, sustainable** place; a **low carbon** place; a **natural, resilient** place; and, a **connected** place.

Climatic Factors

Source	Key objectives	Implications/ Comments
International		
IPCC's Fifth Assessment Report on Climate Change (2014)	To limit and/or reduce all greenhouse gas emissions which contribute to climate change	The SEA should reflect objectives to **support reduction in emissions of greenhouse gases.**
The Cancun Agreement-UNFCC (2011)	Shared vision to keep global temperature rise to below two degrees Celsius, with objectives to be reviewed as to whether it needs to be strengthened in future on the basis of the best scientific knowledge available.	Include sustainability objectives to support the **reduction in greenhouse gas emissions and mitigation to climate change.**
Paris Agreement (United Nations 2015)	The main aim of the Paris Agreement centres on keeping global temperature rise this century below 2°C above preindustrial levels. Frameworks are to be put in place to help achieve these goals.	The SEA should reflect objectives to **adapt and mitigate climate change.**

Source	Key objectives	Implications/ Comments
The Kyoto Protocol to the UNFCCC (1997)	The Kyoto Protocol to the UNFCCC established the first policy that actively aims to reduce greenhouse gas emissions by industrialised countries.	The SEA Framework should include objectives to **reduce greenhouse gas emissions and promote sustainable development.**
European		
Emissions Trading System Directive 2009 Directive 2009/29/EC to improve and extend the greenhouse gas emission allowance trading scheme of the Community	The main aim of the Directive is to improve and extend the greenhouse gas emission allowance trading scheme of the Community	The SEA should reflect objectives to **promote energy efficiency and reduce the emission of greenhouse gases.**
Renewable Energy Directive 2009 Directive 2009/28/EC on the use of energy from renewable sources	The Directive sets targets for renewable energy use within the EU, which requires that 20% of the energy consumed within the EU is renewable.	The SEA should reflect objectives to **promote renewable energy.**
Energy Efficiency Directive 2012 Directive 2012/30/EU on energy efficiency	The purpose of the Directive is to promote energy efficiency by establishing a set of binding measures to help the EU reach its 20% energy efficiency target by 2020.	The SEA should reflect objectives to **promote energy efficiency and prudent use of resources.**
National (Legislation)		
Climate Change (Scotland) Act 2009 Including amendments made by the Climate Change (Emissions Reduction Targets) (Scotland) Act 2019	The 2009 Act sets statutory targets for the reduction of greenhouse gas emissions and makes further provision about energy efficiency and about the reduction and recycling of waste. The Act set an interim 42 percent reduction target by 2020 and an 80 percent reduction target for 2050. In 2019, the Climate Change (Emissions Reduction Targets) (Scotland) Act 2019 amended these reduction targets to a 56% reduction by 2020, 75% reduction by 2030, 90% reduction by 2040 and achieving net-zero emissions by 2045.	The SEA should reflect the objective to **reduce the emission of greenhouse gases and mitigate climate change**

Source	Key objectives	Implications/ Comments
	Secondary legislation has been made under the Climate Change (Scotland) Act 2009, including: ■ The Climate Change (Annual Targets) (Scotland) Order 2010: sets emission reduction targets for 2010-2022 ■ The Climate Change (Limit on Carbon Units) (Scotland) Order 2010: places a limit on the amount of carbon units that may be credited to net Scottish Emissions for the period 2010-2012 ■ The Carbon Accounting Scheme (Scotland) Regulations 2010: establish a scheme for monitoring compliance with annual reduction targets for 2010-22 (as amended in 2015 and 2016) ■ The Climate Change (International Aviation and Shipping) (Scotland) Order 2010: establish a method by which emissions of greenhouse gases from international aviation and international shipping that are attributable to Scotland are calculated. ■ The Climate Change (Annual Targets) (Scotland) Order 2011: sets emission reduction targets for 2023-2027 ■ The Climate Change (Limit on Carbon Units) (Scotland) Order 2011: places a limit on the amount of carbon units that may be credited to net Scottish Emissions for the period 2023-2027 ■ The Climate Change (Limit on Carbon Units) (Scotland) Order 2010: places a limit on the amount of carbon units that may be credited to net Scottish Emissions for the period 2013-2017 ■ The Climate Change (Duties of Public Bodies: Reporting Requirements) (Scotland) Order 2015: requires bodies to prepare reports on compliance with climate change duties ■ The Climate Change (Additional Greenhouse Gas) (Scotland) Order 2015: adds nitrogen trifluoride as an additional greenhouse gas listed in the Climate Change (Scotland) Act 2009 ■ The Climate Change (Annual Targets) (Scotland) Order 2016: sets annual reduction targets for 2028-2032	

Source	Key objectives	Implications/ Comments
	■ The Climate Change (Limit on Carbon Units) (Scotland) Order 2016: places a limit on the amount of carbon units that may be credited to net Scottish Emissions for the period 2018-2022 Part 5 of the Climate Change (Scotland) Act 2009 also includes secondary legislation in relation to the energy performance of buildings and the functions of forestry commissioners.	
National (policies, Plans, Programmes and Strategies)		
Climate Change Plan (The Scottish Government, 2018) Including the Update to the Climate Change Plan (The Scottish Government, 2020)	The Climate Change (Scotland) Act 2009 requires that Ministers publish a report setting out policies and proposals to meet annual targets. With the publication of the Climate Change Plan (2018), the Scottish Government aims to meet its emission reduction targets over the period 2018-2032. The Climate Change Plan sits alongside the Scottish Government's Energy Strategy, and provides the strategic framework for our transition to a low carbon Scotland. Building on previous reports on policies and proposals, the Plan sets out the path to a low carbon economy while helping to deliver sustainable economic growth and secure the wider benefits to a greener, fairer and healthier Scotland in 2032. The Climate Change Plan provides policies and proposals to reduce GHG emissions from seven key sectors, including: electricity; buildings; transport; industry; waste and the circular economy; land use, land use change and forestry; and, agriculture. Following the amendments to emissions reduction targets by the Climate Change (Emissions Reduction Targets) (Scotland) Act 2019, the Scottish Government committed to updating the climate change plan (2020). The new plan continues to drive progress towards the current emissions reduction target of net-zero b 2045. The plan includes an additional sector, negative emissions technologies.	The SEA should reflect objectives to **adapt and mitigate climate change, and support the reduction of greenhouse gas emissions.**
Reducing emissions in Scotland, Progress Report to Parliament (CCC, 2020)	This report documents Scotland's progress towards reducing greenhouse gas emissions. The report sets out strategic policies, objectives and milestones for the coming years, including: ■ Delivering an update to the Climate Change Plan which takes into account recent progress, seeks to deliver meaningful reductions outside of the power sector, and considers the implications of COVID-19. ■ Delivering a strategy for low-carbon heat and energy efficiency in Scotland's buildings.	The SEA should reflect objectives to **adapt and mitigate climate change, and support the reduction of greenhouse gas emissions.**

