

SUPPLEMENTARY INFORMATION

Public understanding of net zero: Conflicted perceptions of different mitigation pathways between feasibility and desirability

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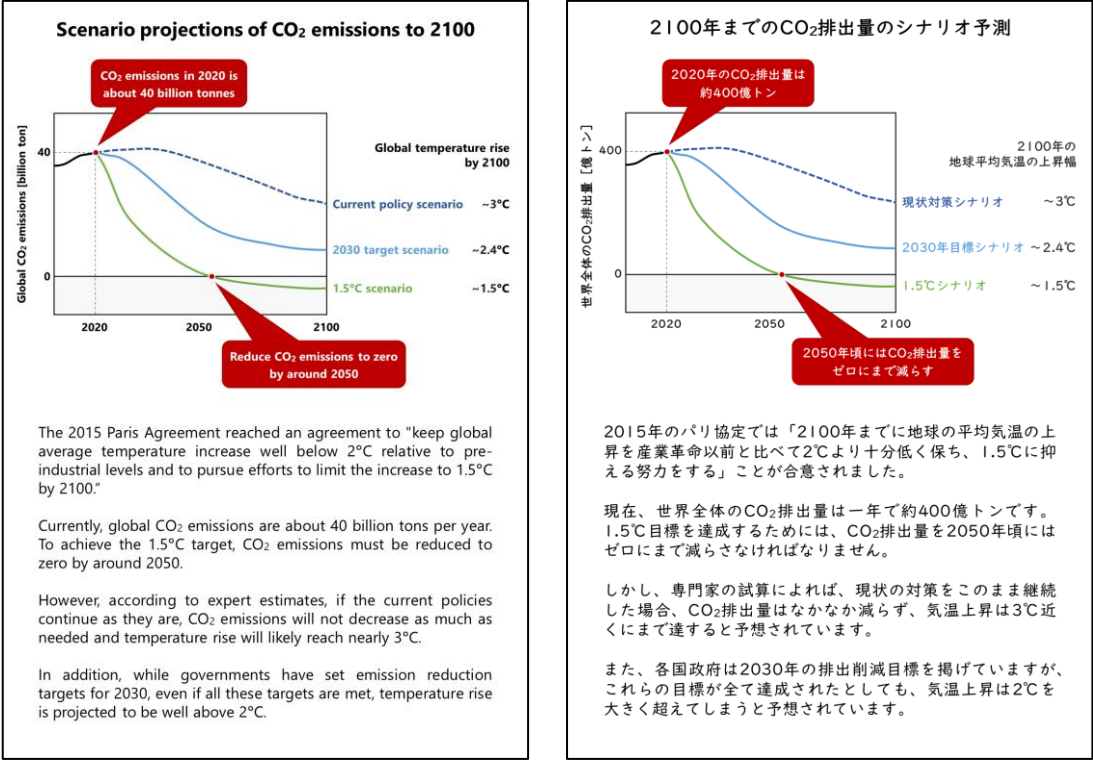
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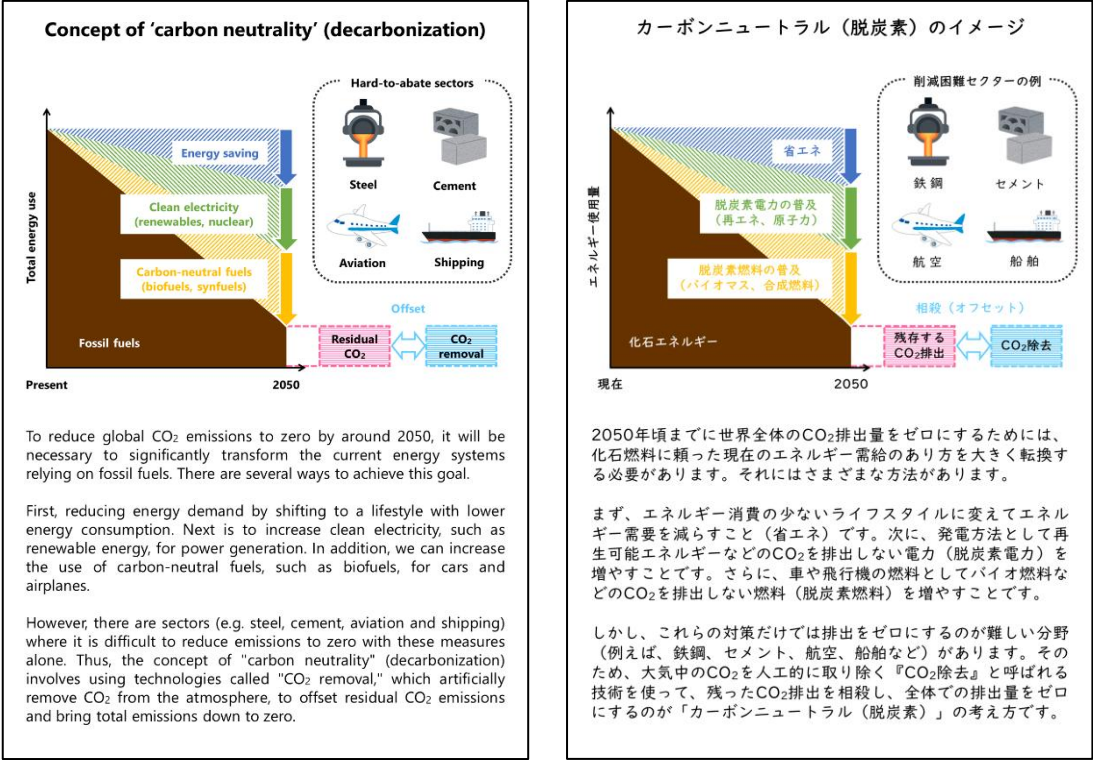
