Hagrannsóknir sf

The EU Emission Trading Scheme, Icelandic Aviation and Tourism
– Final Report –

25.05.2026

Foreword

On January 19 Hagrannsóknir sf agreed to provide technical assistance to the Icelandic Travel Industry Association (SAF) in assessing the potential impacts of the European Union‘s Emissions Trading Scheme (ETS) on Iceland‘s commercial aviation and tourism industry. For this purpose, SAF requested, among other things, the application of Hagrannsóknir’s macro-economic models to estimate the numerical impacts of the ETS on key macroeconomic variables in Iceland.

At SAF’s request, a preliminary incomplete draft report was handed in on February 25. The current report represents the final version of our report.

On behalf of Hagrannsóknir, Dr. Ragnar Arnason, professor emeritus, Dr. Marías H. Gestsson, docent and Eðvarð I. Erlingsson M.Sc. (econ) have prepared this report.

For Hagrannsóknir sf

Ragnar Arnason

Acknowledgements

We would like to thank several individuals who provided valuable assistance in preparing this report including Ingólfur Friðriksson Deputy Director General, European Affairs Ministry for Foreign Affairs, Marta Mirjam Kristinsdóttir. Head of Division at the Ministry of Environment, Energy and Climate, Einar Halldórsson, Team Leader at the Icelandic Environment and Energy Agency and Stefán Már Stefánsson, Professor emeritus at the University of Iceland. Needless to say, any remaining errors this report may contain are solely the responsibility of Hagrannsóknir.

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Executive summary

The following summarizes key findings of this report. The supporting arguments can be found in the chapters indicated in square brackets and references therein.

1. The European Union (EU) Emissions Trading System (ETS) was established in 2005. [Chapter 2]
2. Iceland formally joined the ETS in 2007. Icelandic aviation has been subject to the ETS since 2012. [Chapter 1]
3. The ETS is a variant of so-called cap and trade systems which are extensively studied in economics. [Chapter 2.1]
4. Under certain conditions, cap and trade systems can attain allocative efficiency. [Chapters 2.1 & 2.3]
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18. The ETS as it is currently operated:
    (i) Significantly reduces the international competitiveness of both Icelandic aviation and the Keflavik airport as an international commercial airport. [Chapters 2.4.3 & 3.4]
    (ii) To some extent reduces the competitiveness of Icelandic aviation relative to its European competitors. [Chapter 2.4.3 & 3.4]
    (iii) Reduces the international competitiveness of the Icelandic economy [Chapter 2.4.3]
19. There is a significant risk that the ETS, as it is currently implemented, will lead to a substantial reduction in Icelandic aviation. [Chapter 3.5]
20. The detrimental impacts of the ETS on Icelandic aviation and tourism may be alleviated by a judicious allocation of free GHG emission rights to airlines. [Chapter 4]

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1. Introduction

In an attempt to reign in global warming, many of the world's industrialized nations[1] including the EU, have committed to reducing their greenhouse gas (GHG) emissions by a certain percentage by certain dates. For this purpose, the EU has adopted a number of policies of which the emissions trading scheme (ETS) is one.

Apparently on account of its membership of the European Economic Area (EEA), Iceland formally joining the ETS in 2007 with her aviation sector becoming under ETS restrictions in 2012 (Minister of the Environment 2025). In several respects, however, Iceland's situation differs markedly from that of most EU member countries. For that reason, both the EU's GHG reduction commitments and the ETS are not well-suited to Iceland.

1.1 Iceland's natural conditions

Iceland is small island of 103 thousand km^2 and population of only 390 thousand.[2] The island is located in the north Atlantic bordering the Arctic circle and geographically quite isolated. The nearest country is Greenland and the flight time from Reykjavik to Greenland's capital, Nuuk, is 2.5 hours. The distance from Reykjavik to Bruxelles is 2100 km. with flight time about 3.5 hours. The climatic conditions are adverse. Iceland is a cold and windy country.

With respect to energy needs, Iceland is disadvantaged in many ways. Adverse climate conditions make it necessary to expend much energy for heating. Low population and relative isolation mean that the domestic market is small and transportation costs to larger markets are high. Therefore, Iceland's industries can generally not attain the economies of scale necessary to become internationally competitive. As a result, Iceland's industrial structure is quite simplistic. Manufacturing industry, processing final goods from raw material inputs, so important in Europe and industrialized countries generally, is virtually nonexistent in Iceland. The dominant base industries (i) fisheries, (ii) the so-called power intensive industries consisting of aluminium and ferro-silicon smelting, and (iii) tourism, largely based on Iceland‘s unique landscape, are all natural resource-based. Because of simple industrial structure, Iceland needs to import most necessities and export most of its products. This means that the country is totally dependent on effective transportation to and from its trading partners which, due to the location of the country and long distances, must be either by shipping or aviation. This means that the costs of transportation are high and, because no reasonable substitutes for the use of fossil fuels in aviation and shipping currently exist, its GHG emissions are unavoidably high.

On top of this, the island of Iceland is highly volcanic with many of the most active volcanos located in the glaciers which cover over 10% of its surface. The country, therefore, is prone to natural disasters, volcanic ash fall, lava flows, floodings and earthquakes. Only a couple of years ago (in 2024), a town containing over 1% of the population had to be vacated because of earthquakes and lava flows. 50 years ago, another volcanic eruption virtually within a town on a small island off the Icelandic south coast necessitated a speedy emergency evacuation of the entire population of over 1% of the entire Icelandic population from the island. Other similarly disastrous natural disasters or worse have occurred in the past. This is of relevance

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[1] But by no means all. Thus, the US, Canada, China, India and Russia have not taken on such commitments.

[2] At the beginning of 2025 according to Statistics Iceland (2026).

in this report because it demonstrates the vital importance of an effective and speedy transportation system covering all parts of Iceland.

1.2 High degree of renewable energy use

Iceland is endowed with considerable natural energy resources, primarily of the hydrographic and geothermal variety. Over the past 80 years or so, Iceland has invested heavily in these energy sources replacing fossil fuel use with renewable energy. Virtually all of Iceland's energy needs apart from those for transportation are currently met by these renewable energy sources. Therefore, in spite of its cold climate, geographical remoteness and other causes of uncommonly high energy needs, Iceland has one of the lowest GHG emissions per unit of energy produced. In fact, according to official estimates, about 85% of the total primary energy use in Iceland is derived from domestically produced renewable energy sources. (Government of Iceland, https://www.government.is/topics/business-and-industry/energy/). This, according to the same source, is the highest share of renewable energy in any national energy budget.

Unfortunately for Iceland, most of these accomplishments were completed before the national reference-points for GHG emission reductions (generally those in the year 1990) were set. Therefore, if Iceland is supposed to reduce its GHG emissions relative its emission level in 1990, it appears that the country is being penalized for replacing much of its fossil fuel use by low GHG emission renewable sources too soon!

It may also be noted that Iceland's GHG emissions are tiny compared to the EU. In 2024, according to EDGAR's data bank[3], Iceland's GHG emissions were only 0.14% of those of the EU-27. Subtracting the GHG emissions of the above-mentioned power intensive industries, which is eminently reasonable (see section 1.4 below), this fraction is reduced to about 0.08%.[4] This means that reductions in GHG emissions in Iceland have a negligible impact on Europe´s total emissions.[5] Even if all GHG emissions were to be ended, the impact on total Europe emissions would hardly be noticeable.

1.3 Difficult for Iceland to reduce GHG emissions further

Since Iceland is already primarily using renewable energy sources and the remaining renewable energy using activities, mostly shipping and aviation, do not have economical technical substitutes for their GHG emitting inputs, it can be argued that GHG-reduction arrangements (like the Kyoto protocol and the Paris Agreement) that require the same percentage reduction in GHG emissions of all countries are extremely unfair to Iceland.

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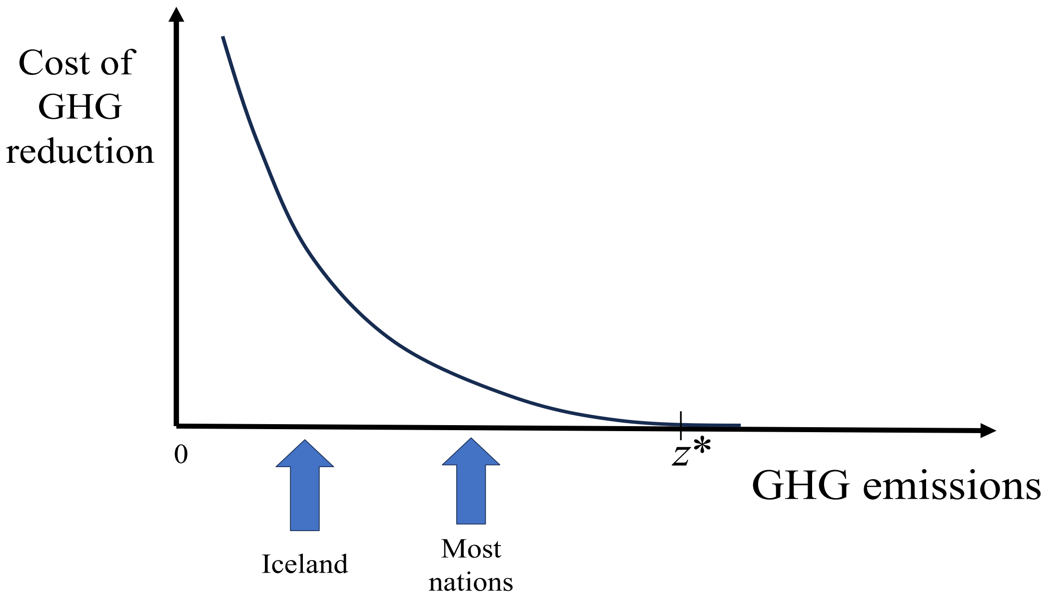
[3] EDGAR (Emissions Database for Global Atmospheric Research) is the EU GHG Database, developed and maintained in collaboration between the European Commission, Joint Research Centre (JRC) & the International Energy Agency (IEA).

[4] According to EDGAR (2026), Iceland's total GHG emissions in 2024 were about 4.280 and about 2.390 Mt CO2eq without the power intensive industries while EU-27 GHG emissions were about 3164.7 Mt CO2eq in the same year.

[5] It may be further noted that Iceland's population is about 0.09% of that of the EU-27. Thus, GFG emissions per capita in Iceland without the power intensive industries are significantly smaller than those of the EU-27.

According to well-established facts of production (diminishing returns to a factor), it becomes increasingly difficult and, therefore, increasingly costly to reduce GHG emissions the closer to zero emissions one gets. Therefore, it should be clear that Iceland, which has already replaced fossil fuels by renewable hydro and geothermal resources for most of its energy use apart from transportation, will find it much more costly to reduce her GHG emissions by the same relative amount as countries that lag far behind Iceland in the adoption of clean energy sources. This point is illustrated in figure 1.1.[6]

Figure 1.1
The cost of GHG emissions reduction



In the diagram in figure 1.1, the horizontal axis measures the amount of GHG emissions (or fossil fuel use). The vertical axis measures the cost of reducing GHG emissions (marginal cost of less emissions, see appendix E). Left to themselves the emitters would emit at z^* where their costs are minimized (benefits maximized). Reducing emissions from this level is costly and, as indicated in the diagram, this cost increases the closer to no emissions one gets.

Now, as mentioned above, most nations primarily use energy sources with much higher GHG emissions than Iceland does. Therefore, they are placed a relatively short distance from z^* along the horizontal axis in figure 1.1. Iceland, by contrast, uses renewable low GHG-emitting energy sources for most of her energy needs. Therefore, Iceland is much further along the horizontal axis to zero GHG emissions than most other countries. It follows that the same percentage reduction in GHG emissions may be much more costly for Iceland than for other countries.

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[6] A formal argument is provided in appendix E.

1.4 The power intensive industries

The power intensive industries, in Iceland, aluminium and ferro-silicon smelting, account for about 44% of her GHG emissions and, thus, almost double the country's GHG emissions. However, since the energy used by these industries comes exclusively from renewable hydro and geothermal energy resources, their GHG emissions (which stem from the smelting process) are much, about 60-70%, less than they would be if the same factories were based elsewhere and run, as is most common around the world, on fossil fuel energy. Therefore, if these Icelandic smelting factories were to be closed down to meet EU's GHG policies, the international demand for their products implies that they would just be replaced elsewhere in the world and global GHG emissions would not decline but increase.

This shows that instead of adding the remaining GHG emissions from the power intensive industries to Iceland's emissions, a much more reasonable procedure would be to award Iceland with GHG credits for the reduced GHG emissions of these factories due to them being fueled by Iceland's renewable energy. Given that the GHG emissions from the power intensive industries is currently about 44% of Iceland's total GHG emissions (EDGAR 2026) and about that 60% of GHG emissions from aluminium smelting comes from the energy used in the process (International Aluminium 2026), it is easy to check that around 26% of Iceland's currently measured GHG emissions should be discounted for this reason.[7]

1.5 Organization of the report

The rest of this report is not concerned with the appropriate GHG policies for Iceland, but only the impact of the ETS on its aviation and tourism sector. Section 2 considers the ETS and its inherent properties. Chapter 3 examines the impact of the ETS on Icelandic aviation and tourism. Chapter 4 suggests modifications of how the ETS is implemented relative to Iceland.

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[7] Let x denote GHG emissions from a smelter run on fossil fuel energy and let y denote the GHG emissions if the smelter is run on renewable energy. Then, the difference in running the smelter on renewable energy in Iceland compared to running it elsewhere on fossil fuels, obviously implies the net GHG emissions $(x-y)-x=-y$, i.e. a reduction of GHG emissions by y! So, if $y=0.6$ and smelters account for 0.44 of Iceland's GHG emissions, the reduction in GHG by running the smelters in Iceland is $0.6\cdot 0.44\approx 0.26$.

2. The ETS and its properties

At Kyoto in 1997 and subsequent international climate conferences (including the Paris Agreement in 2015), the EU committed to a substantial reduction in GHG (Greenhouse Gas) emissions compared to 1990 levels. Current EU reduction targets are 55% reduction by 2030 and climate neutrality, i.e. no net GHG emissions, by 2050 (see https://climate.ec.europa.eu/eu-action/climate-strategies-targets/2030-climate-targets_en).

Most GHGs emissions are not by governments but by households and firms. Therefore, to attain these objectives, the emissions of these private agents must somehow be curtailed. There are many ways to do this. The ETS (Emissions Trading System), established in 2005 (EU Commission 2026), is one of the main instruments chosen by the EU for this purpose.

2.1 ETS and cap and trade systems

The EU Emissions Trading Scheme or ETS is a variant of so-called cap-and-trade systems. The defining characteristics of cap and trade systems are that (i) there is a limit on the total quantity of a certain right (or asset) and (ii) units of this right (very small if desired) can be traded. As a result of trading, there will emerge a market price for the right reflecting its scarcity. If the market works sufficiently well, all active traders will equate their marginal benefits of obtaining and, therefore, holding or using the right to the same market price.