Source	Key objectives	Implications/ Comments
	■ Decarbonising transport by encouraging behavioural change, uptake of active and sustainable means of travel, and promoting '20 minute' neighbourhoods. ■ Accelerating investments in low-carbon technologies (e.g. carbon capture and storage, renewables and hydrogen) and climate adaptation infrastructure ■ Maximise carbon sequestration by increasing tree planting to 18,000 ha per year, and peatland restoration to 20,000 ha per year. ■ Strengthen policies in local plans relating to climate change and adaptation.	
Climate Ready Scotland: Second Scottish Climate Change Adaptation Programme (The Scottish Government, 2019)	The Adaptation Programme provides an overarching framework for adaptation to climate change, setting out Scottish Ministers' objectives as required by the 2009 Act. Building on the work of Climate Change Ready Scotland: Scottish Climate Change Adaptation Programme (2014) this second Programme sets out to address the impacts identified for Scotland by the 2017 UK Climate Change Risk Assessment.	The SEA should reflect objectives to **mitigate the effects of climate change.**
Climate Ready Scotland: Scottish Climate Change Adaptation Programme (The Scottish Government, 2014)	Addresses the impacts identified for Scotland in the UK Climate Change Risk Assessment (CCRA) published under section 56 of the UK Climate Change Act 2008. It aims to increase the resilience of Scotland's people, environment and economy to the impacts of a changing climate.	The SEA should reflect objectives to **mitigate the effects of climate change.**
Hydrogen Policy Statement (The Scottish Government, 2020)	The Statement sets out a vision for Scotland to become a leading hydrogen nation in the production of reliable, competitive, and sustainable hydrogen. It recognises the importance of hydrogen in the transition to renewable energy. The policy statement outlines the commitments of the Scottish Government to help achieve hydrogen production.	The SEA should reflect objectives to **support the reduction of greenhouse gas emissions.**
A Low Carbon Economic Strategy for Scotland – Scotland, A Low Carbon Society (The Scottish Government, 2010)	The main purpose of the Low Carbon Economic Strategy is to achieve the targets as set out in the Climate Change (Scotland) Act 2009, as amended. The document provides a comprehensive framework for developing a low carbon economy across Scotland. The strategy sets out measures that could be undertaken by Parties to cut their greenhouse gas emissions. This vision relates to the energy sector, the built environment, Scotland's resources and businesses.	The SEA should reflect objectives to **support the reduction of greenhouse gas emissions**

Source	Key objectives	Implications/ Comments
Towards a Low Carbon Scotland – Smart Cities (The Scottish Government, 2012)	The purpose of the document is to highlight the ways in which Scotland can become a low carbon society by presenting a number of case studies about sustainable urban development in Scottish cities such as district heating development and a hydrogen bus project in Aberdeen, renewable energy projects in Edinburgh and the 'Energy from Waste' project in Glasgow.	The SEA should **support the reduction of greenhouse gas emissions.**
Delivering for Today, Investing for Tomorrow: The Government's Programme for Scotland 2018-19	One of the key objectives of the Programme is to promote further investments in renewable and low carbon energies in order to tackle climate change.	The SEA should reflect objectives to **support renewable and low carbon technologies.**
The Scottish Energy Strategy (The Scottish Government, 2017)	Scotland's Energy Strategy sits alongside the aforementioned Climate Change Delivery Plan. Three key themes underpin the Strategy; ■ A whole-system view in which energy supply and consumption are seen as equal priorities ■ A stable energy transition towards renewable energies and sustainable transport ■ A smarter model of local energy provision which promotes local energy, community involvement and community ownership of energy generation	The SEA should reflect objectives to **adapt to and mitigate climate change.**
Scottish Emissions Targets 2028-2032 – The high ambition pathway towards a low-carbon economy (Committee on Climate Change, 2016)	Sets out recommendations by the Committee on Climate Change which involves the following; ■ Significant rollout of low-carbon heat pumps and heat networks ■ Promoting sales of electric cars ■ Stimulating afforestation in Scotland ■ Expanding renewable power and shutdown of coal-fired power	The SEA should reflect objectives to **reduce greenhouse gas emissions.**
2020 Routemap for Renewable Energy in Scotland (2011), updated 2013	Reflects the new target to meet an equivalent of 100% demand for electricity from renewable energy by 2020, as well as our target of 11% renewable heat.	The SEA should reflect objectives to **reduce greenhouse gas emissions.**

Source	Key objectives	Implications/ Comments
Sectoral Marine Plan for Offshore Wind Energy (2020)	Sets out the Scottish Government's approach to offshore wind energy to support the continued growth of renewable energy to support a future clean energy system.	The SEA should reflect objectives to **reduce greenhouse gas emissions**
Big Climate Conversation	The Big Climate Conversation engaged over 2,500 people in Scotland, over a six-month period up to November 2019, in a discussion about Scotland's response to tackling the global climate emergency. Cross cutting issues which emerged included: ■ A holistic and system-wide approach requiring an integrated plan. ■ Government leadership ensuring that low carbon behaviours become the most convenient or only option. ■ A just transition to ensure that action to address climate change should not exacerbate inequalities and, where possible, should reduce them.	The SEA should reflect objectives to **reduce greenhouse gas emissions**
Scotland's Economic Strategy 2015	The strategy sets out an overarching framework for a more productive, cohesive and fairer Scotland. The Economic Strategy forms the strategic plan for existing and all future Scottish Government policy. In addition to setting goals for sustainable economic growth, the Economic Strategy also sets out our ambitions for investing in Scotland's infrastructure, and prioritises investment to ensure that Scotland protects and nurtures its natural resources and captures the opportunities offered by the transition to a more resource efficient, lower carbon economy.	The SEA should reflect objectives to **adapt and mitigate climate change, and support the reduction of greenhouse gas emissions.**
Protecting Scotland, Renewing Scotland: The Government's Programme for Scotland 2020-2021	The programme sets out Scottish Governments plans to make Scotland a more successful country, with opportunities and increased well-being for all. Within the context of the global climate emergency it sets out that the Scottish Government is committed to achieving net zero by 2045. The importance of adaption to prepare and manage the impacts of climate change is also set out. The programme sets out the next Infrastructure Investment Plan which will reflect Scotland's commitment to achieving net zero.	The SEA should reflect objectives to **reduce greenhouse gas emissions**