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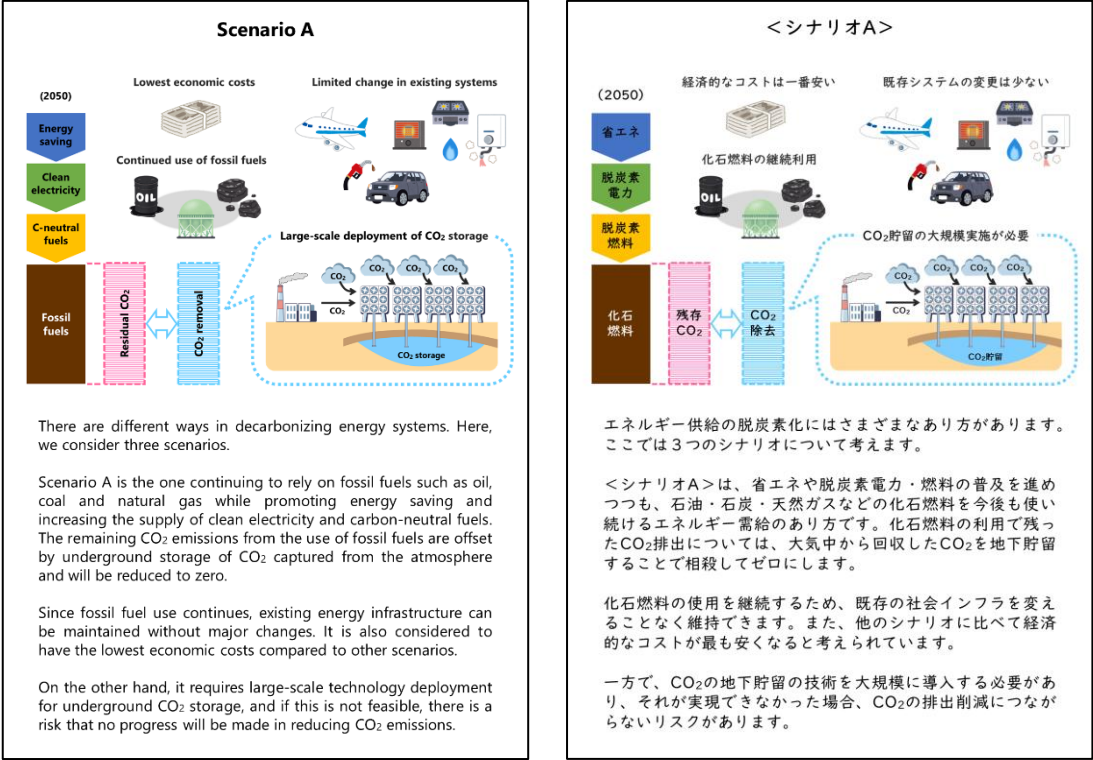
Supplementary Figure 1 Vignette to explain the emission pathway to achieve the net-zero target by mid-century (left: English translation, right: original in Japanese)



