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Citation for published version (APA):
de Coninck, H. C. (2022). *System change, not climate change*. Technische Universiteit Eindhoven.

Document status and date:
Published: 09/09/2022

Document Version:
Publisher's PDF, also known as Version of Record (includes final page, issue and volume numbers)

Please check the document version of this publication:

• A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
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Prof.dr. Heleen de Coninck
September 9, 2022

INAUGURAL LECTURE

System change, not climate change

TU/e
EINDHOVEN UNIVERSITY OF TECHNOLOGY

DEPARTMENT OF INDUSTRIAL ENGINEERING & INNOVATION SCIENCES

PROF.DR. HELEEN DE CONINCK

System change, not climate change

Presented on September 9, 2022
at Eindhoven University of Technology

Introduction

"System change, not climate change". I have climate change activists to thank for the title of this lecture. It is on banners carried around by people who took part in the demonstrations that erupted from 2018 onwards all over the world. I am not completely sure what they meant with it. System change means different things to different people. Some mean changing capitalism, others patriarchy, neo-liberalism or representative democracy, or a combination. Some may not be able to express exactly what it means, and just want to express that something big and pervasive must change. And probably the latter is also roughly what it means in the context of the academic literature on systems transitions, transformative change, etc.

Figure 1. Source: Michael715/Shutterstock

I started my environmental career as an activist. When I was eleven or twelve years old, I was very worried about acid rain. I did not take to the streets, but wrote to the newly formed Ministry for the Environment asking for flyers on the topic, cut out

photographs, took my parents' typewriter, and summarized the contents in short newspapers for any neighbours who were willing to pay for the copying costs. So sort of like an IPCC report avant-la-lettre. (Coincidentally, it was about the time that the IPCC First Assessment Report was being written.) The main differences were that it was not based on peer-reviewed literature, not reviewed by thousands of experts and governments, and they were quite policy-prescriptive. I recommended people to separate waste, buy organic products, and buy a car with a catalyst to reduce sulphur dioxide emissions. At the high point, I had about 10 subscribers, I think.

Fast forward 30 years. Amsterdam, March 2019. Friends of the Earth Netherlands along with many other organisations organized a Climate March. It was cold, it poured the entire day. Despite this, 35.000 people of all ages and backgrounds, from all over the country, made it to the Dam Square. I was there, but officially not as a climate protester: I gave a seven-minute "mini-lecture" on the IPCC Special Report on 1.5°C[1], which had appeared half a year earlier.

Figure 2. 2019 Amsterdam climate march https://twitter.com/milieudefensie/status/1104741017562042368

[1] IPCC (2018). Global Warming of 1.5°C: IPCC Special Report on Impacts of Global Warming of 1.5°C above Pre-industrial Levels in Context of Strengthening Response to Climate Change, Sustainable Development, and Efforts to Eradicate Poverty. Cambridge: Cambridge University Press. doi:10.1017/9781009157940

So what did this SR1.5 teach us that it was compelling enough for the Dam Square? Remember, it came out now almost 4 years ago. It was written in response to a request from the countries signing the Paris Agreement of 2015, who wanted to learn more about the difference between 1.5 and 2 degrees of global warming. The Paris Agreement states that all countries should collectively limit global warming to "well below 2°C" and strive to limit warming to 1.5°C. But what would be the difference? Is it still possible to limit warming to 1.5°C? Or is the price too high?

The conclusions were very clear, and some of them shook me up quite a bit. Especially those from the chapter in which I was not involved, on impacts of climate change. Most conclusions were confirmed in the most recent series of reports by the IPCC, the Sixth Assessment Report[2], although some had to be changed.

One of those key messages is that we can still limit warming to 1.5°C. But if we continue on the same path, we will exceed it around 2030. Actually, the 1.5°C report still said 2040, but it is looking worse based on better analysis and the most recent developments.

A second key message is that there are clear benefits to limiting warming to 1.5°C. In laymen's terms: We would be short-sighted fools if we would not try really, really hard to limit warming as much as possible. A couple of examples of the impacts.

[2] IPCC, 2022: Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [P.R. Shukla, J. Skea, R. Slade, A. Al Khourdajie, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, J. Malley, (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA. doi: 10.1017/9781009157926

Figure 3. Coral reef

Figure 4. Sea level rise affects infrastructure

At 2°C of warming, we will lose practically all the world's coral reefs. At 1.5°C, about a quarter might still be left. One of the largest and most important marine ecosystems will disappear almost completely. This does not only affect fish and corals. It also has consequences for people relying on these ecosystems: for food, for income, for tourism. With the corals, cultures will disappear.

At 1.5°C, global average sea level rise will be about 10 cm less in 2100 compared with 2°C, though this difference becomes much bigger over the centuries after, and regionally this number varies. But the bigger difference is in the longer run: the 'equilibrium' sea level (if there is such a thing) for half a degree warming more is over one meter higher. The tipping point of irreversible melt of polar land ice might be between 1.5°C and just over 2°C. If that point is crossed – and we don't know exactly where this is – sea level would rise more quickly and we would be looking at potentially even multiple meters. The consequences for low-lying areas are strong. 1.5°C will give coastal regions more time to adapt than 2°C.
What that means is that a lot of human and ecological suffering can be prevented.

Figure 5. Extreme weather, such as drought, kills cattle and with that livelihoods of people.

Droughts, floods, hurricanes, heat waves are all projected to worsen significantly beyond current levels. More insects, birds, fish and mammals would lose suitable ecosystems. More areas will be uninhabitable for humans. At 2°C, hundreds of millions of people more may be at risk of poverty already in 2050 compared to 1.5°C. This is mainly because of extreme weather. Because of great efforts of early warning and better disaster response, people's lives are often saved during stronger hurricanes or floods, but such events, and also droughts or heat waves, do tend to rob people of their livelihoods: their cattle or their harvest.

