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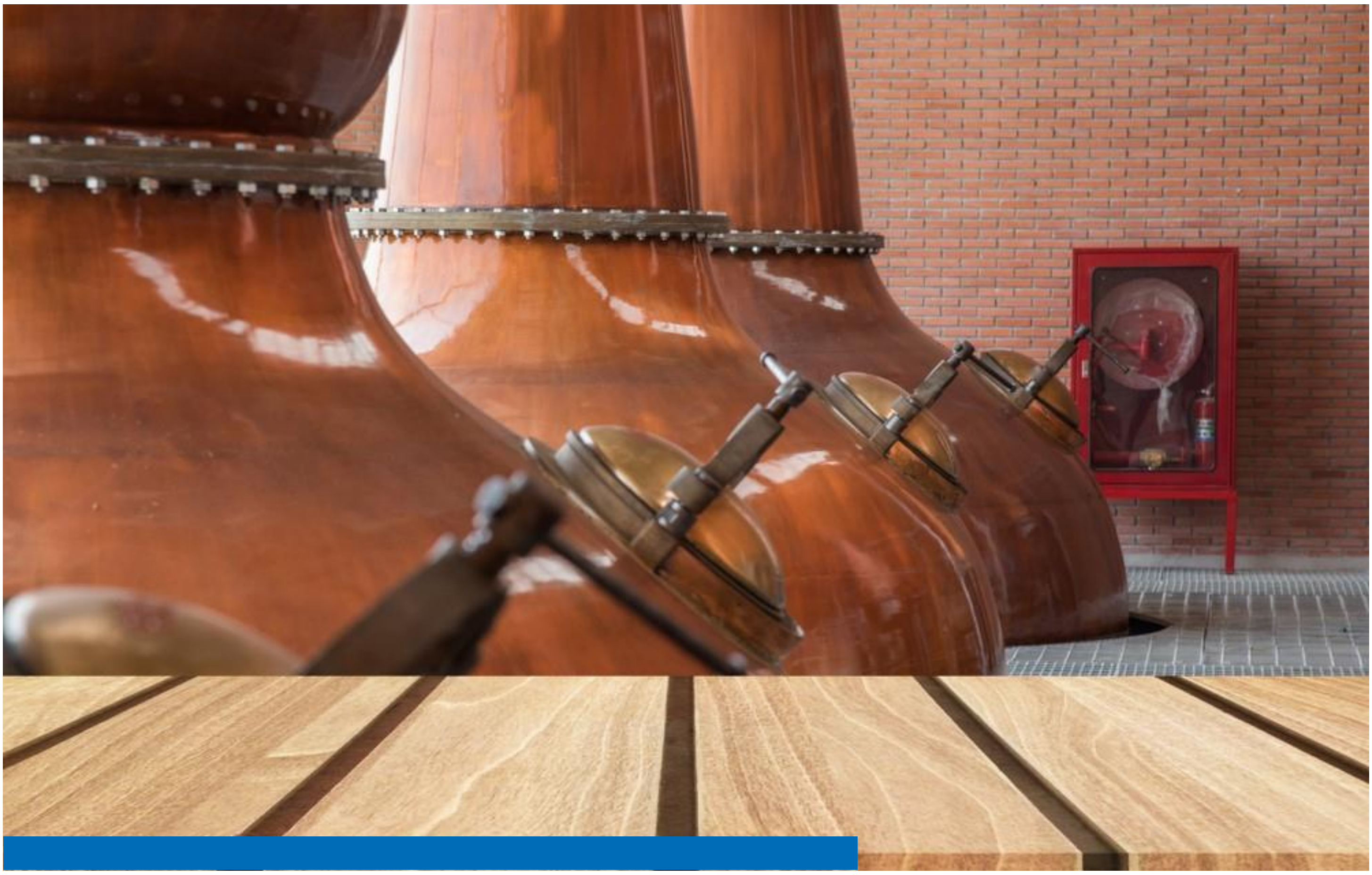

Scotch whisky pathway to net zero

Report for Scotch Whisky Association

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ED13298 | Issue number 3 | Date 11th May 2020

Ricardo Confidential

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Ref: ED 13298

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Executive summary

The Scotch Whisky Association (SWA) commissioned Ricardo Energy & Environment to explore how the sector could meet the Scottish Government's ambitious commitment to net zero emissions by 2045. The SWA's interest in net zero is driven by its members desire to minimise their contribution to climate change, consumer expectations for more sustainable products and the Scottish Parliament's legislative emission reduction targets.

Background

The Scotch Whisky industry launched its first Environmental Strategy (the 'Strategy') in 2009, with a set of ambitious targets driving sustainability. The SWA has reported biannually on the sector's progress against the Strategy targets. The 2018 publication is the fifth progress report and relates to the sector's performance in 2016.

The industry has made significant progress in a number of areas, and the 2018 Report details how the 2020 non-fossil fuel target has been achieved four years early – in 2016. The industry surpassed its 2020 target and achieved 21% of primary energy use from non-fossil fuel sources, up from 3% in 2008 (the base year) with absolute greenhouse gas emissions reduced by 22% during that period.

The SWA is committed to reviewing the entire Strategy. It is actively considering replacing the non-fossil fuel target with one to achieve net zero emissions by 2045. The review of the targets began with a workshop with members in June 2019. The recommendation from the workshop was for the industry to investigate the possible adoption of a net zero target.

Net zero in the whisky sector

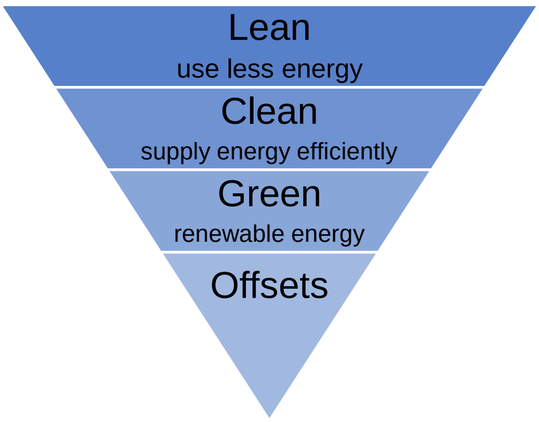
Achieving net zero requires deep reductions in emissions, with any remaining sources offset by removals of CO_2 from the atmosphere (e.g. by afforestation). Net emissions, after accounting for removals, must be reduced by 100%, to zero.

The scope and boundary establish the emissions that the scotch whisky sector currently take responsibility for reducing to zero. They have been set to comprise emissions over which members have direct control and where baseline data has been collected.

This includes all operations of Scotch Whisky production including maltings (owned and operated by distillers, not third-party maltings), distillation, maturation, blending and bottling and warehousing but excluding transportation and all business travel

The approach to developing net zero scenarios for the scotch whisky sector has been guided by a hierarchy of energy measures, which prioritises more sustainable measures and ensures that offsets are only used once all other options have been exhausted.

Energy measure hierarchy



Residual emissions are those that cannot be reduced to zero using lean, clean and green energy measures. Offsets are intended to create an equivalent carbon reduction elsewhere in compensation. There are recognised industry standards for the offsets, which must meet three criteria: additionality, perpetuity and verifiable. This ensures that the offsets are credible and deliver genuine savings. It is a critical tool for net zero strategies that can address the hardest to treat sources of emission.

There is no set definition of offsets within the context of net zero. This allows some flexibility in what options are considered acceptable. While this creates opportunities, it also presents risks to the robustness of offsets and the confidence that emissions are removed from the atmosphere.

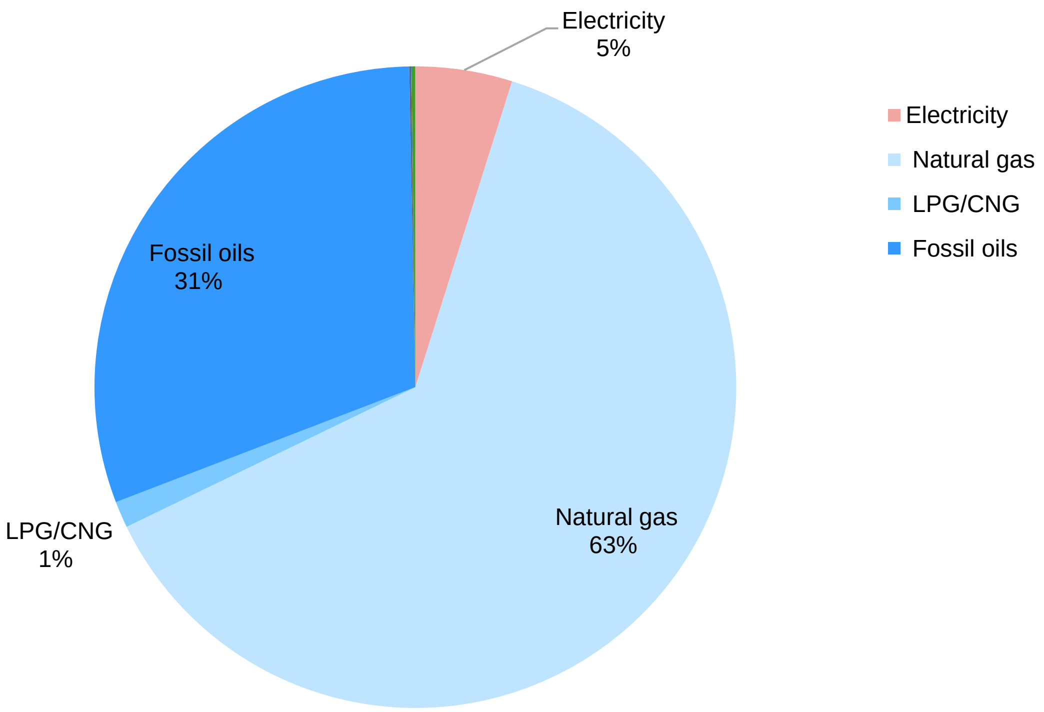
We have defined a broad hierarchy of offsets types, which safeguard the integrity of the offsets. It favours measures that are within the defined boundary and scope, followed by on-site measures which are associated with whisky production and near site measures that are aligned with the operational boundary before considering other options.

Emissions baseline

2018 energy and production data provided by the SWA was used as the baseline data and forms the basis of energy and emissions projections and scenario modelling. The data covers 127 sites including 70 malt distilleries, 5 grain distilleries and 11 packaging sites.

Under the greenhouse gas accounting methodology used to prepare the net zero study, the emissions baseline is 528,792 tonnes CO_2e/year. Fossil fuels dominate the emissions inventory, with 63% from natural gas and 31% from fossil-based fuel oils. Around 5% of emissions are from electricity use with smaller fractions from other fuels, including bioenergy.

Baseline greenhouse gas emissions by fuel 2018



88% of total emissions are related to activities at distilleries, with 11% from non-distilling production sites and around 1% from offices and warehouses.

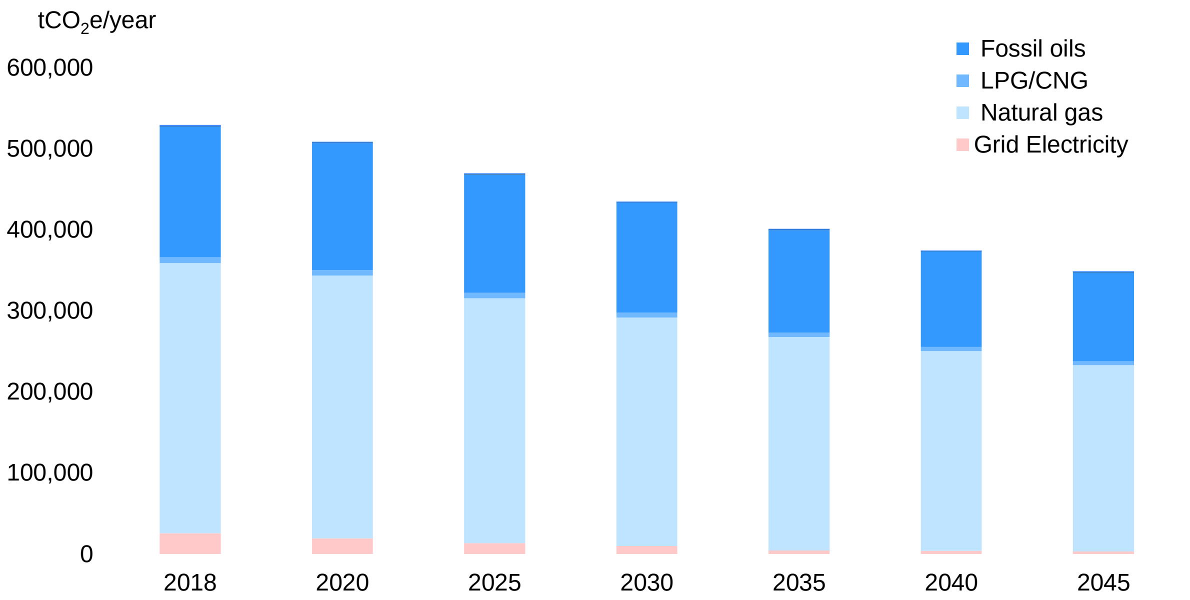
Baseline emissions projections

Understanding the likely sources of emissions in 2045 is central to developing a set of measures that can reduce those emissions to zero. An emissions pathway based on the 2018 baseline data has been developed. A series of assumptions are applied to reflect the key factors which will influence how the sector's emissions are expected to evolve in the absence of new energy measures. These are:

- Changes in the GHG emissions intensity of electricity generation
- Underlying energy efficiency improvements
- Changes in sector production

The baseline emissions projection is illustrated below at 5-year intervals. Total emissions in 2045 are estimated to be 348,481 tCO_2e/year, a 34% reduction on 2018.

Baseline emissions projections to 2045



The falling electricity emissions factor further increases the prominence of process heat in the emissions inventory, with 98.8% of emissions from direct use of fossil fuels and 91% from distilleries sites in 2045. As a result, our assessment of energy measures and scenarios focuses on process heat technologies.

Scenario modelling

We have modelled seven scenarios to explore the net zero gap and to identify viable pathways to 2045. The three types of scenarios are set out below:

1. Planned progress is an enhanced baseline scenario which includes planned energy measures and sustained energy efficiency improvements.

2. Three scenarios explore the maximum potential of individual heat technologies, which helps to understand the contribution they could make. These are:
    - Anaerobic digestion-max
    - Biomass-max
    - Heat pump-max

3. Scenarios that present a route to achieving net zero. They combine complimentary technologies within their maximum potential, in order to meet all member energy demands. These are:
   - Green gas
   - Electrification
   - Balanced

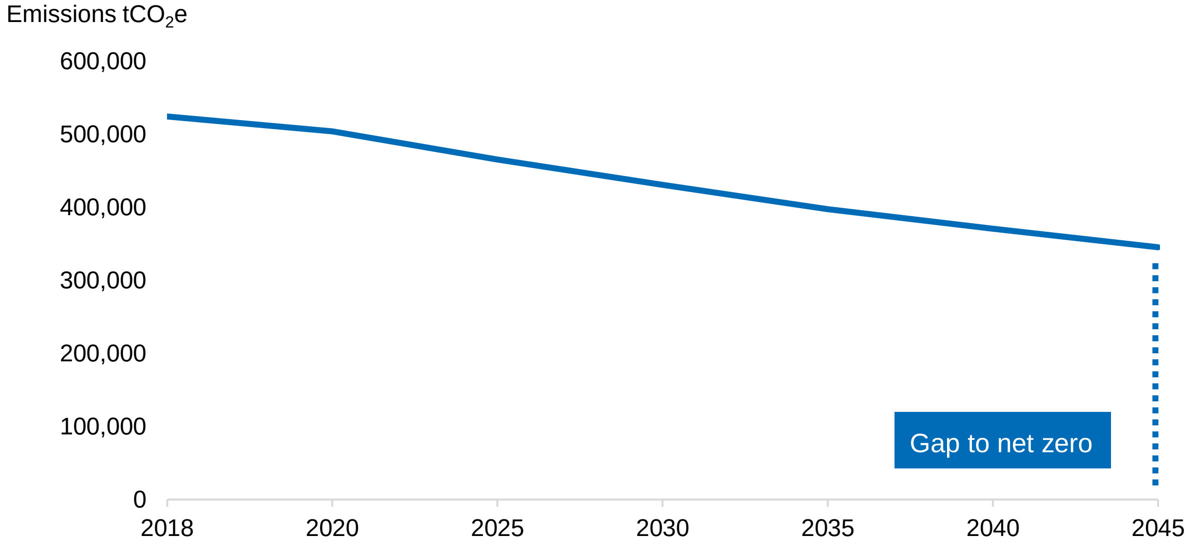
Together these scenarios provide an analysis which sets out the boundaries for the technology pathways as well as credible routes to achieving net zero. The figure below highlights the key technology assumptions that are applied in each scenario.

