RICARDO-AEA

Barr Killoch Energy Recovery Park

Human Health Risk Assessment

Report for Wardell Armstrong

Customer:

Wardell Armstrong LLP

Customer reference:

Wardell Armstrong LLP

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21 May 2015

Ricardo-AEA reference:

Ref: ED60039- Issue Number 3

Executive summary

Introduction

A detailed human health risk assessment to identify potential health risks associated with exposure to emissions from the proposed Barr Killoch Energy Recovery Park has been completed in line with best practice methodologies.

This report sets out the analysis of the health risks associated with the treatment by gasification of up to 85,000 tonnes per annum of residual waste at the proposed facility.

Methodology

The study was carried out in accordance with independent guidance for health risk prioritisation and assessment, developed for use in Scotland. Following the approach in this guidance, attention was focused mainly on assessing the health effects of dioxin and furan concentrations.

A simplified conceptual model was built for the site identifying all relevant sources, receptors and pathways of exposure relevant to each of the receptors. In the absence of specific information in relation to the nature of the local receptors, all default pathways of exposure were assumed to exist for each receptor, to ensure that all potentially significant exposure pathways were assessed.

Dioxin and furan concentrations in the different receiving media were calculated from the particle phase and vapour phase air concentrations and deposition to the soil, using the "Industrial Risk Assessment Program-Human Health" system. The estimated concentrations were based on a number of conservative assumptions to ensure that the study provided a worst-case assessment.

The level of exposure to dioxins and furans emitted from the proposed facility was quantified at selected sensitive receptors within the vicinity of the site. In residential locations, the key exposure pathways include the ingestion of soils and home-grown produce. On agricultural premises and at allotments, potential exposure through the ingestion of home-grown produce, and ingestion of beef, milk, pork, poultry and eggs was included. Both residential and agricultural receptor points were considered to be fisher locations, where key exposure pathways include the ingestion of soils and home grown produce and the ingestion of fish caught in local waterbodies. In view of the importance of dairy farming in the local area, dioxin and furan concentrations in cows' milk were also modelled in order to assess forecast levels against the standard set in Commission Regulation (EU) No.1259/2011.

Throughout this assessment, where there is uncertainty in respect of the data, a precautionary approach (conservative) has been used to estimate the possible risks from exposure to emissions from the proposed facility. The approach ensures that allowance is made for uncertainties in the interpretation of the data provided in order to be protective of human health.

Assessment Criteria

Estimated intake of dioxins and furans, and associated health risks were assessed against relevant standards and guidelines, and against background exposure levels.

For the assessment of lifetime cancer risk, a health benchmark value of 1 in 100,000 lifetime risk was used. This is more demanding than a widely used UK benchmark, which is equivalent to 1 in 14,300 lifetime risk.

For the assessment of health impacts due to individual contaminants, the total health quotient was assessed against a criterion of 1.

For the assessment of exposure to dioxins and furans, the risk posed by the proposed facility was evaluated by comparing estimated worst-case forecast intake against the UK Tolerable Daily Intake (TDI) value of 2 picograms per kilogram body weight per day. Infant intake in breast milk was assessed against UK data on background infant intakes of dioxins and furans in breast milk.

Background exposure to dioxins and furans is dependent on a wide range of complex individual factors, and will vary from one individual to another. For context, the levels of dioxins and furans in soil due to the proposed facility were evaluated against the average rural and urban soil concentration of dioxins and furans as reported in the UK Soil and Herbage Pollutant Survey.

Baseline Conditions

The health of people in East Ayrshire is relatively poor when compared with other regions of the United Kingdom. Life expectancy for both men and women and all-cause mortality at all ages are significantly worse than the average across Scotland[1]. Rates of chronic obstructive pulmonary disease (COPD), emergency hospitalisations and the proportion of patients hospitalised with asthma are significantly higher than the Scotland average. However mortality rates from cancer, coronary heart disease and cerebrovascular disease are at similar levels to the Scotland average.

The 2010 East Ayrshire Health and Wellbeing Profile indicates the health priorities for East Ayrshire include managing the use of alcohol and drugs, chronic diseases including asthma and diabetes and the hospitalisation of older patients.

Assessment of Effects

No significant risks to public health would be posed during the construction phase of the development.

The risks to health were found to comply with the relevant benchmarks at all potentially sensitive locations.

The greatest intake was predicted to result if an individual could theoretically consume only beef, pork, poultry, eggs, milk and vegetables produced at a farm close to the site. The highest theoretically possible intake of dioxins and furans was predicted to be 0.035 picograms per kilogram body weight per day (pg/kg-day). Despite the worst-case approach adopted in the assessment, this incremental intake associated with the proposed facility is a small fraction (1.76 %) of the recommended tolerable daily intake for dioxins of 2 pg/kg-day, and would not be detectable in practice. Similarly, the potential exposure of infants via breast milk and the contribution of the proposed facility to dioxins and furans in cows' milk were assessed, and it was found that the proposed facility would have no significant or detectable influence on exposure in this way.

Mitigation

The proposed facility includes extensive measures to control emissions to air, ensuring compliance with the demanding standards set out in the Industrial Emissions Directive. The health risk assessment found no requirement for further mitigation, over and above that described in the Environmental Statement.

Conclusions

It was concluded that emissions to air from the proposed Energy Recovery Park will not pose unacceptable health risks to the residential or allotment locations identified in the vicinity of the proposed facility.

[1] Scottish Public Health Observatory (ScotPHO) – East Ayrshire Health and Wellbeing Profile 2010 via http://www.scotpho.org.uk

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Appendices

1 Introduction

A detailed human health risk assessment to identify potential health risks associated with exposure to emissions from the proposed Barr Killoch Energy Recovery Park has been completed in line with best practice methodologies.

The study has been carried out in accordance with guidance published by the Scotland and Northern Ireland Forum for Environmental Research. This guidance document sets out six stages for a risk assessment study:

- Step 1: Define the legislative context
- Step 2: Hazard identification
- Step 3: Hazard assessment
- Step 4: Risk estimation
- Step 5: Risk evaluation
- Step 6: Risk management

Following a brief review of information relating to health status of the local population, the six stages set out in the SNIFFER guidance were followed in the present project.

2 Planning policy context

The National Planning Policy Framework for Scotland 2[2] highlights the duty of planning authorities to contribute to sustainable development, and emphasises that this includes the implementation of policies on public health. It states that, "*Sustainable economic and social development depend on healthy terrestrial and marine environments.*" It goes on to state that "*the main elements of the spatial strategy to 2030 are to … promote development which helps to improve health, regenerate communities and enable disadvantaged communities to access opportunities.*" Scotland's Third National Planning Framework (2014) Main Issues Report para 1.3 confirms the importance of the challenge of "*ensuring that new development leads to a healthier environment*".[3] The Framework highlights that the Spatial Strategy should promote "*the creation of high quality, distinctive, sustainable and healthy places.*" (Section 1.14) It goes on to emphasise the role of planning in promoting health, for example through environmental protection (Section 4.33).

The Scottish Government confirms that, in planning terms, the National Planning Framework (NPF) identifies the spatial planning dimension of waste management. To ensure waste management requirements are met, all development plans must identify appropriate locations for required waste management facilities, where possible allocating specific sites, and provide a policy framework which enables the development of these facilities.

Further guidance is provided in Planning Advice Note PAN 63, "Waste Management Planning." This highlights SEPA's role in the planning system, with the objective of ensuring that waste is disposed of or treated without endangering human health or causing harm to the environment. PAN 63 also addresses public attitudes to perceived health effects:

> *"84. A vital objective for any proposed development will be to ensure that it does not pose an unacceptable risk to public health and safety. In the case of waste management facilities, health concerns might relate to possible hazardous materials and to emissions. Safety concerns might include the effects of the proposed development through increased road traffic.*
>
> *"85. In terms of site emissions the principal public concerns normally relate to landfill sites and incinerators, both of which are subject to licensing by SEPA under the Pollution Prevention and Control (PPC) (Scotland) Regulations 2000. SEPA's consideration of whether to grant such a licence will include the possible effects of the proposed development on both public health and the environment. Under those regulations, SEPA's responsibility for consideration of public health concerns is supported by "statutory consultees" including the local authorities, the Health and Safety Executive and the local NHS Board. Planning authorities should therefore accept that PPC licensing, where applicable, is adequate and suitable for public health protection. However, it is important to recognise that PPC licensing does not address public safety and that this aspect of the proposed development is an issue for consideration by the planning authority.*
>
> *"86. By influencing the location of proposed developments, planning authorities have a role in addressing public concerns. Sensitive siting and design can help to allay public concerns about health. Operators should be asked to provide, with their applications, evidence that consideration has been given to siting and design options.*"

This document is designed to provide sufficient information to enable East Ayrshire Council to take account of any concerns with regard to public health and the potential impacts of the proposed facility when fulfilling its responsibility of determining whether the location of the proposed development is acceptable.

Local planning documents, including the Ayrshire Joint Structure Plan[4] and the East Ayrshire Local Plan[5] confirm the importance of ensuring protection of human health in relation to developments such as the proposed Barr Killoch Energy Recovery Park. These are considered in more detail in Section 2

[2] Scottish Government, "*National Planning Framework for Scotland 2,*" 2009

[3] Scottish Government, "*Ambition, Opportunity, Place, Scotland's Third National Planning Framework*," Main Issues Report and Draft Framework, 2014

[4] Ayrshire Joint Structure Plan via http://www.ayrshire-jsu.gov.uk/

[5] East Ayrshire Local Plan 2010 via http://www.east-ayrshire.gov.uk/

of the Air Quality Impact Assessment (AQIA). East Ayrshire Council's Waste Strategy[6] also sets the following overarching principles to be followed in order to achieve the Zero Waste Plan for Scotland:

- *"Minimising the generation of waste from the domestic and commercial waste streams*
- *Maximising the recycling and reuse of any waste generated*
- *Maximising the opportunity to engage with partner organisations to achieve recycling and composting targets as demanded by Scottish, National and European legislation*
- *Maximising the diversion of waste from landfill"*

The key test set out in planning policies is that unacceptable impacts on human health must be avoided. The relevant requirements of national and local planning policy were taken into account in the assessment of the proposed Energy Recovery Park.

[6] East Ayrshire Council Waste Strategy via http://www.east-ayrshire.gov.uk

3 Existing conditions

The health of people in East Ayrshire is relatively poor when compared with other regions of the United Kingdom. Life expectancy for both men and women and all-cause mortality at all ages are significantly worse than the average across Scotland[1]. Rates of chronic obstructive pulmonary disease (COPD), emergency hospitalisations and the proportion of patients hospitalised with asthma are significantly higher than the Scotland average. However mortality rates from cancer, coronary heart disease and cerebrovascular disease are at similar levels to the Scotland average.

The 2010 East Ayrshire Health and Wellbeing Profile indicates the health priorities for East Ayrshire include the use of alcohol and drugs, chronic diseases including asthma and diabetes and the hospitalisation of older patients.

The proposed facility is located in an agricultural area, in which dairy farming dominates. Salmon and trout fishing takes place in the nearby rivers. It is therefore important to ensure that potential exposure to emissions from the proposed facility via these pathways is fully taken into account in the study.

4 Methodology

4.1 Background

In its review of environmental and health effects of waste management, the Department for Environment, Food and Rural Affairs (Defra) reported that a direct measurement of exposure attributable to facilities such as the proposed Barr Killoch Energy Recovery Park cannot be made due to the complexity of the pollutant mixture, the possibility of exposure through multiple pathways, wider environmental and lifestyle influences and the generally non-specific health outcomes.[7]

In order to address the difficulties of directly measuring effects and to provide a predictive analysis, this assessment is based on modelling the various exposure routes, applying outputs from the air quality assessment which takes account of the influence of meteorological conditions and characteristics such as the proposed stack height, discharge velocity and temperature. Such modelling is a means of establishing a worst-case exposure attributable to the sources and forms the basis of this health risk assessment.