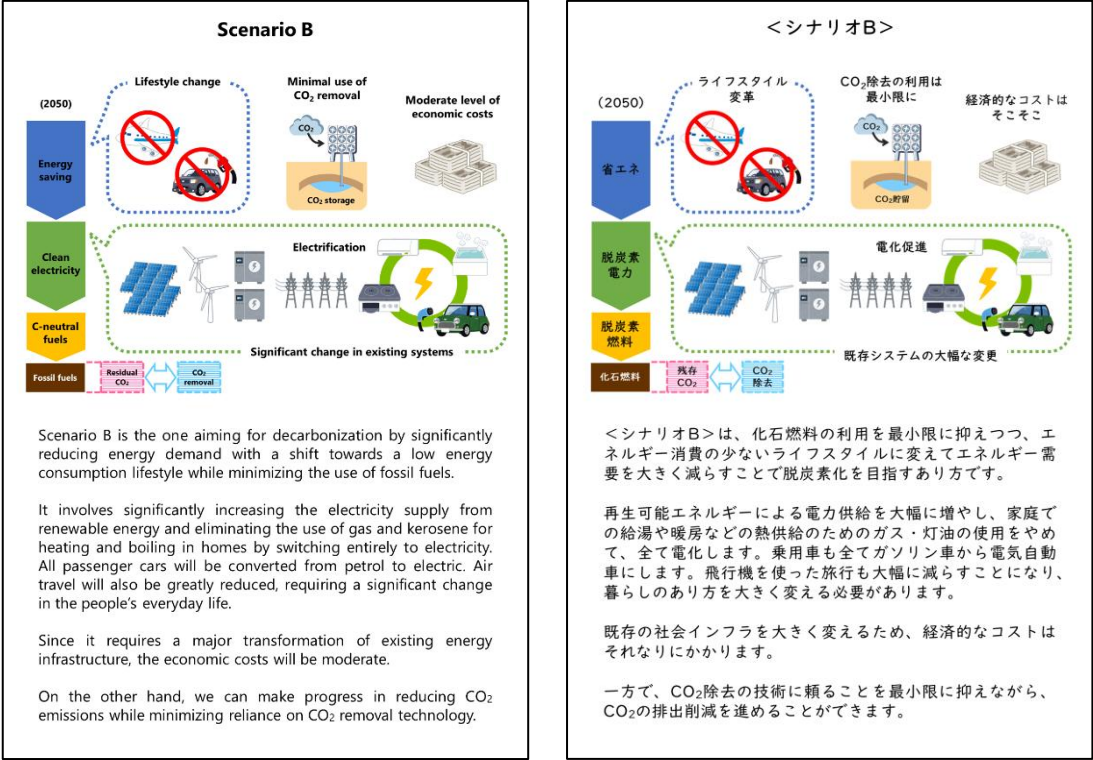
Supplementary Figure 2 Vignette to explain the basic idea of net-zero ('carbon neutrality') (left: English translation, right: original in Japanese)



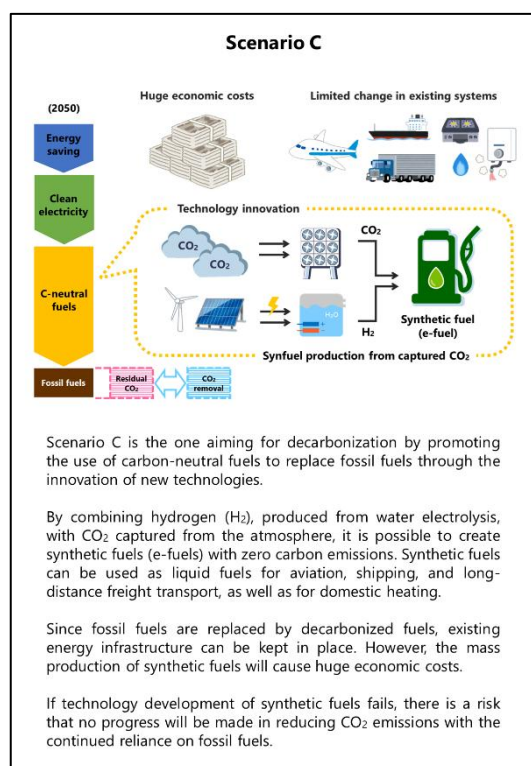
Supplementary Figure 3 Vignette to explain the basic narrative of CDR scenario (left: English translation, right: original in Japanese)



