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Imagination, bravery and action: The Great Energy Transition of the 21st century

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> *Imagination is the only thing we have that is — or could be — radical enough to get us through, provided it is accompanied, of course, by bravery, and by action.*
>
> Rob Hopkins[1]

Writing this chapter in the shadows of the COVID-19 pandemic provides a stark warning against over confident predictions about the ways in which human societies and ecologies will evolve.

At the time of writing in mid 2020, my social media feeds include the full spectrum of utopian and dystopian scenarios. At one end there are those who see glimpses of renewed respect for the scientifically informed decision making; socially inclusive public policy and decisive government leadership capable of driving rapid and equitable climate emergency action.

As the dire social and economic consequences of the pandemic become clearer, many others point to disturbing signs that authoritarian totalitarianism and xenophobic nationalism are becoming even more firmly entrenched. In this future the short-term benefits of temporary emission reductions are quickly overwhelmed with the rich and powerful ramping up

investment in the walls and fortresses designed to maximise protection from unabated global warming and increasingly desperate populations.

The following backcasting narrative, sitting somewhere in the middle of these views, is offered as a provocation — not a prediction. Looking back from 2050, this story is told through a fictional Oration delivered by Professor Sione Apatu, Director of the Global Institute for Climate and Energy Transitions, reflecting on the key events, decisions and actions which drove the great 21st century energy transition at remarkable speed and scale.[2,3]

While celebrating the impressive progress made by 2050 towards achieving the goal of zero net emissions Professor Apatu also notes the severe and ongoing ecological damage and human suffering caused by the failure to reduce emissions with sufficient urgency in the first quarter of the 21st Century. Therefore, Apatu concludes by highlighting the importance of continuing to imagine, design and create a just and resilient zero-carbon future at emergency speed.

The Great Energy Transition of the 21st Century: The 2050 Zero-Carbon World Oration

Transcript of the 2050 Zero-Carbon World Oration delivered by Professor Sione Apatu, Director, Global Institute for Climate and Energy Transitions, Auckland, Aoteroa New Zealand

Good evening. I am delighted to be with you tonight to deliver the 2050 Zero-Carbon World Oration. As you are aware, this

annual oration was inaugurated by the UN Secretary General in 2030 in order to celebrate and accelerate progress in creating a just and resilient zero-carbon world.

In preparing tonight's 2050 Oration, I have been acutely aware of the images we are all seeing of the tragic loss of life from the most recent of the climatic catastrophes which continue to sweep across our planet — the Great Inundation of the Ganges Basin. The grim scenes we have seen in the cities and villages of India and Bangladesh over the last few weeks are one more stark reminder of the need to continue to accelerate progress in achieving our three crucial global priorities: creating a just and resilient zero-carbon economy; protecting and assisting the most vulnerable individuals and communities; and repairing and regenerating our climatically disrupted, burned and flooded world.

My task tonight, however, is to focus on the first of these priorities by addressing two key questions. How, despite facing so many difficult challenges, have we made such remarkable progress towards achieving a zero-carbon global economy? What have been the key turning and tipping points that have driven the global energy transition at such remarkable speed and scale?

I would like to begin by sharing some brief observations on the way this challenge looked back in 2020 at the beginning of the transition period. Following a brief overview of major energy transition trends and outcomes over the last 30 years, I then outline five key drivers of the great Energy Transition. My presentation concludes with some reflections on the difficult journey that still lies before us.

The view from 2020

By 2020 the key elements of the post-carbon economy roadmap were well understood: rapid reduction in energy demand through improved energy efficiency and reduced consumption; comprehensive electrification of energy supply; rapid replacement of fossil fuels by renewables; low carbon agriculture and forestry; carefully managed biosequestration; and the actions needed to ensure that the energy transition was undertaken in an equitable and resilient way.

There was also widespread recognition that the most significant roadblocks preventing rapid decarbonisation were social and political rather than technological. These roadblocks included the power and influence of the fossil fuel industry and other vested interests; political paralysis and denial; social and technological path dependencies; financial, governance and implementation constraints; and the dominant neoliberal economic paradigm of unsustainable consumption and inequitable wealth distribution.