Even the IPCC, which tends to shy away from judgments, concluded after all this: there are clear benefits to limiting warming to 1.5°C. Or, as the BBC put it after the SR1.5 was released: "Scientists politely urge: Act now, idiots!".

Figure 6. BBC Science News tweet after IPCC SR1.5 release (October 2018)

So, what does this action look like? The conclusion was, also upheld after the AR6 of last April, that we can still limit warming to 1.5°C, but this requires deep and immediate emission reductions all over the world. For this, as you can see here, global greenhouse gas emissions need to peak in the next couple of years, and CO_2 emissions need to be halved by 2030, be net zero by 2050, and go net negative thereafter, meaning we would remove large amounts of CO_2 from the atmosphere.

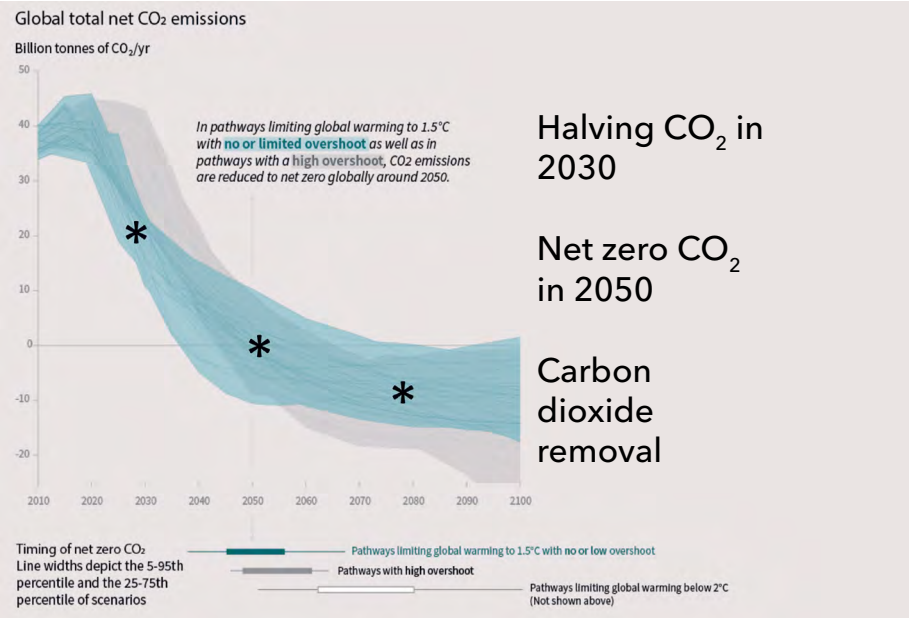

Figure 7. CO_2 emission reduction pathways in the IPCC SR1.5.

This can still be done, but it is no easy feat. We are currently not on track, and the window is closing. Emissions have to drop by almost 10 percent per year, globally. This includes countries that have large populations under the poverty line, but we should not count with these people to help achieve the fast emission reductions needed: those need to come from the high consumers, the high emitters, who bear a greater responsibility, both historical and current. The poor of the world need to start using modern energy, consume more and more nutritious food, and get access to medical care – all things that, in our current systems, lead to greater greenhouse gas emissions. Fortunately, the IPCC AR6 concluded that eradicating extreme poverty "can be achieved without significant global emission growth". That these people are also the ones who are most likely to bear the consequences of climate change, makes it even more pertinent that their needs are met, as this will also reduce vulnerability and increase their capacity to adapt to climate change.

If we translate these global numbers to the Netherlands, we need to up our pace. Fortunately, we will soon have a renewed climate law that will follow the European Climate Law prescribing climate neutrality in 2050 for the European Union.

Climate neutrality is generally seen as a balance of greenhouse gas sources and sinks. As sinks of greenhouse gases are mainly CO_2, and we need these sinks to counterbalance the remaining positive emissions, this means that we will have to reach CO_2-neutrality in the EU – and in the Netherlands – well before 2050. Maybe even as early as 2040, as Bernard ter Haar, the chair of an expert team on the 2050 Dutch energy system, recently said[3]. This means net zero CO_2 emissions in the Netherlands within the next twenty years.

It is becoming increasingly clear that we will not get there by implementing a list of technologies or a list of discrete policy measures. These are all necessary, but more is needed. The changes need to go deeper, and more than our technological set-up needs to change. Climate neutrality rather than halving emissions needs to become the criterion. Policy instruments need to aim beyond 2030 towards net-zero CO_2.

Something big and pervasive needs to change.

System change to avoid climate change.

[3] Interview in Energeia, 15 August 2022

Systems transitions

The rest of this lecture will be on what these "systems transitions" as we call them in the IPCC reports, mean, how they can be brought about, and what the challenges are to do this in a just manner. I will close with my research agenda and some personal reflections.

So, what are the system changes (according to the climate protesters), system transitions (according to the Special Report on 1.5 degrees) or system transformations (according to the Sixth Assessment Report)?[4] For this, I take inspiration from many scholars and researchers who have worked on transition studies and transformational change.[5] My interpretation is that multiple attributes of society need to change at the same time.

If we take the electricity system as an example: it is currently fairly uncontroversial that a change to a largely renewable electricity system is the way to go. We also know that this means more variable and land-intensive technologies, in particular wind and solar energy. We are by now – especially in the Netherlands – also feeling the consequences for the grid. New solar parks cannot be connected anymore in some areas as the grid operators cannot guarantee grid stability. But there is more than just technology and infrastructure. A renewable electricity system means that households, people and neighbourhoods are becoming producers as well as consumers of electricity. Also, they will be confronted more with the spatial needs of renewables. This changes the relationship of people with energy; their energy awareness grows. Business models for companies change; electricity companies are reinventing themselves as we speak. It changes the role of financial sector players, and how loans are given for electricity projects. Financial analysts are still grappling with this. It changes international trade flows and dependencies on materials, and with that on countries. It changes the way the government regulates electricity systems, it requires changing laws, even multiple times as the system transition unfolds. All this will come at a cost to some, and with benefits to others, making it also a political issue. Vested interests will resist the changes, and will use every trick in the book to slow things down and make the transition look like a bad

[4] Although there are academic debates about the difference between change, transitions and transformations, I will stay out of this in this lecture.