Exposure to emissions from waste thermal treatment facilities can be through a number of pathways, with exposure via inhalation and the food chain being the most critical. For certain persistent pollutants, such as dioxins and furans, the cumulative indirect exposure via the ingestion of contaminated food is of paramount importance. Therefore potential exposure through this important pathway has been taken into account, in addition to exposure via inhalation.

4.2 Risk assessment

Guidance on environmental risk assessment and management was published by Defra in updated form in 2011.[8] The Defra guidelines were used as the basis for the assessment and appraisal of potential impact on human health from the proposed facility. These guidelines set out the basic principles which the regulatory authorities would normally intend to use in the assessment and management of environmental risks and which are recommended for all such risk assessments. They are intended to provide decision-makers, practitioners and the public with a consistent language and approach for environmental risk assessment and management.

The framework provides for a tiered approach to environmental risk assessment and management where the level of effort put into assessing each risk is proportionate to its priority (in relation to other risks) and its complexity (in relation to an understanding of the likely impacts). A staged approach has been applied in this assessment.

The updated guidance sets out the following framework for environmental risk assessment:

- Stage I: Identify the hazard(s)
- Stage II: Assess the consequences
- Stage III: Assess their probabilities
- Stage IV: Characterise risk and uncertainty

These four steps correspond to Steps 2 to 5 of the risk assessment methodology set out by SNIFFER.[9]

- Step 1: Define the legislative context
- Step 2: Hazard identification
- Step 3: Hazard assessment
- Step 4: Risk estimation

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[7] Defra, "*Review of Environmental and Health Effects of Waste Management*," (2004) via http://archive.defra.gov.uk/environment/waste/statistics/documents/health-report.pdf

[8] Defra, "Guidelines for Environmental Risk Assessment and Management: Green Leaves III," report ref. PB13670 prepared by Cranfield University, 2011

[9] Scotland and Northern Ireland Forum for Environmental Research, "*Environmental legislation and human health: guidance for assessing risk*," Report Ref. UKCC02, 2007

- Step 5: Risk evaluation
- Step 6: Risk management

This study was carried out in accordance with the six steps set out in the SNIFFER guidance.

4.3 Step 1: Define the legislative context

The legislative context was defined in terms of the planning and permitting regimes, and associated guidance published by the Scottish Environmental Protection Agency for use in the permitting process.

As required by the SNIFFER guidance, the constraints of these regimes were defined, and the relevant standards and guidelines to be used for the assessment of environmental risks were identified.

4.4 Step 2: Hazard identification

The potential hazards which require consideration as part of this risk assessment were identified. This assessment focused on the risks posed by emissions to air from the proposed facility. The assessment of hazards comprised an identification of the substances of potential concern; consideration of how they could be released and transferred into the environment; and identification of those who could potentially be affected by these hazards.

As part of the identification of hazards, a conceptual model of risks was developed and refined (see SNIFFER guidance[9] Figure 2b). The source-pathway-receptor concept was adopted in order to construct a Site Conceptual Model (SCM) and to assess potential risks to health. The source-pathway-receptor 'pollutant linkage' scenario provides a useful basis for developing a site conceptual model, which can be used to identify critical pathways on which a quantitative analysis may be undertaken. The SCM provides a qualitative description of:

- The principal sources of contamination on the site: namely the emissions to air from the proposed waste facility;
- The contaminants of potential concern;
- The behaviour of contaminants within contaminated media, considering potential exposure via airborne pathways, deposition on soils, and uptake in vegetables, fish, dairy and meat products;
- Relevant receptors in the local area;
- Plausible pathways connecting sources of contamination and sensitive receptors, including consumption of home-grown produce, accidental ingestion of soil, and other routes of exposure through the food chain.

4.5 Step 3: Hazard assessment

In Step 3, the hazards and potential source-pathway-receptor linkages identified at Step 2 were evaluated in more detail. This evaluation had regard to the findings of the accompanying air quality assessment.

The outcome of the hazard assessment was a list of potential hazards for which the estimation and evaluation of risk was required in more detail. As discussed for the purposes of this assessment attention has been focused on emissions to air of dioxins and furans from the stack.

4.6 Step 4: Risk estimation

4.6.1 Risk estimation method

The objective of this stage was to quantify the potential exposure of local people to the contaminants of potential concern. The forecast exposure levels were then assessed against standards and guidelines specified in order to provide protection for public health.

Public exposure can take place by a variety of possible exposure pathways including direct exposure by inhalation of dioxins/furans as gases and as fine particulates, and indirect exposure following the deposition of trace contaminants to land and subsequent transfer by biogeochemical processes through soils and vegetation into the food chain. The assessment has evaluated potential impact on human health from the proposed facility's emissions, both in terms of the inhalation pathway, and the overall long-term exposure through additional viable routes such as the food chain.

The risk estimation stage included identification of:

- the type and spatial distribution of relevant hazardous substances;
- the media containing such hazardous materials;
- the concentration of the hazardous substance in the identified media;
- exposure scenarios, whether residential, agricultural, fisher etc.;
- exposure routes – inhalation; ingestion of soil; ingestion of beef; potential exposure of breast feeding infants through the exposure of their mothers, etc.; and
- exposure factors for each scenario and route.

The geographic scope of the study is based on assessment of a range of receptors representative of the highest potential exposure, located up to 3 km from the proposed facility, including "residential" and "farmer" receptor sites. For the purposes of this assessment all receptor sites were also modelled as "fisher" locations. The risk estimation was designed to estimate exposure through direct inhalation of affected air, and indirect exposure through ingestion of affected food, locally grown on soil impacted by the emissions through deposition and accumulation, or sourced from water bodies within the local catchment area. Based on the preceding stages of the assessment, the only relevant sources of emissions considered in this assessment are the stack emissions. At this stage, attention was focused primarily on substances which have the potential to accumulate in the environment over the operational life of the facility.

In the absence of UK protocols for estimating the level of human exposure to Compounds of Potential Concern (COPC) through all relevant pathways of exposure, the United States Environmental Protection Agency (USEPA) "*Human Health Risk Assessment Protocol HHRAP 2005*" was used to estimate all exposures utilising the predicted air concentration and depositions rates provided by the air dispersion modelling. The Industrial Risk Assessment Program-Human Health (IRAP-h View – version 4.0.3) was used for this assessment.[10] This system was used to calculate the transport and fate of dioxins and furans emitted in the stack exhaust gases. The model drew on the results of the air quality assessment carried out using the Atmospheric Dispersion Modelling System (ADMS). The results of this modelling study were copied into the IRAP-h View system.

The default exposure parameters and toxicological data were replaced by those recommended by Defra and the Environment Agency's reports CLR10 and R&D Publication TOX reports.[11,12] These modified parameters include averaging times for carcinogens and non-carcinogens, body weight, consumption and inhalation rates, exposure frequencies and durations.

UK data for consumption of home grown vegetables and, in the absence of UK data, US data for consumption of other foodstuffs were included in the exposure modelling. In this respect, UK consumption patterns will not be greatly dissimilar to US patterns, and uptake mechanisms are identical. Using US data where UK data are not available is normal practice for studies of this nature.

The IRAP-h View model used for the assessment is equipped with a database of physical and chemical parameters used to calculate the media concentrations for dioxins and furans. These are chemical specific values based on current international knowledge of chemicals.

In addition to the default values, which were used for this assessment, IRAP-h requires specific parameters to be identified. These include the following:

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[10] U.S. EPA-OSW. 2005. Human Health Risk Assessment Protocol (HHRAP) (EPA530-R-5 006).

[11] Defra & Environment Agency "The Contaminated Land Exposure Assessment Model (CLEA): Technical basis and algorithms" (2002)

[12] Defra & Environment Agency 2009 , Contaminants in soil: updated collation of toxicological data and intake values for humans Dioxins, furans and dioxin-like PCBs (Science report: SC050021/TOX 12)

Site parameters

- Annual average evapotranspiration – i.e. the amount of water which is removed from the (crop + soil) combination into the air, taken to be 51 cm/year[13].
- Annual average precipitation, 113.9 cm/yr[14].
- Annual average runoff - i.e. annual average precipitation less evapotranspiration is known as the hydrologically effective rainfall, including that recharged to groundwater and flow to rivers (runoff). This is calculated to be 62.9 cm/year.

Watershed / Waterbody parameters

- The watershed area on which emissions could potentially be deposited, approximately 595,000 km^2.
- Impervious watershed area receiving pollutant deposition, estimated to be 4% of the total watershed area[14].
- Depth of water column taken as an average of the values recorded at the two monitoring stations on the River Ayr (Catrine and Mainholm), 0.52 m[15].
- Current velocity taken as an average of the values recorded at the two monitoring stations on the River Ayr, 0.65 m[15].
- Average volumetric flow rate through the water body, calculated by multiplying the estimated width of the River Ayr at the two monitoring stations (22 m at Catrine and 40 m at Mainholm) by the estimated depth and velocity; 333,000,000 m^3/year.
- The USEPA recommend an erosivity value between 50 – 300 yr^{-1}, with 50 representing arid areas and 300 for wet areas. As a higher value generates the worst concentration of COPC in surface water, an erosivity factor of 300 was used for this assessment.
- The USEPA recommend a cover management factor of between 0.1 and 1, representing grass/agricultural crops and bare soil respectively. A value of 0.1 has been used in this assessment.

The IRAP-h View model calculates the average annual volume of water available for generating leachate as the mass balance of all water inputs (includes precipitation and irrigation) and outputs (runoff and evaporation) from the area under consideration. In the absence of information on the proportion of the runoff and the recharge to groundwater to the total hydrologically effective rainfall, the total was divided equally between runoff and recharge (31.5 cm/year).

4.6.2 Concentration in soil

COPC concentrations in soil are calculated from the wet and dry deposition of particulates and vapour to the soil. Soil conditions such as pH, structure, organic matter content and moisture content will affect the distribution and mobility of contaminants. Losses from the soil by mechanisms such as leaching, erosion, runoff, degradation and volatilisation may reduce the concentrations of COPC in soil over time. These are utilised in the model, where appropriate, by using rates that depend on the physical and chemical characteristics of the soil.

4.6.3 Concentration in produce

Indirect exposure resulting from ingestion of produce depends on the total concentration of COPC in the leaves, fruit, and tuber portions of the plant.

Due to general differences in contamination mechanisms, it is generally recommended to separate produce into two broad categories for the purposes of risk assessment: above-ground produce and below-ground produce. In addition, aboveground produce can be further subdivided into exposed and protected above-ground produce.

Above-ground exposed produce is typically assumed to be contaminated by the following main mechanisms:

[13] Tim Hess "*Evapotransporation estimates for water balance scheduling in the UK*" Irrigation News, 25: 31-36 (1996)

[14] SEPA – General catchment characteristics: River Ayr via http://www.sepa.org.uk

[15] SEPA Water Level Data via http://apps.sepa.org.uk/waterlevels/default.aspx

- Direct deposition of particles — wet and dry deposition of particle phase COPC on the leaves and fruits of plants;
- Vapour transfer uptake of vapour phase COPC by plants through their foliage; and
- Root uptake of COPC available from the soil and their transfer to the above ground portions of the plant.

The USEPA methodology estimates of the total COPC concentration in aboveground exposed produce as the sum of contamination occurring through all of these mechanisms. However, edible portions of above-ground protected produce, such as peas and corn, are enclosed within an outer covering. They are therefore protected from contamination from deposition and vapour transfer. Root uptake of COPC is the primary mechanism through which above-ground protected produce becomes contaminated.

