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Infant feeding and the energy transition: A comparison between decarbonising breastmilk substitutes with renewable gas and achieving the global nutrition target for breastfeeding

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ABSTRACT

Renewable gas has been proposed as a solution to decarbonise industrial processes, specifically heat demand. As part of this effort, the breast-milk substitutes industry is proposing to use renewable gas as a substitute for fossil natural gas. However, decarbonising the industrial processing of breast-milk substitutes can increase social license for these products, potentially undermining breastfeeding. World Health Organisation nutrition targets aim to increase exclusive breastfeeding to at least 50% globally by 2025 to improve maternal, infant, and young child health and nutrition. This target will have implications for the energy transition. A weakness of existing energy models is that demands for end-use products such as breast-milk substitutes are typically not considered explicitly. This paper develops an analytical framework for explicitly representing infant feeding methods in energy systems models. We compare the emissions saved in Ireland from decarbonising the industrial processing of breast-milk substitutes with renewable gas with the emissions saved by an increase in exclusive breastfeeding to 50% in both Ireland and a key export market, China. We demonstrate that the emissions saved from achieving the minimum global breastfeeding target are greater than when renewable gas is used to displace natural gas in the production of breast-milk substitutes in Ireland. We discuss the decarbonisation of breast-milk substitutes in relation to the principle of justice as non-maleficence, a principle based on the commitment to avoid harm, a novel application of a principle of justice. We conclude that breastfeeding support can be considered a demand-side measure for mitigating climate change by reducing the demand for energy services to produce breast-milk substitutes. A key recommendation is to position breastfeeding support as both a public health and a climate justice issue that is relevant for a just transition. The framework developed for this paper could be applied to support the inclusion of a wider range of mitigation options with social justice outcomes in energy system models.

1. Introduction

Breastfeeding is the biologically normal method of infant feeding which ensures optimal infant nourishment and development (Brown, 2018). The World Health Organisation recommends exclusive breastfeeding (EBF), where an infant is only breastfed for the first 6 months, and continuing for a duration of two years for optimal infant health (WHO, 2020). Yet no country currently meets all the objectives recommended by the World Health Organisation (WHO) to support mothers to breastfeed (Global Breastfeeding Collective, WHO, UNICEF, 2019). According to *The Lancet* Breastfeeding Series (Rollins et al., 2016; Victora et al., 2016) displacing and replacing breastfeeding can have adverse and long-term effects for mothers, infants, and children. The

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Glossary of terms and symbols

g $CO_{2\text{-eq}}$ MJ^{-1} – Carbon dioxide equivalent emissions per unit of energy, these include nitrogen, methane and carbon dioxide emissions
FFC – Fossil Fuel Comparator, the emissions from a fossil fuel to be compared with a renewable alternative
Biogas – Produced using anaerobic digestion, this gas contains carbon dioxide and methane
Biomethane – Produced by upgrading biogas to remove the carbon dioxide, this gas is normally 97% methane
Renewable gas – This term can apply to both biogas and biomethane, it is also commonly called green gas
Combination feeding – Infant is breastfed and also receives formula
EBF Exclusive breastfeeding – Infant is only breastfed; this refers to an individual infant
BMS Breast-milk substitutes – Any food being marketed or otherwise presented as a partial or total replacement for breast milk, whether or not suitable for that purpose ()
WHO – World Health Organisation

World Health Organisation (WHO) Global Nutrition Target no. 5 aims to increase the rate of exclusive breastfeeding in the first 6 months to at least 50% globally by 2025 (WHO/UNICEF, 2014). An increased rate of breastfeeding with a corresponding decrease in the demand for breast-milk substitutes (BMS) could have important implications for the energy services demand to produce breast-milk substitutes, given the interdependency between the agriculture, processing and socio-cultural systems that influence infant feeding.

It has been established that breast-milk substitutes have a larger carbon footprint in comparison with breastfeeding for four countries, while noting that breastfeeding and breast-milk substitutes are functionally different (Karlsson et al., 2019). Following the analysis by Karlsson et al. (2019), it has been proposed that support for breastfeeding is an environmental imperative (Joffe et al., 2019; Smith, 2019). However, an environmental imperative to support breastfeeding has the potential to hold women responsible for mitigating climate risks and "jeopardise women's reproductive rights, which include how women use their breasts" (Williams et al., 2019). Instead, Williams et al. (2019) suggest engaging with food manufacturers to reduce the carbon footprint of the production of breast-milk substitutes.

Most of the carbon footprint of milk powder (84%) is from the emissions associated with raw milk production which are Scope 3 emissions for the producer. A much smaller share of the emissions is from the processing stage (14%), which includes natural gas use which are scope 1 emissions for the producer and as such directly the responsibility of the producer. The remaining 2% is from other life cycle stages (Finnegan et al., 2017a; WBCSD and WRI, 2012). Renewable gas has been proposed to reduce the emissions associated with production of breast-milk substitutes, by replacing the natural gas currently in use (RGFI, 2019). Biogas can be produced from anaerobic digestion of organic material and can be upgraded to a renewable methane gas that is the same quality as natural gas. Manure from dairy cattle can be used as a feedstock for anaerobic digestion to produce biogas (Wall et al., 2013), with the potential to decarbonise production in the dairy industry as part of a circular economy approach. In Ireland, it is proposed that this will be mixed with grass silage to ensure sufficient biomethane yield (O'Shea et al., 2017). Displacing natural gas with renewable gas use will have an impact on the 14% share of GHG emissions associated with the processing stage.