This kind of systems are well-known in economics and their properties have been extensively studied (see e.g. Debreu 1959, Arrow and Hahn 1971). Fundamentally they deal with situations where the total quantity of something valuable is given and what is left is to allocate it to economic agents by trading. This is the so-called pure trade situation in economic theory (Arrow and Hahn 1971). They are also the essence of numerous asset trading situations in real life such as stock, bond and commodities trading. Cap and trade systems, where the public managers impose the total quantity or cap have been applied in a variety of public management contexts, including fishing quota systems and systems of import quotas (Arnason, 1990, Skully 2001). In recent decades, cap and trade systems have been increasingly utilized for environmental management inter alia to control pollution and emissions of various types (Tietenberg 2016, Schmalensee and Stavins 2017).

In economic theory it is well-established that if the right (or asset) subject to a cap is (i) freely tradable, (ii) perfectly divisible, (iii) permanent and (iv) secure and an (v) efficient rights trading market exists and, the right (or asset) will be used in the most efficient way, i.e., so that the total benefits of using it will be maximized or, equivalently, the cost of the cap constraint minimized (Montgomery 1972, Stavins 1997, Arnason 2007). This, in economics, is often referred to as allocative efficiency (Layard and Walters 1978).

The potential allocative efficiency of cap and trade systems is the main justification for their increasing use in natural resource and environmental management in recent decades. From various EU publication this also seems to have been the main motivation for the adoption of the ETS.

2.2 The ETS: Basic features

The essentials of the ETS are quite simple. In any particular year, EU's objective of GHG emission reduction compared to the emissions in 1990 is translated into some level of total allowable GHG emissions for GHG emitters that are subject to the ETS system.[8] Let us, for convenience, refer to this level of total allowable GHG emissions in year t as $Q(t)$. These allowable emissions are then assigned to the various emitters as emission rights, the sum of which equals $Q(t)$. Emissions by an agent without the corresponding rights are illegal and subject to substantial penalties if detected.

Under the ETS, holders of emission rights are allowed to trade them. Trading in emission rights will generate a market price for the rights. If the allowable emissions are binding (less than emitters would like to emit) and the emissions trading market works sufficiently well, there will at each point of time be a unique, nonnegative trading price. According to economic theory, active emitters will then equate their marginal benefits of GHG emissions to this price. In that case, according to the general cap and trade theory, the economic benefits attainable from the total allowable GHG emissions under the ETS will be maximized. Equivalently, the total cost of complying with the GHG constraint under the ETS will be minimized. This is what is referred to as allocative efficiency in economic theory.

2.3 Does the ETS allocate emissions rights efficiently?

As mentioned above, economic theory has established that if emission rights are sufficiently strong[9] and an efficient rights trading market exists, the emissions rights will be used by the emitters in the most efficient way, i.e., so that the cost of meeting the overall emission constraint will be minimized (Montgomery 1972, Stavins 1997, Arnason 2007).

The essence of this finding can be easily explained in a simple setting. Consider two economic agents who obtain benefits from activities that emit GHGs. Let the total emissions by the two agents be subject to an overall emission constraint, Q, and assume the two agents hold transferable rights to emit summing to Q. Then, they will find it to their benefit to trade these rights until the marginal benefits of their emission generating activity are equal (which also happens to be the collectively optimal use of the emission rights). If the marginal benefits of emission generating activity are not equal, the one with the higher marginal benefits will find it advantageous to offer to buy emission rights from the other party emission at any price up to his marginal benefits of additional emission rights and the other party, the one with the lower marginal benefits, will find it to his advantage to sell emission rights at any price higher than his marginal benefits. Thus, if the marginal benefits of the two emitters are not equal, there is an opportunity for mutually advantageous trades and, therefore, the only equilibrium in the emission right market is where the two marginal benefits are equal. But this is also socially optimal allocation of the limited emission rights (Debreu 1959, Layard and Walters 1978)

This is the economic theory and it provides a justification for the employment of the ETS (EU Commission 2026). In reality, however, the way the ETS is set up and operated does not satisfy the requirements of the economic theory. There are several reasons for this. First, the

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[8] These are only a subset of all GHG emitters within the EU. Various other methods and measures are employed to curtail the GHG emissions of other emitters.

[9] That is to say, (i) freely tradable, (ii) perfectly divisible, (iii) permanent and (iv) secure.

rights are not permanent – if they are not used for emissions, they will certainly elapse when the system is ended, they may even elapse when the system is altered e.g. enters a new phase. Second, for the same reasons, the emission rights are not secure – the system may be revised or ended in which case any rights held may become valueless. Third, the trading market does not appear to be fully efficient – it charges a significant trading commission and the volatility of prices (see figure 2.4 below) suggests a lack of market efficiency.

Most fundamentally, however, the allocative efficiency of the ETS, such as it may be, is conditional upon the total allowable emission constraint that is set. If that is not set optimally, the allocation cannot be optimal either. Unfortunately, it is extremely unlikely that this total allowable GHG emission quantity under the ETS is set optimally. One easy way to see this is by applying the previous argument for the allocative efficiency of the ETS. That argument relied on a unique market price equating the marginal benefits of GHG emissions by the various emitters in the ETS system. However, as already mentioned, the ETS only covers a part of the EU GHG emissions. The other emissions are not subject to market trading. Hence, there is no market price to equate the marginal benefits of GHG-emissions of these other emitters to those within the ETS. Thus, the overall GHG emissions almost surely do not meet the requirements of allocative efficiency. As a result, the possible allocative efficiency within the ETS system is almost surely not allocative efficiency for EU GHG emissions as a whole. In other words, if the ETS were applied to all EU GHG emissions and it achieved allocative efficiency, the allocations to the current members of the ETS would almost surely be different. For individual emitters it might be much higher or much lower. For these reasons, whether the ETS system attains allocative efficiency within its own, somewhat narrow, confines, is beside the point. Seen from the wider perspective of all EU GHG emissions, not to mention those of the world as a whole, the GHG rights allocations within the ETS are almost certainly not economically efficient.

A related point is that there is no market price guidance to set the total allowable GHG emissions under the ETS correctly. Since the basic argument for the ETS is that it provides guidance to allocate GHG-emission rights optimally to the ETS participants, it follows that the same guidance is absent for allocating GHG emissions to the other emitters and, importantly, set the total GHG emissions for the ETS.

The problem is even more fundamental. GHG-emissions are believed to cause a globally collective harm. It follows there is a globally appropriate GHG emission reduction and a globally optimal allocation of emission rights to the various emitters. A global ETS might achieve this optimal allocation. A comparatively small ETS system for a part of the global emissions will almost surely not allocate these emission rights globally optimally even to its own participants.

2.4 Other important economic implications of the ETS

The ETS, even assuming it allocates allowable GHG emission rights efficiently amongst emitters, has other implications that are socio-politically disturbing as well as economically costly. These implications include (i) its distributional impacts, (ii) the possibility the ETS may lead to industrial collapses and regional shifts in economic activity, (iii) the impacts of the ETS on international competitiveness of industries and (iv) its actual impacts on GHG emissions in the world. The following discusses these implications in turn.

2.4.1 Distributional implications of the ETS

The ETS has income implications that in general affect companies, industries and countries unevenly (possibly even inequitably).

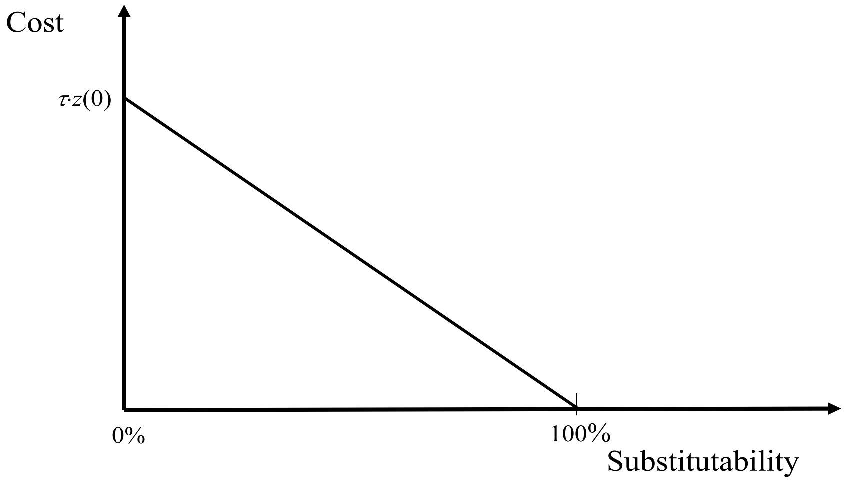
Broadly speaking, the greater the ability to substitute other inputs and/or methods for GHG emitting ones[10] is, the less is the income impact of the GHG restrictions and vice versa. Thus, economic agents (companies, households etc.) that can replace their GHG emitting activities at a low cost or close to costlessly, will experience very little reduction in net income from the GHG restrictions. They may even gain from the ETS system if they receive emission rights at below market prices. On the other hand, economic agents that can only substitute GHG emitting activities at high cost or, perhaps, not at all will experience a comparatively high reduction in net income from the GHG restrictions. For those agents, the ETS system will appear as a more or less fixed tax[11] amounting to the price of ETS-units multiplied by their inflexible or unchangeable emissions (for formal derivation of this finding, see appendix A especially A.3).

In appendix A it is shown that the basic relationship between the degree of substitutability (from 0 to 100%) and the cost experienced under the ETS is a negative one. That is to say, the higher the degree of substitutability is, the less cost does the ETS impose on the company. A simple linear relationship of this kind is illustrated in in figure 2.1 below.

Figure 2.1

Illustrative relationship between substitutability and cost of meeting ETS constraints

(Source: Appendix A)



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[10] This substitution ability is related to the concept of elasticity of substitution in standard economics (see e.g. Varian 1990, Silberberg and Suen 2001)

[11] Obviously, as far as the companies are concerned, ETS charges appears as excise taxes on emissions. To the degree that emissions are inflexible, this tax is like a fixed tax.

These results are formally derived in appendix A of this report.[12] Also, in that appendix it is shown that firms that can costlessly replace GHG emissions for other inputs (i.e., enjoy perfect economic substitutability with respect to GHG) will experience no cost from the ETS. In fact, as mentioned above, to the extent that they receive free emission rights, they will profit from the ETS. This is because they can replace their now expensive GHG emissions with other inputs at no cost while being able to sell their free emissions rights to producers less able to replace their GHG emissions with other inputs.

In appendix A it is also shown that firms that cannot replace their GHG emissions with other inputs either for technical reasons or because it is prohibitively expensive (i.e., have zero economic substitutability with respect to GHG) will suffer costs amounting to the price of the GHG emission rights multiplied by their (unchangeable) emissions. Thus, these companies will experience the ETS system as a new fixed tax on their operations.

So, it emerges that the ETS imposes greater financial burden on companies, industries and countries with low substitution possibilities. This seems unfair and an unreasonable sharing of the burden of GHG emissions reduction, which is supposed to benefit all, unless it is met by the appropriate compensation (e.g. correspondingly more free emission rights to those with limited substitution possibilities) which is not the case within the current ETS.

For small countries and regions with few alternatives (low population, few industries, relative geographical isolation etc.), substitutability is generally lower than in the other countries. Therefore, their burden imposed by the ETS will also be greater. For this reason, the ETS as it is currently operated may also be regionally and nationally unfair.

If GHG emission rights are allocated to emitters for free[13], this will of course alleviate their cost of the ETS. However, as explained in appendix A, it will not fundamentally alter the distributional impacts of the ETS. Thus, if an amount equivalent to the current market value of the firms' initial emissions is handed to them for free, firms with no substitution possibilities will be fully compensated for their additional costs under the ETS while the firms with perfect substitution possibilities will profit by this amount.

Since, the allocation of free emission permits (or more precisely an amount corresponding to emissions in the past) will affect the net profits of the firm (more generally the economic agent's benefit function) under the ETS, it seems intuitively clear that by a judicious allocation of such free emission permits, it is possible to achieve any distribution of the cost of the ETS among the emitters that is desired.[14] Thus, if an equal distribution of this cost is desired there would exist an allocation of free emission permits that would attain this. The same would apply to the utility maximizing allocation of free permits as is demonstrated in appendix B.

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[12] The case of consumers is considered in appendix B. The analysis shows among other things that the optimal allocation of free emission permits should be disproportionately to the consumer with less ability to substitute for GHG emissions.

[13] It is important to recognize that free allocation of emission rights will neither alter the reduction in GHG emissions nor the distribution of these emission reduction amongst those subject to the ETS (see appendix A).

[14] This observation may be recognized as a special case of the 2nd basic theorem of welfare economics (see e.g. Arrow and Hahn 1971,

2.4.2 Industrial collapses and regional shifts

Firms and industries can only exist if their operating income exceeds operating costs. We have already seen that the ETS imposes new costs and, therefore, reduces the profitability of firms and industries unless they can costlessly substitute other inputs or technologies for the GHG emitting ones. Therefore, the imposition of the ETS may result in operating losses and lead to drastic alterations and even disappearance of regional and national industries. This is of course more likely to happen in industries with low economic substitutability and small initial profitability. These cases of discrete industrial shifts (or sectoral collapses) are of course more serious in regions and countries with low populations, simple industrial structure and large distances from other centers of economic activity.

2.4.3 Economic competitiveness

The ETS imposes additional costs on the production of companies. Therefore, the ETS reduces the competitiveness of the companies, industries and countries subject to the system, relative to those who are not required to pay (or pay less) for GHG emissions. It is important to note that this negative impact on economic competitiveness applies even if the companies subject to the ETS receive free emission rights equivalent to their initial emissions.[15] As a result, these companies and industries are forced (or choose) to reduce their operations. The only question is the extent of these reductions which depends on the empirical facts of the situation.

As previously discussed, the ETS has a greater impact on the economic competitiveness of those companies, industries and countries with relatively little ability to substitute their GHG emissions than the others. As a consequence, the alteration in economic competitiveness is not only between companies in and not in the ETS, but also between companies within the ETS.

Needless to say, reduced economic competitiveness of companies and industries implies less net production (GDP) and, therefore, economic growth especially in the longer run in the regions affected.

2.4.4 Impact on global GHG emissions

As discussed above, the ETS reduces the international competitiveness of the EU industries subject to the system. It is, therefore, likely to lead to a transition of economic activities, in particular high GHG emitting ones, to less costly locations abroad. Because of this substitution, sometimes referred to as carbon leakage (see Carbon Market Watch 2026), it is by no means clear that the ETS will actually reduce global GHG emissions. In fact, it is easy to show that the ETS may well increase them. This will happen if the GHG emitting production that is moved from the EU emits more GHG per unit of production in its new location. This would for instance be the case if the energy or other inputs used in the new location was produced with higher GHG emissions than those used in the EU.

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[15] This is because their marginal cost of production (including GHG emissions) is now higher than before.

If this is the case, the installation and operation of the ETS within the EU would be decidedly counterproductive. It increases the cost of production within the EU and thus movers some industrial activity abroad thus reduces the EU GDP compared to what would otherwise be the case, while at the same time increasing global emission of GHG.

Whether this is the actual impact of the ETS or not is not clear. To find that out, requires empirical measurements which apparently have not been conducted. In the meantime, this outcome is a distinct possibility which should be a matter of considerable concern.

