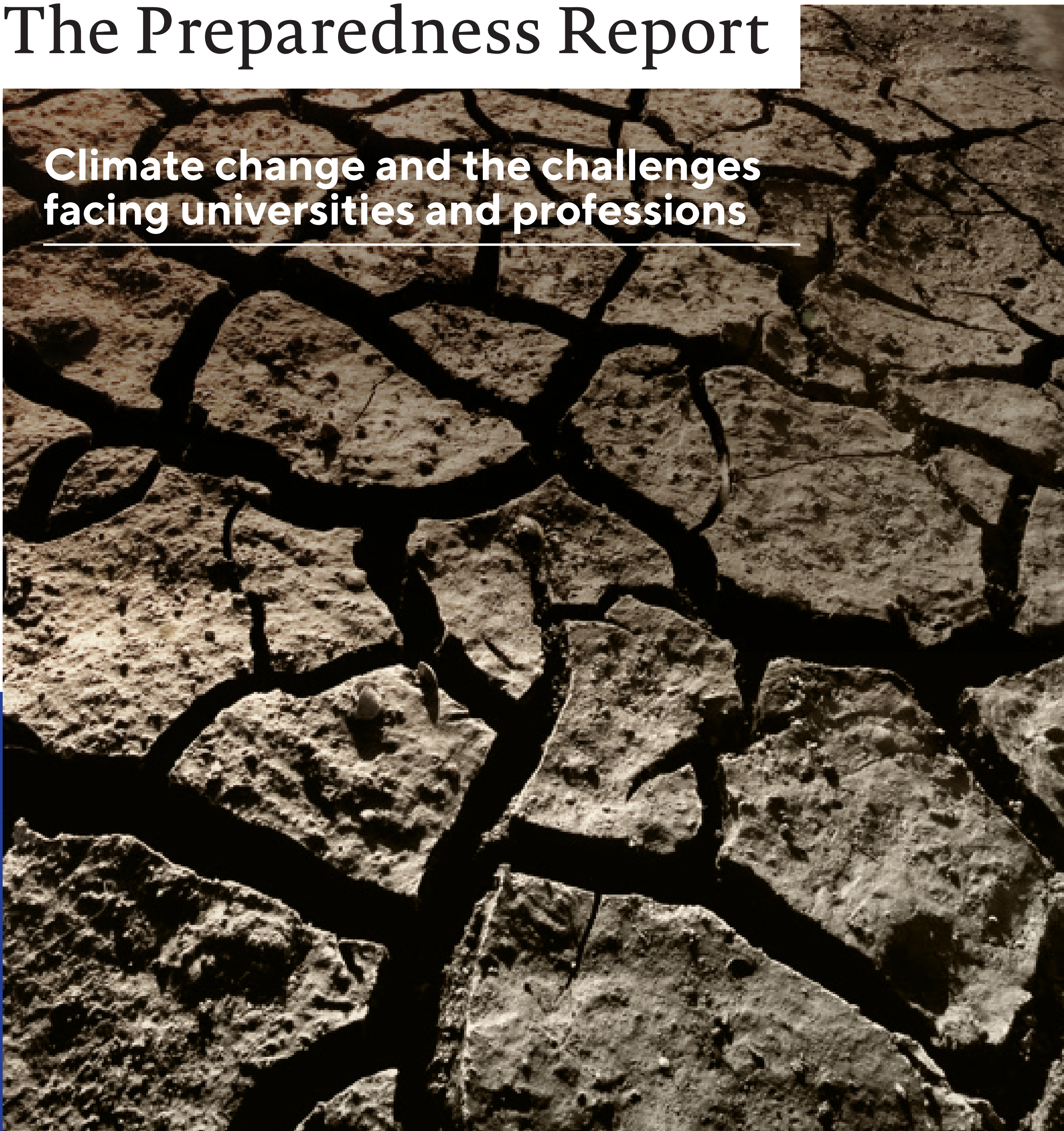
THE UNIVERSITY OF WESTERN AUSTRALIA

UWA Public Policy Institute

The Preparedness Report

Climate change and the challenges facing universities and professions



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The Preparedness Report

Climate change and the challenges facing universities and professions

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Contents

Foreword 3
Amit Chakma

Introduction 5
Shamit Saggar

Engineering a future 9
Anas Ghadouani

Practitioner perspectives 13
The engineer of the future
Jillian Formentin and Brian Haggerty

The challenges and opportunities for architecture 17
Kate Hislop

Practitioner perspectives 23
Defining 'sustainability' in architecture for 2025 and beyond
Gemma Hohen

Mitigation of climate change: Law, policy and ethics 27
David Hodgkinson

Practitioner perspectives 33
Ignited agents: the legal profession's role in the challenge of climate change
Jessica Henderson

How is economics responding to the challenges posed by climate change? 37
David Pannell

Practitioner perspectives 43
Invest in health, divest from harm
Sajni Gudka

Coastal zone management: the role of Australian universities in preparing for change 47
Charitha Pattiaratchi and Julian Partridge

Practitioner perspectives 55
The changing tide of offshore engineering
Scott Draper and Phil Watson

About UWA PPI 58

Foreword

Professor Amit Chakma, Vice-Chancellor

The political and ideological polarisation around the issue of climate change in Australia is a key feature of the policy landscape. This creates a short-term impediment to formulating evidence-rich public policy, as no-one can be confident that governments will spend political capital here when there are so many other priorities. Nevertheless, the fallout from the recent bushfire crisis, and the rising saliency of climate change among the public and business leaders, means a new political settlement seems within reach.

The role of fresh policy thinking to address different aspects of climate change should not diminish or be put on hold in the interim. There is a need for a shared understanding of the challenges ahead.

In particular, there are large and tricky challenges facing a number of professions and disciplines. These include new skills and competencies to be able to tackle particular problems (e.g. engineering of heat-tolerant public transport systems), revised mechanisms to ensure the value of current expertise (e.g. actuaries correctly modelling commercial and household risk for insurance purposes), and greater use of cross-disciplinary and cross-professional collaboration (e.g. in the design and construction of buildings).

Disciplines and professions have vital roles in shaping the future education and validation of their members. Taking a responsible and proactive stance in relation to mitigating climate change causes and effects might conceivably become central to professional standard-setting and continuing accreditation. Such changes would require consultation and professional buy-in, with non-trivial questions to resolve around how such standards and requirements might be monitored, enforced and updated.

Professional bodies in one form or another will be alive to the importance of ensuring the intellectual capital of their members remains relevant to future demands. In short, they have a responsibility to remain fit for purpose.

Universities, meanwhile, are responsible for maintaining the coherence of academic and vocational disciplines. The adequacy of their arrangements for ensuring climate change issues are addressed appropriately will come under greater scrutiny from future students, employers and practitioner bodies.

The University of Western Australia is a major global university and therefore a serious force in developing higher education of the future. We take seriously our responsibility to examine how research and teaching relates to the public good, and the global challenge of climate change could not be more integral to that mission. We have the skills and tools to tackle this agenda and we recognise that, while universities such as ours are ready to provide new ideas and research insights, we must also make the changes needed to ensure even greater contributions in the future.

I commend to you this timely report from the UWA Public Policy Institute, which alerts the academic and professional communities to fresh thinking about their own roles. Above all, the report starts a larger debate about how effectively knowledge and its application can be harnessed to prevent climatic catastrophe. It is a debate that particularly concerns Australia's political leaders, who are key stakeholders in setting national priorities for our universities.

UWA champions bold questions asked by and of researchers and practitioners. *The Preparedness Report* is further proof of our commitment to this vital community role.

Amit Chakma is the Vice-Chancellor of The University of Western Australia. He served as President and Vice-Chancellor of the University of Western Ontario from 2009 to 2019, and Chair of the Council of the Association of Commonwealth Universities from 2017 to 2019.

Introduction

Shamit Saggar

Climate change is a reality that surrounds us in myriad ways, and our understanding of its causes and consequences is the focus of ever-growing interest among researchers. As that body of knowledge expands, it is accompanied by the pressing need for its proper and nuanced translation to constituencies beyond the academy so well-informed and timely action can be taken.

This is not a report about the causes of and the science behind climate change. It is instead concerned with the response (and responsibility) of academic disciplines and professional bodies to the growing challenge of climate change. It involves so much more than questions about how human beings might take mitigating and adaptive steps that require fundamental scientific research. For instance, are our economic incentives and measures of economic value suitable? Do we have the right legal doctrines and processes to challenge existing preferences and interests to affect change? How effectively are we collaborating across the natural, mathematical and social sciences to address risks to coastal communities and economies? And, crucially, how do we go about securing the buy-in of universities and professions who will carry the weight of producing new skills and standards?

These are the sort of questions that stimulated this report. They all reflect the reality that individual disciplines and professions do not exist in isolation, rather they shoulder responsibility jointly for reshaping themselves (and each other). Therefore, rather than focus on a debate that concerns a single discipline or profession, this report's primary purpose is to sponsor a broad conversation about how a multitude of specialists can work together, learning and borrowing to accelerate change, and operate across traditional disciplinary and professional boundaries.

It is also important that this debate is started by universities, and specifically The University of Western Australia. The knowledge sector is central to the challenge because the continuing hope is that research, insight and reflection are at the core of how we address climate change. Academic disciplines are constantly in flux, whereby fresh research is cycled into key theories and principles that purport to explain existing and emerging problems. The bar is set high because university researchers and teachers pride themselves in their desire to be certain, and are understandably perturbed when predictions go awry. In recent memory, more than one pillar of economic thought was shaken by the Global Financial Crisis of 2008, so we should be alert to the need to refresh and retool in order to remain confident in our claims about what is known.

Why is climate change so hard to grapple with?

Less than a year ago, Australians saw close up the effects of summer bushfires that exceeded any recollection of seasonal norms. The front pages were dominated by the spectacle of heat, destruction and erosion of the capacity to respond to save lives and property. There was broad agreement that climate change had contributed to this moment and it undoubtedly spawned climate activism among many non-ideologically minded Australians.

However, in late 2019 the sitting government was one that had been returned earlier in the year without haemorrhaging voter support on climate change issues. Indeed, part of its appeal had come from pointing out jobs that would be threatened by downgrading the country's fossil-fuel extraction and use. The bushfire crisis has been a necessary but not sufficient factor in reformulating the national debate on climate change. Therein lies the first reason why climate change has proven so hard to address, namely that political leaders have little reason to look beyond the electoral cycle (which is unusually short in Australian national politics).

The bushfires led to a political reconsideration, if not a full reset. This is to do with the fact that voter-hungry political leaders have a legitimate interest in anticipating changing public sentiment, particularly if the tectonic plates of long-held public attitudes might be shifting.

The title of this report refers to and is concerned with preparedness among universities and professional bodies, both of which are narrow interpretations of what it is to be prepared as a nation and as a society more broadly. The title equally alludes to preparedness of the political class generally and to specific governments that will be fascinated to know whether, or how far, climate change politics have transformed. Two decades ago, in many European countries, green parties and other environmental political activists went from the margins to occupying office very swiftly. In New Zealand's recent general election, a sitting government has been returned with a bigger mandate to place climate change policy higher up its own agenda. Voters are beginning to choose a direction of travel that was until recently dismissed by conventional thinking.

The second obstacle in coming to terms with climate change relates to uncertainty in the scientific body of knowledge about exact causes and effects, an obstacle touched on by some contributors. The climate change agnostics are only too well aware that natural disasters not only occurred before our current heightened interest in climate dynamics but also cannot always be directly attributed to human activities.

This results in a complicated picture whereby the mainstream scientific consensus points to human causes for rising temperatures on the one hand but is naturally reluctant to attribute such causes to any one disaster. Edward Luce, a prominent journalist, notes that even our words for conveying information and meaning can muddy the true picture[1] – for instance 'global warming' will tend to elicit a dramatic sense of a planet in peril, and contrast with 'climate change', which, he argues, evokes a vague sense of continuing oscillations as old as time and without a feeling of urgency. Why, he asks, do we have a need to preface 'disaster' with 'natural'?

But uncertainty is in itself no roadblock. An urgent call to action arises by fusing together insights about electoral cycles and uncertainty: if voters are worried, they are also consumers and citizens who can exert pressure of their own. The results are more climate awareness, greater civic activism and pressure on big business to address climate risks. Placed together, public opinion and business practices can become an additional important driver for policy reform. ING, a Dutch-based global financial lender, led others in its sector to establish the Collective Commitment to Climate Action, placing a responsibility on signatories to "facilitate an economic transition required to achieve climate neutrality". Governments and regulators have lagged behind this kind of initiative.

Finally, grappling with climate change, like so many other things, is thwarted by point scoring, prejudice and playing to the crowd. The reality is that individuals, working together, lead universities, professions, businesses, campaign bodies and governments – and this means that coalitions of support have to be created and maintained. In any typical democratically elected government, specific political leaders have found that getting climate action going cannot be treated in stand-alone terms. Deals have to be hammered out, trade-offs have to be acknowledged and quid pro quos have to be conceded.