4.6.4 Concentration in beef and milk

The USEPA methodology recommends that COPC concentrations are estimated in beef tissue and milk products on the basis of the amount of COPC that cattle consume through their diet. The human health risk assessment (HHRA) assumes that the cattle's diet consists of:

- Forage (primarily pasture grass and hay);
- Silage (forage that has been stored and fermented); and
- Grain.

Additional contamination may occur through the direct ingestion of soil by cattle. The HHRA calculates the total COPC concentration in the feed items (e.g., forage, silage, and grain) as a sum of contamination occurring through the following mechanisms:

- Direct deposition of particles – wet and dry deposition of particle phase COPC onto forage and silage;
- Vapour transfer – uptake of vapour phase COPC by plants through their foliage; and
- Root uptake – root uptake of COPC available from the soil and their transfer to the above-ground portions of forage, silage, and grain.

It is also assumed, as recommended by the USEPA, that 100% of the plant materials eaten by cattle are grown on soil contaminated by the emission source. This is likely to be a pessimistic assumption for UK farming practice. COPC concentrations in forage and silage result from deposition onto exposed plant surfaces; the same is assumed for above-ground produce.

COPC concentration in beef tissue is calculated from the daily amount of a COPC that is consumed by cattle through the ingestion of contaminated feed items (plant) and soil by including biotransfer and metabolism factors. These transform the daily animal intake of a COPC (mg/day) into an animal COPC tissue concentration (mg COPC/kg tissue).

The metabolism factor (*MF*) estimates the amount of COPC that remains in fat and muscle. In the absence of data to support the derivation of chemical-specific *MF*s, it is recommended by the USEPA HHRAP that a conservative *MF* of 1.0 for all chemicals be used – that is, each of the substances assessed are assumed to be fully retained in fat and muscle. A *MF* of 1.0 was used for this assessment.

COPC concentration in milk is calculated from the daily amount of a COPC that is consumed by dairy cattle through the ingestion of contaminated feed items (plant) and soil by including biotransfer and metabolism factors to transform the daily animal intake of a COPC (mg/day) into an animal COPC milk concentration (mg COPC/kg milk).

4.6.5 Concentration in pork

COPC concentrations in pork tissue are estimated on the basis of the amount of COPC that pigs consume through a diet consisting of silage and grain. Additional COPC contamination of pork tissue may occur through their ingestion of soil.

4.6.6 Concentration in poultry and eggs

Estimates of the COPC concentrations in chicken and eggs are based on the amount of COPC that chickens consume through ingestion of grain and soil. The HHRA assumes that chickens are husbanded in a manner that allows contact with soil, i.e. free range. Consequently, chickens are assumed to consume 10% of their diet as soil, consistent with the study by Stephens et al, 1995. Although highly unlikely in practice, for the screening assessment it is assumed, as recommended, that the remainder of the diet (90%) consists of grain grown at the exposure scenario location. Therefore, it was appropriate to assume that 100% of the grain consumed is contaminated.

4.6.7 Concentration in fish

The USEPA's methodology suggests considering the following characteristics in determining COPC loading of the water column and subsequent uptake by fish stocks:

- Direct deposition;
- Runoff from impervious surfaces within the watershed;
- Runoff from pervious surfaces within the watershed;
- Soil erosion over the total watershed;
- Direct diffusion of vapor phase COPCs into the surface water; and
- Internal transformation of compounds chemically or biologically.

Contributions made by additional mechanisms, such as the influence of tidal movements, can be taken into consideration however the USEPA guidance suggests these are likely to be negligible. Tidal movements are not relevant to the study area.

The IRAP-h View software allows COPC concentrations in fish to be calculated using either bioconcentration factors (BCF), bioaccumulation factors (BAF) or biota-sediment accumulation factors (BSAF). BAF are typically applied where COPCs are known to have a high tendency to bioaccumulate. However dioxins, furans and PCBs are known to be hydrophobic in nature, resulting in a tendency to be sorbed to the bed sediments more than associated with the water phase, therefore, as per USEPA guidance, BSAF have been used to calculate potential concentrations in fish for this assessment.

4.6.8 Other parameters

Soil bio-availability (*Bs)* is the ratio between bio-concentrations for soil and vegetation. The efficiency of transfer from soil may differ from the efficiency of transfer from plant material for some COPC. If the transfer efficiency is lower for soils, then the ratio would be less than 1.0. If it is equal to or greater than that of vegetation, the *Bs* value would be equal to or greater than 1.0. A value of 1.0 is recommended by USEPA and was used for calculating all the above-presented concentrations.

Data used for calculating the concentration of COPC in each media and the human ingestion rates for different food are presented in air quality assessment.

4.6.9 Assessment locations

The level of exposure to substances emitted from the proposed facility was quantified at selected sensitive locations in the vicinity of the site (see Section 6.3). In residential locations, the key exposure pathways include the ingestion of soils and home-grown produce. In farms the key exposure pathways include the ingestion of home-grown produce, and ingestion of beef, milk, pork, poultry and eggs, produced at farms within the vicinity of the site. In fisher locations, the key exposure pathways include the ingestion of soils, home-grown produce and fish sourced from waterbodies within the vicinity of the site.

4.6.10 Assessment criteria

Toxic effects associated with chemical exposure are divided into two categories: threshold toxicity and non-threshold toxicity. Threshold toxic effects apply to chemicals for which there is a level of exposure below which no adverse effects will be observed. That is, there is a quantity of exposure below which no adverse effect is observed.

For non-threshold toxicity, some substances act in a way which indicates that no threshold for effects would be expected to occur– for example, in the case of many genotoxic carcinogens and mutagens. Assessment of these substances is carried out on the basis that any exposure to these substances, no matter how small, will carry some level of risk.

Non-threshold risks to human health were assessed using specified Index Dose values. In the UK the Health Protection Agency and the Department of Health are advised on the health effects by the independent expert advisory committee, the Committee on the Toxicity of Chemicals in Food, Consumer Products and the Environment (COT). The COT has recommended a tolerable daily intake

(TDI) for dioxins and furans[16], which is the amount which can be ingested daily over a lifetime without appreciable health risk. This TDI is based on a detailed consideration of the extensive toxicity data on the most well studied dioxin, TCDD, but may be used to assess the toxicity of mixtures of dioxins and dioxin-like PCBs by use of Toxic Equivalency Factors, which allow concentrations of the less toxic compounds to be expressed as an overall equivalent concentration of TCDD. These toxicity-weighted concentrations are then summed to give a single concentration expressed as a Toxic Equivalent (TEQ). Thus, the COT has recommended a tolerable daily intake for dioxins of 2 picograms TEQ/kg body weight/day based on the most sensitive effect of TCDD in laboratory animals, namely, adverse effects on the developing foetus resulting from exposure *in utero*.

If required, index doses are available for other relevant substances – primarily, trace metals. Tolerable daily intake values are also available for threshold substances.

Risk characterisation involves combining the exposure quantities and the toxicity benchmarks to evaluate the cancer risks and non-cancer hazards for each of the relevant hazards, pathways and receptors. A value of 1×10^{-5} for lifetime cancer risk and a hazard quotient of 1 is used in the HHRAP model as a benchmark for the assessment of individual contaminants. In the UK, a benchmark of 1 in 1 million (1×10^{-6}) annual risk is frequently adopted, following advice from the Royal Commission on Environmental Pollution, Health and Safety Executive and World Health Organisation.[17] Assuming a 70 year lifetime, this is equivalent to a lifetime risk of 1 in 14,300 (7×10^{-5}). In order to provide an additional margin of safety, the HHRAP benchmark for lifetime cancer risk of 1 in 100,000 (1×10^{-5}) was used in this study.

Cancer risk estimates represent the incremental probability that an individual will develop cancer over a lifetime as a result of a specific exposure to a carcinogenic chemical. The UK approach to risk assessment from land contamination for non-carcinogen compounds is based on the health criteria with considerations given to potential background exposure through other sources such as food and water. Where background exposure is equal or greater than 80% of the health criterion or is unknown, 20% of the health criterion is used as the acceptable level from exposure to land contamination with the remaining 80% left to other sources to allow for exposure through the ingestion of food, water and other sources. In a 2006 consultation paper Defra proposed to change the above mentioned value of 20% to 50%.[18] The recommendations set out in this report were followed by updated guidance on the legal definition of contaminated land, which supported the raising of the benchmark to 50%.[19] A threshold of between 20% and 50% was used in the present study.

Background exposure to dioxins and furans is dependent on a wide range of complex individual factors, and will vary from one individual to another. Key issues include individual lifestyle, diet and baseline land quality, especially the background level of dioxins and furans within the locality of the proposed facility. For baseline land quality, an individual exposure cannot feasibly be quantified due to the heterogeneous nature of the soil as a natural medium caused by the anthropogenic influence from the varying use of land over time, and geological/hydrogeological factors. Consequently, the study focused on an assessment of the potential impact of the proposed facility, rather than on the combined effect of the proposed facility and other potential sources of exposure. For context, the levels of dioxins and furans in soil due to the proposed facility were evaluated against the average rural and urban soil concentration of dioxins and furans as reported in the UK Soil and Herbage Pollutant Survey.[20]

4.6.11 Uncertainty

Throughout this assessment, where there was uncertainty in respect of the data, a precautionary approach (conservative) was used to estimate the possible risks from exposure to emissions from the proposed facility. The approach ensured that allowance is made for uncertainties in the available data in order to be protective of human health.

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[16] Committee on Toxicity of chemicals in food, consumer products and the environment, "*Statement on the Tolerable Daily Intake for Dioxins and dioxinlike polychlorinated biphenyls,*" http://cot.food.gov.uk/pdfs/cot-diox-full.pdf

[17] PR Hunter and L Fewtrell, "Acceptable Risk," in World Health Organization (WHO). "Water Quality: Guidelines, Standards and Health," 2001

[18] CLAN 6/06 *Assessing Risks From Land Contamination – A proportionate approach, Soil Guideline Values: The Way Forward, 2006*

[19] Environment Agency – Using Soil Guideline Values via https://www.gov.uk

[20] Environment Agency, "*UK Soil and Herbage pollutant Survey, Report 10: Environmental concentrations of polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans in UK soil and herbage,*" Product code: SCHO0607BMTD-E-P, 2007

In accordance with the tiered approach to environmental risk assessment, this study considered worst-case scenarios for all receptors in assuming multiple exposure conditions where all pathways of exposure in each land use scenario were considered to be potentially viable. The assessment relies on assumptions that are both extremely conservative and also very unlikely, resulting in a substantial margin of safety in the results obtained. These worst case assumptions have been used in the first instance as part of a screening study, to identify receptors that can be excluded from further assessment. In the event of a receptor failing the screening assessment, a further assessment could be carried out with the exposure assumptions refined to reflect the specific circumstances of the relevant locations (referred to as a detailed quantitative risk assessment[7]).

4.7 Step 5: Risk evaluation

The information developed during the preceding stages of assessment was drawn together and a judgment made with regard to the significance of any risks identified. Any necessary remedial action was identified and implemented, and the assessment revised as appropriate. This assessment had regard to the standards required under the relevant legislative regimes, and took account of uncertainty in the assessment and how this had been addressed throughout the risk assessment process. This evaluation and the supporting information is provided to assist the decision-making authorities in reaching their planning and permitting decisions.

4.8 Step 6: Risk management

At this stage of the assessment, strategies to control and manage potential risks through appropriate mitigation measures are identified if needed. This may be achieved through the management of the source or the exposure pathways to prevent the exposure of the receptors, where needed.

4.9 Construction phase

There will be no process emissions such as those described in Sections 4.1 to 4.8 above during the construction phase of the proposed Energy Recovery Facility. Risks to health could potentially arise due to emissions from road traffic accessing the development, or from dust generated during construction. These potential risks to health are addressed in the air quality assessment submitted as part of the planning application for the proposed development.

In the light of these assessments, the potential health risks associated with the construction phase of the development were considered to be minimal and were not assessed in more detail in this study.