Recently there have been calls for greater attention to be placed in energy models on greenhouse gas (GHG) mitigation from energy service demands (Grubler et al., 2018; Pye et al., 2020). Research on the energy transition often has a focus on energy consumption, whereby a change in supply is typically compared with the existing demand (Long and Murphy, 2019). We argue that the demand for energy services is an integral part of the energy transition. Creutzig et al. (2016) outlined a comprehensive set of climate change mitigation options from a demand-side perspective. While healthy diet was included under the 'Agriculture and other land use' category, breastfeeding was not specifically mentioned. Bartle (2020) has stated that WHO policies to protect breastfeeding can be considered a legitimate part of climate change mitigation, a view that is not represented in energy modelling literature. While there are publications relating to the environmental impact of breastfeeding and breast-milk substitutes, there are no studies that translate this research to energy modelling, where it can potentially inform policy decisions in this area.

The innovation in this paper is to build on the work of Karlsson et al. (2019) by proposing an analytical framework to incorporate infant feeding into large scale energy system models. The main objective of the work is to consider the previously unstudied moral implications of an engineering intervention to improve production from an environmental perspective. This is achieved through the following aims:

1. To demonstrate that the emissions saved from decarbonising BMS production have an opportunity cost
2. To discuss the decarbonisation of BMS in relation to the principle of justice of non-maleficence
3. To argue that breastfeeding support can be considered a demand side measure for mitigating climate change

2. Background

While the 'greening' of breast-milk substitutes could reduce carbon emissions, the public health impacts of continued widespread use of breast-milk substitutes are problematic. Approximately 800,000 annual deaths of children under five globally are attributed to suboptimum breastfeeding (Black et al., 2013). Neonatal implications of not breastfeeding include higher infectious morbidity and mortality; increased acute otitis media (type of ear infection) during the first two years of life; reduced protection against diarrhoea; and increased severity of respiratory infections. For mothers, the benefits of breast feeding include lower breast cancer rates; improved birth spacing; and a potentially lower risk of diabetes and ovarian cancer. Even in countries with clean water and good sanitation, infants who are not breastfed are at increased risk of morbidity and mortality (Victora et al., 2016).

Reasons for low breastfeeding rates are multi-faceted since breastfeeding is a complex behaviour dependent on mother and infant individual characteristics, public health systems, family, community and professional support and wider cultural values. Some of these factors are non-modifiable such as maternal age and socioeconomic status, but other factors may be modifiable such as self-efficacy, mode of birth, social and professional support. Promotion of breast-milk substitutes is recognised as one of the factors undermining breastfeeding (Rollins et al., 2016; WHO/UNICEF, 2014). Despite the introduction of the WHO code (World Health Organisation, 1981), and the clarification that it applies to all milk marketed for feeding infants and young children, including follow-on milk and growing-up milk (World Health Organization, 2018), the marketing of breast-milk substitutes remains pervasive (Hastings et al., 2020). Marketing narratives focus on the use of breast-milk substitutes as a simple and easy, equal choice, while breastfeeding is portrayed as painful, difficult, embarrassing and sleep depriving (Bartle, 2011). Concerns have also been expressed about the involvement of manufacturers in the development of nutrition guidance and research (Bartle, 2020). While breast-milk substitutes will remain a legitimate product, this paper is concerned additional demand that arises from aggressive marketing practices while support for mothers who do choose to breastfeed is low.

3. Methods

3.1. Case study details

The production of breast-milk substitutes in Ireland is used as a case study in this paper. The Irish Government has set a target of a national 51% reduction on reported 2018 emissions by 2030, a reduction of 31,077 kt $CO_{2\text{-eq}}$ (Duffy et al., 2020; Government of Ireland, 2021). The analysis in this paper focuses on decarbonising the manufacture of Irish breast-milk substitutes with renewable gas which can reduce the direct emissions associated with production. These are Scope 1 emissions under the GHG protocol (WBCSD and WRI, 2012). While there are also potential effects on land-use if the demand for breast-milk substitutes is reduced, only the emissions associated with the product are considered in this analysis; as such Scope 3 emissions (such as those associated with cattle) are not included. The scope of the study is the first six months of infant feeding. The only foods recommended to be consumed by infants in the first six months are breast-milk or a substitute. The markets considered are Ireland, the country of production, and China, a major international export destination for Ireland. The 50% target is the minimum global nutrition target of at least 50% of children exclusively breastfed for six months (WHO/UNICEF, 2014). Food miles involved in export to China are not considered in the study.

Of the approximately 40–50 (Joffe et al., 2019) milk powder processing plants globally, four are in Ireland (EPA, 2020). These produced approximately 165,000 tonnes of milk powder for export in 2017 (Central Statistics Office, 2018). The European Union (EU) milk quota which limited milk production was abolished in 2015 (Dept of Agriculture Food and the Marine, 2015). To benefit from this, the number of dairy cows in Ireland has expanded significantly in the last decade, from just over 1 million cows in 2010 to 1.4 million cows in 2017 (Duffy et al., 2019). This number is projected to increase to over 1.6 million cows by 2025 (Kelly et al., 2017). The FoodWise 2025 strategy, which is the Irish food industry plan for future growth in agri-food, aims to focus on an export-driven market with a particular emphasis on the emerging markets in Asian and African countries (Dept of Agriculture Food and the Marine, 2015).