This is a harsh truth, certainly. On the positive side, such leaders also have the ability, at least, to adopt a serious posture towards scientific evidence, using the fruits of empirical research to inform how they use their limited political capital. Related to this is another tool, namely embracing and investing in even better-informed evidence and inquiry. These are the very resources many of the authors of this report highlight as part and parcel of their arguments about their own specialist fields. In other words, we have a broad understanding of the implications of climate change for future oceanographers, engineers, lawyers, economists, public health professionals and architects reflecting the various essays that follow in this volume. An even more valuable contribution made by our writers is to challenge their peers to think more imaginatively and rigorously about climate change.

The challenges facing disciplines and professions

This report is the first of its kind. The contributors have assessed how different specialist fields of inquiry, academic disciplines and professions will have to adapt due to climate change. Zooming in on a small group of examples, the authors presents answers to questions such as:

- How will climate change impact in practical terms on the feasibility, processes, sustainability and operations of their respective professions?
- How will these professions have to evolve and adapt in order to keep pace with those changes?
- How will future members of the respective professions need to be educated and trained?
- How will the underlying disciplines change? Which new fields of research and education will emerge?
- How will different disciplines have to develop new cross-overs and synergies?
- How will academic and professional leaders find fresh ways to come together to take action against further global warming?

1 Edward Luce, 'The three hard truths behind climate change complacency', *Financial Times*, 6 January 2020.

The main challenges our authors raised

In reflecting on these questions, the authors put forward their own assessments of where the collective mind of their discipline sits in coming to terms with what climate change means for them. By contextualising the effects of climate change in specific fields and professions, they not only illustrate the manifold challenges we have in front of us, but help reframe the problem and the solutions on offer in ways that may inspire innovative thinking and eagerness to learn from other areas.

There is consensus on the need to abandon a silo-like perception of different disciplines and professions when it comes to tackling the challenge of climate change. It lies in the very nature of this global and complex challenge, but it is also a consequence of the realisation that no single response will suffice in addressing it. And while the authors of this report skilfully demonstrate what their specific fields of work need to, and can, change and do differently, they specifically point to areas with high potential for cross-disciplinary collaboration. As Jillian Formentin and Brian Haggerty put it, "What seems impossible individually is achievable collectively". This applies not only to bringing all members of any one profession on board and to the level of required preparedness, but equally to forming new alliances across the disciplinary borders. This is a point particularly well illustrated by Julian Partridge and Chari Pattiaratchi, who outline the competencies likely to be required in a multi-disciplinary team addressing coastal-zone climate change mitigation options.

Another common feature of preparedness across disciplines revolves around effective translation and communication of science and expertise to members of other professions and the general public. This lies at the heart of the UWA Public Policy Institute's rationale of working towards solid, evidence-based policy responses. It ties back to the ability to inform the direction of national and state policies that cut across partisan lines and are designed based on the best available research and insights from those working on practical solutions to the various manifestations of climate change. As Sajni Gudka notes, universities have a critical role to play in "incorporating science-communication skills development across all curriculums" and "encouraging researchers to use their scientific voice, and engage in health and climate discussions".

There is a range of other challenges our authors identified within their respective fields. While some are more practical in nature – for example, how they can shrink emissions and create sustainability within their own internal operations, as described by Jessica Henderson with respect to law firms that increasingly display 'climate conscious' practices – they also describe a few fundamental theoretical and ethical problems that need to be addressed.

David Hodgkinson raises some of the tough ethical considerations of climate change, such as 'putting a price tag on time' and the responsibility of the present generation for the wellbeing of future generations. On a related point, David Pannell explains the concept of 'discounting': the process used by economists to express future benefits as present values, so decision-makers can weigh them up against current costs of taking action. He concludes that "the question of how to consider inter-generational equity and general uncertainty in discounting remains an unresolved challenge". Still, lawyers and economists have grappled with these uncomfortable truths for a long time and can help bring transparency into the climate change debate by spelling out underlying conceptual questions.

> "Lawyers and economists have grappled with uncomfortable truths about inter-generational equity for a long time and can help bring transparency into the climate change debate by spelling out underlying conceptual questions."

Kate Hislop casts the challenge of preparing the architecture discipline, profession and industry for climate change in the context of the current COVID-19 pandemic and governments' responses to it. She notes that "it seems clear in the current circumstances that mitigation of climate change and boosting economies represent conflicting priorities" and that with "a business-as-usual mindset, 'shovel-ready' may not align with 'Building Back Better' and 'ZERO Carbon Design'". Yet, if we can harness some of the innovative thinking and change in behaviour that has sprung from the necessities of the public health emergency and related economic crisis – such as working from home leading to dispersion from cities into the suburbs – there is no reason why the economic recovery cannot also bear environmental opportunity.

Speaking to environmental opportunity, Scott Draper and Phil Watson discuss how concerns about the impact of climate change are driving the development of new and emerging industries, such as marine renewables and hydrogen. These new fields require expertise and know-how that is oftentimes readily available, but the application of which demands abandoning a business-as-usual mindset and the adoption of innovative thinking. Gemma Hohen, making a similar point, underscores the crucial position of educational institutions in equipping future professionals with knowledge and skills, as well as in providing the space to test new approaches and solutions.

A common thread throughout the report, and a point that is familiar from public discourse, is the discrepancy between what is commonly known and understood about the urgency of addressing and mitigating climate change, and the rate of action taken. It seems most disciplines are cursed with the problem of relating the fullness and catastrophic nature of climate change consequences while those changes occur gradually rather than suddenly. Picking up the problem of discounting, it is a dilemma that needs to be addressed by creating different and better means of delivering the message so that it will resonate with the wider population. It becomes clear that there is a need to fill key gaps in understanding motivation for action and inaction. The role of psychologists, anthropologists, journalists and creative professions in this regard cannot be overlooked.

Finally, Anas Ghadouani makes the significant point that climate change and its implications for the different professions are accompanied by a re-appreciation of their role(s) within society. With increasingly higher levels of awareness among the wider public of the threat climate change poses to our environment (and way of life), the expectations it places on companies and members of certain professions are changing too. This goes both for the general social licence to operate in a way that is environmentally more sustainable, as well as expectations on specific professions, such as engineers, to actively come up with solutions that will mitigate climate change. And while it is clear living up to those heightened requirements for legitimacy will be accompanied by challenges, there is also an opportunity to reimagine, in bold terms, how we do things and take more seriously the responsibilities that come with representing our respective fields and professions.

Structure of the report

The Preparedness Report is organised to give readers a broad overview of how different fields are approaching climate change-related questions. The original scope extended to more than twenty-five specific fields, ranging from the usual suspects (engineers, architects, etc.) to those that are easily overlooked when we cast our mind to climate change-driven challenges (journalists/communicators, public servants, emergency services etc.). We have zeroed in on a generous handful of examples to demonstrate real resonance but have deliberately chosen not to swamp readers with endless case studies. The hope is other disciplines and professions can be brought into scope through further similar reports and projects, and through comparisons being drawn across existing boundaries. We leave open the question of how other sectors, tactically overlooked in this report, will now respond.

The report puts the spotlight on six areas: oceanography (principally the concern with coastal zones, itself an amalgam of various disciplines including biology, engineering, archaeology and several others); law and the legal profession; economics; architecture; healthcare; and engineering. It features contributions by some of UWA's most notable experts, as well as a number of shorter pieces written by professional practitioners and campaigners in order to provide a flavour of the challenges involved from these vantage points.

Acknowledgements

I am enormously grateful to our team of authors, who all embraced the task with excitement and a healthy temperament. They are all significant figures in their respective fields, and it was heart-warming to see their eagerness to tackle the larger exam question that underscores this report.

I am indebted to Bruce Webber (CSIRO Health and Biosecurity and CSIRO Land and Water) who helped plant in my mind the germ of the idea behind this report; to Jillian Formentin and Brian Haggerty (WA division of Engineers Australia) for collaborating on an early policy event on the subject matter of this report; to David Rice for his approach to suggest that collaboration; and to my UWA colleague, Anas Ghadouani, for his typical enthusiasm in giving a keynote address at that event.

I would also like to thank the UWA Public Policy Institute team, Anneke Forster and Anna Zenz, for all their hard work in getting this project across the line.

Finally, I would be remiss if I did not recognise the important influence of Reuben Saggar in his efforts to raise mainstream awareness of climate change, and what should and can be done in response.

Shamit Saggar is the Director of the UWA Public Policy Institute and Professor of Public Policy at The University of Western Australia. He is also Visiting Professor at the Policy Institute, King's College, London.

Engineering a future

Anas Ghadouani

Engineering and industrial economies are substantially intertwined, and this reality means engineers are perforce caught up disproportionately in the challenges of climate change. We need to remember engineering is an academic discipline and profession unlike many others. A modest reform or revision in how engineers are taught or required to perform could therefore provide a larger step in the right direction.

"A sense of helplessness and short-termism is no excuse for inaction on climate change."[1] This rebuke by former justice of the High Court of Australia, The Honourable Kenneth Hayne AC QC, was initially directed at boardrooms, but it should be on the mind of every engineer, not least because of the close relationship engineers maintain with boardrooms. Engineers not only designed and built the industries that most contributed to significant increases in greenhouse gas emissions, they are also the ones everyone will turn to for solutions to those very problems we are facing today. Consider, for instance, the fact that the sectors at the top of the emissions pyramid, including transport, electricity production and manufacturing, contributed over 75 per cent of emissions[2], with the remaining quarter attributable to residential, agricultural and land-use changes. These top emitting sectors have been primarily flush with engineers and engineering companies.

The time has come for engineers to step up to the task of engineering a better future.

I will argue that engineers' professional involvement and their long historic role of, quite literally, building the foundations of civilisations, places them in a unique position. In the modern context, engineering is the profession that applies science to design solutions. While there are questions around the causes and the extent of humanity's role in driving climate change (and it may still be a matter of belief and ideology in some quarters), the public support and expectation for engineers to come up with the solutions to reverse or reduce climate change is overwhelming. What if this is the opportunity of a lifetime for engineers to act upon the social licence handed to them? Could this lead to a renaissance age of engineering in Australia and the world? Could it mean a transformation of the way engineers see their role within society?

> "What is at stake for engineers is the chance of a renaissance age of engineering in Australia and the world. It could mean a transformation of the way engineers see their role within society, and are seen by others."

Is climate engineering part of the solution?

Engineers are usually very comfortable with running numerical models and testing some of the outcomes on physical models before scaling up solutions. This mindset has led to a number of suggestions and the development of a whole field of climate engineering, also known as geo-engineering. While this is considered extreme by many, the ideas and modelling are underway. In very simple terms, climate engineering aims at taking on the giant and extraordinary task of controlling climate systems. This ambition may be seen as excessive given the extraordinarily large scale of climate systems, but it is theoretically possible to think about large-scale interventions in order to strip carbon dioxide out of the atmosphere and into large storage systems, or even rapidly cooling the earth by redirecting and controlling solar energy.

1 James Fernyhough, 'Hayne rebukes directors on climate risk failure', *The Australian Financial Review*, 9 December 2019.

2 United States Environmental Protection Agency, *Sources of Greenhouse Gas Emissions*, 2020.

Is it then unthinkable that humans could tamper with climate systems and develop ways to control the ocean circulation through artificial downwelling (large-scale movement of nutrient-rich cool water from depth to surface waters, resulting in increased productivity), ocean fertilisation, ocean alkalinisation, or solar radiation management? It is certainly theoretically possible, and many models have shown the benefit from one or the other such large interventions. However, Keller et al[3] cast some doubt on the practicality and/or the desirability of such interventions, given their limited effectiveness, as well as the potential undesirable side effects. Some may also argue that some of the problems facing society have emerged as a direct or indirect result of large-scale engineering interventions. How should we interpret those intervention now, armed as we are with a current understanding of their impacts? Could these ideas pass 'the academic pub test'?

The end of engineering as we know it

As the challenges facing society are becoming more complex, requiring multidisciplinary skills and more public accountability, as well as global consideration, engineers are now asked to integrate big-picture thinking, system integration, environmental stewardship, and sustainability requirements into projects. To meet the competing expectations of the public and the various stakeholders involved in engineering projects, a fresh approach is needed. Gone are the days when engineers had the somewhat easy task of designing the technical solution and ensuring accuracy and reliability of their design while only having to live up to minimal public accountability. While a number of sectors have and will see more changes imposed by digital transformation, perhaps the biggest challenge facing engineering is the globalisation of issues such as climate change or waste, which manifest in drastic changes in public expectation and the social licence to operate.[4]

These unprecedented trends in public expectations towards engineers were recently further highlighted by the COVID-19 pandemic. Living up to those expectations will require not only adaption in the way engineering work is delivered, but also the fundamentals of how engineers are trained. There is a shift towards the inclusion of more than just technical competencies, also broader attributes such as emotional intelligence and interpersonal skills, digital intelligence (such as robotics, artificial intelligence, digital technologies and big data), as well as ethical and societal considerations. What are the implications of these changes on the overall practice of engineering in Australia and the rest of the world, and what are some of the risks associated with this broadening of expectations? How challenging could the layers of accountability imposed on engineers become? I will argue that while there are

3 David P. Keller, Ellias Y. Feng and Andreas Oschlies, 'Potential climate engineering effectiveness and side effects during a high carbon dioxide-emission scenario', *Nature Communications*, 5, 3304, 2014.

