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Net Zero, Energy and Transport Committee

Tuesday 30 September 2025

Session 6

The Scottish Parliament
Pàrlamaid na h-Alba

Tuesday 30 September 2025

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NET ZERO, ENERGY AND TRANSPORT COMMITTEE
29th Meeting 2025, Session 6

CONVENER

*Edward Mountain (Highlands and Islands) (Con)

DEPUTY CONVENER

*Michael Matheson (Falkirk West) (SNP)

COMMITTEE MEMBERS

*Bob Doris (Glasgow Maryhill and Springburn) (SNP)
Monica Lennon (Central Scotland) (Lab)
*Douglas Lumsden (North East Scotland) (Con)
*Mark Ruskell (Mid Scotland and Fife) (Green)
*Kevin Stewart (Aberdeen Central) (SNP)

*attended

THE FOLLOWING ALSO PARTICIPATED:

Sarah Boyack (Lothian) (Lab) (Committee Substitute)
Dr Sebastian Eastham (Imperial College London)
Celeste Hicks (Aviation Environment Federation)
Professor Graham Hutchings (Cardiff University)
Professor Mercedes Maroto-Valer (Heriot-Watt University)
Mark Morrison (Optimat)

CLERK TO THE COMMITTEE

Peter McGrath

LOCATION

The Mary Fairfax Somerville Room (CR2)

Scottish Parliament

Net Zero, Energy and Transport Committee

Tuesday 30 September 2025

[The Convener opened the meeting at 09:26]

Decision on Taking Business in Private

The Convener (Edward Mountain): Good morning, and welcome to the 29th meeting in 2025 of the Net Zero, Energy and Transport Committee. Apologies have been received from Monica Lennon.

Our first item of business is a decision on taking items 3 to 6 in private. Item 3 is consideration of the evidence that we will have heard on the Sustainable Aviation Fuel Bill legislative consent memorandum. Item 4 is consideration of the appointments process that is being used to fill a vacancy on the board of Environmental Standards Scotland. Item 5 is consideration of a draft report. Item 6 is consideration of our approach to stage 1 scrutiny of the Ecocide (Scotland) Bill. Are we happy to take those items in private?

Members *indicated agreement.*

Sustainable Aviation Fuel Bill

09:26

The Convener: Item 2 is consideration of the legislative consent memorandum on the United Kingdom Government's Sustainable Aviation Fuel Bill. A legislative consent motion is laid when a UK bill makes provision in areas that lie within the competence of the Scottish Parliament or that affect the executive competence of the Scottish Government. The committee must report to the Parliament on whether the consent should be granted.

We are also taking the opportunity to look more broadly at the prospects of sustainable aviation fuel production in Scotland and its potential role in reducing greenhouse gases from aviation. That will feed into our work later this year, when we consider transport aspects of the Scottish Government's forthcoming climate change plan.

The bill aims to create more stable pricing for sustainable aviation fuel to encourage domestic production to grow. That is in parallel with increasing the mandate for the use of SAF by the industry.

The Scottish Government supports the bill overall, but it is withholding its consent, for now, on some technical matters. I hope that we will be able to see a supplementary LCM shortly.

I welcome to the meeting Dr Sebastian Eastham, associate professor in sustainable aviation at Imperial College London; Celeste Hicks, policy manager for the Aviation Environment Federation; Professor Graham Hutchings, regius professor of chemistry at Cardiff University; Professor Mercedes Maroto-Valer, director of the UK industrial decarbonisation research and innovation centre and the deputy principal of Heriot-Watt University—that is quite a long title; and Mark Morrison, senior consultant at Optimat. Thank you all for giving up your time to attend this morning.

We will move to questions. Celeste Hicks, I understand that you will have to go after about an hour, but a few questions might be asked later than that, so I will try to bring them in earlier. If it appears that we are going out of sync on the subject, it is only so that I can get Celeste's opinion before she leaves.

The first question is from me and it is a simple one, I think. There are a variety of ways of producing sustainable aviation fuel. Which, in your view, offers the greatest prospect in Scotland and the UK overall? Does the best method of production change over time? Are we going to start somewhere and end somewhere else? Which

is best for Scotland? Who would like to start off? Let us start in the room. Mark Morrison, do you want to go with that? You are all going to get a chance to answer this one, but you will not all get a chance at all the other questions.

09:30

Mark Morrison (Optimat): A few years ago, Optimat conducted a study for Scottish Enterprise on SAF supply chains in Scotland. In the long term in Scotland, power-to-fuel has the best prospects. We have legislation and ambition to capture carbon to generate far more renewable electricity than we need in Scotland and to produce green hydrogen as a result. If you have captured carbon as well as hydrogen, you can make fuel. We are bit more limited with other buyer resources. I would put my money on power-to-fuel.

The Convener: When we were looking at this, we were given the definition of first generation, second generation and third generation. It always helps me to keep it simple. Which of those categories would power-to-fuel fall into?

Mark Morrison: It is third generation. Scotland already has companies such as Argent Energy that are producing biodiesel from waste vegetable oils, which is the hydroprocessed esters and fatty acids route and would be classed as second generation. Potentially, we have the opportunity to make fuels out of forest and agricultural waste, but, in contrast to other countries such as the US and Norway, that waste is quite dispersed in Scotland, which might be an issue.

Professor Mercedes Maroto-Valer (Heriot-Watt University): I will reflect on the convener's point about temporal variation, which it is important to keep in mind. In the short term, there is an opportunity to use the Grangemouth terminal infrastructure for blending and distribution. We could get going on that very quickly. In the medium term, because of resource availability or the lack of it, either first or second generation will be available more quickly, because you do not need as much infrastructure.

I agree with Mark Morrison that the largest opportunity is what, on paper, would be called third generation. However, all of that requires significant infrastructure, because, from sourcing hydrogen to green carbon, we will need to build a lot of infrastructure that we do not yet have. We also need to consider temporal dependence. The windows of opportunity will vary with time and will increase with scale as well as the level of investment that we will need.

The Convener: Sebastian Eastham, I will not ask you whether they are right, but do you agree with them? [*Interruption*.]

Hold on, we cannot hear you. I will leave you in the hands of the broadcasting team to sign off and come back in again, if that is possible. We will go to Graham Hutchings next.

Professor Graham Hutchings (Cardiff University): I largely agree. I chaired the Royal Society policy briefing on sustainable aviation fuel, which I hope the committee has had sight of. As is noted in the briefing, access to green hydrogen will be crucial, whichever route you want to take. You require a drop-in fuel that is broadly similar to jet A, which is the current kerosene fuel. Power-to-fuel will be an obvious way to go in the short term. We also considered fuels such as hydrogen and ammonia, which would require changes to the air frame and would not be viable, even up to 2050, for commercial flights.

The Convener: Celeste Hicks, can we hear from you? We can hear you.

Celeste Hicks (Aviation Environment Federation): Great. I broadly agree. As the non-governmental organisation voice, we have a little bit of luxury in being able to take a step back and look at it from a more theoretical point of view. The answer is partly to do with what you decide you want to do. As the other witnesses have just mentioned, you will need to create the infrastructure; the market will not just decide this. It is an interesting situation, because the SAF mandate and the revenue certainty mechanism bill are actually shaping the market.

A problem that we have is that the resources will go where the money is. If aviation fuels—in particular, third-generation e-fuels—become extremely expensive, people will not buy them. Therefore, the answer is to do with the decisions that you make about what you want the industrial strategy to be.

I am quite curious to hear the Scottish perspective on it, because I have been looking a lot at the clusters in the UK more widely—in Liverpool and Teesside—and at the way that they are being developed. Questions that come from that include who gets access to the pipeline, who gets access to the green hydrogen and whether the green hydrogen will be produced next to the refinery. Such questions about how you plan the cluster will define the answer on the fuel.

From a sustainability point of view, we will ultimately need e-fuels, because they are the best, and, theoretically, we will have infinite amounts of green hydrogen and electricity if we want. That is just a question of planning bigger.

The Convener: Sebastian Eastham—are you back with us?

Dr Sebastian Eastham (Imperial College London): I hope so.

The Convener: I am glad to report that you are. We can hear you loud and clear.

Dr Eastham: Excellent. I apologise—I missed a little bit of some of the previous answers, but I will try to be brief nonetheless.