Biodiversity, Flora and Fauna

Source	Key objectives	Implications/ Comments
International		
Bern Convention (1979)	To ensure conservation and protection of wild plant and animal species and their natural habitats (listed in Appendices I and II of the Convention), to increase cooperation between contracting parties, and to regulate the exploitation of those species) listed in Appendix III. To this end the Convention imposes legal obligations on contracting parties, protecting over 500 wild plant species and more than 1,000 wild animal species.	The SEA should consider **the preservation and protection of the environment**.
Bonn Convention on the Conservation of Migratory Species of Wild Animals (1979)	To ensure that contracting parties work together to conserve terrestrial, marine and avian migratory species and their habitats (on a global scale) by providing strict protection for endangered migratory species. The overarching objectives set for the Parties are: - Promote, co-operate in and support research relating to migratory species - Endeavour to provide immediate protection for migratory species included in Appendix I - Endeavour to conclude Agreements covering the conservation and management of migratory species included in Appendix II	The SEA should reflect the objectives **protecting biodiversity and the natural environment.**
Ramsar Convention (1971)	To promote the wise use of wetlands and their resources. The Convention's mission is "the conservation and wise use of all wetlands through local and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world".	The SEA should take into account the **conservation of wetlands and their resources**.
The Convention on Biological Diversity (2010)	The Convention on Biological Diversity (CBD) is a multilateral treaty which served three main goals, including: - Conservation of biological diversity - Sustainable use of its components - Fair and equitable sharing of benefits arising from genetic	The SEA should reflect objectives **protecting biodiversity and sustainable use of its components.**

Source	Key objectives	Implications/ Comments
European		
The Habitats Directive 1992 Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora	To promote the maintenance of biodiversity taking account of economic, social, cultural and regional requirements. Conservation of natural habitats and maintain landscape features of importance to wildlife and fauna.	The SEA should reflect objectives to protect and maintain the natural environment and important landscape features.
The Birds Directive 2009 Directive 2009/147/EC is a codified version of Directive 79/409/EEC as amended	The preservation, maintenance, and re-establishment of biotopes and habitats shall include the following measures: Creation of protected areas. Upkeep and management in accordance with the ecological needs of habitats inside and outside the protected zones. Re-establishment of destroyed biotopes. Creation of biotopes.	The SEA should reflect objectives for the protection of birds.
EU Biodiversity Strategy to 2020 (European Commission, 2011)	The European Commission has adopted an ambitious new strategy to halt the loss of biodiversity and ecosystem services in the EU by 2020. The six targets cover: ▪ Full implementation of EU nature legislation to protect biodiversity ▪ Better protection for ecosystems, and more use of renewable infrastructure ▪ More sustainable agriculture and forestry ▪ Better management of fish stocks ▪ Tighter controls on invasive alien species ▪ A bigger EU contribution to averting global biodiversity loss	The SEA should reflect objectives to value, protect and enhance biodiversity.
EU Seventh Environmental Action Plan to 2020 (European Commission, 2013)	The EU's objectives in implementing the programme are: (a) to protect, conserve and enhance the Union's natural capital;	The SEA should reflect objectives to protect and enhance the natural environment.

Source	Key objectives	Implications/ Comments
	(b) to turn the Union into a resource-efficient, renewable and competitive low-carbon economy; (c) to safeguard the Union's citizens from environment-related pressures and risks to health and wellbeing; (d) to maximise the benefits of the Union's environment legislation; (e) to improve the evidence base for environment policy; (f) to secure investment for environment and climate policy and get the prices right; (g) to improve environmental integration and policy coherence; (h) to enhance the sustainability of the Union's cities; (i) to increase the Union's effectiveness in confronting regional and global environmental challenges.	
National (Legislation)		
Wildlife and Countryside Act 1981 (as amended)	The Act implements the principles of the Bern Convention and the EU Birds Directive in the UK. Since it came into force, the Act has been amended several times. The act applies to the terrestrial environment and inland waters. According to the Act, Scottish Natural Heritage (SNH) is a regulator of the Wild and Countryside Act and is legally responsible for Sites of Special Scientific Interest (SSSIs) and to enforce law when necessary. It is important to note that specific amendments, which only apply in Scotland due to devolution, have been made to the Act.	The SEA should reflect objectives to **value, protect and enhance biodiversity.**
The Conservation (Natural Habitats, &c.) Regulations 1994	The Act amends the Wildlife and Countryside Act 1981 for Scotland. The Act, together with the Nature Conservation (Scotland) Act 2004, implements the EU Birds and Habitats Directives.	The SEA should reflect objectives to **value, protect and enhance biodiversity.**
Nature Conservation (Scotland) Act 2004	The Act amends the Wildlife and Countryside Act 1981 for Scotland, and makes provision for the further conservation of biodiversity. The Act requires the Scottish Government to report on progress in relation to the Scottish Biodiversity Strategy	The SEA should reflect objectives to **protect biodiversity and the natural environment.**

Source	Key objectives	Implications/ Comments
Wildlife and Natural Environment (Scotland) Act 2011 (as amended)	The Act amends the Wildlife and Countryside Act 1981 for Scotland. The Act mainly changed the way land and the environment is managed in Scotland e.g. it made operational changes to how SSSIs are managed.	The SEA should reflect objectives to **protect and enhance designated biodiversity areas.**
The Conservation of Offshore Marine Habitats and Species Regulations 2017	The Regulations form the legal basis for the implementation of the Habitats Directive and the Bird Directive in terrestrial areas and territorial waters.	The SEA should reflect objectives to **value, protect and enhance marine habitats and species**.
National (policies, Plans, Programmes and Strategies)		
UK Post-2010 Biodiversity Framework (JNCC, 2012)	The Framework shows how the work of the four UK countries joins up with work at a UK level to achieve the 'Aichi Biodiversity Targets' and the aims of the EU biodiversity strategy. The Framework identifies the following strategic goals: ▪ Address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society. ▪ Reduce the direct pressures on biodiversity and promote sustainable use. ▪ Improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity. ▪ Enhance the benefits to all from biodiversity and ecosystems. ▪ Enhance implementation through participatory planning, knowledge management and capacity building.	The SEA should reflect objectives to **value, protect and enhance biodiversity.**
Scotland's Biodiversity: It's in Your Hands (Scottish Executive, 2004)	Scotland's Biodiversity: It's in Your Hands presents a 25 year strategy (until 2030) for the conservation and enhancement of Scotland's biodiversity. It sets out a number of outcomes in relation to; ▪ Species and habitats ▪ People ▪ Landscapes and Ecosystems ▪ Integration and Co-ordination ▪ Knowledge	The SEA should reflect objectives to **value, protect and enhance biodiversity.**