4 Caroline Crosthwaite, *Engineering Futures 2035: A scoping study*, Australian Council of Engineering Deans (ACED), 2019.

some undeniable hurdles that lie in the nature of any change, the opportunities overwhelmingly outweigh the challenges.

This is the start of the rebirth of a new engineering.

The urgency of this conversation can be illustrated through two vastly different examples. The first concerns catastrophic failure of mine tailings dams, and the second relates to water security for Western Australia. These two problems are linked by the fact that both have been exacerbated by climate change and both are traditionally the domain of engineers.

Increased risk of failure of mine tailings dams

Since the 1960s, tailings dams have failed at a much higher rate than any other water retention infrastructure and, more alarmingly, the high rate of failure has *remained* very high.[5] The causes of each failure are unique, and involve complex combinations of geotechnical as well as environmental drivers. The results have been disastrous, with both economic and environmental impacts on neighbouring populations. It has also been suggested that the rate of failure is much higher in developing countries. There is no doubt the observed shifts in climate systems resulting in extreme events are likely to significantly increase the risk of failure of tailings dams.

"Design parameters for Tailings Storage Facilities (TSFs) are becoming ever more demanding," says Andy Fourie, a professor of Mining Engineering at the University of Western Australia and a world-renowned expert in mine tailings failure. "This is in the aftermath of a number of recent catastrophic failures. Changes in rainfall intensity of extreme events is an increasingly vexing problem for operators of TSFs."

The suggested disproportional impact on developing countries can be attributed equally to the increase in extreme weather events and the less stringent environmental and operational practices. These circumstances are likely to result in increased severity of any future failure, and there is no doubt these failures will continue to occur in the future at predictable higher rates. The response requires radical changes to the design and the operation of all new tailings infrastructure until a proper management of legacy infrastructure is secured.

> "The new orthodoxy requires balancing the social, environmental and economic impact of any water investment, large and small."

With more than 3,500 tailings dams distributed worldwide, there is not only a monumental task ahead for the affected operators and companies, but also their governments, populations, economies and environment. With billions of tonnes of toxic waste produced every year by the mining industry, there is an urgent need to develop a much deeper knowledge about the risks associated with tailings dams,[6] as well as the implementation of new and upgraded design criteria that take into account the global, regional and local environment and climate conditions.

This issue is likely to be the single highest-risk item at the top of the agenda of many global operators and governments. What role will engineers play in tackling this problem?

Water security and sustainable cities

On another front, water security is a necessary ingredient of any sustainability plan for cities and communities. Major climate shifts have occurred around the world, resulting in a significant decline in precipitation and major disruptions to water supply. For example, Perth's own rainfall recorded a historic low in 2010, with the equivalent of five to ten per cent the amount of rain in comparison to historic record highs, according the Water Corporation of Western Australia.[7] The steady decline since the early 1900s has led to major decisions by the Government of Western Australia to transition to desalination technology as the main water supply for years to come.

To some extent, the adoption of large-scale centralised technology was a last-resort measure that had to be deployed urgently, given the dire situation of rainfall in the early 2000s. Two major desalination projects and one major groundwater replenishment scheme later (and considering the projected doubling of the Australian population by around 2050), it is now, surely, time to talk about securing water supply.

Western Australia has historically resorted, in critical times, to major investment in large-scale one-off engineering solutions – most notable is the Goldfields

5 Zongjie Lyu, Junrui Chai, Zengguang Xu, Yuan Qin and Jing Cao, 'A Comprehensive Review on Reasons for Tailings Dam Failures Based on Case History', *Advances in Civil Engineering*, 2019.

6 J.R. Owen, Deanna Kemp, Éléonore Lèbre, Kamila Svobodova and G. P. Murillo, 'Catastrophic tailings dam failures and disaster risk disclosure', *International Journal of Disaster Risk Reduction*, 42, 101361, 2020.

7 Water Corporation, *Perth Rainfall*, 2020.

Water Supply Scheme, which has been considered an engineering marvel and has received many engineering awards and accolades. This project ensured the growth and prosperity of the state at the time, and today still contributes billions of dollars to economy and ongoing prosperity of Western Australia.[8]

But can we really rely on major engineering solutions for securing the water supply for the future? The short answer is no.

While the size of the investments (billions of dollars) is usually prohibitive for such solutions, centralised systems have limitations when it comes to ensuring supply for large areas like Western Australia. Additional costs of transporting water to various localities will make decentralised systems a less attractive economic solution. This is in addition to the changing expectations of the public, who prefer solutions that are local, with accompanying light footprints and environmentally suitability.

Gone are the times when the provision of water was the business of engineers alone. The new orthodoxy requires balancing the social, environmental and economic impact of any water investment, large and small. Maximising public participation in the decision making is required; as such, the engineers in charge of developing those solutions must be attuned to the public's expectations and will require a much better understanding of stakeholder management, as well the ability to design unique solutions that are not 'off-the-shelf'. Traditional engineering disciplines have for years relied on standards that have not followed the rate of the change in societal expectations.

Public perception is that engineers remain a barrier to any modernisation in water management that encompasses new approaches, such as integrated water management, water-sensitive cities or water-wise cities. While there has been some significant improvement and adaptation of engineering works, the engineering profession will have to undergo a major paradigm shift to be able to deliver the integrated solutions a climate change-aware society expects. The road ahead is full of challenges, but also has great opportunities to ensure solutions lead to enhanced societal and environmental outcomes.

This is the time for engineers to revamp the engineering toolbox, to reach out and demonstrate to the public their unwavering commitment to correcting the mistakes of the past, and to renew their pledge to make the world a better place. Many companies have adopted (and in some cases adapted) the United Nations Sustainable Development Goals as a road map for a sustainable future. Engineers will need to deepen the links with society by forming the right partnerships for the goals.

Anas Ghadouani is Professor and program chair of environmental engineering at The University of Western Australia. He is passionate about teaching and research in water and wastewater engineering, sustainable cities, waste management and environmental policy.

8 Department of Agriculture, Nature and Environment, *National Heritage Places - The Goldfields Water Supply Scheme*, Australian Government.

Practitioner perspectives

The engineer of the future

Jillian Formentin and Brian Haggerty

Engineers take scientific understanding of the natural world and use it to invent, design and build things to solve problems and achieve practical goals.

We play a fundamental role in maintaining and improving the quality of life. Engineers help provide infrastructure for society's basic needs: water, energy, transport links, buildings and communications. It is this infrastructure and their associated functions that enables industries to develop prosperity for the nation.

Challenges with which we are often faced include making the right decisions regarding the economic viability of a project over its lifetime, the choice of materials for their aesthetics as well as performance, and the potential long-term impacts on the environment – locally and globally. The safety of people is a fundamental and critical consideration throughout all stages of the project life cycle, from engineering design and construction through to the use of the facility or product, ongoing maintenance and potentially decommissioning.

Much of our effort is invested in the management of risks, with those with the largest and the most immediate consequences getting the most attention.

Engineers are instinctively drawn to adaptation. History is full of examples where engineers have leveraged emerging science to innovate, realise new solutions to problems and change the world.

Issues of climate change have quickly become real and consequential for many engineers. Some of Australia's most important assets are in areas at risk of climate change impacts, such as:

- sea level rise, tidal flows to estuarine areas, inundation of low-lying areas
- change in rainfall patterns (increase in some areas and drought in others)
- extreme weather events – floods, storms, cyclones, heat
- increased potential for bushfires
- increased potential for injury or death due to extreme heat days and changes in disease transport
- exposure of infrastructure assets to changes in temperature, and
- changes to environmental and natural ecosystems.

The effects of climate change are being felt across Australia and are likely to increase in the future, with little likelihood of reversal in the medium term. It falls to us to manage climate change risks through implementation of adaptation measures. This can impact on engineering design implications, such as where to locate infrastructure, levels of infrastructure redundancy in tandem with sufficient future-proofing, and consideration of disaster and emergency planning.

> "History is full of examples where engineers have leveraged emerging science to innovate, realise new solutions to problems and change the world."

What the future needs of us as engineers

Engineers must develop sustainable solutions for all facilities we design, build, operate and decommission. At the same time, engineers need to reduce the systematic underweighting of catastrophic risk from climate change in decision making, and embark on a reassessment of facilities being used now.

We need to ensure infrastructure is resilient. For example, electricity infrastructure needs to adapt rapidly to distributed generation, such as rooftop solar. Security of resources and services must be developed through geographical diversity. This means a better spread across diverse geographic locations, thus reducing the odds of devastating impacts from a single disaster (e.g. damaging winds from cyclones, bushfires with smoke impacting solar, or rising sea levels inundating coasts). Similarly, having diverse sources of energy provides greater availability, rather than a monoculture. The effects of climate change are causing power and data outages. We must maintain analogue methods for resilience and operational flexibility in case of, for example, the loss of internet/communications (such as in recent Australian bushfires).

Business cases need to consider the embodied energy cost of an investment over its lifespan, including operational emissions. Other costs, such as water use or waste production, might also be modelled in the same way.

Waste is a resource. Engineers can lead the transition from a linear to a circular economy and play a critical role in improving product life cycle design. For example, we need to engineer better packaging with less material and better ability to be recycled.

We need to be able to argue the business case for sustainability in our respective organisations and communities, and respond to the fundamental changes in community and societal expectations. We need to develop our capability to provide public positioning on sustainable development, and engineering professionals and researchers need to explore the challenges presented by climate change and the likely impacts on engineering standards, training and policy.

What engineers need to provide for that future

To realise these objectives, engineers need knowledge and learning on the principles and practice of sustainable development. Ongoing review of our current knowledge and learning stockpile is key to ensuring it is relevant to the present and future environment.

We need to learn together how to navigate the increasing complexity and demands of the world in which we live.

This transformation in our thinking can be referred to as 'adaptive change', something that is very different from the 'technical change' that occupies engineers on a regular basis. Technical problems, while often challenging, can be solved by applying existing know-how and the individual's and/or organisation's current problem-solving processes.

Adaptive problems rely on individuals throughout the organisation or community to alter their ways; as the people themselves are the problem, the solution lies with them.[1]

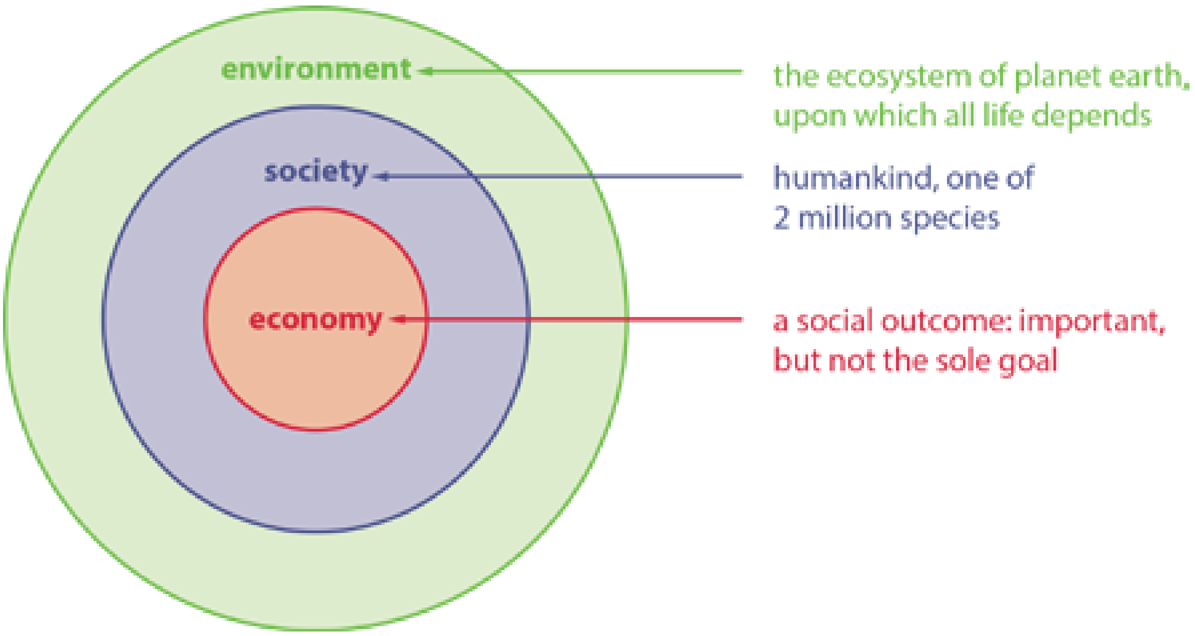
Meeting the adaptive challenges of climate change requires the collaboration of engineers and other professions and disciplines to more fully understand the relationship between environmental, social and economic conditions – recognising we all live in and are fully dependant on the environment. These conditions form an interdependent system, as shown below.

Engineers should seek greater leverage of knowledge and expertise from universities and other research institutions such as CSIRO. We need jointly to develop technological and organisational solutions to the challenges and opportunities of sustainable development.

