OFFICIAL REPORT
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Net Zero, Energy and Transport Committee

Tuesday 20 May 2025

Session 6

The Scottish Parliament
Pàrlamaid na h-Alba

Tuesday 20 May 2025

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NET ZERO, ENERGY AND TRANSPORT COMMITTEE
18th 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:

David Amos (PlusZero)
Sarah Boyack (Lothian) (Lab) (Committee Substitute)
Mark Bradley (Scottish Power)
Nic Braley (Acorn Project)
Professor Hannah Chalmers (University of Edinburgh)
Tim Dumenil (Storegga)
Lewis Elder (Statera Energy Ltd)
Professor Stuart Haszeldine (School of GeoSciences, University of Edinburgh)
Bill Ireland (Logan Energy Ltd)
Professor Mercedes Maroto-Valer (Heriot-Watt University)

CLERK TO THE COMMITTEE

Peter McGrath

LOCATION

The Mary Fairfax Somerville Room (CR2)

Scottish Parliament

Net Zero, Energy and Transport Committee

Tuesday 20 May 2025

[The Convener opened the meeting at 09:17]

Decision on Taking Business in Private

The Convener (Edward Mountain): Good morning, and welcome to the 18th meeting of the Net Zero, Energy and Transport Committee in 2025. Apologies have been received from Monica Lennon and Kevin Stewart. I welcome Sarah Boyack, who is attending as Monica Lennon's substitute.

The first item on the agenda is a decision on taking items 3 and 4 in private. Item 3 is consideration of the evidence that we will hear on the hydrogen aspects of the project willow study and item 4 is consideration of the committee's annual report. Do we agree to take those items in private?

Members *indicated agreement.*

Grangemouth (Project Willow)

The Convener: The second item on the agenda is the second of two days of evidence taking this month on the plans for the future of Grangemouth. As we know, refining has ceased, and the United Kingdom and Scottish Governments are looking for new uses for the site as a green energy hub. We are today considering the project willow study that was published in March, and, in particular, four of its nine proposed projects that relate to the production or the use of hydrogen.

The first panel today gives us an opportunity to touch more widely on the prospects of a thriving competitive green hydrogen sector in Scotland, which lies behind any aspirations for Grangemouth to be a low-carbon energy hub in the future. I am delighted to welcome Lewis Elder, the commercial operations policy director of—how do I pronounce that? Go on, Lewis, tell me.

Lewis Elder (Statera Energy Ltd): Statera.

The Convener: I do not know why I got that wrong—Statera Energy Ltd. I also welcome: Bill Ireland, the chief executive officer for Logan Energy Ltd; Mark Bradley, the hydrogen director in Scottish Power; David Amos, the managing director of PlusZero; and Tim Dumenil, the head of business development for Storegga, who is attending remotely.

At the outset, I refer members to my register of interests, which declares that I am a proprietor of salmon fishings on the River Spey and am a member of the Spey Fishery Board. The board, which is a statutory body, has recently considered a planning application for a hydrogen plant at Marypark, which was submitted by Storegga. As the plant would take water out of the River Spey, the board had to consider the options and its responsibilities regarding protecting the fisheries management of the catchment, and, on that basis, has objected to the application on the ground that it would take water out of the river, which the board feels is inappropriate. I hope that that is a full declaration.

I am going to go straight to questions. The first question is always an easy one—I like to think so, anyway—as it involves asking witnesses for their views on how things are working at the moment. You will each get a chance to answer it, starting with Bill Ireland—I am giving you plenty of warning that I am coming to you.

Project willow does not advocate the use of green or blue hydrogen, and the UK and Scottish Governments have said that it needs a twin-track approach. Do you think that that approach is correct or do you think that more attention should be paid to green or blue hydrogen?

Bill Ireland (Logan Energy Ltd): It is an interesting question. I think ideally, more attention should be paid to green hydrogen. Scotland has masses of wind resource and some solar. However, we are going to have problems with balancing the electricity supply. The only way that you can really do that is through storage, either with batteries, which are expensive when used at large scale, or hydrogen.

Practically speaking, we probably cannot deliver green hydrogen as quickly as blue. Blue is still being developed, as far as I am aware, so there needs to be a dual approach, but the approach should not be based on a short-sighted view of what is the cheapest option at the moment. Rather, the goal should be to transition fully to renewables.

Lewis Elder: Thank you for the invitation to speak today; it is a pleasure to be here. It is an interesting question. On Grangemouth, industry is generally interested in two things: price stability, and stability of feedstock. For both of those, green hydrogen offers the greatest long-term potential, because, as long as you are relying on blue hydrogen production, there is an intrinsic link to natural gas pricing, which will leave industry vulnerable to geopolitical events and the price shocks that we have seen in recent years. You get price stability with green hydrogen because of its link to renewable energy.

To give industry the certainty that there will be stability with regard to the volume of hydrogen that it needs, the answer is probably a combination of both blue and green. In the early years, blue might play a role but, in the longer term, once we have hydrogen storage in place, we can start to offer stable low-price hydrogen to those very large consumers.

Mark Bradley (Scottish Power): Good morning. I largely agree with the gentlemen who have already spoken. Scottish Power's business is all about green power. It is all about renewable power—generating it and moving it to customers.

We value green hydrogen's scalability; its high purity, which creates more market opportunities; and its independence from the gas markets and the impact that that can have on energy security. We recognise that Scotland has great potential in renewables and that the sector presents a growth opportunity for the country. Green hydrogen is a route to market for those assets that the country holds, and for that reason we support green hydrogen.

Having said that, there is most likely space for both technologies, and we expect to see both technologies across the UK in some way.

David Amos (PlusZero): I would approach the question more from a customer perspective. We have spent the past four years delivering hydrogen-based generator solutions to replace diesel generators. Our customers' focus is on what will save the most carbon. Green hydrogen is seen as the gold standard because there is no carbon involved in its production, but there is very little green hydrogen around, so, if it was feasible to produce blue hydrogen from Scottish methane from the North Sea and capture and store the majority of the carbon, I think that our customers would say that that was fine by them, as it achieves their carbon-reduction aims. If the price made that option affordable for them, they would see it as acceptable. Therefore, there is a role for both technologies.

The challenge at the moment is that there is hardly any hydrogen around in any colour. That is the single biggest thing that is holding back the development of the application of hydrogen technology. If blue hydrogen could come on stream and produce hydrogen at an affordable price for customers, that would certainly help companies such as mine.

Ultimately, of course, blue hydrogen will be available for only a short period, because we will run out of natural gas. Renewable energy is, therefore, definitely the way forward, and green hydrogen has to be the key focus. However, if we could get more hydrogen available in the market at a price that was affordable to customers, that would be of great benefit to the Scottish hydrogen technology sector.

Tim Dumenil (Storegga): Storegga is a leading independent developer of both carbon capture and storage and hydrogen projects—that is, both blue and green hydrogen. We are agnostic on the question whether the approach should focus on blue or green hydrogen. I have been working with Storegga for 11 years on the Acorn carbon capture and storage project, and also on the Acorn blue hydrogen project and the north of Scotland hydrogen programme, which is a range of electrolytic hydrogen projects from 15 megawatts up to gigawatts scale. The initial focus of that has been around decarbonising the industrial sector, particularly the iconic distilling sector in the north of Scotland.

Our work in Scotland has shown that green hydrogen is about three to five times more expensive than blue hydrogen. Both green hydrogen and blue hydrogen, on a full chain solution basis, meet the United Kingdom Government's low-carbon hydrogen standard. On David Amos's point, if we look at the three main pathways—pathways 7, 8 and 9 that we are going to be talking about today for project willow—we are starting from three unabated fossil fuel baselines: natural gas direct use for industrial heat; natural gas feedstocks for the grey hydrogen

at Grangemouth and Mossmorran; and petroleum products for our air, sea and surface transport. Compared with our current unabated fuel use, anything that is a step-change in carbon removal is progress.

The key for blue hydrogen is its scale and the ability to scale it up quickly and at significant megawatt capacity, particularly through pipeline distribution. Doing that can set the platform for green hydrogen to follow. The vision for the St Fergus gas terminal, which we produced several years ago, spoke about exactly that: you start with blue, catalyse, get a fluid market going and then use that to set up an enduring green hydrogen or electrolytic hydrogen business.

The Convener: Okay. I think that there is unanimity that the approach should be a mixture of both to start with, followed by a drift towards green hydrogen, which is ultimately where we want to end up.

What is the best site for making that hydrogen? Is it Grangemouth or is it outwith Grangemouth?

I should have apologised to you at the outset that, as there are five of you, you will not necessarily all get to answer. You should wave or try to catch my eye and I will bring you in. If you really do not want to answer a question, you can look the other way. However, if you all look the other way, I will bring in one of you to answer the question. Those are your options. Lewis Elder, you indicated that you want to answer my question.

09:30

Lewis Elder: It is a great question. We are developing an initiative called project Kintore, which is a 3GW scheme in the north-east of Scotland. The advantage in building there is that the green hydrogen facility is located closer to the abundant wind energy that we expect to come into the north-east of Scotland, so we will get access to very low electricity prices and, often, curtailed wind or otherwise curtailed energy, which will allow us to drive down that cost of hydrogen overall. We also need to be conscious of the need for a water source, and building in that area gives us access to the River Don. Access to skills is also important. In the context of the just transition, it would be wrong to focus all of our hydrogen production in one location in Scotland. Rather, we should spread our focus, and some of our thinking involved the large source of skills that are available in Aberdeen that could transition to project Kintore.

Finally, on the question why we should not build everything in Grangemouth, the challenge in doing that would be one of scale. Scotland's peak demand is about 4GW, and the amount of hydrogen that we need in the country will be multiples of that. Is it, therefore, appropriate to focus so much electricity demand in one area? That would very likely drive up prices and might cause further constraints on the system. I think that we have seen that already with RWE's plans, as it was initially looking for a 200MW project but had to scale that back to 100MW, which highlights the challenge of getting import capacity in certain parts of the country.

The Convener: Mark Bradley, we have heard that, once you release the electricity in the National Grid, national pricing comes into effect, and there are costs with producing hydrogen around a loss of power from electricity. Is it better to site hydrogen production close to where the electricity is generated, or do you think that Grangemouth is the right place?

Mark Bradley: On the issue of the scale of Grangemouth, when we look at developing projects at scale, we start with the market. The market tells us that Grangemouth is ideally located—if I want to service the industrial sector, I probably want to be pretty close to it in order to reduce my infrastructure costs.

I accept what has been said already. It is true that, once you get to an economy that has multiple gigawatts of hydrogen being produced, which everybody is striving towards, you need to have a slightly wider approach, but, in the first instance, from a deliverability perspective, I would be looking to supply hydrogen within the region.

The Convener: So, you would pop it all at Grangemouth?

Mark Bradley: Yes.

The Convener: Tim Dumenil, you wanted to come in.

Tim Dumenil: Last week, at the All-Energy conference, I was on a panel with Colin Pritchard from Ineos, who said that there are footprint and power limitations in terms of Grangemouth's ability to build out the necessary scale of electrolytic hydrogen. He took the view that it would be better to develop the pipeline infrastructure to bring low-carbon hydrogen, blue and green, into Grangemouth and instead focus on the core expertise of Grangemouth, which is chemical—synthesis and conversion. You should focus attention on the precious land footprint within the Falkirk region.

The interesting piece around that is that Scotland has the natural capital, particularly in the regions, to potentially become a clean-energy powerhouse. If you approach the issue in that way, you can take an approach that delivers whole-Scotland prosperity through clean energy. Project willow can play a significant part in that through the conversion of low-carbon hydrogen

into products, with that low-carbon hydrogen being moved in from the regions.

The Convener: I understand that, but I think that there are people across the Highlands who feel that they are the battery that powers the motor of the UK but that they get very little from it.

Bill Ireland, you want to come in.

Bill Ireland: We have to be careful, and we have to not look at the present but at where we have come from. The oil and gas skills that we have in Aberdeen were not there in 1950 or 1960; they came in on the back of the developments in the North Sea. We are looking at putting our new energy sources where we have existing industry and existing energy businesses. Something that I like to bring up to make people think about where the developments should be is that we used to have windmills on the top of hills, and we used to take our grain to the miller, because that is where the energy was, and we would take the ground corn back again. We did not put the windmill in the village. We need to look at where our energy sources are.

I know that there is a desire for a hydrogen pipeline from the Western Isles and Orkney, and perhaps Shetland, to take hydrogen to Germany. If we have cheap energy in Scotland—which we do have and we can have—why are we not bringing industry to Scotland and growing the Scottish economy, rather than sending the hydrogen away? Rather than congestion, high prices for property and whatever, we can spread the benefit around, get some social movement and actually repopulate Scotland's far regions.

The Convener: I think that Douglas Lumsden has the next questions.

Douglas Lumsden (North East Scotland) (Con): Is Mark Ruskell going to come in at this point?

The Convener: Sorry—do you want to come in, Mark?

Mark Ruskell (Mid Scotland and Fife) (Green): Yes. I have a quick question. Tim Dumenil mentioned Mossmorran. How do you see Mossmorran potentially fitting in with the hydrogen options from project willow?

Tim Dumenil: At the moment, Mossmorran carries out a fossil fuel conversion process, which will continue for as long as fossil fuel reserves flow down from St Fergus into that facility. Around that location, there is a land footprint and, potentially, some grid footprint that could allow electrolytic hydrogen to be produced and to flow down into Grangemouth through some of the existing pipeline infrastructure in the region, if that makes sense.