I come at this from the perspective of environmental benefits, so I will not try to speak to practicality; other witnesses can speak very well to that. The critical factor is to transition as rapidly as possible towards SAFs that can be shown to achieve a significant reduction in carbon emissions and not to overly emphasise early-generation SAFs that might produce only very limited climate benefits. I would be concerned about locking in too heavily to such SAFs.

The Convener: Turning to the LCM before this Parliament, which relates to the bill that is before the UK Parliament, does the bill go far enough, in your opinion? Does it drive this forward at the pace that we need? Again, I will let you each answer briefly, starting with Graham Hutchings.

Professor Hutchings: Unfortunately, I was not given the draft bill to look at beforehand. I asked whether there were any papers that I should read, but I was not given any. I will not be able to answer the question, because I do not know what is in the draft bill—I do apologise.

The Convener: That is alright. I will not embarrass everyone, then. Does anyone have a view on whether the bill goes far enough? Mark is volunteering.

Mark Morrison: I might regret this.

It is good that part of the bill is dedicated to third-generation power-to-liquid fuels. An issue that Scotland might face is that, as I understand it, the bill aims to achieve a certain percentage of SAF within all aviation fuel across the whole of the UK. If you are being cynical, you might think that that just means London Heathrow, maybe Gatwick and perhaps Manchester, which are the airports where a lot of companies think the majority of SAF will go, so you might not be able to access SAF in other parts of the UK. That is the only consideration. We had discussions with people across the aviation sector, and they were concerned that that might stifle development elsewhere.

The Convener: Usually, if witnesses are in the room and do not want to answer a question, they can just look away, but three of you are looking assiduously at the camera. Does anyone want to come in? Mercedes, do you want to come in on that?

Professor Maroto-Valer: Yes. I was trying to reflect on the question before speaking.

I think that the bill has the right components. As with many of these things, it is in the execution of a general plan where things work out or do not work out. To go back to what Mark Morrison said, it is about the details of how the distribution is going to work. Some market interventions are mentioned, but how will those be implemented? What warranties can you have that the implementation will provide a benefit for Scotland?

Probably unsurprisingly, that level of detail is not there, but you maybe need to get reassurance on how the process will be carried out and who will be in charge of that. Something that allows some sort of cyclic revision of the allocation of SAF or permits would give you an instrument to see how the implementation and deployment happen.

The Convener: Kevin, do you want to come in?

Kevin Stewart (Aberdeen Central) (SNP): I will be very brief, convener. Mark Morrison said that there might be a concentration at Gatwick and Heathrow, yet SAF is available at airports such as Aberdeen, which is in my neck of the woods. Is it a problem that there might be a concentration in one area? Is Aberdeen somewhat different from other smaller airports? Has any airline made the commercial decision—for environmental reasons, which are a good selling point—to move to SAF much more quickly?

I will start with Mark and maybe others could indicate whether they want to come in.

Mark Morrison: My understanding is that, at Aberdeen airport, Air BP is providing a SAF blend to Bristow Helicopters, which services offshore oil and gas rigs. I know that some goes to Prestwick airport, and that Highlands and Islands airports have had some in the past. I am not saying that there will be no SAF available. However, at the moment, the demonstration plants that have been developed for companies such as LanzaTech, Velocys and Fulcrum BioEnergy are all located in England, around the major pipelines that service Manchester and Heathrow.

It is perhaps a concern that, if an airline or supplier has to comply with certain levels, it will put the SAF where it will be cheapest to manufacture and provide, in order to comply with those levels.

Kevin Stewart: For it to be cheaper in Scotland, we need to have production here.

Mark Morrison: Yes.

Kevin Stewart: I see that Celeste Hicks wants to come in.

Celeste Hicks: I will briefly go back to the question about the revenue certainty mechanism bill and whether it goes far enough to stimulate production. I have been following the bill—not at

the committee stage, but I have watched what has been discussed in Parliament as the bill has gone through.

The big question is how high the levy is set. The levy on fuel suppliers needs to be big enough to make sure that there is enough fund in the pot to meet the contract for difference, so that, when the price of the fuel goes up, the producers give money back to the Government and, when the price goes down, the contract will top them up. There needs to be enough money in that pot to ensure that it can influence the market. At the same time, the levy cannot be set at a level that is so high that the airlines will definitely pass the cost on to consumers—the people who buy air tickets.

One of our concerns is that, although the contract for difference mechanism that has been used for the wind industry has been incredibly successful and has stimulated a huge amount of wind production, there are still residual discussions about the fact that those long-term contracts, which were locked in 20 years ago, are still causing green levies on people's energy bills now. Everybody needs to be cautious to ensure that that does not happen again. We do not want our provision of what is basically a subsidy to keep production coming to result in consumers' bills going up and them seeing green levies on their bills as a bad thing. That is an important point to consider.

Mr Stewart, was your question about whether SAF production needs to be close to the airport?

09:45

Kevin Stewart: It was kind of about that. I also asked whether any airlines have made a commercial decision, for environmental reasons, to use SAF more.

Celeste Hicks: I am sorry—I had a lot of things in my head that I wanted to say.

Broadly, it is much better for the fuel production to happen where the green hydrogen is, where the pipelines are, where there is access to the undersea storage for any CO_2 that you remove from the atmosphere or where you carry out point-source carbon capture. In other words, it needs to happen in an industrial cluster, and there are lots of opportunities for that in Scotland.

In response to your question about whether airlines have made a commitment to use SAF, I think that International Airlines Group, which is one of the big airline groups—it includes British Airways and others; I cannot remember all of them—uses SAF for up to 3 per cent of its fleet's fuel. Heathrow airport has made a 3 per cent commitment as well, which is above the SAF mandate of a 2 per cent commitment. Some airlines are going big on it, but they tend to be the ones that can afford the premium because they have the deepest pockets.

Kevin Stewart: I wouldnae say that 3 per cent is big.

The Convener: Just for the record, when it comes to Aberdeen, we asked Loganair whether it would like to take part in today's session, because I think that it has some involvement in the use of SAF. Sadly, there seemed to be a clash of diaries, but we might hear from Loganair at a later date.

Dr Eastham: I will be brief again. The original question was: does the bill go far enough? I would argue that the bill needs to acknowledge the fundamental limitations of SAF. I note that the session began with our talking about the need to reduce greenhouse gases and the fact that the bill sits in the context of the overall environmental impact, climate and otherwise. In that respect, I was struck by the fact that SAF is an important but only a partial answer.

Every year, air quality impacts from aviation are estimated to cause about 74,000 early deaths globally. The contrails that form an aviation exhaust are, even on an optimistic estimate, thought to be reduced by perhaps half if you go to 100 per cent uptake of SAF. Contrails are themselves thought to make up about 20 to 50 per cent of aviation's overall climate impacts.

With that in mind, SAF is important, but when it comes to whether it goes far enough, we must recognise that SAF scale-up should be considered alongside other measures that can be deployed at local scales.

Professor Hutchings: On the point about scale, the amount of SAF that is currently being manufactured is very limited. The 3 per cent figure is good—it represents a move in the right direction because, a couple of years ago, it was only 0.5 per cent. However, at the moment, 12.3 million tonnes of jet fuel is used per annum in the UK, and that requirement is increasing annually. That is a huge figure, and if we want to replace all of that with SAF, we will need to do a lot more manufacturing.

I hate to complicate things by talking about different colours but, at the moment, a lot of what is termed SAF does not use green hydrogen; it uses what is termed blue hydrogen, which comes from fossil carbon—methane or natural gas. The carbon is captured and the hydrogen is used. The use of blue carbon is necessary for a transition because, at the present time, people are finding it difficult to get hold of green carbon. Therefore, scale is an issue.

If you have the opportunity to manufacture SAF in Scotland, that is a superb operation to do. You

need to do it close to the airports, because you do not want to have to transport it for long distances.

The Convener: It sounds as though it might take 100 years to get to the level that we need, which is 100 per cent, although I might have got that wrong.

Michael Matheson (Falkirk West) (SNP): Good morning. I want to turn to the potential for the production of SAF in Scotland. You will be aware of project willow, which identified two potential projects for SAF production in Grangemouth—project 6 and project 8. One was for HEFA and the other was for e-methanol and methanol to jet. Do you have a view on whether the proposals that are set out in project willow are realistic and deliverable within the timeframes that have been set?

In case you are not familiar with the timeframes, the timeframe for the HEFA project was 2032 and that for project 8, which is e-methanol and methanol to jet, was 2035. I was struck by Professor Maroto-Valer's comment that the infrastructure at Grangemouth would allow us to do things more quickly, but those timeframes do not seem to be very short. What are your thoughts on that?