To do it well, engineers and the research institutions need to be more responsive and collaborative to capture the value of those solutions. For example, the world is moving too fast for the traditional, given timeframes to update engineering technologies and standards, or to develop and implement research.

What engineers can do to ensure their skills and purpose remain relevant to climate change-driven problems

Engineers must consider the sustainability and resilience of the performance of existing assets, and acknowledge that a substantial proportion of infrastructure is significantly under-designed for credible future scenarios. For example, extreme weather events have increased in intensity since the original design. This means that infrastructure designed for a 1 in 10,000-year event may now only survive a 1 in 100-year event – that is, one hundred times the risk! This has far-reaching consequences for public safety, risk, insurances, and so forth.



1 Ronald Heifetz and Marty Linsky, 'A Survival Guide for Leaders', *Harvard Business Review*, June 2002.

Collectively, engineers can influence public policy. We have a trusted voice in the debate and can provide knowledge and insight to influencers and decision makers.

We need to strengthen our influence on business, continue to demonstrate that 'sustainability is good business', and engage directly with professional engineer employees.

What seems impossible individually is achievable collectively

As individuals, sustainability is an impossible mission. Thus, it is only achievable collectively through building and utilising relationships across humankind.

For engineers to bring the knowledge, understanding and confidence needed to influence, as well as achieve, more sustainable outcomes, they need access to a body of knowledge, skills and developmental tools that is relevant, up-to-date and anticipates future needs.

Engineers Australia is assisting nearly 100,000 members on their journey to managing complexity, ambiguity and a changing social and political environment. It is building the capability of engineers to engage in longer-term thinking to ensure enhanced community confidence that we, as a profession, have the understanding to guide policy on sustainable development.

Engineers Australia is also providing a collective voice for timely communications on issues and as crises arise, and that advice is accepted and implemented. Our success is hinged on being collaborative and adopting an adaptation mindset. To do this, we need to continue to:

- work directly with the public to ensure public concerns and aspirations are consistently understood and considered
- look for direct advice and innovation in formulating solutions
- collaborate with universities and other educators to access cutting-edge science and research
- partner with the public in each aspect of decision making, including the development of alternatives and the identification of preferred solutions, and
- implement the best solutions for the betterment of all.

Through Engineers Australia, engineers are providing direct input to the development of public policy, as advisers to government agencies like Infrastructure Australia, state infrastructure organisations, and other bodies.

Through the collaboration of committed volunteers, Engineers Australia has published a comprehensive guideline for engineers, *Implementing Sustainability: Principles and Practices,* which is forming the basis of future training and development.

Engineers do things in a variety of ways, whether it is through designing new systems, infrastructure, machines and equipment or coming up with solutions to problems and implementing them. This is what makes engineers valuable to the continued operation and success of many industries, and we need to ensure we are relevant and in service to the quickly changing future.

Jillian Formentin is the President of the WA Division of Engineers Australia. Jillian started her career as a Project Leader, Operations Manager and Principal Engineer of gas supply, distribution and storage facilities, before specialising as a consultant in team performance and risk management in heavy industry. Jillian produces workplace cultures of responsible leaders creating environments that are productive, sustainable, safe and satisfying.

Brian Haggerty is the Deputy President of the WA Division of Engineers Australia. He also is Adjunct Professor at UWA and VP, Innovation Capability at Woodside Energy Ltd. He is passionately interested in ensuring current and future engineers have the capability and skills to adapt to a rapidly changing world, including digital and sustainability opportunities.

The challenges and opportunities for architecture

Kate Hislop

In 2020 the urgency with which the global community needs to address climate change has been harshly illuminated. Key events have reinforced the need for preparedness, but also the realisation that we are currently neither sufficiently prepared nor in the process of preparing.

In the past 12 months, major fire events have seen millions of hectares burn, starting with the Amazon in September 2019. As Greta Thunberg delivered her speech, 'Our house is still on fire', in January 2020 at the World Economic Forum in Switzerland, bushfires were scorching Australian bushland and towns. Accompanied by summer fires raging on the west coast of the United States, the word 'unprecedented' to describe the ferocity of the heat and loss of forest, wildlife, buildings and human life has resounded throughout the year.

Before the flames had waned in Australia, the new COVID-19 virus exerted itself: almost a year later, a million lives have been lost worldwide, livelihoods are suffering and the global situation is not abating. Advocacy and lobby groups are drawing attention to the crises, attempting to provoke action by governments, corporations and individuals alike.

Commentary of all kinds and from the full political spectrum is flourishing, debating the relationship between climate change and COVID-19 as well as the influence of each upon lifestyles, work habits, communications, technologies and environments.

The global reach and impact of these phenomena, broadcast via conventional news outlets and social media platforms, is a new and evolving experience at both personal and societal levels.

The pandemic has problematised attitudes towards climate change. In response to present-day pressures the world is preoccupied with looking forward. This is not surprising as the situation would potentially otherwise be overwhelming: it affords a feeling of control over future actions and outcomes.

However, there are two related factors that can be seen as impeding our preparation for climate change and its associated challenges. The first is the relative inconspicuousness from mainstream consciousness of the 'long view' of historical thinking, without which we are destined not to learn from the past. The second is the rampant globalisation that has compressed experience and communications with increasing rapidity into the immediacy of the digital present.

This has affected how we encounter and measure time and space, privileging the 'here-and-now' and the short term over an extended and deeper understanding of the past that could frame our actions for today and tomorrow. Along with a diminished sense of the collective beneath the privileging of the individual, the combined effect of these factors has been a reduced appreciation for the broad contexts, scales and impacts of human activity. This, in turn, has exacerbated the mounting social, economic and environmental fragility that is a feature of our time.

Our modern experience of globalisation as predicated on three phenomena with spatial and environmental consequences: mobility, dispersion and density. In circular fashion, globalisation has both facilitated and been aided by these factors.

It is not coincidental that the growth in technologies enabling mobility *en masse* and across great distances (starting with rail in the early nineteenth century) occurred in step with the emergence of the suburban ideal across the United Kingdom, the United States of America and Australia. Since the late Middle Ages, each wave of global migration has precipitated mobilisation of populations and diversification of cultures, with consolidation and proximity of people continuing to advance towards the highest urbanisation rate that the world has ever seen. Until now, perhaps.

The spatial and environmental consequences of globalisation are of particular relevance to this chapter in *The Preparedness Report*, which looks at the challenges of climate change facing the discipline and profession of architecture.

Discipline, profession or industry?

In general terms, the challenges emanate from the core of architecture's broad remit and relate to its complex origins and traditions as a discipline, its status as a profession, and its place within the construction industry. Across these modes, questions of climate change impact upon architecture and have to be addressed in practice (including through policy and regulatory frameworks), through the educational and research agendas of universities, and, additionally, in the internal sustainable operations of both.

As a discipline, at least in the Western tradition, architecture inherits from ancient times the Vitruvian ideals of the architect possessing theoretical and practical knowledge spanning art, science and nature and, most famously, of buildings demonstrating the triad of firmness (stability), commodity (usefulness) and delight. The sense in which it is understood today as a design discipline further extends from the Italian Renaissance, and from the earliest school of architecture, the Seventeenth Century École des Beaux Arts in Paris.

With the nineteenth century transition to a profession – essentially an Anglo-Saxon invention occurring roughly in parallel with the Industrial Revolution – came ethics, fees, and regulation leading to the protection of the title, 'Architect'. Through this process it became distinct from allied fields such as engineering. Such is the background leading eventually to architecture as a regulated profession in Australia in the early twentieth century.

Perhaps the most pressing issue, prevalent through the later twentieth century but heightened in the pandemic context, is the enmeshing of architecture within the powerful construction, manufacturing, development and financial sectors. Architecture is typically not seen as a driving force in this wider field and yet it is arguably the discipline best placed to perform the synthesising task of evaluating and reconciling the multifaceted demands and criteria to be met in the design and delivery of buildings.

Architecture's expansive identity – as discipline, profession and industry – is a strength inasmuch as it underpins the generalist nature of the training and practice of architecture. Even in its more specialised modes, it remains an occupation that strategically and artfully synthesises a variety of factors and coordinates the input of specialist consultants.

Buildings are complex and enduring objects and systems that support human as well as non-human activity and requirements. The Vitruvian thinking of architecture as spanning the arts and sciences continues to be the inspiration for practitioners today and informs in very broad terms the educational models found in architecture programs around the world.

The economic challenge

Data sets and experts offer figures that underline the architectural challenges that are specifically related to the design, construction, maintenance and use of buildings and their urban settings. McKinsey & Company's 'The 1.5-degree challenge' calculates the decarbonisation required to reduce temperature rise by 2030. According to their data about 40 per cent of CO_2 emissions come from the power sector; 15 per cent come from deforestation (14 million hectares – almost three times the amount of bushland burnt in Australia's January 2020 bushfires – are deforested each year); and 7 per cent come from cooking and heating in buildings (with space and water heating being the two largest contributors of building emissions).[1] Since buildings are major consumers of power – in their construction as well as use – and necessitate land clearance for the creation of sites, this data points clearly to where savings can be made.

> "Industry transformation to lower CO2 emission involves: regenerative design, adaptive reuse, life cycle costing, carbon modelling, post-occupancy evaluation, waste minimisation and adoption of low embodied carbon materials and systems."

1 Kimberly Henderson, Dickon Pinner, Matt Rogers, Bram Smeets, Christer Tryggestad and Daniela Vargas, 'Climate math: What a 1.5-degree pathway would take', *McKinsey Quarterly*, 30 April 2020.

The 'Australian Architects Declare Climate & Biodiversity Emergency' website states that "globally, buildings and construction [account] for nearly 40 per cent of energy-related carbon dioxide (CO_2) emissions whilst also having a significant impact on our natural habitats". Australian Architects Declare was formed following the launch of the founding UK group in May 2019, and branches have since multiplied around the world. All have signed up to a range of initiatives aimed at raising awareness of the climate and biodiversity emergencies to drive changes in thought and practice across the design and construction sector.

Regenerative design, adaptive reuse, life cycle costing, carbon modelling, post-occupancy evaluation, waste minimisation and adoption of low-embodied carbon materials and systems are some of the key aspirations guiding industry transformation to lower CO2 emissions. Similarly, modelling by McKinsey & Company shows the need for major annual uptake of renewable energy sources (solar and wind), increased recycling of materials, substitution of low-carbon alternatives, carbon capture and reforestation to achieve the desired 1.5 degree temperature reduction in the next decade. All of these strategies are directly related to the design, construction, maintenance and occupation of buildings and as such form an essential part of architecture's concern.

In response to the projections and targets, initiatives such as 'Building Back Better' (BBB) have emerged in recent years, involving recovery planning alongside sustained investment and behavioural change.[2] This has found new relevance in 2020 following the Australian bushfire crisis.

Furthermore, the Australian Institute of Architects' 'ZERO Carbon Design' Series (developed by UWA Adjunct Professor and former Global Executive Chair of Woods Bagot Architects Ross Donaldson) is a commitment to prepare architects and the construction industry to meet the challenges of climate change, embracing the target of a zero carbon economy. Timeliness is of the essence, however, and the targets of BBB and ZERO will be achievable only through education and training, and only if implementation occurs with substantially increased pace and take-up. Key to success also will be government support through policy and investment.

In parallel with these initiatives is the Federal Government's budget commitment of $14 billion to new and accelerated infrastructure projects across Australia over the next four years. This promise has been reinforced by the recent Western Australian Government's announcement of a $2.7 billion spend on infrastructure,

> "Mitigation of climate change and boosting economies represent conflicting priorities. If following a business-as-usual mindset, 'shovel-ready' will not obviously align with 'Building Back Better' and 'ZERO Carbon Design'."

intended to boost the State's pandemic-impacted economy through job creation.

Investment in infrastructure to spur economic growth is a familiar enough strategy, favoured after major downturns. Around the world, governments and private sector firms are looking to the building and construction industry to stimulate employment. 'Shovel-ready' programs have been launched along with planning reform to fast-track building projects, creating thousands of jobs across a range of areas.

In this situation, architecture will be a contributor to infrastructure projects while at the same time acknowledging the likely negative environmental cost of doing so. It seems clear in the current circumstances that mitigation of climate change and boosting economies represent conflicting priorities: if following a business-as-usual mindset, 'shovel-ready' will not obviously align with 'Building Back Better' and 'ZERO Carbon Design'.