China has been a major market for Ireland, with exports of approximately 10,000 tonnes of breast-milk substitutes to China in the first three months of 2020, and a similar amount in the same period in 2019 (Zhouqiong, 2020). Increasing demand in China has been driven by a drop in breastfeeding rates compared to previous generations (UNICEF, 2021), and loss of confidence in local producers (Tang et al., 2014). Expansion of the Chinese market has also been driven by the increase in products marketed as 'follow-on' and 'toddler' milks (Baker et al., 2016). Although such milks are outside the scope of this study, they are a significant part of the breast-milk substitutes market. Although such milks are outside the scope of this study, they are a significant part of the breast-milk substitutes market in China as approximately three quarters of sales are of such follow-on milks (Dadhich et al., 2021).

3.2. An analytical framework for modelling infant feeding

Energy systems models are mathematical representations of a country or region's energy system, explicitly distinguishing sources of supply, transformation, and energy service demands. They are commonly used for energy planning, particularly for long-term decarbonisation at the national level (Balyk et al., 2019;Ó Gallachóir et al., 2012) and form the backbone of many of the Integrated Assessment Models (IAMs) which inform the Intergovernmental Panel on Climate Change (IPCC) assessments on meeting the Paris Agreement targets (Masson-Delmotte et al., 2018). Under the current IPCC methodology, the emissions associated with producing breast-milk substitutes are accounted for in the country and sector of production rather than those of consumption. Similarly, where bioenergy is used for energy consumption, it is considered zero emissions in the Energy sector, as the emissions would already be captured within the Agriculture, Forestry and Other Land Use sector (IPCC, 2019a).

This section will consider an analytical framework related to breastfeeding in energy systems models, based on the existing carbon accounting system in place in energy modelling (See Fig. 1) (Ó Gallachóir et al., 2012). To estimate the impact on energy systems models, the consumption of breast-milk substitutes per child must be estimated. Following the nomenclature normally used in IPCC National Inventory, the emissions from breast-milk substitutes consumption can be estimated as follows:

Equation 1: Breast-milk substitutes consumed per country

$$F_{Ccn} = N * \sum_{M1}^{M12} (1 - EBF_{Mn}) * F_{Mn}$$

Where:

F_{Ccn} = Breast-milk substitutes consumed in country of consumption C_{cn}, (kg product per year)
N = Average number of infants born in a country of consumption
EBF_{Mn} = Fraction of infants exclusively breastfed in country of consumption in month n, dimensionless
F_{Mn} = Mass of breast-milk substitutes consumed in country of consumption in month n per infant, (kg product $child^{-1}$ $month^{-1}$)

Equation 2: Fuel consumption in country of production as a result of breast-milk substitutes production per country, based on (Finnegan et al., 2017b)

$$E_{C_{pn}} = F_{C_{pn}} * (E_{TH_{NG}} + E_{TH_{HFO}} + E_{TH_{LFO}} + E_e + E_{TH_{OF}})$$

Where:

$E_{C_{pn}}$ = Fuel consumption in country of production C_{pn}, MJ
$F_{C_{pn}}$ = Breast-milk substitutes produced in country of production C_{pn}, kg product
$E_{TH_{NG}}$ = Natural gas energy demand per kg product, MJ kg^{-1} product
$E_{TH_{HFO}}$ = Heavy fuel oil energy demand per kg product, MJ kg^{-1} product
$E_{TH_{LFO}}$ = Light fuel oil energy demand per kg product, MJ kg^{-1} product
E_e = Electricity energy demand per kg product, MJ kg^{-1} product
$E_{TH_{OF}}$ = Other fuel energy demand per kg product, MJ kg^{-1} product

The emissions from breast-milk substitutes can then be calculated by multiplying the breast-milk substitutes consumed in the country by the emissions associated with the production of breast-milk substitutes in the country of origin.

Equation 3: Emissions from consumption of breast-milk substitutes per country

$$e_{Cpn} = \sum_{C_{cn}}^{C_{C1}} F_{Ccn} * MC_{pn} * ef_{(f, C_{pn})}$$

Where:

e_{Cpn} = Annual emissions from consumption of breast-milk substitutes produced in country of production C_{pn}, kg $CO_{2\text{-eq}}$ yr^{-1}
F_{Ccn} = Breast-milk substitutes consumed nationally in country of consumption C_{cn}, kg product
MC_{pn} = Fraction of breast-milk substitutes consumed in country of consumption C_{cn} that was produced in country of production C_{pn}, dimensionless
$ef_{(f,Cpn)}$ = Annual emission factor for production of breast-milk substitutes in country of production C_{pn}, kg $CO_{2\text{-eq}}$ kg^{-1} product