[5] There are too many names to list here, but I learned a lot from reading work by Lundvall, North, Geels, Bergek, Grin, Loorbach and Wieczorek.

idea. People, and politicians, are sensitive to such pressures, as we generally don't like change, especially if we already feel vulnerable, if we have difficulties making ends meet or if we feel overwhelmed by other big issues, such as a war nearby, or by a digitalizing world which some elderly people may have difficulty keeping up with.

It sounds like I'm getting distracted, but all this begs the question of what we actually mean by a system. Engineers often define a system as its technological parts. In electricity, we would include the grid infrastructure, transformation stations, etcetera. Social scientists, including many of my colleagues at the Technology, Innovation and Society group here at Eindhoven University of Technology, include things like social norms and institutional aspects. I am of that school: when I speak about systems transitions, assume that I cast the net quite widely when I say that something is "systemic".

Such system transitions can go quite quickly or be stalled for decades, but in any case, they will take time. And in the meantime, climate change is unfolding. The hard reality is that our countries will never be the same again. The Netherlands of harsh winters with ice-skating and cool summers with long rainy days is not coming back. We need to change in order to limit change, and we need to change in order to be able to deal with those changes. Emission reduction and climate change adaptation need to happen at the same time. Adaptation and mitigation used to be separate worlds, but we cannot afford to do adaptation anymore that is not reducing emissions, just as mitigation from now on needs to also increase resilience. And we need to take into account other dynamic changes too: socio-technical developments around digitalization, around planetary boundaries other than climate change (nitrogen is particularly prominent in the Netherlands at the moment) and societal needs such as a reliable government and appropriate housing. Systems transitions, also in the SR1.5, cover both adaptation and mitigation.

So in my example of a system transition in electricity, we should add that this electricity system will need to be resilient in a potentially fast changing climate – significantly higher temperature extremes, changing river run-off levels which are already affecting hydroelectricity and cooling water for nuclear energy. And it has to deal with developments such as digitalization, which offers opportunities in energy efficiency through for instance smart grids, but also threats through steep increases in electricity use for data. Data are practically free, despite the externalities and exponential increase of their use.

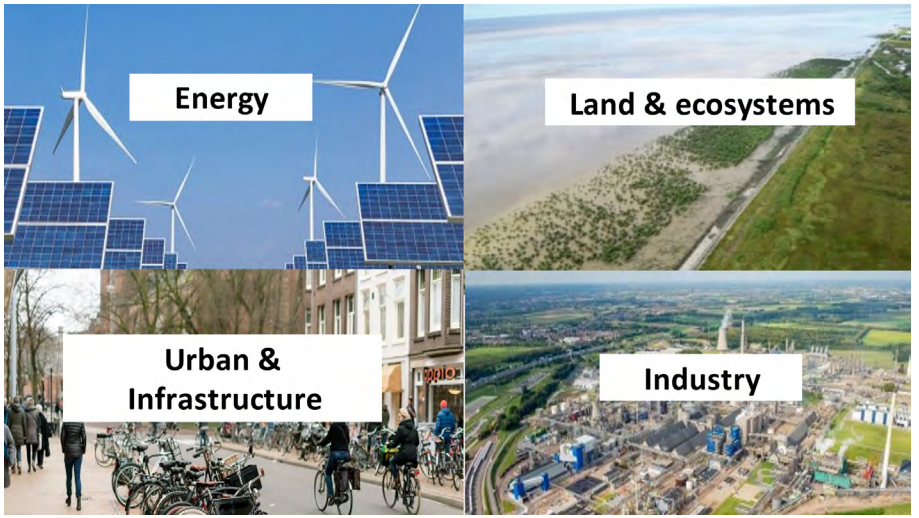

Figure 8. The four systems transitions in the IPCC SR1.5

In the SR1.5, we introduced four systems transitions for mitigation and adaptation in line with limiting warming to 1.5°C: the energy system transition, the land and ecosystem transition, the urban and infrastructure system transition and the industrial system transition. Feedback on these four systems transitions has included that they encourage 'sectoral thinking' and that broader, or 'deep', transitions, changing meta-rules[6] are actually relevant. This is very true: these systems are interlinked and depend on each other, forming a larger system of itself. But at the same time, speaking about land, about buildings, about industry makes what is needed more concrete and tangible. So for now, I will stick to systems transitions.

I already introduced why the energy system transition is systemic. As another example, in the urban and infrastructure transition, in order to have resilient, climate-neutral and healthy cities, we need to change transport systems, buildings, water provision and use, and waste management. In mobility, if we view it from an engineering perspective, replacing internal combustion vehicles with electric vehicles, and changing the fueling stations with charging infrastructure is enough. However, private cars demand huge material resources, they are not energy efficient, and they clog up the streets. The mining of lithium and other resources

[6] Schot, Johan and Laur Kanger, 2018: Deep transitions: Emergence, acceleration, stabilization and directionality. Research Policy 47(6): 1045-1059

needed for batteries and the like are leading to new environmental and social problems, as we speak. A mobility system transition ought to follow what in the literature (and IPCC-reports) is called "avoid, shift, improve" – first see if the mobility demand can be avoided, then shift to other modes, such as walking, cycling or public transport, and if the trip is unavoidable and no feasible alternatives exist, shift to a cleaner mode, such as electric vehicles. As with the electricity example, all this will mean changes in how we view transporting ourselves, in the car as part of identity, as a cult symbol or as technological fascination, in business models, in governmental regulation including how taxation works, in urban and land planning, and in (public) transport infrastructure.