4.10 Cumulative impacts

Carrying out a risk assessment study which takes account of all factors which could affect people's health is not practicable and would be subject to substantial uncertainties. Consequently, the approach adopted in studies of this nature is to evaluate the potential impact on health associated with the proposed facility. Provided this impact is not significant, there is no need to consider wider health issues.

Because the approach is to demonstrate an insignificant health risk due to emissions from the proposed facility, there is no requirement to consider cumulative health risks associated with other existing or proposed sources. Cumulative impacts were therefore not specifically addressed in this report. The air quality assessment found that there were no significant cumulative impacts on air quality, which further indicates that there is minimal likelihood of any potentially significant cumulative health risks.

5 Step 1: Legislative regime

This health risk assessment is provided in support of the application for land-use planning for the proposed facility. It is also provided in support of the application for an operating permit for the proposed facility.

5.1 Land-use planning

The National Planning Policy Framework for Scotland 2[2] highlights the duty of planning authorities to contribute to sustainable development, and emphasises that this includes the implementation of policies on public health. It states that, "*Sustainable economic and social development depend on healthy terrestrial and marine environments.*" It goes on to state that "*the main elements of the spatial strategy to 2030 are to … promote development which helps to improve health, regenerate communities and enable disadvantaged communities to access opportunities.*"

As set out in Section 2, national and local planning policy highlights the importance of ensuring that unacceptable impacts on human health are avoided. The issues addressed in this study necessarily comprise a forecast increase in pollution, although there would be corresponding reductions in pollution elsewhere due to improved treatment of waste which are not assessed as part of this study. National and local planning policy and guidance is therefore interpreted in this context to mean that emissions to air from the proposed facility should have no significant adverse effects on health, thereby enabling the other direct and indirect benefits (including health benefits) of the proposed facility to be fully realised.

5.2 Environmental permitting

SEPA describes process industry regulation in Scotland as follows:[21]

> *SEPA's role is to reduce emissions of pollutants and to prevent and minimise harm to the environment and human health. We protect communities by regulating activities that can cause harmful pollution. Through regulation SEPA aims to help business and industry to understand their environmental responsibilities, enable our customers to comply with legislation and good practice and to realise the many economic benefits of good environmental practice.*
>
> *SEPA currently regulates over 500 major industrial sites that have the potential to cause air pollution. Process industry regulation in Scotland is enacted through the Pollution Prevention and Control (Scotland) Regulations. The Pollution Prevention and Control (Scotland) Regulations 2012 (PPC 2012) came into force on 7th January 2013 replacing the Pollution Prevention and Control (Scotland) Regulations 2000. Operators with existing PPC Permits will continue to operate under the Pollution Prevention and Control (Scotland) Regulations 2000 (as amended) until 7 January 2014. New operators will be permitted under the new 2012 regulations.*
>
> *The PPC 2012 regulations implement the requirements of the Industrial Emissions Directive (IED) which aims to provide an integrated approach to pollution control preventing emissions into air, water or soil wherever this is practicable, taking into account waste management. Where prevention is not possible, the aim is to minimise emissions in order to achieve a high level of protection for the environment as a whole.*

Hence, the requirement for the permitting process as a whole is to prevent emissions where practicable. Where this is not possible, a high level of environmental protection should be demonstrated. This is interpreted for the present study as follows.

- Prevention and minimisation: the approaches taken to prevent and minimise pollution are described elsewhere in this permit application.
- High level of protection: As for the planning process, this guidance is interpreted in the present context to mean that emissions to air from the proposed facility should have no significant adverse effects on health. As described in the SNIFFER guidance[9] the primary reference point

[21] SEPA website http://www.sepa.org.uk/air/process_industry_regulation.aspx, accessed December 2014

for evaluating significance in this context is guidance produced by SEPA.[22] This guidance sets out standards and guidelines specified to ensure a high level of protection of public health, and describes how a facility should be assessed against these standards and guidelines.

[22] SEPA, Environment Agency and NI Environment and Heritage Service, "*Integrated Pollution Prevention and Control (IPPC): Environmental Assessment and Appraisal of BAT*," Version 6 2003

6 Step 2: Hazard identification (site conceptual model)

The development of a site conceptual model (SCM) is the next stage of the risk assessment. The model is used to identify the potential sources, critical pathways and receptors that require assessment as described in the following paragraphs.

6.1 Sources

For the purpose of assessing potential health impacts associated with the effect of emissions from the proposed Energy Recovery Park, the relevant source of emissions is the gasification technology, discharging via a 55 metre stack.

The substances of potential concern emitted from this source include:

- Particulate matter
- Volatile organic compounds
- Hydrogen chloride
- Hydrogen fluoride
- Carbon monoxide
- Sulphur dioxide
- Oxides of nitrogen
- Metals group 1: Cadmium and Thallium
- Metals group 2: Mercury
- Metals group 3: Antimony, Arsenic, Lead, Chromium, Cobalt, Copper, Manganese, Nickel, Vanadium
- Dioxins and furans
- Polycyclic aromatic hydrocarbons (PAHs)
- Ammonia

6.2 Pathways of exposure

The two primary pathways of exposure considered in this assessment are inhalation and ingestion.

On the basis of the significance of exposure and consequently risks associated with the exposure, the following pathways were identified as the relevant pathways of exposure:

- Inhalation;
- Ingestion of soil; and
- Ingestion of locally produced / sourced food.

Exposure through food consumption from the following products was considered:

- Home-grown produce – farms, residential and fisher properties;
- Fish sourced within the parameters of the watershed – all residential / fisher properties;
- Beef produced and used on receptor farms – farms;
- Milk produced and used on receptor farms – farms;
- Eggs produced and used on receptor farms – farms;
- Chicken produced and used on receptor farms – farms;
- Pork produced and used on receptor farms – farms; and

- Breast milk – assessed for the residential, fisher and farm receptors at which the highest exposures were forecast to occur.

Potential exposure through the ingestion of drinking water requires the contamination of the local drinking water sources. The USEPA HHRAP includes the ingestion of locally abstracted surface water as a potential pathway of exposure to allow for modelling of special sites in situations where such pathway of exposure is likely to be of potential concern (e.g. water storage ponds and lakes). The ingestion of groundwater as a potential source of exposure is not considered in this methodology as a feasible pathway of exposure and therefore is not included in the assessment procedure. No surface water abstraction points for drinking water are likely to be present in the vicinity of the site. Therefore, potential exposure through this potential exposure pathway was not considered in this assessment.

6.3 Receptors

The air quality study found that the highest levels of released substances were forecast to occur within 1 km of the proposed facility. Consequently, the assessment of potential health risks associated with the forecast levels of released substances was focused on the areas surrounding the emission sources, and extending out to about 3 km. The purpose of characterising the exposure setting is to identify the type of human activities or land uses which determine the exposure scenarios that may result due to exposure to emissions from the proposed facility.

Within the assessment area around the proposed facility, the locations of potential sensitive receptors were identified. Following the identification of potentially sensitive locations, the highest yearly average value for each modelled air parameter (e.g. air concentration, dry deposition, wet deposition) for each phase (e.g. vapour, particle and particle-bound) was determined at each location.

The assessment was carried out at 63 representative locations, comprising 38 “farm” locations and 25 “residential” locations within 3 km of the proposed facility. Table 1 below sets out details of the assessment locations.

Table 1: Locations at which exposure to emissions was assessed

Ref.	Receptor name		Easting (m)	Northing (m)	Distance from stack (km)
S1	Pennymore	Farm	248884	621862	1.98
S2	Findlayston	Farm	250156	620463	2.45
S3	Holehouse	Farm	249570	619960	1.88
S4	Bardarroch Farm	Farm	247095	618531	1.84
S5	Hunterston	Farm	246279	621583	1.96
S6	Creoch House	Residential	247623	620969	0.72
S7	Ardmhor	Residential	247622	621096	0.84
S8	The Bungalow	Residential	248878	621553	1.74
S9	Knowe View	Residential	249895	620966	2.29
S10	Gallowlee Avenue	Residential	250241	620991	2.63
S11	Torview	Residential	248903	620814	1.31
S12	Mote Toll	Residential	249057	620619	1.39
S13	Netherton	Residential	250498	620708	2.82
S14	North Palmerston	Residential	250712	620043	3.00
S15	The Bungalow	Residential	250697	619775	3.02
S16	Killoch	Residential	247923	620258	0.21
S17	Hilltop	Residential	249337	619489	1.79
S18	Auchness Cottage	Residential	248554	619646	1.04
S19	Lessnessock Bungalows	Residential	248306	619658	0.84
S20	Provost Mount	Residential	247711	619866	0.39
S21	Clydenoch	Residential	247290	619272	1.07
S22	Oakmount	Residential	246933	618100	2.30
S23	The Cottage	Residential	246426	619844	1.36