I have four strong memories from those distant times that I would like to share with you. The first, in Paris in December 2015, was a moment of genuine elation as I joined thousands of delegates in leaping to my feet to applaud the announcement by Conference of Parties (COP) 21 Chair Laurent Fabius that 195 nations had approved the Paris Agreement.[4] Most of us at the time recognised that the Paris Agreement was far from perfect, sharing journalist George Monbiot's astute analysis that 'by comparison to what it could have been, it's a miracle. By comparison to what it should have been, it's a disaster.'[5]

We very well understood that the COP21 national emission reduction commitments would need to be rapidly strengthened if we were to have any hope of keeping global warming below 2º C. Indeed, many of us were also increasingly aware that a strong emphasis on negative emissions would be required to have any real chance of keeping global warming to 1.5º C or even 2º C. We were, however, hopeful that ratifying the Paris Agreement would send a clear, strong message to political leaders and global investors that the rapidly accelerating global shift from fossil fuels to renewable energy was now unstoppable.

Just 12 months later in November 2016, at COP22 in Morocco, I vividly recall the shocked faces of delegates receiving the news that Donald Trump had been elected President of the United States. To what extent, we wondered, would the election of this autocratic champion of climate change deniers and fossil fuel billionaires derail climate and energy action at the very moment at which it needed to be rapidly accelerated? Of even more concern, would the Trump presidency drive a further deterioration in the erosion of trust in scientific methods and evidence?

My third, most inspirational memory is of the actions and words of the 15-year-old Swedish school student Greta Thunberg who, on 18 September 2018, sat down on the steps of the Swedish Parliament to begin her strike from school in protest against the lack of climate action by the Swedish government. Within a few months Greta's strike action had triggered an international School Climate Strike movement bringing together millions of school students from around the world demanding that their governments accelerate decisive, emergency speed climate change action. As we now know,

many of these students continue to play crucial ongoing roles in the Great Energy Transition.

And then, in early 2020 the corona virus pandemic began to sweep across the world. The tragic death toll and huge social and economic dislocation are seared into the memories of all who lived through those strange and distressing times. It was, to paraphrase Charles Dickens, a time of risk and a time of possibility; the age of foolishness and the age of wisdom; the epoch of incredulity and the epoch of belief. While in no way wishing to underestimate the suffering experienced by so many individuals and communities, it is now clear that the disruptive impact of the pandemic did help trigger a series of interlocking social tipping points with profound implications for the direction and speed of the Great Energy Transition.

In the short term, the collapse of global economic growth, the grounding of aircraft and the lockdown of most large cities did lead to a sharp fall in global emissions. While the benefits of these emission reductions were quickly reversed in the rush to restart stalled economies, the pandemic also left a legacy of learning about the desirability and feasibility of car-free streets, shorter supply chains, virtual conferencing and four-day work weeks.

In hindsight, the even more important learning was recognition that the societies most successful in dealing with the pandemic were those that took swift and decisive action well informed by high quality scientific advice and underpinned by strong and inclusive public health and community support systems.

Reflecting back on this complex mix of confronting and inspiring recollections also led me to reread some of the writing

that I remember finding particularly useful at that time. I would like to share a few observations from two of these. *The 2015 Report, World in Transition: A Global Social Contract for Sustainability,* produced by the German Advisory Council on Global Change, brought together a broad array of research and analysis on the sources and drivers of large scale technological, social and economic transformations.[6]

I remember being particularly struck by the report's conclusion that 'avoidance of dangerous climate change, and the aversion of other threats to humankind as part of the Earth system' would need to go 'far beyond technological and technocratic reforms' and would, in fact, require the creation of 'a new global social contract for a low-carbon and sustainable global economic system'. This new social contract, the report argued, would in turn require the creation of a 'culture of attentiveness (born of a sense of ecological responsibility), a culture of participation (as a democratic responsibility), and a culture of obligation towards future generations (future responsibility)'.[7]

The second document I would like to refer to is 'A Roadmap for Rapid Decarbonisation' published in the journal *Science* in March 2017.[8] This article, authored by some of the most well-informed climate science analysts of that time, summarised key actions required to create a 40% probability of keeping global warming below 1.5° C. Importantly, the article began by highlighting the importance of ensuring that emissions peaked by 2020 and of continuing to halve gross CO_2 emissions every decade until 2050. It was in fact rising global alarm at the slow progress towards achieving these targets, combined with the tragic impact of several catastrophic extreme weather events,

that triggered the global citizen movement leading to Jakarta 2025.