Our food and agricultural systems, and industry, and the list goes on, require similarly large overhauls, as practically all human systems are affected by climate change mitigation and adaptation. The industrial system transition I find particularly fascinating as it is such an optimized, locked-in sector that is at the same time crucial for our well-being and progress, a huge emitter of greenhouse gases, very remote to most people, and companies and shareholders are rarely inclined to speak about systemic matters[7].

[7] I have argued this before in a GCCSI webinar and various interviews (See https://www.globalccsinstitute.com/resources/multimedia-library/ccs-talks-transborder-opportunities-and-challenges-for-ccus-projects/ and https://vnpi.nl/actueel/industrie-betrek-omwonenden-bij-transitie-2/)

Just transitions

All such systems transitions have profound consequences for justice. My personal motivation for working on climate change (and a motivation that I share with many who take part in climate demonstrations) is the huge inherent unfairness: that the affluent are causing climate change, while the poor are hit hardest by the consequences. And this injustice is going back decades, if not centuries. If we are not careful in these system transitions, the poor will also be the ones hit hardest by responding to climate change. There will be winners and losers. It is an open question to me whether it is possible that responding to climate change can also address poverty, but at the very least we should make every effort to make sure that existing inequalities are not exacerbated. Because really, that is what these yellow vests protesters were demonstrating for.

Figure 9. Yellow vests protesting in Paris, France. Source: Shutterstock

For this to happen, the systems transitions themselves need to be just. The concept of "just transitions" has emerged from the labour movement. Historical research has revealed much experience, both good and bad, from past transitions[8].

[8] Stichting Historie der Techniek, linked to the TIS group, is a key player in this research field.

Whether it was on coal mine closures, change of agricultural systems or urban reforms: where change happens, some people lose something. Some people even feel that their regional identity is taken away from them, which is a sentiment still pervasive in the former coal region in Limburg. And it is that loss of identity and livelihood, of regional pride, that can, at least partly, explain the love for politicians who promise that things will stay the same, for instance in the United States[9].

Other research[10] has identified three, maybe four, elements of just transitions: distributional, procedural and recognitional or restorative justice (those last two are often taken together). The most well-known one is distributional justice: that costs and benefits are fairly distributed. These costs and benefits can mean income or jobs, but there is more: also community, or a sense of identity, as we see clearly when coal mines are closed down, or the agricultural sector has to change.

Less talked about is procedural justice. This means that people have a chance to influence what is important to them, that they feel they have been involved in a just way, that their concerns are heard and that decision-making is fair. We have seen many examples in system transitions and technological implementation where procedural justice is not observed, for instance in the well-researched Barendrecht CO_2 capture and storage project. In 2008 and 2009, several oil and gas companies and the Dutch government were planning storing CO_2 in a depleted gas field in the deep underground under Barendrecht. The people living in the neighbourhood had to read it in the newspaper, rather than being informed early. In information meetings that followed, their concerns were not taken seriously by dismissive representatives of government and the involved companies. Protests erupted, and the project was abandoned. The consequences extended well beyond Barendrecht. Trust in government was reduced, and no politician dared to say she or he thought CO_2 capture and storage was a necessity for years to come, stymieing development in that technology (which, by the way, I feel is necessary, especially for short-term, fast and deep reductions in the Netherlands). Procedural justice was clearly not observed in this case, and it keeps on surprising me how little we seem to have learned. Things still go wrong continuously, around industrial clusters, around wind energy, around farmers, around solar parks. Procedural justice warrants significant investments but it is generally undervalued.

[9] Senator Joe Manchin of West Virginia, in the news a lot lately for his role in President Biden's Inflation Reduction Act, is an example.

[10] E.g. McCauley, Darren and RaphaelHeffron (2018) Just transition: Integrating climate, energy and environmental justice. Energy Policy 119: 1-8.

The industrial transition is a good example of this. When I was a girl, we lived in Vlissingen, a sea-side town in the south-west of the Netherlands. From the beach, we could see the chemical factories, the refinery and further upstream the immense harbour area of Antwerp. I remember looking in fascination at these mysterious metropoles of pipelines and smokestacks, having no clue what was going on inside. How wonderful would it be if those living near industrial clusters could be made much more part of the industrial system transition? This is also why I am a supporter of citizen's assemblies of some form, such as advocated by Eva Rovers, and of many other tools and techniques to engage people to help make the transitions everyone's transitions. This is an investment and may slow things down at the start, but it reduces risk of complete stalling later on. And it is morally the right thing to do.

The third (and fourth) form of justice is recognitional (and restorative) justice. A project never happens in a place without a past. And it often is the case that those most affected by the change – for instance closest to a new wind energy development – are also the ones who have had it the hardest in the past. This needs to be acknowledged (recognitional) and potentially compensated (restorative). Doing systems transitions in a just way also means taking into account the history of a place, and holds opportunity to make up for past injustices.

Besides to these types of justice, justice also needs someone to whom (in)justice is done. Another silent voice, until recently at least, is that of young people, who will have to live much longer with the consequences of a changed climate than middle-aged people like myself, or the generations before mine, whose collective decisions got us where we are now. The youth movement's appeal to intergenerational justice is well-founded.

And there is more. We can extend the justice question to nature and organisms other than humans. Climate change is intimately related to biodiversity, there is a rich and expanding literature on this relationship. Climate change affects nature: in many cases climate change is happening faster than current ecosystems can adapt. Nature is needed for both adaptation and mitigation, there are many examples of that. In any case, it is clear that solving climate change without improving biodiversity and restoring human-nature harmony is a dead end. It is a very interesting field to see how justice can be done to an entity that does not talk back. However, it is not my field so I will not go into it more here and now.