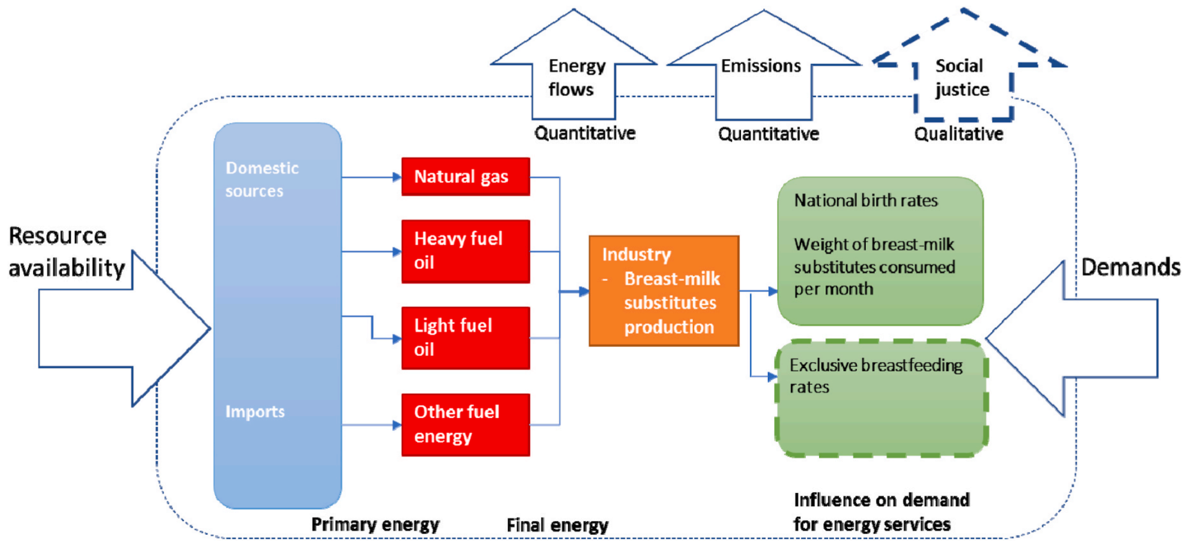

Fig. 1. Proposed analytical framework schematic.

3.3. Data and assumptions

The overall life cycle emissions associated with milk powder production in Ireland are 9.731 kg $CO_{2\text{-eq}}$ kg^{-1} product on a cradle-to-factory gate basis (Finnegan et al., 2017a). The emissions associated with natural gas use are 0.75 kg $CO_{2\text{-eq}}$ kg^{-1} product (Finnegan et al., 2017b). Milk powder in the research by Finnegan et al. (2017a) and Finnegan et al. (2017b) refers mainly to whole milk and skim milk powders. Breast-milk substitutes are normally referred to as specialised nutrition powder by the dairy industry (Bord Bia, 2020). The analysis by Karlsson et al. (2019) estimated the carbon footprint of BMS production as 9.2 ± 1.4, 7.0 ± 1.0, 11 ± 2 and 8.4 ± 1.3 kg $CO_{2\text{-eq}}$ kg^{-1} BMS in New Zealand, USA, Brazil and France respectively. The data for Irish milk powder is assumed as the greenhouse gas emissions associated with Irish BMS production as it is broadly in line with emissions for production internationally. The potentially available renewable gas supply is based on a profitable scenario from O'Shea et al. (2017). This scenario describes 42 anaerobic digesters producing a total of 12 PJ renewable gas per annum from grass silage and cattle slurry at an approximate volatile solids ratio of 80% grass silage and 20% cattle slurry. When natural gas is displaced with renewable gas, it is assumed that the emissions associated with renewable gas are zero, as per the IPCC methodology (IPCC, 2019b).

Data on breastfeeding rates are available internationally from UNICEF (2021), and in national studies. UNICEF data used for China reported an exclusive breastfeeding rate of 20.8% in the first five months. In this study, it is assumed that this is the exclusive breastfeeding rate for the six months under consideration. The most current Irish information available came from the *ESRI Growing up in Ireland* longitudinal study (Layte and McCrory, 2014) which reported an initial exclusive breastfeeding rate of approximately 30% in month one that decreases to 2% by month six. For the Irish scenario, the volume of breast-milk substitutes consumed per infant is estimated and multiplied by the annual birth rate. The rate of consumption will likely change depending on the child, so standard guidelines are used to estimate the volume consumed. There is limited information on partial or mixed feeding, so this is not included in the study.

A key assumption made is that if the breastfeeding rate increases, formula consumption and therefore production will decrease accordingly. However, a standard challenge with modelling is that product consumption is not necessarily linked to production capacity. It is reasonable to assume that the capacity for production of breast-milk substitutes is greater than the actual demand. Therefore, a reduction in demand linked to breastfeeding may not lead to a direct corresponding reduction in production capacity. For simplicity, the assumption remains that if breastfeeding rates increase, then there will be a corresponding decrease in the production of breast-milk substitutes that is assumed to be proportional to current market share.

The analytical framework proposed considers only natural gas consumption in relation to production of breast-milk substitutes. Moving beyond energy modelling to incorporate emissions from agriculture (scope 3 emissions for the breast-milk substitutes industry) is more challenging. Karlsson et al. (2019) include the agriculture emissions associated with producing the product, and the additional calories consumed by the mother when breastfeeding (Karlsson et al., 2019). The diet of Irish mothers is assumed to be the same as the UK diet as the UK diet is most likely to resemble the Irish diet due to proximity and cultural relationships (Karlsson et al., 2019). In the scenarios considered here, the emissions associated with the increased calories consumed are considered total emissions given the global nature of world food markets.