Professor Maroto-Valer: My comment about the infrastructure in Grangemouth was particularly about the opportunity to jump on it very quickly to use it as a fuel terminal for blending for SAF. We can do that quickly.

On project willow, when you start to look at those two opportunities for SAF, you realise that the timescales are probably a bit optimistic, given the amount of investment that is needed. Let us not forget that we have some infrastructure available that could be repurposed to an extent, but the opportunity for repurposing goes very quickly if you do not take care of that infrastructure. There is a window of opportunity that will allow us to meet those timelines, but we need to make sure that financial commitments are made soon, and it is not clear that that is happening.

There is one aspect of project willow that could make Grangemouth very attractive, which relates to the amount of SAF that we need to produce. Right now, we produce less than 1 per cent of what we need globally. Where should we start to produce a lot more of what we need? We have published a paper on the concept, which involves identifying green flight paths. As we have done in the maritime sector with the Clydebank declaration on freeports, we can do something similar with flight paths. The fact that Grangemouth is next door to Edinburgh gives us an opportunity—along with some of the existing infrastructure that we have—to make project willow very attractive, but that window of opportunity will not be there for a long time.

Michael Matheson: Mark Morrison, you have done some work for Scottish Enterprise in this area.

Mark Morrison: The issue with HEFA is access to feedstock and whether Scotland would have enough of that. We could certainly do it at the moment. I have already mentioned Argent Energy, which is a company that uses that process to produce biodiesel. It has a big plant in Motherwell.

Lots of Government agencies have done analysis of the feedstocks that they have access to. For companies, the security of those feedstocks has been the biggest issue. If everything in Scotland plays out as we expect it to in terms of our having excess renewable energy and the ability to produce hydrogen, if project Acorn comes to fruition and we have all the infrastructure in place—I agree with Professor Maroto-Valer that we simply do not have the infrastructure, but it is all doable—we have a great opportunity for power-to-fuel.

On everything else, a lot more analysis would need to be done of what the waste is currently used for. Some of the other SAF production is using municipal solid waste, but that process requires a huge amount of waste. The two companies that we spoke about earlier—Velocys and Fulcrum—are transporting MSW from across the whole of England to their sites in the north-west and north-east of England. Whether Scotland has sufficient MSW to do that and whether it has sufficient waste oils and fats to go down the HEFA route would need to be looked into in a lot more detail.

As far as the timeline for power-to-fuel is concerned, I think that 2035 is probably ambitious.

Michael Matheson: The timeline for HEFA is 2032 and the timeline for e-methanol and methanol to jet is 2035. Do you think that both of those timelines are ambitious?

Mark Morrison: I think that the HEFA one could be met, but there is the question of the amount of feedstock that is available. I do not know how much Argent Energy is taking out of its suppliers—as I said, basically, its feedstock is waste oils and waste fats—to produce biodiesel in Motherwell. Argent Energy is not considering producing SAF in Scotland—or, at least, it was not considering that a few years ago. It is part of a larger American group, Swire's, that was considering producing it in other places, such as the Netherlands and the far east, where there was a much bigger demand for SAF.

Michael Matheson: I want to go back to the point about the way in which the bill is currently

drafted. If the bill sets a threshold for what the sector must achieve, that could incentivise the production of SAF close to the major airports, which would make it cheaper for the airlines to purchase SAF. Therefore, the development of SAF could be concentrated in areas around Manchester and London, to service Heathrow, Gatwick and Manchester airports. Is there a danger that that could act as a disincentive to invest in some of the projects that are highlighted in project willow, which would involve a significant level of capital expenditure? If the Government takes an approach that does not encourage greater use of SAF across all our airports in the UK, is that a risk?

Celeste Hicks: I go back to what I said before about how realistic any of the proposals are—that is partly to do with what decisions get made now in relation to the infrastructure.

On the HEFA pathway, the SAF mandate currently says that the HEFA cap will start in 2030, because it is one of the least sustainable fuels. It does not have the same life-cycle emissions savings that the other fuels have, so, from 2030 on, there will be a cap on how much HEFA is allowed to be used. It will drop to 70 per cent and then, by 2040, it will be even lower. Therefore, if something comes on stream in 2032, there will already be a HEFA cap and a mandate saying that you cannot use HEFA.

The mention of biodiesel is interesting, because we look at that, too. At the moment, all the used cooking oil in the country gets used for road transport, so if you wanted to use it for SAF, the SAF industry would somehow have to get it all off the biodiesel producers. How that would happen, I do not know. I guess that it would have to be a lot more expensive for people to do that.

It is not simply the case that there is competition for the feedstocks among the different producers in different industries; the Government policies are slightly in competition with one another, too. For example, you mentioned municipal solid waste. There is a waste hierarchy in the UK, which means that all the councils have strategies for where their solid waste goes. A lot of it is already being used for energy-from-waste plants. Some of them have been given the green light at some of the industrial clusters in England that I mentioned. Again, the issue comes back to whether there will be enough feedstock. There will not be enough if there is another Government policy that directs feedstock to an alternative use.

10:00

We are not there yet, but there will also be a business model or a subsidy or contract for difference-type arrangement for greenhouse gas removal, which will mean that there will be another competing Government mandate pulling greenhouse gas removal towards a different pathway.

It is a difficult question, but we have to look at the whole economy and ask whether the Government is ensuring that feedstocks are going to the correct place, where they can have the most environmental benefit. I do not know what the answer is, but where that ends up will be based partly on decisions that the Government might make now about the infrastructure that it wants to invest in and partly on the impact of policy measures and of the financial competition between all the different sectors. I hope that that gives you a flavour of how complex it all is.

Michael Matheson: That is helpful; thank you.

Is there a danger that the bill as drafted could act as a disincentive to capital investment in SAF production at Grangemouth? One investment might be £900 million, with the other project having up to £2.1 billion of capital expenditure, both at today's prices.

Professor Maroto-Valer: You could look at that as a risk, but I would look at it as an opportunity. You need demand and then supply. We have Edinburgh and Glasgow airports, so the question is whether we can get Grangemouth to start producing SAF in time and at the volumes required, bringing the demand and supply together. That is the opportunity. I do not see it as a risk, provided that we make the investment at Grangemouth in time to actually begin producing SAF.

There may be another opportunity. We are producing a very low level of SAF now and must ramp that up. The other opportunity for Scotland is that we have small airports on some islands—it is a very different type of transportation with very different aeroplanes. That market is far more concentrated, which could give us a head start in getting the market going because of an opportunity that is not available in any of the industrial clusters in England.

We need to think about where the opportunities are to get the market going so that we can ramp up to the required level. We have to start somewhere. Grangemouth is a really big place, but we could start on the islands, where there are far more controlled markets, and then expand production.

Mark Morrison: The planned developments in England are not going to meet the UK's needs for SAF. Even globally, not enough development is being planned to meet the need for SAF. There is an opportunity to be ahead of, or at least on, the curve. Demand is going to go up. Everyone in the airline sector recognises that there will be

opportunities to shift away from SAF, and from aviation fuel, later this century, but, in the medium term and until at least 2050, if not 2070, we will need SAF. That creates an opportunity.

The sites that are being planned have a capacity for something like 50 kilotonnes, but, as Graham Hutchings said, we use 12 million tonnes of aviation fuel a year. Even at full operational capacity, after a commercial plant has been built, there will be 500 kilotonnes of capacity, so you would need to have 25 of those plants around the UK. The current sites in England just would not be able to cope, so we need something here in Scotland that is forward thinking and can adapt to new feedstocks as they and the infrastructure become available.

I agree that this is not a risk; it is something that we should be doing, and sooner rather than later.

Michael Matheson: I turn to the issue of the role that low-carbon hydrogen might play in supporting development of the SAF sector.

Graham Hutchings made specific reference to the issue of green and blue hydrogen and the way in which they are being used at the moment. Graham, can I get a bit more detail from you? How important will the low-carbon hydrogen sector be to the development of the SAF sector? [*Interruption*.]

Hold on—I cannot hear you.

The Convener: Can I make a suggestion? I am sure that this is right, but broadcasting colleagues will correct me if I am wrong. Broadcasting will activate the witnesses' microphones. If you try to activate them, you will deactivate what broadcasting colleagues are trying to achieve. I am sure that you were not doing that, Graham, but I say that just in case you were. In that way, we are giving broadcasting colleagues a chance to make sure that they have got it right.