Key climate and energy transition milestones 2020–2050

An overview of key energy transition milestones in the last 30 years is set out below.[9] It is striking to note that these have generally followed a similar, although slightly slower, trajectory to the priority actions proposed in the Deep Decarbonisation Roadmap article. Evidence continues to mount that the ongoing implications of this delay have included a faster than hoped for rise in emissions and global temperatures; a higher incidence of extreme weather events — and an increased reliance on negative emission interventions.

2020–2030

Extreme weather events

2023: Los Angeles Firestorm
2024: Delhi Air Evacuation
2025: Mexico City Water Crisis
2027–2030: China-India 'Water Wars'
2028: Cyclone Kali (Bangladesh)

Key political and policy events and interventions

- 2021: Paris Agreement Review further strengthens energy transition goals and targets
- 2022: Climate Emergency Alliance wins majority in US Congress. US Climate Emergency Act passed.
- 2025: Jakarta Climate and Energy Summit
- 100 countries commit to 2050 carbon neutral economy
- Comprehensive decarbonisation plans announced by all major cities and corporations

- Cap and trade schemes in place in most jurisdictions
- Carbon price rises to $150 a metric ton
- Fossil fuel subsidies eliminated
- Global moratorium on new unabated coal energy

Energy transition milestones

- Renewables provide 50% of global energy mix
- Energy storage and smart grids enable affordable management of renewable energy intermittency issues
- Leading cities (e.g. Copenhagen, Hamburg, San Francisco) carbon neutral
- Internal combustion engines in new cars phased out
- Decarbonisation of long distance transport through renewable fuels and electrification
- Rail replaces air traffic for short haul freight and passenger transport
- Coal exits global energy mix

Emissions trends

- Land use emissions decrease to 2 gigatonnes of equivalent carbon dioxide (GtCO2e) pa
- Gross CO_2e emissions decline from 40 to 24 gigatons
- Bio-energy with Capture and Storage (BECCS) and Direct Air Capture and Storage (DACS) technology removes 0.5 GtCO2e pa

2030–2040

Extreme weather events

2030: Central Africa Drought and food riots

2035: East Coast Australia Firestorm

2038: Collapse of Antarctic Larsen Ice shelf

Key political and policy events and interventions

- Carbon pricing expanded to cover all GHG emissions, including air travel and shipping
- Carbon price rises to $300 per metric ton
- 2030: Cape Town Climate Justice Summit mobilises funds to address climate impacts on most vulnerable populations.
- 2035 Delhi Climate Engineering Summit rejects proposals for atmospheric aerosol injections and ocean fertilisation.

Energy transition milestones

- Renewables provide 75% of global energy mix
- All building construction carbon neutral (including emissions free steel and concrete)
- Electrification of all sectors in lead countries
- Phase out of internal combustion engines
- Aircraft fuel entirely carbon neutral
- Oil exits global energy mix

Emissions trends

- Land use emissions 12 GtCO2e pa
- Gross CO_2e emissions decline to 14 gigatons
- BECCS and DACS removing 2 GtCO2e pa

2040–2050

Extreme weather events

2040: Collapse of Atlantic fishing grounds
Siberian Methane Explosion

2050: Ganges Basin Inundation

Key political and policy events and interventions

- 2040: Paris Climate Summit celebrates 25 years of progress on achieving Paris Agreement goals. Identifies key ongoing

priorities with increased focus on protecting cities and regions most vulnerable to climate impacts.
- Carbon price: $400 per metric ton
- Zero-Carbon World Global Festival, 1 January 2050

Energy transition milestones

- Renewables provide 75% of global energy mix
- All major European countries and US carbon neutral by 2040
- Electrification of all sectors in most countries
- Most other nations carbon neutral by 2050

Emissions trends

- Land use emissions decrease to zero
- Gross CO_2e emissions decline to 5 gigatons
- On track for zero CO_2e emissions 2050–2060

Drivers of the Great Energy Transition

While in no way underestimating the enormous climatic challenges still ahead of us, it is, I believe important to remember and reflect on the key actions and decisions that have driven the Great Energy Transition thus far.

Sustained leadership from national and subnational governments, business, civil society and the military in ratcheting up and accelerating implementation of the Paris Agreement

As noted earlier, ratification of the 2015 Paris Agreement provided a clear, strong signal that governments representing the vast majority of the world's population were firmly committed to decisive climate action. While the commitment of particular national governments has varied over time, there has been sustained leadership from countries responsible for

the largest proportion of emissions including China, Germany, India, Indonesia and, after a dreadfully slow start, the United States. International agreement and cooperation to support a rapid rise in the price of carbon (reaching $US400 a tonne in 2040) has been fundamental to the achievement of an energy transition at such an impressive speed and scale.