Source	Key objectives	Implications/ Comments
2020 Challenge for Scotland's Biodiversity – A Strategy for the conservation and enhancement of biodiversity in Scotland (The Scottish Government, 2013)	The aims of the 2020 Challenge are in line with the targets set by the aforementioned United Nations Convention on Biological Diversity (20100 and the European Union's Biodiversity Strategy for 2020, and include: ■ Protect and restore biodiversity on land and in Scotland's SAs ■ Involve and engage people in decisions about the environment ■ Promote sustainable economic growth ■ The 2020 Challenge and the 'Scotland's Biodiversity: It's in Your Hands' together make up the Scottish Biodiversity Strategy.	The SEA should reflect objectives to **value, protect and enhance biodiversity.**
Scotland's Biodiversity: A Route Map to 2020 (The Scottish Government, 2015)	The 'Six Big Steps for Nature' identified in the Route Map are: ■ Ecosystem restoration ■ Investment in natural capital ■ Quality greenspace for health and education benefits ■ Conserving wildlife in Scotland ■ Sustainable management of land and freshwater ■ Sustainable management of marine and coastal ecosystems	The SEA should reflect objectives to **value, protect and enhance biodiversity.**
Scottish Biodiversity Strategy; Report to the Scottish Parliament 2014-2016	Report to the Scottish Parliament which sets out progress with delivery of the Scottish Biodiversity Strategy. It records progress from 2014-2016 and highlights the remaining challenges that must be overcome to meet the aims of the 2020 Challenge for Scotland's Biodiversity	The SEA should reflect objectives to **value, protect and enhance biodiversity.**

Population and Human Health

Source	Key objectives	Implications/ Comments
International		

Source	Key objectives	Implications/ Comments
International Health Regulations, 2007	The International Health Regulations provide a legal instrument for upholding global public health security by preventing and responding to acute public health risks. The Regulations require countries to report certain disease outbreaks and public health risks to the World Health Organisation.	The SEA should reflect the objective that **acknowledges the potential health hazards** that could be caused by the different development types.
European		
The Bathing Water Quality Directive 2006 Directive 2006/7/EC on the quality of water intended for human consumption	The overall objective of the revised Directive remains the protection of public health whilst bathing.	The SEA should reflect the Directive requirements and **protect the quality of bathing waters**.
The Drinking Water Directive 1998 Directive 98/83/EC on the quality of water intended for human consumption	Protect human health from the adverse effects of any contamination of water intended for human consumption by ensuring that it is wholesome and clean.	The SEA should reflect objectives to **protect and enhance drinking water quality.**
The Noise Directive 2000/14/EC	▪ Monitor the environmental problem by drawing up strategic noise maps. ▪ Informing and consulting the public about noise exposure, its effects and the measures considered to address noise. ▪ Addressing local noise issues by requiring authorities to draw up action Plans to reduce noise where necessary and maintain environmental noise where it is good.	The SEA should reflect objectives to **reduce noise pollution.**
National (Legislation)		
Public Health etc. (Scotland) Act 2008	The Act updates the law on public health, enabling Scottish Ministers to protect public health. It also makes provision for law on statutory nuisances.	The SEA should reflect objectives to **protect public health.**
National (policies, Plans, Programmes and Strategies)		

Source	Key objectives	Implications/ Comments
National Performance Framework (The Scottish Government, 2016)	The main purpose of the National Performance Framework is to promote sustainable economic growth by setting out a measurement set that can be used to determine the extent to which key targets are being fulfilled. It sets seven broad targets in relation to: ■ Growth – stimulating economic growth ■ Productivity – improving productivity ■ Participation – improving economic participation ■ Population – increase population growth ■ Solidarity – reduce income equality ■ Cohesion – reduce inequalities in economic participation ■ Sustainability – reduce greenhouse gas emissions	The SEA should reflect objective to **promote the principles of sustainable economic growth.**
Scotland's Public Health Priorities (Scottish Government, 2018)	Sets out the six public health priorities for Scotland and how they are to be developed. The 6 priorities are: ■ A Scotland where we live in vibrant, healthy and safe places and communities ■ A Scotland where we flourish in our early years ■ A Scotland where we have good mental wellbeing ■ A Scotland where we reduce the use of and harm from alcohol, tobacco and other drugs ■ A Scotland where we have a sustainable, inclusive economy with equality of outcomes for all ■ A Scotland where we eat well, have a healthy weight and are physically active	The SEA should reflect objectives which **support Scotland's public health priorities.**

Soil

Source	Key objectives	Implications/ Comments
European		
EU Management of Waste from Extractive Industries (2006/21/EC)	The purpose of the Directive is to prevent water and soil pollution from the deposition of waste into heaps or ponds and puts emphasis on the long-term stability of waste facilities to help avoid major accidents. The main elements of the Directive are: ■ Conditions for operating permits. ■ General obligations concerning waste management. ■ The obligation to characterise waste before disposing of it or treating it. ■ Measures to ensure the safety of waste management facilities. ■ A requirement to draw up closure plans. ■ An obligation to provide for an appropriate level of financial security.	The SEA should reflect objectives to **protect soil quality and minimise soil pollution.**
The Industrial Emissions Directive 2010 Directive 2010/75/EU on industrial emissions (integrated pollution prevention and control)	This Directive lays down rules on integrated prevention and control of pollution arising from industrial activities. It also lays down rules designed to prevent or, where that is not practicable, to reduce emissions into land and to prevent the generation of waste, in order to achieve a high level of protection of the environment taken as a whole.	The SEA should reflect objectives to **protect soil quality and minimise soil pollution.**
Thematic Strategy for Soil Protection (European Commission, 2006)	Includes a thematic strategy which aims to: ■ Establish common principles for the protection and sustainable use of soils ■ Mitigate potential threats to soils ■ Preserve soil functions ■ Restore degraded and contaminated soils	The SEA should reflect objectives to **protect soils and minimise soil pollution.**
National (Legislation)		