David Amos: In relation to Mossmorran, it is worth bearing in mind that, as I said earlier, there is not much green or blue hydrogen around, which a number of us involved in applications feel is holding the industry back. A huge amount of grey hydrogen is produced at Mossmorran and Grangemouth. Although grey hydrogen does not offer the decarbonisation opportunities that blue and green hydrogen do, it could provide a source of hydrogen to allow some technological developments and testing to be done. We have tried to engage with Mossmorran, Grangemouth and Ineos, but those big industrial chemical plants are not geared up to engage at a small level. However, we produce lots of hydrogen in Scotland and, if there was a way of releasing some of it to support the sector at this early stage, that would help to accelerate things.

Douglas Lumsden: I think that all nine potential project willow projects are doable, but are they commercially feasible, especially the ones that involve production of sustainable aviation fuel or shipping fuels, for example? Do you see a way of making those projects commercially feasible, given the high capital costs that would be involved?

Bill Ireland has looked at me, so I will come to him.

Bill Ireland: It depends on whether we want such projects to be commercially feasible, because we subsidise the energy field and the chemicals field, so there is not a level playing field. The sectors are subsidised, taxed or whatever, so it is up to politicians to make such projects economically viable.

We also have to bear in mind what is going on in the rest of the world. The easy thing to do is to pick the low-hanging fruit—carrying on as normal by taking oil and gas from the ground without even bothering to capture the CO_2. However, energy is naturally going to get more expensive, because we are trying to replace the easy bits, but we have already done the easy stuff. It is a bit like when you try to save energy in buildings—you do all the easy bits, such as having lights that automatically switch off, and then you get to the difficult bits, such as how to insulate an old building, which are more costly.

Will such projects be economically viable? It will depend on the taxes and the incentives—the carrot and the stick. If there are more processes, there will be more capital outlay, more operations and reduced efficiency, so, at the end of the day, the projects will potentially be more expensive.

We could break up the electricity pricing system, as we have spoken about. The hydrogen allocation round 2 includes a very good map of the UK, and some of the projects will be assessed

from the point of view of alleviating issues with the grid. We can produce more electricity cheaply in Scotland, but we are constrained by the grid. Projects involving electrolytic hydrogen and green hydrogen are very much down to the cost of electricity—probably 80 to 90 per cent of the cost of producing hydrogen is the electricity cost—so they are taken off the grid. Most of the projects that we deal with are behind the meter and involve producing hydrogen straight from a renewable source. They are not even on the grid, because the grid prevents us from producing economic hydrogen at the moment. Bringing down those costs will help with all these processes.

Douglas Lumsden: When projects are off the grid, does that mean that there are no contracts for difference or anything?

Bill Ireland: Basically, you produce your own electricity and put it straight into your plant, so you do not go on to the grid. As soon as you go on to the grid, there are grid capacity charges and transmission charges. The charges are binary to start with and then depend on how far you are transmitting the electricity, and there are also restrictions on the grid. Projects such as the Whitelee wind farm will involve going straight on to electrolysers and will not go on to the grid. Proposed large-scale projects will not go on to the grid.

Lewis Elder: I will clarify that, as a developer of Europe's largest electrolyser, we take a slightly different approach. We think that, if you put all the renewable energy from a project directly into an electrolyser, you syphon that renewable energy away from other sources of demand. The first stage of decarbonising our energy system involves electrifying as much as possible. For example, if you are co-locating, you might be taking renewable energy from a wind farm during a very cold winter peak, whereas that electricity would be better directed towards households. That is a result of the design of the current business model, and it is a major issue in not having projects of scale that can operate dynamically at very low cost.

I will make a point in relation to the first question. We have recently become a member of the Grangemouth future industry board—we have been to only one session so far, so we are still getting up to speed on some of the details. The elephant in the room with Grangemouth is the volume of hydrogen that would be required to fulfil the four areas: hydrotreated esters and fatty acids, fuel switching, e-ammonia and e-methanol. I will touch on each of those. The report talks about capital expenditure and jobs, and we have had to calculate, using those numbers, what we think the hydrogen requirements would be. These figures might not be totally accurate, but, for HEFA, we think that about 100,000 tonnes of hydrogen per annum would be required; for fuel switching, our figure is 50,000 tonnes; for e-methanol, our figure is half a million tonnes; and, for e-ammonia, our figure is half a million tonnes.

In total, about a million tonnes of hydrogen per year would be needed to meet those objectives. That would require 7GW of electrolysis running as a baseload, but electrolysis runs when the wind blows, so it would run for perhaps half of the year. Therefore, we are talking about 14GW—or even more; perhaps 20GW—of electrolysis to fulfil the project willow interest. From our perspective, that cannot be achieved—along with most of the other ambitions that we talk about, such as exporting hydrogen and decarbonising the power system and industry—without a large-scale network that links up very large projects that produce hydrogen with major sources of demand.

The Convener: It is probably fair to say that people find it particularly difficult to stomach when, if there is too much electricity so power cannot be generated, constraint payments are given to people with wind farms. That power could perhaps be diverted not to massive battery storage sites but to hydrogen sites or wherever we wanted it to go.

Tim Dumenil wants to come in.

09:45

Tim Dumenil: I will pick up on a couple of Lewis Elder's points. The majority of hydrogen end use cases are continuous, including the feedstock for the chemical synthesis processes. The exception is cases involving dispatchable hydrogen to power. The main point that Lewis Elder and the convener were making was about the need for a whole energy system approach to the hydrogen network, covering the transport of hydrogen and, in particular, its storage, in order to provide security of supply and resilience.

We are caught in a liquified natural gas and energy trilemma. There is a tension between, on the one hand, decarbonisation and the reduction of CO_2 emissions and, on the other, affordability of energy, security of supply and, rolling on from that, domestic resilience.

At the moment, the UK does not manufacture any ammonia. The last two plants closed down when there was the last spike in natural gas, so we currently import all our ammonia for fertiliser. Are we, as a nation, happy to continue to do that, or do we want to have that manufacturing capability in the UK? If we do, we need to consider my earlier point about current gas and power prices and the question of the economics of that. Green hydrogen is three to five times more

expensive than blue hydrogen, but they both meet the low-carbon hydrogen standard.

If we want to create perpetual and enduring hydrogen production and hydrogen-derivative outcomes, we need to reduce that multiplier and make the levelised cost of power in the UK notably lower. In relation to Bill Ireland's point, the majority of the levelised cost of hydrogen and hydrogen derivative is the cost of power, so a reduction in that cost will flow through the system. To reduce the multiplier, we need a range of policy changes, including a review of electricity market arrangements, changes to the National Energy System Operator constraints or curtailments in relation to collaboration projects and some regional changes to the low-carbon hydrogen standard. That would help to reduce Scottish Power pricing and, therefore, make green hydrogen pricing more attractive.

Douglas Lumsden: I want to pick up on something that we asked about last week. You have said that most of our ammonia is now imported, but we heard last week that the price of e-ammonia would be a lot more expensive than importing ammonia, so how would we force somebody to pay a higher price for e-ammonia instead? I know that we should be getting the price down, but that will not happen initially.

Tim Dumenil: That is the conundrum that we are caught in and why these debates are really important. Back in 2020 or early 2021, the Scottish Government was the first Government in the world to declare a climate emergency and legislate on reaching net zero by 2045. At that time, 230GW of hydrogen was produced globally, and nearly all of it involved unabated fossil fuel—coal and gas—so it was black and grey hydrogen. Back in 2020, about 200MW of electrolytic hydrogen was produced globally. The majority of that 230GW—about 60 per cent—was used to make ammonia for fertiliser for our food.

We are talking about a global commodity that is traded by shiploads, so it is very price sensitive. Delivered power price in the UK is in the range of £80 to £120 per megawatt, whereas the price is £30 to £40 per megawatt for solar and £40 to £80 per megawatt for wind across 10 jurisdictions. Those figures are from a Fraunhofer Institute report on power-to-X pathways that was published in September 2023 for the German H2 Global programme. If we blend the £30 to £40 per megawatt for solar and the £40 to £80 per megawatt for wind, that gives about half of our current cost of power. We are now seeing £10 per megawatt for solar being deployed in the middle east, so it will be really challenging to remain competitive in global commodity markets.

In Scotland, particularly for project willow, we need a combination of policies relating to directives and mandates that will address the energy trilemma. We need the system to be underpinned by security of supply and domestic resilience, and we need to put in place various mechanisms to try to reduce the cost of power.

Douglas Lumsden: The cost of power is up. For example, floating offshore wind, which we probably have an abundance of, costs about £155 per megawatt hour. How are we ever going to be price competitive when the cost of it is still so high?

Tim Dumenil: It comes back to what Scotland's unique selling points are. I passionately believe that Scotland could be a clean energy powerhouse, as we have some of the best wind resources in the world—you just need to look at our amount of sea bed and the capacity factor of offshore wind to see that. We have access to biogenic CO_2 via the gathering network at project Acorn and we can pipeline hydrogen from the regions into central processing areas, not just at Grangemouth but down the east coast into Teesside and Humberside.

The way I look at this—I have spoken about this before—is that if you were a global wind developer and you had £10 billion to invest in offshore wind, where would you invest that? You would go to where you had the best wind reserves, and you would deploy that capital and build whatever size of wind farm you needed. Based on the capital that you have deployed and the cost of that capital, the cost of the electricity at the end of that array cable should be the same in Scotland—if it is a 50 per cent wind capacity factor with a set sea bed—as it is in, say, Newfoundland with that same sea bed and capacity factor. So, we have the ability; it is within our reach to be able to get competitive power at the end of the array cable. It is how the electricity market is structured after that that makes it challenging.

Lewis Elder mentioned Statera's Kintore hydrogen project, and at Storegga we have been working on a similar concept with our Highland project. We talk about that as a fully integrated wind to transported molecule solution. If you can accept a project-on-project risk, you can take the end of an array cable and put that straight into an offshore wind load-following electrolytic hydrogen plant and convert the product into the molecules that society need.

To go back to a point that David Amos made, we have to be able to reverse engineer back from the demand. We have to be clear that the demand is there within the UK, and we have to be clear that we can produce hydrogen in the UK at a price point that is competitive on an enduring basis. Otherwise, we will be pushed by the UK Treasury to import that product from overseas because of an affordability and value for money viewpoint.

Douglas Lumsden: I was just about to ask about getting electric prices down to actually make hydrogen competitive.

Bill Ireland: One of our projects is Arbikie distillery, which has limited connectivity to the grid. It can export 50KW and it wants to go zero carbon. It has a combination of wind and solar generating the hydrogen on site, and it is storing the hydrogen for use to generate steam for the distilling process when electricity is not being generated. It uses hydrogen in a hydrogen steam boiler to do that. It has cost certainty for its energy bills for the next 20 to 25 years.

The issue is security of supply and security of cost. When we are talking about a long-term view, we are not saying that we should not be looking at other options. What worries me about going down the blue hydrogen route is that we will focus on blue, and green will be left behind, when we should actually bring green along because it has a longer development time.

That is an example. If you can do that for a distillery, there is no reason why you cannot do it for Scotland or for the UK. It is just about increasing the lengths of cable or pipelines or whatever.

Douglas Lumsden: Lewis, did you want to come back in?

Lewis Elder: Yes. There are quite a few points there, but your point around the levelised cost of energy links back to something that I mentioned earlier. The wrong way to design electrolysis production is to design it using just the levelised cost of energy from a specific source. The way that we see green hydrogen's role in the hydrogen system evolving is through using energy that would otherwise be curtailed. To give some headline numbers, Scotland's peak demand is something like 4GW and today we have a generation capacity of about 18GW. By 2030, there will be 45GW of generation capacity in Scotland against domestic demand of 4GW. We will have multiples more energy generation capacity than we will have demand.

As we have already mentioned, that means that we either try to get the energy out or we curtail it. At the moment, according to the forecast for the planned network build-out to 2030, we are going to see curtailment costs—this is National Grid's own number—rise to £7.8 billion per year. If an even bigger network is built, National Grid will get that down to something like £3.5 billion to £4 billion, but there are questions as to whether that can be achieved.

So, what is the point here? The point is that taking wind from a specific source all of the time would be the wrong way to construct electrolysis production. The right way would be to operate it when curtailment periods occur. As we are discussing, the frequency with which those occur will increase quite significantly.

I have one other very quick point on competitiveness against other markets. We should not overlook the jobs contribution and the economic benefit that investing in a facility in Scotland would provide. We should not just compare such investment with importing on a £1 per kilogramme versus £1 per kilogramme basis; we should look at all the other wider societal factors, such as jobs and security of supply.

We have talked a lot about price. As Tim Dumenil alluded to, green hydrogen is about £241 per megawatt hour, which, in our view, is very high. We believe that if changes were made to how electrolysers sourced their electricity—which is a policy change that could be made today—that £241 per megawatt hour could be reduced by about £70, which would be a 30 per cent reduction. If you then introduced a network and allowed hydrogen producers to decouple from having to locate next to demand, you could reduce that price by another 30 per cent. With two policy decisions, you could get your hydrogen price to around about £100 per megawatt hour. By making further enhancements in scale and backing projects that are very large, you could get that down even further, to £60 to £70 per megawatt hour.

You can see the pathway to delivering very competitive low-cost hydrogen, which—this goes back to Tim Dumenil's earlier point—would make green hydrogen competitive with blue. Two major blockers for us at the moment are policy decisions that could be changed by Government.