Net zero technology scenarios matrix

	Energy efficiency	Gas & LNG/CNG	Anaerobic Digestion	Biomass	Heat pumps	Hydrogen	Offsets
Planned progress	3%	Replaces fossil heating by 2025	Planned growth	Planned growth			
Anaerobic digestion-max	3%	Replaces fossil heating by 2025	**Max potential**	Planned growth			
Biomass-max	3%	Replaces fossil heating by 2025	Planned growth	**Max potential**			
Heat pump-max	3%	Replaces fossil heating by 2025	Planned growth	Planned growth	**Max potential**		
Green gas	3%	Replaces fossil heating by 2025	**20% by-product potential**			Meets remaining demand	Yes
Electrification	3%	Replaces fossil heating by 2025	20% by-product potential		**90% of technical potential**	Meets remaining demand	Yes
Balanced	3%	Replaces fossil heating by 2025	20% by-product potential	**80% of potential**	**50% of process heat pot.**	Meets remaining demand	Yes

In each case, the focus is on closing the gap between the baseline pathway and zero in 2045 as illustrated in Figure 13.

Figure 1: Baseline scenario



Net zero technology pathways

The study has identified the key energy technologies that can reduce emissions from whisky production to net zero. Generating heat for distillation is the primary source of emissions and the key technical challenge.

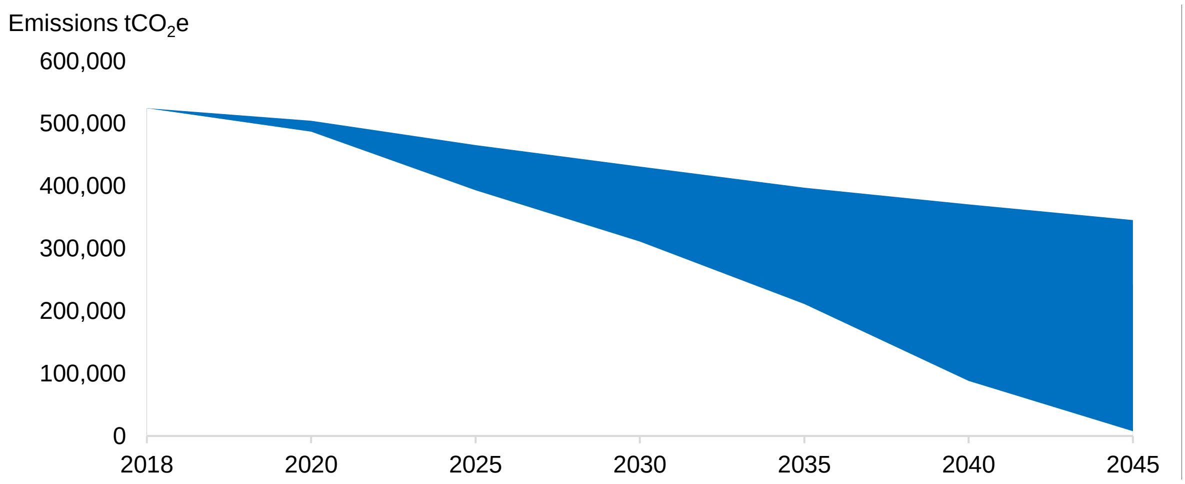
The scenarios looked at how anaerobic digestion, biomass, hydrogen & high temperature heat pumps could be deployed across the industry. Our analysis indicates that there are a range of credible pathways to net zero, making use of each technology to varying degrees within their maximum technical potential.

The option to deploy multiple technologies, such as through the balanced scenario, provides important flexibility to members, with each site able to use the technology most suited to their operations and constraints. At the sector-level, it means that the changing viability of one technology could be compensated for by another.

The balanced net zero scenario

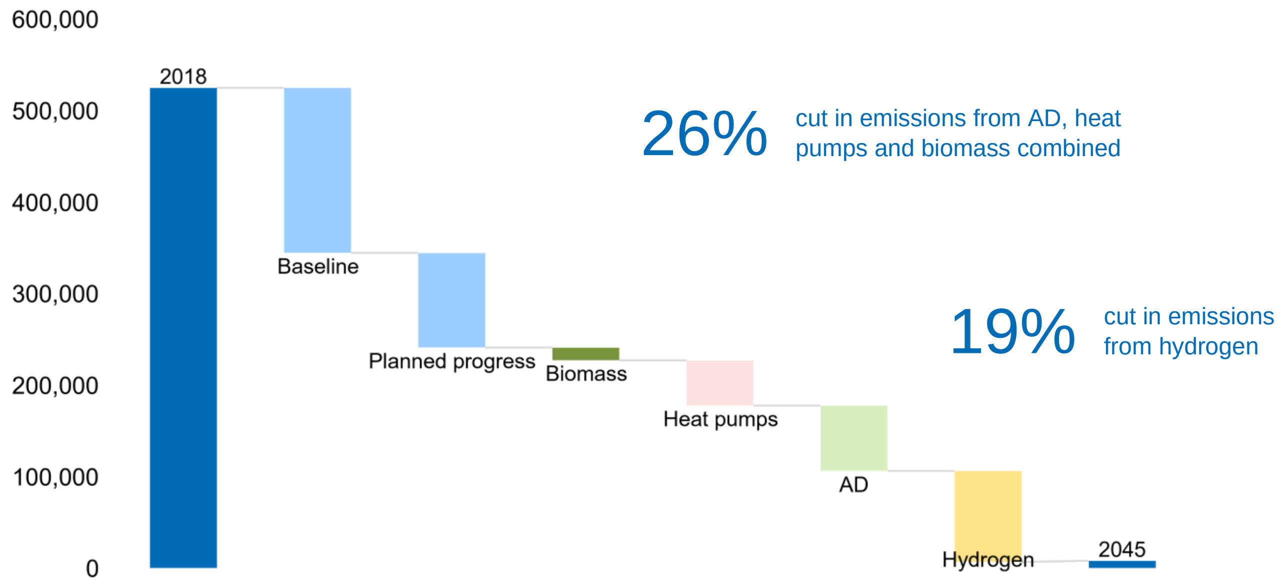
The balanced scenario applies a combination of the key heat technologies well within their maximum technical potential and achieves net zero emissions in 2045. It was seen as the most credible of the options presented to SWA members at a workshop in February 2020.

Balanced scenario emissions projections



The waterfall chart below shows the contribution from each measure. Heat pumps (9%), biomass (3%) and AD (14%) together are responsible for 26% of emissions reductions, with hydrogen accounting for 19%.

Balanced scenario - emissions reduction by measure



The Balanced scenario demonstrates that there are pathways to net zero which sit well within the maximum technical potential of the key heat technologies.

Policy Recommendations

With COP26 in Glasgow, the new Westminster government's and also the Scottish government's strong stance on climate change and the legislative backlog caused by Brexit, this is an important time for the SWA to be actively engaged in shaping net zero policy.

A series of policy recommendations have emerged from our analysis and through discussion with the SWA and members. This includes policy and regulatory changes that are necessary if members are to achieve net zero. The policy options related to a specific technology are categorised by the type of intervention proposed.

1.1.1 A net zero commitment, emissions measurement and reporting

1.1.1.1 A net zero commitment

The SWA should make a public commitment to net zero by 2045. This should include all Scope 1 and 2 emissions, including those that are not currently included in emissions reporting.

The SWA should commit to a regular review of progress and should have a mechanism which enables ambition to be ratcheted up in future. This could be used to incorporate Scope 3 emissions or bring forward the target date.

1.1.1.2 Net zero definition

Net zero currently doesn't have a formal definition and the standards that will define how GHG emissions are measured, reported and offsets accounted will have an impact on the energy measures that can be used to meet industry targets.

This will also define the sector's options for offsetting its residual emissions. Peatland restoration is a highly credible negative emissions measure that should be possible to count towards industry targets, which isn't currently the case with Carbon Neutrality under PAS2060.

1.1.1.3 Standardised emissions reporting

The GHG methodology review included a series of recommendations for improving the SWA's emissions reporting. These include:

- Fully adopting GHG Protocol Corporate Standard / ISO14064
- Clarify scope and boundary
- Use UK Government emissions factors and update them annually
- Report using both location based & market based approach
- Define net-zero and the GHG accounting measures that will be used to measure it

The recommendations are described in more detail in the methodology report under separate cover.

1.1.2 Policy & regulation

1.1.2.1 UK and Scottish industrial decarbonisation strategy

The policy framework for decarbonising industry is out of date and is no longer consistent with net zero. The Committee on Climate Change are currently looking at an industrial decarbonisation strategy in more detail and are clear that concerted effort needs to start now in order to bring forward viable technology options in the 2030s. With the expectation that multiple energy solutions will need to be used, the SWA should promote a policy and regulatory framework that is technology agnostic.

The SWA should engage with policy makers to ensure that industrial policies and incentives are consistent with net zero, including energy taxes, incentives and innovation funding.

1.1.2.2 Scottish government bioenergy action plan

The Scottish government are preparing a bioenergy strategy and the SWA should continue to engage in its development. AD is a consistent feature of the net zero scenarios developed and further expansion of installed capacity will need to be made consistent with regulations around the treatment of residues and by-products.

1.1.3 R&D and demonstration

Some of the key heat technologies identified require further R&D before they can be deployed by members at scale.

High temperature heat pumps for industrial use may be the least mature of the technologies identified. On-going R&D efforts will need to be scaled up in order to prove the technology, reduce costs and increase efficiency. Operation of high temperature heat pumps will need to be demonstrated at distilleries in the UK.

The relative immaturity of hydrogen technology, including strategic uncertainty about its role, production methods and distribution mean that continuing R&D will be crucial. In the build up to the anticipated wider adoption in the 2030s, pilots and demonstrations in related industrial sectors will be required.

Anaerobic digestion is a relatively mature technology which is already in use in the whisky sector. However process and operational efficiency improvements can be expected from further R&D.

1.1.4 Implementation and price signals

The RHI is coming to an end and is due to close 31st March 2021. The Government has not announced how it will encourage low carbon heating after this. In January 2020 the Prime Minister stated that the Government was “looking for successor arrangements to the renewable heat incentive” during PM’s Questions[1]. No further information is available. The RHI’s successor should be established in time to provide continuity of subsidy with mechanisms to support industrial switching to fuels consistent with net zero.

1.1.5 Infrastructure

It is clear that hydrogen has a central role in all our net zero scenarios and in the CCC’s proposals for industry. Hydrogen distribution is a major known barrier to deployment, with the optimal production and delivery configuration highly uncertain. This will require the development of national supply infrastructure and the SWA should work with government to ensure that it is in place in the 2030s.

The whisky sector already makes use of shared AD infrastructure, which takes distillation by-products from multiple sites. This allows the AD plant to run at higher efficiencies and increases the options for using the fuel, including upgrading to biomethane and injection to the grid. The SWA can support efforts for more shared AD capacity to be developed and could encourage partnerships beyond the whisky sector, potentially engaging with government on national biogas infrastructure.

[1] https://hansard.parliament.uk/commons/2020-01-22/debates/6B6FAD67-CA8C-4AF2-9CC9-07F6175ABC4C/Engagements

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1 Introduction

The Scotch Whisky Association (SWA) commissioned Ricardo Energy & Environment to explore how the sector could meet the Scottish Government's ambitious commitment to net zero emissions by 2045. The SWA's interest in net zero is driven by its members desire to minimise their contribution to climate change, consumer expectations for more sustainable products and the Scottish Parliament's legislative emission reduction targets.

In order to deliver forward-looking energy insights to the SWA, Ricardo has built a net zero gap analysis tool which is capable of producing sector energy & emissions trajectories; this was used to model the impact of the different energy technology uptake scenarios set out in this report. Evidence from the net zero scenarios and engagement with the SWA and its members provides a strong basis for recommended policies which will be required to overcome the barriers for the sector to reach net zero emissions by 2045.

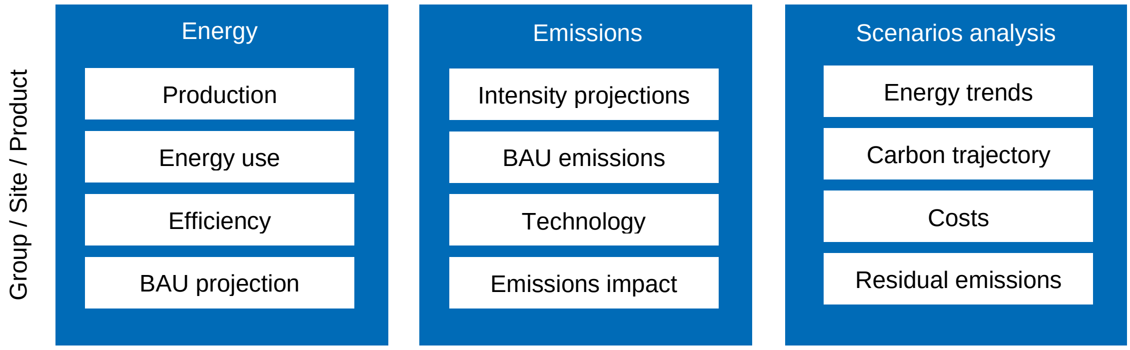
SWA's members were consulted throughout the study, which informed the technology options and the different pathway scenarios. We are grateful for the knowledge and experience they shared.

1.2 Methodology

The net zero study was delivered through the following tasks:

1. **Greenhouse gas reporting methodology**: we reviewed the SWA's existing reporting methodology. Using a review of best practice reporting standards we made recommendations as to how the methodology could be updated. The revised methodology was used to produce the baseline emissions inventory and an emissions forecast. The methodology review report has been provided to SWA separately.
2. **Gap analysis:** Interviews with member companies representing the majority of sites within the sector helped us to understand the use of energy, existing and planned energy investments and company climate goals. This was used to determine the direction the sector is currently heading.
3. **Technology identification:** Ricardo's energy technology experts who have worked in the whisky and related sectors identified a long list of technologies that could be implemented to reduce sector emissions. These were validated through discussions with SWA members.
4. **Scenario analysis**: A net zero gap analysis and forecasting tool was developed to model sector energy use and emissions to 2045. It models the energy & emissions impact of energy technology measures and helps explore their potential contribution to meeting the net zero target. Figure 1 illustrates the structure of the model, showing how energy, emissions and cost data is combined to produce the net zero scenarios.
5. **Identify policy options**: the study has brought to light a number of policy recommendations which would help to bring forward developments in the energy technologies identified and would help to create a supportive regulatory environment.

Figure 2: The net zero modelling tool schematic



2 Background

2.1 SWA Environmental Strategy

The Scotch Whisky industry launched its first Environmental Strategy (the 'Strategy') in 2009, with a set of ambitious targets driving sustainability. The SWA has reported biannually on the sector's progress against the Strategy's targets. The 2018 publication is the fifth progress report and relates to the sector's performance in 2016.

The industry has made significant progress in a number of areas, and the 2018 report details how the 2020 non-fossil fuel target has been achieved four years early – in 2016. The industry surpassed its 2020 target and achieved 21% of primary energy use from non-fossil fuel sources, up from 3% in 2008 (the base year) with absolute greenhouse gas emissions reduced by 22% during that period.

The SWA is committed to reviewing the entire Strategy. It is actively considering replacing the non-fossil fuel target with one to achieve net zero emissions by 2045. The review of the targets began with a workshop with members in June 2019. The recommendation from the workshop was for the industry to investigate the possible adoption of a net zero target.

2.2 Policy context

The UK Climate Change Act 2008 legally commits the UK to taking responsibility for its contribution to climate change by reducing greenhouse gas emissions. The UK was the first country to introduce long-term legally binding climate legislation which has become the model for other nations.

The Act created the current climate policy framework, including:

- Mechanisms for changing the emissions reduction target based on the latest evidence.
- Carbon budgets that act as interim targets to ensure we remain on a trajectory towards long term goals.
- Establishing the Committee on Climate Change (CCC) who hold the government to account.
- Provisions for climate change adaptation as well as mitigation.

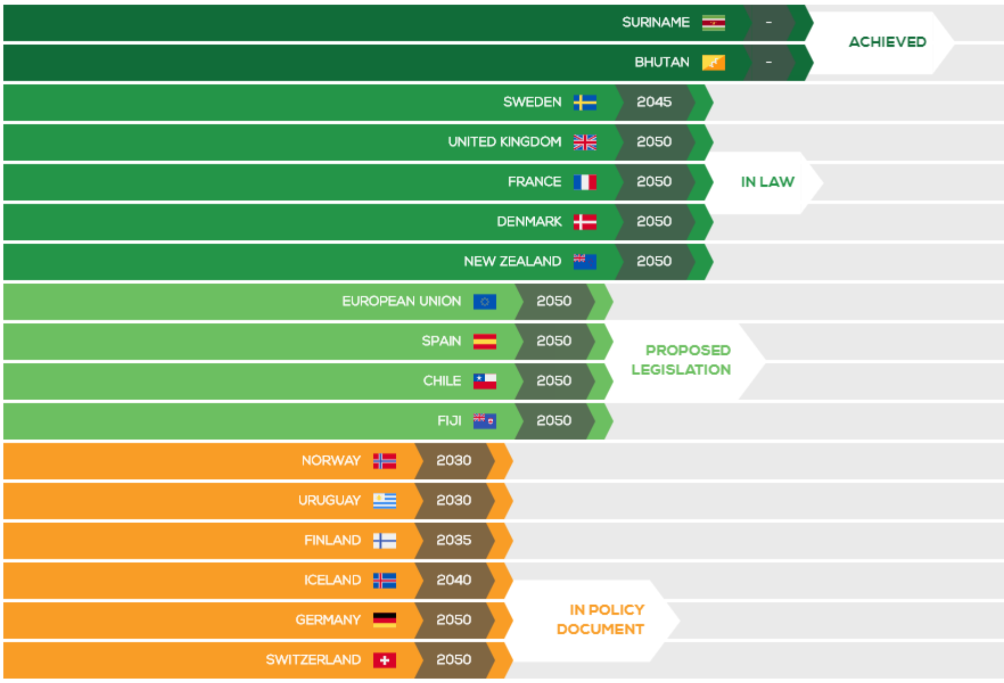
The original climate target adopted required an 80% cut in emissions by 2050 relative to a 1990 baseline. In the wake of the Paris Climate Agreement and a growing understanding of the impacts of climate change, pressure grew for a more ambitious target. On the 27 June 2019 the Climate Change Act was amended to revise the 2050 target and set in law the net zero goal, becoming the first major economy to do so.