Source	Key objectives	Implications/ Comments
Environmental Protection Act 1990 (as amended)	Sets out legislation for the management and remediation of contaminated land that, in its current states, is causing or has the potential to cause significant pollution of the environment.	The SEA should reflect objectives to **protect soil quality.**
Contaminated Land (Scotland) Regulations 2000	Provides a detailed framework for the definition, identification and remediation of contaminated land.	The SEA should reflect objectives to **protect soil quality.**
National (policies, Plans, Programmes and Strategies)		
The Scottish Soil Framework (The Scottish Government, 2009)	The Soil Framework sets out a vision for the enhancement and protection of soil consistent with the economic, social and environmental needs of Scotland. The Framework identifies 13 key outcomes, as follows: ■ Protecting and enhancing soil organic matter ■ Reducing soil erosion ■ Maintaining soil structure ■ Reduce greenhouse gas emissions from soils ■ Protecting soil biodiversity ■ Ensuring that soils contribute to sustainable flood management ■ Enhancing water quality through sustainable soil management ■ Enhancing soil's productive capacity ■ Reducing soil contamination ■ Reducing pressure on greenfield land and redirect development to brownfield sites where appropriate ■ Protecting soils with significant historical and cultural features ■ Enhancing knowledge base ■ Promoting effective coordination between stakeholders	The SEA should reflect objectives to **protect soils and minimise soil pollution.**

Source	Key objectives	Implications/ Comments
Scotland's National Peatland Plan *Working for our future (Scottish Natural Heritage, 2015)*	This plan sets out proposals for the sustainable use, protection, management and restoration of Scotland's peatlands. It identifies the following outcomes: ■ Protect those areas of peatland currently in good condition and supporting their potential range of ecosystem functions; ■ Enhance ecosystem resilience to climate change through appropriate management; ■ Restore peatland ecosystem functions and biodiversity, evaluating and understanding the benefits to help inform future decisions; ■ Secure greater peatland restoration capabilities and understanding of these amongst land managers, developers, advisers and the public; ■ Ensure peatland values are reflected in the support given to those who manage and restore them; and ■ Demonstrate and communicate the wider public benefits of healthy peatland landscapes and peatland restoration.	The SEA should reflect objectives to protect and promote sustainable use and management of peatlands.

Water

Source	Key objectives	Implications/ Comments
International		
Convention on the Law of the Sea (1982)	Defines the rights and responsibilities of national in their use of the world's oceans, establishing guidelines for businesses, the environment, and the management of natural resources.	The SEA should reflect objectives to **protect and enhance the water environment**.
European		
The Water Framework Directive 2000	The main aim of the Directive is to protect of inland surface waters, transitional waters, coastal waters and ground waters.	The SEA should reflect objectives to **protect and minimise the impact on water quality.**

Source	Key objectives	Implications/ Comments
Directive 2000/60/EC establishing a framework for community action in the field of water policy		
The Bathing Water Quality Directive 2006 Directive 2006/7/EC on the quality of water intended for human consumption	The overall objective of the revised Directive remains the protection of public health whilst bathing.	The SEA should reflect the Directive requirements and **protect the quality of bathing waters**.
The Floods Directive 2007 Directive 2007/60/EC on the assessment and management of flood risks	Establish a framework for the assessment and management of flood risks, aiming at the reduction of the adverse consequences for human health, the environment, cultural heritage and economic activity associated with floods.	The SEA should reflect objectives that relate to **flood management and reduction of risk.**
Marine Strategy Framework Directive 2007	The MSFD extends the requirements of the Water Framework Directive (WFD) into seas beyond 1nm. The MSFD requires Member States to "take necessary measures to achieve or maintain good environmental status in the marine environment by the year 2020 at the latest".	The SEA should reflect objectives to **protect and enhance the water environment**.
National (legislation)		
Marine (Scotland) Act 2010	The Act provides a framework which will help balance the competing demands of Scotland's seas. It introduces a duty to protect and enhance the marine environment and includes measure to help boost economic investment and growth in areas such as marine renewables. The main measures include: ▪ Marine Planning - a new statutory marine planning system to sustainably manage the increasing, and often conflicting, demands on Scotland's seas ▪ Marine Licencing - a simpler licensing system, minimising the number of licences required for development in the marine environment to cut bureaucracy and encourage economic investment	The SEA should reflect objectives to **protect and enhance the marine environment**.

Source	Key objectives	Implications/ Comments
	▪ Marine Conservation - improved marine nature and historic conservation with new powers to protect and manage areas of importance for marine wildlife, habitats and historic monuments ▪ Conservation - much improved protection for seals and a new comprehensive licence system to ensure appropriate management when necessary ▪ Enforcement – a range of enhanced powers of marine conservation and licensing	
Bathing Waters (Scotland) Regulations 2008	The Act implements the EU Bathing Water Quality Directive.	The SEA should reflect objectives that relate to **flood management and reduction of risk.**
Flood Risk Management (Scotland) Act 2009	The Act requires local authorities to assess bodies of water to determine potential flood risk and carry out measures if required. The Act implements the EU Floods Directive.	The SEA should reflect objectives that relate to **flood management and reduction of risk.**
Water Environment (Controlled Activities) (Scotland) Regulations 2011 (as amended)	Provides a regulatory framework for controlling activities which could have an adverse effect on Scotland's water environment including abstraction, impoundments, dredging, impoundments, surface water drainage and pollution. The primary objective of the Regulations is to protect and restore Scotland's water environment.	The SEA should reflect objectives to **protect and restore the water environment.**
Water Environment and Water Services (Scotland) Act 2003	The Water Environment and Water Services (Scotland) Act 2003 is the enabling legislation for the Water Framework Directive and makes major changes to the administration of water and sewerage provision in Scotland. It identifies the Scottish Environmental Protection Agency (SEPA) as the competent authority. Part 1 makes provision for protection of the water environment, whilst Part 2 deals with water and sewerage services.	The SEA should reflect objectives to **protect the water environment.**
Water Environment (Miscellaneous) (Scotland) Regulations 2017	The Regulations amend existing general binding rules and introduces requirements for particular projects to have a construction license in place before works can commence.	The SEA should reflect sustainability objectives to **protect the natural environment.**