Subnational governments and cities, from California to Scotland and from Shanghai to Stockholm, have also played a critical role in demonstrating the feasibility and desirability of zero-carbon pathways and partnerships. The courageous role which the Californian government played in countering the initial destructive impact of US withdrawal from the Paris Agreement is, of course, legendary. Step 1 was the announcement that California would lead ratification of the Paris Agreement by US states and other subnational jurisdictions. Step 2 was the formal declaration by the Governor of California of a Climate Emergency and the passage of the Californian Climate Emergency Act 'authorizing the deployment of public, private and military resources and expertise required to i) address climate change risks and impacts and ii) to ensure the implementation of energy transition and emissions reduction actions at the speed and scale fully required to achievement the Paris Agreement targets'.

Unprecedented levels of grassroots protest, civil disobedience and demonstrations; the recognition by investors that the economic tipping point from fossil fuel to renewables had now arrived; the impact on the US economy of Chinese, EU and Indian trade sanctions were clearly all important — as was climate and energy leadership from high ranking business, military, public sector and community leaders. Most important

of all, I continue to believe, was the leadership provided by wave after wave of students and young people carrying on the work of the initial leaders of the School Climate Strike movement.

In reflecting on the importance of wise and courageous leadership, I am also reminded of the following reflections on active hope by the the great ecological activist and Buddhist teacher Joanna Macy. 'Active hope', Macy argues, depends on 'a readiness to discover the size and strength of our hearts, our quickness of mind, our steadiness of purpose, our own authority, our love for life, the liveliness of our curiosity, the unsuspected deep well of patience and diligence, the keenness of our senses, and our capacity to lead.'[10]

The mobilisation of millions of citizens imagining and creating a diverse array of fossil fuel divestment, consumer boycott, trade sanction and civil disobedience resistance strategies

In hindsight, the massive demonstrations and protest movements such as the People's March for Climate and the Sunrise Movement that erupted across the US in response to the Trump administration's assault on climate action were just the first wave of a far broader global mobilisation.

The truly transformational moment arrived in early 2023 with the Congressional vote to approve financing for the Climate Emergency Act and the emergency speed implementation of the Green New Deal — the comprehensive package of measures designed to trigger an emergency speed decarbonisation of the US economy. As the eminent climate justice and human rights advocate Alexandria Ortasio-Cortez correctly noted with considerable prescience, 'this is going to be the

Great Society, the moonshot, the civil rights movement of our generation. That is the scale of the ambition that this movement is going to require.'[11]

The escalating frequency and severity of catastrophic climatic events

Tragically, the history of the first half of the 21st century is as much a history of catastrophic climate driven disasters as it is of transformational change in social, economic and technological systems. The devastating impact of cyclones Katrina, Tracy and Haiyan, the great droughts in Somalia and California, and the heatwaves and wildfires that swept Australia, Chile, Canada and Russia were only the first of many climate wake-up calls that too many of us continued to ignore for too long.

Finally, however, the escalating frequency and severity of extreme weather events overwhelmed the carefully constructed defences of our wishful thinking and denial — not to mention the patience of investors in the world's largest insurance companies. The terrible bushfires that swept the east coast of Australian in 2019–2020; the Los Angeles Firestorm (2023); the Delhi air quality evacuation (2024); the Mexico City water crisis (2025); the India-China 'Water Wars' (2027–2030); the Central African 'Famine Wars' (which reached their darkest hours in 2030); and the collapse of the Atlantic fishing grounds all played key roles in strengthening support for further acceleration of the energy transition. Increasing understanding of the link between extreme weather events, food insecurity, refugee flows and military conflict also further strengthened support for the adaptation and resilience investments needed to protect vulnerable populations.

Disruptive, game changing technological Innovation

The most visible drivers of transformational change have often been technological: cascading, and disruptive innovations in energy efficiency; solar, wind, tidal and geothermal energy; energy storage (batteries and pumped hydro); electrified and autonomous transport systems; startling breakthroughs in aviation biofuels, low carbon construction materials and digital fabrication have all played important roles, as have new technologies for recording and exchanging value such as bitcoin and blockchain.