The Scottish Government introduced separate legislation in 2009 – Climate Change (Scotland) Act 2009 – which targets specific to Scotland, including a 2050 target 0f 80% and a 2020 target of 42%. In November 2019, Scotland set a yet more ambitious legal target of net zero emissions of all greenhouse gases by 2045, and a series of stretching targets on the path to achieving that goal, including an interim target of 75% reduction in 2030[2]. Scotland's targets include a fair share of emissions from international aviation and shipping.

Figure 3 shows how Scotland has positioned itself as a global leader with this target, which is the most ambitious legislation among comparable countries. The CCC considers it to be the quickest decarbonisation achievable by Scotland.

[2] https://www.gov.scot/policies/climate-change/reducing-emissions/

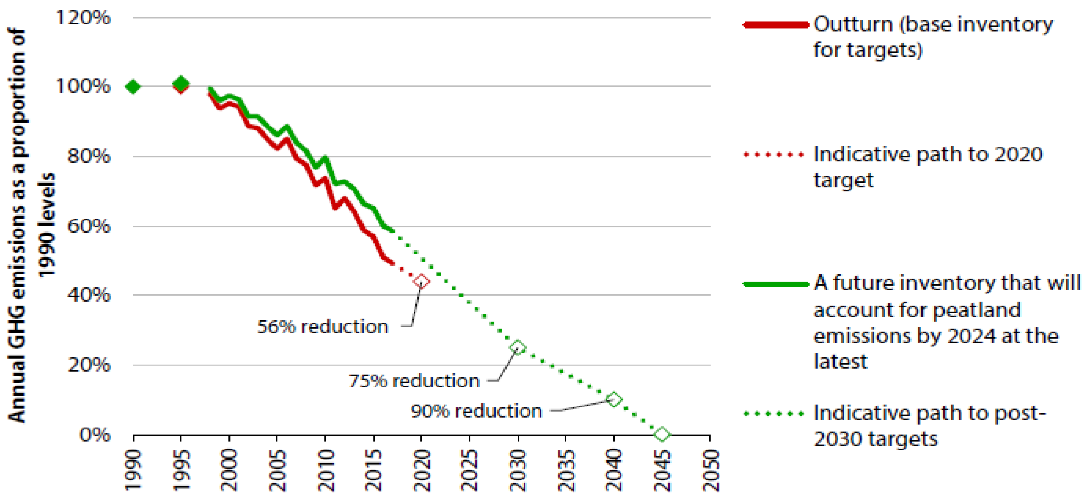
Figure 3: Excerpt from the Net Zero Tracker 2020 Scorecard – a league table of national climate change goals by the Energy & Climate Intelligence Unit, which would place Scotland alongside Sweden



2.3 Reducing emissions in Scotland

The CCC regularly assesses Scotland's progress and the December 2019[3] report makes the national challenge clear. Scotland's greenhouse gas emissions have more than halved since 1990 and economic growth has been decoupled from emissions. The net zero by 2045 target will require concerted year-on-year delivery of emissions reduction measures.

Figure 4: Indicative pathways to Scotland's legislated emissions targets, CCC 2019



[3] CCC 2019 Progress Report to Parliament. https://www.theccc.org.uk/publication/reducing-emissions-in-scotland-2019-progress-report-to-parliament/

Much has been achieved but reducing emissions to net zero means addressing energy use in sectors of the economy that are harder to decarbonise. It will require extensive changes across the Scottish economy, with a complete switchover to low-carbon technologies and development of new industries for carbon capture and storage, hydrogen production & distribution. The adoption of a stringent economy-wide target means that all sectors must contribute and rapid improvements in one sector cannot be used to offset the lack of progress in another. Work must begin now to confront long-term decarbonisation challenges, including emissions from industrial processes.

Where there are remaining emissions these will need to be fully offset by removing CO_2 from the atmosphere and permanently sequestering it, for example through afforestation and restoration of peatlands, and using sustainable bioenergy in combination with CCS. The opportunities for removing emissions are limited and there is little scope for continued use of fossil fuels in most sectors of the economy.

The Scottish Government has formally accepted the recommendations of the CCC.

3 Net zero in the whisky sector

This section sets the parameters for assessing pathways to net zero for the whisky sector. It establishes the net zero definition in use, the boundary and scope of the analysis and the principles underpinning the selection and prioritisation of decarbonisation measures.

3.1 Net zero definition

Achieving net zero requires deep reductions in emissions, with any remaining sources offset by removals of CO_2 from the atmosphere (e.g. by afforestation). Net emissions, after accounting for removals, must be reduced by 100%, to zero.

There is no formal definition of net zero. Our working definition is:

> *"Balancing greenhouse gas emissions through their managed avoidance, mitigation and removal from atmosphere within the boundary and over time"*

Carbon neutrality is a related concept and is defined and covered by a BSi standard PAS 2060. Whilst this definition is widely accepted, it does limit the options open to organisations as the only 'offsets' allowed are those purchased via accredited schemes.

The available definitions leave broad scope for interpretation. Below we define further how net zero is applied to the whisky sector to ensure that this study produces analysis and insights that have integrity and deliver on credible emissions reductions that can be backed up by verifiable evidence.

3.2 Boundary and scope

The scope and boundary establish the emissions that the scotch whisky sector currently take responsibility for reducing to zero.

The boundary that has been agreed is all operations of Scotch Whisky production including maltings (owned and operated by distillers, not third-party maltings), distillation, maturation, blending and bottling and warehousing but excluding transportation and all business travel. Included are Scope 1 energy use and Scope 2 energy purchase emissions from within the boundary as these figures are collated and reported across the sector by the SWA. Specifically, this includes all energy use at whisky production facilities plus those associated with energy purchases or imports.

This scope and boundary have been set to comprise emissions over which members have direct control and where baseline data has been collected. There are a number of emissions sources that are excluded from the study as a result, including transport, process and fugitive emissions as well as Scope 3 supply chain emissions. Not all members provide data and are not included within the baseline inventory and net zero scenario analysis undertaken.

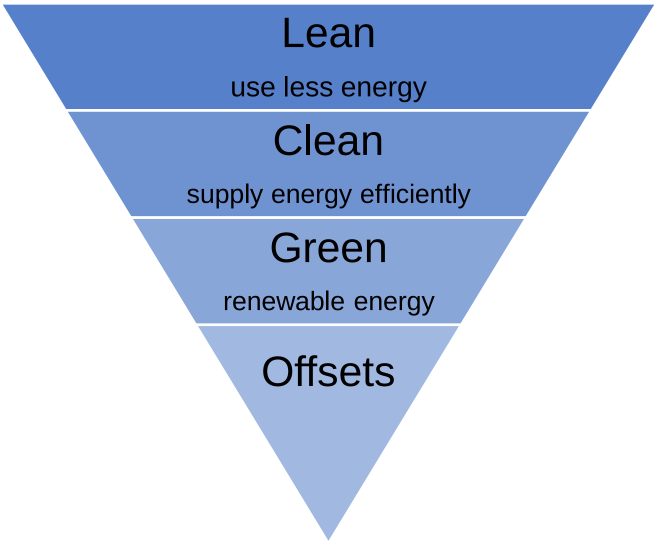
The greenhouse gas methodology review recommends changes to the SWA's data collection and reporting processes.

3.3 Energy measure hierarchy

Energy measures should be implemented in accordance with the energy hierarchy, which prioritises more sustainable measures and ensures that offsets are only used once all other options have been exhausted.

1. Be Lean: use less energy – measures that reduce energy demand through efficiency measures.
2. Be Clean: supply energy efficiently – measures that use increase the efficiency of any fuels used or purchased. This applies equally to zero carbon and fossil fuels.
3. Be Green: use renewable energy – zero carbon energy supply technology.
4. Offsets: to be used to address residual emissions that cannot be reduced to zero. Offsetting is covered in more detail below.

Figure 5: Energy measure hierarchy



3.4 Offsets

Residual emissions are those that cannot be reduced to zero using lean, clean and green energy measures. Offsets are intended to create an equivalent carbon reduction elsewhere in compensation. There are recognised industry standards for the offsets, which must meet three criteria: **additionality**, **perpetuity** and **verifiable**. This ensures that the offsets are credible and deliver genuine savings. It is a critical tool for net zero strategies that can address the hardest to treat sources of emission.

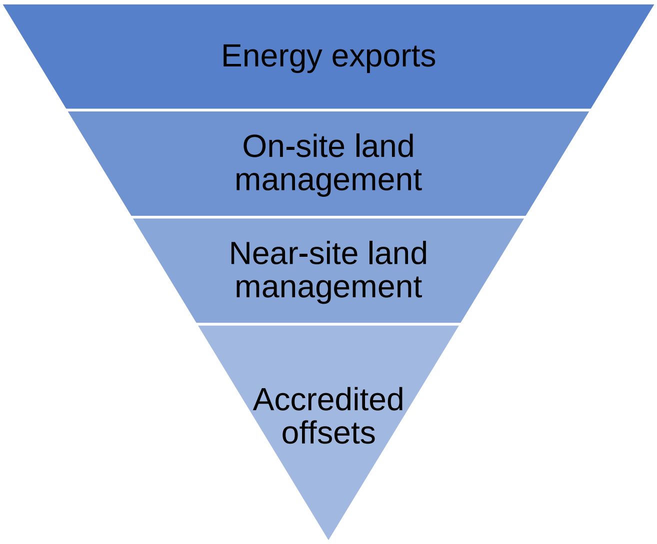
There is no set definition of offsets within the context of net zero. This allows some flexibility in what options are considered acceptable. While this creates opportunities, it also presents risks to the robustness of offsets and the confidence that emissions are removed from the atmosphere.

We have defined a broad hierarchy of offset types, which safeguard the integrity of the offsets. It favours measures that are within the defined boundary and scope, followed by on-site measures which are associated with whisky production and near site measures that are aligned with the operational boundary before considering other options.

The offsetting hierarchy:

1. Energy exports: producing energy on-site that is then exported for use by others (such as renewable electricity or supplying low carbon heat) creates an emissions credit that can be used to offset residual emissions.
2. On-site land management: Carbon sequestration through peatland restoration and/or afforestation. The sector's existing work on peatland restoration could offer a route towards this.
3. Near-site land management: Carbon sequestration through peatland restoration and/or afforestation in the communities where whisky is produced.
4. Accredited offsets: The Scottish government have been explicit in indicating that international offsets are not within the scope of the national net zero target. Accredited offsets would need to be sourced from a certified project in Scotland/UK, depending on how this is defined.

Figure 6: Offsetting hierarchy



4 Energy & emissions projections

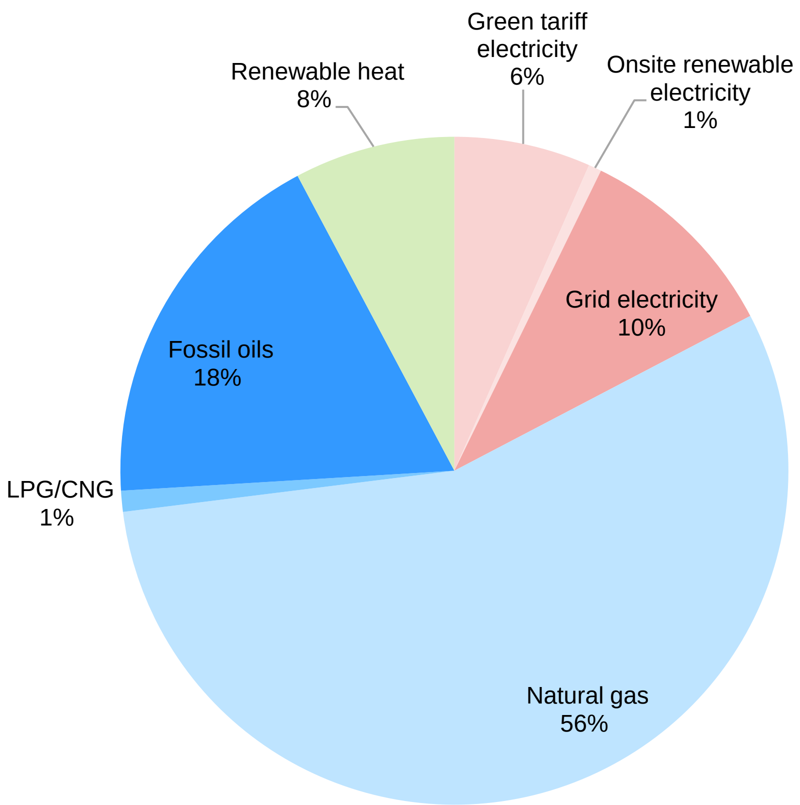
4.1 Introduction

2018 energy and production data provided by the SWA was used as the baseline data and forms the basis of energy and emissions projections and scenario modelling. The data covers 127 sites including 70 malt distilleries, 5 grain distilleries and 11 packaging sites.

4.2 Energy baseline

The production of heat is the dominant energy requirement. In 2018 heat represents approximately 82.7% of fuel consumption with electricity at 17.3%. The distillation heat requirement accounts for approximately 91% of the heat-related fuel consumption with around 8% for non-distillation activities, like malting. A small fraction of fuel consumption is associated with space heating and low temperature hot water requirements. Figure 7 below breaks down the sector's fuel consumption.

Figure 7: Baseline fuel consumption 2018



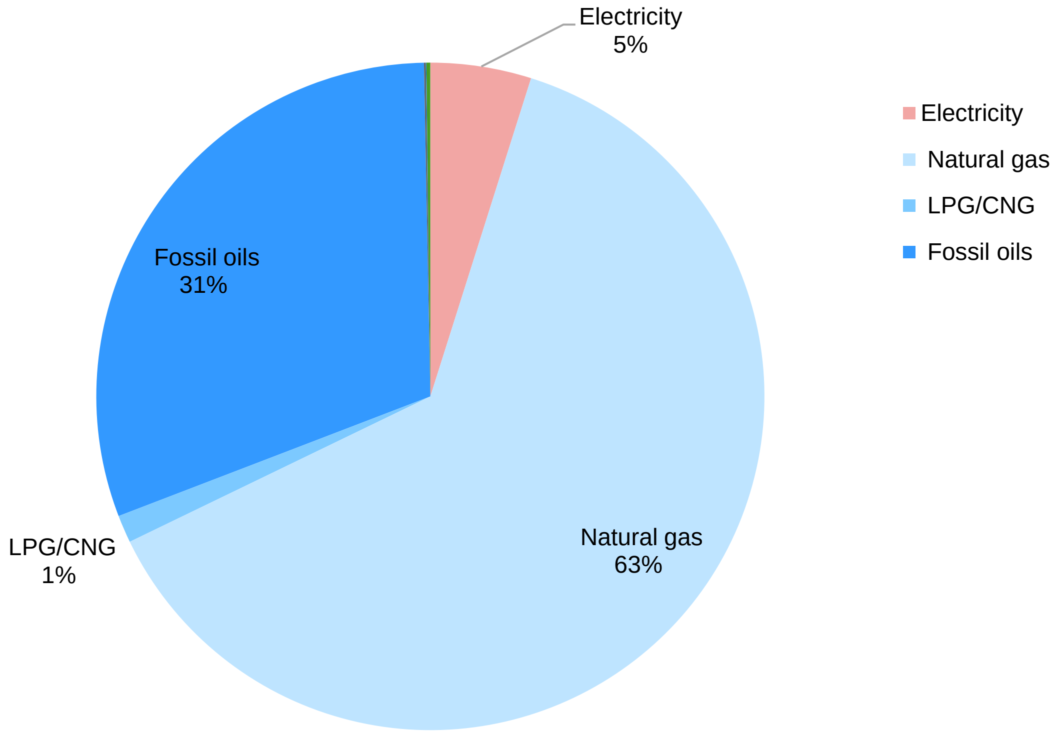
It shows that the majority of fuel consumption is fossil-based (in blue hues), primarily natural gas. Bioenergy is around 7.8% of fuel consumed, which is primarily from the processing of distillation by-products as well as combustion of wood chip and pellets.

Most of the zero carbon electricity consumed is electricity purchased under a 'green tariff'. Exports of electricity from gas-fired CHP plant offset a small proportion of the sector's fuel use.

4.3 Emissions baseline

Converting baseline fuel consumption into greenhouse gas emissions creates the starting point for the emissions projections. Under the GHG accounting methodology used to prepare the net zero study, the emissions baseline is 528,792 tonnes CO_2e/year. Fossil fuels dominate the emissions inventory, with 63% from natural gas and 31% from fossil-based fuel oils. Around 5% of emissions are from electricity use with smaller fractions from other fuels, including bioenergy.