Source	Key objectives	Implications/ Comments
The Flood Risk Management (Flood Protection Schemes, Potentially Vulnerable Areas and Local Plan Districts) (Scotland) Amendment Regulations 2017	Provides a regulatory framework for flood risk management amending the previous regulations made in 2009.	The SEA should reflect sustainability objectives to relate to flood management and reduction of risk.
National (Policies, Plans, Programmes and Strategies)		
National Marine Plan 2015	The plan covers the management of both Scottish inshore waters (out to 12 nautical miles) and offshore waters (12 to 200 nautical miles). It also applies to the exercise of both reserved and devolved functions. It provides guidance to decision-makers and users within Scotland's marine environment.	The SEA should reflect sustainability objectives to protect the sustainable use of the marine environment.
SEPA Draft River Basin Management Plans Scotland River Basin District / Solway Tweed River Basin District 2008	Identifies key pressures and environmental impacts on Scottish water bodies, which may be exacerbated by climate change.	The SEA should reflect objectives that relate to **flood management and reduction of risk.**
Scotland's Bathing Waters: A Strategy For Improvement (Scottish Executive Environment Group, 2002)	The main purpose of this strategic document is to reduce water pollution in bathing waters by implementing changes to agricultural practices, ensuring compliance with controls on industrial discharges and making use of SUDs.	The SEA should reflect the Directive requirements and **protect the quality of bathing waters**.

Air

Source	Key objectives	Implications/ Comments
International		
UNECE Convention on Long Range Transboundary Air Pollution (1979)	The purpose of the UNECE Convention was to address the environmental consequences of air pollution. The main aim of the Convention was to reduce and prevent air pollution in order	The SEA should reflect the objectives to **protect and enhance air quality** from factors such as eutrophication and acidification

Source	Key objectives	Implications/ Comments
	to improve air quality on the local, regional and national levels. To achieve this, the Convention sets out measures to be taken by parties to cut their emissions of air pollutions. The UNECE Convention has been extended by eight other protocols that identify measures to be undertaken by Parties to cut their emissions of air pollutants. These eight protocols include the following: - EMEP Protocol on Long-Term Financing of the Cooperative Programme for Monitoring and Evaluation of the Long-Range Transmission of Air Pollutions in Europe (1984) - Helsinki Protocol on the Reduction of Sulphur Emissions (1985) - Nitrogen Oxide Protocol (1988) - Volatile Organic Compounds Protocol (1991) - Oslo Protocol on Further Reduction of Sulphur Emissions (1994) - Protocol on Heavy Metals (1998) - Aarhus Protocol on Persistent Organic Pollutants (1998) - Gothenburg Protocol on Abate Acidification, Eutrophication and Ground-level Ozone (1999)	
European		
The National Emissions Ceiling Directive 2001 Directive 2001/81 EC on national emission ceilings for certain atmospheric pollutants	The Directives sets limits for the main causal factors of acidification, eutrophication and ground-level ozone.	The SEA should reflect the objectives to **protect and enhance air quality** from factors such as eutrophication and acidification.
The Air Quality Directive 2008 Directive 2008/50/EC on ambient air quality and cleaner air for Europe	Avoid, prevent and reduce harmful effects of air pollution on human health and the environment. The Directive Brings together existing legislation (at the time) on air quality, including objectives for key pollutants such as SO_2, NO_x, particulates, lead, benzene and ozone. The Directive sets out statutory limits for the concentration of different pollutants (Annex XI) and thresholds for human and environmental health (Annex II).	The SEA should reflect the objectives to **reduce harmful effects of air pollution.**

Source	Key objectives	Implications/ Comments
The Industrial Emissions Directive 2010 Directive 2010/75/EU on industrial emissions (integrated pollution prevention and control)	This Directive lays down rules on integrated prevention and control of pollution arising from industrial activities. It also lays down rules designed to prevent or, where that is not practicable, to reduce emissions into air in order to achieve a high level of protection of the environment taken as a whole.	The SEA should reflect the objective for **reducing air pollution caused by industrial emissions.**
The Clean Air Policy Package and Clean Air Programme for Europe 2013	The Clean Air Policy Package and Clean Air Programme for Europe set targets up to 2030, and also introduces measures and proposals to reduce emissions and improve air quality across the EU.	The SEA should reflect the objectives to **protect and enhance air quality.**
National (Legislation)		
The Environment Act 1995	The Act requires the UK government and devolved administrations to produce a national air quality strategy. The most recent version of this national air quality strategy is The Air Quality Strategy for England, Scotland, Wales and Northern Ireland, which defines the roles of the local and central government, as well as the Scottish Environment Protection Agency (SEPA), industry, business, transport, individuals and other groups. In addition, the Act sets objectives for specific emissions and measures for monitoring. Where limits are not met, the local authority must declare it an Air Quality Management Area (AQMA)	The SEA should reflect the objective for **reducing air pollution**.
The Air Quality (Scotland) Regulations 2000 As amended by the Air Quality (Scotland) Amendment Regulations 2002 and the Air Quality (Scotland) Amendment Regulations 2016	Sets out air quality objectives for several substances in line with the Environment Act 1995. In contrast to EU requirement, Scotland has set stricter levels for specific pollutants including PM_{10} and $PM_{2.5}$.	The SEA should reflect the objective for **reducing air pollution.**
The Air Quality Standards (Scotland) Regulations (2010)	Sets statutory targets for concentrations of pollutants in ambient air in accordance with EU Directives. The Act allows for Air Quality Management Zones to be identified and makes provision for the sharing of this information with the public.	The SEA should reflect the objective for **reducing air pollution**.

Source	Key objectives	Implications/ Comments
	The Regulations were amended through The Air Quality Standards (Scotland) Amendment Regulations 2016.	
Pollution Prevention and Control (Scotland) Regulations 2012	Implements the requirements of the EU Industrial Emissions Directive in Scotland. The Act states that emissions to air, water and land must be considered together, and permits are considered based on the nature of the activity. The Act has been amended several times since 2012.	The SEA should reflect the objective for **reducing air pollution.**
National (policies, Plans, Programmes and Strategies)		
The Air Quality Strategy for England, Scotland, Wales and Northern Ireland (2011)	The key objective of the strategy is to improve and protect ambient air quality in the UK, with the overall aim of health protection. The strategy sets out key objectives and monitoring recommendations for specific emissions.	The SEA should reflect the objective for **reducing air pollution, particularly in relation to health protection.**
Cleaner Air for Scotland – The Road to a Healthier Future (the Scottish Government, 2015)	Presents a single framework which sets out further proposals for delivering improvements to air quality in Scotland. It summarises six broad types of key actions that could help to reduce air pollution and improve air quality; ■ **Transport** – reducing transport emissions by promoting active travel and/or low and zero emission fuels ■ **Legislation and Policy** – comply with European and Scottish legal requirements ■ **Communication** – inform and engage citizens ■ **Health** – protecting citizens from air pollution ■ **Placemaking** – minimise air pollution through appropriate design ■ **Climate Change** – achieve Scotland's renewable targets	The SEA should reflect the objective for **reducing air pollution and promote active/sustainable travel**.