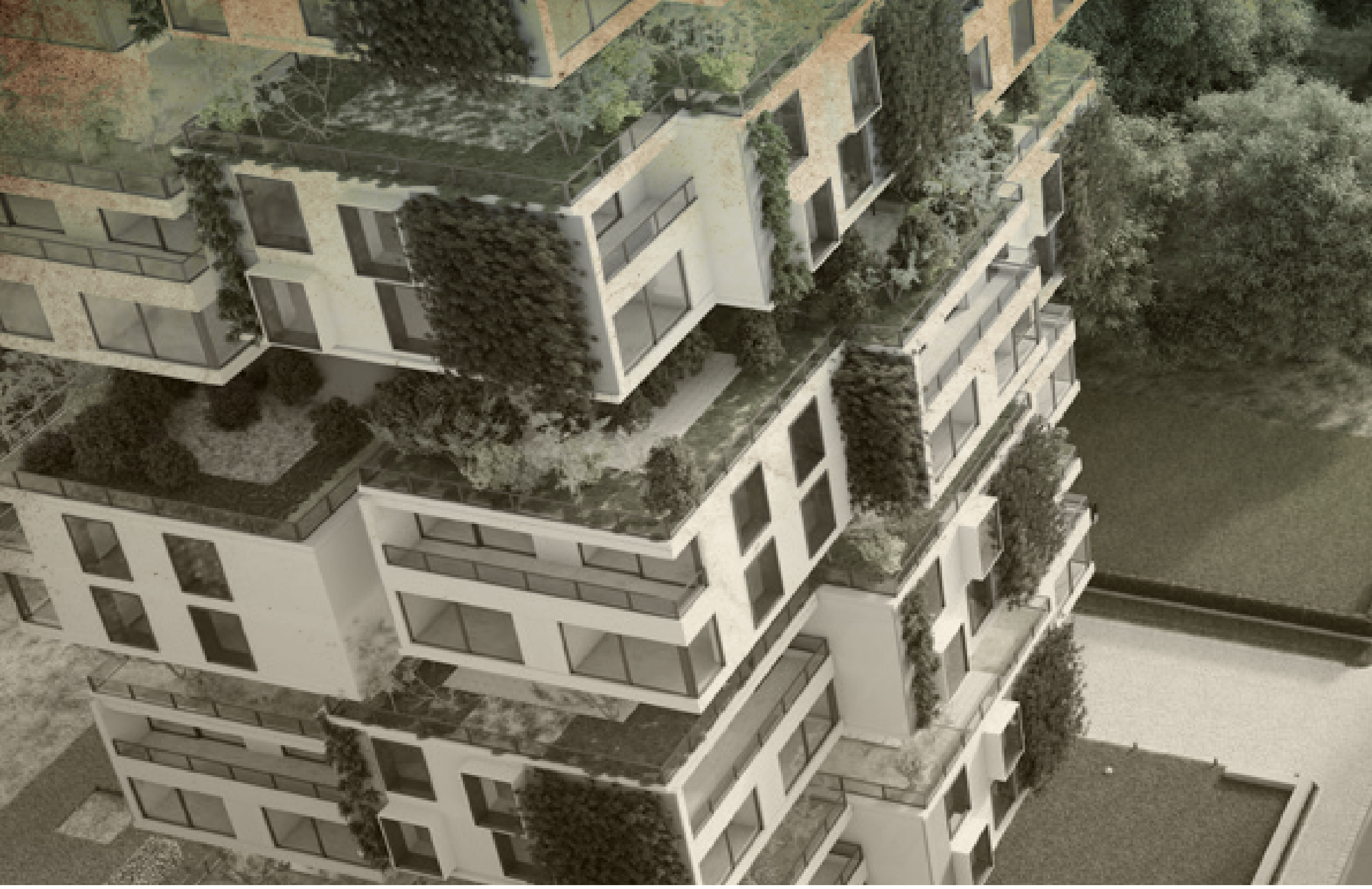
The environmental opportunity

It is in this direct conflict of ambitions related to the design of buildings that we see evidence of the pandemic challenging attitudes towards climate change. However, from this same context it is possible to identify an opportunity for architecture and the broader construction and development sector.

The pandemic has triggered a global shift towards working from home for some in the workforce, which in turn has opened the door to considerations about how we might design and use our buildings and environments in alternative ways. Social media has featured a proliferation in commentary around the future of work, housing, economies, transport, suburbs and cities.

Australian social commentator and demographer, Bernard Salt, among others, foregrounds the desirable activation of suburbs resulting from the transfer of activity

2 First coined in 2015 in relation to the United Nations' Sendai Framework for Disaster Risk Reduction, this term has been used to refer to recovery approaches after the 2020 Australian bushfires and, more recently, by the OECD in planning for 'durable and resilient' pandemic recovery packages. OECD Policy Responses to Coronavirus (COVID-19) 'Building Back Better: A sustainable, resilient recovery after COVID-19', 5 June 2020.



and investment away from the capital cities.[3] A Committee for Perth webinar featuring research on outer suburban residents' thoughts on working from home and/or returning to the office (based on a survey conducted by National Growth Areas Alliance NGAA) revealed that 74 per cent of outer suburban workers commute by car, and 76 per cent of full-time workers have commutes in excess of 10km, with the average commuting distance being 40km.

For those surveyed in WA, 44 per cent of people wanted a blended approach to working, including at home, in the office and potentially at a local hub; 19 per cent preferred to continue working from home full-time; and 30 per cent wanted to return to the workplace.[4] Two-thirds wish to spend less time in the workplace. In taking the long view, we see again a mobilisation of populations and the cyclical phenomenon of dispersion from cities to suburban areas.

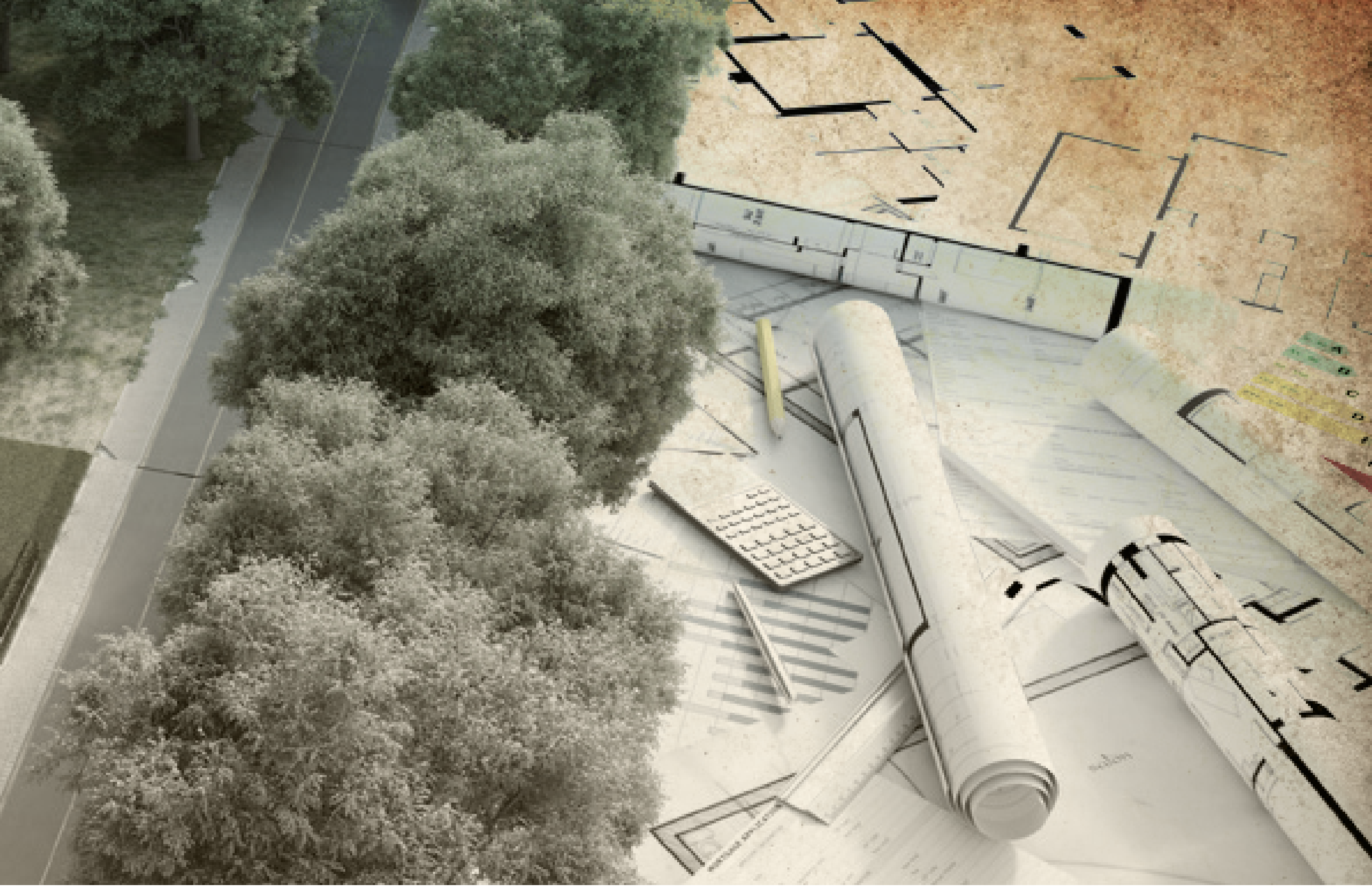
Comparing contemporary and historical episodes of suburban consolidation shines a light on the forces that are different today, as well as those that might be common. Governments, planners, developers and architects can take away from this the knowledge about how to anticipate and prepare for suburban growth. An opportunity presents itself for the reconciliation of pandemic and climate change ambitions by rethinking the suburban realm through a targeted increase in the efficient use (or the 'occupancy rate') of our suburban fabric.

At the same time, there is an opportunity to persuade governments to direct a portion of job creation funding to the adaptive reuse of existing buildings. As a strategy for pandemic recovery this also ticks numerous boxes responding to climate change challenges.

Repurposing of existing infrastructure and built fabric is a key initiative identified by Architects Declare and others to minimise the amount of demolition and new building required. The environmental benefits are clear in minimising the use of resources and amount of waste to be disposed. There is also cultural value that ensues from the repurposing of buildings – heritage listed or otherwise – offering social cohesion, continuity and connections to the past. In turn, this sense of belonging to a place can enhance individual and societal wellbeing.

A final significant benefit worth seriously investing in is the potential creation of a specialised construction sector focused on adaptive reuse and building transformation. These investments would be supported by new training programs and apprenticeships that form part of Federal and State government economic recovery packages.

3 Bernard Salt, 'Proactive planning in a pandemic', presentation at the 2020 Urban Development Summit. 21–22 October 2020.
4 Committee for Perth webinar, 'New Horizons: Working from home in outer suburbs', 16 September 2020.



The university contribution

Universities have an important role to play in relation to the issues that are identified in this paper. I have suggested that in responding to climate change, augmented by pandemic-related impacts, architecture can be focused on preparing for two main challenges (and, on the flip side, opportunities).

First, greater progress would come from a clearer definition and ownership of a role within the construction industry that enables architects (in party with consultants) to better develop, describe and implement their capacities for generalist and strategic thinking across a range of related issues that have social, ethical, scientific, aesthetic, historical and economic dimensions.

Secondly, additional traction would result from the promotion of designs for the extension of building life and functionality through adaptive reuse, participation in the circular economy and other initiatives that minimise the need for new construction and avoid building on greenfield sites.

For these two ambitions to be realised in practice, universities have clear mandates to pursue. Two stand out.

First, there are research prospects that are necessarily interdisciplinary and closely intersecting with industry partners. Analysis and modelling of spatial and environmental data paired with technical exploration and historical thinking would support testing of design strategies for the diversification of the suburban realm and consolidation of its built fabric. This would allow for double-functioning or shared land uses to make the otherwise vacant or redundant suburban space and built form more active or productive. Here, application of long-term and comparative thinking becomes an important guide to research-led innovation in the planning, design and architectural fields.

Secondly, as educational and degree-granting bodies, universities have an obligation to comprehensively prepare current and future generations of students, graduates and practitioners for the challenges of climate change. Most obviously this occurs through study programs and include mentorship and curriculum development, aligned with clearly stated course outcomes and attributes as well as professional regulatory requirements and industry targets such as the Sustainable Development Goals (SDGs).

Content and delivery needs to focus on engaging learners in creative ways to bring fresh ideas and possibilities to these most complex of challenges. But it also starts on university campuses and in the school workplaces through the adoption of sustainability agendas and environmental targets for their own internal operations and consumption habits.

In design and architecture programs the educational responsibility and opportunity extends further. It requires attention to the array of decarbonising strategies and targets mentioned in this chapter that are already progressively being integrated into teaching and learning about the design, construction and inhabitation of buildings and environments.

Further encouragement is also needed for the production of assessment work (especially models and drawings) that is consciously minimal in its consumption of materials. In Australia, demonstration of students' competency in environmental knowledge and application is required as part of the accreditation of the professional Master of Architecture course, with reference to an industry standard governed by Architects Boards in each state and territory, and within the broader context of the Higher Education Standards Framework (Threshold Standards) 2015.[5]

The industry framework – the National Standard of Competency in Architecture (NSCA) – is the key document defining the range of competencies that must be demonstrated at various stages in the journey to registering as an architect in Australia. This document represents the codification of what the profession believes is relevant as the threshold criteria defining architecture's responsibilities and concerns across the gamut of social, ethical, technical, regulatory and environmental dimensions.