Figure 8: Baseline greenhouse gas emissions by fuel 2018



88% of total emissions are related to activities at distilleries, with 11% from non-distilling production sites and around 1% from offices and warehouses.

4.4 Emissions pathways

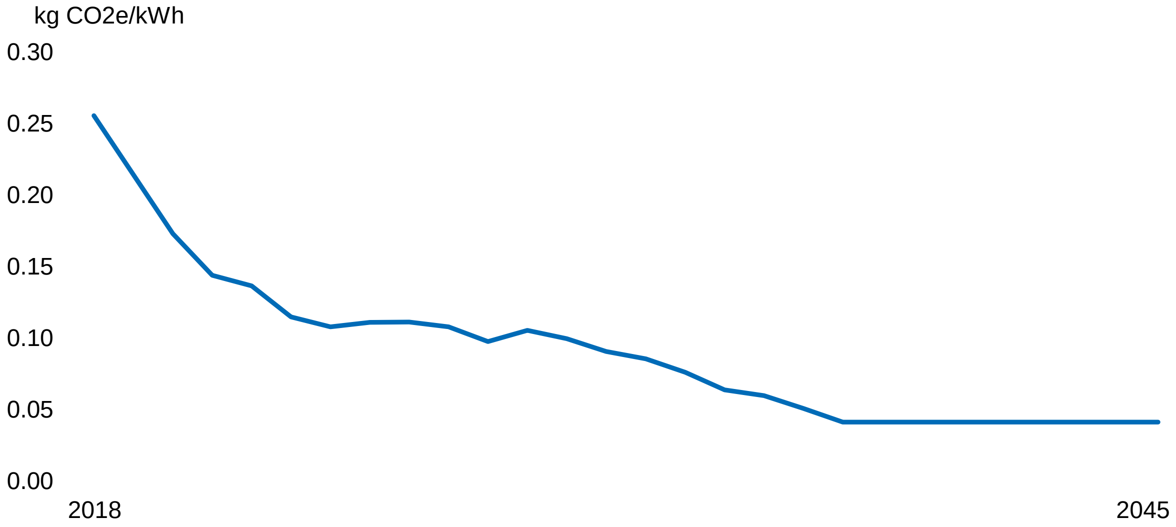
Understanding the likely sources of emissions in 2045 is central to developing a set of measures that can reduce those emissions to zero. An emissions pathway based on the 2018 baseline data has been developed. A series of assumptions are applied to reflect the key factors which will influence how the sector's emissions are expected to evolve in the absence of new energy measures. These are:

- Changes in the GHG emissions intensity of electricity generation
- Underlying energy efficiency improvements
- Changes in sector production

4.4.1 Changes in the GHG emissions intensity of electricity

The electricity supply in the UK has been decarbonising rapidly over the past 10 years and this trend is expected to continue. As a result the emissions associated with electricity consumption are modelled to fall from 0.2773 to 0.0527 kgCO_2e/kWh by 2045 - an 80% reduction. Under the government's net zero plans this may ultimately be reduced further than shown in Figure 9.

Figure 9: Government grid electricity decarbonisation forecasts

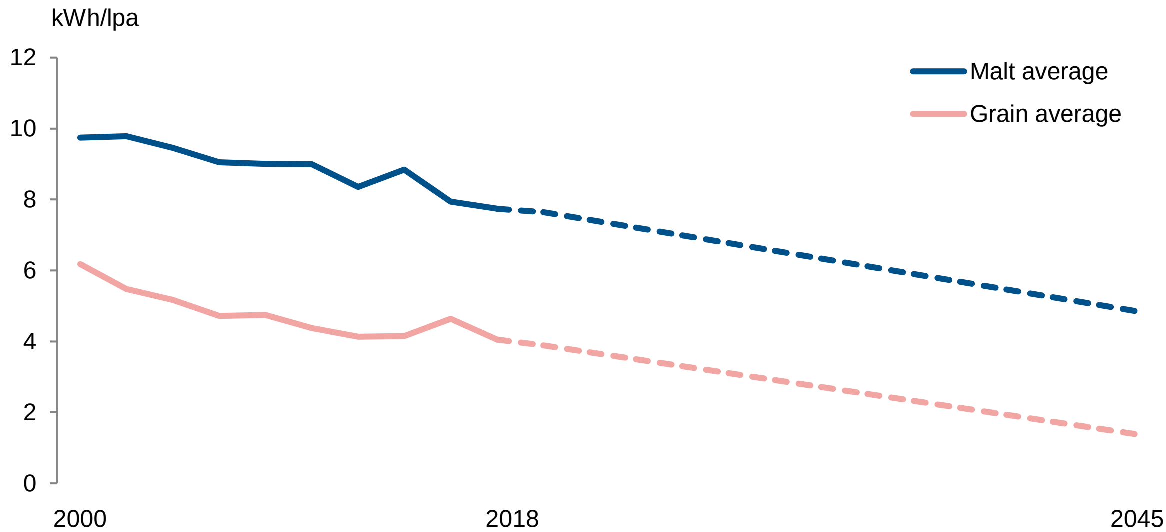


4.4.2 Underlying energy efficiency improvements

Continual improvement in process operations and production methods as well as parts replacement programmes mean that production energy efficiency has been improving steadily over the last 10 years.

The historic trend has been a 3% year-on-year improvement for grain and malt at industry level. Our baseline projections assume that energy efficiency improvements continue, but at the lower level of 2% per year, reflecting member views that were obtained during a meeting in December 2019.

Figure 10: Energy efficiency trends in Whisky production 2000-18. Dashed line forecast based on historic trends



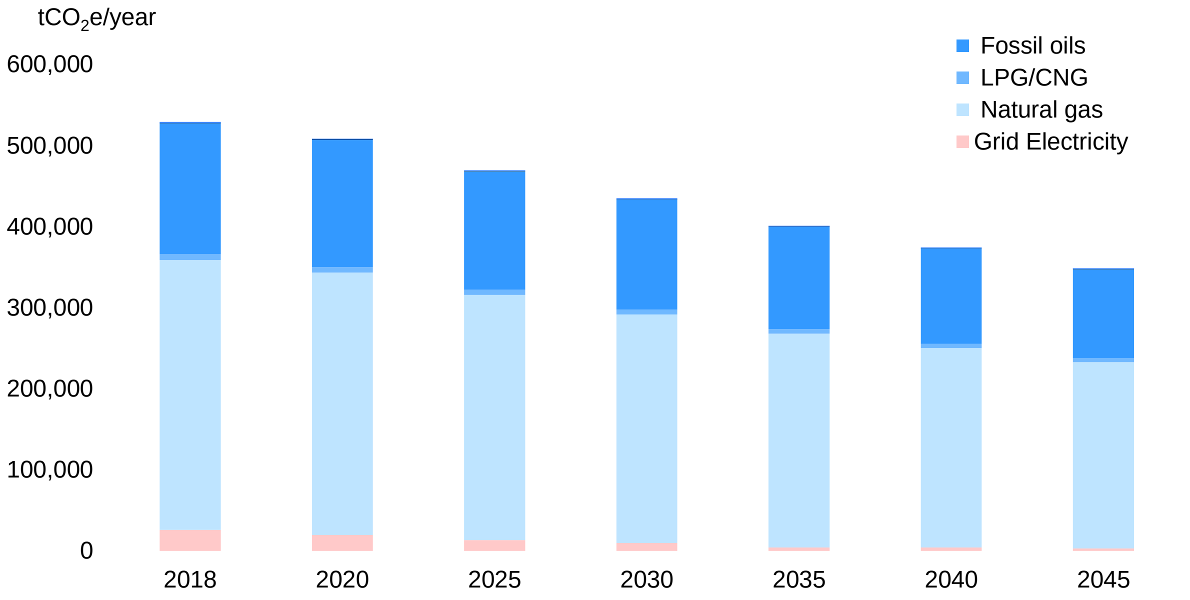
4.4.3 Changes in sector production

We have assumed a small year-on-year increase in whisky production based on the information provided by members. Because this factor is highly uncertain, we undertook a sensitivity analysis and found that the scenarios have a low sensitivity to the production rate. A bigger change in production would however feed through to the cost estimates but would not change the available technology pathways.

4.4.4 Baseline projection

The baseline emissions projection is illustrated in Figure 11 below, shown at 5-year intervals. Taking into account the factors above, total emissions in 2045 are estimated to be 348,481 tCO_2e/year, a 34% reduction on 2018.

Figure 11: Baseline emissions projections to 2045



The falling electricity emissions factor further increases the prominence of process heat in the emissions inventory, with 98.8% of emissions from direct use of fossil fuels and 91% from distillery sites in 2045. As a result, our assessment of energy measures and scenarios focuses on process heat technologies.

5 Scenario modelling

We have modelled seven scenarios to explore the net zero gap and to identify viable pathways to 2045. The three types of scenarios are set out below:

1. Planned progress is an enhanced baseline scenario which includes planned energy measures and sustained energy efficiency improvements.

2. There are three scenarios that explore the maximum potential of individual heat technologies, which helps to understand the contribution they could make. These are:
   - Anaerobic digestion-max
   - Biomass-max
   - Heat pump-max

3. These scenarios present a route to achieving net zero. They combine complimentary technologies within their maximum potential, in order to meet all member energy demands. These are:
   - Green gas
   - Electrification
   - Balanced

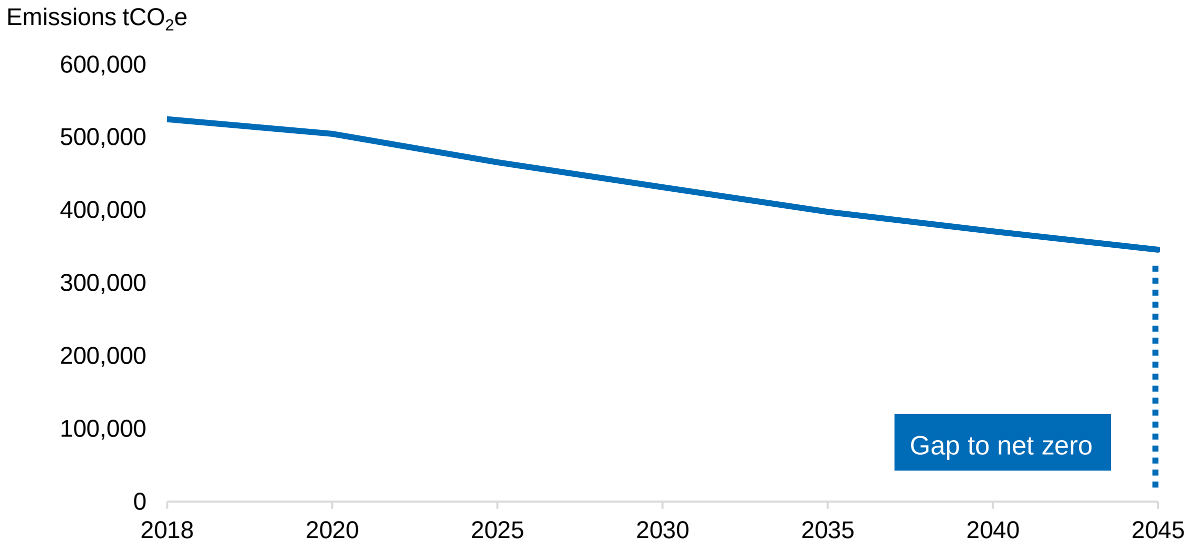
Together these scenarios provide an analysis which sets out the boundaries for the technology pathways as well as credible routes to achieving net zero. The figure below highlights the key technology assumptions that are applied in each scenario. These are described in more detail below.

Figure 12: Net zero technology scenarios matrix

	Energy efficiency	Gas & LNG/CNG	Anaerobic Digestion	Biomass	Heat pumps	Hydrogen	Offsets
Planned progress	3%	Replaces fossil heating by 2025	Planned growth	Planned growth			
Anaerobic digestion-max	3%	Replaces fossil heating by 2025	**Max potential**	Planned growth			
Biomass-max	3%	Replaces fossil heating by 2025	Planned growth	**Max potential**			
Heat pump-max	3%	Replaces fossil heating by 2025	Planned growth	Planned growth	**Max potential**		
Green gas	3%	Replaces fossil heating by 2025	**20% by-product potential**			Meets remaining demand	Yes
Electrification	3%	Replaces fossil heating by 2025	20% by-product potential		**90% of technical potential**	Meets remaining demand	Yes
Balanced	3%	Replaces fossil heating by 2025	20% by-product potential	**80% of potential**	**50% of process heat pot.**	Meets remaining demand	Yes

The scenarios are described in more detail below and the modelling outputs analysed. In each case, the focus is on closing the gap between the baseline pathway and zero in 2045 as illustrated in Figure 13.

Figure 13: Baseline scenario



5.1 Planned progress

The planned progress scenario represents an enhanced baseline for use in subsequent scenarios.

It includes planned energy investments which are expected to be operational in the next few years. Fossil-based fuel oils continue to be replaced by gas and it sets an enhanced energy efficiency improvement rate. These low carbon measures are included in all our subsequent scenarios.

Figure 14: Planned progress scenario map

	Energy efficiency	Gas & LNG/CNG	Anaerobic Digestion	Biomass	Heat pumps	Hydrogen	Offsets
Planned progress	3%	Replaces fossil heating by 2025	Planned growth	Planned growth			

5.1.1 Energy measures

The key energy measures and assumptions which form this scenario are described below.

5.1.1.1 Energy efficiency

The baseline energy efficiency assumption is set at a 2% year-on-year improvement. The planned progress scenario assumes that the historic whisky sector energy efficiency trends of 3% (presented in Figure 10 above) is maintained. This is intended to reflect the importance energy efficiency in any energy strategy, which should be prioritised above low and zero carbon generation.

Our analysis identified a wide range of energy efficiency measures that can be deployed today in whisky distillation, including more significant and challenging measures like Mechanical and Thermal Vapour Recompression (MVR/TVR). The long list of energy efficiency measures is included in the appendix. We recognise the sensitivities around its use and its potential impact on character. The planned progress energy efficiency target incorporates these measures at industry-level.

5.1.1.2 Gas switching

Gas boilers are common at sites with access to the gas grid. While off-gas grid sites have tended to rely on fossil fuel oils, the recent trend has been a switch towards gas boilers, with fuel delivered by road as CNG/LNG/LPG.

This trend has been driven by the favourable economics of gas, particularly where sites have access to existing fuel supply chains. The switch away from fuel oils is also being driven by the Medium Combustion Plant Directive, which limits emissions from new and existing plant.

We have assumed that all fuel oils are replaced in the mid-2020s with CNG/LNG/LPG. These are then phased out and replaced by zero carbon heat technologies in subsequent scenarios.

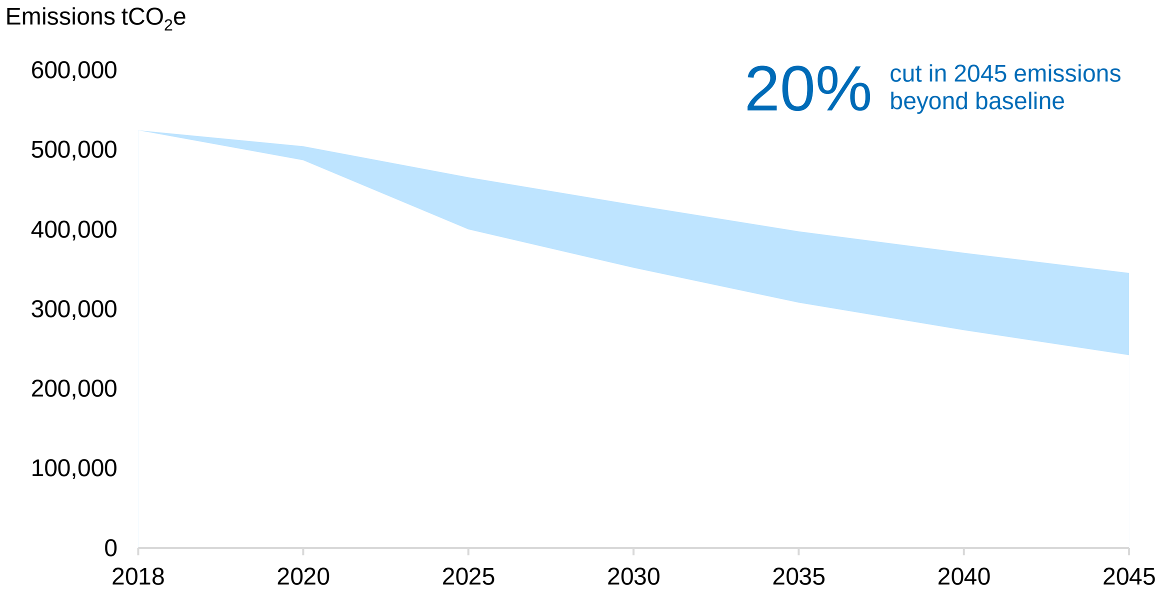
5.1.1.3 Planned growth in renewable heating capacity

Interviews with members identified substantial energy investments in recent years across a range of technologies. In addition to discussions regarding longer-term corporate objectives and energy measures, a number of near-term biomass and anaerobic digestion capacity additions are planned. The contribution of these installations has been estimated.