2.5 The evolution of EU and global GHG emissions

Of the industrial nations, the EU and its member states have consistently been in in the forefront of the fight against global warming. As soon as 1990, shortly after the release of the first summary report of the Intergovernmental Panel on Climate Change (IPCC), the EU formulated the policy of stabilizing greenhouse gas GHG emissions of the European Community at 1990 levels by 2000. (Climate Policy INFO Hub. 2026).

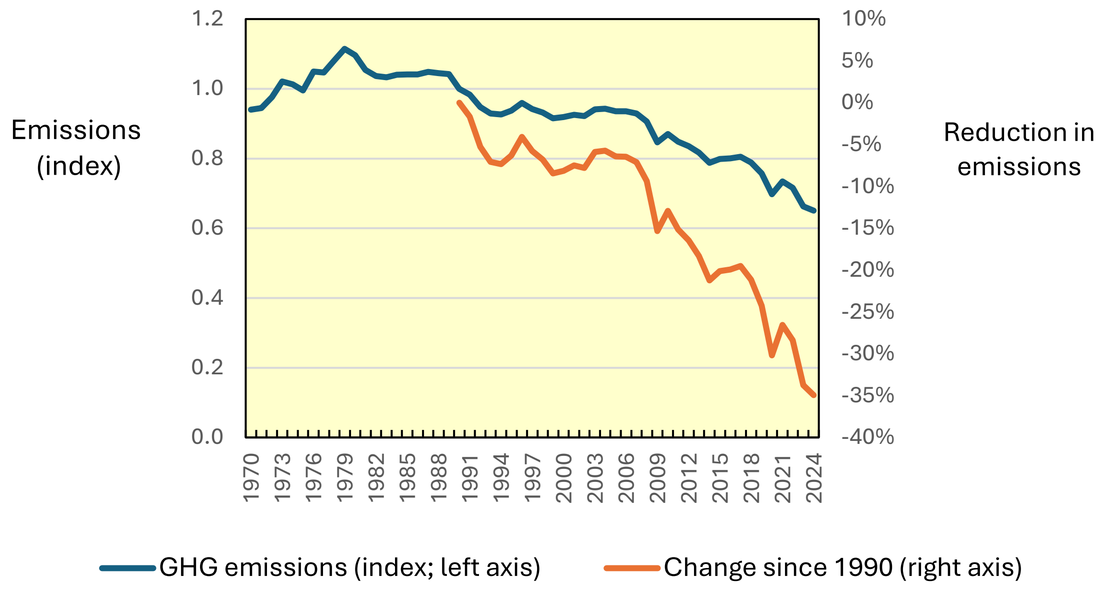
At the climate summit in Kyoto in December of 1997 the industrialized countries agreed on a set of quantitative GHG emission targets, with the European Community committing to 8% reductions of GHG emissions compared to 1990 levels. To implement this policy, the EU has employed a range of methods both market-based ones and non-market based ones. An important component of EU's methods is the Emissions Trading Scheme (ETS). Various other (technical and economic) measures to curtail GHG emissions have also been adopted.

Following more restrictive GHG commitments made at Kyoto II, the EU agreed on further EU-wide GHG measures in 2007. This consisted of a threefold approach (i) strengthened ETS, (ii) measures to develop renewable energy and (iii) measures to promote energy efficiency.

In 2014, the European Council agreed on a new GHG target reduction of 40% (compared to 1990 levels) to be reached by 2030. To implement this target, ETS emission rights were to be reduced by 43% (compared to the initial 2005 targets) and non-ETS sector targets (30% compared to 2005). In 2023, the EU adopted an even more ambitious target of reducing EU GHG emissions by at least 55% by 2030, compared to 1990 levels, further stating that this will enable the EU to become the first climate-neutral continent by 2050.

According to EDGAR (Emissions Database for Global Atmospheric Research), the EU GHG emissions reduction policy seems to have been reasonably successful so far. Thus, in 2024 the GHG emissions by the EU-27 (the 27 member countries) had been reduced by almost 35% compared to 1990 levels. This is illustrated in figure 2.2 as well as the evolution of GHG emissions since 1970. Continuing the historical rate of annual GHG emission reductions, the target of 40% reduction compared to 1990 will be approximately reached by 2030. To reach the more ambitious target of 55% reduction, the annual rate of GHG emission reductions has to be substantially increased.

Figure 2.2
EU-27 GHG emissions and accumulated change
(Source EDGAR, 2026)



As shown in figure 2.2, EU's GHG emissions increased until 1979, but have since declined. The rate of decline increased after 1990 and increased further in the 21. century. This may be taken as evidence that the EU policy of reducing GHG emissions is working.

The EU, however, does not account for a large fraction of global GHG emissions. Thus, in 2024, its emissions amounted to less than 6% of global GHG emissions.[16] Consequently, from the perspective of the real target, curtailing global warming (or climate change) to acceptable levels, the EU reductions do not amount to very much.

Figure 2.3 illustrates the evolution of global GHG emissions since 1970 as well as those of the EU, United States and China. As can be seen from this diagram, the EU GHG emissions have declined substantially compared to 1990. The US emissions, on the other hand, have not declined. The most striking feature in the diagram, however, is the huge increase in China's emissions which are currently well over four times higher than they were in 1990. This is of major importance globally as China now accounts for about 30% of global GHG emissions. Primarily because of the increase in China's GHG emissions and those of several other BRIC countries, global GHG emissions since 1990 have increased by some 70%.

So, EU's policy of substantially reducing its GHG emissions, although quite successfully implemented, has not accomplished much in terms of global GHG emission reduction. If the EU had, as the US has, been satisfied with maintaining its GHG emissions at 1990 levels, global GHG emissions in 2024 would only have been 3.2% more than they actually were. Now the annual rate of global GHG emissions growth is about 1.6% (see figure 2.3). So, all

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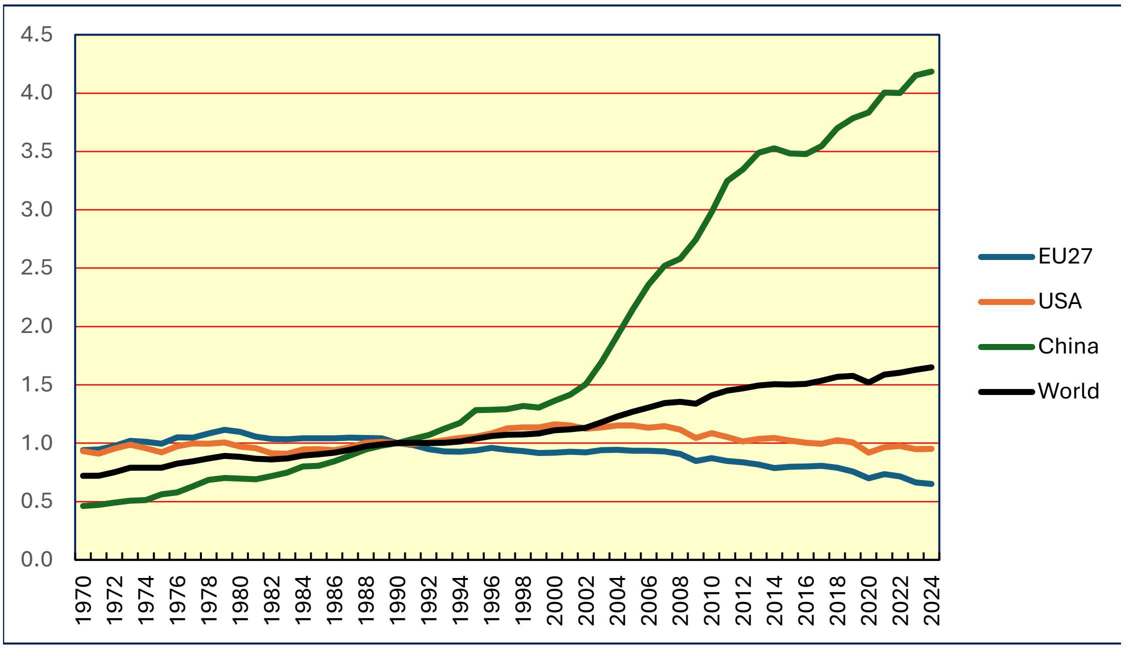
[16] Interestingly this was down from some 13% at the Kyoto conference in 1997.

the EU GHG reduction efforts have managed to accomplish so far is to slow down the speed of GHG accumulation in the atmosphere by some 2 years.

Figure 2.3
The evolution of EU and global GHG emissions
(Indices: 1.0 in 1990. Source EDGAR 2026)



This, negligible as it is, may even be overly optimistic. The reason is that the EU's policy has undoubtedly resulted in transferring a part of EU's GHG emitting industries from the EU to Asia and BRIC countries, which accounts for some of the increase in GHG emissions in these countries. This geographical transition of GHG emissions is sometimes referred to as carbon leakage from the EU GHG reduction system.

2.6 The ETS market and prices

The ETS emission rights are tradable although not perfectly divisible. A substantial part of the rights allocated to national governments are sold at formal auctions operated by the EEX European Energy Exchange (EEX-group 2026) a large commodities trading company[17]. Secondary spot markets for ETS emission rights are operated by a number of intermediaries (brokers) who offer trading assistance services in a similar way to typical stock and bond brokers. Thus, apparently a fairly smooth trading market for ETS rights is in place.

The European Environmental Agency (EEA) maintains a database for ETS prices based on data from the Union Registry and other sources. The evolution of daily ETS emission rights prices since 2010 according to these sources is illustrated in figure 2.4.

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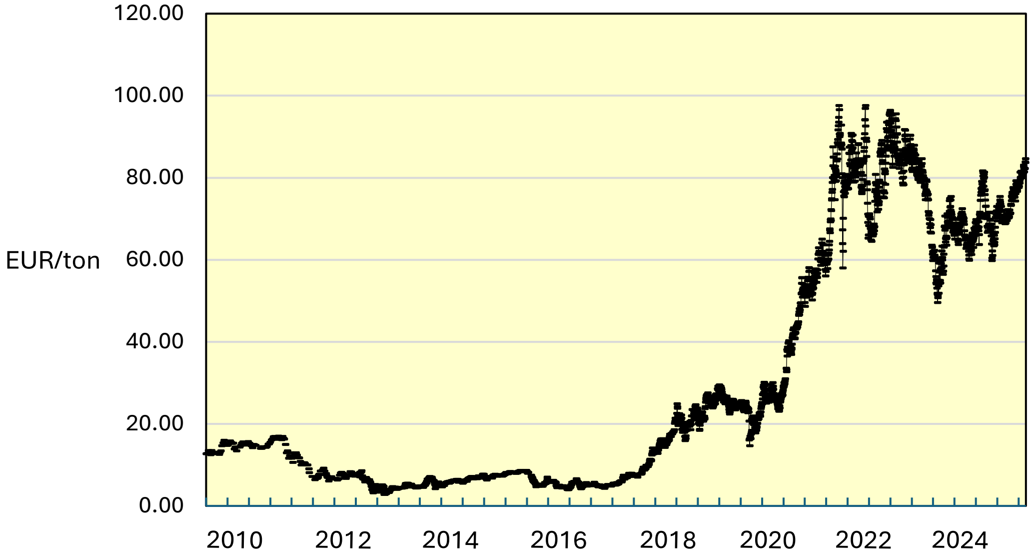
[17] Part of the Deutsche Börse Group.

Figure 2.4
ETS emission rights daily prices
(EUR/ton. Source EEA 2026)



A striking feature of figure 2.4 is the dramatic increase in ETS emission prices from 2019 onwards. This, undoubtedly, reflects increased scarcity of ETS emission rights caused by an increasingly restrictive total allowable GHG emissions in accordance with the EU policy.

Another noteworthy feature of the ETS emission price evolution apparent in figure 2.4 is the high volatility of these prices.[18] It is important to recognize that significant volatility of market prices works against their function as a guiding hand toward optimal allocation of the valuable in question. How can traders reach the jointly optimal allocations when the guiding signs continually shift around? Thus, this high volatility of ETS emission prices are a matter of some concern from the perspective of efficient allocation of the emission rights.

The high volatility of ETS emission prices may be indicative of a substantial degree of uncertainty about the EU's GHG policy and the operation ETS system or jittery market participants or both. It may also indicated market weaknesses – the market is simply not deep enough (trades sufficiently frequent) to generate more stable prices.

As discussed above, the EU is on course of reaching a 40% reduction in GHG emission by 2030. Recently, the Commission announced its intention to curtail GHG emissions even further to reach 55% reduction by 2030 and carbon neutrality by 2050. Thus, obviously, carbon emission rights will become even more scarce and their market prices will correspondingly increase. Several predictions about the future path of carbon prices exist (exmples are provided by Enerdata 2023 and Guschenko 2025). These predictions agree that the emission rights prices will increase but predicted price increases range widely. The

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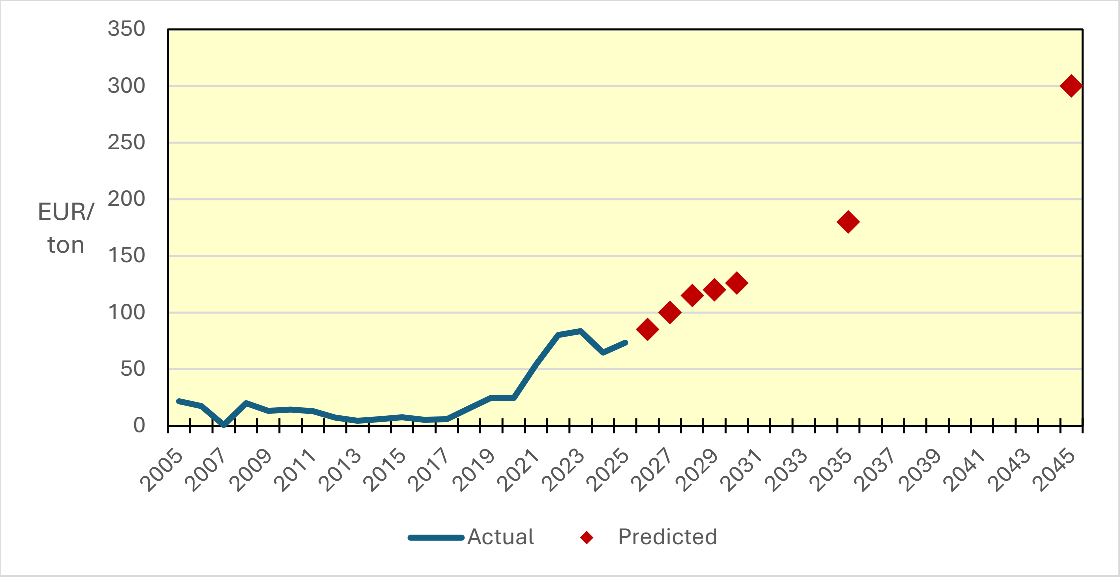
[18] The coefficient of variation for these prices, a limited measure of their volatility, is 0.86 which means that on average the daily variation in the emission prices is 86% of their average.

following diagram, figure 2.5, illustrates certain average predicted price rises based on available predictions.

Figure 2.5

ETS emission rights prices: Actual and predicted

(EUR/ton. Source Enerdata 2023, Guschenko 2025, AI predictions 2026)



According to the predictions illustrated in figure 2.5, the ETS GHG emission rights are expected to approximately double by 2030 compared to 2005 and then continue to rise and to reach 300 EUR/ton or almost four times their 2025 levels by 2045.