In this case study, the emissions associated with natural gas energy demand is displaced. The scenarios consider the reduced emissions from displacing natural gas only, from reaching exclusive breastfeeding targets only, and then from a combination of reaching the minimum global nutrition target and displacing natural gas in the remaining product. Additionally, emissions associated with increased calorie consumption are considered. The emissions saved are then compared with emissions reduction targets for Ireland. The following scenarios are applied to both the Irish and Chinese market for breast-milk substitutes:

- Scenario 1: Potential emissions saved from decarbonising current consumption of product produced in Ireland with renewable gas
- Scenario 2: Potential emissions saved from achieving 50% EBF rate
- Scenario 3: Potential emissions reduction from achieving 50% EBF rate and displacing natural gas in remaining product

3.4. Introducing the principle of justice as non-maleficence

While some prioritise engagement with BMS manufacturers to reduce GHG emissions, alternative strategies arise from the principle of 'first do no harm' in relation to such environmental imperatives. We can systematically consider the variety of harms and benefits of changing support for breastfeeding by appealing to a principle of justice such as justice as non-maleficence, proposed by (Bufacchi, 2020) as follows:

The primary goal of just institutions in the distribution of goods and resources, opportunities and rights, is to fulfil a legitimate duty to reduce harm. Any harm that derives from the criteria of distribution being endorsed must be accepted by the parties being harmed, after due consultation and deliberation, to ensure that their voices have been heard, and their opinions duly acknowledged. (3)

The broad definition of harm that is considered within the scope of the principle of justice as non-maleficence is what Joel Feinberg calls a setback to welfare interests (Feinberg, 1984). These interests include exercising positive normal bodily functions, which Bufacchi (2020) indicates are covered by justice as non-maleficence, and which include breastfeeding.

Introducing the principle of justice as non-maleficence helps to draw attention to costs or harms that breast-milk substitutes are associated with, both in social and environmental terms. In this paper, it is employed to assign importance to the results and draw attention to the moral implications of the engineering intervention. The principle applies in this instance with respect to the public health implications of breastfeeding, the well-being of the mother and child, and parenting values and practice. While the decision between breastfeeding or breast-milk substitutes is an individual decision, it is made in a context that is not always fully supportive of the decision that is made, whether materially or culturally. Due to these harms, the environment in which this decision is made is subject to questions of ethics and justice. Indeed, we endorse a stronger claim: that practically supporting the decision to breastfeed for those who are able can contribute to both social and climate justice, and that this support can contribute to more sustainable, population-level health. In particular, the principle of justice as non-maleficence is applied on the basis that decarbonising production will lead to harms due to a potential increase in the social licence of the product and associated marketing methods used.

The potential interactions between breastfeeding and the social licence of breast-milk substitutes can be traced, noting that the breastfeeding relationship and influences on it can be complex (Fig. 2). In relation to the agri-food sector, price and 'greenness' are factors in consumer decisions that can influence supply chain design to optimize both profits and sustainability (Cao et al., 2020). In addition, companies in the food and beverage industry and other sectors that address sustainability challenges either directly or indirectly can significantly outperform business-as-usual scenarios in terms of reputation and social licence (Gray et al., 2020). The term 'social licence' has origins in the extractive industries and is understood in place when a company's activities are seen as acceptable and legitimate by the local community and other stakeholders (Dumbrell et al., 2020). A key concern is that decarbonising the production of breast-milk substitutes without addressing the associated agricultural emissions is problematic because it potentially increases social licence. This greater social licence could lead to further increases in consumption of breast-milk substitutes and associated decreases in breastfeeding, a larger carbon footprint, and even greater demands on agricultural production.

Furthermore, once the demand for renewable gas for production of breast-milk substitutes is established, the renewable gas industry has the potential to become dependent in turn on the aggressive promotion of breast-milk substitutes that undermines the breastfeeding experience for many mothers. The production of renewable gas could therefore become 'locked-in' to the production of breastmilk substitutes. All these potential implications of increased social licence are negative; and combined may be even more so.

4. Results

4.1. Availability of renewable gas in relation to BMS production energy demand in Ireland

To make a credible claim of zero carbon (scope 1 emissions) processing of breast-milk substitutes, a steady and reliable supply of renewable gas will need to be in place, with contracts to provide a guarantee of supply. A potentially profitable scenario for renewable gas in Ireland was described by O'Shea et al. (2017) as 42 anaerobic digesters producing 12 PJ per annum of renewable gas from grass silage and cattle slurry. One such digester could generate approximately 54 GWh per annum, equivalent to a 2 MW_e facility producing electricity at 35% efficiency, which equates to 194,400 GJ per annum. One large breast-milk substitutes plant can secure a steady supply from four anaerobic digesters producing biomethane for grid injection (See Box 1). There are four major breast-milk substitutes manufacturing plants in Ireland. Assuming a typical large plant produces 40,000 tonnes of milk powder per year, this equates to a maximum thermal energy demand of 5.44 kWh (or 19.6 MJ) kg^{-1} milk powder produced (Finnegan et al., 2017a).