5.1.2 Scenario findings

The planned progress scenario resulted in a 20% cut in emissions below the baseline in 2045. This leaves a 46% net zero gap remaining from emissions today.

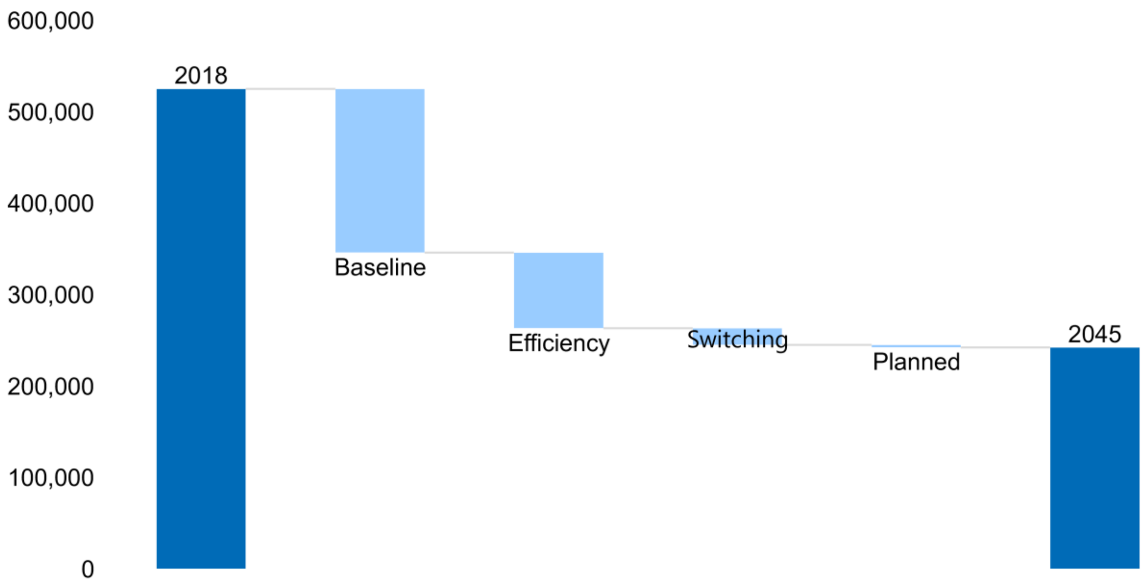
Figure 15: Planned progress emissions projections



The waterfall chart in Figure 16 breaks down emissions reduction, so the relative importance of each measure can be understood.

It indicates that a third of the emissions reduction is attribute to the changing baseline. Planned progress has reduced this by a further 20%, with 16% of that due to the enhanced energy efficiency improvement rate (3% per annum), 3% from fuel switching and around 1% from the planned renewable heating installations.

Figure 16: Planned progress emissions reduction by measure



The 3% energy efficiency rate was discussed at the net zero workshop with members. There were a range of views on it. Around half of respondents were concerned that there is a thermodynamic limit to efficiency improvements, which couldn't keep improving year on year forever. This is a valid concern. To validate our energy efficiency improvement estimates, we looked at the average and most efficient grain and malt distilleries. This suggests that convergence towards leading energy performance would deliver most of the improvements assumed in the baseline. An additional ~0.5% year on year improvement would be required to deliver the planned progress energy efficiency rate.

Table 1: Net zero workshop votes: 3% per year energy efficiency improvement - is it credible?

Choices	Votes
Too demanding	10
About right	4
Not demanding enough	4
Not sure	2

5.2 Anaerobic digestion-max

Anaerobic digestion-max scenario models the maximum possible uptake of anaerobic digestion (AD) using all distillation by-products to produce heat. The planned progress measures are also included in this scenario.

Figure 17: Anaerobic digestion-max scenario map

	Energy efficiency	Gas & LNG/CNG	Anaerobic Digestion	Biomass	Heat pumps	Hydrogen	Offsets
Anaerobic digestion-max	3%	Replaces fossil heating	**Max potential**	Planned growth			

5.2.1 Anaerobic digestion

Anaerobic digestion is a process whereby biodegradable materials are broken down in the absence of oxygen, to produce biogas and a resultant digestate. The produced biogas can then either be converted into electricity, burned directly in a biogas boiler to produce heat, or injected into the gas grid.

Here, maximum uptake incorporates all available whisky process by-products (pot-ale & draff, including dark grains) being used as feedstock for AD, with 100% of the resulting biogas being used to deliver process heat demand. While CHP has a higher overall fuel efficiency, decarbonising process heat is the biggest challenge for the sector and the focus is therefore on maximising heat generation.

In modelling the maximum use of by-products for AD, we removed any current alternative use of by-products from the 2018 baseline, stripping confirmed instances of use in AD and solid biomass systems. We then estimated the potential maximum volume of biogas, and hence heat energy, available from industry by-products. The calculation called on estimates from a number of best-practice industry reports[4&5] to quantify:

- Potential mass of by-products per litre of pure alcohol (lpa) produced
- Dry matter content of by-products
- Biogas yield per tonne of by-product
- Methane content of biogas
- Energy content of methane

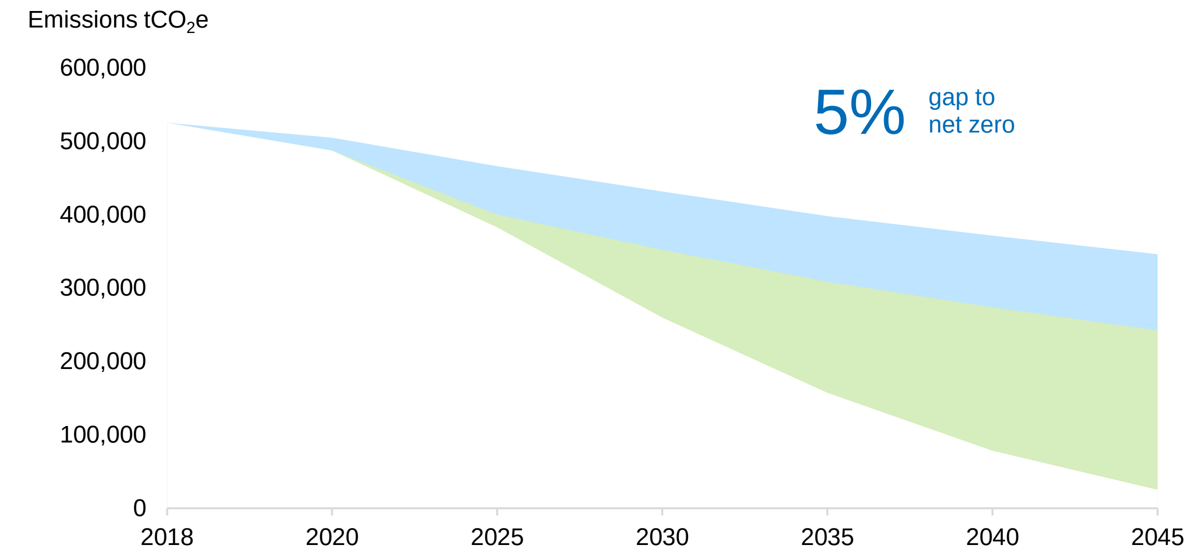
Existing AD plants used by the whisky sector include both small systems serving a single distillery and larger operations taking by-products from multiple sites and using different by-product feedstocks. We have assumed that a combination of on-site and shared infrastructure is deployed to make best use of by-products, with the carbon benefit accruing to the whisky sector.

It is important to note that the biogas yield from any AD feedstock is highly sensitive to the quality and moisture content of that feedstock, and it is widely accepted that pot ale in particular can be problematic for AD plant if not properly prepared. Therefore AD systems need to very precisely designed, and the feedstock used needs to be properly prepared to ensure the highest possible yield efficiencies.

5.2.2 Scenario findings

Figure 18 shows that the AD-max scenario reduces baseline emissions by 61% in 2045. There remains just a 5% gap to net zero.

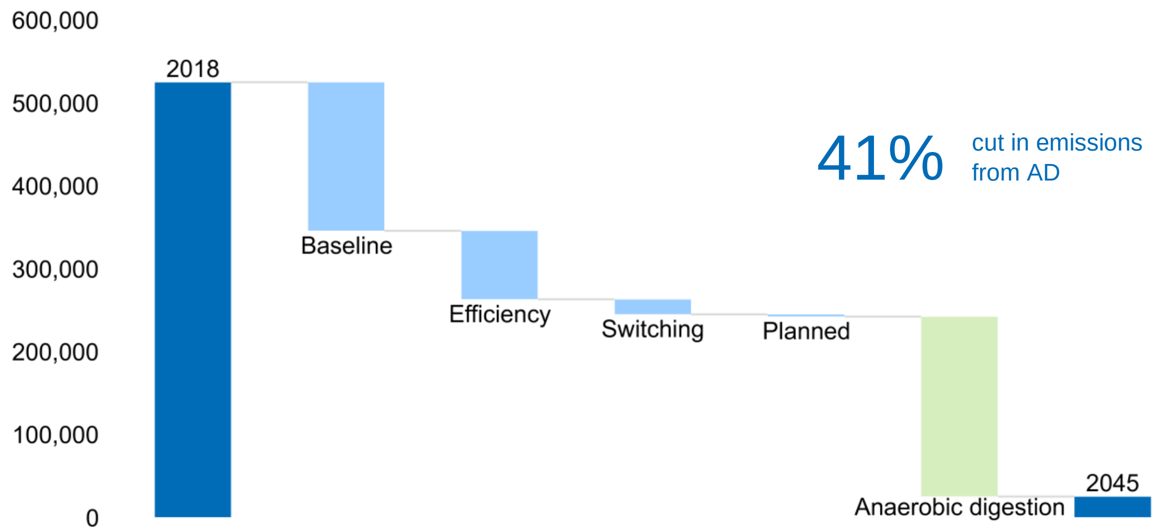
Figure 18: Anaerobic digestion-max emission pathway



[4] https://www.zerowastescotland.org.uk/sites/default/files/ZWS645%20Beer%20Whisky%20Fish%20Report_0.pdf
[5] http://www.esru.strath.ac.uk/Documents/MSc_2016/Duguid.pdf

The waterfall chart below indicates that maximum uptake of heat AD results in a 41% reduction in emissions over planned progress.

Figure 19: AD-max emissions reduction by measure



Anaerobic digestion has the potential to make a significant contribution to overall carbon reductions by 2045. It is, though, important to bear in mind the sensitivity to feedstock variation discussed above, and the subsequent vital role of system design and feedstock preparation.

Another important factor to consider is that by-products are already used for other purposes. Much is currently processed into animal feeds. In mid-century, the biogas produced could be a scarce low carbon fuel which is highly valued in other parts of the economy, such as heavy goods transport. The question of whether biogas from distillation by-products should be used to meet process heat demand was raised at the workshop. CCC analysis, explored further in the biomass-max scenario below, suggests that some 'wet' by-products, as in the whisky sector' are likely to continue to be best used by AD plants. At smaller or more remote sites they accept that best use is to meet local energy demand.

Where possible, the biomethane should be injected into the gas grid and combustion carbon emissions captured in order to secure the greatest abatement. This won't always be viable, particularly away from the gas grid and carbon capture infrastructure. Shared infrastructure that processes by-products at scale on behalf of multiple sites could have additional advantages as part of a net zero strategy.

Table 2 summarises members' view of AD based on votes at the net zero workshop. The consensus was that it has a role in net zero, with a range of views expressed regarding the diversion away from use as animal feed.

Table 2: Net zero workshop votes: Your view of AD - importance to net zero?

Choices	Votes
No role in to zero	0
A role in net zero	14
A big role in net zero	8
Not sure	0

5.3 Biomass-max

The biomass-led scenario explores the impact of deploying wood-fired biomass boilers to their maximum potential within technical constraints while reflecting concerns about sustainable & low carbon biomass supply. The planned progress measures are also included in this scenario.

Figure 20: Biomass-max scenario map

	Energy efficiency	Gas & LNG/CNG	Anaerobic Digestion	Biomass	Heat pumps	Hydrogen	Offsets
Biomass-max	3%	Replaces fossil heating	Planned growth	**Max potential**			

5.3.1 Biomass boilers

5.3.1.1 Technical

Biomass is already relatively widely adopted across the whisky sector and the key technologies used are direct heat boilers, steam boilers and biomass fired combined heat and power (CHP) plant. Heat supply from biomass cannot be ramped up and down as quickly as a gas heating system. This makes them well suited to large distilleries with a constant demand. While it is technically feasible for biomass to meet all distillation heat demands, the fluctuating demand at small distilleries can reduce system efficiency. We have assumed that around 20% of heat is supplied by a secondary fuel at smaller sites.

5.3.1.2 Supply constraints

Sustainable low-carbon biomass is a flexible and finite resource. The wide range of possible uses of biomass in energy generation means that demand is likely to exceed sustainable supply on a UK and a global level. This means decisions will need to be made as to where this finite biomass resource is best used across the economy, with priority given to uses that give the greatest overall levels of emissions abatement.

The CCC's Biomass in a Low-Carbon Economy[6] report suggests that this will generally be achieved where the carbon in biomass is stored, rather than just displacing a fossil fuel use. This means reserving biomass supplies for:

1. Timber used in construction which stores the carbon long term
2. Biomass energy with carbon capture and storage and where there are no good low carbon alternatives. This is likely to be:
    - Displacing coal in heavy industry
    - Biofuels for aviation
    - Some heating in rural areas

In mid-century the CCC sees only limited use of biomass to heat buildings or as biofuels in cars and vans or as unabated biomass/biomass CHP. This represents a break with current views of biomass in the energy sector and limits the applications we have modelled for the whisky sector.

There are however justifiable uses of biomass in whisky production, at remote distilleries where other heat options are limited. Here, biomass without carbon capture could have a role alongside other technologies where it makes local biomass resources economically viable to use.

This is the use case we have modelled in this scenario. Spatial mapping has been used to identify sites that are most likely to be remote from supply chains that could deliver alternative low carbon fuels, such as biogas or hydrogen. This means sites away from built up areas, transport connections

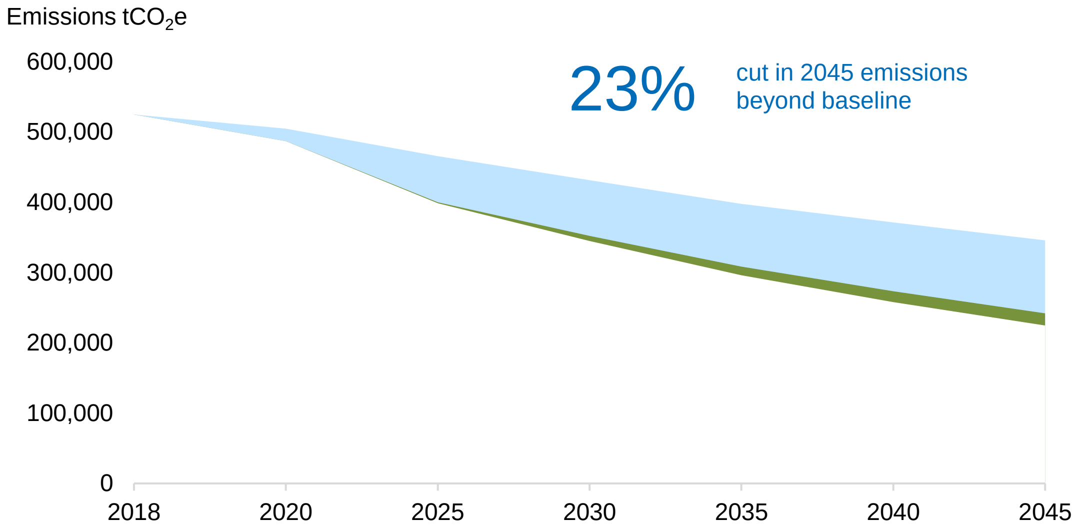
[6] CCC, Biomass in a low-carbon economy 2019

and other distillery sites who could otherwise potentially work together to develop a shared supply chain. This analysis identified 15-20 malt distilleries could be able to use biomass for heating.

5.3.2 Scenario findings

The biomass-max scenario reduces baseline emissions by 23% in 2045. There remains a 43% gap to net zero from 2018 emissions.

Figure 21: Biomass max emissions projection



The waterfall chart below indicates that maximum technical uptake of heat pumps represents a 3% reduction in emissions over planned progress.