Needless to say, there is great uncertainty about these predictions and reasonable confidence bounds, if they were worked out, would be very wide. Thus, future ETS GHG emission prices could be both substantially lower and higher than indicated in the diagram. The predicted prices in figure 2.5, however, may be seen as reasonable point predictions.

3. The impact of the ETS on Icelandic aviation and tourism

As discussed in chapter 1 above, most of Iceland's human GHG emissions come from power intensive industries and transportation. It is important to recognize that the power intensive industries, despite being subject to the constraints of the ETS, actually serve to reduce global GHG emissions. This is because in Iceland they are run on renewable energy sources (hydro and geothermal) and, therefore, placing them elsewhere in the world would almost surely substantially increase their GHG emissions.

Transportation includes a variety of transportation modes employing the internal combustion technology, including cars, fishing vessels, merchant shipping and aviation. Of these, aviation is already subject to the ETS. Merchant shipping formally came under the ETS in 2024 and its phase-in to the system will be complete by the end of 2026.

Due to its various demographic and geographical features, not the least its remote location (see chapter 1), Iceland's base industries are heavily reliant on long distance shipping and aviation. Tourism, by now possibly Iceland's most important base industry, is to a great extent dependent on wide-ranging connections by air. Without it, there would not be a sizeable tourism sector in Iceland.

3.1 The importance of tourism in the Icelandic economy

Tourism is one of Iceland‘s three most important base-industries[19]. The others are the fishing industry and the so-called power intensive industries consisting mostly of metal smelting (aluminium and ferro-silicon).

According to Statistics Iceland (https://www.hagstofa.is), in 2024 tourism accounted directly for about 8.7% of Iceland's GDP. Combining direct and indirect contributions the total contribution of tourism to the Icelandic GDP in 2024 may have well have amounted to 15-20%. If this is the case, tourism may well be Iceland's most important base industry.

To appreciate the contribution of tourism to the national economy of Iceland, it should noted that base industries, i.e. the industries that form the basis habitation in a given region, normally generate well under half of the GDP as it is traditionally measured. The remainder of the GDP comes from (i) industries producing inputs for the base industries, (ii) industries producing goods and services for the population and (iii) the governance sector producing government services for the population.

The tourism industry is comparatively labour intensive and, therefore, is a major source of employment in Iceland. According to available statistics (Statistics Iceland) it appears that well over 10% of total employment in Iceland is generated by the tourism industry.

The Icelandic tourism industry has expanded very fast since 2010. In 2024, the number of foreign arrivals was more than five times the number in 2010. This development is illustrated in figure 3.1. Most of these foreign arrivals are by air. This expansion of the tourism industry, thus, explains a good part of the increase in GHG emissions attributed to Iceland since 2010.

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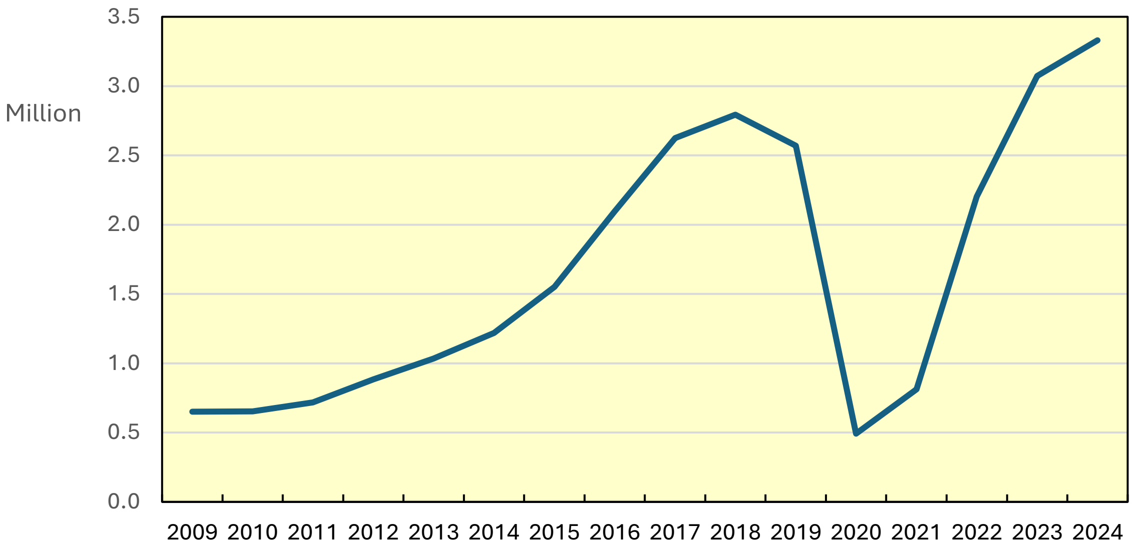
[19] Base industries are industries that can operate on their own without the support of other industries. As such they are the foundation for other industries in the region that serve the base industries and the labour they require (Tiebout 1956, Krumme 1968, Roy et al. 2009).

Figure 3.1
The number of foreign arrivals in Iceland
(Millions. Source: Statistics Iceland 2026)



The expansion in tourism has been the primary driving force of Iceland’s impressive economic growth since 2010. Average annual economic growth in Iceland during 2010-24 is about 2.6%. Of this, according to Statistics Iceland estimates, about 0.5% or 1/5 the of the economic growth may be directly attributed to the tourism industry.

So, tourism is one of the main pillars of the Icelandic economy. It follows that any significant reduction in this industry would constitute a major shock to the Icelandic economy.

3.2 The importance of aviation for tourism

About 80% of foreign tourists travel to Iceland by air. (Statistics Iceland 2026). The remaining 20% are mostly passengers on foreign cruise liners. Therefore, aviation accounts for substantially more than 80% of foreign tourism income in Iceland.

There is no practical way of travelling to Iceland except by air. Travel by boat simply takes too much time - the shipping time from London to Reykjavik is close to four days and this is just one way. This implies that aviation is absolutely fundamental for the tourism industry in Iceland. Without it there would be very little tourism in Iceland. Therefore, strong and extensive air connections are vital for the continuation, not to mention further growth, of the Icelandic tourism industry.

Thus, extensive aviation connections are really the foundation on which Icelandic tourism is built. It follows that anything that threatens aviation to and from Iceland is also a threat to the tourism industry.

It should be noted that strong aviation links from Iceland to the surrounding world are also important for other industries in Iceland. This holds especially for Iceland's food industries, the fishing and aquaculture sectors, which are heavily dependent on getting their fresh products to high quality restaurants and retail outlets on both sides of the Atlantic. These valuable market outlets are made possible by the strong aviation connections and would largely disappear if the aviation were to substantially decline.

Of the passenger air traffic to and from Iceland, about 2/3 are by Icelandic airlines (now for the most part Icelandair). The remainder arrive by several different airlines mostly European and American.

The ETS imposes additional costs on the airlines that operate within the system including the Icelandic and EU ones. Since airlines operate with very low profit margins and for other reasons, these costs will most likely be passed on in air ticket prices. Therefore, if the demand is price elastic, which is likely for tourist aviation[20], it will contract with the result that tourism to Iceland will be correspondingly reduced and with it the profitability of the airlines.

The profit margins in Icelandic aviation are small. Two major Icelandic airlines Wow air and Play have gone bankrupt in the past seven years. The remaining airline, Icelandair, continues operating but at a very low profitability. In fact, it reported operating losses in both 2024 and 2025. Thus, it is clear that the additional costs imposed by the ETS will negatively impact Icelandair, Iceland's only remaining airline.

It seems unlikely that foreign airlines would provide anything like the same air connections for Iceland in case Icelandic airlines stop operating. There are two main reasons for this: First, it seems unlikely that these airlines can serve the Icelandic market more efficiently than Icelandair has. If they could, they would probably already have replaced Icelandair. Second, the attainable profit margins in providing aviation services to Iceland seem small and probably insufficient to meet foreign airlines' required rates of return.

Thus, it is difficult to avoid the conclusion that the tourism industry in Iceland stands and falls with the connections and that foreign airlines will not provide anything like the same aviation connection that Icelandair provides now.

3.3 Macroeconomic impacts: Attempt at quantification

The ETS GHG emission charges result in higher production costs of industries subject to the system. Production cost increases normally result in higher prices of the products. Higher prices of the products lead to less demand and, therefore, reduced production. These initial impacts on the industry are then transmitted to the larger economy where after a process of adjustments and readjustments the longer run economic impacts emerge. Given the size of the tourism industry relative to the rest of the economy, these longer run economic impacts may well have a significant impact on macro-economic variables.

In this section, it is attempted to assess the potential magnitude of the macro-economic impacts of the ETS emission costs imposed on Icelandic aviation. The estimation process

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[20] Numerous studies of the elasticity of demand with respect to price in international aviation suggest a price elasticity less than one -1. Tourism price elasticity could be around -1.5 or even higher (Brons et al. 2001, Njegovan 2006, Perera and Tan 2019).

consists of two steps; first, an assessment of the initial impact and second the subsequent economy-wide adjustments and re-adjustments. For the latter step, two macro-economic models of the Icelandic economy specially adapted to account for the tourism industry will be used.

3.3.1 Initial impact assessments

In aviation, higher costs due to the ETS system will almost certainly lead to higher plane ticket prices and, consequently, fewer passengers travelling. Since aviation is the main means of passenger transport to and from Iceland, this results in less tourism in Iceland and less value added in the Icelandic tourism industry.

The relationship between higher ticket prices and value added in tourism is examined in appendix C of this report. There it is found that the magnitude of the impact depends on several factors including (i) how much marginal costs in aviation increase, (ii) how much plane ticket prices increase (elasticity of prices with respect to marginal costs), (iii) how the quantity of passengers responds to price changes (price elasticity of demand), and (iv) how much value added in tourism responds to changes in quantity of passengers. The fundamental relationship relating these factors to the initial impact on tourism value-added is given by equation (C.1b) in appendix C where empirical estimates of the magnitude of the factors are also discussed.

Since there is much uncertainty about future ETS emission costs and that of GHG emission restrictions more generally, it appears reasonable to proceed in terms of scenarios. The scenarios considered are as follows:

Scenarios I. Doubling of net ETS and CO2 costs (relative to 2025)[21]
    Ia. Doubling of net ETS costs
    Ib. Doubling of net CO2 costs

Scenarios II. Tripling of net ETS and CO2 costs (relative to 2025)[22]
    IIa. Tripling of net ETS costs
    IIb. Tripling of net CO2 costs

Scenarios III. Contraction shocks to tourism (relative to 2025)
    IIIa. 5% contraction
    IIIb. 10% contraction
    IIIc. 20% contraction.

The first two sets of scenarios (I and II) are motivated by the predicted increases in ETS emission costs (see e.g. section 2.6 and figure 2.5). The third set (III) reflects a range of plausible corresponding impacts on Icelandic tourism.

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[21] Net ETS costs are ETS costs less free ETS rights. Net CO2 costs are the net ETS costs + Corsia and SAF costs.

[22] Net ETS costs are ETS costs less free ETS rights. Net CO2 costs are the net ETS costs + Corsia and SAF costs.

Applying the results developed in appendix C and equation (C.1b) more specifically yielded estimates of the initial impact on value added in tourism in Iceland under the above seven scenarios listed in table 3.1

Table 3.1

Scenario outcomes: Estimates of initial changes in value added in Icelandic tourism

(Estimates based on appendix C, equation (C.1b))

Scenarios	Change in tourism value added	
	Percentage (%)	Value. M. EUR* (2025 price level)
Ia	-2.4	-67
Ib	-2.9	-81
IIa	-4.8	-135
IIb	-5.9	-166
IIIa	-5	-140
IIIb	-10	-281
IIIc	-20	-561

* In addition to the factors entering equation (C.1b), these estimates are based on the Central Bank of Iceland‘s GDP forecast for 2025 and the share of tourism in the Icelandic GDP

The results in table 3.1 list the initial percentage change in value-added in Icelandic tourism and the corresponding value in Euros under the various scenarios. For instance, under scenario Ib, doubling of net CO2 costs, results in an initial 2.9% reduction in value added in tourism, which amounts to 81 million euros at 2025 prices.

The initial impacts in table 3.1 are used as inputs the macroeconomic simulations presented below.

3.3.2 Macro-model assessments

From a macroeconomic perspective, an increase in production costs and product prices in the tourism industry in Iceland has both direct and indirect effects on macroeconomic variables such as GDP and unemployment. Higher tourism prices result in less demand for tourism, which reduces GDP and increases unemployment. These are the direct effects. The indirect effects come from the fact that (i) less tourism output results in less demand by the tourism industry for inputs from other industries, (ii) higher tourism prices results in increased demand by consumers for goods produced by other industries, and (iii) less output in the tourism industry results in it demanding less labour and capital factors imposing a downward pressure on wages and interest rates.

The second and third effects mitigate the initial decrease in GDP and employment while the first exacerbates the initial decrease in GDP and employment. The net sum of these effects is a matter of relative empirical magnitudes. However, in normal circumstances, the direct effects are expected to be stronger than the sum of the indirect effects leaving the GDP lower and unemployment higher following an increase in tourism costs due to the ETS system.

The macroeconomic impacts of the even scenarios defined above are explored using two macroeconomic models of the Icelandic economy. These are a version of the QMM model used by Statistics Iceland and a DSGE (dynamic stochastic general equilibrium) model (see appendix D for further description of the models). Both simulation models account for the tourism industry in the Icelandic economy, which enables us to simulate to effects of the scenarios on the Icelandic economy.

The two macroeconomic models are structurally different. The QMM model is based on estimated behavioral relationships suggested by historical data, while the DSGE model is a calibrated general equilibrium model where the economic agents rapidly make new choices by optimally altering their behaviour when conditions change. Therefore, adjustment of macroeconomic variables to changes, such as production costs due to the ETS system, are therefore much faster in DSGE model than the QMM model. This results in the DSGE model producing smaller effects on macroeconomic variables than the QMM model. For this reason, the results from the QMM model may be regarded as being closer to the short term macroeconomic outcomes of the initial impact of ETS price increases and those of the DSGE model closer to the longer term ones.

Due to the modelling and estimation uncertainties in the macro-economic calculations presented here, the numerical results obtained should not be interpreted literally but rather as providing information about the likely magnitude of the effects. Further, due to the extreme flexibility of the economic behaviour assumed in the DSGE model, the outcomes of that model should be interpreted as belonging to the lower end of likely effects.

The following table shows the simulated effects of the seven scenarios on GDP, employment and net exports:

Table 3.2
Scenario outcomes in %: Macro-economic variables

Scenarios	Percentage (%) changes (compared to status quo (no increase in ETS or CO2 emission costs))					
	GDP		Employment		Net exports*	
	OMM	DSGE	OMM	DSGE	OMM	DSGE
Ia	-0.31	-0.14	-0.06	-0.04	-0.28	-0.14
Ib	-0.38	-0.17	-0.08	-0.05	-0.34	-0.17
IIa	-0.63	-0.28	-0.12	-0.07	-0.56	-0.28
IIb	-0.77	-0.34	-0.15	-0.09	-0.69	-0.34
IIIa	-0.64	-0.23	-0.13	-0.09	-0.58	-0.25
IIIb	-1.29	-0.47	-0.26	-0.19	-1.16	-0.49
IIIc	-2.57	-0.93	-0.51	-0.38	-2.33	-0.99

* Changes in net exports are relative to GDP

The results listed in table 3.2 inter alia inform us that doubling the net CO2 costs (scenario Ib), which is well within the predicted increases under the ETS in the near future, is likely to result in 0.17 to 0.38% reduction in the GDP and substantially weaken the balance of trade.