Smart grids and integrated transmission networks have significantly enhanced the scale and efficiency of energy distribution systems. Heroically ambitious engineering projects linking renewable energy producers with consumers in North Africa and Europe, North and South America, and Australia and South-East Asia have all made major contributions, as have impressive improvements in long-distance high-voltage DC electricity transmission. At more local scales, urban smart grids have enabled and accelerated lateral energy trading between local households and businesses.

Dramatic improvements in soil science, livestock feeding practices, forestry and savannah management have all contributed to reducing land use emissions. These advances have been augmented by a slow but continuing cultural shift towards reduced demand for meat, a decrease in the wastage of food and an increase in consumption of locally grown food.

And then there is the profoundly important — and profoundly troubling question — of negative emissions. Thirty years ago I led debates highlighting the ecological and political

risks of an over-reliance on Bioenergy with Carbon Capture and Storage (BECCS) technologies.[12] My key concern, which I still believe was correct, was that even if it was possible to deliver large-scale BECCS solutions at affordable cost, the implications for the capacity of the planet to produce sufficient bio-mass for human and animal consumption would be unacceptable. BECCS solutions were also consistently being inserted into emissions reduction scenarios as a 'get out of jail card' to avoid tough decisions about changes in lifestyle and consumption.

Both these concerns have turned out to be well founded. It is now very clear that the failure to act with sufficient speed to reduce emissions in the first half of this century has had the long-term effect of further intensifying arguments for expanding investment in BECCS — and further intensifying pressure on the biodiversity and carrying capacity of the Earth's ecosystems. I can also not finish this section of my presentation without mentioning the most bitter of all Climate Summit debates — the 2035 Delhi Climate Engineering Summit, which by a very narrow margin finally rejected proposals for the most dangerous large-scale geoengineering initiatives such as atmospheric aerosol injections and ocean fertilisation.

Disruptive game changing innovation in social, economic and political systems

I have spent my whole life working shoulder to shoulder with the most brilliant engineers and scientists of my generation. I have the highest admiration for the ingenuity and dedication they have brought to the mission of designing and building the extraordinary, game-changing technologies we have seen brought to scale over the last 50 years.

However, my personal view remains that the most powerful drivers of the great energy transition have been radical and disruptive transformations in our social and economic systems — and in the cultural values and political institutions that underpin these systems. Let me highlight four of the key trends in social, economic and political values and practices which have, in my view, been particularly influential.

Increasing recognition that reducing the global consumption of goods and services is an essential basis for decreasing energy demand and addressing sustainability and climate change challenges

There has been a belated and contested, but, in my view, crucial shift in understanding that the long working hours and high stress lifestyles required to accumulate an endlessly expanding wish list of material possessions are incompatible with sustained improvements in health and wellbeing. This realisation has triggered and been informed by multiple experiments exploring localised, low consumption systems of energy, food, transport and housing production and consumption.

In thinking about the distance we still have to travel on the road to a more sustainable economic paradigm, I am often drawn to this reflection from an old Bhutanese friend of mind: 'Expanding the time we have to spend with our friends and family or the time we have to explore our creative goals may in the end be far more important than spending more and more time at work in order to further expand the size of our houses and our cars.'

Increasing popular support for the global Climate Justice movement, informed by growing awareness that ever-increasing levels of inequality are economically counterproductive, socially corrosive and ecologically unsustainable as well as ethically unjust

These were the arguments that informed the central resolutions of the 2030 Cape Town Climate Justice Summit, approving comprehensive new measures to mobilise funds to address the impact on the most vulnerable populations and communities of climate change and energy transitions.

An ongoing shift towards more distributed and collaborative economic paradigms and systems characterised and driven by open source, peer-to-peer networks of technological knowledge and skills

As a number of insightful analysts have usefully noted, the 'age of information and telecommunications', which began to emerge in the early 21st century, can be usefully understood as a 'fifth revolution' in techno-economic paradigms, building on four earlier 'ages': the first Industrial Revolution (characterised by the introduction of mechanised production systems); the age of steam and railways; the age of steel, electricity and heavy engineering; and the age of oil, automobiles and mass production.[13] This transition to a more collaborative and distributed economy has created enormous opportunities for the acceleration of the knowledge and innovation driving the Great Energy Transition.