Figure 22: Biomass-max emissions reduction by measure

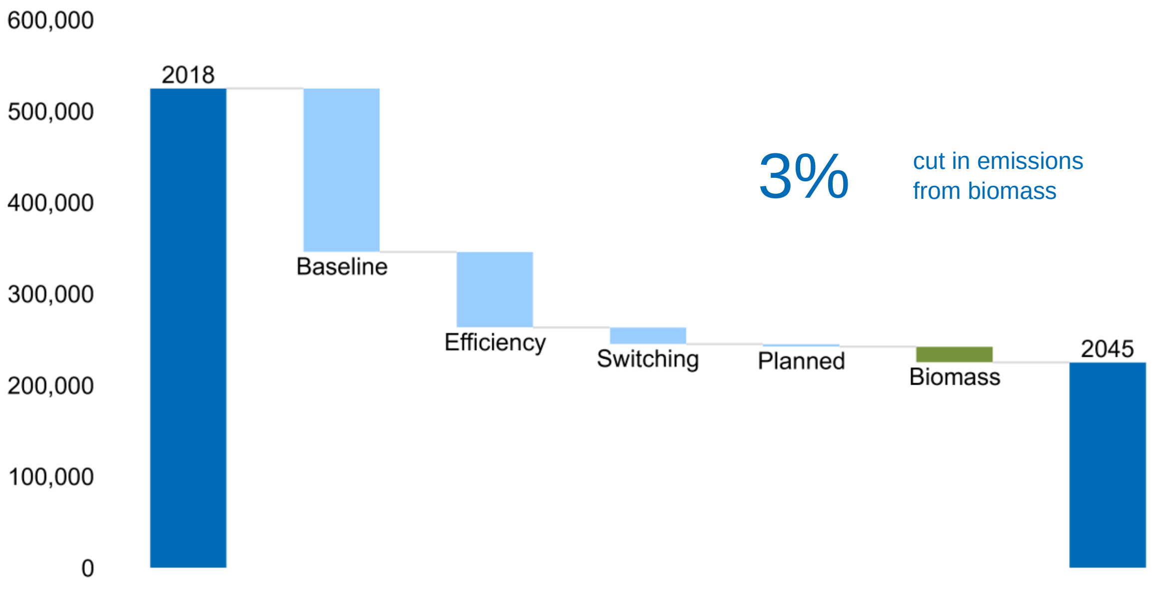


Table 3 summarises member's view of biomass based on votes at the net zero workshop. There appeared to be general agreement that the supply of low carbon sustainable biomass is an issue and we were pointed to good examples where local biomass is being exploited in remote areas. Our analysis also raised the question of whether existing or planned biomass systems might become stranded assets.

Table 3: Net zero workshop votes: Your view of biomass - importance to net zero?

Choices	Votes
No role in net zero	7
A role in net zero	14
A big role in net zero	0
Not sure	0

5.4 Heat pump-max

The heat pump-led scenario models the maximum potential impact of heat pumps.

At the time of writing, there are a range of heat pump technologies available including those which are technically capable of raising steam and reaching the temperatures required for whisky production. However commercial scale demonstrator projects have not yet been implemented in the whisky sector. This scenario assumes that developments in high temperature heat pump technology mean it becomes a technically feasible & financially viable option for whisky distilleries.

Figure 23: Heat pump-max scenario map

	Energy efficiency	Gas & LNG/CNG	Anaerobic Digestion	Biomass	Heat pumps	Hydrogen	Offsets
Heat pump-max	3%	Replaces fossil heating	Planned growth	Planned growth	**Max potential**		

5.4.1 Energy measures

The scenario deploys high temperature heat pumps to the maximum extent possible within the technical constraints described below. The planned progress measures are also included in this scenario.

5.4.1.1 Site heat supply

A heat pump can't always meet 100% of a site's process heat demand. The capital cost of heat pump systems means that they would typically be sized to 30% of peak capacity in order to meet 85% of total energy demand. 85% has been assumed for continuous processes but a lower figure of 70% has been used to reflect use in batch processes.

Heat pumps providing space heating and low temperature hot water are already commercially available and we have assumed that all this demand is met.

5.4.1.2 Water sources

Although the heat pump systems are likely to predominantly use recovered heat, we have assumed that they will need to absorb or reject naturally occurring heat at some point and that the only sites suitable for heat pumps at this scale are those near a water source. Spatial analysis of sites has been undertaken and only sites within 500m of a water body are included. This includes 72% of sites.

Heat pumps providing space heating and low temperature hot water are modelled as air source heat pumps and we have assumed that all this demand is met.

5.4.1.3 Availability of grid capacity

Electrifying process heating requires access to significant grid capacity, which is unlikely to be available at all sites, particularly where they are remote. For example, a distillery with 10MW of thermal demand would have a heat pump sized to meet 30% of peak operating at a Coefficient of Performance (COP) of 3. This would require a 1MW grid connection to serve the heat pump.

We have assumed that the extent of electrification that can be achieved is linked with local network constraints. Spatial analysis of sites associated each production site with a distribution substation. The Distribution Network Operator publishes constraints red, amber, greed ratings and we have assumed that a proportion of heat pump capacity can be installed as follows:

- Red - 20%
- Amber - 60%
- Green - 90%

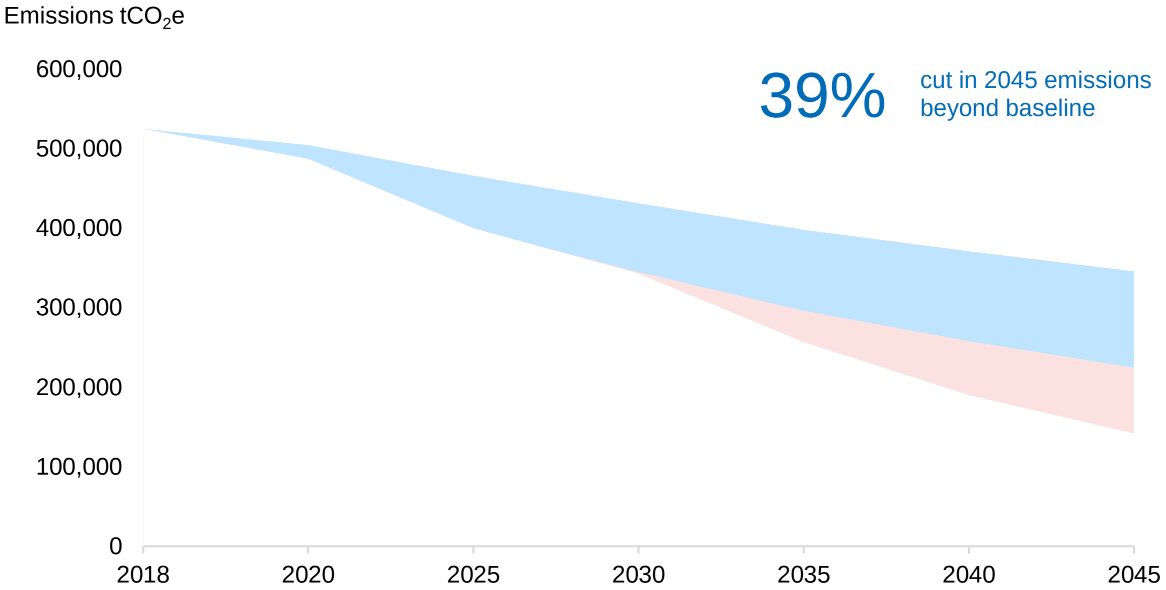
5.4.1.4 Practicality and installation constraints

The installation of a heat pump system at an existing distillery is likely to require additional space. We have assumed that 20% of distilleries will not be suitable for heat pumps due to lack of space.

5.4.2 Scenario findings

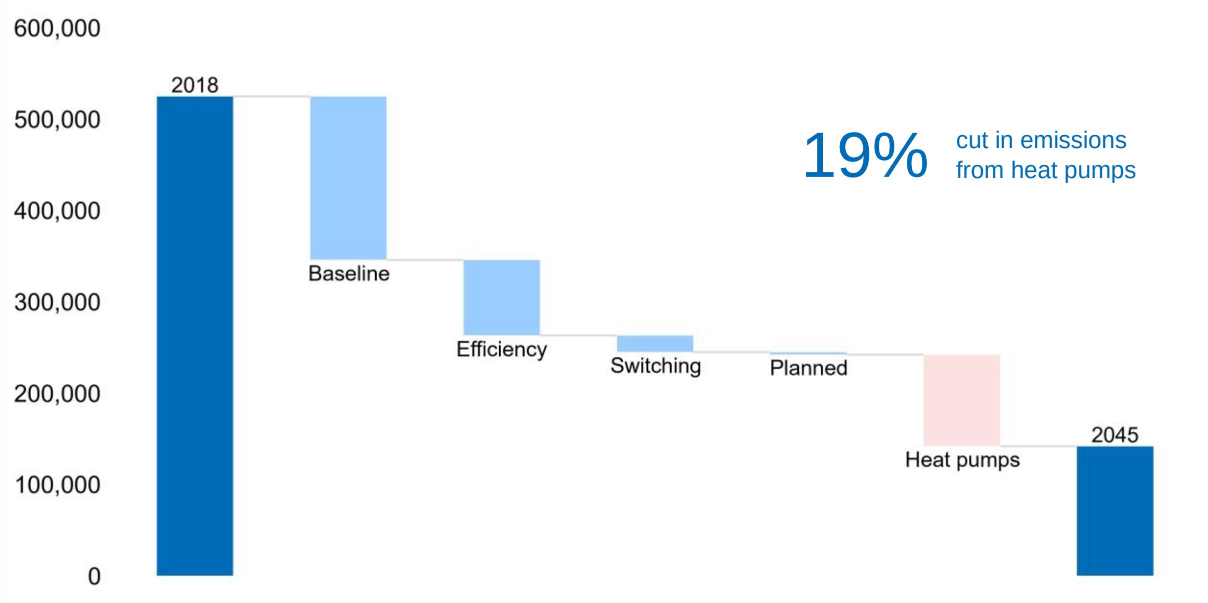
The heat pump-max scenario reduces baseline emissions by 39% in 2045. There remains a 27% gap to net zero from 2018 emissions.

Figure 24: Heat pump-max emissions projections



The waterfall chart below indicates that maximum technical uptake of heat pumps represents a 19% reduction in emissions over planned progress.

Figure 25: Heat pump-max emissions reduction by measure



High temperature heat pumps could potentially make a substantial contribution to a net zero strategy. However, this scenario shows that even with the optimistic assumption that they become commercially attractive for distillation, heat pumps will need to be deployed alongside other technologies to achieve net zero.

Table 4 summarises member's view of heat pumps based on votes at the net zero workshop. The consensus was that heat pumps have a role in net zero, with views tempered by the lack of technology maturity and UK demonstrators, although we were pointed to equivalents in other countries.

Table 4: Net zero workshop votes: Your view of heat pumps - importance to net zero?

Choices	Votes
No role in to zero	0
A role in net zero	17
A big role in net zero	2
Not sure	1

5.5 Green gas

Green gas is the first of our scenarios that provide a route to net zero. These scenarios deploy the low carbon heat technologies within the maximum potentials we have defined.

The green gas scenario is driven by increased uptake of AD starting in the 2020s with hydrogen displacing remaining natural gas demand from the mid-2030s. Using gas fuels reduces practical and installation challenges faced by some other technologies. Each site can use the fuel, or combination of fuels, that are most economic and available to them.

Figure 26: Green gas scenario map

	Energy efficiency	Gas & LNG/CNG	Anaerobic Digestion	Biomass	Heat pumps	Hydrogen	Offsets
Green gas	3%	Replaces fossil heating	**20% by-product potential**			Meets remaining demand	Yes

5.5.1 Energy measures

5.5.1.1 Anaerobic digestion

We have modelled AD being deployed up to 20% of the potential estimated in the AD-max scenario. This represents increased use of distillation by-product for energy production but does not imply wholesale change to existing uses. This is assumed to be a combination of on-site AD delivering process heat and shared infrastructure, which could include biomethane grid injection.

5.5.1.2 Hydrogen

Hydrogen has the potential to be an all-purpose clean energy source that can fuel transport, homes and businesses without harmful emissions. Hydrogen is flexible – it can be combusted for heating or fed into a fuel cell to produce electricity – which gives it the potential to become ubiquitous, earning the 'hydrogen economy' moniker. 'Green' hydrogen is produced by electrolysing water using renewable electricity., The only by-product is water. Other producing methods are associate with varying levels of carbon emissions. See below. As hydrogen needs to be manufactured, it is currently a more expensive option. While the potential is near limitless, the relative immaturity of the technology, the cost of fuel production, and its storage and distribution, has to date limited its uptake.

Industrial processes, including whisky production, are considered to be some of the hardest to decarbonise. Hydrogen is one way this could happen and it could be used where there are no alternative low-carbon options. The CCC's projections suggest that hydrogen will be more cost-effective at producing process heat or steam than the low carbon alternatives in many industrial sectors. Hydrogen boilers are expected to be relatively cheap, with costs comparable to gas boilers, making fuel production and distribution costs the key determining factor. These are expected to remain significantly higher than for natural gas, until carbon prices are factored in. Economy wide carbon prices of £70-100/tCO_2 are projected for 2030 onwards and could be sufficient to encourage switching.

Hydrogen distribution is a major known barrier, with the optimal combination of local electrolysis vs centralised production and delivery unknown. Despite the uncertainties, hydrogen has a central role in economy-wide net zero scenarios and we have assumed that its wide adoption brings supply infrastructure with it. The ongoing programme of replacing iron gas distribution pipes with polyethylene means that, by the 2030s, gas distribution could be suited to carrying hydrogen.

The method of hydrogen production that will be adopted remains highly uncertain, with competing technologies and installation contexts. The key variants include on-site vs off-site production, electrolysis vs steam methane reforming (SMR), with carbon capture (known as 'blue' hydrogen) or without carbon capture (known as 'brown' hydrogen). Each is associated with different cost and carbon intensity factors. We have assumed that hydrogen will be produced at centralised plant and delivered to site in the majority of cases. The scenario modelling assumes that hydrogen is zero carbon in mid-century. The impact of higher carbon forms of hydrogen production is considered in Section 6.4 where we discuss offsetting residual emissions.

The uncertainty surrounding hydrogen is reflected in the net zero scenarios, with deployment starting in the 2030s only.

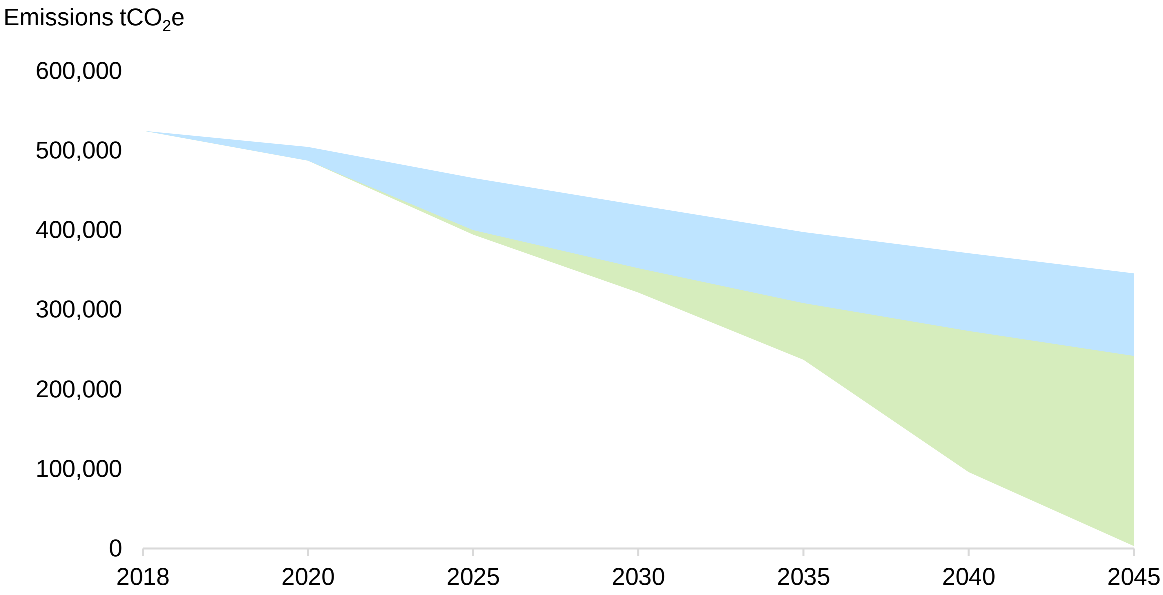
5.5.1.3 Carbon offsets

Carbon offsets are likely to be required to address residual emissions. These are discussed in more detail in Section 6.4.

5.5.2 Scenario findings

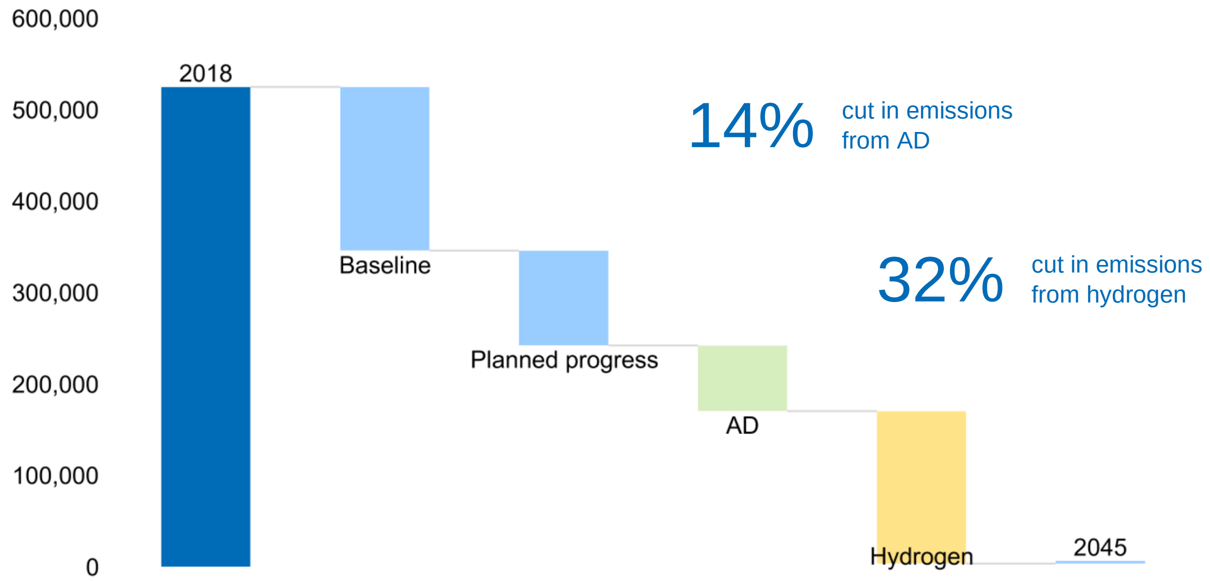
Figure 27 shows the Green Gas scenario to achieving net zero by 2045.