Supplementary Figure 4 Vignette to explain the basic narrative of LED scenario (left: English translation, right: original in Japanese)



Supplementary Figure 5 Vignette to explain the basic narrative of CCU scenario (left: English translation, right: original in Japanese)



Supplementary Table 1 General flow and interview guide of focus group

| Length | Task |
|--------|--|
| 5 min | Explain the research purpose and obtain consent to participation |
| 5 min | Short self-introduction and icebreaking |
| 20 min | Discuss general perceptions of climate change issues <ul style="list-style-type: none">• Ask their knowledge and attitudes about net-zero targets• Ask their awareness of the Paris Agreement and the IPCC• Ask their views on climate activists (e.g. Greta Thunberg) |
| 20 min | Discuss the attainability and necessity of the 2050 net-zero target <ul style="list-style-type: none">• Explain the emission pathway to achieve the net-zero target by 2050 [Suppl. Fig. 1]• Ask their perceptions of the attainability and necessity of the target |
| 50 min | Discuss the feasibility and desirability of three net-zero scenarios <ul style="list-style-type: none">• Explain the concept of net zero ('carbon neutrality') [Suppl. Fig. 2]• Introduce three net-zero scenarios [Suppl. Fig. 3-5]• Ask their perceptions of the feasibility and desirability of each scenario |
| 10 min | General discussions |
| 5 min | Q&A with a research team |

Supplementary Table 2 Exemplary quotes from focus group discussions on perceptions of the 2050 net-zero target

| Net zero is infeasible to be achieved by 2050 |
|--|
| <i>"Absolutely impossible! The US and China were not cooperative in the Kyoto Protocol. It seems impossible when only Japan tries its best."</i> (Group A, Participant 1) |
| <i>"As long as we are living, there are always CO₂ emissions. It seems impossible to reduce it to absolutely zero."</i> (Group B, Participant 6) |
| <i>"There is no way to take something that has been slowly rising and make it zero in just 30 years ... I don't mind setting a target, but it seems a bit too extreme and not very realistic."</i> (Group C, Participant 5) |
| <i>"I think it's impossible. It's 2022 now. It's difficult to achieve in such a short time."</i> (Group D, Participant 3) |
| <i>"I don't think we can achieve it ... The goal is set for 2050, so when we reach 2040, they'll assess the situation at that point and then push the target back to 2060 or 2070."</i> (Group E, Participant 1) |
| <i>"It seems impossible to achieve. The green line [1.5°C pathway] in this figure looks unnatural no matter how you look at it. There's no way it can drop so sharply. It's like you'd have to suck it up with a vacuum cleaner."</i> (Group E, Participant 2) |
| <i>"Even if Japan made it, it's probably not possible. The question is, who is going to convince China? Perhaps China will keep doing it until 2035, so emissions will keep rising ... It seems impossible to me."</i> (Group F, Participant 2) |
| <i>"In the end, no matter how hard Japan tries, when you look at the map, I can't help but feel like such a small country's efforts won't really matter."</i> (Group F, Participant 6) |
| Net zero is difficult to imagine it being achieved |
| <i>"The goal is too high. 2050 is still a long way off, so I can't picture at all how we would achieve it in that time."</i> (Group C, Participant 1) |
| <i>"It's a bit hard to imagine. Can you do that? Why? Because it's zero!"</i> (Group C, Participant 2) |
| <i>"It doesn't ring a bell. There is nothing specific about what needs to be done to reduce it to this level. Even if I'm told that we should do that, but how?"</i> (Group C, Participant 3) |
| <i>"I don't get it at all. It doesn't feel familiar to me ... It's like something on a global scale, too distant from my everyday life."</i> (Group C, Participant 6) |
| <i>"It's too big a theme. I wish it were easier to understand, like if I do it this way I can achieve these results."</i> (Group E, Participant 4) |
| <i>"By 2050, emissions will reach zero. After that, they will go negative. I've been wondering, what does it even mean for emissions to go negative? ... I can't understand how to make emissions fall below zero. Is there something that can do this, or is it really just an impossible task?"</i> (Group E, Participant 5) |
| Net zero is only a pretence of being achieved |