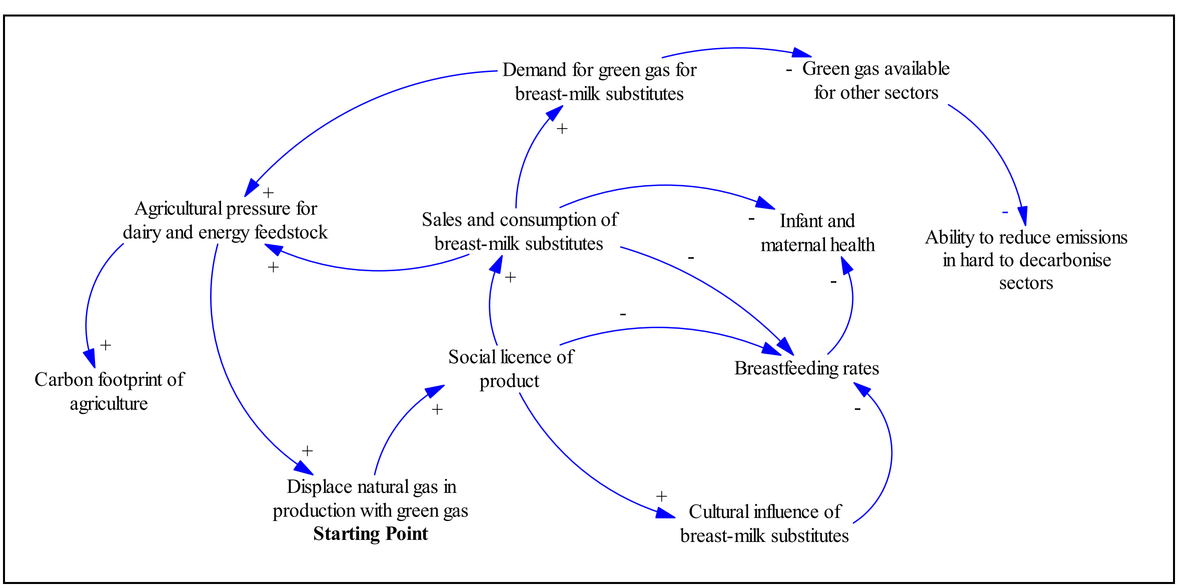

Fig. 2. Potential impacts of decarbonising breast-milk substitutes with renewable gas.

Box 1
Calculation of average number of anaerobic digesters required for production plant

Plant production = 40,000 tonnes milk powder
Maximum energy demand = 19.6 MJ kg^{-1} milk powder
Total thermal energy requirement: 19.6 MJ kg^{-1} milk powder * 40,000 tonnes milk powder = 784,000 GJ
From O'Shea et al. (2017):
Digester treating 76 kt wet weight feedstock per annum with a volatile solids ratio of 4.2:1 Grass silage: Cattle slurry = 194,400 GJ per annum
Number of anaerobic digesters providing energy = 784,000 GJ/194,000 GJ = 4

4.2. *Emissions reduction from improved breastfeeding rates*

4.2.1. *Consumption of Irish products in Ireland*

The average breast-milk substitutes consumption in the first six months, based on packaging guidance, is 23.84 kg per infant. In Ireland, the birth rate is approximately 60,000 infants born annually (Central Statistics Office, 2019). Considering Irish rates of exclusive breastfeeding (Layte and McCrory, 2014), approximately 1225 tonnes of breast-milk substitutes are consumed in Ireland in the first six months (Table 1). If the global nutrition target of at least of 50% (WHO/UNICEF, 2014) of infants exclusively breastfed for at least six months were reached, the consumption is reduced to approximately 715.2 tonnes (Table 1).

4.2.2. *Consumption of Irish products in China*

The data available on exclusive breastfeeding rates for China is less detailed than that available for Ireland so a total EBF rate is used to estimate consumption. Given the larger share of consumption in China it is expected that reaching the global nutrition target would result in a greater emissions reduction. The current estimated annual consumption of Irish breast-milk substitutes in China is 40,000 t BMS (Zhouqiong, 2020). Therefore, approximately 20,000 t BMS have been assumed to be consumed over the first six months, noting that information on the type of product exported is not available. This consumption is assumed to decrease on a pro-rata basis as exclusive breastfeeding increases from the current rate of 20.8% (UNICEF, 2021) to the minimum target of 50% EBF. The potential consumption of Irish breast-milk substitutes in China is 12,626 tonnes of product [(20,000/79.2%)*50%].

4.2.3. *Emissions savings*

For both markets, the emissions savings achieved from achieving the minimum 50% EBF target are greater than decarbonising the current consumption with renewable gas alone. The emissions savings are the greatest when a combination of effort is utilised to achieve the global nutrition target and decarbonise the product. This remains the case when the diet of the mother is considered. The results of the empirical analysis are presented in Table 2. Ireland has committed to reduce its GHG emissions by 51% in compared to 2018 by 2030; this gives an emissions savings target of 31,077 kt $CO_{2\text{-eq}}$ (Duffy et al., 2020; Government of Ireland, 2021). The potential emissions saved from achieving the 50% EBF rate in China and decarbonising the natural gas demand of the remaining product could contribute towards 0.26% of this target in 2030.

4.3. *Applying the principle of justice as non-maleficence*

In addition to the physical health benefits, Brown (2018) has argued that, for women, breastfeeding has intrinsic value beyond the achievement of basic nutrition for their infant. It is a means of parenting, of bonding with the child, and provides a sense of achievement for meeting their goals as a mother. These values must be recognised as an intrinsic part of mothering for those who aspire to breastfeed. Mothers who do not achieve their breastfeeding goals may be affected by depression, anxiety, pain and guilt, and conversely, mothers who choose not to breastfeed are negatively affected by messaging that breastfeeding is the safest and best option for infant feeding (Fahlquist, 2016). This messaging can also negatively impact mothers who choose to breastfeed, when expectations are raised without breastfeeding support and protection to realise this aspiration (Brown, 2018).

The influence of the breast-milk substitutes industry can have a negative effect on the breastfeeding experience of mothers. The harms that are the focus in this discussion are related to health, society, and the environment. Our claims are, firstly, that in each context there are harms associated with breast-milk substitutes; and secondly, that these harms

Table 1
Comparison of current breast-milk substitutes consumption in Ireland and Exclusive Breastfeeding Rate (EBF) of at least 50% (WHO/UNICEF, 2014) (WHO Nutrition Target).