Cultural Heritage and the Historic Environment

Source	Key objectives	Implications/ Comments
International		
European Convention on the Protection of the Archaeological Heritage (Valletta, 1992) Revision of the 1985 Granada Convention	Protection of the archaeological heritage, including any physical evidence of the human past that can be investigated archaeologically both on land and underwater. Creation of archaeological reserves and conservation of excavated sites.	The SEA should reflect objectives to **protect the archaeological heritage**.
UNESCO World Heritage Convention (1972)	The 1972 World Heritage Convention links together in a single document the concepts of nature conservation and the preservation of cultural properties. The Convention recognizes the way in which people interact with nature, and the fundamental need to preserve the balance between the two. The Convention defines the kind of natural or cultural sites which can be considered for inscription on the World Heritage List. It also sets out the duties of States Parties in identifying potential sites and their role in protecting and preserving them. By signing the Convention, each country pledged to conserve not only the World Heritage sites situated on its territory, but also to protect its national heritage.	The SEA Framework should include objectives relating to **the conservation and enhancement of cultural heritage and natural heritage.**
European		
European Spatial Development Perspective (1999)	Economic and social cohesion across the community. Conservation of natural resources and cultural heritage. Balanced competitiveness between different tiers of government.	The SEA should reflect objectives to **conserve natural resources and cultural heritage.**
National (Legislation)		
Planning (Listed Buildings and Conservation Areas) (Scotland) Act 1997	Provides main legislation to: - list buildings of special architectural or historic interest - providing requirements in relation to changes affecting listed buildings and conservation areas	The SEA should reflect objectives to **conserve cultural heritage, particularly in relation to Listed Buildings, Conservation Areas and buildings of special architectural or historic interest.**

Source	Key objectives	Implications/ Comments
	- setting out a framework for designating and managing Conservation Areas	
National Parks (Scotland) Act 2000	Sets out for main aims for the National Parks of Scotland: - Conserving and enhancing the natural and cultural heritage of the area - Promoting sustainable use of the natural resources of the area - Promoting understanding and enjoyment of the area by the public - Promoting sustainable economic and social development of the area's communities	The SEA should reflect objectives to **conserve cultural heritage in National Parks.**
Historic Environment Scotland Act 2014	The Act established Historic Environment Scotland (HES) as a Non-Departmental Public Body (NDPB). Under the Act, HES will be a statutory consultee in relation to listed buildings and conservation area consents, as well as in relation to EIA. The Act also amended statutory processes in relation to the historic environment by changing the processes for the designation of sites and buildings (by scheduling and listing) and for consents relating to scheduled monuments, listed buildings and conservation areas.	The SEA should reflect objectives to **conserve cultural heritage and the wider historic environment.** In addition, the role of Historic Environment Scotland should be taken into account.
The Town and Country Planning (Development Management Procedure) (Scotland) Regulations 2013 The Town and Country Planning (Neighbouring Planning Authorities and Historic Environment) (Scotland) Direction 2015	Both Acts state that Historic Environment Scotland must be consulted on any development affecting a UNESCO World Heritage Site in Scotland.	The SEA should reflect objectives to **conserve cultural heritage and the wider historic environment.**
National (policies, Plans, Programmes and Strategies)		
Our Place in Time – The Historic Environment Strategy for Scotland (The Scottish Government, 2014)	The Strategy provides a high-level framework which sets out a 10-year vision for safeguarding the cultural, social, environmental and economic value of Scotland's heritage assets. The Strategy sets out three main aims: - Investigating and recording the assets that make up Scotland's historic environment	The SEA should reflect objectives to **conserve the historic environment.**

Source	Key objectives	Implications/ Comments
	■ Protecting Scotland's historic environment ■ Sharing information on the significance of Scotland's historic environment ■ Each ambition is underpinned by a number of strategic priorities e.g. application of new technologies.	
Historic Environment Policy for Scotland (HEPS)	This policy replaces the 2016 Policy Statement and supports the protection and enhancement of the historic environment, and sets out the principles for designation.	The SEA should reflect the principles of the protection and enhancement of the historic environment.

Landscape and Geodiversity

Source	Key objectives	Implications/ Comments
European		
European Landscape Convention (Florence, 2002)	The convention promotes landscape protection, management and planning.	The SEA should reflect objectives **to protect, manage and plan for landscape provision.**
National (Policies, Plans, Programmes and Strategies)		
Getting the best from our land A Land Use Strategy for Scotland 2016-2021	The Strategy supports sustainable land use, and recognises the interactions between different interests and land use. The objectives of the strategy include: ■ Land-based businesses working with nature to contribute more to Scotland's prosperity. ■ Responsible stewardship of Scotland's natural resources delivering more benefits to Scotland's people. ■ Urban and rural communities better connected to the land, with more people enjoying the land and positively influencing land use.	The SEA should reflect the need to support **sustainable land use**.
Scottish Land Rights and Responsibilities Statement 2017	This statement sets out 6 principles relating to land rights and responsibilities. It aims to work towards a Scotland with a strong and dynamic relationship between its land and people, where all land contributes to a modern and successful country, and where rights and	The SEA should reflect objectives to promote a strong relationship between Scotland's land and people.

Source	Key objectives	Implications/ Comments
	responsibilities in relation to land are fully recognised and fulfilled. The 6 principles outlined are: ■ The overall framework of land rights, responsibilities and public policies should promote, fulfil and respect relevant human rights in relation to land, contribute to public interest and wellbeing, and balance public and private interests. The framework should support sustainable economic development, protect and enhance the environment, help achieve social justice and build a fairer society ■ There should be a more diverse pattern of land ownership and tenure, with more opportunities for citizens to own, lease and have access to land. ■ More local communities should have the opportunity to own, lease or use buildings and land which can contribute to their community's wellbeing and future development. ■ The holders of land rights should exercise these rights in ways that take account of their responsibilities to meet high standards of land ownership, management and use. Acting as the stewards of Scotland's land resource for future generations they contribute to sustainable growth and a modern, successful country ■ There should be improved transparency of information about the ownership, use and management of land, and this should be publicly available, clear and contain relevant detail. ■ There should be greater collaboration and community engagement in decisions about land	
Scotland's Forestry Strategy 2019-2029	The strategy supports an increase in Scotland's forests and woodlands that will be sustainably managed and better integrated with other land uses. It has 3 main objectives: ■ Increase the contribution of forests and woodlands to Scotland's sustainable and inclusive economic growth ■ Improve the resilience of Scotland's forests and woodlands and increase their contribution to a healthy and high-quality environment ■ Increase the use of Scotland's forest and woodland resources to enable more people to improve their health, well-being and life chances	The SEA should reflect objectives to promote an increase in the number and use of forests and woodlands.