Figure 27: Green gas scenario emissions projection



The waterfall chart below indicates shows the contribution to reductions from each measure. AD is responsible for 14% of emissions reductions hydrogen for 32%.

Figure 28: Green gas scenario - emissions reduction by measure



The Green Gas scenario expects a significant proportion of energy to be supplied by hydrogen, which is currently expensive and lacks the production and distribution infrastructure that would be required. A more cautious, risk averse, variant of this scenario would increase the use of biogas from AD. The flexibility of the fuels gives this scenario some inherent resilience.

Table 6 summarises member's view of the scenario based on votes at the net zero workshop. The uncertain credibility of the scenario was linked to the technology readiness and viability of both heat pump and hydrogen technology.

Table 5: Net zero workshop votes: Is the green gas scenario credible?

Choices	Votes
Yes	18
No	0
Not sure	4

5.6 Electrification

The Electrification scenario provides a route to net zero through a significant deployment of heat pumps, with the rest of process heat demand met by a combination of AD and hydrogen.

It reflects the Heat Pump-Max scenario, which assumed that developments in high temperature heat pump technology would make it a technically feasible & financially viable option for whisky distilleries to adopt.

Figure 29: Electrification scenario map

	Energy efficiency	Gas & LNG/CNG	Anaerobic Digestion	Biomass	Heat pumps	Hydrogen	Offsets
Electrification	3%	Replaces fossil heating	20% by-product potential		**90% of technical potential**	Meets remaining demand	Yes

5.6.1 Energy measures

5.6.1.1 Heat pumps

In the heat pump-led scenario we estimated a reasonable maximum level to which heat pumps could be deployed in the sector. Here it is assumed that 90% of that amount is deployed, representing an ambitious but credible rate of uptake.

5.6.1.2 Anaerobic digestion

AD is deployed in line with the Green Gas scenario, using 20% of industry by-products.

5.6.1.3 Hydrogen

We have assumed that the remaining process heat demand is fuelled by hydrogen, in line with the Green Gas scenario. Hydrogen is not deployed until 2035, reflecting the current immaturity of the technology.

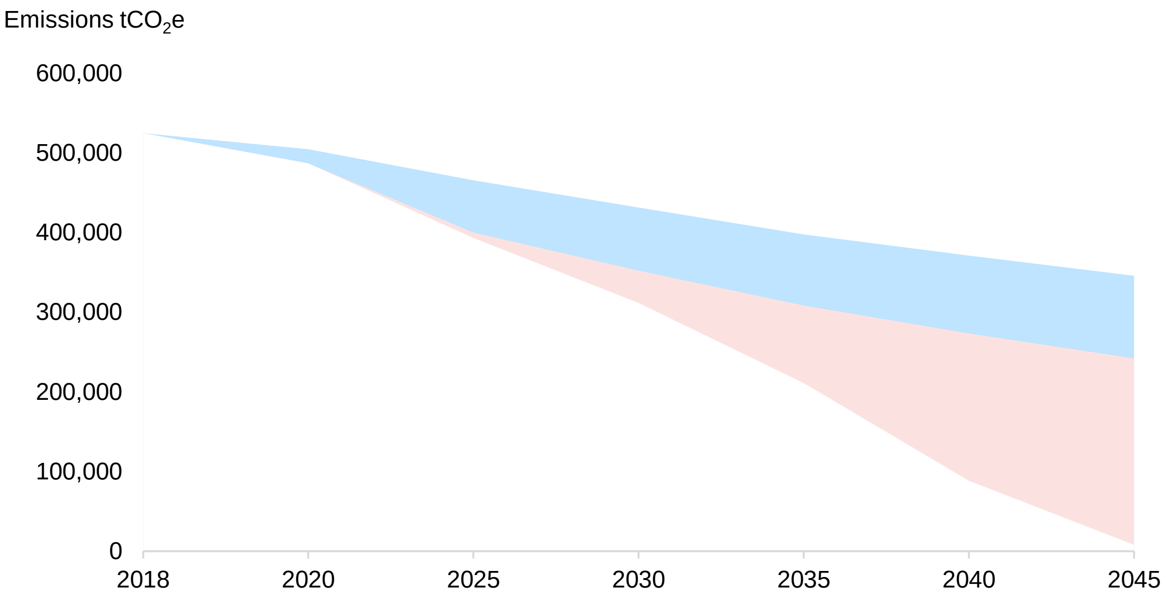
5.6.1.4 Carbon offsets

Carbon offsets are likely to be required to address residual emissions. These are discussed in more detail in Section 6.4.

5.6.2 Scenario findings

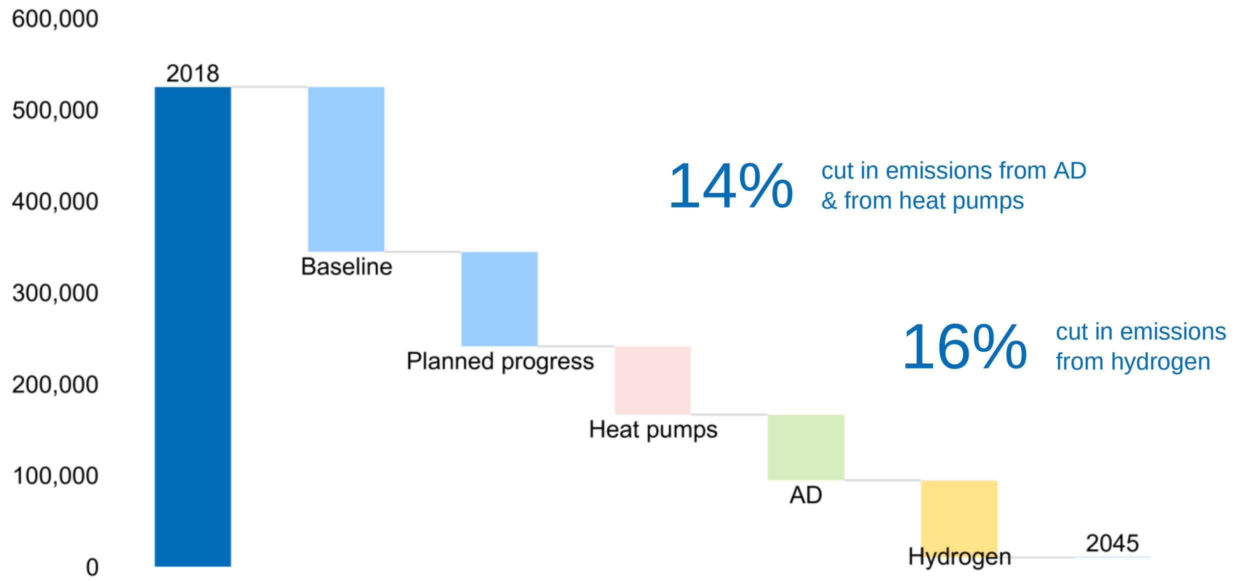
Figure 30 show the Electrification scenario achieving net zero by 2045.

Figure 30: Electrification emissions projections



The waterfall chart below shows the contribution from each measure. Heat pumps and AD are responsible for 14% each with hydrogen accounting for 16%.

Figure 31: Electrification emissions reduction by measure



The Electrification scenario reflects the Heat Pump-Max finding, that high temperature heat pumps could potentially make a substantial contribution to a net zero strategy but will need to be deployed alongside other technologies. The gap can be met by an increase in AD uptake with hydrogen. The use of heat pumps has cut the proportion of hydrogen use in half, in comparison to the Green Gas scenario.

Table 6 summarises member's view of the scenario based on votes at the net zero workshop. The uncertain credibility of the scenario was linked to the technology readiness and viability of both heat pump and hydrogen technology.

Table 6: Net zero workshop votes: Is the electrification scenario credible?

Choices	Votes
Yes	9
No	1
Not sure	11

5.7 Balanced

The balanced scenario applies a combination of the key heat technologies well within their maximum technical potential.

Figure 32: Balanced scenario map

	Energy efficiency	Gas & LNG/CNG	Anaerobic Digestion	Biomass	Heat pumps	Hydrogen	Offsets
Balanced	3%	Replaces fossil heating	20% by-product potential	**80% of potential**	**50% of process heat pot.**	Meets remaining demand	Yes

5.7.1 Energy measures

5.7.1.1 Anaerobic digestion

AD is deployed in line with the Green Gas scenario, using 20% of industry by-products.

5.7.1.2 Biomass

Biomass is deployed at 80% of the Biomass-Max scenario reflecting its utility at remote sites.

5.7.1.3 Heat pumps

High temperature heat pumps are deployed at 50% of the process heating technical potential defined in the Heat Pump-Max scenario. Low temperature heat pumps are already commercially available and widely used. It is assumed that 100% of space heating and low temperature hot water demand is met by heat pumps.

5.7.1.4 Hydrogen

We have assumed that the remaining process heat demand is fuelled by hydrogen, in-line with previous net zero scenarios. Hydrogen is not deployed until 2035, reflecting the current immaturity of the technology.

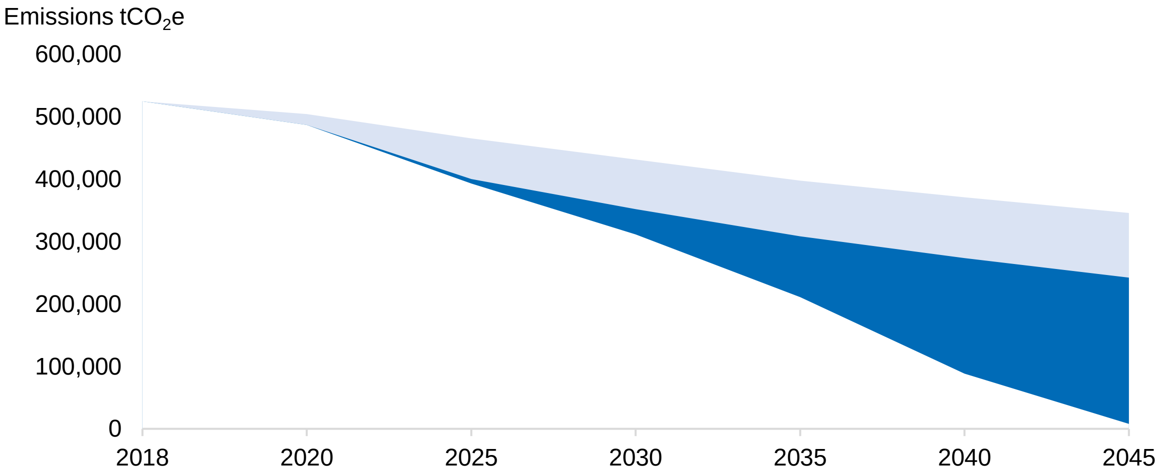
5.7.1.5 Carbon offsets

Carbon offsets are likely to be required to address residual emissions. These are discussed in more detail in Section 6.4.

5.7.2 Scenario findings

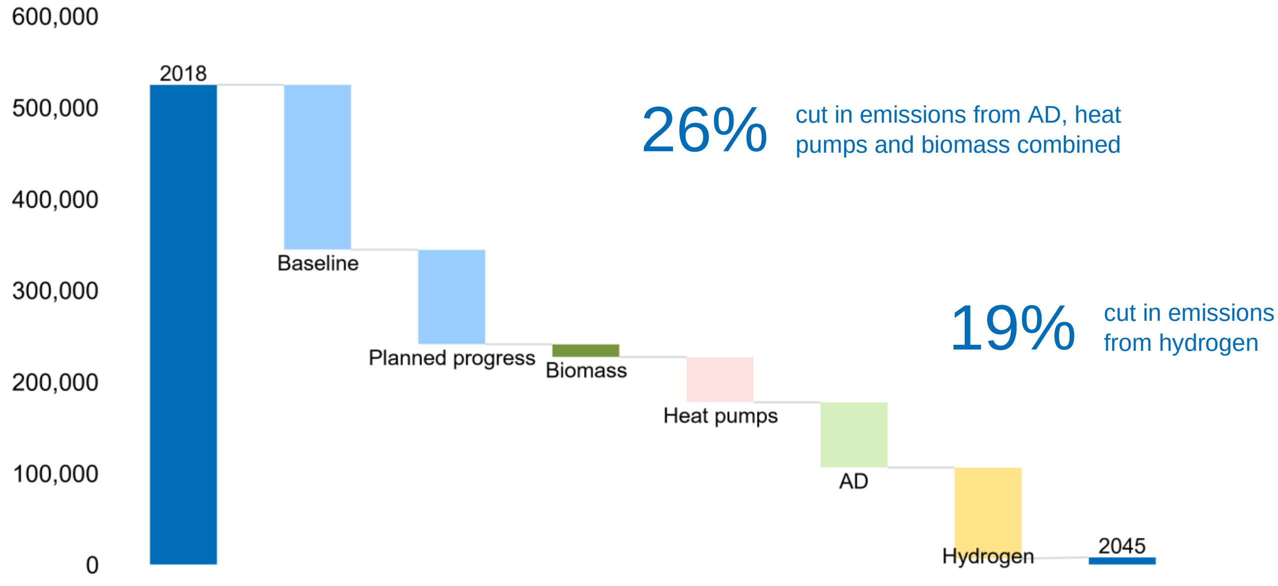
Figure 33 show the Balanced scenario achieving net zero by 2045.

Figure 33: Balanced scenario emissions projections



The waterfall chart below shows the contribution from each measure. Heat pumps (9%), biomass (3%) and AD (14%) together are responsible for 26% of emissions reductions, with hydrogen accounting for 19%.

Figure 34: Balanced scenario - emissions reduction by measure



The Balanced scenario demonstrates that there are pathways to net zero which sit well within the maximum technical potential of the key heat technologies.

Table 7 summarises member's view of the scenario based on votes at the net zero workshop. The Balanced scenario appears to have garnered support, with 80% of responses seeing it as credible.

Table 7: Net zero workshop votes: Is the balanced scenario credible?

Choices	Votes
Yes	17
No	1
Not sure	4

6 Net zero pathways analysis

6.1 Technology pathways

The study has identified the key energy technologies that can reduce emissions from whisky production to net zero. Generating heat for distillation is the primary source of emissions and the key technical challenge.

The scenarios looked at how anaerobic digestion, biomass, hydrogen & high temperature heat pumps could be deployed across the industry. Our analysis indicates that there are a range of credible pathways to net zero, making use of each technology to varying degrees within their maximum technical potential.

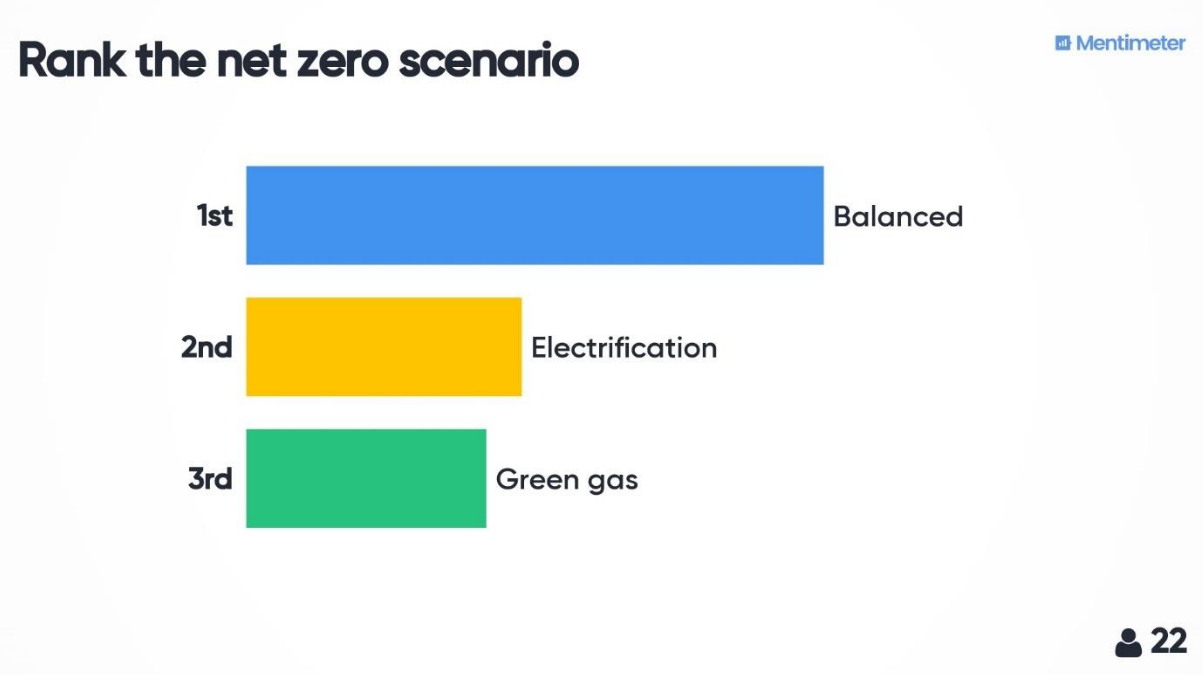
The option to deploy multiple technologies provides important flexibility to members, with each site able to use the technology most suited to their operations and constraints. At sector level, it means that the changing viability of one technology could be compensated for by another.