The impact on employment, however, is not predicted to be very great, presumably because much of the employment in the tourist sector is foreign. Tripling the net CO2 costs (scenario IIb), which is also within the predicted increases under the ETS in the near future, is likely to reduce GDP by 0.34 to 0.77% and have a correspondingly greater impact on exports and employment.

The macro-economic consequences of larger initial contractions of the tourism industry under scenarios IIIb and IIIc, which, as discussed in chapter 2 and more specifically in sections 3.4 and 3.5 below, are well within the bounds of realism, may be inferred from the last two lines in table 3.2.

The macro-economic values (in EUR) corresponding to the outcomes in table 3.2 are provided in table 3.3:

Table 3.3
Scenario outcomes in Million EUR: Macro-economic variables

Scenarios	Changes (M. EUR)* (compared to no increase in ETS or CO2 emission costs)			
	GDP		Net exports	
	OMM	SDGE	OMM	SDGE
Ia	-106	-48	-96	-48
Ib	-130	-58	-116	-58
IIa	-216	-96	-193	-96
IIb	-263	-116	-237	-116
IIIa	-219	-89	-200	-92
IIIb	-441	-178	-398	-188
IIIc	-879	-352	-798	-373

* ISK are converted to EUR using the average exchange rate in 2025

To see the entries in table 3.3 in context, it is useful to note that in 2025, the Icelandic GDP is estimated to have been about 34211 M. EUR.

3.4 International competitiveness of Icelandic aviation under ETS

Icelandic aviation is to a significant extent based on a hub-and-spoke model, where Iceland serves as a connecting point between Europe and North America. As a result, a considerable share of passenger traffic consists of transfer passengers, and overall traffic volumes are very sensitive to changes in relative costs and competitiveness.

Iceland currently now operates only one international airline of note, Icelandair. Two other major international airlines based in Iceland, Wow air and Play, went bankrupt in 2019 and 2025, respectively.

Icelandair operates a year-round regular air routes from its hub at Keflavik airport (a short distance from Reykjavik) to a high number of European and North American destinations.

Almost all of Icelandair's air routes go through the Keflavik hub. Icelandair focuses on strengthening is hub in Iceland and does not offer direct transatlantic flights.

Icelandair has regular flights to eighteen destinations in Europe – most major cities in the EU are served by Icelandair. Regular destinations in North America are fifteen all of which major cities in Canada and the US and covering both the continent's east and west coasts. In addition to these regular routes, Icelandair operates several seasonal destinations.

This high degree of air connectivity is of great benefit to the Icelandic public as well as its export and import industries. For Icelandic tourism, it is nothing less than crucial as discussed in previous chapters.

Importantly, all of Icelandair's destinations abroad are also served by other carriers, most of which are much larger than Icelandair and, therefore, able to exploit larger economics of scale. The same applies to Icelandair's home base or hub at Keflavik airport. This airport is also served by a high number of European and North American airlines. More precisely, this airport is also served by at least five major North American airlines (including Delta, United and American airlines) and ten European ones (including British Airways, SAS, Lufthansa, EasyJet and Wiss Air) on a regular basis in addition to a more seasonal flights by several other airlines.

Given this, it is obvious that Icelandair is engaged in direct competition for passengers and other business with a high number international airlines most of whom are much larger than Icelandair. Clearly, to survive in this environment and continue operations, Icelandair must be sufficiently competitive.

It is well known that aviation is a low margin business and that the margins have been getting thinner over time. To counter this, airlines have strived to increase passenger volume and improve seat utilization. As a result, competition for passengers has been fierce, often taking the form of lowering prices, thus squeezing profit margins even further. Average profit margins in 2025 have been estimated to be only 3.9% and margin per passenger only about 7-8 USD (IATA 2025).

It appears that in this environment, Icelandic aviation is barely competitive. In recent years two major Icelandic have become bankrupt and the remaining one, Icelandair, is currently barely profitable and has seen its share price fall precipitously.

In this situation, extra operating costs such as the cost of ETS emission rights, can have a large impact on competitiveness. If profit margins are sufficiently low, these additional charges can even render an airline unprofitable. Even if the airline remains in the black (i.e., stays profitable), the extra ETS charges can easily mean that the airline will lose out in the competition with other airlines, especially those who incur lower ETS emission costs or, as the American airlines, none at all.

For some years now, only European airlines have had to incur ETS costs which have, moreover, been rapidly increasing over time. American and other non-European airlines have not been subject to these costs. It follows, that the competitiveness of European airlines (including Icelandic ones) relative to American and other non-European airlines has been correspondingly eroded.

Now, as explained above, Icelandair is in direct competition with North American airlines both as regards Iceland as a destination and on the transatlantic routes. Icelandair's business model of using Keflavik as a mid-Atlantic hub means that its Keflavik-Europe legs become subject to ETS charges. Direct transatlantic flights by North American airlines, however, avoid these charges. The same applies to flights by North American airlines to Keflavik. Thus, Icelandair's competitiveness relative to these non-European airlines is clearly reduced by the ETS. Given the hub-based structure of Icelandic aviation, this may also contribute to a reallocation of transfer traffic to competing hubs outside the ETS

It is important to realize that not only is Icelandair's competitiveness relative to non-European airlines reduced by the ETS. It is also reduced relative to the European airlines on the transatlantic route. The reason is that Icelandair incurs ETS charges on its Europe-Keflavik legs while, under the current ETS rules, the direct transatlantic flights by European airlines are not subject to ETS charges at all.

What is not as obvious is that Icelandair's competitiveness relative to its European (and therefore ETS paying) competitors may also be eroded. The reason is that Icelandair's average European flight legs are longer than those of most other European airlines. This is because of Iceland's location at the geographical extreme of the EES. Therefore, Icelandair emits more GHG per flight leg and, therefore, incurs more ETS costs. Depending on other aspects of the cost structure, fuel safety requirements and pricing, this difference may imply that Icelandair (and other Icelandic aviation) pay higher ETS charges per unit of revenue than the other EU airlines.

We conclude that under the ETS as it is currently operated:

- Icelandair's international competitiveness is clearly eroded.
- The same applies to Keflavik as a commercial airport and destination for aviation.
- Icelandic aviation competitiveness relative to its non-European competitors is clearly reduced.
- Icelandic aviation competitiveness relative to European airlines is also eroded on transatlantic routes and possibly also intra EU flight routes.

3.5 Replacement of Icelandic aviation: Possible ETS implication

Above, in chapter 3.4, it was established that the ETS erodes the international competitiveness of Icelandic aviation. It was also explained that for a number of reasons Icelandic aviation is not very competitive to begin with. Given the hub-based structure, increases in relative costs, such as those associated with the ETS, may not only reduce demand but also lead to a reallocation of traffic to competing hubs, with potential implications for the scale and structure of Icelandic aviation.

In this situation, it is clear that any displacement of traffic to operators or routes outside the ETS may result in emission reduction within the system being offset by increase elsewhere, known as carbon leakage. This may occur, for example, through the rerouting of transfer traffic to competing hubs outside the scope of the ETS.

Unlike many regions within the EU, Iceland has very limited opportunities for substitution in international transport. There are no viable alternatives to aviation for most passenger travel, implying that increased costs are less likely to induce a shift to lower-emission transport modes and more likely to reduce connectivity or displace activity.

Therefore, it appears virtually inevitable that Icelandic aviation will contract as a result the ETS. There is even a distinct likelihood that it may diminish greatly. That, by itself, constitutes a significant reduction in the Icelandic GDP. It is also likely to lead to a significant contraction in the Icelandic tourism industry which will further reduce the Icelandic GDP. Indeed, that is bound to happen if the contraction in Icelandic aviation is not fully replaced by expansion in foreign aviation to Iceland.

However, as explained in chapter 3.4, the likelihood of foreign airlines fully replacing contraction in Icelandic aviation is small. Therefore, we conclude:

- There is a significant risk that the ETS as it is currently implemented and planned to develop will lead to a significant reduction in and even the virtual disappearance of Icelandic aviation.
- In that case, Icelandic tourism would inevitably experience a substantial contraction, at least in the short run (a few years). Since the tourism industry is Iceland’s largest base industry, Iceland’s GDP would also be substantially reduced.
- In the longer run, it is likely (but by no means certain) that a contraction in Icelandic aviation would be met by some expansion in foreign aviation services to the island.
- A part, possibly a large part of that replacement will avoid the ETS emission charges, at least as they are now implemented. Therefore, to the extent that the ETS works to reduce GHG emissions by Icelandair, this development will nullify that impact.
- The extent to which foreign aviation replacement happens will alleviate the negative impact on Icelandic tourism. It is unlikely, however, that it will offer the same extent of connections as Icelandair currently does.

3.6 Conclusions- Summary

The previous section in chapter 3 has generated some key findings which may be summarized as follows:

1. Foreign tourism is a large base industry in Iceland.
2. This tourism is based on good aviation connections.
3. These aviation connections are made possible by demand for flight services to and from Iceland.
4. Much of that demand is from tourists travelling to Iceland.
5. This demand, as that for other aviation services to Iceland is highly price sensitive.
6. The ETS GHG emissions charges necessitate a corresponding increase in airfares.
7. Therefore, they lead to a contraction in aviation and, therefore, also of the tourism sector.
8. Macro-economic simulations suggest that this is likely to have a considerable negative impact on Iceland’s GDP, employment and balance of payments in the short run.

9. Icelandic aviation operates in a highly internationally competitive environment composed of a number of European and American airlines.
10. The ETS as it currently operates erodes Icelandair’s competitiveness relative to non-European airlines and also relative to European airlines on transatlantic routes. Depending on various factors it may also erode Icelandair’s competitiveness relative to European airlines on European routes.
11. There is a distinct possibility that the ETS as it is currently operated and predicted to evolve, will lead to the substantial reduction and possibly the disappearance of Icelandic aviation.
12. Reduction in Icelandic aviation is unlikely to be fully replaced by an expansion of foreign aviation to Iceland
13. To the extent that the ETS has the impact of replacing Icelandic aviation with non-European airlines and European ones on transatlantic routes, the ETS will not reduce global GHG emissions.

4. Suggested improvements

The ETS is an instrument to allocate scarce GHG emission rights to producers. As a cap-and-trade system, the ETS has the potential for allocative efficiency. However, since the ETS applies only to a very small part of global GHG emissions, it cannot possibly generate efficiency in the allocation of world-wide GHG emissions. On the contrary, by penalizing some emitters and rewarding others, it is highly likely to result in more severely suboptimal allocation of global emissions than before. In addition, because of its design, especially the limited duration of the emission rights and uncertainty about their value, it cannot attain full allocative efficiency, even within its own confines (i.e., for the part of the total allowable GHG emissions it controls). For this reason, it is obvious that claims of allocative efficiency for the ETS are, at best, misleading.

Moreover, since the ETS does not apply to a large group of GHG emitters within the EU and not at all to emitters in the rest of the world, it may be taken for granted that much of the reduction in GHG emissions generated by the system will be met by an increase in GHG emissions elsewhere. Thus, despite imposing costs on certain European industrial GHG emitters, the ETS is relatively ineffective in reducing global GHG emissions.

The ETS imposes costs on certain European emitters of GHGs. These costs are disproportionately borne by those who are least able to substitute other inputs or methods for GHG emitting ones. Other producers, those who can easily replace GHG emitting inputs by other inputs/methods, will experience much lower costs. Due to the tradability of emission rights, they may even gain from the operation of the ETS. These distributional impacts are both economically distortionary across industries and regions and arguably unfair.

Thus, notwithstanding claims to the contrary, the ETS does not attain allocative efficiency except perhaps in a very limited (and economically irrelevant) sense. In addition, the ETS has a number of serious drawbacks including (i) distributional ones of possibly severe magnitude, (ii) an economically distortionary shift of GHG emitting industries from the EU and (iii) impotency in reducing global GHG emissions.

For all these reasons, the ETS does not appear to be a good tool for allocating scarce GHG-emission rights, at least not in its current form. This suggests that the system should either be discontinued or adequately modified. The purpose of this report, however, is not to consider the advisability of the ETS as such and even less so the EU GHG reduction policy. It is to consider the impact of the ETS on Icelandic aviation and tourism and, on that basis, suggest modifications in how the ETS is run.

Minimal modifications seem to be:

1. A different and more acceptable allocation of free GHG emission rights to emitters (countries/industries/companies). This modified allocation should favour countries/industries/companies whose ability to substitute non-GHG emitting inputs for their current GHG emitting ones is limited. In appendix A, section A.4, it is shown that there generally exists a sharing of free emission rights amongst emitters that attains a more socially acceptable distribution of the burden of GHG emission restrictions under the ETS system than the current one, including an equal distribution of this burden.

2. Compensation for eroded competitive position relative to foreign countries /industries/companies induced by the ETS. Again, this compensation will have to be carefully designed to attain its objective, i.e. to maintain unaltered competitiveness while still providing the incentive to reduce GHG-emissions. Note that this type of compensation seems to imply that the cost of GHG reductions within the EU will be shifted from particular countries/industries/companies to the EU society more generally which, incidentally, consists of those who are supposed to benefit from reduced GHG emissions.

The gain from these modifications is threefold. First the reduction in production within the EU from the GHG policy will be less – industries will contract much less. Second, the transfer of GHG emissions to other parts of the world will diminish– there will be less need to replace lost production within the EU. Third, the questionable country/industry/ company distributional impacts of the current ETS will be largely avoided.

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Appendix A

The ETS and the ability to substitute for GHG emissions

Consider an economic agent. Let his benefit function, which we may without loss in generality refer to as his profit function, be represented by:

$$V(z,x,\tau)=\Pi(z,x)-\tau\cdot z\,,$$

where z denotes emissions of GHGs, x other activities (incl. input use) and τ the price of GHG emissions. The function $\Pi(.,.)$ is the agent's operating profit function before the cost of emissions.

Presumably at each point of time, the agent will select his optimal z and x given the GHG price. Thus, at GHG price $\tau(0)$ the agent's profits will be:

$$V(0)=\Pi(z(0),x(0))-\tau(0)\cdot z(0),$$

where $z(0)$ and $x(0)$ are optimal input uses at $\tau(0)$.

Now consider a higher GHG price, $\tau(1)$. Then the agent's profits will be:

$$V(1)=\Pi(z(1),x(1))-\tau(1)\cdot z(1),$$

where $z(1)$ and $x(1)$ are the new optimal levels of z and x.

The change in profits (more generally benefits) will be:

$$\Delta V\equiv V(1)-V(0)=\Pi(z(1),x(1))-\tau(1)\cdot z(1)-\left(\Pi(z(0),x(0))-\tau(0)\cdot z(0)\right).$$

A little algebraic rewrite and obvious notation simplification yields:

$$\text{(A.1)}\quad \Delta V=\left(\Pi(1)-\Pi(0)\right)+\left(\tau(0)\cdot z(0)-\tau(1)\cdot z(1)\right).$$

It is useful to note that $\Delta V\leq 0$. This is because a higher price of an input cannot increase the profitability (attainable benefits) of the economic agent. One way to see this is that, if that were the case, the agent could have obtained these additional benefits before by just paying more for the $z(0)$. Therefore, at best, the change in profits (benefits) is zero.