The first stage is the graduation with a professional Master of Architecture qualification at an accredited tertiary institution; the final stage is the completion of the three parts of the Australian Practice Examination. The NSCA undergoes regular evaluation and, following this current review cycle, is likely to incorporate increasingly explicit expectations of preparedness to address climate change and environmental challenges.[6]

Concluding remarks

In thinking about architecture's preparedness for the challenges of climate change, the most important conclusion is that they need to be considered in parallel in workplaces, in professional associations, in training organisations and in educational institutions. The processes by which we proceed will be underpinned equally by research, education and formation of policy.

Architecture's status as an occupation with generalist knowledge and expertise (even with specialist areas of focus) is its greatest strength in looking ahead to the future of the profession. This will be tested by the profession's capacity to be prepared and to innovate in response to the pressing challenges of climate change in a disrupted world.

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5 *The Higher Education Standards Framework* is Australian Government legislation. Section 3.1 relating to Course Design requires that the 'content and learning activities of each course of study engage with advanced knowledge and inquiry consistent with the level of study and the expected learning outcomes, including … emerging concepts that are informed by recent scholarship, current research findings and, where applicable, advances in practice.'

6 *The National Standard of Competency for Architects* is maintained by the Architects Accreditation Council of Australia (AACA), in collaboration with the architectural sector and Australian state and territory Architects Registration boards.

Practitioner perspectives

Defining 'sustainability' in architecture for 2025 and beyond

Gemma Hohnen

In 2019, Australian Architects Declare Climate and Biodiversity Emergency (AAD) was launched in recognition of the Special Report by the Intergovernmental Panel on Climate Change (IPCC). Architects have a big role to play in reducing CO_2 emissions, with the built environment contributing roughly 40 per cent of greenhouse gas globally.

A year on, surveys undertaken by Architects Declare in the UK and Madlen Jannaschk of AAD indicate little shift in practice since signing. With signatories representing roughly 15 per cent of the profession (there are currently 958 signatories in Australia), clearly we have a long way to go.

For the majority of practising architects, knowledge of designing to zero carbon requires education, yet, faced with maintaining a steady workflow, most default to the business-as-usual approach – the "palatable and known"[1] – despite the knowledge and the tools being readily available.

Scott McAulay describes the education and training provision in bleak terms: "The contemporary architectural education system – through both academia and continuing professional development (CPD) – does not equip current practitioners nor the practitioners of the future to work within the ongoing climate emergency. This must be addressed urgently."[2]

Education can and must do more to equip future architects to fill this knowledge gap.

Currently, regulators and government bodies do not mandate realistic targets or requirements in climate mitigation or adaptation. This will change, and the most likely source of change will be the National Construction Code (NCC), coupled with client awareness. In Western Australia, this problem is more acute – with the 2019 Code delayed, we are currently building to 2010 standards.[3] Substandard buildings are being erected, which not only contribute to the problem but will be ill-equipped to provide the level of comfort required in a changing climate.

However, there are countervailing pressures. As Madlen Jannaschk states, "It is expected that the required energy ratings for residential dwellings will be raised to a 7 star NatHERS (Nationwide House Energy Rating Scheme) minimum in the next NCC review in 2024,"[4] demonstrating a trend towards mandating higher standards required in energy efficiency.

1 Madlen Jannaschk, *How Successful can Australian Architects Declare Climate & Biodiversity Emergency be as a Voluntary Agreement?*, unpublished dissertation, University of London, 4 September 2020.

2 Scott McAulay, 'Educating for our Future: Tackling architecture's apathy to the climate emergency', *Crumble Magazine*, May 2019.

3 Darren O'Dea, 'NCC 2019: The Climate Emergency Opportunity', *LinkedIn*, 26 November 2020.

4 Madlen Jannaschk, *How Successful can Australian Architects Declare Climate & Biodiversity Emergency be as a Voluntary Agreement?*, unpublished dissertation, University of London, 4 September 2020.

And Ross Donaldson argues that, "If all buildings by 2030 should be zero carbon and you think about how long it takes to procure a building that gives us a scary deadline of 2025, for the whole of the architecture profession and the whole of university education, the schools of architecture, to be re-engineered for carbon zero capability in our practices."[5]

It is well understood that current government-mandated targets are inadequate, and the built environment globally needs to design to zero carbon for "100 per cent of new builds by 2030, 100 per cent existing buildings by 2050 if we are to meet overall climate targets in line with the Intergovernmental Panel on Climate Change (IPCC) Special Report."[6]

Grasping the challenge as a profession

The architectural profession appears to be at an impasse.

There are many elements to be addressed in design to optimise the performance of buildings and reduce embodied carbon. There is the potential for architects to bring this unique skill set to an industry with thoughtful collaboration using a well-selected consultant team. Students are in the unique position of being able to test new design solutions, to look at strategies that are inherently sustainable by design, from first design moves in spatial planning all the way to detailed specification, tested using life cycle analysis software to evaluate their design work.

5 Ross Donaldson, Introductory comments to the ZERO Series – Lecture 1 'Design for energy demand reduction' given by Prasanna Suraweera at the Institute of Architects WA, 12 August 2020.

6 World Green Building Council, *New report: the building and construction sector can reach net zero carbon emissions by 2050*, 23 September 2019.

Architecture student Peter Tibbitt indicates that things will start to look and feel different: "...if we all truly put climate change at the centre of our concerns, architecture shouldn't look or feel the same as it does now, why should it? We are holding on to a style that we know and understand and trying to make it work, where maybe we need to be rethinking buildings from the ground up. I don't know what that might look like, but I can be fairly sure it won't look like what we are currently building."[7]

Students are asking for more, with many well-informed that climate change poses an existential threat to them directly. Consequently they want the skills to contribute to its mitigation.[8] This is an exciting moment where we potentially see or lead significant cultural developments within the profession.

Where there is a deficit there is space to grow. In the UK, architecture graduate Scott McAulay has formed the Anthropocene Architecture School, holding intensive workshops for students skilling up on climate literacy independent of the universities, while the Architects! Climate Action Network (ACAN) works on targeted climate campaigns, including architecture education. "Few, if any, schools are equipping students with the tools and technical knowledge they will need to address the climate emergency," ACAN reports. "Whilst sometimes (necessarily) provocative, our group aims to work positively with other groups towards new structures and value systems."[9]

The Living Building Challenge by the International Living Future Institute offers a framework for regenerative architecture, for the design of buildings that are not only zero carbon but that seek to regenerate. This provides us with exceptional examples of sustainability, our benchmark for a zero carbon future, including the Sustainable Buildings Research Centre at the University of Wollongong by COX Architecture.

Designing to zero carbon requires skills and knowledge that are readily available if we know where to look. It has been an absolute joy to work with master's level students in this area this year, steering them towards sources of knowledge, asking them to question what sustainability means in the current context, and introducing them to resources and software they can use now to get them started. We have had many guests join us and assist with this line of enquiry, and a number of highly skilled consultants have demonstrated their eagerness to share their knowledge. The potential here is for students to be an integral part of a transformative approach to design with the critical thinking required to see a broader uptake and implementation of sustainability.

> "Students are in the unique position of being able to test new design solutions and experiment with design strategies that are inherently sustainable."

What will business-as-usual look like in the coming decades? One can only assume further targets and compliance requirements are going to accelerate quickly as the effects of climate change become increasingly difficult to ignore. UWA – and the higher education sector more broadly – needs to deliver climate-and-carbon-literate graduates of architecture, who are conversant in what is necessary, who understand what sustainability means in the context of the climate crisis, and who know what the profession can and should provide for climate mitigation and adaptation.

Current and future graduates hold the key because they can bridge this transition in practice, and thus move the profession forward. The prize is that architecture leads the transition to net-zero by 2030, but we need to act fast. We need to act now.

Gemma Hohnen is an architecture consultant and former facilitator of Australian Architects Declare. Currently Gemma is a studio coordinator of 'The Crisis Studio' Masters Technical Design Studio, and coordinator of Graduating Portfolio at the UWA School of Design.

7 Peter Tibbitt, Masters Detailed Design Studio UWA. 'The Crisis Studio' Studio Coordinator Gemma Hohnen 2020.

8 Megan Tatum, 'We deserve to be taught about it: Why students want climate crisis classes', *The Guardian*, 28 September 2020.

9 ACAN Architects! Climate Action Network.

Mitigation of climate change: Law, policy and ethics

David Hodgkinson

Introduction

Climate change poses a few different challenges.

The scientific challenge How can the significant amounts of CO_2 in the atmosphere, causing the earth's climate to change, be lowered? How can the climate be stabilised such that global temperatures rise no more than 2°C? That ship appears to have sailed…

The economic challenge How can the economy be decarbonised while addressing global economic disparities?

The social challenge How can human societies alter their climate-changing behaviour and adapt to climate change?

The legal/policy challenges What laws/regulations can be introduced to reduce emissions and assist people, species and ecosystems vulnerable to climate change?[1]

In other words, mitigation.

For well over a decade, the focus of my teaching and research has been climate change law and policy, with a focus on mitigation. I set out below legal and policy matters and challenges that are considered in the various climate change-related courses I run. I also briefly discuss climate change ethics.

1. Mitigation generally

Climate change mitigation involves reducing greenhouse gas emissions and reducing the rate and magnitude of global warming. Many of the impacts of climate change can be delayed or reduced by mitigation. Adaptation means coping with or adjusting to climate change. With mitigation, adaptation becomes easier. Mitigation and adaptation are not alternatives.

In terms of policy instruments to mitigate climate change, the question is whether to rely on price-based or quantity-based instruments. This means whether to increase the price of carbon, to limit emissions and to encourage the development of alternative energies. An example of the price-based policy instrument is a carbon tax. A tax sets a price on carbon, and emitters choose how much to emit. An example of the quantity-based approach is an emissions trading scheme (ETS). An ETS sets a total quota for emissions; emitters (that is, the market) work out the price. A carbon tax, unlike an ETS, does not involve a quantitative target.

2. Carbon taxes

A carbon tax – a direct pricing mechanism, as opposed to an indirect mechanism such as an ETS – imposes a fee for every ton of carbon produced. This means a carbon tax imposes a fee on fossil fuels (coal, oil and natural gas) in proportion to the carbon they contain. Fuels that are more carbon-intensive (such as coal) become more expensive under a carbon tax and fuels such as solar become more competitive. A carbon tax would raise the price of fossil fuels.

1 See Adrian Parr, *The Wrath of Capital*, Columbia Press, 2013, p 4.

Such a tax could begin at a relatively low level (so as to avoid disruption) and would increase steadily, and predictably, over time, providing incentives to affected corporations to lower emissions. It encourages corporations to use energy more efficiently and to move to lower-emissions technology. Accurate assessments of the costs of investing in lower-emissions technology can be made because the amount of the tax imposed is certain, unlike a carbon price under an ETS, which can be highly volatile.

While there are a number of points at which to impose a carbon tax, there is some agreement that the most simple and efficient way is for it to be introduced as close to the source of the fuel as possible – that is, as far 'upstream' in the energy supply train as possible. One result of an upstream approach is that increased costs would be passed along by suppliers and would be borne, ultimately, by consumers. They would be passed into downstream prices of electricity, for example, and energy-intensive goods. The tax is applied to all sectors of the economy that use fossil fuels and, thus, would have a very broad scope.

No matter its rate, a carbon tax could be introduced progressively, over time, which may assist both affected entities and consumers in terms of adjusting to it.

Some advantages of a carbon tax are as follows:

- Taxation is a proven instrument. Tax systems are applied around the world and are understood.
- Taxes capture revenue more easily than quantitative instruments such as an ETS, and are less costly.
- Taxation is more direct and more transparent than emissions trading, and affords less opportunity for corruption. Money moves from polluters directly to the government.
- A carbon tax provides price certainty and stability, as opposed to potentially high-level price volatility associated with ETS and the price of permits, and a fixed price for carbon emissions across all economic sectors and markets.
- A carbon tax would provide revenue that could be used to cut, offset or remove other taxes.
- A tax has a much broader scope than an ETS.

3. Emissions trading schemes

An ETS is a market-based instrument under which limits are placed on the quantity of carbon that can be emitted. The government or regulatory authority issues emissions permits or credits covered by the scheme (participants) and those permits or credits can then be traded. The market determines the price of each permit or credit.

One of the main ideas behind an ETS is to allow participants to reduce their emissions at the least cost, either by purchasing permits or credits, or investing in less emissions-intensive technology, or a combination of the two.

The most common type of an ETS is a cap-and-trade scheme. Under this scheme, the limit or cap on the amount of carbon that can be emitted applies either across the economy overall or in different sectors. The government then determines how many emissions permits are to be issued on the basis of that cap. Each permit represents the right to emit a certain amount of carbon (typically, one ton of CO_2-e).

Participants must acquire and surrender to the government a number of permits equivalent to the amount of carbon they have emitted in a given compliance period (for example, a financial year). If a participant has acquired more permits than it needs, the additional permits can be banked or traded on the market. If a participant has emitted more carbon than it is entitled to emit under the permits it has acquired, it must acquire additional permits.

When compared to other instruments used to mitigate climate change, it seems to me there are a number of advantages associated with an ETS. First, the fact that there is a limit on the total quantity of carbon that can be emitted means that an ETS provides certainty about the level of emissions reductions that will occur. Instruments such as a carbon tax, in contrast, do not provide such certainty. In addition, the focus on reducing emissions may lend greater credibility to an ETS, since the link between the policy instrument and the environmental objective is clear.