You are live.

Professor Hutchings: I am live—thank you.

It is crucially important to think about that issue. As I keep saying, there is a transition. At the moment, people can use fossil carbon and get the processes going. For example, a BP and Johnson Matthey plant on Teesside is using natural gas, but it is going to be sequestering the CO_2 and taking the hydrogen, which is the blue hydrogen.

All these processes need to be used to get the whole infrastructure there for when the CO_2 becomes a viable source—initially from point sources, such as cement manufacture, but eventually from air capture, which will happen decades into the future. The difference between blue and green hydrogen does not matter at the moment. You just want to get things going with hydrogen and get the processes built.

To come back in on Grangemouth, Scotland has a superb opportunity to start getting into manufacturing. In terms of a world-scale plant that will produce fuels, the last costing I saw for a major one, which was going to be in America—and I think that Sasol was going to build it—was $20 billion. That was about 10 years ago, and Sasol backed off from it. The amount of financial capex that is required to do this—at the scale for fuels rather than chemicals—is huge. A price tag of £2.1 billion sounds very large, but it is not large in the context of the investment that is really needed.

I do not know whether I have helped you.

Michael Matheson: No—that was helpful. I do not know whether anyone else wants to comment on the importance of the sector.

The Convener: I do not like interrupting people, but Celeste Hicks's time is quite short. I wonder whether we could move to questions from Mark Ruskell.

Mark, could you be mindful that Celeste is leaving at 10.25? I would like to put a question to her before she goes, so you cannot use up all the time between now and then with your questions.

Mark Ruskell (Mid Scotland and Fife) (Green): I want to ask about the broader context, particularly around the changes in the UK emissions trading scheme, such as the withdrawal of the free allocation, and the international carbon trading scheme, which is the carbon offsetting and reduction scheme for international aviation—CORSIA. Do you think that the changes will have a significant impact on emissions reduction? How do you see those measures working? Celeste, I will start with you, and then I will take some views from around the panel.

Celeste Hicks: It is hard to say. At the moment, the carbon price in the ETS is way below what we need it to be. We can look at the figures that were used in the jet zero modelling. The jet zero strategy was designed by the previous Government and set out a pathway for how aviation would decarbonise. SAF was actually only one part of it. There were five measures—carbon pricing, greenhouse gas removals, SAF, new technologies and airspace modernisation. With regard to the chunk of the carbon abatement in the jet zero strategy that was due to be delivered from carbon pricing, I do not have the figures off the top of my head, but I think that the estimate was that, by 2050, the carbon price in the ETS would be something like £370 per tonne. Currently, it is about £40, which is way below what we need it to be if it is going to be an effective alternative lever for SAF roll-out.

The other thing to say is that the ETS does not cover most aviation emissions; it covers only intra-European Union flights and flights from the UK to the EU. It does not take into account international emissions, which make up the huge bulk of emissions. They come mostly from long-haul flights, and obviously such flights create more emissions. A few weeks ago, we did some calculations based on figures from last year, and we think that 12.5 per cent of emissions from flights were covered by the ETS. In other words, 87.5 per cent of flights did not pay any ETS price.

As for CORSIA, which you mentioned, we really do not have any faith in that, because, basically, it is an offsetting scheme. It is not meant to reduce emissions; it is meant only to offset growth in emissions. My boss is actually at the International Civil Aviation Organization in Montreal at the moment, and he is following what is happening with the future there. Things are moving incredibly slowly. Because the ICAO is a United Nations body, everything needs to be agreed across the board by everybody, and some interesting stuff is going to happen when it comes to how the US and China will interact with that scheme in the coming years. I am sorry—I do not want to rain on your parade, but I think that we have to be quite cautious about CORSIA.

The EU ETS could be interesting if the UK agrees to link its own ETS with the EU scheme—there could be some scope there. The EU might try to include international flights as a result of a review in 2027; that could be something, but it will have to stand up to an enormous amount of pressure from countries such as the US in that regard. For now, the ETS has some potential, but it is nowhere near what we need it to be.

Mark Ruskell: Are runway expansions, expansions in capacity and so on in any way compatible with our climate targets, given the ETS, SAF and other attempts to try to curb emissions?

Celeste Hicks: We do not think so. We really do not understand it; after all, the things that I mentioned in the jet zero strategy are all fairly nascent technologies. Kevin Stewart asked whether 2 or 3 per cent use of SAF is a good achievement. Well, it is in the context of where SAF production was a few years ago, but when we look, for example, at greenhouse gas removals, under carbon budget 6 we were expecting 5 megatonnes of greenhouse gas removals to be operational by 2030. At the moment, we have something like 0.8 megatonnes, and that is not even in construction yet—it is just in the pipeline.

There has been some movement on airspace modernisation. The Government has just brought in a new body called the airspace design service, which is meant to push on with modernisation, but we have not seen very much on that or, indeed, on zero-emission flight, which would basically be hydrogen flight, hydrogen electric fuel cell technology flight, or battery electric flight. Actually—and this is a good thing—a company called ZeroAvia has just announced that a new factory in Glasgow will build some fuel cell components for its planes. It is quite small, but it could be useful for companies such as Loganair, which does the Highlands and Islands drops. However, let us consider how significant those flights are in the context of global aviation emissions. Given that we have frequent flyers flying to New York and back several times a year, we see that the development of zero-emission technology is way behind where we need it to be.

What we really cannot understand is why you would take the risk of expanding aviation or airports at this point, before you know how these technologies are developing. If, in five or 10 years, SAF production has gone up, removals are happening, and zero-emission technology is coming along, we might say: why not expand? The problem is that none of those things is happening right now, and it just feels like a huge risk that will increase emissions. All it means is that you will have to abate those emissions, and if you have no real credible plan in place—which we do not think that there is at the moment—you are going to have an even bigger problem further down the line.

Mark Ruskell: Would anyone else like to come in on those questions? You will have to put your hand up, and then the convener will let you in.

The Convener: Mercedes wants to come in.

10:15

Professor Maroto-Valer: I just wanted to add a point. I agree with what Celeste Hicks was saying. I think that we might have potentially misaligned incentives, although we need to keep in mind that some of them were never intended to incentivise the production of more SAF. The EU ETS, which we are still using, was not intended to promote SAF production.

As for the things that we can control and the market interventions that we can make in Scotland and the UK, we have to be careful that we do not make market interventions that will result in our importing fuel that has been produced elsewhere. We can have more control here rather than through EU emissions trading schemes; even if the UK were to align its scheme with the EU's, we will not have a lot of control over it.

Therefore, I would turn the question around a little bit and ask that we think about the market interventions that we can really have control of to ensure that we promote fuel production in the UK.

With some of the things that are being put forward, there is a huge risk that that fuel production will not happen in the UK. We need to keep that in mind.

Mark Ruskell: Do others want to come in?

The Convener: Graham Hutchings and Sebastian Eastham want to come in.

Professor Hutchings: I can see that I am online.

I just wanted to come back to the point that was just made about hydrogen and fuel cells and batteries. I think that Scotland has a real opportunity when it comes to island hopping but, in my opinion, it would probably be better to develop battery-powered planes for those very short hops rather than use a hydrogen-powered plane. After all, you will have to store hydrogen—or the fuel that is going to make the hydrogen—on the plane. We know that hydrogen, as a fuel, has less density than, say, kerosene, and that when you use electricity to generate hydrogen, you lose 50 per cent of the energy. No one has mentioned that up until now. You might have abundant green energy, but if you turn it into hydrogen, you will automatically lose about 50 per cent of it. It is a problem that is not readily soluble, and lots of scientists are working on it.

Therefore, it is best to use electricity where you can, instead of turning it into something else and losing half the power. If you can develop battery-powered planes, I think it would be very feasible to use them for island hopping. Personally, I do not view hydrogen as an opportunity for air travel.

I would also point out that a hydrogen-powered engine has never been tested at altitude. Someone talked earlier about contrails; at the present time, we have no idea what will happen with a hydrogen-powered plane at that sort of altitude.

The Convener: Sebastian, you wanted to come in. [*Interruption*.] [*Interruption*.] We are getting more than a slight lag in the camera—we seem to have gone to a blank screen. I suspend the meeting briefly so that we can try to sort this out.

10:18

Meeting suspended.

10:19

On resuming—

The Convener: Welcome back after that short unplanned interruption. Sebastian, I think that you were ready to go and got cut off in mid flow.