Time period of feeding by Age	Consumption (kg)	Exclusive Breastfeeding Rate (EBF)	1-EBF_n	Consumption per child in time period (kg)	Number of infants	Consumption in country (tonnes)
						Current consumption
<2 weeks	1.16	0.32	0.68	0.79	–	47.3
2–4 weeks	1.29	0.304	0.696	0.9	–	53.8
4–8 weeks	3.45	0.24	0.76	2.6	–	157.3
8–12 weeks	4.14	0.2	0.8	3.3	–	198.7
3–4 months	4.14	0.12	0.88	3.6	–	218.6
4–5 months	4.83	0.08	0.92	4.4	–	266.6
5–6 months	4.83	0.024	0.976	4.7	–	282.8
Total	**23.84**			**20.42**	**60,000**	**1225.2**
						WHO Nutrition Target
0–6 months	**23.84**	**0.5**	0.5	**11.92**	**60,000**	**715.2**

Table 2
Comparison of emissions saved.

Emissions per product	Irish Market	Chinese Market	Unit
e_{NG} = Emissions associated with natural gas energy demand per kg product = 0.75 kg CO_2 kg^{-1} product (Finnegan et al., 2017b)	0.75	0.75	kg CO_2 kg^{-1} product
$ef_{(f,Cpn)}$ = Annual emission factor for production of breast-milk substitutes in country of production C_{pn}, kg $CO_{2\text{-eq}}$ kg^{-1} product = 9.731 kg $CO_{2\text{-eq}}$ kg^{-1} milk powder (Finnegan et al., 2017a); this includes emissions associated with natural gas	9.731	9.731	kg CO_2 kg^{-1} product
Consumption per market			
Current consumption of product produced in Ireland	1225.2	20000	tonnes of product
Estimated consumption if minimum target of 50% EBF is reached	715.2	12626	tonnes of product
Potential reduction in consumption	510	7374	tonnes of product
GHG Emissions Saved – Energy only			
Scenario 1: Potential emissions saved from decarbonising current consumption of product produced in Ireland with renewable gas	918.9	15000	t CO_2
Scenario 2: Potential emissions saved from achieving 50% EBF rate	4963	71756	t CO_2
Scenario 3: Potential emissions reduction from achieving 50% EBF rate and displacing natural gas in remaining product	5499	81226	t CO_2
GHG Emissions Saved – Energy and agriculture			
Carbon footprint from the average diet in each consumption case country (Karlsson et al., 2019)	6.9	6.5	kg CO_2 kg^{-1} product
Total potential emissions saved from achieving 50% EBF rate, including increased diet of mother	1444	23825	t CO_2
Total potential emissions saved from achieving 50% EBF rate, including increased diet of mother, and displacing natural gas in remaining product	1980.4	33294.5	t CO_2

will be exacerbated if greater social license is granted to breast-milk substitutes via decarbonised production, with a greater demand for breast-milk substitutes a potential risk. After discussing these harms, this section concludes by considering the role of public deliberation.

The public health harms of breast-milk substitutes involve both health losses to the mother and the infant, and increased mortality rates. We recognise that there are cases where breast-milk substitutes may be medically necessary; however, major health organisations indicate clearly that we are in a global context with too little breastfeeding as opposed to too much (WHO/UNICEF, 2014). The social harms of breast-milk substitutes involve the costs to mothers of removing the maternal identity associated with breastfeeding. Lessening chances for bonding and experiencing a normal bodily function are significant potential harms (Brown, 2018).

While many reasons point towards encouraging breastfeeding as opposed to feeding with breast-milk substitutes, one obvious concern is that diverting renewable gas to other uses would harm the breast-milk substitutes industry, because it would reduce potential options to lower Scope 1 emissions, such as direct on-site emissions from natural gas combustion associated with production. However, there are important considerations which point against drawing this conclusion, namely, that the process has not yet occurred; renewable gas is not currently used in the production of breast-milk substitutes in Ireland. It would be harmful to the industry if it had already implemented renewable gas in the production chain at scale; however, since it has not yet done so, it is relatively undisruptive to divert it at this point to, for instance, freight transport, which is responsible for 14% of transport emissions in Ireland (SEAI, 2020) and has limited existing options for decarbonisation (Gray et al., 2021).

The health concerns are exacerbated by the potential social licence that could accrue from decarbonising breast-milk substitutes which may increase demand for the product when compared to the current manufacturing process. The potential preferrable route for green gas in transport justifies removing the sustainability endorsement of using renewable gas for breast-milk substitutes, since increased demand can be expected to increase the health, social and environmental harms associated with the product. Indeed, the case is worse because increasing the social licence for breast-milk substitutes produced in Ireland is likely to add to their potential overconsumption. Even if green gas had already been implemented at scale, we believe these various social harms decisively outweigh benefits to industry. However, given that renewable gas has not been pursued at scale by the dairy industry, the case is more straightforward.

Some may disagree with the evaluation so far. This brings us to the second part of Bufacchi's principle: the role of public deliberation. In this context, there are two special concerns about putting the use of renewable gas to produce breast-milk substitutes to public deliberation. The first concern is that one of the primary impacted groups potentially affected by increases or decreases in breastfeeding is infants, who clearly cannot advocate for themselves. While parents and the medical community could advocate on behalf of infants, there is a large disparity between the financial and social power of large manufacturers of breast-milk substitutes and these groups. The power dynamic between industry and the medical community of doctors, nurses and midwives is complicated by the role that manufacturers assume in influencing medical practice through sponsorship of research and events (Save The Children, 2018). The capacity and resources of manufacturers to advocate for their product can be expected to be far greater than that of parents. For these reasons we should expect that having others advocate for infants and their mothers or not having their needs represented would systematically underestimate the benefits of breastfeeding. This reason justifies avoiding public deliberation on this policy choice.