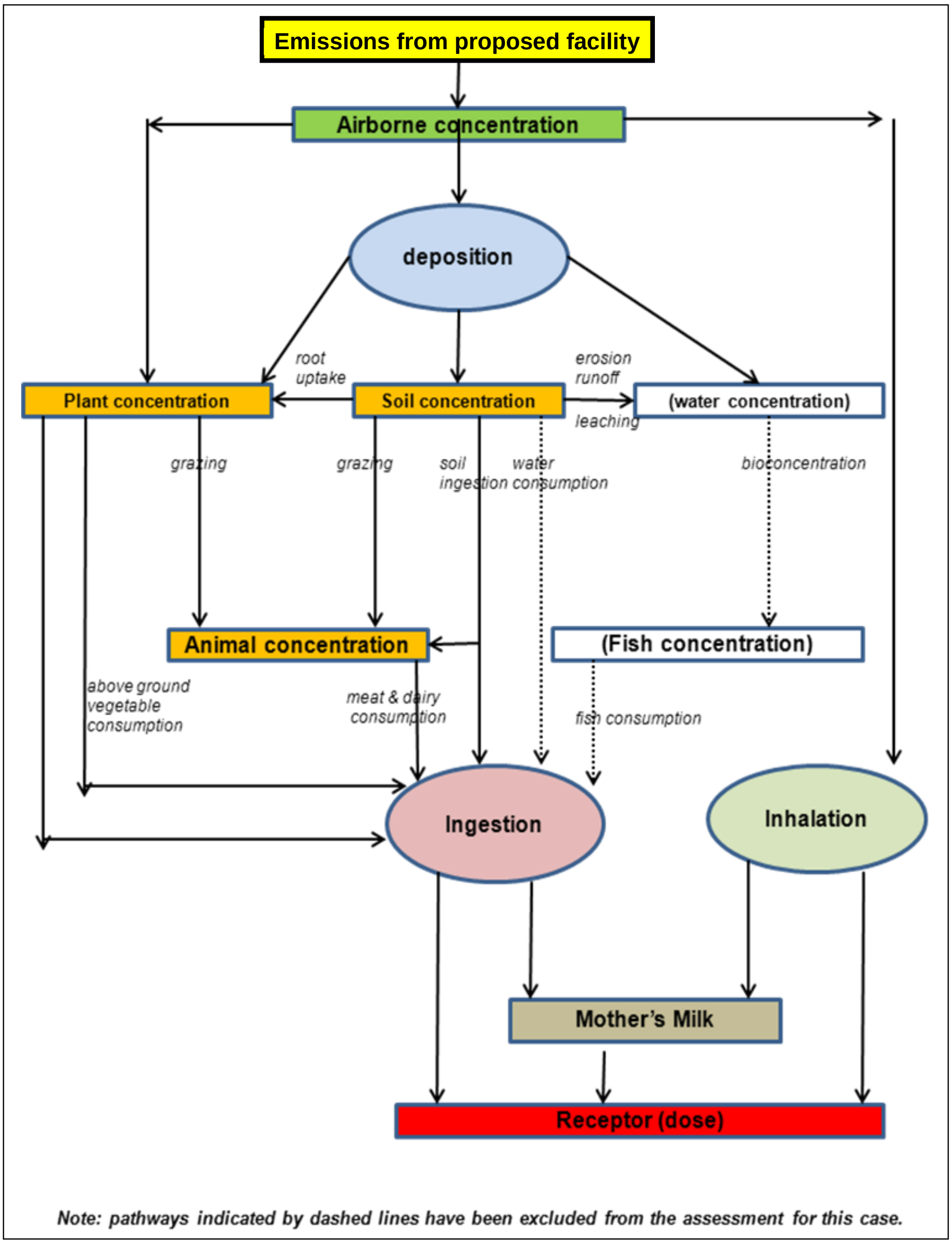
Ref.	Receptor name		Easting (m)	Northing (m)	Distance from stack (km)
S24	Shield	Residential	245279	619923	2.46
S25	Briardene Cottage	Residential	245108	621159	2.76
S26	Alpbach	Residential	245396	621344	2.56
S27	House Fox Hollow	Residential	246050	621589	2.13
S28	Gowanpark House	Residential/farm	247977	622321	2.08
S29	Gargowan	Residential/farm	247489	622329	2.08
S30	Steelpark	Residential/farm	248503	622454	2.33
S31	Corselet	Residential/farm	248450	621650	1.57
S32	Cawhillan	Residential/farm	249237	621552	2.00
S33	Slatehole	Residential/farm	249078	623077	3.13
S34	Barturk	Residential/farm	249516	622088	2.57
S35	Low Carston	Residential/farm	249945	621752	2.68
S36	Hill of Ochiltree	Residential/farm	250016	621331	2.54
S37	High Tarbeg	Residential/farm	248610	620713	1.00
S38	Back o'Hill	Residential/farm	250217	619821	2.54
S39	South Palmerston	Residential/farm	250786	619544	3.15
S40	Glenconner	Residential/farm	249470	619350	1.97
S41	Barquharrie	Residential/farm	250259	619079	2.80
S42	Burnockstone	Residential/farm	250123	618685	2.87
S43	Lessnessock	Residential/farm	248181	619633	0.78
S44	Barlosh Court	Residential/farm	248066	618199	2.09
S45	High Plyde	Residential/farm	248906	617702	2.82
S46	Burnton	Residential/farm	249367	617985	2.81
S47	Bardarroch	Residential/farm	247373	618715	1.58
S48	Killochside	Residential/farm	247386	620184	0.34
S49	Treesmax	Residential/farm	246082	618570	2.35
S50	East Tarelgin	Residential/farm	246665	619857	1.13
S51	Macquittiston	Residential/farm	246068	619250	1.93
S52	Lochmark Farm	Residential/farm	245065	619639	2.72
S53	West Tarelgin	Residential/farm	246137	620014	1.60
S54	Chipperlaigan	Residential/farm	245629	620735	2.14
S55	Hoodston	Residential/farm	245937	620972	1.92
S56	Speirston	Residential/farm	246330	621261	1.71
S57	Braehead	Residential/farm	246828	621708	1.70
S58	Trabbochburn	Residential/farm	246676	621872	1.92
S59	Laigh Tarbeg	Residential/farm/B&B	248730	620437	1.03
S60	Tarelgin Smokehouse	Residential/retail	246115	619720	1.69
S61	Gemmell's Garden Centre	Retail	245656	621496	2.40
S62	Ochiltree Primary School	School	250523	621047	2.91
S63	Watson	Residential/farm	249647	621013	2.07

For residential and farm scenarios, in accordance with the UK guidelines as published in CLR10,[11] the critical receptor is considered to be a female child aged 0-6.

6.4 Site conceptual model

The conceptual model for consideration of the potential health effects associated with emissions to air from the proposed facility is summarised in Figure 1. Further details of sources, pathways and receptors are given in the preceding sections 6.1, 6.2 and 6.3.

Figure 1: Overview of the potential pathways of exposure used in this study



7 Step 3: Hazard assessment

The substances which would be emitted to air from the proposed facility are listed in Section 6.1. The air quality assessment report provides a detailed assessment of these emissions to air, with the exception of dioxins and furans because of the nature of this group of chemicals. The air quality assessment includes a modelling study to forecast levels of these substances against air quality standards and guidelines which have been specified for the protection of health. The levels of released substances are forecast to comply with all relevant air quality standards and guidelines. In the limited number of cases where baseline levels are above the relevant standards and guidelines (as is the case in many locations throughout Scotland), the proposed development would make an insignificant contribution to environmental levels, as defined on the basis of guidance published by SEPA.[22] Assessment of these substances against the established air quality standards and guidelines is protective of human health via both direct and indirect pathways. On this basis, it is concluded that further assessment of these hazards is not required as part of this health risk assessment.

This is consistent with the approach adopted by the Environment Agency for England and Wales in relation to applications for thermal treatment processes. For example, in relation to the proposed Beddington Lane Energy Recovery Facility, London Borough of Sutton, the Environment Agency commented: "*As regards metal emissions, it should be noted that the environmental standards for ground level concentrations are considered to be sufficiently protective of human health, consequently the HHRA* [Human Health Risk Assessment] *should be concerned solely with dioxins and furans.*"[23] A similar approach was recommended by the Environment Agency in relation to the proposed Willows Power and Recycling Centre, Kings Lynn, Norfolk: "*For other pollutants such as heavy metals, in principle, we consider each EQS' as protective of human health. It is not therefore necessary to model the human body uptake of metals.*"[24]

Dioxins and furans could not be assessed in this way because the main issues are associated with indirect exposure pathways. Consequently, it is important for this risk assessment chapter to estimate public exposure to levels of dioxins and furans more fully. This is described in Step 4 below.

Hence, the detailed assessment of risks to health posed by the facility has focused on emissions of dioxins and furans, and does not provide further calculations of indirect exposure to other substances as this would not add significant value to the assessment against air quality standards and guidelines.

Emissions of dioxins and furans from the proposed Energy Recovery Park are presented in Table 2 below.

Table 2: Dioxin and furan congener emissions from the proposed facility

Congener	Annual mean emission concentration (I-TEQ ng/m³)	I-Toxic equivalent factor (as in Waste Incineration Directive)	Annual mean emission concentration (ng/m³)	Emission rate (TEQ g/s)
2,3,7,8-TCDD	0.0031	1	0.0031	7.99×10^{-11}
1,2,3,7,8-PeCDD	0.0123	0.5	0.025	3.16×10^{-10}
1,2,3,4,7,8-HxCDD	0.0029	0.1	0.029	7.40×10^{-11}
1,2,3,6,7,8-HxCDD	0.0026	0.1	0.026	6.65×10^{-11}
1,2,3,7,8,9-HxCDD	0.0021	0.1	0.021	5.28×10^{-11}
1,2,3,4,6,7,8 HpCDD	0.0017	0.01	0.17	4.39×10^{-11}
OCDD	0.0004	0.001	0.4	1.04×10^{-11}
2,3,7,8-TCDF	0.0028	0.1	0.027	7.14×10^{-11}
1,2,3,7,8-PCDF	0.0014	0.05	0.028	3.57×10^{-11}
2,3,4,7,8-PCDF	0.0268	0.5	0.054	6.90×10^{-10}
1,2,3,4,7,8-HxCDF	0.0218	0.1	0.22	5.62×10^{-10}

[23] Environment Agency Air Quality Modelling and Assessment Unit, "Beddington Lane ERF: Response to NPS Request," Ref. AQMAU_C952_RP01
[24] Environment Agency Air Quality Modelling and Assessment Unit, "Willows Power & Recycling Centre," Ref. C791

Congener	Annual mean emission concentration (I-TEQ ng/m^3)	I-Toxic equivalent factor (as in Waste Incineration Directive)	Annual mean emission concentration (ng/m^3)	Emission rate (TEQ g/s)
1,2,3,6,7,8-HxCDF	0.0081	0.1	0.081	2.08×10^{-10}
1,2,3,7,8,9-HxCDF	0.0004	0.1	0.0042	1.08×10^{-11}
2,3,4,6,7,8-HxCDF	0.0087	0.1	0.087	2.25×10^{-10}
1,2,3,4,6,7,8-HpCDF	0.0044	0.01	0.44	1.13×10^{-10}
1,2,3,4,7,8,9-HpCDF	0.0004	0.01	0.043	1.11×10^{-11}
OCDF	0.0004	0.001	0.36	9.19×10^{-12}
Total	1	-	2	2.58×10^{-09}

8 Step 4: Risk estimation

In summary, the risk assessment presented in this report results in the following outputs:

- Estimates of the combined cancer risks and non-cancer risks (Hazard Quotients) for all identified receptors;
- Estimates of risk and hazards associated with exposure to relevant COPC;
- Estimates of risk and hazards associated with pathways of exposure;
- Evaluation of infant exposure via breast milk to COPC with appropriate biotransfer factors; and
- Estimates of the soil concentrations at most affected receptors to compare with urban and rural soil concentrations.

Additionally, in view of the prevalence of dairy farming in the local area, calculated levels of dioxins and furans in milk are also provided. As for all other parameters, these are worst case values based on highly conservative assumptions. These calculated values could be used as a reference point in relation to any future assessments of milk quality, e.g. for the purposes of quality assurance.

8.1 Risk estimates

The total cancer risk (TCR) and total hazard quotient (THQ) estimated by the model, based on the air dispersion modelling prediction of air concentrations and depositions by ADMS, for the proposed facility for all identified receptors are presented in Table 3, Table 4 and Table 5 below. The highest modelled risk estimates for farm, residential and fisher receptors are highlighted in yellow.

Table 3: Risk summary at all "farm" locations considered

Receptor	Receptor name	Farmer adult		Farmer child	
		TCR	THQ	TCR	THQ
S1	Pennymore	3.91×10^{-07}	2.93×10^{-04}	5.55×10^{-07}	4.19×10^{-04}
S2	Findlayston	3.15×10^{-07}	2.36×10^{-04}	4.47×10^{-07}	3.37×10^{-04}
S3	Holehouse	3.61×10^{-07}	2.71×10^{-04}	5.13×10^{-07}	3.88×10^{-04}
S4	Bardarroch Farm	1.16×10^{-07}	8.65×10^{-05}	1.64×10^{-07}	1.24×10^{-04}
S5	Hunterston	1.77×10^{-07}	1.33×10^{-04}	2.52×10^{-07}	1.90×10^{-04}
S28	Gowanpark House	3.60×10^{-07}	2.70×10^{-04}	5.11×10^{-07}	3.86×10^{-04}
S29	Gargowan	2.96×10^{-07}	2.22×10^{-04}	4.21×10^{-07}	3.18×10^{-04}
S30	Steelpark	2.83×10^{-07}	2.12×10^{-04}	4.02×10^{-07}	3.03×10^{-04}
S31	Corselet	4.36×10^{-07}	3.27×10^{-04}	6.19×10^{-07}	4.68×10^{-04}
S32	Cawhillan	5.13×10^{-07}	3.85×10^{-04}	7.29×10^{-07}	5.51×10^{-04}
S33	Slatehole	1.81×10^{-07}	1.35×10^{-04}	2.57×10^{-07}	1.94×10^{-04}
S34	Barturk	3.22×10^{-07}	2.41×10^{-04}	4.57×10^{-07}	3.45×10^{-04}
S35	Low Carston	3.71×10^{-07}	2.78×10^{-04}	5.26×10^{-07}	3.97×10^{-04}
S36	Hill of Ochiltree	3.93×10^{-07}	2.94×10^{-04}	5.58×10^{-07}	4.21×10^{-04}
S37	High Tarbeg	1.46×10^{-06}	1.10×10^{-03}	2.08×10^{-06}	1.57×10^{-03}
S38	Back o'Hill	2.27×10^{-07}	1.70×10^{-04}	3.23×10^{-07}	2.44×10^{-04}
S39	South Palmerston	1.60×10^{-07}	1.20×10^{-04}	2.27×10^{-07}	1.71×10^{-04}
S40	Glenconner	3.57×10^{-07}	2.67×10^{-04}	5.07×10^{-07}	3.83×10^{-04}
S41	Barquharrie	2.20×10^{-07}	1.65×10^{-04}	3.13×10^{-07}	2.36×10^{-04}
S42	Burnockstone	2.15×10^{-07}	1.61×10^{-04}	3.05×10^{-07}	2.30×10^{-04}
S43	Lessnessock	2.71×10^{-07}	2.03×10^{-04}	3.84×10^{-07}	2.90×10^{-04}
S44	Barlosh Court	4.85×10^{-08}	3.63×10^{-05}	6.91×10^{-08}	5.21×10^{-05}
S45	High Plyde	4.51×10^{-08}	3.37×10^{-05}	6.44×10^{-08}	4.85×10^{-05}