The Convener: Mark, did you have a follow-up on this?

Mark Ruskell: No.

The Convener: Sarah, over to you for your questions.

Sarah Boyack (Lothian) (Lab): Thanks very much. I will focus on the issue of hydrogen support from the UK and Scottish Governments. When you look through the different options, it is complicated, because there are quite a lot of them. What are your views on the current schemes? You are trying to generate industry to create incentives. The net zero hydrogen fund is supporting new commercial deployment and, I think, six projects for green hydrogen in Scotland. Are the schemes effective? Are they working properly? Are they targeted sufficiently? There are other examples, including the Scottish Government's hydrogen innovation scheme and the UK Government's hydrogen production business model. For those going into the sector, are those the right mechanisms to generate the support to get

projects off the ground? I am trying to look at who is nodding. David, you nodded first.

10:00

David Amos: It is an interesting question, Sarah. There are a number of different schemes. As a company, we have benefited from support from the Scottish Government's emerging energy technologies fund. That gave us a grant contribution towards building our first green hydrogen production facility, which is currently in construction, just outside Stornoway in Lewis. It is a small-scale facility compared with the type of facilities that Tim Dumenil and Lewis Elder are working on, but it is equally as important for moving the industry forward in an island context. It is fair to say that without that Scottish Government support, we would not have been able to move that project forward because we are a small company and that contribution made all the difference.

On the application side, the hydrogen access around the HAR scheme, which the UK Government has brought in, will be quite transformational because it is addressing the difference in cost between the customers' current fossil fuel use, diesel or natural gas, depending on the application, and the cost of hydrogen.

We are a partner to a number of HAR-supported producers on the offtake side so that we can offer our customers a packaged clean power solution, which will benefit from hydrogen at a cost that is equivalent to diesel. That removes that very high cost barrier because, at the moment, our customers are having to pay anything from four to eight times more for a hydrogen-based solution than a diesel-based solution. Therefore, that UK Government subsidy scheme will be quite transformational in moving the sector forward and being able to offer customers a solution that does not cost them any more, so that they save the carbon, but it does not cost them anything additional. That type of long-term government support is critical to moving a new industry, such as the hydrogen sector, forward.

The schemes that are in place have been helpful and will continue to be helpful. On whether more could be done, there is always more that could be done, but the two examples that I have just given have made quite a significant difference for the sector and will continue to do so in the future.

Sarah Boyack: So those schemes are enabling confidence for investment to actually deliver?

David Amos: Yes.

Sarah Boyack: Does anyone else want to come in on that?

Mark Bradley: I would largely agree. There are two different types of funding out there—generally, there is development funding and there is long-term revenue support. There are a number of routes for development funding. As a business, we have made use of one particular opportunity through the Westminster Government and one through the Scottish Government. Both have worked well, and they have enabled us to develop opportunities without having to commit to building something that is still to be understood. That has been positive. The Scottish Government funds in particular have been agile and were relatively quickly deployed once the scheme was in place.

On the revenue support side, the Government has a very significant scheme in place through the hydrogen allocation rounds awarding low-carbon hydrogen agreements. Fifteen years of revenue support is certainly very positive when you are trying to get projects to market. I would suggest that, to date, those have not been market specific. They have been open to all markets of consumers of hydrogen. I think that that has been the right thing to do in the early rounds.

Going forward, hydrogen will be a premium solution to decarbonisation. Therefore, it has to be targeted at the right markets, and we will probably need some shaping of that. That is not to exclude some of the early markets, but it is about making sure that we have balance and proper targeting of those hard-to-abate sectors that hydrogen will have to focus on.

Sarah Boyack: Lewis, do you want to come in?

Lewis Elder: I would echo some of those comments. The hydrogen business model has been excellent at bringing forward investment, but to turn to some of the discussion that we have had today in the room, we keep talking about getting low-cost renewables to produce our hydrogen. That is not currently happening in the hydrogen business model. We also keep talking about locating electrolysis close to the abundant renewables, and that is only happening to a limited extent. Clearly, the business model has been helpful in starting the industry, but reform of that business model is needed.

To keep my policy asks quite targeted, I will focus on how we can get there. The first thing is a network. The UK Government is going to release its hydrogen strategy in the next few months. I do not know whether the Scottish Government is planning to do the same or if it will be feeding into that report, but we need to make strong representations that a network is core to that hydrogen strategy.

Linked to that, we need to get production going at scale. The way to do that is to blend hydrogen into the existing natural gas system. That would

immediately begin to resolve the challenge of constraints in Scotland. It would immediately relieve the pressure to build more pylons because we would be taking some of that excess energy, converting it to another vector and moving it through the gas pipeline. It would also begin to scale production, so we would start to see some of those benefits that I have been describing coming through, such as reductions in the strike price.

We need supporting networks and blending. The UK Government is going to consult on blending hydrogen into the existing natural gas transmission system imminently—in the next couple of weeks. Therefore, similarly, strong representations need to be made that blending should be an eligible route for these projects to begin their operations to ensure that that becomes a focus for the business model.

Sarah Boyack: Will that require investment in the existing gas network, given the nature of hydrogen?

Lewis Elder: There are three steps to that process. The first is a Government policy decision on whether it is appropriate to blend into the existing natural gas infrastructure. That is the first step that we need to get a green light on. The next step is for the Health and Safety Executive and National Gas, which have been running various trials such as future grids, to test whether their systems can accommodate hydrogen. They will then hopefully approve and sign off on the safety case.

The third step is the market arrangement. If we wanted to blend at Kintore, for example, there might be another participant nearby. We need to make sure that both have appropriate access rights to that network. There are three steps in the chain, but the most important step is the first one, to get that green light from Government to say, "This is the right thing to do, and this will unlock hydrogen production potential in Scotland".

Sarah Boyack: Do you want to come in, Bill?

Bill Ireland: There are two scales that we need to look at. One is the industrial scale of support, which is what the HAR programmes are basically supporting. I think that the minimum size on HAR1 was 7MW. That is a relatively large amount for a farmer or a group of farmers, for example, to pull together. It is very much aimed at industrial support for regional development.

It is a bit like milk aggregating, where you go around and pick up a few gallons or a churn of milk from various farmers, pull it all together and take it back to the processing plant. It is a similar sort of thing. You are actually going to aggregate some of this; some of it is through pipelines.

On your point about the support so far, we have had support from the UK Government and the Scottish Government, which has been very much appreciated. Without it, we would not be here, so that support is working. Could it work better? Of course it could—everything could work better—but we also need to look at where we are providing support and actually it needs to be across all scales of hydrogen production.

Sarah Boyack: That is very useful.

The Convener: I am sorry, but just before we go on, I think that Tim Dumenil wants to come in. Tim, you missed my pep talk at the start of the meeting—I said that, as there were five people on the panel, it would not always be possible to get everyone in on every single question.

I am conscious that we are nearly an hour into this session, and we are not even halfway through the questions. I will let you in, Tim, but I must ask all of you to be careful with the time. I do not want anyone to go away from here at the end of the day, feeling that they have not had a chance to say their bit, because I would have failed in my job. I will come to you, Tim, and then go back to Sarah Boyack.

Tim Dumenil: I will keep it short, convener. We have had strong collaboration and more co-ordination between the Scottish and UK Governments on some of the key aspects of the policy and, in particular, the whole energy system approach. The national strategic energy plan will cascade down into regional energy spatial plans and then into local energy spatial plans. It is all about trying to have a road map and blueprint for net zero by 2050 in UK and by 2045 in Scotland and being able to reverse engineer back to that.

I come back to Mark Bradley's earlier point about the need to understand what the right-use cases of hydrogen will be in 2045 and 2050. We need to get that mapped out as soon as possible and then reverse engineer back from that, which will mean having the funding support mechanisms today to help catalyse growth towards those eventual outcomes.

Sarah Boyack: That was pretty interesting, because I note that project options six to nine in the project willow report involve the use of hydrogen. Do you need to have the finance in place to make those projects viable? After all, there is producing the hydrogen on the one hand, and on the other, there is the market for it, and the question is where that fits in with Grangemouth and project options six to nine in the report. Do you have the funding in place to make that link work?

Mark Bradley: First of all, you will forgive me, because I do not know exactly what options six to nine are—I do not have the report in front of me—

but I think that we are talking about sustainable fuels.

Sarah Boyack: They are about sustainable fuels, fuel switching, converting e-methanol and methanol to jet fuel and e-ammonia.

Mark Bradley: First, we should be talking about a market-first approach—I have already talked about that, and Tim Dumenil just agreed with me. Project willow is attempting to do that, which is very positive. Mr Lumsden asked earlier whether we can be competitive in those markets, and that is a fair challenge that will have to be overcome, but if we identify the markets first of all, we will at least we know the challenge that we want to resolve.

Whether the right subsidies are in place is a slightly complicated question, because sustainable aviation fuels, for example, will not be subsidised through the low-carbon hydrogen agreements. They should be driven by their own targets. A complex scenario is developing for these future fuels, and again, we need to map it all out. What route will allow all of these things to happen?

In order to make sustainable aviation fuels, we have to produce renewable energy, first of all, then green hydrogen and then sustainable aviation fuels. We have to link all of those things together and, if Scotland—or, indeed, the UK—intends to be an early mover in that market, we need to be co-ordinated in and collaborating on thinking about how we will do that in that specific location. Depending on the subsidies, as they exist today, will not allow you to get there quickly enough.

Sarah Boyack: So, that is a “not yet”. I see everyone else smiling, but they are not volunteering to come in.

I want to ask about the jobs that are currently at Grangemouth, several hundred of which we have lost in the past few weeks. How transferable are those jobs and skills? We have been talking about producing green hydrogen at Grangemouth, but there is also the issue of using that hydrogen there. How transferable are those jobs?

David Amos: When it comes to the production of liquid synthetic fuels, which projects six to nine refer to, Grangemouth is a long-standing and very successful petrochemical plant, and chemical processes are used to produce these fuels. Therefore, I would have thought that the skills necessary for a move towards the production of synthetic fuels will be broadly available in the workforce and management at Grangemouth and, therefore, could be transferred to support that activity.

Indeed, one of the key arguments that the project willow report makes is that we have those fantastic skills in Scotland. If we are talking about using legacies to become a green hydrogen production superpower, we could be using that hydrogen to produce a whole range of synthetic chemicals that we will require in one way or another. In that respect, Grangemouth would be an obvious place to focus on that work.

10:15

Bill Ireland: I completely agree with that, but the skills need to be supplemented. We will be dealing with different processes, and potentially different chemicals to a degree. Obviously, a lot of the skills involved in operating chemical plants—accounting, human resources and so on—are all transferable, but they need to be supplemented with specific hydrogen generation and power management skills to deal with questions such as whether we take power from the grid when there is surplus electricity, whether we can actually modulate to produce hydrogen storage et cetera. The sorts of issues that we are talking about are very specifically hydrogen production related; they are not about the use of hydrogen. In effect, it is all about what is done at Grangemouth to produce these things, and that work is, as I mentioned earlier, very much more chemical based.

Mark Bradley: When it comes to those jobs, we have to recognise that that is a challenge that exists today—right now—and because the opportunities that we are talking about are emerging and coming forward, things have to be done for those people today. I am pleased to say that, over the past year or so, Scottish Power has been working with Ineos on jobs fairs, identifying opportunities and so on, and we have started to see some people transferring from Ineos to Scottish Power. It is all about where our investment is going today, and the investment being made in Scotland in renewables and networks is providing opportunities for skilled and talented people.

Looking forward, I would say that what is proposed in project willow requires a long-term plan, with a training and development plan sitting behind it. Inevitably, time will pass, and we must have everything lined up so that they all flow through and ensure that, when these plants are commissioned, the people are there with the skills ready to operate.

Sarah Boyack: That was really useful. I am thinking about the timing of all this and the briefing that we had on project willow. This is not just about having a plan to do something; it is about actually delivering it when the jobs come online. Indeed, you can see that both at Grangemouth and in the oil and gas sector more generally—the issue is how you use the skills that people have now if they are moving into other fields.

If nobody else has any answers to my questions, I will hand back to you, convener.

The Convener: Mark Ruskell wants to ask some questions.

Mark Ruskell: I want to hear some more of your reflections on the sectors that you think should be the priority for hydrogen use. You will be aware that there has been some discussion of an appropriate hierarchy of hydrogen use, and Tim Dumenil has already talked about the right-use case for hydrogen and really drilling down into those sectors.

From your earlier comments, Mark, I take it that you see no use for hydrogen in the domestic heating sector. Is that right?

Mark Bradley: Yes. We have made it clear that domestic heating is best served by electrification.

Mark Ruskell: So, which sectors should be prioritised for hydrogen use?

Mark Bradley: I alluded to this in a previous answer. We see hydrogen as a premium solution to decarbonisation. So, there should be an electrification-first approach—in other words, if you can electrify it, you should—but the fact is that there are some spaces where electrification will not reach. If we consider certain industries that exist today—the glass industry, for example—it will be challenging for electrification to reach the full temperatures that they need, and it feels like there is a space for hydrogen in that respect.

Outside of some of those high-temperature processes, I think that you will be moving away from gas fuel switching and looking more at feedstocks and the opportunities identified by project willow with regard to sustainable fuels for aviation, shipping, some heavy transport and so on. The Climate Change Committee recently suggested that, in its eyes, the space for hydrogen in transport has narrowed, and that is probably true. I guess that the question, then, is this: where is the line and what are the driving factors? It might become too expensive to electrify some of the rail in Scotland, for example, and it feels reasonable for us to be thinking about that sort of thing when it comes to transport.