6.2 Member views

The net zero workshop on 4th February 2020 concluded with a series of votes which sought to gather members views on the scenarios presented and the net zero challenge.

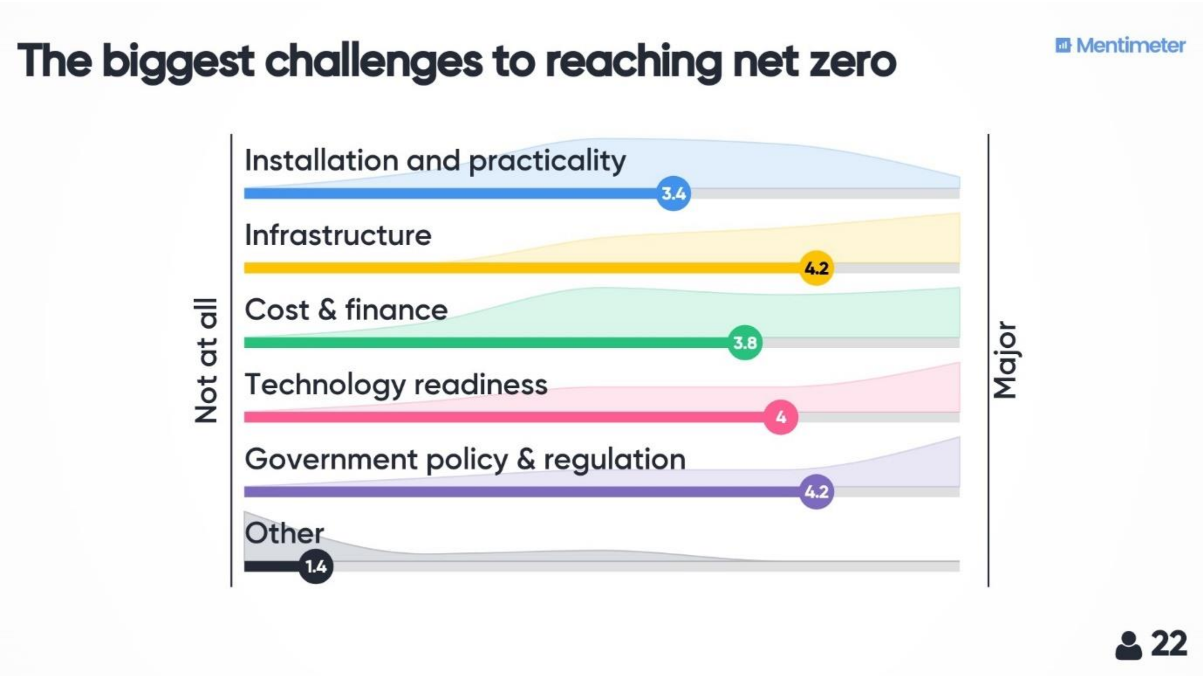
Attendees ranked the 3 net zero scenarios. Balanced was the 1st choice vote for almost everyone with Electrification and Green Gas receiving an almost equal split of 2nd and 3rd choice votes. This supports our conclusion that a strategy that offers members maximum flexibility is preferable.

Figure 35: Interactive voting output - rank the net zero scenario



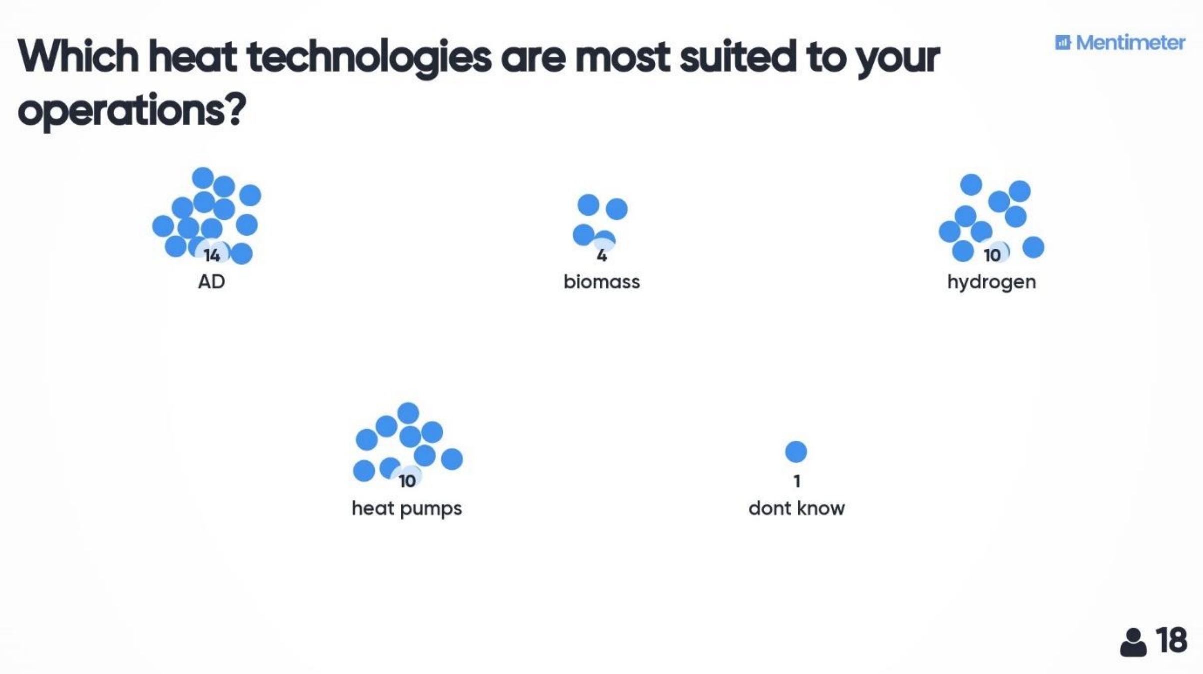
A vote sought to weigh the relative importance of different barriers to reaching net zero. There was consensus that *Government Policy & Regulation* needs to support the industry and *Infrastructure* must be provided that enables zero carbon technologies to be adopted. *Technology Readiness* was also broadly agreed to be a major challenge. Views diverged more on the relative importance of *Installation and Practicality* and *Cost & Finance* challenges.

Figure 36: Interactive voting output - the biggest challenges to reaching net zero



Finally attendees were asked to reflect on the key heat technologies and to select all of the ones which they feel are suited to their operations. There was broadly even split between AD, hydrogen and heat pumps with a smaller number including biomass among their choices. This supports our contention that members will need flexibility to choose energy measures which works for them.

Figure 37: Interactive voting output - which heat technologies are most suited to your operations?



6.3 Cost analysis

We have modelled the costs of each scenario at a high level which can be used to understand the relative costs of the net zero scenarios. The analysis draw upon the measures identified in each scenario and applies a series of financial assumptions. This includes capital, operating and fuel costs projections as well as the following:

- A plant lifetime of 20 years was assumed for all the measures, after which a complete replacement of the equipment takes place. As a result, capital costs are sensitive to whether the scheduled replacement falls before or after 2045.
- Load factor (the average utilisation of the plant's full capacity) are assumed to be 25% for all measures selected. The load factor, in conjunction with the energy demand, determines the capacity of the plant, which in-turn governs capital and operating costs (calculated per kW of capacity).
- The cost of carbon and policy costs are not included. The price of offsetting residual carbon in 2045 are estimated separately below.
- The net present cost calculation applies a 6% discount rate to future costs.

Each factor introduces a measure of uncertainty, and the analysis should be used as a basis for comparison only. The cost estimates are presented below.

Table 8: Estimated costs of the net zero scenarios

Scenario	Capital cost (£m)	Total annual operating cost (£m)	Total fuel cost (£m)	Net present cost (£m)
Green gas	£578	£28	£627	£612
Electrification	£569	£26	£604	£604
Balanced	£536	£26	£603	£589

It indicates that the difference in the assumed cost of the scenarios is small. The differences are primarily driven by the cost of the hydrogen component, with Green Gas involving the largest uptake, starting in the 2030s. The future costs of hydrogen are highly uncertain.

Fuel costs are presented as total cumulative costs up to 2045 and are compared to the BAU scenario below. Estimating capital and operating costs changes between BAU scenario would require more detailed site-level information about existing plant than is available.

Table 9: Net zero scenario fuel costs and estimated change from baseline

Scenario	Total fuel cost (£m)	Change from BAU scenario
Green gas	£627	-8%
Electrification	£604	-12%
Balanced	£603	-12%

This indicates that fuel costs are also comparable across the net zero scenarios and all fuels costs fall relative the BAU projection. The savings as a result of energy efficiency improvements offset the higher costs of some fuels.

6.4 Residual emissions

There are residual emissions that cannot be reduced further in all three net-zero scenarios. These will need to be offset. In our modelling, the remaining emissions in 2045 are associated with the following:

- Biomass derived fuels: solid biomass and biogas are low carbon, not zero carbon fuels.
- Grid electricity: current government projections are for the electricity grid to be largely, but not fully decarbonised by 2045.
- Hydrogen has no emissions at the point of use, but significant emissions can result from production and distribution, depending on the method uses.
- Peat, which is burned during the barley drying step by some distillery malting operations.

We have produced a range of estimates of residual emission for each of the net-zero scenarios to provide an indication of the scale of emissions and potential cost to offset.

In our low estimate:

- The electricity supply is fully decarbonised
- Peat emissions are eliminated
- Hydrogen is produced without emissions using electrolysis

These leaves only emissions from biomass derived fuels. The residual emissions in 2045 are presented below.

Table 10: Low estimate of residual emissions

Scenario	Residual emissions per year tCO_2eq	Percentage of 2018 baseline emissions
Green gas	831	0.2%
Electrification	831	0.2%
Balanced	1,976	0.4%

In our high estimate:

- Emissions from biomass derived fuels
- The electricity supply is largely decarbonised according to current government projections, with 41gCO_2eq/kWh in 2045
- Peat emissions are unchanged from the 2018 baseline
- Hydrogen is produced at SMR plants equipped with CCS. This results in some emissions as not all are captured[7]

The residual emissions in 2045 are presented in below.

Table 11: High estimate of residual emissions

Scenario	Residual emissions per year tCO_2eq	Percentage of 2018 baseline emissions
Green gas	42,988	8%
Electrification	27,100	5%
Balanced	29,819	6%

We have estimated the cost of offsetting residual emissions in mid-century at £160/tCO_2 based on a recent assessment by the Grantham Institute[8]. This sets the carbon price at a level equivalent to the projected marginal abatement cost, the price signal considered necessary to deliver net zero in UK industry. The resulting costs to the Scotch whisky sector under the low and high emissions estimates in each net zero scenario are summarised below.

Table 12: Annual cost of offsetting residual emissions in the three net-zero scenarios

Scenario	Low offset cost	High offset cost
Green gas	£4,362,069	£29,607,552
Electrification	£2,760,290	£19,120,934
Balanced	£3,401,882	£22,098,326

6.5 Policy Recommendations

With COP26 in Glasgow, the new Westminster government's and also the Scottish government's strong stance on climate change and the legislative backlog caused by Brexit, this is an important time for the SWA to be actively engaged in shaping net zero policy.

A series of policy recommendations have emerged from our analysis and through discussion with the SWA and members. This includes policy and regulatory changes that are necessary if members are to achieve net zero. The policy options related to a specific technology are categorised by the type of intervention proposed.

6.5.1 A net zero commitment, emissions measurement and reporting

6.5.1.1 A net zero commitment

The SWA should make a public commitment to net zero by 2045. This should include all Scope 1 and 2 emissions, including those that are not currently included in emissions reporting.

[7] Emissions from hydrogen SMR equipped with CCS at 41gCO2eq/kWh from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/798243/H2_Emission_Potential_Report_BEIS_E4tech.pdf
[8] http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2019/05/GRI_POLICY-REPORT_How-to-price-carbon-to-reach-net-zero-emissions-in-the-UK.pdf

The SWA should commitment to a regular review of progress and should have a mechanism which enables ambition to be ratcheted up in future. This could be used to incorporate Scope 3 emissions or bring forward the target date.

6.5.1.2 Net zero definition

Net zero currently doesn't have a formal definition and the standards that will define how GHG emissions are measured, reported and offsets accounted will have an impact on the energy measures that can be used to meet industry targets.

This will also define the sector's options for offsetting its residual emissions. Peatland restoration is a highly credible negative emissions measure that should be possible to count this towards industry targets, which isn't currently the case with Carbon Neutrality under PAS2060.

6.5.1.3 Standardised emissions reporting

The GHG methodology review included a series of recommendations for improving the SWA's emissions reporting. These include:

- Fully adopting GHG Protocol Corporate Standard / ISO14064.
- Clarify scope and boundary
- Use UK Government emissions factors and update them annually
- Report using both Location based & Market based approach
- Define net-zero and the GHG accounting measures that will be used to measure it

The recommendations are described in more detail in the methodology report under separate cover.

6.5.2 Policy & regulation

6.5.2.1 UK and Scottish industrial decarbonisation strategy

The policy framework for decarbonising industry is out of date and is no longer consistent with net zero. The Committee on Climate Change are currently looking at industrial decarbonisation strategy in more detail and are clear that concerted effort needs to start now in order to bring forward viable technology options in the 2030s. With the expectation that multiple energy solutions will need to be used, the SWA should promote a policy and regulatory framework that is technology agnostic.

The SWA should engage with policy makers to ensure that industrial policies and incentives are consistent with net zero, including energy taxes, incentives and innovation funding.

6.5.2.2 Scottish government bioenergy action plan

The Scottish government are preparing a bioenergy strategy and the SWA should continue to engage in its development. AD is a consistent feature of the net zero scenarios developed and further expansion of installed capacity will need to be made consistent with regulations around the treatment of residues.

6.5.3 R&D and demonstration

Some of the key heat technologies identified require further R&D before they can be deployed by members at scale.

High temperature heat pumps for industrial use may be the least mature of the technologies identified. On-going R&D efforts will need to be scaled up in order to prove the technology, reduce costs and increase efficiency. Operation of high temperature heat pumps will need to be demonstrated at distilleries in the UK.

The relative immaturity of hydrogen technology, including strategic uncertainty about its role, production methods and distribution mean that continuing R&D will be crucial. In the build up to the anticipated wider adoption in the 2030s, pilots and demonstrations in related industrial sectors will be required.

Anaerobic digestion is a relatively mature technology which is already in use in the whisky sector. However process and operational efficiency improvements can be expected from further R&D.

6.5.4 Implementation and price signals

The RHI is coming to an end and is due to close 31st March 2021. The Government has not announced how it will encourage low carbon heating after this. In January 2020 the Prime Minister stated that the Government was “looking for successor arrangements to the renewable heat incentive” during PM’s Questions[9]. No further information is available. The RHI’s successor should be established in time to provide continuity of subsidy with mechanisms to support industrial switching to fuels consistent with net zero.

6.5.5 Infrastructure

It is clear that hydrogen has a central role in all our net zero scenarios and in the CCC’s proposals for industry. Hydrogen distribution is a major known barrier to deployment, with the optimal production and delivery configuration highly uncertain. This will require the development of national supply infrastructure and the SWA should work with government to ensure that it is in place in the 2030s.

The whisky sector already makes use of shared AD infrastructure, which takes spent grains from multiple sites. This allows the AD plant to run at higher efficiencies and increases the options for using the fuel, including upgrading to biomethane and injection to the grid. The SWA can support efforts for more shared AD capacity to be developed and could encourage partnerships beyond the whisky sector, potentially engaging with government on national biogas infrastructure.

[9] https://hansard.parliament.uk/commons/2020-01-22/debates/6B6FAD67-CA8C-4AF2-9CC9-07F6175ABC4C/Engagements

Appendix: energy efficiency measures long list

Measure	Energy source
General site energy management/efficiency - staff behaviour etc.	Electricity
Energy management & maintenance	Heat
Digital Combustion Control	Heat
Voltage optimisation	Heat
Lighting	Electricity
HVAC systems improvement	Heat
Insulation to avoid heat loss	Heat
Economisation on fossil-fuel plant	Heat
Thermal fluid heating	Heat
Variable Speed Drives	Electricity
Compressed air improvements	Electricity
Process optimisation	Heat
Heat recovery - waste heat from process and cooling	Heat
Thermal Vapour Recompression (TVR) - on wash stills only	Heat
Mechanical Vapour Recompression (MVR) - on wash stills only	Heat
Steam production, distribution and end-use	Heat
Drying improvement technologies	Heat
Dewatering before drying	Heat

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