S46	**Burnton**	7.50×10^{-08}	5.61×10^{-05}	1.07×10^{-07}	8.05×10^{-05}
S47	**Bardarroch**	1.08×10^{-07}	8.12×10^{-05}	1.54×10^{-07}	1.16×10^{-04}
S48	**Killochside**	1.02×10^{-06}	7.61×10^{-04}	1.44×10^{-06}	1.09×10^{-03}
S49	**Treesmax**	2.24×10^{-07}	1.68×10^{-04}	3.18×10^{-07}	2.40×10^{-04}
S50	**East Tarelgin**	4.00×10^{-07}	3.00×10^{-04}	5.67×10^{-07}	4.29×10^{-04}
S51	**Macquittiston**	2.86×10^{-07}	2.15×10^{-04}	4.07×10^{-07}	3.07×10^{-04}
S52	**Lochmark Farm**	1.79×10^{-07}	1.34×10^{-04}	2.55×10^{-07}	1.92×10^{-04}
S53	**West Tarelgin**	3.13×10^{-07}	2.34×10^{-04}	4.44×10^{-07}	3.35×10^{-04}
S54	**Chipperlaigan**	2.42×10^{-07}	1.81×10^{-04}	3.43×10^{-07}	2.59×10^{-04}
S55	**Hoodston**	2.22×10^{-07}	1.66×10^{-04}	3.16×10^{-07}	2.38×10^{-04}
S56	**Speirston**	2.11×10^{-07}	1.58×10^{-04}	3.00×10^{-07}	2.26×10^{-04}
S57	**Braehead**	2.16×10^{-07}	1.62×10^{-04}	3.07×10^{-07}	2.32×10^{-04}
S58	**Trabbochburn**	1.82×10^{-07}	1.36×10^{-04}	2.58×10^{-07}	1.95×10^{-04}
S59	**Laigh Tarbeg**	1.17×10^{-06}	8.74×10^{-04}	1.65×10^{-06}	1.25×10^{-03}
S63	**Watson**	5.00×10^{-07}	3.75×10^{-04}	7.10×10^{-07}	5.37×10^{-04}

Table 4: Risk summary at all “residential” locations considered

Receptor	Receptor name	Residential adult		Residential child	
		TCR	THQ	TCR	THQ
S6	**Creoch House**	1.33×10^{-08}	9.06×10^{-06}	3.39×10^{-08}	2.39×10^{-05}
S7	**Ardmhor**	1.26×10^{-08}	8.62×10^{-06}	3.22×10^{-08}	2.27×10^{-05}
S8	**The Bungalow**	9.04×10^{-09}	6.16×10^{-06}	2.30×10^{-08}	1.62×10^{-05}
S9	**Knowe View**	7.20×10^{-09}	4.90×10^{-06}	1.83×10^{-08}	1.29×10^{-05}
S10	**Gallowlee Avenue**	5.84×10^{-09}	3.97×10^{-06}	1.48×10^{-08}	1.04×10^{-05}
S11	**Torview**	1.72×10^{-08}	1.17×10^{-05}	4.39×10^{-08}	3.10×10^{-05}
S12	**Mote Toll**	1.41×10^{-08}	9.64×10^{-06}	3.61×10^{-08}	2.54×10^{-05}
S13	**Netherton**	5.01×10^{-09}	3.40×10^{-06}	1.27×10^{-08}	8.90×10^{-06}
S14	**North Palmerston**	3.55×10^{-09}	2.40×10^{-06}	8.94×10^{-09}	6.24×10^{-06}
S15	**The Bungalow**	3.32×10^{-09}	2.24×10^{-06}	8.37×10^{-09}	5.83×10^{-06}
S16	**Killoch**	1.35×10^{-08}	9.22×10^{-06}	3.45×10^{-08}	2.43×10^{-05}
S17	**Hilltop**	7.09×10^{-09}	4.83×10^{-06}	1.80×10^{-08}	1.27×10^{-05}
S18	**Auchness Cottage**	1.15×10^{-08}	7.87×10^{-06}	2.94×10^{-08}	2.07×10^{-05}
S19	**Lessnessock Bungalows**	8.39×10^{-09}	5.71×10^{-06}	2.14×10^{-08}	1.50×10^{-05}
S20	**Provost Mount**	3.97×10^{-09}	2.69×10^{-06}	1.00×10^{-08}	7.00×10^{-06}
S21	**Clydenoch**	4.84×10^{-09}	3.28×10^{-06}	1.22×10^{-08}	8.58×10^{-06}
S22	**Oakmount**	1.91×10^{-09}	1.28×10^{-06}	4.76×10^{-09}	3.27×10^{-06}
S23	**The Cottage**	5.86×10^{-09}	3.98×10^{-06}	1.49×10^{-08}	1.04×10^{-05}
S24	**Shield**	4.08×10^{-09}	2.76×10^{-06}	1.03×10^{-08}	7.20×10^{-06}
S25	**Briardene Cottage**	3.44×10^{-09}	2.32×10^{-06}	8.67×10^{-09}	6.04×10^{-06}
S26	**Alpbach**	3.19×10^{-09}	2.15×10^{-06}	8.02×10^{-09}	5.58×10^{-06}
S27	**House Fox Hollow**	3.13×10^{-09}	2.11×10^{-06}	7.89×10^{-09}	5.49×10^{-06}
S60	**Tarelgin Smokehouse**	4.87×10^{-09}	3.30×10^{-06}	1.23×10^{-08}	8.64×10^{-06}
S61	**Gemmell's Garden Centre**	3.05×10^{-09}	2.05×10^{-06}	7.66×10^{-09}	5.33×10^{-06}
S62	**Ochiltree Primary School**	5.13×10^{-09}	3.48×10^{-06}	1.30×10^{-08}	9.11×10^{-06}

Table 5: Risk summary at all "fisher" locations considered

Receptor	Receptor name	Fisher adult		Fisher child	
		TCR	THQ	TCR	THQ
S1	Pennymore	4.33×10^{-07}	4.38×10^{-04}	3.21×10^{-07}	3.21×10^{-04}
S2	Findlayston	4.32×10^{-07}	4.37×10^{-04}	3.17×10^{-07}	3.18×10^{-04}
S3	Holehouse	4.32×10^{-07}	4.38×10^{-04}	3.19×10^{-07}	3.20×10^{-04}
S4	Bardarroch Farm	4.28×10^{-07}	4.35×10^{-04}	3.07×10^{-07}	3.10×10^{-04}
S5	Hunterston	4.29×10^{-07}	4.36×10^{-04}	3.10×10^{-07}	3.13×10^{-04}
S6	Creoch House	4.39×10^{-07}	4.43×10^{-04}	3.40×10^{-07}	3.35×10^{-04}
S7	Ardmhor	4.39×10^{-07}	4.42×10^{-04}	3.38×10^{-07}	3.34×10^{-04}
S8	The Bungalow	4.35×10^{-07}	4.40×10^{-04}	3.27×10^{-07}	3.26×10^{-04}
S9	Knowe View	4.33×10^{-07}	4.38×10^{-04}	3.21×10^{-07}	3.21×10^{-04}
S10	Gallowlee Avenue	4.32×10^{-07}	4.38×10^{-04}	3.17×10^{-07}	3.18×10^{-04}
S11	Torview	4.43×10^{-07}	4.45×10^{-04}	3.52×10^{-07}	3.44×10^{-04}
S12	Mote Toll	4.40×10^{-07}	4.43×10^{-04}	3.43×10^{-07}	3.37×10^{-04}
S13	Netherton	4.31×10^{-07}	4.37×10^{-04}	3.15×10^{-07}	3.16×10^{-04}
S14	North Palmerston	4.30×10^{-07}	4.36×10^{-04}	3.10×10^{-07}	3.13×10^{-04}
S15	The Bungalow	4.29×10^{-07}	4.36×10^{-04}	3.10×10^{-07}	3.12×10^{-04}
S16	Killoch	4.39×10^{-07}	4.43×10^{-04}	3.41×10^{-07}	3.36×10^{-04}
S17	Hilltop	4.33×10^{-07}	4.38×10^{-04}	3.21×10^{-07}	3.21×10^{-04}
S18	Auchness Cottage	4.38×10^{-07}	4.41×10^{-04}	3.35×10^{-07}	3.31×10^{-04}
S19	Lessnessock Bungalows	4.34×10^{-07}	4.39×10^{-04}	3.25×10^{-07}	3.24×10^{-04}
S20	Provost Mount	4.30×10^{-07}	4.36×10^{-04}	3.12×10^{-07}	3.14×10^{-04}
S21	Clydenoch	4.31×10^{-07}	4.37×10^{-04}	3.14×10^{-07}	3.16×10^{-04}
S22	Oakmount	4.28×10^{-07}	4.35×10^{-04}	3.05×10^{-07}	3.09×10^{-04}
S23	The Cottage	4.32×10^{-07}	4.38×10^{-04}	3.17×10^{-07}	3.18×10^{-04}
S24	Shield	4.30×10^{-07}	4.36×10^{-04}	3.12×10^{-07}	3.14×10^{-04}
S25	Briardene Cottage	4.29×10^{-07}	4.36×10^{-04}	3.10×10^{-07}	3.13×10^{-04}
S26	Alpbach	4.29×10^{-07}	4.36×10^{-04}	3.09×10^{-07}	3.12×10^{-04}
S27	House Fox Hollow	4.29×10^{-07}	4.36×10^{-04}	3.09×10^{-07}	3.12×10^{-04}
S28	Gowanpark House	4.32×10^{-07}	4.38×10^{-04}	3.19×10^{-07}	3.20×10^{-04}
S29	Gargowan	4.31×10^{-07}	4.37×10^{-04}	3.16×10^{-07}	3.17×10^{-04}
S30	Steelpark	4.31×10^{-07}	4.37×10^{-04}	3.15×10^{-07}	3.17×10^{-04}
S31	Corselet	4.34×10^{-07}	4.39×10^{-04}	3.23×10^{-07}	3.23×10^{-04}
S32	Cawhillan	4.35×10^{-07}	4.40×10^{-04}	3.27×10^{-07}	3.26×10^{-04}
S33	Slatehole	4.29×10^{-07}	4.36×10^{-04}	3.10×10^{-07}	3.13×10^{-04}
S34	Barturk	4.32×10^{-07}	4.38×10^{-04}	3.17×10^{-07}	3.18×10^{-04}
S35	Low Carston	4.33×10^{-07}	4.38×10^{-04}	3.20×10^{-07}	3.20×10^{-04}
S36	Hill of Ochiltree	4.33×10^{-07}	4.38×10^{-04}	3.21×10^{-07}	3.21×10^{-04}
S37	High Tarbeg	4.51×10^{-07}	4.51×10^{-04}	3.75×10^{-07}	3.62×10^{-04}
S38	Back o'Hill	4.30×10^{-07}	4.36×10^{-04}	3.12×10^{-07}	3.15×10^{-04}
S39	South Palmerston	4.29×10^{-07}	4.36×10^{-04}	3.09×10^{-07}	3.12×10^{-04}
S40	Glenconner	4.32×10^{-07}	4.38×10^{-04}	3.19×10^{-07}	3.20×10^{-04}
S41	Barquharrie	4.30×10^{-07}	4.36×10^{-04}	3.12×10^{-07}	3.14×10^{-04}
S42	Burnockstone	4.30×10^{-07}	4.36×10^{-04}	3.12×10^{-07}	3.14×10^{-04}
S43	Lessnessock	4.31×10^{-07}	4.37×10^{-04}	3.15×10^{-07}	3.16×10^{-04}