Dr Eastham: Thank you, and apologies to broadcasting—I feel like I am cursed.

I will respond quickly on two elements. First, Mark Ruskell asked about the broader context, and Professor Hutchings just brought in the issue of contrails, which I appreciate. It is worth noting that the EU's monitoring, reporting and verification requirement will now include non-CO_2 outcomes by 2027, including contrails. That might diminish—but not eliminate—the relative benefits of SAF by including an element that it does not address as completely.

The second component is runway expansion. My point is similar to Celeste Hicks's, in that I would argue that framing SAF as an enabler of runway expansion gets things the wrong way round. Actually, runway expansion increases the urgency of SAF. In that sense, the bill is made more urgent by the apparent fact of imminent expansion.

The Convener: Mark, back to you.

Mark Ruskell: That is fine, convener. I will maybe come back in later.

The Convener: Due to the shortness of time, I will ask a simple question. The message that I am getting is that we need to go quicker down this route, as aeroplane travel is one of the most difficult things to crack when it comes to reducing emissions. If we use more SAF, how much will that put on the price of an aeroplane ticket? Will it mean that people can no longer afford to fly and that therefore we will achieve the reductions in a different way? Is there a correlation between increasing use of SAF and ticket price? If SAF use goes up to 10 per cent, will aeroplane tickets go up by 10, 20 or 30 per cent?

Who would like to have a go at that? Celeste, you are leaving, but you are not going to get away without answering that, so you can start.

Celeste Hicks: That is the million-dollar question, right? We think that the Department for Transport uses a price elasticity of -1 when calculating the impact of ticket price rises on demand. As I was trying to say about the revenue certainty mechanism bill, the Government has to get the balance right because, if it puts too heavy a levy on the fuel producers, which are big oil companies such as Shell and BP, and asks them to pay a lot into the levy, the levy will be more successful, because it will be able to stimulate production, but I am fairly sure that the prices that fuel suppliers have to pay for that will be passed on to the airlines, and the airlines will argue that they have very tight margins and so will pass that on in ticket costs.

That is why I said that you have to be a little bit aware of the narrative that happened with the contracts for difference for wind farms, because that issue is still playing out now. People are still talking about the green levies 15 years after they

were introduced, even though they delivered what we needed them to.

It is hard to say what the impact on demand will be. We really struggled with that when the Climate Change Committee gave its seventh carbon budget advice in February. Previously, it had said that airport expansion should be a kind of natural cap on demand. I am sure that the situation is not the same in many airports in Scotland, but Heathrow is already at capacity, so there is a natural cap on demand, just because you cannot get any more planes in there. The Climate Change Committee had previously stuck with its line on airport expansion but, this time round, it changed that slightly and gave the slightly cryptic advice that passenger numbers should not increase by any more than 2 per cent by 2035. The Climate Change Committee was not clear how that is supposed to be achieved, but the implication is that it will be through carbon pricing and ticket prices increasing and therefore dampening demand.

We had a complicated discussion at the Environmental Audit Committee in Parliament in which we were sort of asked, "Do you want everyone to stop flying?" and we said that demand management does not necessarily mean a cap on the number of flights; it can involve assuming that ticket prices will rise and that therefore people will not fly as much. However, I am not sure that anybody has been able to completely model that and so knows what will happen and what the level is.

You also get into huge equity issues because, if you make flying too expensive for ordinary people to go on holiday every year, there will be a huge backlash, and the rich will just continue to fly because they can afford to. That is the question, and I am not sure that anybody knows the answer.

The Convener: Mercedes, before I come to you, I will make an observation. I was looking at electricity prices the other day. If the average electricity bill is £880, for example, roughly £145 of it is used to pay green levies, which seems a huge amount. On that basis, in this context, we know that the price will be passed on to the end consumer, so certain people will be priced out of their trips. As Celeste rightly said, those people or businesses who can afford it will fly and everyone else will have to suffer. Have I got that wrong, Mercedes?

Professor Maroto-Valer: I agree with your point on levies, which I think are likely to be passed quickly to passengers. However, I disagree with the point that was made before that it is only if they go over a certain value that they will be passed on. We need to be cautious about that, because history tells us that, as soon as a levy is put on, it goes very quickly to the end user.

We did a study and published what the increment on the ticket price for a specific flight path will be. We studied the London-Dubai flight path. It all has to be very specific about the type of flight, number of passengers and the fuel consumption, so you cannot really generalise—you have to go flight path by flight path. We studied London to Dubai, which we picked because the type of planes that are used for that route are more likely to be able to take SAF more quickly. We estimated and published that there will be an increase of 3 to 12 percentage points per ticket for that particular route. You can do something similar for routes that leave from Scotland, but it is route specific. It is very difficult to give a number if you do not go into specific flight paths. An additional point that we made in that report is that that would be a way to stimulate production of SAF.

To return to issues of equity, I note that we need to accept that it will be flight paths from more developed parts of the world that will be the first ones jumping into the use of SAF. However, those might be used as a way to stimulate production, reduce costs and mature the technology so that, subsequently, the technology could become cheaper, with the price that is passed to the consumer becoming lower, too. We found that the increase went down to 2 to 6 percentage points over time.

The Convener: I want to push back a little bit on that. Are you suggesting that long-haul flights will get away with small increases and short-haul flights will be the ones that bear the brunt of the cost increase, or have I got that wrong?

Professor Maroto-Valer: I am suggesting that the way to get the market going and to minimise the price to the consumer is perhaps along the lines of what you said: by going to long-haul flights because those give you the opportunity of having a lower increment on the price of the ticket.

The Convener: Is that because there are more tickets?

Professor Maroto-Valer: It is because there are more tickets and passengers for the amount of fuel that you consume. It is all pulled together and you come up with that.

The Convener: I wonder where the dividing line will be, and whether it will be cheaper to go to Australia than to Spain. That is an interesting concept.

Celeste, before you disappear, do you want to add to that? I am happy to go to other witnesses, but I realise that you are pushed for time. I appreciate you staying longer.

Celeste Hicks: I will jump in on what Mercedes just said. We are worried about that, as well, partly

because of the ETS. At the moment, operators do not have to pay under the ETS for a flight that is going to, say, Turkey or India—anywhere outside of Europe, basically. We are worried that the way that the ETS is set up at the moment incentivises more long-haul flights because they do not have to pay the price to go there, which is a concern.

Thank you very much for the opportunity to speak, and please let me know if you need anything else. It sounds like a really interesting inquiry.

The Convener: Thank you, and thanks for your input. I will stop that line of questioning there, unless someone else wants to come in on pricing. Witnesses are shaking their heads.

Michael, I cut you off in mid-flow, which was very rude. Is there something that you want to finish on your line of questioning?

Michael Matheson: There is nothing else to finish on my line of questioning, but I want to pick up on the issue of pricing and the 3 to 12 percentage point increase that was mentioned. I presume that all of that cost does not have to go into the ticket. The airline could try to push some of it across its wider cost base, whether that involves its maintenance companies, service companies, terms and conditions of staff or airport operations. That is how some of the low-cost carriers operate. I presume that the cost could be dispersed in other ways, rather than being put straight on to tickets. Is that a fair assessment?

10:30

Professor Maroto-Valer: Yes. We did not go into the distribution of the price increase as you describe it, but we considered what the total increase in the ticket cost would be, which may or may not be passed on to the passenger. Going back to an earlier argument and a point that Celeste Hicks made before she left, I note that we need to be careful that it does not always end up with the passenger. There could be different ways in which the increment could be distributed.

The Convener: Mark, did you ask all your questions? Is there anything else that you want to ask?

Mark Ruskell: I am fine. Thanks, convener.

The Convener: Okay. Thank you. I am sorry that we got slightly out of sync.

Douglas, I think that you have some questions.

Douglas Lumsden (North East Scotland) (Con): Yes. I want to pick up on the point that the cost of a flight from London to Dubai could increase by 3 to 12 percentage points. That seems a huge range. Is there a reason why it is so big? Also, would the SAF percentage be 1 per cent or 3 per cent? What mixture of SAF and normal jet fuel would give rise to a cost increase of 3 to 12 percentage points?

Professor Maroto-Valer: In that study, we went all the way to considering flights with 100 per cent SAF. The variation would apply from 2030 to 2050, and the increase in the price of the ticket will reduce over time.