Second, an ETS provides flexibility in the way emissions reductions can occur. Other instruments, such as technology standards – which stipulate a particular technology that must be used – do not provide this flexibility. Such flexibility allows participants to find the most cost-effective way to reduce emissions.

Finally, it may be easier to link an ETS to international markets than it is to link other policy instruments to such markets.

4. Discounting – or putting a price on time

In popular discourse, no one really talks about 'discounting' in terms of climate change, but an understanding of the concept is essential to climate change action (mitigation, in other words) and to the choices we make in addressing climate change. It goes to the responsibility of present generations for the wellbeing of future generations.

The discount rate weighs future people's benefits against costs borne by people in the present. It determines how societies value their future. If a cost benefit analysis uses a high discount rate, it discounts future benefits to a high degree, giving little weight to the interests of future people on the basis future people will be cleverer, richer and they'll work it out (the approach, more or less, of Yale economist William Nordhaus in his books *A Question of Balance* and *The Climate Casino*). Lord Nicholas Stern in *The Economics of Climate Change* uses or refers to a low discount rate, and asks the present generation to make urgent sacrifices for the sake of future people.

The issue is put well by Richard Posner in his book *Catastrophe: Risk and Response*.[2]

Posner writes:
"Although there is a strong case for taking measures against global warming now rather than waiting decades to do so, the question remains what measures to take – how much cost to incur – and the answer depends in part on the weight to be given the welfare of future generations, since it is most likely that the costs of global warming will be borne primarily by them. That weight depends on the discount rate used to translate future into present costs, and there is no objective guide to the choice of that rate when the costs to be discounted will be borne primarily by remote future generations. At any significant discount rate, even one as low as 2 or 3 percent, the distant future receives almost no consideration, while at a zero discount rate...the cost of a risk that will affect an indefinite number of future generations will approach infinity."[3]

"The main issue at stake is that if we agree to reduce emissions now, people living in the future will benefit, not those living today. But we will, today, bear the costs of reducing such emissions."

It seems to me, then, that the main issue in terms of addressing the climate change problem is that, if we agree to reduce emissions now – and there are currently no truly *effective* global or other agreements in sight that provide for such reduction – people living in the future will benefit, not those living today. But we will, today, bear the costs of reducing such emissions. Oxford's John Broome says this: "[The current generation] will be sacrificing some of its own well-being for the sake of greater well-being that will come to people far in the future. Is the sacrifice worthwhile? Does it improve the world on balance? This is a question of weighing: How do increases in future well-being weigh against sacrifices of present well-being?"[4]

It is an ethical question.

5. 'If global warming is the devastating threat that Al Gore says it is, then why aren't people freaking out about it?'

The editor of the *Los Angeles Times* newspaper asked Harvard psychologist Professor Daniel Gilbert this question a few years ago.

Mr Gilbert's response was that there are a few reasons: "[It] doesn't put our brains on orange alert [because]...it doesn't violate our moral sensibilities. It doesn't cause our blood to boil (at least not figuratively) because it doesn't force us to entertain thoughts that we find indecent... or repulsive...Although all human societies have moral rules about food and sex, none has [such] a...rule about atmospheric chemistry. And so we are outraged about every breach of protocol except Kyoto...

"[Another] reason why global warming doesn't trigger our concern is that we see it as a threat to our futures — not our afternoons...

2 Richard Posner, *Catastrophe: Risk and Response*, Oxford University Press, 2004.

3 Ibid, p 255.

4 John Broome, *Climate Matters: Ethics in a Warming World*, W. W. Norton, 2012.

"There is a [final]...reason [Gilbert says] why we just can't seem to get worked up about global warming. The human brain is exquisitely sensitive to changes in light, sound, temperature, pressure, size, weight and just about everything else. But if the rate of change is slow enough, the change will go undetected...

"Because we barely notice changes that happen gradually, we accept gradual changes that we would reject if they happened abruptly."[5]

As Professor Gilbert says, "[e]nvironmentalists despair that global warming is happening so fast. In fact, it isn't happening fast enough."[6]

6. Implications for climate change law as an academic discipline

New approaches to international cooperation will be required if strong steps are to be taken with respect to global climate change. It has been said that in democracies fear does the work of reason. Perhaps as concern increases about the consequences of global warming, the willingness of nations to enter into truly binding agreements will increase. But I suspect considerable imagination will be required as to how agreements can be made attractive to the major developing countries or made to be effective without their participation.[7]

The nature of the climate change challenge demands visionary and innovative thinking. Universities are the place for such thinking.

"The nature of the climate change challenge demands visionary and innovative thinking. Universities are the place for such thinking."

5 Daniel Gilbert, 'If only gay sex caused global warming', *Los Angeles Times*, 2 July, 2006.

6 Ibid.

7 Lawrence Summers, 'Foreword' in Joseph Aldy and Robert Stavins (eds), *Architecture for Agreement: Addressing Global Climate Change in the Post Kyoto World*, Cambridge University Press, 2007, p xxii.

There are a number of implications for law as an academic discipline in terms of climate change. Climate change law is incredibly multi-faceted and wide-ranging. It involves both domestic and international law. It is multi-disciplinary. For example, an intensive three- or five-day climate change law course could, in part, involve the international climate change regime, consisting of: (a) the United Nations Framework Convention on Climate Change; (b) its Kyoto Protocol; (c) the 2015 COP21 Paris Agreement; and (d) subsequent developments.

Other matters to consider in any such course could include: geo-engineering (or bio-energy with carbon capture and storage [BECCS]); Australian climate change law and policy (including the Commonwealth and the states and territories); the National Greenhouse and Energy Reporting Scheme; the Emissions Reduction Fund (ERF) and its safeguard mechanism; carbon capture and storage; decarbonising cities and low-carbon sustainable precincts; and the ethics of climate change law and policy.

Learning outcomes could include: the critical analysis of instruments available to address the climate change problem, both in Australia and internationally; understanding the interaction between climate change law and policy, both in unitary and federal systems; and demonstrating an understanding of the ethical underpinnings of climate change law and policy, both at national and international levels.

Outcomes could also include the development of key analytical skills through comparison of climate change law at local, state and federal levels (as appropriate), and the drafting of outline agreements that address particular climate change-related problems.

Joseph Romm (an academic and former United States Assistant Secretary of Energy) argues that, in the near future,

"more money and resources and people will be devoted toward (1) adapting to whatever climate change we fail to stop; and (2) stopping climate change from getting even worse. Climate change and our response to it will create trillion-dollar industries in low-carbon energy, energy efficiency, sustainable agriculture, and every type of adaptation imaginable. *Students who want to be employable in a carbon-constrained world while contributing to the solution will have a great many choices and options available to them*... [emphasis added]."[8]

8 Joseph Romm, *Climate Change*, Oxford University Press, 2016, p. 256-257.

Romm further states:
"Investment in clean energy is already a few hundred billion dollars a year, and over the next decade or so it should hit $1 trillion a year, and then double again in the next decade or two after that. Therefore, there will be a great need for engineers and *researchers* and entrepreneurs of all type. There will also be a great need for people with specific expertise in solar power and wind power, energy storage, electric cars, and energy efficiency in every sector, from buildings, to industry, to transportation. These projects will need *financing and legal contracts and the like* [emphasis added]."[9]

7. Conclusion: 'Math, chemistry and physics'

American environmentalist Bill McKibben has commented that limiting the global temperature increase to 2 degrees or even 1.5 degrees – the aim of the Paris Agreement – is 'the most ambitious project the world has ever embarked on.'

McKibben, however, also said this (in 2016), which still has currency:
"Say you really are going to hold the temperature rise of the planet to 2°C. We know with some precision what you'd have to do. A study published in *Nature* about a year ago…looked at all the world's fossil-fuel reserves, and found that most of them would need to stay in the ground. You couldn't, for instance, drill for any oil or gas in the Arctic – those reserves would have to stay untouched. Countries like Australia and the US would need to leave around 90 per cent of their coal reserves underground.

"Oh, and say you were going to try and meet a 1.5 °C target. In that case you'd have to stop mining coal tomorrow."

"This is not ideology," he says. "This is not propaganda. This is math, chemistry and physics."[10]

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9 Ibid, p. 257.

10 Bill McKibben, 'This is not ideology,' *The Monthly*, February 2016.

Practitioner perspectives

Ignited agents: the legal profession's role in the challenge of climate change

Jessica Henderson

I live in a place where bushfire evacuations were taught at primary school, and spring holidays were for clearing boundary lines of bush. To this day the smell of unexpected smoke makes me remember to 'get down low and go, go, go'. Fires destroying homes was something that could happen, but could be prevented, controlled and, as a last resort, escaped. We were taught to decide early whether we were staying or going, and it was understood that protecting a home was a realistic possibility. Preparation was the key.

Last summer was something else. The world watched, helpless, as we burned.

As the catastrophic destruction ripped through our sense of security and brought Australia plummeting into the grim reality of global climate change, the legal profession responded, quickly and powerfully.

New South Wales' Young Lawyers declared a climate emergency. Importantly, they declared it to be an unprecedented challenge for human rights and the rule of law.[1] Community legal groups and activists called for lawyers to 'nurture their creativity and robust skill sets as agents of change...to revitalise the legal profession and reignite the lawyer's agency in this critical decade.'[2] As climate activists swelled in numbers and in rage, the need for information about the legal parameters of civil disobedience and voter pressure was both real and urgent.

"One of the ways in which responsibility must be sheeted home to politicians is through the legal system," Greg Barns said for the Australian Lawyers Alliance.[3] "The abject failure of the political class to protect the life and environment of millions of Australians now exposed to bushfires must be punished. And Australia's courts and legal system is a place where government needs to be made accountable."

With his powerful war cry, Barns – a respected barrister and former adviser to state and federal Liberal governments – gave new weight to calls for injunctive relief against government decisions and implementation of policies that have the effect of increasing Australia's overall level of emissions.[4] In February 2020, the International Bar Association released for consideration and possible adoption by governments its *Model Statute for Proceedings Challenging Government Failure to Act on Climate Change*, which has been welcomed in Australian legal circles.

> "The legal profession is uniquely placed to challenge the government's climate change response, sitting, as we do, at the heart of climate change risk and regulation faced by private industry."

1 NSW Young Lawyers, *Climate Change and the Law Policy Statement*, 1 November 2019.

2 Anna Reynolds, Briana Collins and Clare Scrine, *Action Ready: Legal Resources for the Climate Movement*, NSW Community Legal Centres, 26 September 2019.

3 Greg Barns, 'Governments face a reckoning in the courts over climate change failure', *Mercury*, 6 January 2020.

4 Tim Baxter, 'Urgenda-Style Climate Litigation Has Promise in Australia', *Australian Environment Review*, 32, 2017, p 70–83.

The role and power of the legal profession

The legal profession is uniquely placed to challenge the government's climate change response. We have sat at the heart of climate change risk and regulation faced by private industry for years. There has already been a wave of climate change litigation in Australia focused on approvals for developments of fossil-fuel projects. In 2019, a second wave was identified, forcing companies directly and indirectly affected by climate change risks (including the transitions needed to mitigate them) to assess and report on those risks.[5] Litigation against companies responsible for significant emissions had started internationally, and was anticipated in Australia.[6]

As a profession we are, of course, fighting litigation on both sides: navigating the legal system for those promoting the fossil-fuel projects as well as those trying to prevent them. There is nothing jarring in that – our role has always been to facilitate the rule of law and assist the courts to reach the better outcome by providing our knowledge of legislation and authority to both sides of each case.

As the regulatory, technological and stakeholder landscapes have shifted, we have identified significant implications for business operations. Traditional risk management tools and techniques lacked the required precision. We have moved to climate-related financial disclosures, insurance for climate-related exposures, and crisis management in the event of environmental regulation breaches. Firms have identified a real need for incorporation of climate risks and opportunities into governance, risk management and corporate strategy. The Recommendations of the G20 Financial Stability Board's Task Force of Climate-related Financial Disclosures changed the expectations of Australian regulators and global investors, and crystalised the obligation to consider material climate-related assumptions in accounting estimates and make appropriate disclosures in the financial statements. As actuarial antennae tuned into (and quantified) climate change risk, lawyers responded by creating new areas of specialisation.[7]

New areas of practice and 'climate-conscious' ways of operation

Gone are the days of 'environmental law' being a niche area with a relatively small hourly rate. Top-tier firms with established climate risk governance teams compete for a market preoccupied with corporate exposures. Springboarding from existing global platforms and multinational client relationships, these firms maintain specialist divisions variously described as 'Climate Change Risk Practice', 'Climate Risk Governance', and 'Global Climate Change Practice' to guide multinational corporations and directors through the interaction of climate change with their fiduciary duties, financial reporting/disclosure obligations, and the litigation arising from increasingly complex regulatory schema.