"I wonder if companies are just trying to appeal to the public. They care about their brand image, so probably they are doing such activities to keep that image. I guess that's a part of it." (Group A, Participant 2)

"I also think these things are just for the sake of political appeal. The results are not getting better, so they are not serious." (Group A, Participant 6)

"There are no concrete policies. They just say things like slogans, but it's not clear what kind of policy actions they are actually taking." (Group B, Participant 3)

"It feels like they're doing it for appearance, but in reality, it hasn't taken hold ... The government isn't doing anything, but there's a sentiment that they should do something, so perhaps they just say they will and it leaves everything up to the people." (Group F, Participant 5)

"I don't think they're really trying to achieve it because it's just an effort target set by the UN. There are no penalties or anything like that." (Group F, Participant 6)

It is necessary to have a net-zero target and aim to achieve it

"It's better to have a target." (Group B, Participant 5)

"We've already come this far. It's a bit like a gamble, but if we don't try what we can do, it's only going to get worse. So, I think we should do something big." (Group C, Participant 5)

"I can't hold onto optimism, but I think we must do what we can. If we don't, it will only get worse." (Group D, Participant 5)

"It's important to set some form of a target and to make an effort towards it, regardless of whether we can achieve it or not. Without that, it really has no meaning at all." (Group E, Participant 4)

"It's better to achieve it if you can." (Group F, Participant 4)

There is no need to achieve a net-zero target

"When I hear about carbon neutrality, I wonder what benefits it has for us. If specific benefits are shown to us, I might think, 'Well, maybe I'll give it a try.'" (Group A, Participant 5)

"If the 3°C rise goes up all at once, it's a different story, but if it goes up gradually, we will be able to cope with it with new technology. Personally, I don't think it's a good idea to set such a big target." (Group E, Participant 1)

"Personally, it doesn't really matter. As a matter of fact, I don't think we need to reduce CO₂." (Group F, Participant 2)

Supplementary Table 3 Exemplary quotes from focus group discussions on perceptions of CDR scenario

| CDR scenario is most feasible because of low economic cost |
|--|
| <p><i>"The impact on economic activity is too big for both [LED] and [CCU scenarios]. If we go with [CDR scenario], the costs are lower and we don't have to change our current lifestyle, so it seems like we can keep developing civilization as it is."</i> (Group A, Participant 2)</p> <p><i>"There would definitely be a lot of pushbacks against [LED] and [CCU scenarios]. [CDR scenario] would be the best option ... As a sales pitch, I can say that the cost is cheaper than others if I'm in a position to have a say."</i> (Group A, Participant 4)</p> <p><i>"It's because of the lower cost ... I think we have to consider ways to reduce costs at this point on the planet now."</i> (Group B, Participant 4)</p> <p><i>"I think [CDR scenario] is the most feasible option ... Since it doesn't require a significant change in lifestyle or impose a high economic cost, I feel like it's most realistic."</i> (Group E, Participant 4)</p> <p><i>"Because it's the cheapest option. We can't meet 1.5 unless we all align globally ... If you do it in your own country, you go first with the least economic burden."</i> (Group E, Participant 5)</p> <p><i>"By the process of elimination ... [CDR scenario] doesn't cost that much, so if we add nuclear power, maybe it will work out."</i> (Group F, Participant 6)</p> |
| CDR scenario is undesirable due to concerns over CCS safety or capacity |
| <p><i>"I've heard about CO₂ storage for the first time. I'm concerned about whether it will have some impacts on underground ecosystems."</i> (Group A, Participant 1)</p> <p><i>"Japan is a disaster-prone country. If we were to have underground storage, we don't know what might happen with earthquakes or tsunamis. There are also land issues."</i> (Group A, Participant 3)</p> <p><i>"Even if we can store CO₂ underground, the land area is finite. How long can it be stored? Just like the contaminated water from [Fukushima nuclear power plants], the number of tanks will probably increase. Then what happens when it comes to the point where it's said we can't build here?"</i> (Group B, Participant 3)</p> <p><i>"Nuclear waste is stored in tanks, but in the end, only storing it in tanks doesn't solve anything, so it ends up being discharged into the ocean. This then causes marine pollution, so I'm a bit concerned that there is nothing good."</i> (Group C, Participant 3)</p> <p><i>"The risk is high. There is no proof of what kind of impact underground storage will have and how it affects the environment. If it leads to other issues, that would be a problem."</i> (Group D, Participant 5)</p> <p><i>"I thought this might be difficult. There's no land available for storage, and it might cause issues with the local residents too."</i> (Group D, Participant 6)</p> <p><i>"CO₂ storage, to some extent, involves creating something unnatural, putting into a situation that goes against nature."</i> (Group F, Participant 3)</p> |
| CDR scenario is undesirable because CCS is a false solution |