Note that the first term (parenthesis) on the right-hand side of (A.1) must be nonpositive (zero or less). This is because an increase in the price of GHG emissions cannot increase the operating profits of the agent. If he does not change his input use, the term is zero. If he alters it, the operating profits will fall (unless there perfect costless substitutability) because the initial input use was profit maximizing.

The second term (parenthesis) on the right-hand side of (A.1) can, in contrast, be of any sign. It may seem strange that an increase in the price of an input will lead to less expenditure on the input. However, this will obviously occur if there is sufficient reduction in the use of emissions z as a response to the higher price. Note, however, that that the size of the second term (parenthesis) can not exceed the numerical value of the first term because $\Delta V \leq 0$.

Thus, the two terms in (A.1) may be of opposite signs. Therefore, as already observed, ΔV may be zero.

Expression (A.1) can be employed to investigate the impact of a rise in the price of GHG emissions on profitability under different ability to substitute other inputs for GHG emitting inputs (x for z in our framework). We proceed to consider the two polar cases of perfect substitutability and no substitutability whatsoever.

A.1 Perfect substitutability

Assume that there is perfect substitutability in the sense that the use of z can be costlessly replaced by an increase in the use of x.[23] Therefore, for any τ, the first term on the right-hand side of (A.1) is zero. I.e.,

$$\Pi(1) - \Pi(0) = 0 .$$

Therefore also, the second term of (3) would also be zero. It cannot be negative because it makes no sense to pay for unnecessary products that increase in price and it cannot be positive because then $\Delta V > 0$. Actually, a moment's thought will show that under perfect substitutability in the above sense, there would not ever be any use of z if its price, τ, was positive. Therefore, if $\tau(0) > 0 \Rightarrow \tau(0) = 0$.

We conclude:

Under perfect substitutability in the above sense, an increase in the price of GHG emissions will not reduce the profits (benefits) of the agent.

A.2 No substitutability

If there is no substitutability, $z(1)=z(0)$. Therefore, $x(1)=x(0)$ as well and, as in the case of perfect substitutability:

$$\Pi(1) - \Pi(0) = 0 .$$

The second term of (3), however, becomes:

$$\left(\tau(0) \cdot z(0) - \tau(1) \cdot z(1)\right) = \left(\tau(0) \cdot z(0) - \tau(1) \cdot z(0)\right) = -\Delta\tau \cdot z(0) .$$

Therefore by (A.1)

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[23] Note that this is not the same as infinite elasticity of substitution. First, the current concept of substitutability is not constrained to an iso-quant (indifference curve). Second, it refers to profitability not the level of production.

$$\text{(A.2)} \quad \Delta V = 0 - \Delta\tau \cdot z(0) = -\Delta\tau \cdot z(0).$$

In other words, an increase in the GHG price has exactly the same impact as the same increase in a fixed tax on the operation.

We conclude:

Under no substitution possibilities, an increase in the price of GHG emissions amounts to an equivalent increase in a fixed tax on the agent.

A.3 Allocation of free GHG emission rights

Consider now the possibility that a certain volume of emission rights are allocated to emitters for free. Moreover, let this volume be a fraction, $a \in [0,1]$, say, of the initial emissions $z(0)$.[24] In that case expression (A.1) becomes:

$$\text{(A.1b)} \quad \Delta V = \left(\Pi(1) - \Pi(0)\right) + \left(\tau(0) \cdot z(0) - \tau(1) \cdot z(1)\right) + a \cdot \tau(1) \cdot z(0).$$

Obviously, provided $a>0$, ΔV, the change in profits is now larger than before and can be greater than zero. Indeed, it is easy to see that under perfect economic substitutability, the gain in profits will amount to the value of free emission rights, i.e.:

$$\Delta V = a \cdot \tau(1) \cdot z(0).$$

In the case of no economic substitutability, on the other hand, the allocation of free emission rights does not lead to a net gain from the ETS but merely alleviates the costs. More precisely, from (A.1b) and (A.2), the change in profitability for these firms[25] will be:

$$\Delta V = -\tau(1) \cdot z(0) + a \cdot \tau(1) \cdot z(0) = (a-1) \cdot \tau(1) \cdot z(0),$$

which is negative unless $a=1$, i.e., the entire initial emissions are allocated as free emission rights.

We state these findings as the results:

Under perfect substitutability, the allocation of free emission permits amounts to a net increase in profits for the agent.

Under no substitutability, the allocation of free emission permits alleviates the ETS costs for the agent.

To avoid misunderstanding, it should be stressed that free allocation of an amount corresponding to previous emissions does not in any way alter the reduction of GHG emissions or its distribution amongst the firms. This is because the current overall emission

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[24] Note that this allocation of free emission rights does not affect GHG emission or trading choices of firms under the new GHG emission price because it depends only on emissions in the past.

[25] Where for simplicity we have assumed the initial price, $\tau(0)=0$.

constraint is still binding and, because the value of free emission rights depends on emissions in the past, the firms are faced with exactly the same maximization problem as before.

A.4 "Fair" allocation of free emission rights

Above we have seen that if some emission rights are allocated for free, some firms, those enjoying a high of or perfect economic substitutability may gain, while others saddled with no or low degree of economic substitutability will have their losses reduced.

This suggests that there may be a distribution of free emission rights to the firms that leads to equal net profits impacts.

To see this more clearly, let's consider the same two groups of emitters as above, namely those with perfect economic substitutability, group I, and those with no economic substitutability, group II. Assume, moreover, that the volume of free emission rights to be allocated is X. Finally, let α denote the share of the free emission rights allocated to group I and the rest (1-α) to group II. Note that we do not require α to be nonnegative.

Then, after the allocation of free rights the net gains from the ETS to group I would be:

$$\text{(A.3)} \quad \Delta V(\text{I}) = \alpha \cdot \tau(1) \cdot X \,.$$

And the net gains to group II would be:

$$\text{(A.4)} \quad \Delta V(\text{II}) = -\tau(1) \cdot z(0;\text{II}) + (1-\alpha) \cdot \tau(1) \cdot X \,,^{26}$$

where $z(0;\text{II})$ represents the initial (and final) emissions by group II (see equation (A.2)).

Now, let us assume that it is thought "fair" that the change in net profits be equal for the two groups. Then a little algebraic manipulation of (A.3) and (A.4) reveals that the share of free emission rights going to group I to attain this objective is given by:

$$\text{(A.5)} \quad \alpha = \frac{1}{2} - \frac{z(0;\text{II})}{2 \cdot X} \,.$$

As seems intuitive, according to (A.5), the share going to group I is falling in the volume of emissions (loss) of group II and rising in the volume of free emission rights, *X*.

Moreover, the share going to group I is always less than half and, depending on ratio $z(0,\text{II})/X$ may even be negative. That means that to attain equality, group I must provide group II with free emission rights (of course by buying them in the market).

The relationship between α, the share of group I, and the allocation of free emission rights, *X*, is illustrated in figure A.1. Note that there is an upper bound on *X* defined by total allowable emissions. This is arbitrarily indicated by Xmax in the diagram.

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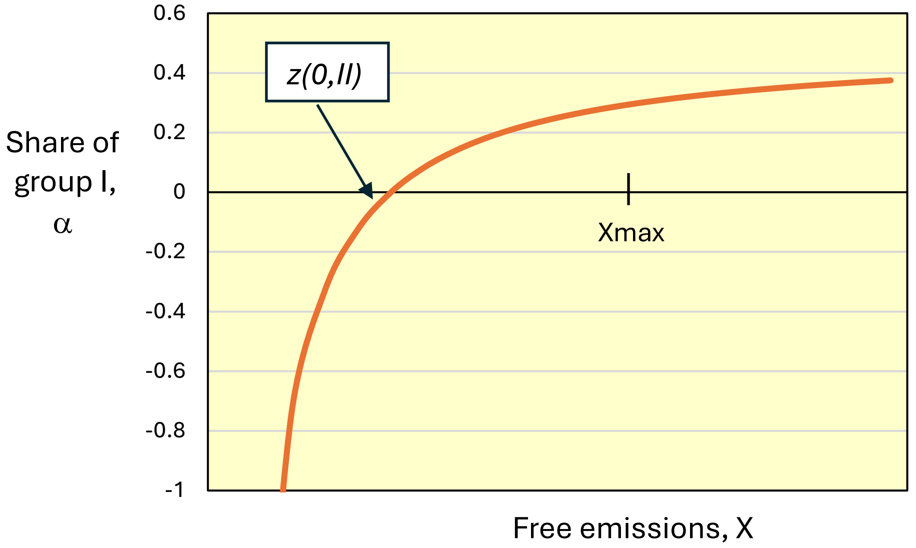
[26] Assuming (for simplicity) that the initial emission price is zero.

Figure A.1

Relationship between the share of group I and free emission rights



Note in figure A.1 that when the volume of free emission rights equals the emissions by group II, i.e. X=z(0,II), α, the share of group I, equals zero. In other words, all the free emission rights go to the group that has no substitution possibilities. Nore also, that when the volume of free allocations fall below z(0,II), which is bound to happen eventually under the EU GHG reduction policy, that share going to group I becomes negative meaning that they will have to provide some emission rights to group II (possibly by buying them in the market).

Needless to say, there exists a distribution of free emission rights that will attain any other distribution of the burden of the GHG emission restrictions between the parties.

Appendix B

Elasticity of substitution and optimal distribution of reduction in GHG emission

This appendix develops an example of two individuals choosing between consumption of two goods where consumption of one of the two goods causes GHG emission. For a given (exogenous) reduction in emission, a policy maker imposes welfare maximizing GHG tax on consumption of that good. The result shows that optimal tax differs between the two individuals such that it is lower for the individual that is less willing to switch between consumption of the two goods.

The two individuals can be thought of as travelers travelling similar distances choosing between flights and other means of transportation (trains, ferries etc.), where one individual travels between Iceland and continental Europe and the other travels between two places within continental Europe, and a policy maker imposes GHG tax on flights. Since other transport methods than flights are much more time consuming for the individual travelling between Iceland and continental Europe, he is less willing to switch between flights and other transportation methods than the individual travelling within continental Europe.

The outcome of the example should not be interpreted as a general result. However, it indicates that there may be welfare arguments for a lower GHG tax on flights between Iceland and continental Europe than between similar flights within the continent.

B.1 Model

Consider two individuals (A and B) receiving utility from two types of goods (1 and 2), The constant elasticity of substitution (CES) utility functions are:

$$U^A(c_1^A, c_2^A) = \left[[c_1^A]^{\frac{\sigma^A - 1}{\sigma^A}} + [c_2^A]^{\frac{\sigma^A - 1}{\sigma^A}} \right]^{\frac{\sigma^A}{\sigma^A - 1}}$$

$$U^B(c_1^B, c_2^B) = \left[[c_1^B]^{\frac{\sigma^B - 1}{\sigma^B}} + [c_2^B]^{\frac{\sigma^B - 1}{\sigma^B}} \right]^{\frac{\sigma^B}{\sigma^B - 1}}$$

where c_1^A is consumption of good 1 by individual A etc. and $\sigma^A > 0$ is elasticity of substitution between consumption of goods 1 and 2 for individual A etc. The individuals' budget constraints are as follows:

$$I^A = p_1^A c_1^A + p_2^A c_2^A$$
$$I^B = p_1^B c_1^B + p_2^B c_2^B$$

where I^A is individual's A income etc., which is exogenous in the model, and p_1^A is the unit price of good 1 paid by individuals A etc.

The elasticity parameter σ^A indicates how willing individual A is to switch between consumption of the two goods such that the lower its value is the less willing the individual is to switch between consumption of the two goods. The same goes for σ^B and individual B.

An individual decides on his optimal consumption of the two goods by maximizing his utility with respect to his budget constraint. This gives the following optimal consumption decisions (demand functions) for the two individuals:

$$[c_1^A]^* = \frac{[p_1^A]^{1-\sigma^A}}{[p_1^A]^{1-\sigma^A} + [p_2^A]^{1-\sigma^A}} I^A$$

$$[c_2^A]^* = \frac{[p_2^A]^{1-\sigma^A}}{[p_1^A]^{1-\sigma^A} + [p_2^A]^{1-\sigma^A}} I^A$$

$$[c_1^B]^* = \frac{[p_1^B]^{-\sigma^B}}{[p_1^B]^{1-\sigma^B} + [p_2^B]^{1-\sigma^B}} I^B$$

$$[c_2^B]^* = \frac{[p_2^B]^{-\sigma^B}}{[p_1^B]^{1-\sigma^B} + [p_2^B]^{1-\sigma^B}} I^B$$

Given prices of the goods paid by the individuals, the functions above determine consumption of the goods. It can easily be verified that an individual‘s consumption of a good is strictly decreasing in its own price and strictly increasing in the price of the other good if the elasticity parameter is greater than unity ($\sigma^A > 1$ etc.), in which case the goods are substitutes (if $\sigma^A < 1$ etc. the goods are complements).

Let us now assume that the goal is to reduce GHG emission caused by consumption of good 1 and that emission equals consumption of the good for simplicity:

$$c_1^{max} \geq [c_1^A]^* + [c_1^B]^*$$

where $c_1^{max} > 0$ is maximum total emission allowed. To achieve this goal, a policymaker can choose the price of good 1 paid by the two individuals p_1^A and p_1^B. To achieve reduction in emission it is clear that the policy maker has to choose to increase the price paid by at least one of the two individuals compared to the market price before an emission reduction policy is implemented. The increase in the price can be interpreted as a GHG tax.

The policymaker chooses p_1^A and p_1^B such that welfare is maximized:

$$W(p_1^A, p_1^B, p_2^A, p_2^B, I^A, I^B) = U^A([c_1^A]^*, [c_2^A]^*) + U^B([c_1^B]^*, [c_2^B]^*)$$

$$= \left[[p_1^A]^{1-\sigma^A} + [p_2^A]^{1-\sigma^A}\right]^{\frac{1}{\sigma^A-1}} I^A + \left[[p_1^B]^{1-\sigma^B} + [p_2^B]^{1-\sigma^B}\right]^{\frac{1}{\sigma^B-1}} I^B$$

subject to the emission constraint:

$$c_1^{max} \geq \frac{[p_1^A]^{-\sigma^A}}{[p_1^A]^{1-\sigma^A} + [p_2^A]^{1-\sigma^A}} I^A + \frac{[p_1^B]^{-\sigma^B}}{[p_1^B]^{1-\sigma^B} + [p_2^B]^{1-\sigma^B}} I^B$$

This gives the following necessary conditions for a solution:

$$\frac{p_1^A\left[[p_1^A]^{1-\sigma^A}+[p_2^A]^{1-\sigma^A}\right]^{\frac{\sigma^A}{\sigma^A-1}}}{p_1^B\left[[p_1^B]^{1-\sigma^B}+[p_2^B]^{1-\sigma^B}\right]^{\frac{\sigma^B}{\sigma^B-1}}}=\frac{[p_1^A]^{1-\sigma^A}+\sigma^A[p_2^A]^{1-\sigma^A}}{[p_1^B]^{1-\sigma^B}+\sigma^B[p_2^B]^{1-\sigma^B}}$$

$$c_1^{max}=\frac{[p_1^A]^{-\sigma^A}}{[p_1^A]^{1-\sigma^A}+[p_2^A]^{1-\sigma^A}}I^A+\frac{[p_1^B]^{-\sigma^B}}{[p_1^B]^{1-\sigma^B}+[p_2^B]^{1-\sigma^B}}I^B$$

which can be used to solve for optimal p_1^A and p_1^B.