You are right—the variation between 3 and 12 percentage points is a significant margin. It is to do with the fact that the routes do not always operate at full capacity, and it is also to do with the types of planes and their efficiency. That is why we could not give a single figure. We have to give a range.

Douglas Lumsden: So, with 100 per cent SAF, we are looking at an increase of 3 to 12 percentage points.

Professor Maroto-Valer: Yes.

Douglas Lumsden: Okay. My next question takes me back to a subject that Mark Ruskell raised. I think that you said that no work has been done on surplus feedstock or where all the feedstock is going to come from. Is that correct?

Mark Morrison: Some work has been done on that. Some work was done maybe five years ago that looked at bioresources across Scotland—everything from waste foods to forestry, agriculture and manure—and whether they could be used as different types of feedstock. That would not necessarily be about fuels; it could also be about chemicals and materials.

When we look around Scotland, we might think that we have lots of material, but it is all dispersed. For example, forestry arisings are generally located in remote places up hills, where all the good timber has been taken out. The cost of harvesting that is high compared with the costs in Scandinavian countries, the US and Canada, because they have much larger forests and can access much larger volumes.

Those are the main concerns. Quite a few people, including Celeste Hicks, have mentioned that we are already using food waste such as oils and fats for biodiesel, which is used to run trucks and buses—well, not so much buses any more—around the country. However, we will not have a good supply that is secure enough to produce SAF on a large scale unless we start diverting some of those existing supplies to it.

Douglas Lumsden: Are we talking about giving up some agricultural land that we use for food production and changing it to SAF production?

Mark Morrison: This is just my personal view but, if we take the path that we all hope that we will take and generate a lot more renewable energy, we will be capturing carbon and perhaps

importing carbon from countries, so we will have feedstock that we can convert into SAF. However, it is important to note that this is not just about producing SAF, because the feedstocks can also be used to produce building blocks for the chemical industry and other types of material. They can be seen as multipurpose sites: they might produce SAF one day as part of their output or they might produce other feedstocks that go into chemical manufacturing, and those outputs could be switched at various points.

Douglas Lumsden: What are other countries doing when it comes to SAF production? We mentioned Europe, but what about China and the US? From our papers, I can see that we import a huge amount of used cooking oil from China. Does China not require that for its own SAF production? What are other countries doing in that area?

The Convener: Graham Hutchings wants to come in on your previous question. Perhaps he can answer both at the same time.

Professor Hutchings: I do not know about doing both, but I will try.

I will start on the availability of biomaterial. You asked about whether we would have to give up agricultural land to create fuel—that would be a travesty. In the policy briefing that we did on the issue, we noted that if you wanted to use agricultural land in the UK to produce all the SAF, it would take more than 50 per cent of current agricultural land to create the necessary crops. Going down that pathway is a non-starter.

As has been pointed out, the availability of biomaterial is quite diverse, and it is far better suited to chemicals production than fuels, because chemicals are produced on a much smaller scale. Chemicals can be produced at a scale of 30,000 to 50,000 tonnes per annum, which is a really useful level for products that go into everyday use. There is a push from the public to use green carbon in shampoos and other products that they interface with. At the moment, the companies that make such products are being priced out of the green carbon, because all that available biomaterial is going into SAF. Earlier, we talked about the tension in the marketplace. Unilever wants to get hold of green carbon, but it is finding that it is priced out because SAF is taking it. That carbon should not be going into SAF; it should be going into chemicals.

On what other countries are doing, China is getting very well ahead. About 18 months ago, we had a meeting between the Royal Society and the Chinese Academy of Sciences, and it became clear that China is putting a lot of production into making methanol by more sustainable routes. There is a lot of on-going technology development. As a centrally planned economy, China does not seem to have the same constraints, so it moves very quickly, and we should be aware of what is going on there. America has totally pushed back on SAF, from what I understand.

Douglas Lumsden: Thank you. I have one other question. Earlier, we took evidence about Grangemouth and looked at e-fertilisers. One problem that was identified was that green hydrogen production is too expensive at present. In France, where they have a lot of nuclear, they produce hydrogen at a much lower cost than we do. When we are looking to produce e-fuels in future, will it be a problem for us that our costs will be too high because our hydrogen production is currently too expensive?

The Convener: Graham, you leaned forward, which is dangerous, because it means that you are now on camera. You can answer the question, if you like.

Professor Hutchings: Sorry, I must not lean forward in the future. Sorry—can you repeat the question, so that I can answer it?

Douglas Lumsden: At present, green hydrogen production is too expensive, which means that things such as e-fuels are too expensive. We cannot compete with other countries, such as France, which uses excess nuclear power to produce hydrogen at a cheaper cost.

Professor Hutchings: I do not think that that will dissuade us. We need to produce SAF in the UK. Carbon is traded on the high seas, so if SAF is available and can be imported, we will import it. We are importing an enormous amount of our energy at the present time. It is a commodity that you will purchase if it is available, so I do not think that that will be a problem, especially as we are at the moment producing only around 1 per cent or 2 per cent of what we actually need globally.

I go back to what we were saying earlier. You have an opportunity to repurpose Grangemouth to get a cluster of activity for your airports in Glasgow and Edinburgh. That should be a focus of what you are trying to do.

The UK will probably start to focus on using small modular nuclear reactors. That is an opportunity to use waste heat to create e-fertilisers and e-fuels, which is a very live topic.

Douglas Lumsden: As you say, SAF is a commodity that can be imported. If you are an airline, you may be mandated to use 3 per cent SAF; if you can import it cheaper than using home-grown SAF, so to speak, would you not do that instead?

Professor Hutchings: That is the commercial aspect, is it not? We need to make sure that we are producing SAF. We can import it at the present time, but we are facing geopolitical

aspects that mean that we may not be able to import it in the future. There is a strategic importance in producing SAF on the mainland of the United Kingdom. As we said, it needs to be produced locally to the airports, because you do not want to transport it too far. There is a cast-iron strategic case for Scotland to produce SAF locally to its own airports.

Douglas Lumsden: Does anybody else want to comment on the costs?

Professor Maroto-Valer: There are two points to add to the conversation. One of them is about how expensive it is to produce hydrogen in the UK. We need to remember that the cost of electricity in the UK is very expensive compared with the cost in the rest of Europe. That puts us in a very difficult position when it comes to decarbonising a number of sectors.

I spoke last week at the British Institute for Energy Economics, and we had a good discussion around market incentives and how the price of electricity in the UK is dictating or taking away possibilities to decarbonise the industrial sector in general, not just aviation. We need to remember the price of electricity and what market interventions we can do. In the case of industry, there are plans for 2027-28 that will bring down the cost of electricity.

That relates to the discussion about the domestic production of SAF, and it brings me back to the earlier point about what market interventions we can do that will stimulate production in the UK. That is where we need to be very careful. What those market interventions are will guarantee whether that domestic production happens. Otherwise, we may end up not having a supply chain, and we may have what we have in other sectors. We do a great job of decarbonising them, but the supply chain is not in the UK or in Scotland.

Douglas Lumsden: Will the bill produce the policies that we need to stimulate both demand for and supply of SAF?

Professor Maroto-Valer: There are the right elements in terms of the market interventions. It is then about how to engineer those mechanisms and the detail of how you will do that, but it still leaves you exposed to the risk that the production does not happen domestically.

Mark Morrison: I echo what Mercedes Maroto-Valer said. It is about security of supply. It is also about not thinking about it in the way we do about oil and gas production. SAF need not be produced on the same scale. We could have modular plants.

10:45

I will take a case in point. As part of our study, we spoke to the Royal Air Force. It was keen on the development of modular SAF production plants that it could use in a forward position. Such modular plants are not yet built. We need to develop the technology to do that effectively. However, they could equally well be used in remote islands, whereby fuel would not have to be provided to the islands; eventually, it might involve power to fuel, because the islands will have access to lots of renewable energy. You could have modular plants there.

Everybody we spoke to recognised that there would be far more SAF plants in the whole of the UK than there are refineries. A number of about 50 plants was quoted, as opposed to the five or six refineries that we have now. It is important to think about it in those terms. We are not talking about something that is necessarily the size of Grangemouth—Petroineos, as was. There could be smaller, modular plants. Maybe in the north-east, around St Fergus in Aberdeen, we could have the capability to produce hydrogen, as we do in Orkney, through the European Marine Energy Centre. There is a lot of offshore energy, not just wind; there is tidal energy and wave energy.