Outside of that, though, I would be looking at feedstocks. Where does electrification not reach? What sustainable fuels do we want to bring in and how do we support them?

Mark Ruskell: I think that most of the other witnesses were nodding at that, but does anyone have another view?

David Amos: From the discussions that we are having with customers, we see the construction sector as one of the markets looking significantly at hydrogen, given the type of technology required. You are looking at a comparison between battery electric and hydrogen versions of, say, vehicles, off-road machinery, generators and so on, and one of the interesting things about the energy transition is that those technologies are improving all the time.

However, a view has been taken in the construction sector that battery electric options will not enable it to decarbonise everything that it does. We provide hydrogen generators to replace the diesel generators that were used widely across the sector, and currently they are the only option available, because it is too expensive to store the sorts of large batteries needed to power a construction site for weeks on end without recharging them.

JCB has made a major investment in developing hydrogen combustion engine versions of its off-road machinery, because battery technology was not giving their customers what they needed, and the construction industry is using hydrogen fuel cell versions of lighting towers, scissor lifts and the like. That sector seems to have come to the view that hydrogen will be one of the ways in which it can decarbonise in the timescale that it is looking at.

I would also point to the use of heavy transport in, say, the mining industry as well as the forestry industry, which we have been talking to recently. Those sectors are seeing that battery electric will not provide a route forward, and they are looking at hydrogen fuel cells and hydrogen combustion engines.

I agree that electrification is the right way forward for domestic heating and the like, but with the caveat that there is no one right solution. At last week's session, Professor John Andresen mentioned combined heat and power, which has been used in Denmark and other Scandinavian countries.

One criticism of hydrogen is efficiency. When you convert hydrogen into electricity or heat, you will only get a certain amount back. A combined heat and power system that uses a hydrogen combustion engine as its source will produce electricity at around about 35 per cent to 40 per cent efficiency, but you can capture all the heat from the hydrogen combustion engine—from the exhaust, the coolant and so on—much more effectively and efficiently than with a fossil fuel engine, because the exhaust from a hydrogen engine is primarily superheated steam. It is quite benign and safe.

Mark Ruskell: I think that Professor Andresen was talking about CHP systems that were set up on the back of existing industrial sites, which is quite a niche application.

David Amos: But you could see a scenario in which, if you were close to a hydrogen production facility, you could use a hydrogen-based CHP, which would be highly efficient, to provide either a district heating system or a heating system for larger buildings. I would not rule out hydrogen entirely as an efficient heating system in some scenarios.

Lewis Elder: I agree. We align with the CCC's view with regard to sectors, and I would echo Mark Bradley's comments on industry.

For us, the other key issue is power. Statera is one of the market leaders in battery storage; we have 900MW delivered or under construction, including Europe's largest battery, which we are about to bring online just outside east London. We deal a lot with energy storage, and we also have a pump storage project under development in Scotland. However, both of those technologies, as fantastic as they are at moving energy intraday and perhaps across days—and, with pumps, potentially across weeks—cannot manage the seasonal storage requirement that is needed to give us security of power supply. Therefore, we strongly feel that hydrogen production with storage and then generation is a way of balancing that.

Moreover, electrolysis is clearly able to absorb excess wind and convert it into a resource that is then used at the other end when we have these dunkelflautes—that is, those days on end with no wind. It has a particular elegance in the power system when it comes to balancing that energy.

Mark Ruskell: Yes. I will bring in Tim Dumenil in a second, but I was struck by something that Lewis Elder said earlier. The potential demand for all the project willow projects would be around 20GW of generation to do the electrolysis and create the hydrogen.

Does that conflict with what you said earlier about blending hydrogen into the gas grid? If we have the demand for a huge amount of power to produce as hydrogen—and potentially we cannot meet all the projects that could be developed through project willow—why would we then want to put it into the gas grid? Surely we should focus the hydrogen production on two or three applications coming out of project willow. Are you making the case for blending hydrogen into the gas grid as a way of pump priming things? If you are, how do you get out of that to use the hydrogen where you really want to put it, which might be in a fertiliser factory or some other form of derivative manufacture where you do not have any alternative but to use hydrogen because electric will not cut it? Does that make sense?

Lewis Elder: Yes, it absolutely does—it is a great question. In our view, the use of blending is just a stepping stone. Having a dedicated network there today would be the right way to do this, but we are cognisant of the fact that repurposing parts of the gas network will take time. A lot of the projects that willow is talking about—in particular the ones of real scale involving e-methanol and e-ammonia—have a commercial operations date of 2035, which does align with having project union and a dedicated hydrogen backbone.

The first point is that we need to be clear that that dedicated network is coming forward to keep investors confident that we are moving in the right direction but, as a stepping stone towards that, targeted, strategically located, large-scale hydrogen-production facilities should be allowed to blend into the natural gas system. That would allow us to scale up production and it would allow the entire hydrogen economy to begin to get the confidence that there will be production at scale at a certain cost, which, as I have said, can get competitive. That then gives us a clear pathway for industries at Grangemouth to come forward and say, "Okay, if a dedicated pipeline will be there in 2035 and you can produce hydrogen at £60 to £70 per megawatt hour, yes, we will start investing in the facilities to turn that into ammonia or SAF." It would help us on this journey.

Mark Ruskell: The concern, though, would be that we then build in dependence on natural gas, which will be 90 per cent of what flows through the pipes—10 per cent might be hydrogen. If this is seen as a transition, how do you make sure that there actually is a transition, rather than effectively locking in dependency?

Lewis Elder: Let us be clear. The natural gas will be flowing anyway. The blended hydrogen going into that system will be decarbonising some offtakes. The point is that it does not target which offtake it is decarbonising. Hydrogen is a valuable resource—it should do that. How do we then move away from natural gas? That comes back to having certainty about a dedicated network to give us the confidence that there will be a route away from natural gas as a fuel source.

10:30

Tim Dumenil: My earlier point was going to be around energy efficiency. Energy efficiency should precede everything. The more that we can reduce the primary energy that we need and use, the better that will be for the transition that we will then have for these right-use cases.

Five years ago, I was project managing Acorn hydrogen. I had managed to pull together expressions of interest for 850MW of hydrogen demand for the three 300MW reformers that we were going to deploy. Acorn hydrogen's business model required that blending into the national transmission system. That project is currently

sitting on the shelf because, despite five years of lobbying, we have not yet managed to move forward that interim blending position ahead of having the permanent enduring hydrogen core network that Lewis Elder spoke about.

The key is that you want to have that commercial contract. If you are blending in, you want the commercial contract to be with that enduring right-use offtaker in the longer term. That is the approach that the Department for Energy Security and Net Zero has been taking with a risk-taking intermediary within the low-carbon hydrogen agreements. It needs the developer to interact directly with the end user to ensure that that full contract is set up and is in place. That is how you can use blending to catalyse and get things moving toward, by making sure that there are contracts with the right end users ahead of that core pipeline network.

To go back to the original question about those right-use cases, it is absolutely about dispatchable power generation. Lewis Elder spoke earlier about how the best opportunity that the UK has at the moment is taking that curtailed wind and converting it to electrolysis, but you then need somewhere to move it and store it for when you have those doldrums and the dunkelflautes and you can then pull it back out again. It goes back to my earlier point about the national strategic energy plan: we need to understand where we will be in 2050, where that energy need will be, where we will be able to make it, how we will move it from A to B and where we have the resilience in terms of storage in place to underpin all that.

Finally, I will relate this back to project willow and the three main low-carbon hydrogen pathways. Pathway 7 is to use low-carbon hydrogen from across Scottish regions to enable fuel switching within Grangemouth and beyond in Scotland's key industries such as malting and ethanol distillation for the Scotch whisky sector.

Pathway 8 is on e-methanol and methanol—using low-carbon hydrogen from across Scottish regions and Scotland's more than 3 million tonnes per annum of biogenic CO_2, synthesising those two to produce methanol and SAF to enable fuel switching for our air, sea and surface fleets.

Finally, pathway 9 is about e-ammonia, using low-carbon hydrogen from across the regions and air-separation units that separate nitrogen from the air, for hydrogen and nitrogen synthesis into ammonia. That can enable fuel switching for our air, sea and surface fleets. It produces the fertiliser for Scottish barley and wider agriculture.

The final right-use case piece, separate from the three pathways, is around dispatchable power generation. That again is beneficial to project willow because, when you have the doldrums, you are able to draw back from those reserves to keep the core synthesis processes that generally need a baseload to underpin them.

Bill Ireland: I will, hopefully, be quite quick with some facts. Storage of energy as hydrogen rather than in batteries has less than 10 per cent of the capital cost. The efficiency does come into it, but it is about the capital cost. There is a switchover, and hydrogen is not the answer. Hydrogen needs to be used in particular cases and it will vary from region to region and application to application, in terms of connectivity to the grid et cetera.

I think that we underestimate the amount of electricity that we will need. We need to build more and more renewable electricity generation—way more than the demand that we currently have for electricity. We currently use 40GW or 50GW. We will need hundreds of gigawatts of renewables to replace our fossil fuels. The example of how many gigawatts we need for willow is exactly that. How much we need to produce is quite astounding when you look at the figures.

I disagree slightly with the Climate Change Committee on the transport side of things. It basically said that hydrogen has no place in heavy goods vehicles. That is not the case and it is overestimating the advancement of batteries. We do not have the electrical infrastructure to distribute our electricity from renewables, let alone charge vehicles at 500KW. The Ember bus that goes between Glasgow, Dundee and Edinburgh needs a 250-kilowatt if not a 500-kilowatt charger to charge it to keep it running. That is the electricity supply for about 400 homes. The infrastructure is not being built into all the homes going up around Edinburgh to support the electric charging of vehicles. We have all these things to deal with.

If you are talking about HGVs going backwards and forwards—150 trucks—which produce 16 per cent of the CO_2 emissions in transport, you will not do that with batteries. We need to look at the right uses in the right places.

I turn to something that is close to David Amos's heart. In the Western Isles, for many years, 250MW of land-based wind was not developed because we could not afford the interconnector, or the interconnector was not put in there. Curtailment, in my view, is bad management and bad planning. If we are talking about curtailment going up, I completely agree with what Lewis Elder says about using electricity when it is available, but we will need to produce far more electricity than we can consume to make our other fuels and store our energy. To do that, we need to generate electricity but then also store it as far as hydrogen and batteries are concerned—it is a balance. Exactly as we do at the distillery, using electricity immediately to generate steam is by far the way

best way to do it, but the wind does not blow all the time and the sun does not shine all the time.

Bob Doris (Glasgow Maryhill and Springburn) (SNP): We have heard quite a lot about making sure that we can get the hydrogen to where it needs to be and where it has to be used, and we heard a little bit from Lewis Elder about project union. According to my notes, that is the plan for 1,500 miles of hydrogen transmission network by the early 2030s. However, Lewis talked about limitations in the existing network as well as barriers to getting on to it. How important is the development of that particular network? Given that it will not all happen at one time, what connections and locations should be prioritised as the network is developed to support hydrogen?

Lewis Elder: That is a good question. We keep coming back to the role of networks. It is absolutely critical to have large-scale hydrogen networks in development to scale the hydrogen that we are planning and to deliver on the vision.

On the phasing of project union, I believe that National Gas's priority is to first link up the clusters in northern England, in Merseyside, Humberside and Teesside. I was pleased to see that the next phase that National Gas is now prioritising is the Scotland leg and connecting from those clusters right the way up to Acorn. From our perspective, that is absolutely critical.

The Scottish Government should do everything that it can to place pressure on the timescales for that, because Grangemouth and many businesses will be reliant on that and, as we have discussed, the constraint cost will only rise until the issue is addressed. The Scottish Government definitely has quite a big role in driving forward that network and ensuring that milestones and deliverables from National Gas on that network are kept to.

Bob Doris: You talk about joining all this up in a network and priority areas for developing, and you gave some welcome news for the next stage. Putting aside the timescale, the phasing and the prioritisation, is there anything that project union is not doing but should be doing?

Lewis Elder: We are missing certainty on its delivery. From an industry perspective, we do not have certainty that that network will come forward. Giving industry and investors—both investors in hydrogen production and investors in Grangemouth and the potential uses there and so on—the certainty that the network is coming forward will galvanise a lot of industry to move. At the moment, it is not clear whether that network will come forward, so action is required on that.

As I mentioned, in the short term, allowing projects to begin to scale to help support that decision and make it easier to make the case for a dedicated network through blending into the existing natural gas system will kickstart the wider hydrogen economy.

Bob Doris: I do not want to put words in your mouth but, to paraphrase, you are, in part, saying that the lack of certainty and clarity is impacting on investment now.

Lewis Elder: Yes, it is. There is no certainty on a dedicated network. From our perspective, how can we raise investment to bring forward a large hydrogen production facility if we do not know where that hydrogen will go? At the moment, that is a blocker. Also, the hydrogen business model precludes blending—the stepping stone that we have discussed for the projects—from entry into the hydrogen subsidy regime. That needs to be addressed, too.

Bob Doris: Tim, you said that, in a previous existence, you were involved with Acorn and you mentioned some of those issues. Do you want to comment on anything that you have heard so far?