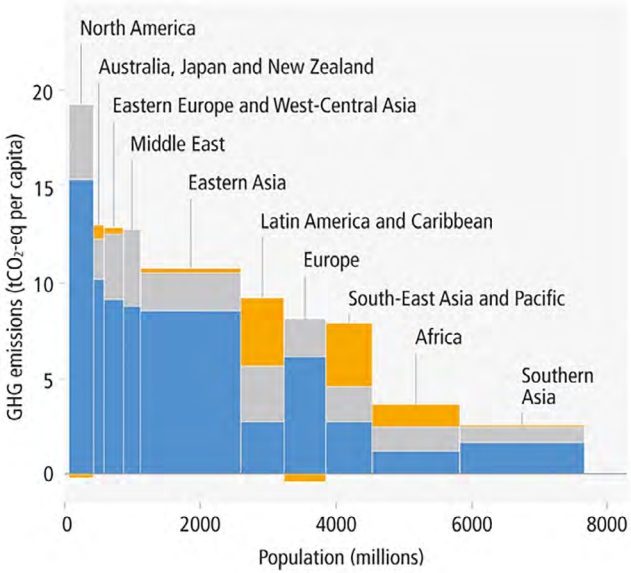

Figure 10. Net anthropogenic greenhouse gas emission per capita and for total population, per region (2019). Source: IPCC AR6 WGIII contribution, Figure SPM.2c.

And there are more angles to justice. Inter-country justice, which plays a dominant role in the international climate negotiations and to which the 2015 Paris Agreement is the latest answer (see also Figure 10). But also intra-country. About ten years ago, I worked with a number of colleagues at Princeton University, under Shoibal Chakravarty's lead, on an analysis of per person greenhouse gas emissions[11]. Rather than looking at average per capita emissions of countries, the paper looked at individual emissions (by multiplying an income distribution curve with the country's CO_2 intensity number). The result for 2003 data showed, interestingly, that using these averages leads to very different results. For instance, there was a whole France (about 60 million people) in India that had per person emissions that were at the level of high-income countries. Yet these people, who bear as much responsibility as individuals in France based on their current activities, are not asked by international treaties to reduce their emissions. Why? Because there is widespread poverty in their country, which brings the average per capita emission down considerably. They are hiding behind their own poor.

[11] Chakravarty, S., A. Chikkatur, H. de Coninck, S. Pacala, R. Socolow, M. Tavoni, 2009. Sharing global CO_2 emission reductions among one billion high emitters Proc. Natl. Acad. Sci. USA, 106 (29), pp. 11884-11888

Many of them try to change things, but this is an issue we need to grapple with – intra-country justice is linked to inter-country justice in complex ways.

And it gets even more complicated. When the climate negotiations started, and countries needed to register their emissions, it was decided to register so-called territorial emissions. So, the emissions that occur in a country. If an industrial plant is in the Netherlands, its emissions are there. For a car, we cannot know where the car drives, so the fuel sold at the gas station is the basis for the emission. (this actually makes Luxemburg's emissions really high, as it has one refinery and low gas prices, so many cars go there to get fueled up, and then drive back to Germany, France or Belgium, where they actually are from and where they emit the CO_2, but the emissions are allocated to poor small Luxemburg). It made sense at the time given the still low levels of international trade, and the limited data availability. But in the meantime, international trade has boomed, and we can trace much better where emissions are happening. And there is something to say for the emissions of producing, say, a television in Korea for a German family are at least partially allocated to Germany. Consumption-based emissions, and tracing and quantifying the actual, full life-cycle emissions of activities is a theme that my colleagues at the Department of Environmental Science at Radboud University as well as at the TIS group in Eindhoven are working on. I think it will gain importance, if it can serve the reality of policy-making. And it emphasises that systems extend beyond emission point sources.

My personal view is that justice and fairness are important enough in their own right. But I am researching it also because not observing them is eventually going to erode support for climate policies. Even if the moral aspects play no role, there are valid, self-interested arguments to pay due attention when people are bringing up justice and just transitions.

Enabling and speeding up just systems transitions

I hope I made it clear that change is inevitable. And that these changes will have to be big and pervasive, so systemic, to keep our planet livable and healthy. And that these changes themselves need to be just.

The question is, how can we make this happen? It obviously does not happen automatically. And how can we make it happen quickly enough – how can we accelerate systems transitions?

To me it is very clear that a systemic problem will never have a non-systemic solution. So, what are our points of intervention? We cannot innovate ourselves out of climate change as technology always has a social side. Behaviour can change quickly, but changing social norms, such as the norm to own a car or to eat meat, usually takes more time. Investors are not going to change their policies and their risk assessments overnight. Firms may resist change, some need to completely reinvent themselves. Some, maybe many, will disappear as their core businesses become unattainable. The sector they're in may get reorganized. Even governments are not empowered to act alone – they need public support and they need to know that firms can continue supplying key products, or else chaos follows[12].

To capture all these elements, in the IPCC SR1.5 we identified six "enabling conditions" that are all needed. I often present them as six pieces of the a jigsaw puzzle.