It will be expensive in the short term, and we cannot get round that, However, we need to look to the longer term in the confidence that, globally, people will need SAF. If we leave it for another five years, other countries will have stepped into that gap, and it will be too late. At that point, people will think, “We do not have the infrastructure or the capability to do this, so yes, we will just continue to import,” and we will lose the supply chain.

Douglas Lumsden: As you said, it is expensive in the short term. Is the bill a way of getting that money to invest to bridge that gap?

Mark Morrison: As I said, it has all the right elements. One concern is that it is not about fuelling individual aircraft; it is about the overall position. Each supplier has to commit to a certain percentage of its UK-wide fuel supply being SAF, and that may be a concern. However, it is going in the right direction. Having a CFD approach supports the industry to develop SAF and make it a commercially viable proposition.

The Convener: Graham Hutchings, I know that you want to come in, but I will let Kevin Stewart ask his question first, as you might be able to answer the two together.

Kevin Stewart: Mercedes Maroto-Valer, I want to pick up on a point that you made about the electricity pricing regime being an impediment to decarbonisation. Do you think that the UK Government has listened on electricity pricing and on changing that regime so that SAF production

and other decarbonisation tools can come into play more easily? Is it listening about changing that regime?

Professor Maroto-Valer: From my experience in the work that we have been doing in IDRIC—the Industrial Decarbonisation Research and Innovation Centre, which is based in Heriot-Watt University—it is listening.

It is known that there will be a new scheme to reduce the price of electricity for industries. To go back to something that we discussed, the challenge is that that scheme will not enter into effect before 2027. That is a long way away for industries that, every day, as we know, are making decisions on whether they stay here, shut down or go elsewhere. It is more about being timely—how quickly we may be able to bring that forward—rather than not having it, at this point.

Kevin Stewart: Would it be wise for the UK Government to take a holistic view of all of this, including electricity pricing—as Celeste Hicks said, to look at entire areas rather than just one particular sector, in order to get everything right when it comes to SAF, other decarbonisations and the use of waste? Is that strategy there? That would be the right approach, but it is very complex because it requires a level of cross-departmental co-ordination that is not there in some cases.

Professor Hutchings: I will answer your question, but I want to go back to electricity costs, because the UK has higher electricity costs. If we look back 10 years or more, the costs of renewables were considerably more expensive than the cost of producing power from gas. Those costs have come down because of innovations and direction of travel, and if we move forward on that, costs will come down. The same thing will happen with green hydrogen. If we start producing it and getting into it, the cost will come down because of innovations in the sector.

Having said earlier that I did not look at the bill because I did not read the email properly, I have now looked at it and I can see that the bill's direction of travel should help the pricing structure and bring costs down. If we do not start, we will not make the innovations where the real savings will be made. It is a case of increasing the scale of production of SAF.

I agree that we will not be dealing with massive refinery-type structures. Production can be dispersed around Scotland and the UK, with smaller units that produce it where it needs to be made. I hope that that will help you, but I am not sure that it has.

Kevin Stewart: Does anybody else want to come in on the electricity pricing regime?

Professor Maroto-Valer: I agree with Graham Hutchings that technology can bring the cost down, but ultimately it is about how we price electricity in the UK and the spark gap. That requires market intervention, because that is how we price electricity and natural gas. Technology will be able to bring the prices down but, ultimately, we need to try to close the spark gap through market interventions.

Kevin Stewart: The regime is not working.

The Convener: It is an interesting concept. We know that hydrogen costs about 17 per cent more than electricity. If electricity was forced to use hydrogen in the same way that we are doing this, it might bring the cost down and make it easier and cheaper to use hydrogen. It might be a precursor to making hydrogen cheaper. Bob, the next questions are yours.

Bob Doris (Glasgow Maryhill and Springburn) (SNP): It is almost as though you knew that I was going to mention hydrogen and did a link for me, convener.

I know that we have spoken about hydrogen, and Graham Hutchings in particular talked about some drawbacks of using liquid hydrogen in flights. We spoke a bit more about using it as a power source to produce SAF, but there are opportunities for using liquid hydrogen directly as an aviation fuel, not as SAF, because it is not a drop-in fuel. Does it have the potential to lower emissions and be part of the mix in making aviation carbon neutral? Given that I have taken Graham Hutchings's name in vain, perhaps we should go to him first.

Professor Hutchings: I will give you my personal view on that. Personally, I would not wish to get on to a hydrogen-powered plane. Liquefied hydrogen is an extremely difficult material, and it would need a whole new infrastructure and a whole new airframe. I do not think that hydrogen as a fuel for long-distance travel by aviation will be viable in the next several decades, because we have to have a healthy regard for cryogenic hydrogen, which is what we would have to use. The airports would have to be able to store it, because you cannot just fly out of the UK on a hydrogen-powered plane—certain airports around the globe would also have to have it.

Bob Doris: Graham, can I come in here? I read the briefing papers in the past few days, and this is all new to me. I get what you are saying about the major adaptations that would have to be made to storage and so on. Could liquid hydrogen be used for short haul, say Aberdeen to Dublin or Glasgow to London? Could there be fleets that service that market? Is that worth pursuing?

Professor Hutchings: Yes. Another point that I was going to make is that the energy density of

hydrogen is much lower than that of kerosene or e-fuels. For the same volume of fuel that you put into a plane, you would fly fewer miles. For short haul, it becomes possible to have a sort of hybrid hydrogen plane. It would need a whole new airframe, which makes timescales quite long, because the airframe would have to be certified for commercial use, and it takes a long time to design an airframe and then get it certified for commercial use. If you want to go down that line, realistically, you are looking at about 2050. Airbus particularly likes the idea, but I have always thought—this is my personal view—that that was to show shareholders that it was doing something. A plane has been flown with something like four people on it. There is a long way to go with hydrogen, but I would not rule it out for short haul. In different airports, you could have that fuel available for refuelling the planes, but you could argue that it would be better to get a battery plane to do short haul.

Bob Doris: That is helpful, because my next question was going to be about battery electric for planes. Hold on to that thought, because I want to know whether the other witnesses have any views on liquid hydrogen. All that I can go on is the notes that I made in preparation for the meeting, which say that, by 2027, we are looking at 80-seater planes using liquid hydrogen for short haul. The question is whether, if technological advances go further, that is worth pursuing. I have no view on it. The committee wants to ensure that every aspect of technological advancement to pursue net zero for aviation is being explored. Liquid hydrogen is one of those technologies, so I want to tease that out. Are there any other views on liquid hydrogen? If not, perhaps you could comment on the use of battery electric for planes. Sebastian? Hold that thought, because Mark Morrison is taking up the cudgels.

Mark Morrison: I will let Sebastian go first.

Dr Eastham: I wanted to jump in on this, because you mentioned the issue not only of lower emissions but of plausibility. I fully agree with Graham Hutchings about this being a big infrastructural issue. If a large fraction of aviation were to be liquid hydrogen powered, we are talking about disruptive change in the sector. That is one of the reasons why SAF has sometimes been discussed as a stepping stone to liquid hydrogen, because both need green hydrogen production at scale.

I very much agree that the timescales are long. I have somewhat less scepticism about the eventual viability of long-haul hydrogen aircraft, but we are talking about a long timescale, because we would need entirely new airframe designs, which would mean new certification routes and so on. For that scale of hydrogen uptake, we are talking about the second half of the century.

You mentioned emissions. On the one hand, many air quality-relevant emissions are likely not to be affected. We would not really expect any change in nitrogen oxide emissions, for example. On contrails, the science is unsettled. There are some claims of the potential for a large reduction in contrail impacts, far beyond what could be achieved with SAF, but there is also research suggesting that that would not be achieved. I do not think that we will know the answer to that in the foreseeable future.

It is worth pointing out again that, with hydrogen, there is not as much of a challenge in terms of closing the cycle on carbon. At the end of the day, hydrogen is a zero-carbon fuel, so there is something to be said for it having a serious emissions benefit that might go beyond what we can get with carbon-based SAF.

11:00

Bob Doris: Before I move on to Mark Morrison, do you want to say anything about battery electric aircraft, Dr Eastham? I think that it said in our papers that Norway is hoping to move by 2030 to all short-haul and some medium-haul flights being battery electric, with the new fleets for those flights being almost exclusively battery electric.

Dr Eastham: Whereas hydrogen could eventually fill long-haul needs, battery is forever going to be a short-haul solution. Battery faces much stricter physical limits in that respect. You will still have the question of what mix of fuels will be provided to the grid to give you the electricity, of course. Having said that, I think that there is promise for battery electric for the short-haul market.