Tim Dumenil: I have just two points. On the point about investor confidence, Storegga is an SME that originated in north-east Scotland and is now headquartered in London. Through the backing of a group of significant global infrastructure investors, we were able to develop a leading portfolio of CCS projects both in the UK—in Acorn—and internationally, and then hydrogen projects. However, several of those projects are on hold at the moment because we are waiting for the right messages and signals to come from the UK Government to unlock investment and bring forward those projects.

You asked what project union is not doing. One important thing that it is doing is harmonisation of standards on low-carbon hydrogen between the UK and the European Union. We have existing interconnectors that connect the UK to the European gas networks. The EU is moving to a 5 per cent blend of hydrogen imminently, so there is harmonisation not just on blending percentages but on the low-carbon hydrogen standards. That is a bit of on-going activity.

My main point is on what project union is not doing. It is focused on creating the onshore network between the industrial clusters but, to go back to an earlier point, offshore pipeline infrastructure can also be built. We have been part of the funding consortia for the Net Zero Technology Centre's European hydrogen backbone link project. As part of that, we have been saying that, in addition to putting in an eastbound pipeline, we should also be working on a southbound pipeline into Grangemouth and into Teesside and Humberside as part of a broader parallel network to project union.

To put that into context, in terms of affordability and value for money, in September last year, the

2GW high voltage direct current interconnector cable from Peterhead down to Hull was announced. That 2GW cable has a capital cost of £3.4 billion. A 10GW gaseous hydrogen pipeline to Germany costs £2.7 billion—that is what the NZTC phase 1 project spoke about. Therefore, a shorter pipeline down to Teesside could have a capital cost of, say, £2 billion. That 10GW of hydrogen is the same as 14GW of load-following offshore wind. If we were to deploy all that 14GW as electrons, we would need seven cables. Therefore, we could spend £24 billion on moving seven cables' worth of energy in the form of electrons down to Teesside, or we could spend £2 billion on a pipeline.

10:45

That comes back to a point that I have made twice already to the committee about the blueprint for 2050. What do we need? If we are to move those electrons down to the north of England and deploy them purely as electrons, that is great. However, why would we move those electrons down to the north of England and then convert them into hydrogen and hydrogen derivatives? Why not do that up here in Scotland at Grangemouth? Also, we will not have enough footprint in and around Grangemouth to do all of that, so also being able to move Scottish pipelined hydrogen down to Teesside to produce the fuels, ammonia and fertiliser that society will need in the future would be a neat outcome.

Bob Doris: I will be disciplined and will not follow up on some of the interesting points that you made there, as I must move on to my next question, given the time constraints.

We have heard primarily, but not exclusively, about green and blue hydrogen. Do the different forms of hydrogen production affect how we plan for future transportation infrastructure? Does the balance between green and blue matter for investment in that infrastructure?

I am seeing no takers on that. David Amos might want to come in.

David Amos: That balance makes no difference whatsoever to the technologies that use the hydrogen.

When you refer to transport infrastructure, do you mean the infrastructure for moving the hydrogen around?

Bob Doris: Yes.

David Amos: Green hydrogen production can be based anywhere. You can produce green hydrogen and put plants in island communities, so it gives the ability to devolve the energy system. As Bill Ireland is doing with Arbikie, you produce the green hydrogen for use on site. Therefore, green hydrogen offers more flexibility as it reduces the need to transport the hydrogen to the end user. Blue hydrogen is linked to where the gas grid and the reformers are based. Green hydrogen offers more flexibility in the location of the end uses.

Bill Ireland: It depends on the scale. If you are going down the blue hydrogen route, it will be produced where you have the natural gas and the storage. It is about the location and where you put the generation, rather than the technology. It is a bit like the situation with the electricity grid. We used to have a small number of large producers of electricity, and we had a big backbone. I think that there will be a mixture of industrial large-scale production and distributed generation of hydrogen for use in local catchment areas.

There will be large and small-scale production. We need to focus on where the big energy is and where the big users are. We need to look at the big backbone and the big pipelines, as Tim Dumenil said. We forget that we had a hydrogen distribution system, which was called the national grid. Town gas was 55 per cent hydrogen. We spent 10 years converting it from hydrogen to natural gas, and now we are doing it in reverse.

Bob Doris: I will go to my final question. I will bring in Tim Dumenil, because he might also want to reflect on the previous answer. I know that there are time constraints.

What are your views on the potential transportation of hydrogen by ship, either as ammonia or compressed hydrogen? Our notes say that, as the years go by, that will become more viable and potentially more important. I am interested to know your views on that. Tim, do you want to come in on that? You can also reflect on the previous question if you wish.

The Convener: I encourage people to be brief, because I have to get Douglas Lumsden in and we have another panel of witnesses, who will need some time as well.

Tim Dumenil: Blue hydrogen and green hydrogen both produce hydrogen that is more than 99 per cent pure. They both meet the low-carbon hydrogen standard and so can both use the same infrastructure. In fact, the only application that would need a greater than 99.9 per cent purity is fuel cell applications and, at the point of use, you can put in a pressure swing adsorption process to achieve that extra purity.

You can ship but, again, that has incremental cost. The biggest opportunity that we have is to develop our regional solutions and connect those into a national solution. If we are looking to export, we should export via a pipeline to the hydrogen core network for Europe.

Bob Doris: I see nodding heads. I do not want to put words in your mouth, Tim, but are you suggesting that pivoting towards shipping in the years ahead might compromise the infrastructure that we need for long-term sustainability? Could shipping be counterproductive?

Tim Dumenil: To go back to one of my earlier points, these are global commodities. Ammonia is a global commodity that is already shipped internationally. The ships already exist, so it is about being price competitive. Will we be able to be price competitive with low-cost power jurisdictions elsewhere? Our biggest unique selling point is our geographical proximity. The major German offtakers, such as Thyssenkrupp Steel, which I have spoken to, want security of supply, and they see pipelined hydrogen as offering them greater security of supply.

Bob Doris: I have no further questions. For the record, I point out that Mr Ireland was agreeing with that as you were saying it, Tim.

Bill Ireland: Yes. Given the scale of hydrogen usage that we need in the UK, we need to focus on usage here to start with. As I said, the scale of energy that we need to produce to replace fossil fuels is enormous.

The Convener: Douglas Lumsden has the final question, unless the deputy convener wants to come in.

Douglas Lumsden: We have heard about production taking place only during curtailment. I guess that, on the back of that, quite a lot of storage will be required. Is there any storage? How easy is it and how much is planned so far? No storage is proposed at the Kintore hydrogen plant, for example, so where would all the storage be? I will start with Lewis Elder.

Lewis Elder: It goes back to the point about networks. We need large-scale networks in place that link up production, storage and demand. We have four key storage opportunities: lined caverns, salt caverns—

Douglas Lumsden: Do we have any of those?

Lewis Elder: Scotland has no onshore salt caverns, but it has saline aquifers and depleted gas fields, which are opportunities for storage.

My key point on storage—beyond the one about networks and the need to make sure that we are all linked up so that we do not require production to be co-located with storage and demand, which is an extremely hard task—is that we need to have development funding to get moving on storage. A UK Government business model for hydrogen storage is being planned, but it is clear that you will get certainty on your development expenditure only at the point that you reach commercial operations, whereas a number of hydrogen storage projects will fall away because the integrity of the substrata geology is not sufficient for hydrogen. Developing hydrogen storage has a high risk profile, because you really need to understand the interaction of the geology with hydrogen. My policy ask would be that development support funding is granted to kickstart hydrogen storage opportunities.

Douglas Lumsden: Do we need that storage plan in place before we move on with many of the other things?

Lewis Elder: By the time that you have a dedicated network in place for green hydrogen, you will want storage. For the stepping stone of blending into the existing natural gas system, you do not need storage. You can rely on the UK's existing storage, such as the Rough gas facility, which is a large project.

The Convener: The deputy convener wants in with a follow-up question.

Michael Matheson (Falkirk West) (SNP): My question is for each of the panel members. If the Government could take forward one single policy option to support the sector, what should it be?

The Convener: I will be tight. To reiterate what the deputy convener said, he is asking for one option per panel member, and that is not one long list.

Why do we not start with Bill Ireland and work our way along?

Bill Ireland: I knew that you were going to come to me.

There is not one. I would have to come back to you on that. There are many requirements to get hydrogen to work and that involve the longer term. I do not have one particular piece of policy—there is no silver bullet. The policy around energy is complicated and covers everything from electricity grid regulation encouraging electricity grid development rather than production and so on. Loads of policies need changing.

Lewis Elder: In representing Statera today, I have spoken about reforming the business model, the need for hydrogen storage and networks, and unlocking low power prices for electrolysis.

For us, the number 1 and first step is blending into the existing natural gas system. That will immediately allow projects to scale and will allow hydrogen production cost to drop by about 30 per cent. To be clear, on a full 3GW Kintore project, a 30 per cent reduction on the hydrogen business model equates to about £10 billion in avoided subsidies. Those are policy points where changes could be made today with material consequences or outcomes.

Mark Bradley: Tell us where you want it. Identify the clear market that you want us to address with scale. Where is it? Who is it? They have to be at the table with us. Then we can get on and try to solve some of the problems.

David Amos: We need a policy that encourages the co-location of green hydrogen production alongside our waste water treatment plants, because of the opportunities to use the waste heat and oxygen produced by electrolysis to drive significant efficiencies in the waste water treatment plants, which in turn adds value to what are traditionally waste products from electrolysis that have no value in the big schemes that we have been talking about. That then brings down the cost of the hydrogen that is produced. A policy trying to combine those two elements would be helpful for part of the sector.

Tim Dumenil: My point is a combination of Mark Bradley's and Lewis Elder's. It is about the whole energy system national strategic energy spatial plan and, as part of that, blending and enabling the hydrogen core network on an enduring 100 per cent hydrogen basis.

The Convener: Deputy convener, are you happy with the answers?

Michael Matheson: Yes. There was a fair mix in there, convener. Thank you.

The Convener: I thank the panel members for their evidence and for helping us as we look at the future of hydrogen.

I briefly suspend the meeting to allow a changeover of witnesses. I ask members to be back here at five past 11.

10:58

Meeting suspended.

11:07

On resuming—

The Convener: We will now hear from our second panel of witnesses on hydrogen aspects of the project willow study, with a focus on Grangemouth and its potential role in relation to blue hydrogen and the use of carbon capture and storage technology to decarbonise the industry.

I welcome to the meeting Professor Stuart Haszeldine, who is professor of carbon capture and storage in the University of Edinburgh's school of geosciences—Stuart, thank you for submitting written evidence to us—Nic Braley, who is general manager of the Acorn project; Professor Hannah Chalmers, who is personal chair of sustainable energy systems in the institute for energy systems, which is part of the University of Edinburgh's school of engineering; and Professor Mercedes Maroto-Valer, who is director of the Industrial Decarbonisation Research and Innovation Centre at Heriot-Watt University. Those are some of the longest descriptions that I have had to read out.

There are four of you on the panel. If you keep your answers short, each of you will get in. If your answers are too long, you will exclude your fellow panel members. Please bear that in mind. The first question is from Sarah Boyack.

Sarah Boyack: Thank you, convener. Panel members, what do you think about the current options for hydrogen support schemes from the Scottish and UK Governments? There are quite a few. Could they be improved? The net zero hydrogen fund, for example, has approved six projects in Scotland. There is also the hydrogen innovation scheme in Scotland and the UK Government's hydrogen production business model. Are they the right schemes for funding, are they targeted enough and are they well enough funded?

Nic Braley (Acorn Project): I come at this from the Acorn transport and storage side. We work with customers who will seek support.

Sarah Boyack: Sorry—could you move your mic up? That is better—thanks.

Nic Braley: As I said, I come at this from the transport and storage side. It is our customers that receive support through the hydrogen business models, so I am not deeply familiar with the differences between all the business models.

It is fair to say that the Government is trying to provide a foundation for the establishment of an industry, by taking and sharing risks with industry. As the industry evolves and develops, the risks will change and it will be necessary for the business models to evolve so that they become fit for purpose at all times.

It has been great to see hydrogen projects moving forward in different locations and at different scales. Different business models are appropriate, and they will continue to evolve over time.

Professor Stuart Haszeldine (University of Edinburgh): My answer is that it depends what we are trying to do, and I am not quite clear what we are trying to do. There are lots of small to medium-sized projects that are creating capacity, capability and enthusiasm in Scotland and England and that might in the future produce local hydrogen for local use in remote communities—especially in Scotland, where we have abundant wind power.

However, I am not yet seeing a national vision for where the grid will go, which was discussed at

the tail end of the previous session. Will we supply local homes or will we supply national industries at large scale? How will we solve the problem of generating hydrogen in the summer but using it in the winter? The storage problem is immense, and we have not tackled that properly. I am not clear about the Westminster Government's thinking on the big decision about whether we put hydrogen into lots of domestic homes using the existing pipe network, or whether we decide that everything in our homes is pretty much electrified so hydrogen is directed for use in remote areas and some transport and to places where electrification is difficult, for whatever reason.

I am not clear on it. I do not see any master plan. There are pieces of money coming at different times without, necessarily, any connection between them.

Sarah Boyack: Do you want to come in, Professor Maroto-Valer?

Professor Mercedes Maroto-Valer (Heriot-Watt University): Yes, thank you. First, thank you very much for having me here this morning.