5. Discussion

The analysis shows that the emissions savings achieved by meeting the minimum WHO nutrition target of 50% are much greater than the emissions saved from fossil fuel substitution alone in the processing stage. While producers of breast-milk substitutes can accurately report that production is lower carbon for Scope 1 emissions when renewable gas is used, the remaining Scope 1 emissions and emissions from agriculture and transport (Scope 3 emissions) would still need to be offset. Equations 1, 2 and 3allow us to estimate the potential emissions reduction from increasing the share of breastfeeding and reducing the emissions associated with breast-milk substitutes. When emissions associated with food processing are explicitly represented in energy modelling it possible to incorporate breastfeeding rates. It can therefore be recommended to consider the breastfeeding support required to meet WHO nutrition target no. 5 a demand-side measure in the energy transition, while remaining cognisant of reproductive rights in policy recommendations.

A focus of this work was to consider decarbonising the processing of breast-milk substitutes as an appropriate end-use for renewable gas. We suggest that decarbonising a single product type will need to be considered in the context of the wider energy system of multiple products and energy uses. Green gas will be a limited resource that can address the decarbonisation needs of heavy transport systems that have limited decarbonisation options (Gray et al., 2021). The transport sector could be considered a priority for this resource as a result. For the dairy sector, alternatives such as wood chips are an option to meet the remaining energy demand once global nutrition targets are met. The principle of justice as non-maleficence would also be applicable in this case also, and as such, is a relevant consideration for future research.

The analysis established that the harms associated with marketing of breast-milk substitutes will increase if the product processing is decarbonised with renewable gas, which is not aligned with a just transition. The authors do not suggest that manufacturers should not aim to reduce emissions. The onus is on the regulatory environment to apply measures already in place such as the WHO code and to take practical steps to protect and support breastfeeding. Where efforts are made to decarbonise the product, then efforts to protect and support breastfeeding can make a legitimate claim to access just transition funding. Just transition funds are a means of assisting groups of people that are adversely affected by the low carbon transition (Green and Gambhir, 2020). The emissions analysis demonstrated that the greatest saving can be achieved through a combined effort of meeting the WHO minimum nutrition target and decarbonising breast-milk substitutes. Where this effort takes place in tandem, prioritising meeting breastfeeding targets is compatible with the principle of justice as non-maleficence.

5.1. Uncertainties, limitations, and further research

This study establishes an analytical framework to incorporate breastfeeding and breastfeeding support and protection into energy system models. While this study considered only the first six months of infant feeding, future work could explore potential emissions savings from decarbonising the 'follow-on' and 'toddler' milks which are driving market growth. Further research to apply the principle of justice as non-maleficence to these 'follow-on' and 'toddler' milks is potentially important given the difference in the nature of the product and the context in which these products have been developed.

This paper sought to move beyond emissions and consider the social justice elements of the energy transition. The principle of justice as non-maleficence applied in this case could be applied when considering the justice implications of decarbonising a wide range of 'status quo' or business as usual scenarios.

6. Conclusions

The analysis in this paper finds that when decarbonising production of breast-milk substitutes in Ireland with renewable gas is compared with reaching WHO minimum breastfeeding targets in key countries of consumption, the GHG emissions savings are far greater when breastfeeding targets are reached. If the WHO minimum breastfeeding target is reached in China and the remaining product demand is decarbonised with renewable gas, 81 kt $CO_{2\text{-eq}}$ will be saved. This is 0.26% of Ireland's GHG reduction target for 2030. This is applicable for the first 6 months of infant feeding. The analysis also demonstrates the link between breastfeeding rates and GHG emissions associated with consumption of breast-milk substitutes. Breastfeeding rates will have an influence on the demand for energy services associated with breast-milk substitutes; therefore, this influence needs to be incorporated into energy models.

A contention of this paper is that, although fuel-substitution with renewable gas appears to be a solution for decarbonisation, it does not necessarily align with social long-term value. When women are not supported to reach their breastfeeding goals, and breast-milk substitutes are decarbonised, then decarbonising breast-milk substitutes does not meet the principle of justice as non-maleficence. Thus, breastfeeding support can simultaneously be a public health and a climate justice issue. Consequently, breastfeeding support programmes can make a legitimate claim to access to just transition funds. Positioning access to breastfeeding support as a climate justice issue can mitigate the concern with jeopardising women's reproductive rights or interfering with their individual choices. Furthermore, understanding that both breastfeeding or use of breast-milk substitutes are functionally different and reproductive rights (Karlsson et al., 2019; Williams et al., 2019) will be imperative to discussing implications in modelling.

CRediT authorship contribution statement

Aoife Long: Conceptualization, Writing – original draft, Project administration. **Kian Mintz-Woo:** Writing – original draft, Conceptualization, Writing – review & editing. **Hannah Daly:** Writing – original draft, Writing – review & editing. **Maeve O'Connell:** Writing – original draft, Writing – review & editing. **Beatrice Smyth:** Conceptualization, Writing – review & editing, Supervision. **Jerry D. Murphy:** Resources, Writing – review & editing, Supervision, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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