"After all, it's just storing CO₂, not eliminating it. It's just not on the ground. I wonder if this is really solving the problem. There are also worries like what happens when there's no more space to store or is this going to end up emitting again?" (Group C, Participant 3)

"It feels like CO₂ storage is only a temporary solution. As the storage capacity is limited, we'll eventually have to face a problem." (Group C, Participant 4)

"If we can avoid doing [CO₂ storage], that would be best. It's simply leaving the waste for future generations of our children. And we don't even care about eliminating it." (Group D, Participant 1)

"It's not like they're cheating to achieve the target, but it feels like something is off ... It would be good if CO₂ could be reused for something to reduce it, but there's eventually going to be a limit to how much can be stored. So, I don't think it's a very good solution." (Group E, Participant 1)

"If it's only for hitting the number, I think this could work. But the point is whether that's a fundamental solution ... If we find ourselves in a situation where we just have to hit the number at some point, this could be a viable option, so I don't deny it. But, we shouldn't fool ourselves into thinking that everything is fine by this alone." (Group E, Participant 2)

"Storage is fine, but can this really be done on such a large scale to achieve the target? ... The amount of storage will keep increasing since emissions won't decrease at the source. I'm a bit sceptical about whether this system is sustainable ... It feels like we're just moving it from one place to another." (Group E, Participant 2)

"It feels more like postponing the problem rather than seeing any dramatic change." (Group E, Participant 4)

"Since CO₂ in the air is just being stored, it's like putting clutter from a messy room into a closet and closing the door—nothing really changes." (Group E, Participant 6)

Supplementary Table 4 Exemplary quotes from focus group discussions on perceptions of LED scenario

LED scenario is most feasible because electrification is already underway

"Even now, electrification is being gradually promoted. This is a hopeful outlook ... but if we tighten things up little by little, we can do it by 2050. It feels like we're already moving in this direction." (Group A, Participant 6)

"I think now you can't use gas at high-rise apartment buildings. They should have only electricity options. As a matter of fact, it will gradually lean more towards electrification ... This would be the easiest way to go forward." (Group B, Participant 2)

"Nowadays there are quite a few all-electric homes, so this is the most feasible option. It also said that the costs are moderate. It looks like a middle-ground option compared to others, so it's most likely to be done." (Group B, Participant 6)

"I put [LED scenario] in the first place because this could be done simply by doing what we can do now without relying on future technology development." (Group D, Participant 1)

"Because it's covered by existing technology. Basically, this is just a matter of people's will. In terms of infrastructure, [LED scenario] says that everything can be managed with today's technology. So, when it comes to decarbonization, it feels like 'This can work!'" (Group E, Participant 6)

LED scenario is most feasible because changing lifestyle is possible

"Our lifestyle was changed forcibly before and after COVID, like wearing masks or staying home. So, if it's enforced, people will probably do it. I can do it." (Group D, Participant 1)

"Changing our lifestyle to reduce our energy use will have a direct impact on our everyday life. But I feel like it's doable since there are things we're already doing now, like, travelling by train instead of flying or using public transport instead of a car. Of course, there are pros and cons too." (Group D, Participant 6)