[12] Some transition scholars argue that transitions always need to go through a time of chaos. See e.g. Loorbach, D., N. Frantzeskaki and F. Avelino, 2017. Sustainability transitions research: transforming science and practice for societal change. Annual Review of Environment and Resources, 42: 599-625. https://doi.org/10.1146/annurev-environ-102014-021340

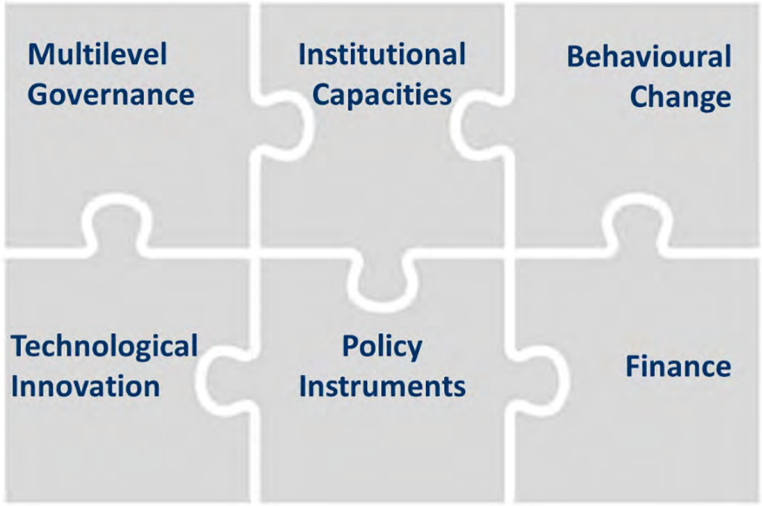

Figure 11. The six enabling conditions for accelerating systems transitions in the IPCC SR1.5.

All pieces are needed. However, if we look at what is happening, there are definitely favourite pieces of the puzzle for different actors. I would say that innovation and policy instruments are most popular. What is happening in the others is much less developed, and a key point of this lecture is that strengthening those might bring about much more rapid changes that maybe we can imagine now.

At an innovation studies group in a university of technology, I have to start with innovation. The IPCC AR6 sends a mixed message on this enabler. Most media pick up the good news: costs of renewables and electric vehicle batteries have dropped tremendously over the past 20 years, and deployment is increasing rapidly too. The report attributes this success to public policy: both innovation and deployment policies.

In addition, complicating the message further, the report warns against technology optimism. Rebound effects – where savings in one space lead to emissions in another – can be significant, so the drop in emissions is not as clear. Developing countries benefit less from technology than developed countries and emerging economies. Renewables and batteries lead to new environmental and social problems as a result of mining in areas where human and environmental rights

are not necessarily protected. Innovation tends to exacerbate rather than reduce inequalities, leading to questionable justice performance.

This is also why I have a bit of a love-hate relationship with technologies such as CO_2 capture and storage and CO_2 removal, and even with solar and green hydrogen. They tend to be liked by those who think we can innovate our way out of climate change. I know we need such technologies. But I also see the risk of relying on them too much.

So, no matter how tempting it is to believe in technology, it would be shortsighted to exclusively rely on it. It needs to be combined with other enabling conditions, and it needs to be just.

The other enabler that is very obvious is policy instruments: every measure that government takes to respond to climate change. For mitigation, governments can price emissions, as in the EU emissions trading scheme or through a carbon tax, but this is not enough. It can regulate, including prohibiting polluting or dangerous activities. It can educate, it can subsidise. And it can influence transitions through green procurement and clear leadership. There is barely anyone denying the crucial role of the government anymore, even when it seems to move slowly at times.

Behaviour is gaining some prominence lately, also in the AR6, which concluded that emissions could be reduced, theoretically, by 40 to 70% in 2050 through demand-side measures and behaviour change. But there is much more to behaviour: it also includes public support for technology, and voter behaviour, which determines how ambitious government, and how just their policies, will be.

Finance is another enabler, although currently the financial sector acts more like a barrier to systems transitions. It is a sector of its own with a very particular dynamic. It consists of many different types of actors, such as commercial banks, central banks, insurers, pension funds, development banks and rating agencies, each with their own role, and it relates to the real economy in complicated ways. Financial crises have shown that the financial sector is a dynamic system, which can spin out of control. Once it starts to move, it can move quickly. When we wrote, together with the Green Climate Fund, a "summary for financial decision-makers" of the SR1.5, we asked a large number of actors from the financial sector what should be in such a document. At the London meeting, one banker mentioned what he called the "herd mentality" of banks. If one goes and has success, they go en masse. This

feature, which was disastrous in the context of the financial crisis, can perhaps be turned into an advantage for making the financial system an accelerator of systems transitions.

The fifth enabling condition is multi-level governance: how different levels of governance and other actors work together. All actors need to be aligned to accelerate systems transitions, in the private and public sector, in banks, with healthcare workers: everyone has the possibility to act in their own way. To align these actors, more collaboration and less inefficient competition is needed. (We are seeing in universities how an escalating competitive culture is causing havoc amongst its employees and is not leading to the useful and productive academic environment that we need.)

Within such multi-level governance, international cooperation is a field close to my heart, it was the topic that I started working on at the Energy research Centre of the Netherlands in 2002, it was the topic of my PhD thesis and I still work on it with TU/e PhD candidate Clara Caiafa and also Wolfgang Obergassel at Wuppertal Institute. Chapter 14 in the IPCC AR6 notes that the role of international cooperation has changed strongly over the past 25 years. In the 1990s, when international climate change governance started in earnest, treaties were strong and the international community was relatively united. The Kyoto Protocol was agreed in 1997, and led to an international emission trading scheme for developed countries, and a Clean Development Mechanism, a project-based carbon market, for developing countries.

But it quickly became clear that this model was not going to be replicable in a changing world. The United States, then the largest emitter, never ratified. My PhD thesis in 2009 was on the role of technology in the climate negotiations, and argued that agreements on technology implementation (or regulation) in sectors might work better than internationally agreed emission reduction targets, which would never find support from large countries such as the United States and China. After the failed Copenhagen COP, a technology mechanism was set up under the UN climate negotiations, but its operations have been fairly limited so far.

Figure 12. The moment the Paris Agreement was agreed. Source: ENB

The Paris Agreement of 2015 took a path very different from Kyoto: countries could submit their own plans, depending on what they feel they can contribute. Although current policies still lead to around 3 degrees of warming, so way more than the 1.5 degrees that is kind of safe, countries are committing to stronger emission reduction targets because of peer pressure and new, more dire climate impacts unfolding.