Radical innovation in governance arrangements improving the transparency and accountability of economic and political institutions and relationships

Legal and regulatory interventions mandating far tougher corporate standards for the transparent disclosure of climate change and energy transition risks were a crucial driver in shifting investment from fossil fuel to renewable energy industries. At the same time, increasing concern about the political influence of vested interests (particularly in the fossil fuel industry) and a corrosive decline in public trust for politicians led many governments to significantly tighten — or in many cases ban outright — corporate donations to political parties.

The Zero Carbon Energy Transition: A great leap forward on a long and challenging road

In concluding this speech, I am delighted to announce that the *2050 World Energy Report* to be released tomorrow will show that we are indeed on track to achieve a net zero carbon economy by 2060. This is an extraordinary achievement and one which I must say has far exceeded my most optimistic expectations in the difficult years following the signing of the Paris Agreement.

Many profound challenges and tough questions, however, remain. Despite the remarkable speed of the Great Energy Transition, further acceleration in negative emissions innovation will clearly be required to bring long-term global warming trends back below 1° C. The question we still have no answer to is: How can negative emissions at this scale be achieved without overwhelming the capacity of the biosphere to feed 9 billion people?

Despite the progress towards the achievement of a zero-carbon global economy, too many crucial economic decisions with profound implications for the future lives of all the species on the planet are still made in ways that are largely invisible and unaccountable. The complex social and cultural pathways leading to a genuinely sustainable, genuinely equitable post-growth economy have yet to be traversed.

Despite the passionate commitment and creativity of so many inspiring scientific, political, business and community leaders over the last 50 years, I am still unable to provide my grandchildren the simple, essential gift I most wish to give them: the ecological conditions which enable human beings to continue to thrive and prosper — alongside the many species with which we share this extraordinary planet.

The rapidity of the 21st century energy transition does provide a timely, powerful reminder of the potential for human imagination and ingenuity, combined with ethical and visionary leadership to drive transformational change at remarkable scale and speed. As Nelson Mandela famously reminds us: It always looks impossible until its done!

I look forward to working with you all on the next steps in meeting the great challenges that lie before us.

References

1. Hopkins R. *From What is to what if: Unleashing the power of the imagination to create the future we want*. Chelsea Green; 2019.
2. The author of this 'Oration' is a fictional character 'Professor Sione Apatu'. I have deliberately chosen a Pacific Island name for the eminent scientist delivering this speech in order to highlight the likelihood that climate change leadership will increasingly come from societies with the earliest and most devastating experience of climate change impacts.

3. This chapter is a revised and updated version of a previously published article: Wiseman J. The great energy transition of the 21st century: The 2050 Zero-Carbon World Oration, *Energy Research and Social Science,* 2018, 35: 227–232.
4. *United Nations Framework Convention on Climate Change, Paris Agreement, Paris, 2015.* https://unfccc.int/process-and-meetings/the-paris-agreement/what-is-the-paris-agreement
5. Monbiot G. Grand promises of Paris Climate Agreement undermined by squalid retrenchments. *The Guardian.* 2015, December 13. https://www.theguardian. com/environment/georgemonbiot/2015/dec/12/paris-climate-deal-governments-fossil-fuels
6. German Advisory Council on Social Change. *World in transition — A social contract for sustainability.* WBGU, 2015. http://www.wbgu.de/en/flagship-reports/fr-2011-a-social-contract/
7. German Advisory Council on Social Change. See note 5.
8. Rockstrom J, Gaffney O, Roegelj J, Meinshausen M, Nakicenovic N, Schellnhuber J. A roadmap for rapid decarbonsation. *Science*, 2017, 355, (6331): 1269–1271.
9. Macy J, Johnstobe C. *Active hope: How to face the mess we're in without going crazy*. Novato; 2012.
10. Macy J, Johnstobe C. See note 8.
11. Ortasio-Cortez A. Ocasio-Cortez: Fighting climate change will be 'the civil rights movement of our generation'. *The Hill*. 2018, March 13. https://thehill.com/policy/energy-environment/419564-ocasio-cortez-fighting-climate-change-will-be-the-civil-rights
12. For an overview of initial debates on negative emissions see, for example, Fuss S, Canadell J, Peters G, Tavoni M, Andrew R, Ciais P, Jackson R, Jones D, Kraxner F, Nakicenovic N, Le Quere C, Raupach M, Sharifi A, Smith P, Yamagata Y, Betting on negative emissions. *Nature Climate Change*, 2014, 4: 850–853.
13. J. Rifkin. *The Third Industrial Revolution.* Palgrave Macmillan; 2013.