I will build on what my colleagues have said. We need more co-ordination across the different projects and on where they will take us. Are we learning anything from the projects as they develop? There are multiple types, sizes and colours of projects, but what lessons are we learning at the scale at which the projects are being deployed now that will allow us to go to the much greater scale to which we want to go? That is the concern. It is good to have a range of projects, but we need them as a catalyst for something bigger. I do not see how that transformative step will happen without more co-ordination.

Sarah Boyack: One comment in the earlier session was that the funding is transformative. How does that relate to the funding that is available through project willow? Does it have the incentives that will help to deliver the transition? We were looking at projects 6 to 9.

Professor Hannah Chalmers (University of Edinburgh): In project willow, we are starting to look at bigger scale projects 6 to 9. That is one place where the current mechanisms are not designed for the project willow vision. We can unpack that—that is what we are here for. My view is that there is not a good fit between what we already have and what project willow needs.

11:15

Professor Haszeldine: There is a big decision to be made about green and blue hydrogen. Blue hydrogen is made from methane, and green hydrogen is made by electrolysis of water. The more we focus on blue hydrogen—which is a popular approach among incumbents because it exists, so you can build it now and make it work now—the more we are locked into a supply of methane gas from other countries that we have to bring here, so, in some ways, it is not a sustainable option. It is a hydrogen option, but it is not as smart as the green option.

If we are truly thinking ahead on a 10, 15 or 20-year timescale, by the time we could build and operate some blue hydrogen, I hope—"hope" is the word, because we do not know—that green hydrogen development will have caught up to a reliable level, if not necessarily at scale, so that there could be lots of small or medium-sized electrolysis equipment to produce the amount of hydrogen that we need. If the whole ethos of the Grangemouth shift and project willow is to be sustainable, circular and ecologically great, it seems perverse to go down the blue hydrogen route.

The Convener: Nic, thank you for not pointing out my bad manners for not thanking you for your written submission, as well. I formally thank you for providing a paper.

Sorry, Mark—do you want to come in at this stage, or are you happy for me to go on with my question?

Mark Ruskell: No, I am fine.

The Convener: We heard this morning about hydrogen being produced, although probably not at Grangemouth, but then moving production to Grangemouth so that the site is used. Do you all agree with that? Is that how it should go?

Nic Braley: As we think about the evolution of the hydrogen networks and the evolution of Grangemouth, we need to think about the pathway that we are on, the first steps that we take and how it evolves over time. Picking up what Stuart Haszeldine was saying, I note that we can move to create blue hydrogen at Grangemouth quickly—we can do that now and at scale. It can deliver a low carbon fuel-switching option for Grangemouth; therefore, that is likely to be developed on site. However, if we are looking at the long term and you want to encourage the development of green hydrogen, the sites for providing those green hydrogen molecules for Grangemouth should be developed in the places where the electricity is and that have the most advantageous electricity price to feed into a network, and those sites can be anywhere.

Perhaps another point to bear in mind is that, as we move to the development of green products from Grangemouth, we are looking for biogenic CO_2 and we are looking for green hydrogen to produce green molecules such as SAF. In the short term, when we do not have as many green

hydrogen molecules, we want to ensure that those go into high-value green products, perhaps using blue hydrogen for some of the fuel-switching projects.

I think that Grangemouth will evolve through a pathway. It will have some production on site; then, increasingly—as in its history, whereby Grangemouth has brought in products from around the world and synthesised those into the chemicals and petrochemicals that we need—biogenic CO_2 and hydrogen will be brought in as raw materials for products from Grangemouth.

The Convener: One issue, though, is the fact that, as soon as the electricity that is generated across the Highlands hits the national grid, the price goes through the roof and it prices hydrogen out. I come from an area that seems to have a proliferation of wind farms, pylons and all the problems that go with that and a community that does not seem to benefit from it. Some regionality in hydrogen production would seem quite good where there is wind power.

The other issue is water. We are in a situation where just about all of Scotland is potentially in a drought situation, yet we seem to be concentrating on hydrogen from water on the east coast when, traditionally, it has always been the west coast that has had more water. Do we need more joined-up thinking about all those points?

Professor Maroto-Valer: That is pretty much the point that I was going to make. We are in the earliest stages of a market that we want to ramp up tremendously in a short time. We need to start considering the best places to get the market going and, if we are looking at green hydrogen, the price of the electrons. We need to be strategic in how we deploy the first projects that will start giving us the market, the offtakers and the scale that we need. We need to be pragmatic. Where do we have the cheapest electricity and where do we have water, if we are going for electrolysis?

In the short term, we need to consider how we can take decisions that will get the market going, understanding, as Nic Braley said, that relocation may happen as the market progresses and becomes larger.

The Convener: Is this a legacy of the fact that we did not plan where all the wind farms were going? Are we going to have everything dotted around the landscape because we do not have joined-up thought on the whole system of electricity and power generation? Mercedes, do you want to come back in on that? I am also happy to bring anyone else in.

Professor Maroto-Valer: Do you want to comment first, Hannah?

Professor Chalmers: No, go ahead.

The Convener: You are all very polite, which I love. Mercedes, if you comment first, I will then bring in Hannah.

Professor Maroto-Valer: That is a really good point, and it is something that we consider at IDRIC. As we look at the transition, we can look at the problem in two ways—where are our existing assets and how do we start transitioning them? They may not be where we will want to place our infrastructure and assets tomorrow. Again, this is all about the transition. We need to play to the strengths of where our assets are now, but we should be strategic in considering where we want to place them for the second and third generations, when hydrogen will be at a much larger scale.

Professor Chalmers: It is important to bear in mind that different technologies have different demands for water. The availability of water is obviously a concern for green hydrogen, but in the case of blue hydrogen there is not necessarily a large water demand.

We absolutely need spatial planning, and the previous panel of witnesses talked about storage as well. That immediately makes me think about marine spatial planning. With blue hydrogen, we are trying to move a lot of carbon dioxide around, as well as a lot of hydrogen, and we are potentially looking at similar geological formations. Efforts are under way to do a reasonable job on marine spatial planning, which is really important.

The Convener: Nic, do you want to comment on that? I can see where you probably want it, but it is not where the water is.

Nic Braley: As we look at any energy system, we try to consider the competitive advantages that each side has. The problem with green hydrogen is about the price of electrons. We hope that, in future, with increasing levels of wind, we will be able to get lower-priced electrons, and we should place the green hydrogen production at the locations where those cheaper green electrons are and where we have access to water. As Tim Dumenil said, we can then ship hydrogen relatively cost effectively over large distances.

For each situation, we need to think about what infrastructure we have, what infrastructure we need, where our raw materials are and, therefore, what the right solution is for each site. It is a multivariate problem that we have to solve. That is why the pathway piece is really important. We have to play to the strengths that we have today while planning for the system that we will need tomorrow and trying to plan the route from one to the other. That is what the spatial planning is all about.

The Convener: Stuart, do you want to comment on sorting out the problems that are before us?

Professor Haszeldine: It is difficult. We have heard the word “network” used several times in this meeting. The network will try to work out where enough low-cost electricity is stranded that it will be sold cheaply. We also need to overlay on that where we might get abundant supplies of water. At the moment, sea water is not an option for electrolysis, but I guess that it would be sensible to make that an option.

I agree that hydrogen should be generated close to the source of the electrons because, in terms of energy per kilometre, it is much cheaper to pipeline the hydrogen than it is to build wires and numerous battery farms around Elgin or wherever it is happening at the moment.

We will have to generate the hydrogen close to the electrons, shift some of the hydrogen to where it is used and shift even more hydrogen to where it will be stored. Where it will be stored will be determined geologically, and it is clear that the best places are likely to be the depleted gas fields of the southern North Sea, some of the depleted gas fields around Shetland and some of the salt deposits in the Irish Sea, because the rest of the salt in most of the southern North Sea is too deep.

The problems are to do with shifting different products at different times large distances around the UK. It is a question of analysing what the options are and what is likely to be the most flexible and cheapest option in the future.

The Convener: This might be a daft laddie question that I will regret later but, if we are generating power offshore on floating wind farms, is there any reason why we could not create the hydrogen offshore straight from the wind farms and then transmit it by pipeline to an offshore storage facility, which could be close by, or bring it on shore?

Professor Haszeldine: My perception is that SSE has a well-advanced plan to build a big island on the Dogger Bank and do exactly that.

The Convener: Okay. I may need to look at that a bit more. Nic, do you want to comment?

Nic Braley: It depends on the size of the offshore facility. Offshore real estate is extremely expensive, so it may be cheaper to ship the electrons onshore and create the hydrogen there than to put a hydrogen generation plant offshore. It is all about the economics. Every energy choice is about trying to work out what the best approach is given the circumstances that we have.

The Convener: Whatever the option is, it appears that putting it into the national grid and buying it off the national grid to create hydrogen is not the way forward.

Mark Ruskell has a question.

Mark Ruskell: My question is on carbon capture and storage. The new Scottish climate change plan will come on the back of the carbon budget. The previous plan had quite a heavy reliance on CCS and Acorn. Do you think that that will change with the new climate change plan? We are aware of the track 1 and track 2 issues around delays, but has anything else changed in the past couple of years in relation to the prioritisation of CCS and its contribution within the climate change plan?

Nic Braley: CCS plays a hugely important role in the pathway to decarbonisation, but also in industrial development and clean power and jobs for Scotland. It plays multiple roles. The Acorn project involves storing CO_2 safely offshore, supporting the development of the CCS-enabled clean power plant in Peterhead so that we can keep the lights on when the wind is not blowing, providing a route for the decarbonisation of Scottish industry, and supporting Grangemouth in the development of a new product suite and the green products that we need for the future. CCS is playing a critical enabling role across multiple policy areas and not just in the delivery of decarbonisation.

11:30

Mark Ruskell: Okay. That is the pitch. I have heard that quite a few times before, but I am interested in the reality of where that now sits within the climate change plan. The previous climate change plan relied quite heavily on having CCS up and running by now, or very soon, to meet the 2030 targets. The Climate Change Committee warned that we would need to have a plan B, but that never came.

Leaving aside the strong arguments that you put forward, I am interested in where CCS now sits in terms of being deployable on the ground and able to capture carbon at an efficient rate. When will that happen? How much reliance on it should there be in the plan?

Professor Chalmers: The UK Climate Change Committee document was an interesting read. It focused on CCS for hard-to-abate sectors and leaving power decarbonisation to other ways of doing decarbonisation, which is a shift from what it has said. However, power projects are going ahead in the track 1 clusters. A final investment decision has been made on a power project in Teesside and it will go ahead. There is now a disconnect between what the Climate Change Committee is saying about a balanced pathway and what we are actually seeing in the clusters that are putting forward projects for UK Government support.

I wonder whether one reason why that has happened is that the CCC is assuming that there will be residual emissions from the carbon capture plants of, perhaps, 10 per cent. Technically, we do not have to have residual emissions that are that high. They can be much lower without incurring huge costs, but I am not sure that the system modellers have caught up yet. I wonder whether the reason why CCS is not being seen in the power sector is that there is an assumption that residual emissions would become too much by 2040-ish.

If we care about the residual emissions, we can slightly tweak the way that we do our carbon capture. We can pay a small amount—a few per cent more—and we will not have those residual emissions. I have not spoken to the CCC about it, but I wonder whether such things are driving the change, rather than other things that might be more concerning.

Mark Ruskell: Okay. You think that it is not about the timescale for deployment but is more about how the CCC is modelling residual emissions. Are you saying that we are on track with that and the other track 1 projects?

Professor Chalmers: There is a natural gas combined cycle with post-combustion capture project that has a final investment decision in England, so it can be done. Obviously, that is being done with Government support, so there is then a question about where we put the money. Is it better to put it into natural gas for CCS or into something else? A whole bunch of factors come into that decision, and one of those is whether the investment is future proof. For me, that includes the residual emissions that we might be committing to. I think that that is a key thing that has affected the Climate Change Committee's modelling, but real people are investing in real projects. We then get into the politics of it all.

Mark Ruskell: Okay. Thanks. Stuart, do you want to comment?

Professor Haszeldine: I think that there is a UK answer and then a rest of the world answer. The UK is proceeding diligently and precisely but incredibly slowly along the track 1 development route. We will probably have about a third of the CO_2 that we promised in the ground by 2030. It is all performing too slowly and it may well underperform. However, that is not necessarily a capture problem. It is just about the complexity of putting everything together into complicated clusters where we have to co-ordinate 10 different projects simultaneously.

If we look at the rest of the world, and specifically Europe, Denmark decided about two years ago that it wanted to do carbon capture and it will have its carbon dioxide in the ground later this year with Ineos. Ineos launched its European shipping tanker for CO_2 last week. Ineos is serious about doing it, but it is not choosing to do carbon capture and storage in the UK because it is too slow here, I think.

Norway has been capturing and storing carbon dioxide very effectively since 1996, but because it has been successful, as I often say, it is not newsworthy. We tend to hear about the failures rather than the successes. That has worked very well, and off the back of that experience, Norway has now opened up a carbon dioxide business west of Bergen. Norwegian shipping tankers will come along the coast, collect the carbon dioxide and take it north of Bergen, where it will be pipelined offshore for storage as a business. That is what we should be doing with projects such as Acorn.

I am interested in what happened yesterday in the Brexit partial reset. There is a specific mention that we want to open up trading of CO_2 across the North Sea. The UK could make a big offer to bring in carbon dioxide and store it with projects such as Acorn if we want to. That could transform the pace of movement in the UK.