In the discussions around the Paris Agreement, and also the media, there is much attention to the temperature limits and the provision of climate finance (not to be confused with the aforementioned financial system, by the way, which is much bigger and more all-encompassing). These issues are important, but this obscures one very important part of the Paris compromise: in order for developing countries, especially the poor ones that have very low emissions and bear almost no responsibility for the climate problem, to commit to submitting their nationally determined contributions to the UN climate secretariat, developed countries would have to provide the "means of implementation" that would allow these countries to do mitigation and adaptation.

These "means of implementation" are finance, technology and capacity. Finance from developed to developing countries is falling short, we saw clearly during the latest COP in Glasgow. The technology mechanism under the UNFCCC is very weak. But by far the area with the least investment is capacity building, despite that it is very clear that we need people who are well educated and climate- and technology-literate, and have the skills to make the right decision. This is the sixth and last enabling condition. We need engineers – I don't have to convince you of that in this Auditorium – but also for example policymakers who know what to do, people in the financial sector who have the skills to evaluate risk of an investment not just based on past but also on future information, we need skilled facilitators for citizen assemblies and procedurally-just public engagement. And we need them not just in developed countries, where there is already a shortage, but all over the world.

Research agenda

Although better with every government, current Dutch climate policy is still largely stuck in the enabling conditions of innovation and policy instruments, and primarily aimed at the 2030 emission goals. I hope I made it clear that we need all enabling conditions to focus on accelerating systems transitions towards net-zero CO_2 emissions in or just after 2040 in the Netherlands. And I hope to contribute what I can as an academic.

Some people are accused of not seeing the forest for the trees. My largest problem is that I cannot keep all trees in focus if I try to see the forest. My research agenda is very broad. But I'm convinced that it's a good thing if there are researchers who keep an eye out for the forest and how approach things more systemically.

My central hypothesis is that mutually reinforcing enabling conditions can accelerate the systems transitions. I take courage from that, as transitions can run away, they can go more quickly than we think. This may give us a shot at limiting warming to 1.5°C. But we need to do this in a smart way.

I take inspiration from colleagues Vincent de Gooyert and Floor Alkemade, who have introduced me to the system dynamics world. A giant on whose shoulders we all stand is Donella Meadows, who argued that intervention points can set things in motion, and can bring about the tipping points that could be the systems transition accelerators. My aim is to work on understanding these interventions and to make sure that the right actors are aware of the much greater realm of possibilities. With Vincent de Gooyert, Floor Alkemade, Johanna Höffken, Mara Hauck, Arjan Kirkels and Prapti Maharjan, helped by historian of technology Frank Veraart, we have formed a project group which tries to flesh this out more and look for those intervention points in the enabling conditions so that they can reinforce each other in a dynamic and just way. Really, this is our best shot at limiting warming to 1.5°C. In particular, I will work on policy instruments, innovation, finance and capacity building in the international context. Finance is a new theme for me there. A system transition all in itself, with Pieter Pauw and several others, I hope to take a systemic perspective on the question of financial system change.

In terms of the systems transitions, I hope to continue the work with Vincent de Gooyert, Mark Huijbregts, Steef Hanssen, Moises Covarrubias, Sara Gonella, Kiane de Kleijne and Floris Swennenhuis as well as many others in both companies and industrial clusters on industrial decarbonization. The Climate-Friendly Materials Platform, hosted by DIW and Climate Strategies, with Karsten Neuhoff, Timo Gerres and many others, is also a source of inspiration, and I really hope to strengthen links with the technical and business administration departments at TU/e, and EIRES, the energy institute at TU/e, on this crucial sector. And with Stefan Bakker, the first PhD candidate I supervised, now at the Knowledge Institute Mobility, Floor Alkemade, Auke Hoekstra, Hans Jeekel and others at TU/e and in the NEON research project, I hope to collaborate more on the mobility transition. With Aromar Revi, Chandni Singh and Marjolijn Haasnoot, we are trying to break down the barriers between the mitigation and adaptation worlds, in the IPCC and in the Netherlands, in part with a focus on cities.

I also hope to continue and strengthen the international cooperation research. There is so much more potential in innovation cooperation, also for capacity building, and I hope to continue working on this with TU/e colleagues, with PhD candidates Clara and Wolfgang, and with my 'technology' buddies all over the world, notably Ambuj Sagar at IIT Delhi, Gabriel Blanco at UNICEN in Argentina, Sara Traerup at UNEP Climate Centre, Harald Winkler and Britta Rennkamp at University of Cape Town in South Africa. I am glad that the TU/e has a "Technology for Global Development" initiative, which signals that I have come to the right place for this topic!

Finally, working on accelerating systems transitions also means something for the research world itself. When I moved from the very applied and impact-driven research institute ECN to academia, almost on the dot ten years ago, I was confronted with the challenges that our university structures and incentives pose to academics who want to be policy-relevant and work together with the people who are actually *doing* the transition work, such as policymakers, engineers in companies, project developers, and community workers. There is just no time for such collaborative work and there are no incentives to spend hard-acquired research funds on own hours so you can actually spend time yourself on working with actors in society. I was thrilled to be asked to chair a task force by NWO and the KNAW on setting up a climate research initiative. We called it Klimaatonderzoek Initiatief Nederland (KIN) (Steef, thank you for the name) and it forms a fairly radical departure from the current competitive, publication-driven way of doing research towards a mission-driven, collaborative model. I am convinced that this is needed

and I am encouraged by the fruitful and pleasant collaboration within the Taskforce and the warm reception by NWO and KNAW. KIN will be operating with the core goal to accelerate systems transitions for both mitigation and adaptation, and it has a significant international programme to build capacity in a selection of low-income countries. I look forward to contributing further to making this the success that the systems transitions need!