S44	**Barlosh Court**	4.27 x 10^{-07}	4.34 x 10^{-04}	3.03 x 10^{-07}	3.08 x 10^{-04}
S45	**High Plyde**	4.27 x 10^{-07}	4.34 x 10^{-04}	3.03 x 10^{-07}	3.08 x 10^{-04}
S46	**Burnton**	4.28 x 10^{-07}	4.35 x 10^{-04}	3.05 x 10^{-07}	3.09 x 10^{-04}
S47	**Bardarroch**	4.28 x 10^{-07}	4.35 x 10^{-04}	3.06 x 10^{-07}	3.10 x 10^{-04}
S48	**Killochside**	4.43 x 10^{-07}	4.45 x 10^{-04}	3.52 x 10^{-07}	3.45 x 10^{-04}
S49	**Treesmax**	4.30 x 10^{-07}	4.36 x 10^{-04}	3.12 x 10^{-07}	3.14 x 10^{-04}
S50	**East Tarelgin**	4.33 x 10^{-07}	4.38 x 10^{-04}	3.21 x 10^{-07}	3.21 x 10^{-04}
S51	**Macquittiston**	4.31 x 10^{-07}	4.37 x 10^{-04}	3.15 x 10^{-07}	3.17 x 10^{-04}
S52	**Lochmark Farm**	4.29 x 10^{-07}	4.36 x 10^{-04}	3.10 x 10^{-07}	3.13 x 10^{-04}
S53	**West Tarelgin**	4.32 x 10^{-07}	4.37 x 10^{-04}	3.17 x 10^{-07}	3.18 x 10^{-04}
S54	**Chipperlaigan**	4.30 x 10^{-07}	4.37 x 10^{-04}	3.13 x 10^{-07}	3.15 x 10^{-04}
S55	**Hoodston**	4.30 x 10^{-07}	4.36 x 10^{-04}	3.12 x 10^{-07}	3.14 x 10^{-04}
S56	**Speirston**	4.30 x 10^{-07}	4.36 x 10^{-04}	3.12 x 10^{-07}	3.14 x 10^{-04}
S57	**Braehead**	4.30 x 10^{-07}	4.36 x 10^{-04}	3.12 x 10^{-07}	3.14 x 10^{-04}
S58	**Trabbochburn**	4.29 x 10^{-07}	4.36 x 10^{-04}	3.10 x 10^{-07}	3.13 x 10^{-04}
S59	**Laigh Tarbeg**	4.46 x 10^{-07}	4.47 x 10^{-04}	3.60 x 10^{-07}	3.51 x 10^{-04}
S60	**Tarelgin Smokehouse**	4.31 x 10^{-07}	4.37 x 10^{-04}	3.14 x 10^{-07}	3.16 x 10^{-04}
S61	**Gemmell's Garden Centre**	4.29 x 10^{-07}	4.36 x 10^{-04}	3.09 x 10^{-07}	3.12 x 10^{-04}
S62	**Ochiltree Primary School**	4.31 x 10^{-07}	4.37 x 10^{-04}	3.15 x 10^{-07}	3.17 x 10^{-04}
S63	**Watson**	4.35 x 10^{-07}	4.40 x 10^{-04}	3.26 x 10^{-07}	3.25 x 10^{-04}

As stated previously, a value of 0.00001 (1 × 10^{-05}) was used as the benchmark for cancer risk and a hazard quotient of 1 was used as a benchmark for the assessment of individual contaminants. The data in Tables 3, 4 and 5, presents the combined risks from exposure to all contaminants to identify the most affected receptor.

It can be seen from the above results that the highest identified cancer risk and hazard quotient at a farm receptor is at High Tarbeg with highest predicted values of 2.08 × 10^{-06} for cancer risk and 0.00157 (1.57 × 10^{-03}) for the hazard quotient. This evaluation is based on the assumption that an individual living at this location would consume only beef, pork, poultry, eggs, milk and vegetables produced from the farm at this location. This will result in a substantial over-estimate of the exposure that could conceivably arise in practice.

The highest identified cancer risk and hazard quotient for a residential receptor is at Torview with predicted values of 4.39 × 10^{-08} for cancer risk and 0.000031 (3.10 × 10^{-05}) for the hazard quotient. This evaluation is based on the assumption that an individual could be resident at or near this location, and would consume only vegetables produced at this location, and would also experience exposure via soil at this location. This will result in a substantial over-estimate of the exposure that could conceivably arise in practice.

The highest identified cancer risk and hazard quotient for a fisher receptor is at High Tarbeg with predicted values of 3.75 x 10^{-07} for cancer risk and 0.000362 (3.62 x 10^{-04}) for the hazard quotient. This evaluation is based on the assumption that an individual could be resident at or near this location, and would consume only vegetables produced at this location, fish caught in waterbodies within the River Ayr catchment and experience exposure via soil. Again, this will result in a substantial over estimate of exposure.

These values are well within the benchmarks of 0.00001 (1 × 10^{-05}) for cancer risk and 1 for the hazard quotient, and also comply with the value of 20% - 50% of these benchmarks, used when background exposure is not known.

8.2 Intake of dioxins and furans

The tolerable daily intake (TDI) for dioxins estimated by the model, based on the air dispersion modelling prediction of air concentrations and depositions by ADMS, for the proposed facility for the two locations at which the highest exposures were forecast are presented in Table 6 below.

Table 6: Predicted oral intake at the two most affected locations

Receptor	Torview		High Tarbeg		High Tarbeg	
	Resident adult	Resident child	Farmer adult	Farmer child	Fisher adult	Fisher child
	Predicted oral intake (pgTEQ/kg body weight/day)					
Intake above ground vegetables	3.89×10^{-04}	8.96×10^{-04}	7.33×10^{-04}	1.69×10^{-03}	5.66×10^{-04}	1.30×10^{-03}
Intake fish	-	-	-	-	1.03×10^{-02}	7.26×10^{-03}
Intake beef	-	-	5.38×10^{-03}	3.31×10^{-03}		
Intake chicken	-	-	1.77×10^{-05}	1.21×10^{-05}		
Intake eggs	-	-	1.15×10^{-05}	8.28×10^{-06}		
Intake milk	-	-	1.76×10^{-02}	2.93×10^{-02}		
Intake pork	-	-	5.53×10^{-04}	4.22×10^{-04}		
Intake soil	6.23×10^{-05}	2.91×10^{-04}	9.05×10^{-05}	4.22×10^{-04}	9.05×10^{-05}	8.45×10^{-04}
Total intake	4.52×10^{-04}	1.19×10^{-03}	2.44×10^{-02}	3.51×10^{-02}	1.10×10^{-02}	9.41×10^{-03}
Tolerable Daily Intake	2 pgTEQ/kg body weight/day					
% of threshold	0.02 %	0.06 %	1.22 %	1.76 %	0.55 %	0.47 %

The greatest intake at any assessed location is predicted to occur at High Tarbeg. On the basis that an individual at this location could theoretically consume vegetables, meat and dairy produce grown in that location, the maximum predicted intake is 3.51×10^{-02} pg/kg-day (0.0351 pg/kg-day). Despite the worst-case approach adopted in the assessment, the maximum incremental intake associated with the proposed facility is a small fraction (1.76 %) of the recommended tolerable daily intake for dioxins of 2 pg/kg-day, and would not be detectable in practice. At residential and fisher locations, the highest forecast increment would be 0.06 % and 0.55 % of the tolerable daily intake respectively.

As noted above, where background exposure is unknown or relatively high, Defra suggests the use of a benchmark of 20% to 50% of the health criteria. Background exposure to dioxins and furans is dependent on individual environmental, lifestyle and physiological factors, and no single representative value can be derived for background exposure. This indicates that a benchmark of 20% to 50% of the health criterion would be appropriate for the assessment of the proposed facility. The highest modelled exposure level is 1.76 % of the relevant criterion, well within both these benchmarks.

8.3 Levels of dioxins and furans in cows' milk

Modelled levels of dioxins and furans in cows' milk at farmer receptors due to emissions from the proposed facility are set out in Table 7.

Table 7: Modelled levels of dioxins and furans in cows' milk

Receptor	Receptor name	Dioxin and furan concentration (pgTEQ/g fat)
Standard (Commission Regulation (EU) No. 1259/2011)		**2.5**
S1	Pennymore	0.00034
S2	Findlayston	0.00028
S3	Holehouse	0.00032

Receptor	Receptor name	Dioxin and furan concentration (pgTEQ/g fat)
S4	Bardarroch Farm	0.00010
S5	Hunterston	0.00016
S28	Gowanpark House	0.00032
S29	Gargowan	0.00026
S30	Steelpark	0.00025
S31	Corselet	0.00038
S32	Cawhillan	0.00045
S33	Slatehole	0.00016
S34	Barturk	0.00028
S35	Low Carston	0.00033
S36	Hill of Ochiltree	0.00035
S37	High Tarbeg	0.0013
S38	Back o'Hill	0.00020
S39	South Palmerston	0.00014
S40	Glenconner	0.00031
S41	Barquharrie	0.00019
S42	Burnockstone	0.00019
S43	Lessnessock	0.00024
S44	Barlosh Court	0.000042
S45	High Plyde	0.000039
S46	Burnton	0.000066
S47	Bardarroch	0.00010
S48	Killochside	0.00090
S49	Treesmax	0.00020
S50	East Tarelgin	0.00035
S51	Macquittiston	0.00025
S52	Lochmark Farm	0.00016
S53	West Tarelgin	0.00028
S54	Chipperlaigan	0.00021
S55	Hoodston	0.00020
S56	Speirston	0.00019
S57	Braehead	0.00019
S58	Trabbochburn	0.00016
S59	Laigh Tarbeg	0.0010
S63	Watson	0.00044

The highest modelled level of dioxins and furans in cows' milk was found at the High Tarbeg receptor point (S37) and is a minute proportion of the benchmark set in Commission Regulation (EU) No.1259/2011 at 0.052% of the standard. This represents an insignificant contribution from the proposed Energy Recovery Park.

The Commission Regulation also sets a standard of 5 pgTEQ/g fat for levels of dioxins, furans and dioxin-like PCBs in cows' milk. A preliminary assessment using Environment Agency data for levels of PCBs in emissions from waste to energy facilities indicated that the contribution of the proposed facility to levels of dioxins, furans and dioxin-like PCBs would be lower still.

8.4 Infant exposure to dioxins and furans through breast milk

IRAP-h View calculates the exposure through breast milk by calculating infant exposures, and risks associated with such exposures for 2,3,7,8-TCDD TEQ. There is no UK or USEPA target level for acceptable infant exposure. However, one approach USEPA has taken to evaluate forecast exposure to dioxins and furans is to compare the estimated exposure levels to national average background exposure levels. The Defra and Environment Agency R&D publication TOX 12, reported a UK background adult exposure of 1.8 pg TEQ/kg-day. The Former Ministry of Agriculture, Forestry and Fisheries (MAFF) calculated dietary intake by breast-fed infants to be 170 pg TEQ/kg-day at two months, dropping to 39 pg TEQ/kg-day at 10 months. Despite the relatively high intakes of dioxins experienced by nursing infants (about 100-fold those of an adult per kilogram body mass), the impact of breast-feeding on infant body burden of dioxins and furans is markedly less dramatic. Peak infant body burdens are around twice those of an adult, a consequence of the infant's rapidly expanding body weight and lipid volume, as well as a possibly faster elimination rate.