B.2 Numerical results

Let us now consider a numerical example where the pre-tax price of good 1 for both individuals, i.e. the price in the market when no GHG emission reduction policy is implemented, is $p_1^A=p_1^B=1$ and the market price for good 2 for both individuals is the same $p_2^A=p_2^B=1$. Further, let us assume that the individuals have the same income $I^A=I^B=1000$. This gives consumption of the two goods for the individuals in the absence of GHG emission reduction policy:

$$[c_1^A]^*=[c_2^A]^*=[c_1^B]^*=[c_2^B]^*=500$$

And total consumption of good 1 (GHG emission):

$$[c_1^A]^*+[c_1^B]^*=1000$$

Now let us use the same numerical assumptions as above and that the policy maker wants to decrease GHG emission down to 500, i.e. by 50%. If both individuals have the same elasticity of substitution ($\sigma^A=\sigma^B=2$), this gives the following optimal policy results:

Table B.1 Optimal price, GHG tax and consumption for identical elasticities

	Individual A	Individual B
Price of good 1	1.56	1.56
GHG tax	0.56	0.56
Consumption of good 1	250	250
Consumption of good 2	609.6	609.6

As is expected, the individuals pay the same GHG tax when the elasticity of substitution is identical. However, if individual A has lower elasticity of substitution (is less willing to switch between consumption of the two goods) than individual B ($\sigma^A=2$ and $\sigma^B=2.2$), the optimal policy results become:

Table B.2. Optimal price, GHG tax and consumption for different elasticities

	Individual A	Individual B
Price of good 1	1.28	1.97
GHG tax	0.28	0.97
Consumption of good 1	343.7	156.3
Consumption of good 2	560.9	692.5

and individual A pays a lower GHG tax.

The example presented above can be thought of as an application of the second welfare theorem of economics which states that any Pareto optimal allocation can be supported by a competitive equilibrium allocation achieved by redistribution of resources. In the example, a policy maker (social planner) allocates scarce GHG emission resources.

Appendix C

Assessing the initial impact of the CO2 tax on tourism value-added:

A change (e.g. an increase) in the CO2 emission price has an initial impact on the price of air travel and from there on tourism value-added. This initial or direct impact is subsequently transmitted thought the economy leading to various adjustments and readjustments ultimately producing the final impact.

Assume that the value-added in tourism in a certain location may be explained by the following function:

$$v = V(n, z).$$

where n is the number of tourists and z a vector (set) of other variables affecting value-added.

Economic considerations suggest that n depend on the price (cost) of tourism.

$$n = N(p),$$

where p denotes the price of tourism.

Presumably, increased production costs (due to input price rises, taxes etc.) will positively affect the price of tourism:

$$p = P(\tau),$$

where in the current context it is useful to think about τ as the cost of CO2 emissions.

Combining these three equations yields:

$$v = V(N(P(\tau)), z).$$

Assuming sufficient differentiability, this equation yields the following basic expression for the percentage change in tourism value added as a function of a percentage change in the cost of CO2 emissions:[27]

$$\text{(C.1)} \quad \frac{\partial v}{v} = E(v,n) \cdot E(n,p) \cdot E(p,\tau) \cdot \frac{\partial \tau}{\tau},$$

where the expressions *E*(*a*,*b*) represents the elasticity of *a* with respect to *b,* i.e., the percentage change in *a* when *b* changes by 1 percent. Therefore, *E*(*v*,*n*) is the elasticity of value-added in tourism with respect to the number of tourists, *E*(*n,p*) the elasticity of number of tourists when a carrier (e.g. Icelandair) alters its transport price and *E*(*p,* τ) is the elasticity of transport price with respect to the CO2 emissions cost.

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[27] It is important to note that this expression is only accurate from small changes in the CO2 price. For larger changes, it should be regarded as a linear approximation to a possibly nonlinear relationship.

The symbol "∂x" denotes a change in the variable x and, therefore, $\partial x/x$ measures the relative (or percentage) change in x. Thus, the ratios $\partial v / v$ and $\partial \tau / \tau$ represent relative changes in tourism value-added and the CO2 emission price (or cost), respectively.

Thus, as a whole, expression (C.1) explains the relative change in tourism value-added as a function of the three elasticities and the relative change in the cost or price of CO2 emissions.

Let there be two carriers of tourists to Iceland each with his own demand function. Then, assuming that the two demand elasticities are equal, straight-forward algebraic manipulation yields the following expression for middle elasticity on the right-hand side of (C.1):

$$\text{(C.2)} \quad E(n,p_1) = E(n_1,p_1)\cdot\left(\frac{n_1}{n}\right) + E(n_2,p_2)\cdot E(p_2,p_1)\cdot\left(\frac{n_2}{n}\right),$$

where n_1 denotes the number of tourists with the first carrier, n_2 the number of tourists with the other carriers and p_1 and p_2 the corresponding prices. Obviously, by definition, $n_1+n_2=n$, where, as before, n is the total number of tourists. An important component of (C.2) is $E(p_2,p_1)$, the elasticity of p_2 with respect to p_1, measuring how the travel price of other carriers responds to 1 percent change in the travel price of carrier 1.

If carrier 1 uses a constant mark-up pricing rule, the elasticity of carrier's 1 ticket price with respect to the cost of CO2 emissions, $E(p, \tau)$ would be:

$$\text{(C.3)} \quad E(p,\tau) = \frac{\tau}{c0+\tau},$$

where $c0$ represents other costs of supplying the travel service, so the denominator of (C.3), $c0+\tau$, measures the total cost of producing travel services. It may be noted that according to (C.3) the $E(p, \tau)$ is simply the share of CO2 costs in total costs.

Combining (C.1), (C.2) and (C.3) yields the final expression for the initial or direct impact of a change in the CO2-emission costs on tourism value-added.

$$\text{(C.1b)} \quad \frac{\partial v}{v} = \left(E(v,n)\cdot\left(E(n_1,p_1)\cdot\left(\frac{n_1}{n}\right) + E(n_2,p_2)\cdot E(p_2,p_1)\cdot\left(\frac{n_2}{n}\right)\right)\cdot\frac{\tau}{c0+\tau}\right)\cdot\frac{\partial\tau}{\tau}.$$

So, to apply expression (C.1b) requires empirical knowledge of:

(i) $E(v,n)$,
(ii) $E(n_1,p_1)$,
(iii) $E(n_2,p_2)$,
(iv) $E(p_2,p_1)$,
(v) n_1/n,
(vi) n_2/n,
(vii) $\tau/(c0+\tau)$.

To this, we now turn:

C.1 Empirical estimates

(i) $E(v,n)$; the elasticity of value-added with respect to number of tourists.

On the basis of a statistical regression estimation explained in appendix F, it was found

$$E(v,n)=0.7 \text{ with a 95\% confidence interval } E(v,n) \in [0.62,0.76]$$

(ii) $E(n_1,p_1)$; the elasticity of number of passengers with Icelandair with respect to the price of travel

On the basis of statistical estimation of the price elasticity for air flights around the world discussed in appendix G, it was concluded that

$$E(n1,p_1)= -1.5 \text{ with a 95\% confidence interval } E(n1,p_1)\in[-1,-2.5].$$

(iii) $E(n_2,p_2)$; the elasticity of number of passengers of other tourist carriers with respect to the price of travel

In appendix G, it was argued that since other tourist aviation carriers were similar to Icelandair their elasticity of passengers with respect to price would be similar to or (numerically) larger than that of Icelandair.

$$E(n2,p2)= -1.5 \text{ with a 95\% confidence interval } E(n2,p_2)\in[-1,-3.0].$$

(iv) *The elasticity of other travel prices with respect to Icelandair's price*, $E(p_2,p_1)$

In appendix G, it was argued that a reasonable estimate for this cross-price elasticity was

$$E(p_2,p_1)=1.$$

The main reason is that Icelandair which accounts for over 3/5 of the air travel to Iceland is likely a price leader in this market and other air carriers (which account for the remaining bulk of tourist travel to Iceland) have a similar cost and operating structure to Icelandair.

(v) The share of Icelandair in total number of passengers at Keflavik airport, n_1/n

We would ideally like to know the share in total number of tourists to Iceland that are carried by Icelandair. The available data, however, do not allow this kind of a direct estimate.

ISAVIA has provided data on total number of passengers going through Keflavik airport since 2004 subdivided into arrivals in Iceland, departures from Iceland and transit passengers.

Icelandair has provided data on its total sales of seats since 2017 subdivided into the categories "to" (presumably to Iceland), "from" (presumably from Iceland)[28], "via" (presumably transit passengers) and "within" (possibly seats on air-routes within Iceland).

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[28] This interpretation of the „from" numbers is problematic in that they are much lower (about half) than the seats classified as „to" while it stands to reason that most flights to Iceland are return flights.

The ISAVIA arrivals figures and the corresponding Icelandair "to" figures are provided in the following table.

Table C.1

Total and Icelandair passenger arrivals in Keflavik

(Sources: ISAVIA and Icelandair)

Year	ISAVIA arrivals	Icelandair "to"	Icelandair/ ISAVIA
2017	2886636	1440324	0.4990
2018	2950842	1462466	0.4956
2019	2604900	1852745	0.7113
2020	597956	446054	0.7460
2021	914110	687113	0.7517
2022	2294101	1505800	0.6564
2023	2816327	1782786	0.6330
2024	2858270	1517580	0.5309
2025	2957024	1736745	0.5873
Average			0.6235

It may be noted that the ratios of total Icelandair passengers (seats sold) to total arrivals in Keflavik airport is very similar to those listed in table C.1.

So, assuming that the total arrivals in Keflavik airport provides a reasonable estimate of the total number of foreign tourists in Iceland (the correlation for the period 2017 to 2024 is about 0.998), and that the share of foreign tourists in Icelandair's arrival passengers is the same as that in arrivals in general, it appears that a reasonable point estimate of the share of Icelandair in the arrival of foreign tourists in Iceland.

$\boldsymbol{n_1/n}$**=0.624**

Since as may be inferred from the above discussion, this estimate is subject to considerable uncertainty, a reasonable confidence bound for the estimate is:

$\boldsymbol{n_1/n \in [0{,}58;0.67]}$**.**

(vi) The share of other carriers in total number of passengers at Keflavik airport, $\boldsymbol{n_2/n}$

Given the above estimate for Icelandair's share, the corresponding estimate for other carriers is

$\boldsymbol{n_2/n \in [0{,}33;0.42]}$.

(vii) The share of CO2 costs in Icelandair’s total costs, $\tau/(c0+\tau)$

According to data supplied by Icelandair, the company’s total operating costs and net cost due to its CO2 emissions and the ETS[29] during the years 2017-2025 was as listed in the following table:

Table C.2

Icelandair’s operating costs, ETS and CO2 emissions costs

(Source: Icelandair)

	Icelandair Total cost	ETS cost brutto	Other C02 costs	C02 cost brutto	C02 cost netto	ETS costs netto	Net C02 cost/ total cost	Net ETS cost/ total cost
	1000 ISK	1000 ISK	1000 ISK	1000 ISK	1000 ISK	1000 ISK		
2017	96536815	361486		361486	231936	231836	0.0024	0.0024
2018	108712076	1 325714		1325714	945498	945498	0.0087	0.0087
2019	130349599	1811573		1811573	1155073	1155	0.0089	0.0000
2020	74871539	547777		547777	191766	191766	0.0026	0.0026
2021	55721716	1988002		1988	316730	316730	0.0057	0.0057
2022	132906714	4282041		4 82041	2047136	2047136	0.0154	0.0154
2023	176443029	5590456		5590456	3211018	3211018	0.0182	0.0182
2024	185550608	4894795	151407	5046202	3512246	3360857	0.0189	0.0181
2025	174435960	5535397	935345	6470742	4886825	3951580	0.0280	0.0227

As indicated by the table, the bulk of Icelandair’s CO2 costs during this period are due to the ETS. Other costs associated with CO2 emissions, due to SAF purchases[30] and the Corsia system, only emerge in 2024 and 2025.

The table also shows that as a fraction of total costs, the specific net ETS and all CO2 net costs have increased very rapidly. This is illustrated in figure C.1.

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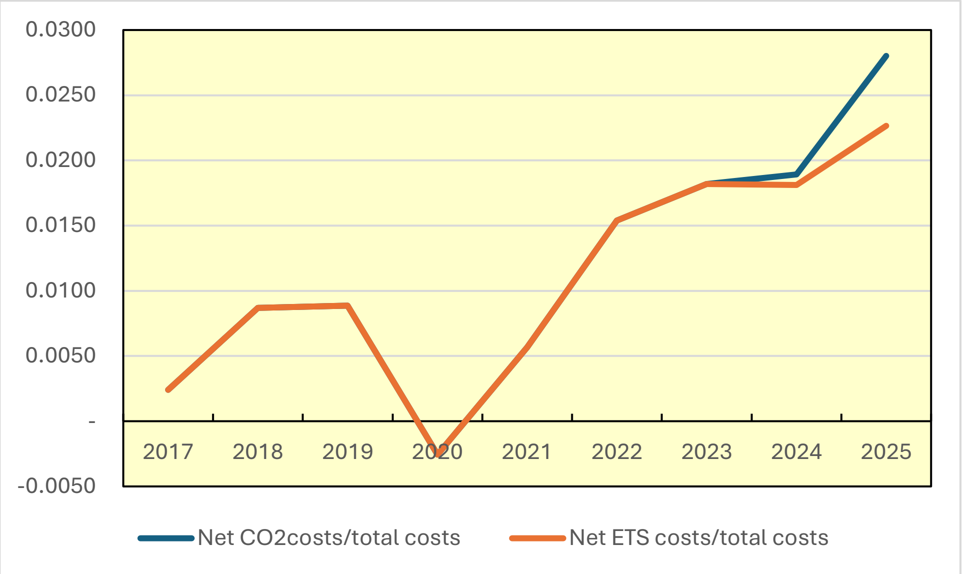
[29] In calculating this net cost it is assumed that all offsetting income and „free emission rights“ relate to the ETS.

[30] Actually, since the SAF purchases are primarily motivated by the high cost of ETS permits, they may be attributed to the ETS.

Figure C.1

Net ETS and CO2 costs as fractions of Icelandair's total operating costs



Currently (2025) these CO2 cost fractions are between 2,3 and 2,8% of total operating costs, for the net ETS costs and all CO2 costs, respectively.

On this basis the ETS cost as a fraction of total costs in 2025 is estimated to be:

ETS: $\boldsymbol{\tau/(c0+\tau)=0.023}$,

and total CO2 costs in 2025 as a fraction of total costs is estimated to be:

CO2: $\boldsymbol{\tau/(c0+\tau)=0.028}$.