"Since we're talking about 2050, it's more about how younger generations can change their lifestyle, and that seems possible ... With the internet, you can watch movies or anything. Meetings can be done online too ... Sometimes you want to travel by plane, but that could be also done virtually without having to travel so much. I guess things can and will change." (Group F, Participant 2)

LED scenario is infeasible because changing lifestyle is hard

"To what extent do we have to change our lifestyle? Telling people not to fly, that's too much ... It seems quite hard to make it in terms of feasibility." (Group B, Participant 3)

"It seems a bit unrealistic. Things like no flying, no gasoline — I kind of feel there are many things without that society won't function well." (Group C, Participant 5)

"You can get rid of cars in the city, but for people in rural areas, their lives depend on owning a car ... (What if they were electric cars?) Well, if everyone switched to electric cars at once, would there be enough parking space for all of them?" (Group C, Participant 6)

"If we were going to do this globally, some countries would likely be against it, making it difficult to achieve. Some people like flying; for them, it would be frustrating and take away

some of the pleasures of life. It's difficult to force people to sacrifice for the sake of the environment." (Group D, Participant 3)

"Since we are talking about changing the existing system, there will be people who suffer disadvantages as a result of those changes. If we are told not to fly, what will happen to the airlines? That will create a lot of friction, so from this perspective, I think it's quite hard." (Group E, Participant 4)

"I think it might be possible in countries like China or North Korea, somewhere with a one-party dictatorship, but in a country like Japan, it would be quite difficult. (It's a bit challenging for democracy.) Exactly." (Group F, Participant 3)

LED scenario is undesirable because of too much restriction on individual life

"I feel resistant to the idea of such a major lifestyle change, so I'm not in favour of this." (Group A, Participant 3)

"The biggest issue is that there is a strong backlash against lifestyle change, and I personally don't like it either." (Group A, Participant 4)

"I wonder if we can really change our lifestyle. Can we just give up things we've grown so accustomed to? For me, flying is the sticking point—I want to get on a plane ... Travelling far by train is tough and takes a lot of time, so the idea of no air travel is a deal-breaker." (Group C, Participant 3)

"It feels like closing the country off, with things like no flying ... If it reaches that point, it feels like we'd be returning to an agrarian society, and I think that would be tough." (Group D, Participant 4)

"I think it's good for the planet, but it's hard to go all-electric and rely only on electricity ... It seems like taking the highest toll on individual life, so I personally don't like it." (Group D, Participant 5)

"I don't want my lifestyle to be restricted in the first place." (Group E, Participant 5)

"I think everything would work out if we were told to live like the Amish, but it's probably not doable for Japanese people." (Group E, Participant 6)

Supplementary Table 5 Exemplary quotes from focus group discussions on perceptions of CCU scenario

CCU scenario is infeasible due to high economic cost

"If it costs a lot, it will likely have an economic impact on our lives to recover that cost. Then I want to avoid anything with extremely high costs." (Group A, Participant 3)

"If we do something that costs a lot, like [CCU scenario], taxes might go up again, causing inconvenience for everyone in their daily lives." (Group C, Participant 2)

"There are things that we don't know if we actually can or can't do ... When thinking about economic costs, Japan doesn't have much money, and I don't think we can afford such high costs." (Group C, Participant 5)

"It would cost the most, and if it couldn't work out, the price to pay would be significant." (Group D, Participant 3)

"If we consider this only in Japan, the cost will be enormous. For example, using synthetic fuels made from hydrogen and CO₂ for cars means an incredibly high cost per vehicle ... The expense would be incomparable. Frankly, it would be difficult to do it from a cost perspective." (Group F, Participant 3)

CCU scenario is infeasible because technology is still under development

"Frankly, betting on one technology for innovation is a gamble. I'm really worried that if it doesn't work out, the whole project might flop ... It's better to try out different options in parallel." (Group A, Participant 4)

"When it comes to this kind of technical stuff, there would be a big hurdle to first establish it as a viable technology and then implement it for practical application. At present, I feel the chances are slim." (Group A, Participant 6)

"I'm really sceptical if someone actually said that they are going to make synthetic fuels ... I'm very doubtful whether it's even possible or it can be a real alternative. So, the risk seems very high." (Group B, Participant 2)