Am I an activist?

This actually brings me back to my early days as a twelve year-old activist. I am a researcher now, but a researcher who sees it as their duty to use research to make this world a better place, both socially and environmentally. Does that make me an activist? I heard a colleague working on Parkinson once call himself an activist, combatting a disease. If I would say this, I would according to many disqualify myself as an independent researcher. I once got asked after giving a talk whether I considered myself radicalized, although all I had done was present the IPCC results. If I say that I think it is still possible to limit warming to 1.5°C, because we haven't exhausted the possibilities yet, there is a very clear need, and I see it as my duty to stay hopeful to keep temperature rise as low as possible, does that make me an activist?

I don't know, and it is probably in the eye of the beholder. So, a plea to you all: as I'm trying to play a constructive and science-based role in this debate, please continue telling me if I have become too activist. Or if I am not activist enough. This for sure is something I will continue to ponder in the years to come.

Vote of thanks

I would also like to use this podium to thank the huge amount of people – colleagues, friends, family – who have been kind to me and showed me around in life. Too many people to mention all personally here. A couple of them have played a role in my life's tipping points, and I'd like to mention them specifically.

During my studies of chemistry and environmental science, Koos Willemse and Irene Dankelman had a big impact. Irene Dankelman was the one whose contacts invited me to the Grupo de Estudios Ambientales in Mexico-City for a Master's research project, which was a life-changing experience. Koos taught a course on atmospheric chemistry. I was the only student, which was probably as uncomfortable for him as for me, and in that class room, my fascination with climate change and the atmosphere began. Koos was also my university supervisor during my research thesis at the Max Planck Institute in Mainz, where I had a great time and met many friends, some of whom, Karo and Roland, I deeply regret are no longer with us.

At ECN Policy Studies, my first position in climate policy, where I stayed for over ten years, I matured as a researcher. Remko Ybema was the best manager that I could wish for. He was a real stimulus and also facilitated that I could do a PhD next to my work at ECN. It is such a shame that ECN fell prey to political and managerial mayhem, leading to the departure of so many good people, some permanently lost for the energy transition.

During my external PhD at the Vrije Universiteit, my promotor Frans Berkhout taught me how to be a social scientist, and I still appreciate all the time he invested in me. During that time, in particular during my stay at Princeton University with Rob Socolow, I got a taste of what research in a stimulating environment could be like. Thank you both!

At Radboud University, I would like to thank Mark Huijbregts and also Stan Gielen for supporting me at a moment that I really needed it. Working with Mark means being on one's tiptoes all the time, but in a very human and humoristic way. Some special PhD candidates have accompanied me, initially as students in the first full-blown edition of the Energy and Climate course, and now as colleagues: thank you,

Kiane and Floris, for your companionship and everything I could learn from you! A big boon of being in the IPCC is the many interesting and inspiring people one meets over the years. For an impact-driven researcher, the IPCC is like a gold mine of role models. I could mention many, but Bert Metz I want to mention in particular. His unrelenting focus on content and his drive to always make a difference has been an example to me for twenty years now.

And at the moment at TU Eindhoven, in the TIS group and with EIRES, I am again very fortunate to work with colleagues doing fascinating work such as Floor Alkemade, who by the way is also a great group chair, Richard van de Sanden, Henny Romijn, Mara Hauck, Arjan Kirkels, Pieter Pauw, fantastic PhD candidates Clara, Vera, Prapti, Emiel and Wolfgang, and many others.

This lecture is about work, so I will not bore you by dwelling on friends and family too much. They know who they are and how thankful I am that they have accompanied me during various phases in my life – from high school, university, Mainz, ECN, Nijmegen, and other walks of life. And finally my family. My welcoming American in-laws have really enriched my life with Appalachian culture and kindness, and gave me a whole new appreciation of tomatoes.

My parents are not climate activists but they are a huge support and have laid the basis for my moral compass and my hunger for knowledge. My siblings Leon, Peti and Harm: it is wonderful to be able to rely on family in all our diversity. This is very important to me, so thank you for putting up with my climate single-mindedness.

And finally, my closest family. My partner Forrest is the most loving support and critic I could wish for. And to our daughter Mies: the future is yours.

Ik heb gezegd.

Curriculum Vitae

Prof.dr. Heleen de Coninck was appointed as a full professor of Socio-Technical Innovation and Climate Change at the Department of Industrial Engineering and Innovation Sciences at Eindhoven University of Technology on April 1, 2020.

Prof.dr. Heleen de Coninck holds MSc degrees in Solid State Chemistry and Environmental Science (2001) from Radboud University and a PhD on the role of technology in international climate negotiations from Vrije Universiteit Amsterdam (2009). She worked for the Policy Studies unit of the Energy research Centre of the Netherlands (ECN) for over ten years and has worked at Radboud University since 2012, where she still is a part-time associate professor. As a Technical Support Unit member, Lead Author and Coordinating Lead Author, Heleen de Coninck has contributed to several reports by the Intergovernmental Panel on Climate Change (IPCC), most notably the Special Report on Global Warming of 1.5°C (2018) and the mitigation part of the Sixth Assessment Report, in which she co-coordinated the innovation and technology transfer chapter (2022). She serves on several governmental and international boards and committees, all focusing on energy and climate change, as well as various editorial boards. Heleen de Coninck's research as part of the Technology, Innovation and Society group aims to contribute to the acceleration of system transitions that limit climate change in a sustainable and just way. Her research and publications span international climate policy, innovation cooperation with developing countries, innovation studies, carbon trading, energy and development, financial system change, and the societal aspects of energy technology and a climate-neutral energy-intensive industry.

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Communication Expertise Center

Cover photography
Bart van Overbeeke Photography, Eindhoven

Design
Grefo Prepress, Eindhoven

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