The growth rates in ETS and all CO2 costs since 2017 have been variable (presumably due to covid in 2020 and 2021). However, the annual average growth rate has been 30%. Therefore, unless the system is altered, these cost shares may be expected to increase drastically in the coming years.

C.2. Estimating the impact of an increase in the net ETS cost

Given the above empirical estimates, is it now straight forward to apply expression (1b) to obtain estimates of the initial impact of changes in the ETS cost as well as CO2 costs as a whole. The empirical estimates are summarized in table 3.

Table C.3
Empirical estimates: Summary

		Empirical estimates	
	Parameter	ETS	CO2
(i)	$E(v,n)$	0.7	0.7
(ii)	$E(n_1,p_1)$	-1.5	-1.5
(iii)	$E(n_2,p_2)$	-1.5	-1.5
(iv)	$E(p_2,p_1)$	1	1
(v)	n_1/n	0.624	0.624
(vi)	n_2/n	0.376	0.376
(vii)	$\tau/(c0+\tau)$	0.023	0.028

Now the impact on tourism value added depends on whether we are considering only changes in the ETS cost or in CO2 costs as a whole (i.e. including SAF purchases and Corsia).

The estimates of the impacts in both of these cases are presented in tables C.4 and C.5.

Table C.4
Initial impact of change in ETS cost on tourism value-added
(Application of equation (1b))

Percentage change in ETS cost	Percentage change in tourism value-added
50%	-1.21%
100%	-2.42%
150%	-3.62%
200%	-4.83%
250%	-6.04%
300%	-7.25%
350%	-8.45%
400%	-9.66%
450%	-10.87%
500%	-12.08%

Table C.5

Initial impact of change in total CO2 cost on tourism value-added

(Application of equation (1b)

Percentage change in ETS cost	Percentage change in tourism value-added
50%	-1.21%
100%	-2.42%
150%	-3.62%
200%	-4.83%
250%	-6.04%
300%	-7.25%
350%	-8.45%
400%	-9.66%
450%	-10.87%
500%	-12.08%

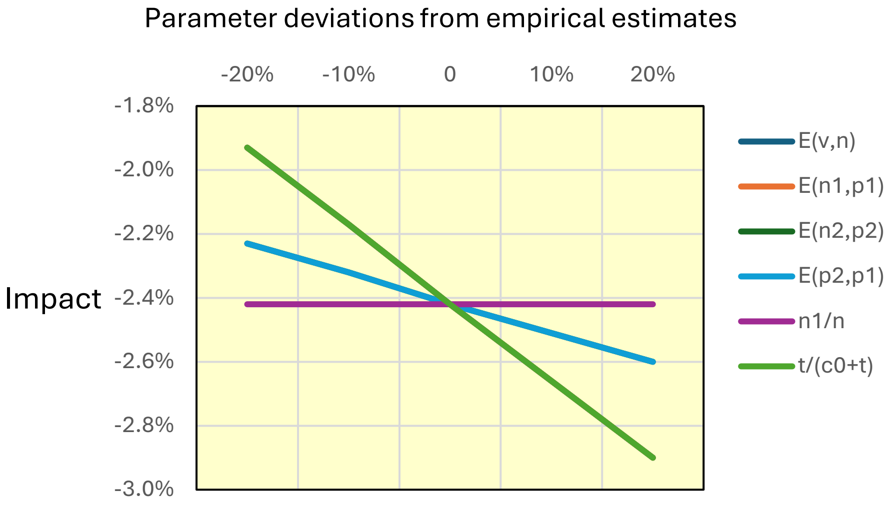
It is important to note that the results in table 4 and 5 only measure the initial direct impacts of a change in the cost of CO2 emissions. These impacts will subsequently flow through the macro-economy leading to responses in the various macro-economic variables which may exacerbate or alleviate the direct impact on tourism value-added and the GDP.

C.3. Sensitivity to empirical estimates

The numerical impacts listed in tables 4 and 5 depend critically on the empirical estimates entering equation (1b) and listed in table 3. To provide an idea of the sensitivity of the results to these empirical inputs, a simple sensitivity analysis has been conducted. The procedure is to alter each of the empirical input parameters in turn by percentages ranging from -20% to +20% and calculate the resulting direct impact from doubling the ETS cost on tourism value-added. The findings from this sensitivity analysis are illustrated in the sensitivity graph in figure C.2.

Figure C.2

Sensitivity of the impact on tourism value added to empirical parameters: The impact of doubling ETS costs.



The sensitivity analysis illustrated in figure 2 indicates that the estimated impacts of doubling the ETS cost are not particularly sensitive to possible errors in the estimates of the input parameters. In all cases the direct impact is between -1.9% and -2.9%. The greatest sensitivity is to the elasticity of value-added to the number of tourists and the current share of ETS cost in total operating costs (the green line).[31]

As figure 2 shows, the share of Icelandair in the total number of foreign tourists does not have any impact on the size of the direct impact of increase in ETS costs on tourism value added. This is because we have assumed the same elasticity of transport price to ETS costs and a cross price elasticity of unity.

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[31] Note that due to the structure of equation (1b), the $E(v,n)$ has exactly the same effect on tourism value-added as $\tau/(c0+\tau)$. The same applies to $E(n_2,p_2)$ and $E(p_2,p_1)$ as well as a couple of other parameters. Therefore the sensitivity lines for these parameters cannot be differentiated in figure 2.

Appendix D
The macroeconomic models

Short descriptions of the macroeconomic models and simulations assumptions are provided in this appendix. Two such models are used, the QMM model and the DSGE model.

D.1. The QMM model

The QMM model is a tourism augmented version of QMM model used by Statistics Iceland, which in turn is a backward looking version of the QMM model developed and used by the Central Bank of Iceland (see Ásgeir Daníelsson, et. al., 2019). The model is a one sector macroeconomic model of the Icelandic economy based on empirically estimated behavioral equations and accounting identities.

The tourism augmented version of the QMM model explicitly models the tourism industry's role in service exports. The model contains three variables that describe the tourism industry:

(i) real tourism exports (exogenous),
(ii) prices of tourism exports (endogenous),
(iii) nominal tourism exports (defined as the product of the first two variables).

To analyze the effects of changes in ETS costs (scenarios I and II) in the model assumptions consistent with the initial effects on value added in tourism shown in table 3.1 are made regarding the impact on tourism prices, general prices, and tourism demand in the model for each of the sub-scenarios. For simulating the effects of decreases in tourism demand (scenario III) only assumptions about tourism demand are made.

D.2. The DSGE model

The DSGE model is a general equilibrium model calibrated using Icelandic data (see Hagrannsóknir sf., 2023). Like other macroceconomic model of small open economies, it consists of households, firms, Government and foreign households and firms. The model is designed and calibrated such that the tourism sector is a separate industry in the model and its output is a special good in both domestic and foreign households‘ consumption basket.

The model is a real model where flexible prices are assumed which implies that the effects of shocks on real variables, like GDP, are smaller than observed in data, at least in the short run. Except for this and industry- and good separation in the model, the model follows the construction of the so-called DSGE (Dynamic Stochastic General Equilibrium) models for small open economies (see Smets and Wouters (2002) and Stefán Þórarinsson (2020) etc.).

Tourism prices are endogenous in the model such that tourism firms price their output at a constant markup over marginal costs. For analyzing the effects of changes in ETS costs (scenarios I and II) on the economy it is therefore necessary to make assumptions about the impact on marginal costs for each of the sub-scenarios. This is done such that these are consistent with the initial effects on value added in tourism shown in table 3.2 For simulating the effects of decreases in tourism demand (scenario III) only assumptions about tourism demand are made.

For both models, simulations are made such that changes (to prices, marginal costs, tourism demand etc.) last for one year after which they return to zero. The effects on macroeconomic variables (GDP, employment, net exports) shown in tables 3.2 and 3.3 are for the same year as the changes occur.

Appendix E
Increasing costs of reducing GHG emissions

Consider a company profit function:

$$\Pi(z, x),$$

where z denotes it emission of GHG (due to particular input use) and x the use of other inputs.

We assume, as is generally done in economic analysis and seems in accordance with empirical reality, that this profit function is dome-shaped and concave in both inputs.

Profit maximization implies a certain level of z. Denote it by z^*.

The cost of being forced to use different z than z^* is the reduction in profits of doing so. It is easy to see that this may be expressed as:

$$C(z,x) = -\left(\Pi(z,x) - \Pi(z^*,x^*)\right) .$$

Since, z^* represents profit maximization, if $z \neq z^*$, this cost is positive. Moreover, due to the dome-shape of the profit function, if $z < z^*$, the cost is falling in z; the cost curve has a negative slope. More formally, this is because

$$\frac{\partial C(z,x)}{\partial z} = -\frac{\partial \Pi(z,x)}{\partial z} < 0 .$$

Furthermore, if the profit function is concave in z and if $z < z^*$, the cost function must be convex in z. More formally:

$$\frac{\partial^2 C(z,x)}{\partial z^2} = -\frac{\partial^2 \Pi(z,x)}{\partial z^2} > 0 .$$

This establishes, the shape of the GHG reduction cost function in figure 1.1 and thus that costs of reducing GHG emissions increase as GHG emissions are less.

Appendix F

The elasticity of tourism value added with respect to the number of tourists

Well known features of the Icelandic tourism industry and standard economics suggest that the value-added generated by the Icelandic tourism industry is positively related to the number of aviation passengers travelling through Keflavik airport (Flugstöð Leifs Eiríksonar).

A simple formulation expressing this hypothesis is:

(F.1) $v = V(n,z)$, $\partial v / \partial n > 0$,

where *v* denotes the value-added in tourism, *n* the number of passengers via Keflavik airport and *z* other variables affecting the relationship.

Statistics Iceland provides time series data on *v, n* and several other explanatory variables in the set *z* for the period 2009-2024. On the basis of these data it is possible to employ standard statistical techniques to:

(i) Test the hypothesis expressed by (F.1).

(ii) Obtain empirical estimates of the relationship including the crucial quantity, the elasticity of the value-added in tourism with respect to the number of passengers via Keflavik airport.

F.1 Statistical estimation

Following statistical exploration of the data, it appeared that they could be adequately represented by the following functional formulation of (1):

(F.2) $v(t) = e^{a+b\cdot t} \cdot n(t)^{\alpha} \cdot u(t)$,

where *t* refers to the year, *u*(*t*) is a stochastic white noise error term and *a*, *b* and α are parameters.

The key estimation results are:

Estimation technique: OLS
Estimation period: 2009-2024 (annual)
Estimation data: See appendix A

$R^2 = 0.9825$
Standard error of the estimate $\sigma = 0.069378$

Table F.1
Parameter estimates

Coefficients	Estimates	t-values
a	1.976	3.8
b	0.0275	5.9
α	0.688	17.9

DW-statistic: 2.19
Jarque-Bera text of normality of residuals: $\chi^2(2)=1.04$
Chi-squared test for nomality of residuals: $\chi^2(1)=3.69$.

Interpretation

The fit of the function (2) to the data is very good. $R^2=0.98$. The standard error of the estimate is 0.069, i.e. about 7% of the measured value-added is also good.

The diagnostic tests (for serial correlation and normality) do not contradict the 0-hypothesis that the residuals are white noise. Therefore, the t-tests are probably statistically consistent.

Needless to say, according to these results, the two hypotheses contained in (F1) are not rejected.

The estimated parameters seem reasonably well determined. This holds in particular for the parameter α, the elasticity of the value-added in tourism with respect to the number of passengers via Keflavik airport.

According to these estimates: $\boldsymbol{\alpha=0.69}$ and with 95% confidence $\boldsymbol{\alpha\in[0.62,0.76]}$

The elasticity of value-added in tourism with respect to the number of passengers via Keflavik airport is estimated to be close to **0.7**.

It is interesting to note that the impact of the number of passengers via Keflavik on the value -added from tourism (albeit not the elasticity) seems to be gradually increasing according to these estimates by some 2.8% per annum. This may reflect more spending per passenger.

Alternative functional formulations

1. Possible variables in z (exchange rates, gdp etc.) were not found to improve the statistic properties of the estimates or be statistically significant.
2. Splitting the passengers into Icelandic and foreign did not improve the statistical properties (was statistically insignificant)
3. More complicated dynamic evolution (higher powers of t) did not improve matters either (was statistically insignificant).
4. Other functional forms tested did not do better.

F.2 The data

Table F.2
Data

Value-added in tourism. M. ISK Fixed (2020) prices	Number of passengers via Keflavik		
	Icelanders	Foreigners	Total
86231.5	254537	464536	719073
82810.8	293770	459252	753022
90832.2	341091	540824	881915
104206.2	358201	646921	1005122
121284.3	364912	781016	1145928
144937.2	400002	969181	1369183
178454.6	450274	1261938	1712212
237321.8	536257	1767726	2303983
245291.0	618952	2195271	2814223
254591.1	668093	2315925	2984018
255602.1	611383	1986153	2597536
86633.0	127229	482108	609337
150319.3	219367	687691	907058
253119.3	586650	1696785	2283435
294143.9	603109	2214182	2817291
309570.2	600905	2261391	2862296

Appendix G

Elasticity of travel demand and cross price elasticity

Iceland is an island in the North Atlantic far removed from the continents. Travel to Iceland, therefore, is almost exclusively by air.[32]

We are unaware of published studies of the demand elasticity of Icelandic air tickets to Iceland. However, there are many other studies of the elasticity of air-travel w.r.t. price. The broad finding from these studies is that this elasticity is generally between [-1,-2] (see e.g. the Brons et al. 2001, Pererra and Tan 2019). More to the point, in their meta study Brons et al. (2001) find the average estimated elasticity from 204 studies to be -1.15 with a standard error of 0.619. A more recent study by Perera and Tan (2019) employing global data and robust statistical techniques produced a remarkably similar estimate of -1.16 but with a considerably a smaller standard error of estimate of 0.29.

Icelandair and in fact other airlines serving the Icelandic tourist market are generally low-price airlines catering to price sensitive, low fare paying passengers. It stands to reason and is well-established that low price air travellers generally exhibit higher price sensitivity than high-price travellers (Brons et al. 2001). For this reason, it seems reasonable to estimate the elasticity of demand for trips to Iceland with respect to the ticket price to be:

$\boldsymbol{E(n1,p_1)= -1.5}$ with a confidence interval $E(n1,p_1)\in[-1,-2.5]$.

$\boldsymbol{E(n2,p2)= -1.5}$ with a confidence interval $E(n2,p_2)\in[-1,-3]$.

The reason for the higher upper bound on the confidence interval for other carriers is that they are even more oriented to the tourist demand than Icelandair.

The elasticity of other travel prices with respect to Icelandair's price, $E(p_2,p_1)$

Icelandair is the largest aviation passenger carrier to Iceland with almost 3/5 of the total arrivals in Keflavik airport. Also many of the other aviation carriers serving the Icelandic market are similar to Icelandair. Therefore, it appears most likely that other carriers will adjust prices similarly to Icelandair.

Therefore, a reasonable estimate of this cross price elasticity is $\boldsymbol{E(p_2,p_1)=1}$.

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[32] There is ferry operating between Europe and Iceland. This accounts to less than 3% of total passenger arrivals in Iceland.