Source	Key objectives	Implications/ Comments
Natural Heritage Futures 2002	This programme aims to guide the sustainable management and use of Scotland's nature and landscapes up until 2025. The programme's six national prospectuses cover: - farmland - coasts and seas - hills and moors - settlements - freshwater - forests and woodlands And each prospectus describes: - what is distinctive to each region in Scotland - a vision for the natural heritage for 2025 - objectives and actions required to pursue that vision.	The SEA should reflect objectives to **conserve and enhance the landscape and natural environment.**
Landscape Policy Framework 2017	The policy aims to 'safeguard and enhance the distinct identity, the diverse character and the special qualities of Scotland's landscapes as a whole, so as to ensure tomorrow's landscapes contribute positively to people's environment and are at least as attractive and valued as they are today'. The principles of approach are based on four propositions: - Scotland's landscapes are a shared responsibility. - All of Scotland's landscapes deserve attention. - Scotland's landscapes will continue to change. - Scotland's landscapes deserve greater care.	The SEA should reflect objectives to **conserve and enhance the landscape and natural environment.**

Material Assets

Source	Key objectives	Implications/ Comments
European		
The Landfill Directive 1999 Directive 99/31/EC on the landfill of waste	Prevent or reduce negative effects on the environment from the landfilling of waste by introducing stringent technical requirements for waste and landfills.	The SEA should reflect objectives to **increase recycling and reduce the amount of waste**.
The Waste Framework Directive 2008 Directive 2008/98/EC on waste	Prevention or reduction of waste production and its harmfulness. The recovery of waste by means of recycling, re-use or reclamation. Recovery or disposal of waste without endangering human health and without using processes that could harm the environment.	The SEA should reflect objectives that **minimise waste production as well as promote recycling**.
The Urban Waste Water Directive 1991 Directive 91/271/EEC concerning urban waste water treatment	Protect the environment from the adverse effects of urban waste water collection, treatment and discharge, and discharge from certain industrial sectors.	The SEA should reflect objectives to **reduce water pollution.**
EU Management of Waste from Extractive Industries (2006/21/EC)	The purpose of the Directive is to prevent water and soil pollution from the deposition of waste into heaps or ponds and puts emphasis on the long-term stability of waste facilities to help avoid major accidents. The main elements of the Directive are: ■ Conditions for operating permits. ■ General obligations concerning waste management. ■ The obligation to characterise waste before disposing of it or treating it. ■ Measures to ensure the safety of waste management facilities. ■ A requirement to draw up closure plans. ■ An obligation to provide for an appropriate level of financial security.	Include sustainability objectives that encourage recycling and the prudent use of natural resources and the protection of the environment. Also promote a reduction in water and soil pollution.

Source	Key objectives	Implications/ Comments
National (Legislation)		
Environmental Protection Act 1990	The Act implements the EU Waste Framework Directive (2008) and includes provisions for improved control of pollution and waste generation arising from certain industrial processes Moreover, the Act places a duty on local authorities, as the primary regulators, to identify and secure the remediation of contaminated land in their respective areas. The Environmental Protection Act comprises the following parts: Part I: Integrated Pollution and Control Part II: Waste Management Licencing Part III: Statutory Nuisances Part IV: Criminal Offences Concerning Litter Part VI: Statutory Notification and Risk Assessment for Genetically Modified Organisms (GMOs) Part VII: Creation of Nature Conservancy Council for England, the Nature Conservancy Council for Scotland and the Countryside Council for Wales.	The SEA should reflect objectives to **reduce pollution**.
The Management of Extractive Waste (Scotland) 2010 Regulations	EU directive 2006/21/EC was transposed in the form of the Management of Extractive Waste (Scotland) 2010 Regulations, also known as 'MEW'. It sets out conditions for granting planning permission for extractive waste areas and waste facilities, along with additional requirements for category A (high risk) waste facilities.	The SEA should reflect objectives to **minimise the environmental impact of waste.**
Waste Management Licencing (Scotland) Regulations 2011 (as amended)	Sets out requirements for the management of waste and related activities with regard to granting site licences and consolidating existing licences.	The SEA should reflect objectives to **minimise the environmental impact of waste.**
Pollution Prevention and Control (Scotland) Regulations 2012 (as amended)	Implements the requirements of the EU Industrial Emissions Directive in Scotland. The Act states that emissions to air, water and land must be considered together, and permits are considered based on the nature of the activity. The Act has been amended several times since 2012.	The SEA should reflect objectives for **reducing air/water/soil pollution.**

Source	Key objectives	Implications/ Comments
Scotland Rural Development Programme (SRDP) 2021-2024	The key purpose of the SRDP 2014 - 2020 is to help achieve sustainable economic growth in Scotland's rural areas and the priorities remains broadly the same as the previous programme: The main priorities are: ■ Enhancing the rural economy ■ Supporting agricultural and forestry businesses ■ Protecting and improving the natural environment ■ Addressing the impact of climate change ■ Supporting rural communities	The SEA should reflect objectives for **protecting the environment.**
National (policies, Plans, Programmes and Strategies)		
Scotland's Zero Waste Plan (2010)	The Zero Waste Plan presents a vision to minimise waste transport to landfills, promote recycling and enhancing collection methods. The key objective of the Plan is to maximise the economic and environmental opportunities of waste reduction and reuse.	The SEA should reflect objectives to **minimise the environmental impact of waste and promote recycling**.
Planning Advice Note 63: energy from waste (2013)	Sets out guidance for planning authorities on proactively planning for waste management	The SEA should reflect objectives to **minimise the environmental impact of waste and promote recycling**.
A strategy for improving waste data in Scotland (2017)	Sets out a strategy to improve the relevance, quality and availability of data on waste from all sources (e.g. households, commerce and industry). The primary objective of the strategy is to improve waste data strategies in order to enhance Scotland's waste and resources sector.	The SEA should reflect objectives to **minimise the environmental impact of waste and promote recycling**.

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