On project willow and Grangemouth, my reading of the outlines of the projects suggests that at least half of them will generate some sort of CO_2, which will want taking away to secure and permanent storage. In the frame of the committee's inquiry, I note that CCS is essential nationally and essential for the various components of project willow.

Professor Maroto-Valer: There are two aspects here. One is that carbon capture utilisation and storage is a market opportunity and there are questions about how we can make sure that it happens. It is not just a question of our territorial missions.

The other aspect is what carbon budget 7 is telling us for our territorial emissions. In CB7, electrification has picked up significantly compared with carbon budget 6 and previous versions. Electrification plays a much bigger role in CB7, not just for domestic use but in relation to electrifying industry. There are opportunities around electrifying heat, particularly if it is low to medium heat.

For all the reasons that Stuart Haszeldine mentioned, we should have more CO_2 in the ground than we have at present. We need to pick up the pace. Other opportunities may be coming up, but we need to consider the absence of that pace. We need CCUS not only for our territorial emissions but because it represents a market opportunity for Scotland given all the storage that we have in the North Sea. We should remember that there are two ways of looking at this: what we

do with our territorial emissions and the fact that our market opportunities go well beyond those.

Mark Ruskell: Thanks for those answers.

Going back to hydrogen, I would like to ask a question that I asked the first panel, about which sectors we should prioritise for hydrogen use. We have had some discussion, in the past couple of weeks, about the potential to bring back fertiliser manufacturing, and we have talked about hard-to-abate sectors in particular. There has been some discussion about the wider use of hydrogen in heating and its applicability or otherwise. I am interested in your thoughts on that.

Mercedes, you are nodding. Would you like to come back in on that?

Professor Maroto-Valer: I need to stop nodding. Absolutely—no problem.

When we look at hydrogen, it has to be courses for horses—or whatever the expression is. We need to move a little bit away from the idea that hydrogen can do everything. If we want to catalyse the market going soon, we need to find where the best opportunities are for hydrogen, and, right now, those are in the industrial sector. The industrial sector is already using hydrogen and has experience of doing that. We need to make sure that it uses it more sustainably, but it has the infrastructure, the skills and the transport for it within some sites. We need to focus on the industrial sector.

Other sectors, such as domestic use and transport, offer other opportunities. In the much longer term, you may see an opportunity for hydrogen to decarbonise difficult sectors—possibly even aviation—but that will be in the longer term. In the shorter term, industry can use hydrogen now—we are already using it, and we need to do more of that. Industries like the steel industry do not have many other options, and hydrogen is used in the industrial sector. In the medium term, hydrogen may be used to produce sustainable aviation fuels, rather than being used directly as a fuel, and in the longer term—we have published a paper on this—hydrogen may be used directly as a fuel for aviation. However, we need to look at timelines for that.

Mark Ruskell: Would you say that the project willow projects broadly align with what you see as being the priority sectors going forward? Is anything missing there? It is all about hard-to-abate sectors and derivatives. Are those projects aligned to where you think the markets need to go?

Professor Maroto-Valer: Yes. In projects 6 to 9—the ones that we are looking at today—we are looking at HEFA. There will be a small market for HEFA, because it has low availability, so it will never tip the scales towards sustainable aviation, but we can start using it now. We are also looking at fuel switching with e-methanol and e-ammonia. Those are all commodities that the industrial sector needs on a much bigger scale.

Mark Ruskell: Okay. Stuart, do you want to come in?

Professor Haszeldine: I basically agree with the argument that we should target hydrogen at the added-value products, whereby we make something with hydrogen and make more money as well as displacing carbon. I am not a real fan of building a hydrogen pipeline from here to Germany and selling the stuff as fast as we can make it, because we can use it to create much more value than we would get from selling it as a commodity. It is about choosing the places where we can make a sensible impact.

I am not a chemical engineer, but I assume that it is feasible to make that suite of products in project willow, and that seems a pretty sensible way forward. It is about trying to put us where we want to be in 10, 20 and 30 years' time by using hydrogen to create added value and to create cleaner products and cleaner versions of all the plastics and associated waste that we throw away. All of that should be a resource rather than a waste product, and hydrogen can help with that.

Mark Ruskell: Thank you. Hannah, do you want to come in?

Professor Chalmers: I do not have much to add. I agree with what you say. It seems that there is a good match between what is in the project willow proposal and where I would see the priority being at the moment.

Nic Braley: Everybody talks about the hydrogen ladder—how it fits in, where it goes and so on—but I think that individual projects in individual locations will choose the right option for themselves. In many cases, electrification may be a better option. In some cases, the delivery of hydrogen from a local source will be the best option. In all cases, we need to invest in what will be the best option for a particular location, to drive the economics and make it as investable as possible. There will be a patchwork of projects. In some projects in hard-to-abate sectors, there looks to be a strong case for hydrogen, but, depending on circumstances, that may not be the case.

Mark Ruskell: I do not know whether any of you has a view on the uncertainty around global markets for derivatives. Derivatives are quite easy to transport. Will we end up in the same situation that we are in with other sectors, whereby somebody comes in, undercuts us and takes the bottom out of the market that we were hoping for? Do any of you have views on the risks and

uncertainties? Professor Haszeldine, you suggested that we should not build a pipeline but should focus on manufacturing things. If we are in a global market, is there the certainty for us to do that?

Professor Haszeldine: We are in a global situation in which it looks as though shorter supply chains will be sensible in the future. If we are less dependent on importing fossil fuel ingredients to make blue hydrogen and we can generate our own green hydrogen, we will have autonomy and security. That is important.

There is a lot of conversation about making low-cost hydrogen from our wind power in Scotland, which I agree would cost much less than what we are potentially paying for green hydrogen just now. However, the vast solar panel arrays that could be built in China, in the Mediterranean parts of Africa and in Australia could produce hydrogen with electricity at a fraction of the cost that we are paying for our wind power. There is a risk that we will be undercut in some respects, but that depends on how effective the global shipping of hydrogen is, because there could be a big cost depending on how people choose to ship it.

11:45

You asked what we should direct our attention to. I will answer that question differently. There is a huge problem with storing energy. At the moment, we store energy by leaving the gas in the ground until we want it, and then we pull the gas out of the ground. In 20 years' time, we will not have the gas in the ground; we will have to make hydrogen and store it in the ground. For the first time in about 300 years, we will be dependent on what we can make locally rather than on exploiting a natural resource. That could be by far the biggest use for hydrogen, in my opinion. We will pay more than we do now, because we do not pay anything much for storage now, but in the future it could be an important part of our whole energy system.

Professor Maroto-Valer: On the issue of storage, we have not touched on the opportunities that hydrogen will bring us to balance the energy system, which we should maybe think about as well. That may be what you were referring to.

Professor Haszeldine: I am sorry to interrupt, but we have had two or three weeks of little wind. What will happen in 10 years' time, when we do not produce our own natural gas and we put limits on the running of our gas-fuelled power plants?

Professor Maroto-Valer: As we move to using all renewables, we will have to significantly—by orders of magnitude—oversize our renewable power to compensate for the difference between winter and summer. Even if we are able to do that, there will be times when the wind will not blow or the sun will not shine, and that is when hydrogen can buffer the energy system. It is important that we will use it not only as a vector, but also as a key element of storage.

Going back to Mark Ruskell's question about how global markets will operate, we can start thinking about carbon border adjustment mechanisms, but, alongside those, we will need global standards and certificates if we are going to export or import products on a low-carbon certificate that we do not have right now. A whole market has to be developed not only from taxes, finances and subsidies; we also need the whole standardisation of the market, which we do not have.

Douglas Lumsden: I would like to continue the discussion about the storage of hydrogen. Stuart, in your submission, you say that the storage of hydrogen is expensive and difficult. What do we need to do to get the cost down? What do we need to plan for the future?

Professor Haszeldine: There are several different methods of storage, which the previous witnesses would have talked to you about. It can be stored in pipelines, in lime caverns, in salt, in depleted gas fields or in giant gas tanks. For its use on a large scale, which is what I am talking about, effectively to power everything in the country for three weeks, it looks as though underground storage has by far the lowest economic cost. That means that we will need to create new salt caverns and try to reuse depleted gas fields. People have talked about the Rough gas field, but we want about 10 Rough gas fields, and we need about another 20 or 30 salt caverns. All of those will be offshore.

That capacity is being planned and worked on academically. The University of Edinburgh, University College London and so on have worked on that sort of thing, but there has been no Government consensus. It will take maybe four years to build one salt cavern, and we might want 20 if we go for a hydrogen system. We need to be thinking and planning ahead a lot more than we are doing. To be clear, none of that is in Scotland, which means that we have to be part of a UK network.

Douglas Lumsden: Do you have any estimate of the cost for that?

Professor Haszeldine: I knew you that would ask me that. I cannot remember it, but I can send it in.

Douglas Lumsden: Okay. That would be helpful.

Professor Haszeldine: It has been worked out. It has been calculated. It is an accessible cost, but

it requires a hydrogen business model for storage that spreads that cost among the users.

Douglas Lumsden: Okay. Looking at the cost of green hydrogen, a climate change report that was written on behalf of the Scottish Government says:

"It is more costly to produce hydrogen in Scotland as compared to all other case study countries. This is because the cost of offshore wind generated power in Scotland is higher than the other low carbon power technologies used."

The lowest cost was in France, where nuclear power was being used to produce hydrogen.

It goes back to the point that Mark Ruskell raised. How do we become competitive when we are looking at things like e-methanol and SAF as well? How do we become competitive when the cost to us of producing hydrogen is so high?

Professor Chalmers: In a UK context, blue hydrogen helps with the cost issue.

Douglas Lumsden: I am slightly confused why you would use blue hydrogen to make e-methanol. By my understanding, you break the hydrocarbon up to make blue hydrogen, take it to Grangemouth, for example, and then reintroduce CO_2 to remake it. To me, that does not make sense.

Professor Chalmers: There are an awful lot of steps in the process. I suppose that there are two parts to it. First, have you decided to go for hydrogen? Secondly, if you have decided to go for hydrogen, what is the most cost-effective and sensible way to do that? If you have decided to have hydrogen as a big part of your energy system, there is a good chance that having some blue hydrogen in the UK hydrogen supply mix will help your economics. Whether going big on hydrogen is a good idea is a separate question that we touched on earlier. There is a lot of push to use hydrogen quite carefully and for very specific things, for reasons such as you have just given.

Douglas Lumsden: Okay. Nic, I want to ask you about the Acorn project. It has track 2 status just now, but there is no funding agreement—is that correct? What do you need to take the project forward?

Nic Braley: Acorn is in track 2, and track 2 has been significantly delayed. We have been in discussions to secure some clarity around the funding timeline and process, which we really need. We recognise that the UK is in difficult fiscal circumstances, and we are delighted to see that the track 1 projects have made some good progress, but we need to see a clear timeline and process, and ultimately funding to support the Acorn project moving forward.

We understand that, when the energy secretary has spoken in Parliament, he has always referred to the comprehensive spending review as the point at which some further announcements will be made. We are hopeful that we will get some of the clarity that we need over the next few weeks, whenever the CSR is finally concluded.

Douglas Lumsden: In the meantime, is your work continuing? Are you still progressing the project as much as you possibly can?

Nic Braley: We are working on a reduced scale at the moment. We are continuing to work on one or two key commercial and technical aspects of the project for maturation. However, there is a significant risk that, without the required clarity, the private sector investors will not be able to continue to invest. The Acorn project is at a critical juncture right now and needs that certainty.

Douglas Lumsden: The Scottish Government has committed £80 million as well. What will that money be used for? Are there discussions about that?

Nic Braley: We were delighted to hear from the First Minister about the support of the Scottish Government. The release of that £80 million, though, is dependent on support being announced by the UK Government. Fundamentally, as we are establishing the CCS business in the UK, we need the underlying business model support that has been put in place for track 1 to be extended to the track 2 projects, and we are seeking clarity around that. The funding that the First Minister referred to is also tied to securing clarity from the UK Government around the long-term funding of Acorn.

Douglas Lumsden: Do you have any clarity about what that £80 million would be used for?

Nic Braley: Not yet. We have had discussions with both the UK Government and the Scottish Government about the programme of works for the next few years to continue to mature Acorn and to learn the lessons from the track 1 projects in order to bring the next phase of CCUS forward at a lower cost. Everybody wants to see that done successfully. Ideally, we will be looking to see how funds could be deployed over the next couple of years to deliver that, to move the project forward and to learn the lessons from track 1. However, right now, we need clarity from the UK Government around the intent on track 2, making the funding available and setting out the timetable and the process through which it will progress.

Douglas Lumsden: How much funding are you hoping for from the UK Government? What is the ask there?

Nic Braley: Ultimately, we are looking to secure a commitment that the business model support

that it has provided for track 1 will be extended to Acorn and Viking in track 2. The fundamental requirement is the long-term support programme, which runs right the way through the life of the project. Both track 1 projects were supported with an overall funding package including liabilities, and £21 billion was the overall cost. We are looking at how we can deliver track 2 with less support from the UK Government.

Professor Haszeldine: If I were the Scottish Government, I would be trying to change the narrative on that. The conversation that I heard in London last week around the comprehensive spending review was about where we are going to invest in jobs, growth and sustainability to make the UK a leader; it was not about how we are going to solve our climate problem any more. I wonder whether a sensible point to make is that investing in Acorn will create jobs and safeguard jobs for the future in project willow, so it will allow a much larger tonnage of CO_2 to be removed through Acorn for project willow.