Table 8 below presents the estimated infant Additional Daily Dose (ADD) values for Torview (Residential) and High Tarbeg (Farmer and Fisher), at which the highest exposures due to the proposed facility were forecast to occur.

Table 8: Estimated infant additional daily doses (pgTEQ/kg body weight per day)

Receptor		Additional daily dose (pgTEQ/kg body weight/day)
Torview	**Residential**	0.006
High Tarbeg	**Farm**	0.316
High Tarbeg	**Fisher**	0.148

All of the estimated values at all locations are well below the range of UK infant background exposures discussed above with the highest being 0.316 pgTEQ/kg/day at High Tarbeg when modelled as a farmer location.

Based on the above presented data the proposed facility will not pose a significant risk via the ingestion of contaminated breast milk even at the most affected receptors.

8.5 Soil concentration

As discussed previously, the background level of dioxins and furans within the locality of the proposed facility is an unknown quantity and is not practically feasible to quantify at a receptor scale. Table 9 below presents the highest estimated concentration of dioxins and furans in soil due to the proposed facility, in comparison to UK rural and urban soil concentration of the assessed contaminants as provided in "The UK Soil and Herbage Pollutant Survey".[20]

Table 9: Concentration of dioxins and furans in soils at Torview and High Tarbeg

Location	Maximum predicted soil level due to proposed facility (ng TEQ/kg)	Rural soil level (mean – ng TEQ/kg)	Urban soil level (mean – ng TEQ/kg)
Torview	0.044	4.7	9.19
High Tarbeg	0.063		

The highest predicted soil level is less than 1.5 % of the rural mean soil level identified in the 2007 survey, and would not constitute a significant additional burden in the context of the variability of soil levels of dioxins and furans between locations.

9 Step 5: Risk evaluation

9.1 Summary of exposure assessment

This chapter provides an assessment of possible effects on the health of humans due to emissions from the proposed Barr Killoch Energy Recovery Park. As set out at Step 3, this focused on dioxins and furans, for which any effects are likely to be chronic arising from prolonged exposure. Potential secondary exposures, following the deposition of dioxins and furans, through the ingestion of affected soils, home-grown produce, beef, milk, pork, poultry and eggs at receptors within the vicinity of the site were also considered in the assessment.

The USEPA methodology "Human Health Risk Assessment Protocol 2005" was used to carry out the study. The USEPA default exposure parameters and toxicological data were replaced by those recommended by Defra and the EA reports CLR10 and R&D Publication TOX reports where available.

A simplified conceptual model was built for the site identifying all viable sources, receptors and pathways of exposure relevant to each of the receptors. In the absence of specific information in relation to the nature of the local receptors, all default pathways of exposure were assumed to exist, for each receptor scenario, to screen receptors with potentially significant exposure and consequently greater risks.

Dioxin and furan congener concentrations in the different receiving media were calculated from the particle phase and vapour phase air concentrations and deposition to the soil. The estimated concentrations were based on a number of conservative assumptions to ensure that worst-case scenarios were assessed.

To identify the level of potential risk from exposure to each individual chemical in all relevant pathways of exposure, the hazard quotients for each medium were calculated. Potential cancer risk was also estimated and compared with relevant acceptable risk levels and recommended tolerable daily intake.

The risks to health were found to comply with the relevant benchmarks at all potentially sensitive locations. Intakes were predicted to be higher if an individual could theoretically consume vegetables, meat and dairy produce grown at the location of highest concentration. Levels of released substances at farms in the vicinity of the proposed facility were taken into account in the study. The highest theoretically possible intake of dioxins and furans was predicted to be 0.0351 pg/kg body weight/day. Despite the worst-case approach adopted in the assessment, this incremental intake associated with the proposed facility is a small fraction (1.76 %) of the recommended tolerable daily intake for dioxins of 2 pg/kg-day, and would not be detectable in practice. Similarly, the potential exposure of infants via breast milk was assessed, and it was found that the proposed facility would have no significant or detectable influence on exposure in this way.

Modelled levels of dioxins and furans in cows' milk at nearby farms were found to comprise a minute proportion of the benchmark set in Commission Regulation (EU) No.1259/2011, with the highest value contributing just 0.052% of the benchmark. This represents an insignificant contribution from the proposed Energy Recovery Park.

There is uncertainty associated with the assessment of emissions to air from facilities such as the proposed Barr Killoch site. These uncertainties relate to aspects such as the variability in exposures of individuals resulting from differences in diet and lifestyle. There are also uncertainties in the dispersion modelling of emissions from combustion processes.

To account for these uncertainties, a worst-case approach was adopted throughout the study. This means that, wherever there is uncertainty in an aspect of the study, the most pessimistic available assumption was adopted. Hence, for example, it was assumed that the proposed facility would operate continuously at the maximum limit set down in the Waste Incineration Directive. Information provided in the air quality study indicates that emissions of dioxins and furans may typically be 5% or less of the emissions limit. It was assumed that individuals could be present at the locations of highest exposure continuously, resulting in a pessimistic view of potential exposure to released substances.

9.2 Significance of risks to health

On the basis of the information set out above, it was concluded that emissions to air from the proposed Barr Killoch Energy Recovery Park will not pose unacceptable health risks to residential, fisher or farmer receptors in the vicinity of the proposed facility.

9.3 Remedial action

On the basis of this assessment, no further remedial action or mitigation measures are required to further reduce the forecast impact of emissions to air from the proposed facility on health. The focus should be on ensuring that the detailed design, construction, operation and decommissioning of the proposed facility are carried out in accordance with best practice and in accordance with the assumptions used to develop this risk assessment.

10 Step 6: Risk management

10.1 Risk management for the proposed development

On the basis of this assessment, no further risk management measures are required to further reduce the forecast impact of emissions to air from the proposed facility on health. As highlighted above, the focus should be on ensuring that the detailed design, construction, operation and decommissioning of the proposed facility are carried out in accordance with best practice and in accordance with the assumptions used to develop this risk assessment.

The study outlined above demonstrates that the proposed facility would make a minute contribution to levels of dioxins and furans in cows' milk. Nevertheless, in view of the prevalence of dairy farming in the surrounding area, a programme of sampling and measurement of dioxin levels in cow's milk could be carried out in order to provide reassurance. It is recommended that 5 aggregated samples should be taken from each of 5 farms closest to the proposed development site during the year prior to commissioning, subject to agreement of the competent individual (e.g. farm owner or manager). Following commissioning, an identical programme of sampling could be carried out. Sampling and analysis should be carried out in accordance with the requirements of Commission Regulation (EU) No 589/2014 Annex III, or a comparable methodology.

10.2 Communication

It will also be important to ensure that the assessment of risks is clearly presented to decision-makers, local communities and other stakeholders. This discussion may need to be widened to encompass more widespread public concern with regard to the risks to health posed by waste incineration in general. In this regard, reference should be made to a review of health risks carried out by Health Protection Scotland and SEPA.[25] This study concluded:

> "*Based on the limitations of available research literature, attempting to provide an overall conclusion on the health effects of incineration in total is particularly difficult.*
>
> *For waste incineration as a whole topic, the body of evidence for an association with (non-occupational) adverse health effects is both inconsistent and inconclusive. However, more recent work suggests, more strongly, that there may have been an association between emissions (particularly dioxins) in the past from industrial, clinical and municipal waste incinerators and some forms of cancer, before more stringent regulatory requirements were implemented.*
>
> *For individual incineration waste streams (clinical, hazardous, industrial and municipal), the evidence for an association with (non-occupational) adverse health effects is inconclusive.*
>
> *The magnitude of any past health effects on residential populations living near incinerators that did occur is likely to have been small.*
>
> *The majority of research work in this field is of historical relevance but tells us little about the current risk of (non-occupational) adverse effects potentially associated with incineration plants in operation now.*
>
> *Levels of airborne emissions from individual incinerators should be lower now than in the past, due to stricter legislative controls and improved technology. Hence, any risk to the health of a local population living near an incinerator, associated with its emissions, should also now be lower.*"

[25] Health Protection Scotland/Scottish Environmental Protection Agency, "*Incineration of Waste and Reported Human Health Effects*." Health Protection Scotland, Glasgow, 2009.

Appendices

Appendix 1: Model input data

Appendix 1 – Model input data

Description	Resident adult	Resident child	Farmer adult	Farmer child	Fisher adult	Fisher child	Units
Averaging time for carcinogens	30	6	40	6	30	6	Yr
Averaging time for noncarcinogens	30	6	40	6	30	6	Yr
Consumption rate of BEEF	0.0	0.0	0.00122	0.00075	0.0	0.0	Kg/kg-day FW
Body weight	70	15	70	15	70	15	Kg
Consumption rate of POULTRY	0.0	0.0	0.00066	0.00045	0.0	0.0	Kg/kg-day FW
Consumption rate of ABOVEGROUND PRODUCE	0.00032	0.00077	0.00047	0.00113	0.00032	0.00077	Kg/kg-day DW
Consumption rate of BELOWGROUND PRODUCE	0.00014	0.00023	0.00017	0.00028	0.00014	0.00023	Kg/kg-day DW
Consumption rate of DRINKING WATER	1.4	0.67	1.4	0.67	1.4	0.67	L/day
Consumption rate of PROTECTED ABOVEGROUND PRODUCE	0.00061	0.0015	0.00064	0.00157	0.00061	0.0015	Kg/kg-day DW
Consumption rate of SOIL	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	Kg/day
Exposure duration	30	6	40	6	30	6	Yr
Exposure frequency	350	350	350	350	350	350	Day/yr
Consumption rate of EGGS	0.0	0.0	0.00075	0.00054	0.0	0.0	Kg/kg-day FW
Fraction of contaminated ABOVEGROUND PRODUCE	1.0	1.0	1.0	1.0	1.0	1.0	--
Fraction of contaminated DRINKING WATER	1.0	1.0	1.0	1.0	1.0	1.0	--
Fraction contaminated SOIL	1.0	1.0	1.0	1.0	1.0	1.0	--
Consumption rate of FISH	0.0	0.0	0.0	0.0	0.00125	0.00088	Kg/kg-day FW
Fraction of contaminated FISH	1.0	1.0	1.0	1.0	1.0	1.0	--
Inhalation exposure duration	30	6	40	6	30	6	Yr
Inhalation exposure frequency	350	350	350	350	350	350	Day/yr
Inhalation exposure time	24	24	24	24	24	24	Hr/day
Fraction of contaminated BEEF	1.0	1.0	1.0	1.0	1.0	1.0	--
Fraction of contaminated POULTRY	1.0	1.0	1.0	1.0	1.0	1.0	--

Fraction of contaminated EGGS	1.0	1.0	1.0	1.0	1.0	1.0	--
Fraction of contaminated MILK	1.0	1.0	1.0	1.0	1.0	1.0	--
Fraction of contaminated PORK	1.0	1.0	1.0	1.0	1.0	1.0	--
Inhalation rate	0.83	0.49	.83	0.49	0.83	0.49	m^3/hr
Consumption rate of MILK	0.0	0.0	0.01367	0.02268	0.0	0.0	Kg/kg-day FW
Consumption rate of PORK	0.0	0.0	0.00055	0.00042	0.0	0.0	Kg/kg-day FW
Time period at the beginning of Combustion	0.0	0.0	0.0	0.0	0.0	0.0	Yr
Length of exposure duration	30	6	40	6	30	6	Yr

'*kg/kg-day FW/DW = typical daily intake by kilogram of produce per kilogram of body weight per day, FRESH WEIGHT or DRY WEIGHT of plant or animal foodstuff

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