CCU scenario is most desirable because of optimism for tech-innovation

"It's the taxpayers' money, so I want to put it all into the development of promising, visionary technology." (Group D, Participant 1)

"I have high hopes for synthetic fuels. If this works out, it would be great." (Group D, Participant 6)

"Technology has a bit of a chicken-and-egg situation. When you think, 'This is how it should be done or what we want to do,' there are quite a few things that become possible ... In that sense, I have high expectations for [CCU scenario]." (Group E, Participant 2)

"I think it would be ideal if we could invest more money in developing groundbreaking technology of some kind." (Group E, Participant 4)

"With some wishful thinking, it would be good if we can harness technology to produce synthetic fuels and reduce CO₂." (Group F, Participant 4)

"We've gone through many technological innovations, like what was a horse before has now become a car. I believe that if we all come together and share ideas, we can solve this problem as well." (Group F, Participant 6)

CCU scenario is most desirable because of least intrusive solution

"I think it is most desirable to achieve decarbonization without changing our current lifestyle." (Group C, Participant 2)

"I think this is the best option where no one has to feel unhappy ... The more people who are negatively affected, the more dissatisfaction builds up ... [CCU scenario] seems like the option where no one gets the short end of the stick." (Group D, Participant 2)

"There are people from all walks of life. If we can make it work with new technology, not forcing people to make sacrifices, then [CCU scenario] would be the best option." (Group D, Participant 5)

"Because this means reusing CO₂ instead of storing it ... It replaces fossil fuels, so there's no more uncertainty about relying on something that may not last forever." (Group D, Participant 5)

CCU scenario is most desirable but infeasible due to high economic cost

"[CCU scenario] is my favourite. In terms of feasibility, it's [CDR scenario] ... because of the costs ... When comparing all three, [CCU] has no downsides." (Group B, Participant 1)

"Because there's a risk if the development of synthetic fuels doesn't go well, and it also costs a lot of money, I choose [CDR scenario as most infeasible]. But ideally, I would prefer [CCU scenario]." (Group B, Participant 5)

"The biggest difference is definitely the cost. If it is too high, it will take more time to implement everything ... In the future, I think [CCU scenario] would be the best since it doesn't involve [CO₂] storage." (Group C, Participant 3)

"If money weren't a concern, I feel like [CCU scenario] would be the best option." (Group C, Participant 5)

"For me personally, [CCU scenario] is most pleasing and gratifying, but this is doable only for developed countries. I don't think developing countries would be able to keep up at the same pace. So, if it's just for Japan, [CCU] would be ideal, but on a global scale, we would need to change our view ... Yet, this is my favourite." (Group E, Participant 6)

"I'm personally in favour of [CCU scenario], but when you think about the time of 2050, it's not feasible. It seems difficult to make it only in Japan. On a global scale, some people want to make money out of this, so I think they will take on the challenge." (Group F, Participant 2)

Supplementary Table 6 Participant's choice of the most feasible and the most desirable scenario in each focus group

| | Most <i>feasible</i> scenario | | | Most <i>desirable</i> scenario | | |
|---------|--------------------------------------|------------|------------|---------------------------------------|------------|------------|
| | CDR | LED | CCU | CDR | LED | CCU |
| Group A | 5 | 1 | 0 | 1 | 0 | 5 |
| Group B | 3 | 3 | 0 | 1 | 3 | 2 |
| Group C | 2 | 3 | 1 | 0 | 0 | 6 |
| Group D | 3 | 2 | 1 | 0 | 0 | 6 |
| Group E | 3 | 2 | 1 | 1 | 0 | 5 |
| Group F | 2 | 2 | 2 | 0 | 1 | 5 |
| Total | 18 | 13 | 5 | 3 | 4 | 29 |

Supplementary Table 7 Change of participant's choice from the most feasible to the most desirable scenario

| Change from <i>feasible</i> to <i>desirable</i> | Number |
|---|--------|
| CDR → CDR | 2 |
| CDR → LED | 0 |
| CDR → CCU | 16 |
| LED → CDR | 1 |
| LED → LED | 3 |
| LED → CCU | 9 |
| CCU → CDR | 0 |
| CCU → LED | 1 |
| CCU → CCU | 4 |