Looking ahead, it is highly probable that the Mossmorran plants will also close imminently, because of the shortage of hydrocarbon, so our problem will get bigger in this part of Scotland. That creates a very different investment case for the Acorn style of project, which is that it will take away CO_2 from the new green industrial area and enable us to compete with probably 10 million tonnes a year, which the Viking project will offer. Compared to that, we are not competitive in investing in large amounts of CO_2 takeaway. So, I would change the argument.

Michael Matheson: I want to pick up on Nic Braley's point about delay in the track 2 process to date. It would be helpful to understand a bit more about the potential implications of that for the partners in Acorn. Exactly how much longer do you think that the partnership will remain together if there continue to be delays to the decision on providing the commercial support that is necessary for Acorn to be delivered?

12:00

Nic Braley: There are not only the Acorn partners; we have to look more widely through to the Scottish cluster, to all of the potential users of the Acorn transport and storage network.

We have a very clear vision about how we can deliver CCUS for Scotland in a way that will provide benefits through clean power and the decarbonisation of and support for industrial development in Scotland. I think that that is really important. We see Acorn as a critical project for Scotland that underpins a large portion of the economic future of its industrial base.

Unfortunately, Acorn has been subjected to extended delays, not just with track 2 but right the way through. There has been a 10 or 15-year history of trying to secure progress for CCS in Scotland. Many of the investors in Acorn and the Scottish cluster have invested significant sums over a very extended period. I think that there is a real risk that, without clarity around the next steps, those investors will not be able to continue to invest and so the project would be put on ice. It is really important right now that we get clarity from Government on the intention to move forward with Acorn.

Michael Matheson: If we fast forward to this time next year and no substantial progress has been made on track 2 status, do you think that the investors will remain engaged in the project, whether at the Acorn level or within the wider Scottish cluster?

Nic Braley: I think that all the Scottish cluster partners want Acorn to be a success. The question that they are struggling with is how they will continue to justify any further investment in development expenditure to continue to move the project forward. Some of the customer projects will be struggling to demonstrate to their boards that they have a viable project to move forward with on a timescale that is reasonable. Therefore, their boards may cease to want to invest and those projects may slip away.

From a T and S network perspective, investors are looking at opportunities around the world, and you will have seen that, as Professor Haszeldine said, CCS is progressing quickly in other jurisdictions. Some of the funds that would have been directed into the UK and Scotland may indeed seek investment opportunities elsewhere. Without clarity around the funding support and the timescale, it is very hard for any board to continue to invest devex at risk. That is just a reality, unfortunately.

Michael Matheson: Yes, which is perfectly understandable, given the cost involved in making investments. Do you have a view on how close we are to Acorn being put on ice?

Nic Braley: I think that we are at a critical junction right now. Looking back, we can see that all the statements have been around the importance of the CSR for clarity on track 2. We are looking to secure some statements in the CSR about the Government's intention to move forward with Acorn and the other track projects.

Michael Matheson: If that clarity is not provided, is it likely to be put on ice?

Nic Braley: We will have to see what is said. I do not know. I cannot speak, obviously, for my individual investors as to what their perspectives will be. There has been a huge amount of

commitment over a very long time and everybody wants to this to be a success. At the moment, I am planning on success for the project. However, without some clear steer from Government, it is very hard to stay on that trajectory.

Michael Matheson: Yes, the longer that there is uncertainty, the more difficult it is for boards to make a stop-go decision on any investment. If clarity is not provided, the project will eventually run into trouble.

The Convener: Thank you. We almost got involved in politics there for a moment—in fact, maybe we did.

Bob Doris will ask the next question.

Bob Doris: Good afternoon, everyone. You probably heard me put a similar question to the previous panel—you were coming in as Mr Lumsden and I were asking questions. It is about a national network of hydrogen pipes moving hydrogen around Scotland and the UK, and project union was mentioned. I asked the first panel about the hope that that will be in place by the mid-2030s but it will not all happen at the one time—it will be phased and prioritised for the benefit of Scotland, the Scottish economy and our net zero targets. How should that work be phased and prioritised in the Scottish context? It would be helpful to know that.

Nic Braley: I can speak about our thinking on Acorn. Right now, in the short term, we see blue hydrogen being developed at the Grangemouth site, with CO_2 being shipped offshore and stored safely for millennia. Blue hydrogen will fill that role.

There are some green hydrogen projects at Grangemouth, and the intention is that those green hydrogen molecules will be prioritised for use in green products. As we have said, going forward we increasingly see a green hydrogen world evolving. Ideally, we want to see low-cost green electrons available in Scotland, generating hydrogen, and for those then to be shipped down to Grangemouth to provide feedstock and fuel switching in the future. I see a phased programme of development.

Bob Doris: I do not see any other takers, so, without putting words in your mouth, I will just nudge you slightly on the connections and locations that should be prioritised as part of that project. I expect your clear answer to be, of course, the work around the Acorn project and the wider Grangemouth cluster, for the benefit of the Scottish economy. However, is there any other prioritisation in the Scottish context that you think should happen? You do not have to give an answer to that. It is just that we heard earlier on that, although it is hoped that we will do everything that is required to be done, the uncertainty about when it will happen, and the sequencing of how it will happen, is leading to some uncertainty for business investment. Investors want that certainty and to get back their investment; they want to know whether the structure will be there. Has that been your experience in talking with investors? Are there any other parts of Scotland where that network should be prioritised?

Nic Braley: All industrial investors seek certainty. That is what fundamentally underpins their ability to make investment choices. Innovation means that businesses are continuously looking to find ways in which to create effective business opportunities, and those opportunities will change over time. Acorn plays a critical role in helping to support the next stage of development of Grangemouth. It provides the evacuation route for CO_2, allows fuel switching and supports the development of the product suite.

We have a few energy-from-waste customers who wish to join in the network. They will be producing biogenic CO_2 as part of their waste stream, which could be an important feedstock for Grangemouth. Not only does that encourage the development of energy-from-waste processes around Scotland but it provides feedstock for Grangemouth.

There are multiple dimensions here. We need the network to start, which then provides certainty for emitters that their CO_2 can be evacuated and they can continue their existing businesses on a low-carbon basis. It provides a framework through which new businesses can be developed, developing the products of the future at Grangemouth. Providing the network basis is the right first step in providing confidence for business to move forward.

Bob Doris: I will turn to Professor Haszeldine. Do you want to add to that? I was going to ask you a separate question, but any reflection on that is welcome.

Professor Haszeldine: I will try adding to that and I am happy to take another question.

I will give a sort of trite answer: it is the low-hanging fruit and the no-regrets options for hydrogen, which could easily be feeding 20 per cent into the domestic gas grid. The domestic gas grid is allegedly rated for that already, so it requires very little modification. Then you have to decide where you will be producing your hydrogen. We talked earlier about whether you want to produce the hydrogen close to wind power or close to the users. The key question is: do you want to move molecules or electrons? I do not think that we have had a proper conversation—not here, but nationally—about that yet. Then we also have to solve the problem of storage of hydrogen

on the grid system and that conversation has not been started at all.

I go back to the very beginning of our evidence session. There are lots of interesting hydrogen projects in different towns, villages and cities dispersed around Scotland, but that does not seem to be giving us a foundation for a big decisive move forward on to what we actually want.

Bob Doris: There are lots of reasonable points in that. You made a comment about potentially exporting hydrogen, and you mentioned a pipeline to Germany. That is interesting, because David Amos, I think, who was on the first panel, took a different view. He spoke about a different pipeline that would cost about £2 billion. I see that Scottish Government research shows that, even if our hydrogen was sold at high prices compared with global prices, there could still be a market for that because the EU would not have enough hydrogen to meet its needs. We also heard earlier that there are lots of ways of driving down the price of hydrogen.

I think that it was Mr Amos who suggested that that would be a good-quality investment for future export opportunities. I think that he compared that pipeline to Germany with cables moving energy down the east coast to serve the north-east of England, which he said would cost £24 billion to complete. He questioned whether that was for consumption and use in England or whether wider infrastructure would be built up to use hydrogen for other things, such as they are hoping to do at the Grangemouth cluster. Indeed, he queried why we would not develop that capability in Scotland.

We are trying to get our heads around where that investment should go, why it should go there and whether that might compromise future potential Scottish jobs and growth, depending on what that the infrastructure looks like. Another witness, who we thought was an expert, took the converse view from yours about having a pipeline to Germany. Rather than my putting a specific question to you, I am keen to have your reflections on all that.

Professor Haszeldine: My reflections on that are that pipelines are definitely the most effective way of transporting large amounts of energy compared with electricity wires, which are less effective.

How many pipelines do we have in the ground? We have a polythene pipeline network in the inhabited areas of Scotland, hence my comment about that potentially being an easy target for selling hydrogen into that pipe network.

That is valued on the basis of what you would you get for making hydrogen and selling it. You are just valuing the calorific value—the heat value—of that hydrogen. I was positing that there might be smarter leverages to use hydrogen for making different plastics or sustainable aviation fuel—a suite of things where you can create a price premium. Instead of just selling the hydrogen for the heat that you can get out of it, you sell it for the chemical that you are making out of it. Those are all foundation chemicals, so they are not the highest-value pharmaceutical chemicals, but they still have more value than the raw hydrogen itself.

12:15

That is my point of view on trying to target those areas of greater value creation and also on trying to get greater skills creation in and around the Grangemouth and Mossmorran area so that we are investing in our workforce for the future. If we do not do that, in 10 years' time, we will have no Mossmorran and no Grangemouth. It would be completely deindustrialised of the big, heavy traditional industries.

I had another point of view, but I have temporarily forgotten it.

Bob Doris: I am sure that another member will let you come back in later. It is one of those issues on which another witness seemed to give a converse view, so I was trying to work out where we are with it.

Professor Haszeldine: All those things are true. It depends on which question you are answering. Again, I am not sure which question we are asking. Is the question, do we want lots of little hydrogen projects and not quite cottage industries but specialist bespoke manufacturing of hydrogen equipment? Is the question, do we want to go big time for hydrogenating our entire country, which is the opposite end of the spectrum? Both require different decisions on the pathway through those different things.

Bob Doris: I feel like we are almost having a hydrogen economy version of "Yes Minister", listening to all this. I am not an expert, and that is something that I need to get my head around and work out the best way forward, so I really appreciate that.

Mercedes Maroto-Valer, do you want to come in?

Professor Maroto-Valer: Fundamentally, like so many things, that is a business decision on whether you want to sell a product in large volumes with a low margin or you want to sell higher-value products that hopefully will have a higher margin. Obviously, when you make a decision like that and you go for the latter, you will have to transport the hydrogen. That will require significant investment in infrastructure that we do not have if you want to do that via pipelines. Then

you need to identify what your break-even point is and, beyond that, where you will be investing in infrastructure locally. You have to decide whether to sell less product of a higher value or simply go on volumes of hydrogen at the lower value, such as SAF or some of the e-methanols.

Bob Doris: That is helpful, because—

The Convener: I am really getting quite concerned, timewise.

Bob Doris: I have no more questions, convener.

The Convener: Perfect.

Bob Doris: That is helpful, because it ties in quite well with what Mr Amos said about how you get that high value and a bigger boost for your economy and everything else. Thank you.

The Convener: Douglas Lumsden has a question. You have to limit that to two of the witnesses.

Douglas Lumsden: I will limit it. We heard about pipelines earlier. How easy is it to repurpose pipelines from natural gas to hydrogen? We have had some conflicting views about that over the past couple of weeks. Does anyone have a view on that?

Professor Haszeldine: It depends on what the pipe is made of. Some steel is more compliant for hydrogen; cheaper sorts of steel are more compliant for methane. It also depends on how the pipe has been looked after during the 10 or 20 years that it has been operating. Have the pressure been changed lots of times? Has it been kept dry? Has it been cleaned out? It is all those things. Would you buy a used car from that company? How well has it looked after it, and is it designed properly?

Douglas Lumsden: It might not be an easy thing just to switch from natural gas to hydrogen on, let us say, the main pipeline between—

Professor Haszeldine: Well, there are trunk pipelines and there are distribution pipelines.

Douglas Lumsden: The trunk ones.

The Convener: I am sure that Scottish Gas Networks will come back and say that of course you would buy its pipes.

Nic Braley: I know that National Gas have done a huge amount of work on that, including a lot of testing work down at Spadeadam. I believe that it has some pretty positive conclusions about the use of the existing network for hydrogen. However, I am not an expert in that and National Gas is very well placed to answer that question.

The Convener: Douglas, can I make the suggestion? That might be outwith the technical competence of the panel of witnesses, which I am sure is very varied. We ought to write to SGN and find out how easy it would be to transport hydrogen. Would it use steel pipelines like the one that runs from Aberdeen to Inverness—I know about that because it comes through the farm—or would it use plastic ones?

We should ask it that, because it is clear that, if we move to hydrogen, we will have to transport it. It would be useful to know how easy it would be to do that. Are you happy with that?

Douglas Lumsden: Yes, absolutely, convener.

The Convener: On that basis, we have come to the end of the discussion. We are slightly over time, for which I apologise. Thank you all for coming today and for the two submissions that we had. I also thank Hannah Chalmers and Mercedes Marto-Valer for volunteering to answer the questions when they came up and for doing so with such clarity.

12:20

Meeting continued in private until 12:39.

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Email: official.report@parliament.scot
Telephone: 0131 348 5447

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