Bob Doris: Thank you.

Mark Morrison: I echo what everybody else has said. In my mind, though, hydrogen is less likely for long-haul flights, because of energy density issues. The design of the aircraft would have to be dramatically different from what it is now.

I have seen some modelling for Airbus aircraft; Airbus is exploring design for hydrogen much more than Boeing is. The modelling uses a fixed wing approach—it is almost like a kite—because of the dynamics involved in having to cryogenically store the hydrogen and in how it is used up during the flight. I see an opportunity for hydrogen in association with battery technology for short-haul flights, particularly if we look at it as fuel-cell technology rather than just burning the hydrogen.

For heavy-duty vehicles across the UK, the most likely solution for refuelling them will be

hydrogen, because battery tech at the moment is just not sufficiently energy dense to be used for that. So, there would be an infrastructure for hydrogen and I could see that being used on the islands and for short-haul flights.

Bob Doris: That is helpful.

Mercedes, I will bring you in, but because of time constraints, I will ask you an additional question. You can answer this final one or you can reflect on the two that I have already asked—that is up to you.

I have a wee note that says that there have been really good improvements in fuel efficiency over a number of years. Have we squeezed that as far as we can, or can we make more improvements?

That particular question does not have to be for you, Mercedes. I have asked three questions now; do you have reflections on any of them? If any of the other witnesses want to come back in on any of those, I would also be delighted to hear from them.

Professor Maroto-Valer: We have made significant improvements in efficiency. We can probably still make more, but that will not take us to the level of emissions reduction that we need.

I would like to quantify a bit the points about flight length and the opportunities around battery, SAF and hydrogen. We have published work on that, and I would be happy to share that paper with the committee. We have identified that, between 2030 and 2050, what we consider the distance for battery, hydrogen and SAF will increase. What we see as the distance limit for electric flights in 2030 will be around 250km, and we will probably be able to fly up to 500km with hydrogen. That will make up a very small percentage of the market. Moving into 2050, with technology development, we see that electric could push its boundaries to 500km and hydrogen could take us a bit further—around 3,000km.

Long haul will always be dominated by SAF, but by how much might change a little; some of that market might be taken by hydrogen, but that will only happen from 2050 onwards.

I thought that it would be important to quantify that.

Bob Doris: That is very helpful. Do any other witnesses have final reflections on the questions that I have asked?

Professor Hutchings: I think that Mercedes has those figures perfectly right, and I totally agree with her.

I go back to my point that, when you make hydrogen out of electricity, you lose 50 per cent of the energy, so you should use batteries where you can use batteries and SAF where you can use SAF. You would have to think very carefully if you wanted to have a third fuel in the mix for aviation. As for having batteries for short-haul flights, I still think that hydrogen will be always a problem in many people's minds, and certainly in mine. There are, at the present time, lots of safety issues to address with it as a fuel.

Bob Doris: Okay. Thank you.

The Convener: I promised that I would bring Mark Ruskell back in, as he had a supplementary earlier that got lost in all the chopping and changing.

Mark Ruskell: What I am hearing this morning is that it will be the third-generation fuels—the e-fuels—that will dominate and will be the future as we move forward, because of the potential conflict with growing biofeedstocks.

However, what might happen in, say, 10 or 20 years down the line, in a world in which the whole of society is electrified, and where we have electric-battery surface transport, hydrogen being used, electric heating and so on? All of those things are going to create a huge demand for generation. Our briefing notes suggest that, if we wanted to fully lean into e-fuels for aviation, we would need seven to eight times more electricity-generating capacity in the UK than we had in 2020.

It is not exactly the same situation as it is with biofuel, where you are competing with food and obviously there are limits to the amount of land that we have, but do you acknowledge that there will be a point where, even with renewable electricity generation, we will hit the buffers, because everything will be electrified and the need for generation is going to double, treble, quadruple or—potentially—quintuple in the years ahead? Do you have any thoughts on that?

The Convener: Graham, do not lean back. Does anyone want to come in?

Mark Morrison: As a personal reflection, I agree that we are moving towards a much more electrified society. Ultimately, there are going to be decisions that we as a society will have to make with regard to how much resource we have available to us and how best we can use it, and that might mean having to change attitudes as we go forward.

I think that, as a country, we are in quite a unique position, because, proportionally, we have a lot more renewable energy potential than the rest of Europe, and we could be a net exporter. Of course, that does not necessarily help other people in the UK.

Globally, I know that, in the middle east, a lot of investment is being made in solar projects, some

of which are looking at SAF and at harnessing renewable energy to produce chemicals and other types of feedstocks. I think that it is a balance, and it involves a lot more than simply looking at whether we will have enough electricity to produce SAF and these other things. We are facing a much wider societal issue.

The Convener: Does anyone else want to come in? Graham, you did lean forward.

Professor Hutchings: I did, and I do want to say something.

As we move to total electrification of ground transportation in the UK and globally, the refineries that currently produce kerosene, which is a by-product of making gasoline and diesel, will no longer do so. Therefore, we are going to need something that is an e-fuel or a sort of kerosene, because it is a particular cut—about 5 per cent—of the oil barrel. If you do not have refineries making gasoline and diesel, you will not have any jet fuel, and you will probably end up having to import all of it, which will give rise to a security of energy problem for aviation.

The direction of travel, therefore, is that we need a way of making SAF locally. The point is that an unintended consequence of electrification is that kerosene is not going to be available in the UK for ever.

The Convener: Okay.

Mark Ruskell: I think that Sebastian Eastham wanted to come in, too.

The Convener: Sebastian, you are on.

Dr Eastham: I will be very brief. If I have understood the question correctly, it boils down to the fact that a massive volume of energy is currently being extracted from the ground, and we need to find an alternative way of, essentially, supplying what that energy supplies right now. I would just turn that around a little bit and suggest that it increases the sense of urgency. In the same way that runway expansion unlocks demand, which increases the urgency to produce SAF, the production of SAF itself increases the urgency to identify scalable renewable options for the grid. I think that all of these things imply a great deal of additional pressure on electrification and the electrical grid. Therefore, my answer would be yes, I agree with you.

The Convener: Just before we close off the evidence session, one thing that has struck me is that we are going to be really short of SAF, and that we will need to produce it at much bigger rates than we are at the moment. Someone—I think that it was Mercedes Maroto-Valer—commented that some of the bigger airlines were using more SAF than anyone else. Surely, if the fuel is in short supply and the big users who have the buying power buy it all up, that is going to put pressure on the smaller airlines, as they will not be able to get their hands on it. By increasing demand for SAF, are we not going to force smaller users out? Do you want to say anything about that, Mercedes?

Professor Maroto-Valer: I think that that is the sort of thing that, through smart construction of market interventions, you can try to moderate. If you do nothing, it is likely that that is where the market will end up going. That takes me back to the levies and the other mechanisms that we discussed earlier, because the question is how we engineer those things in practice to ensure that that does not happen.

The other point that we have been making this morning is about the opportunity that this presents. If there is a mandate with regard to the amount of SAF that we need, there will be an opportunity to produce it, because it will have to be produced, and it will have to reach a number of users. It is about putting in place market interventions that will actually get us what we want and ensure domestic production.

The Convener: I hear what you are saying, and I guess that it brings us back to Graham Hutchings's comment that SAF might not be suitable for smaller airlines that provide, say, island-hopping trips. My point, though, is that if they wanted to use it, they might not be able to get their hands on it, because British Airways might be buying it all, simply because it can and because the fuel might not be being produced locally. I think that we ought to consider that issue, too.

Thank you all very much. I have to say that I am disappointed to find that all those days that I spent as a child, looking at the patterns of the contrails across the sky, were actually spent looking at pollution. It has been a very interesting session. I am also slightly concerned that we could distort things to the extent that it would be cheaper to fly to Australia on a long-haul flight than it would be to fly to Spain on a short-haul flight. That might affect a lot of people's holidays.

Before we move into private session, I just want to put on record that, in line with standing orders, Monica Lennon, who is not here this morning, would not have been able to be present for the discussion on item 6, and that Sarah Boyack was to join us instead. That is because the discussion is going to be on Monica Lennon's bill. I thank our witnesses very much, and I am sorry for the slight problems that we had with broadcasting. We will now move into private session.

11:14

Meeting continued in private until 12:42.

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