The expertise of these specialist lawyers goes beyond risk mitigation into strategic advice on carbon emissions schemes, clean-tech opportunities, environmental commodity transactions, and resilient infrastructure projects. Their practices are distinct from traditional planning and environment divisions dealing with the regulatory approvals, tenure, regulatory risks, and land access strategies of the development market.

The practices of the profession are also displaying some marked changes. Firms increasingly advertise taking a 'climate-conscious' approach to their practice. It is not uncommon to see arm-flapping fee earners trying to persuade automatic light switches that there is still a person in the room after a period of prolonged (and stationary) concentration. Lifts have become 'efficient' and those hastily jumping into one someone else has called are baffled to discover there are no buttons inside with which to direct it to their preferred floor. The most prominent change from the perspective of the WA Bar is perhaps the paperless office and consequential electronic brief, a change that is increasingly supported by the courts' willingness to pursue paperless trials.

5 Andrew Korbel, *A new era of climate change litigation in Australia?*, Corrs Chambers Westgarth, 8 April 2019.

6 Geetanjali Ganguly, Joana Setzer and Veerle Heyvaert, 'If at First You Don't Succeed: Suing Corporations for Climate Change', *Oxford Journal of Legal Studies*, 38, 4, 2018, p. 841–868.

7 Sharanjit Paddam and Stephanie Wong, *Climate Risk Disclosure – Financial Institutions Feel the Heat*, Actuaries Institute Dialogue Paper, 21 November 2017.

Where to from here?

The legal profession is at the heart of assessing and advising on the challenges posed by climate change. In keeping with the nature of the profession, we are, for the most part, taking responsibility for the futures of our clients in the face of the unknown and where predictions are hazardous.

It appears to be meaningfully understood by a significant proportion of the legal profession that there is a tight planning horizon for climate change, that the effects of climate change will be pervasive and affect all our clients and our own businesses. As professionals, we recognise that although the changes may develop gradually, the effect of them could be abrupt, catastrophic and irreversible.

Fear is the anathema of the investment community. Inconvenience can be overcome, risk can be mitigated, change can be adapted to, but fear sends money into hiding. The danger posed by climate change is no longer ethereal. It has manifested as a legal, financial and reputational issue for our clients.[8] It poses a physical risk to our safety and our property. It has also given rise to new and exciting opportunities, many of which are yet to be taken advantage of.

Climate change is here, and we need leadership. The legal profession is in a position to provide it.

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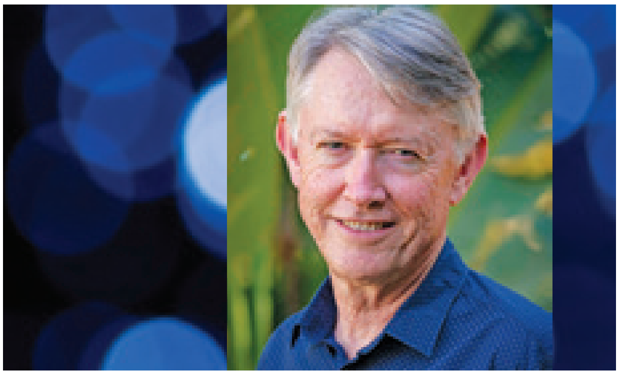
8 Adopting the language used in the A4ID/KCL Workshop Briefing Paper 'What Lawyers can do about climate change', King's College London, 2016.

How is economics responding to the challenges posed by climate change?

David Pannell



Introduction

Economists have been involved in studying climate change and its potential management since the issue first emerged as a public concern. As one indication of the importance and influence of this work, one of the first economists to start working on climate change, William Nordhaus from Yale University, was awarded the Nobel Prize for Economics in 2018. In his Banquet Speech for the award, Professor Nordhaus observed that, "The signal contribution of economics is to recognise that climate change is a harmful unintended side-effect of economic growth, known in economics as an external effect or externality. The CO_2 externality arises from the fact that the damages from CO_2 emissions are not paid for by the emitters. The result is too much burning of fossil fuels, too much climate change, and too many harms to humans, wildlife, ecosystems, and more."

Actually, the contributions of economists to understanding the issue have been more diverse than that suggests. Their research has examined climate change from every possible economic angle, including the following questions:

- What would be the cost of unmitigated climate change?
- To what extent can the cost be reduced by policy measures?
- Is climate change worth addressing through policy measures to mitigate greenhouse gas (GHG) emissions?
- How rapidly should emissions be reduced?
- What policy mechanisms should be used to mitigate GHG emissions?
- How should specific policy measures be designed?
- What would be the timing of benefits and costs from policy measures?
- How should benefits (costs avoided) that occur more than 100 years in the future be weighed up against costs of mitigation that start much sooner?
- What should be the balance between mitigation of emissions and adaptation to climate change?

In this article I provide insights into how economists have addressed some of these questions and what they have concluded. I also outline some of the key concepts from economics that are relevant to decision making about climate change policy. In the process I will discuss a number of conceptual and practical challenges that have faced economists and continue to do so.

Policy

The need for a policy response

Economists generally respond cautiously to proposals for new government policies. We recognise many past policies have not been as beneficial as intended, or have been more costly than expected. For various reasons, it is easy to over-estimate what the benefits of a policy would be. For example, for some issues, the private sector would provide similar benefits as the policy, meaning the additional benefits of the policy are small. In the case of climate change, however, the fact it is an externality – an unintended side effect of economic activity, the costs of which are mainly not borne by the people or businesses who cause it – means a free-market solution would not occur spontaneously. In other words, there is 'market failure' and government intervention is potentially justified.

Having established there is a potential role for government intervention, the second hurdle for a policy proposal to pass is that its overall benefits should exceed its overall costs. In estimating the benefits of a proposed policy, a key insight is that they should be measured relative to a baseline 'without-policy' scenario. The without-policy scenario is likely to involve change even in the absence of a policy. In the context of climate change, changes within the without-policy scenario are likely to include that the problem will get worse over time, people or businesses will take action to adapt to the consequences of climate change (reducing its costs to some degree), and technological changes will occur to make the problem easier to address. The first and third of these changes make it more likely the benefits of a policy to mitigate emissions would exceed the costs, and the second change makes it less likely.

A number of challenges in measuring the benefits and costs of a climate change policy (long time frames, uncertainty, equity) are teased out further below.

Comparison of policy options

There are many different mechanisms governments can potentially use to try to mitigate GHG emissions, including: subsidies for selected practices or technologies; charging a price or tax for emissions; placing regulatory restrictions on the level of emissions, backed up by penalties for non-compliance; investing in the development of improved technologies that reduce emissions; placing mandates on the use of renewable energy; providing information to people and businesses about the benefits of reducing emissions; and reducing subsidies that encourage activities that emit GHGs.

Economists have evaluated all of these options[1], and they have reached a very strong consensus that the key policy response is to place a price on GHG emissions. There are two ways to do this: by imposing a tax on emissions, or by creating a market in permits that allow emissions, with the quantity of permits declining over time. There are differences of opinion about whether a tax or a market in permits would be superior, but there is almost no dissent among economists that one or the other of these is needed.

An advantage these two approaches share is they allow emitters to choose for themselves how they will reduce emissions, with the result that any desired level of emissions reduction is achieved at the lowest feasible cost. By contrast, policies where governments choose to support particular practices or technologies (e.g. subsidies for photo-voltaic panels on household roofs, or mandates on use of bioenergy in transport fuel) are always more expensive, and often much more expensive, per unit of GHG abatement.

A second advantage is the price on emissions creates an incentive for emitters to innovate, inventing and using methods that abate GHG emissions more cheaply, making the pricing approach even more efficient.

From 2012 to 2014, Australia had a carbon tax in place. An advantage of this approach was revenue from the tax was able to be recycled to reduce other taxes or increase other benefits to the community, allowing most people to be no worse off financially as a result of the tax. A disadvantage was it involved large changes in the incidence of tax, prompting some political resistance. The plan was for Australia to transition to a market for emission permits, as a member of the European scheme. An advantage of this approach is more direct control of the volume of emissions. A disadvantage is the risk of volatility in the price of emissions permits, which has indeed been observed in the European scheme.

Although the Australian carbon tax seems to have been working well, reducing emissions steadily without highly damaging consequences for business or inequitable consequences for consumers, it was repealed in 2013 following a change of government. In its place, the new government introduced a scheme that asks people to submit proposals for projects that would reduce emissions or sequester carbon, and the government selects and funds those projects it judges are cost-effective. In its current form, this policy has serious problems: it lacks an effective mechanism to stop emissions increasing overall, it fails to create an incentive for businesses to innovate in their emission abatement strategies, and it is likely many of the projects being funded would have happened anyway, even without the policy. As a result, it is probably delivering little if any net benefit. The changes needed to make it operate efficiently would have the effect of putting a price on emissions, returning it to an approximation of the policy it replaced.

Implementation of policy

Designing an efficient climate change policy involves difficult judgements about the trade-offs between the costs of running the policy and the benefits that it generates. For example, some people are enthusiastic about the potential for sequestration of carbon in agricultural soils to make a major contribution to Australia's climate policy. However, a theoretically ideal policy would need to keep track of the amount of carbon that is sequestered in each field that is part of the program, requiring regular visits by technical experts to each field, collection of soil samples from different depths at each site, testing of those samples, analysis of the results and what they indicate about changes in carbon

1 For example, see Ross Garnaut, *The Garnaut Review 2011: Australia in the Global Response to Climate Change*, Cambridge University Press, 2011.

levels, judgements about whether the conditions of the program were being violated, and administrative and legal actions to enforce better compliance where needed. The costs of such a comprehensive system would probably outweigh the benefits of the scheme. There would also be costs to landholders involved in the scheme, including costs of their time, expert advice and perhaps legal costs. In addition, it is extremely difficult to know whether the land management actions needed to sequester carbon are 'additional' for any particular farmer (i.e. whether the farmer would not have done them without the policy). Without considerable effort and cost, there is a high risk a policy rewarding farmers for sequestering CO_2 would largely be non-additional, meaning that it would contribute nothing to climate change mitigation.

In practice, the design of a policy involves a compromise between effectiveness and cost. A contribution economists make is to assist with judgements about where that compromise should be struck. Policy design questions economists are interested in include who should be included within the scope of a policy, how intensely compliance with the policy should be monitored and enforced, what constitutes compliance (e.g. paying for actions versus paying for outcomes), and how to assess additionality.

Concepts and theoretical challenges

Valuing benefits and costs of climate policy

The predicted impacts of climate change are extremely diverse, ranging from simple financial costs (e.g. reductions in crop yields in regions where rainfall is reduced) to non-financial costs (e.g. loss of life from spread of diseases or higher temperatures, or loss of suitable habitat for particular species of plants and animals), some of which are relatively intangible (e.g. loss of cultural identity for people forced to leave low-lying islands affected by rising sea levels).

When assessing the benefits of climate policy options, one challenge is to quantify the magnitudes of the changes that will occur in the without-policy scenario: how much will crop yields change in different locations, how many people will die, and how many people will be forced to leave their island homes? An equally difficult challenge is quantifying how these numbers would change as a result of a policy. Both sets of predictions may rely on computer modelling, extrapolation and expert judgement. Obtaining these predictions requires economists to work with non-economists from the relevant fields (e.g. agriculture, health, ecology, as well as climate science). As noted earlier, the benefits of a policy need to be estimated as the difference between the two scenarios: with and without the policy. This insight is actually relevant to all types of evaluation, not just economic ones, but is often not handled well in non-economic evaluations.

Having quantified the predicted changes that are attributable to the policy, the next step is to express them in monetary terms. This allows policy options that generate different types of benefits to be compared with each other on a consistent basis, and for the benefits to be compared directly with the costs. Even for financial impacts, estimating the benefits of a policy in monetary terms involves some non-obvious and non-intuitive aspects. For example, the benefits to a consumer from consuming a product is not measured by the price of the product, but by the difference between the price paid and the highest price the consumer would have been willing to pay for that product. In other words, we seek to measure the net benefits after the cost of the product has been deducted. Of course, the maximum willingness to pay for a product is different for each consumer, so we need information about how that varies across the population, as reflected in market demand curves.

Another non-obvious aspect is costs resulting from the impacts of climate change on production can affect market prices, leading businesses to adjust their production decisions. Such adjustments often mean the cost of climate change is reduced to some degree, relative to the cost if prices did not change.

For non-financial impacts, no price is observable for affected goods and services, so monetising the impacts is more difficult still. Fortunately, economists have developed a range of techniques that assist with this task. The most widely used techniques are based on surveys of the public or on observations of market transactions or costly behaviours that are affected by non-financial impacts. In all cases, the aim is to detect people's willingness to pay for particular benefits[2], providing the equivalent of the information derived from market demand curves.

One such technique has been widely discussed during the COVID-19 pandemic: the value of a statistical life (VSL[3]). One way to estimate this is to observe the decisions that people actually make that involve a trade-off between a cost and the probability of them dying. For example, some jobs are more dangerous than others, involving a higher probability of dying on the job, and

2 Or sometimes their willingness to accept compensation for the loss of a benefit.

3 Timothy Taylor, *Value of a Statistical Life: Where Does It Come From?*, Conversable Economist, 27 March 2020.

typically the employers need to offer higher salaries to attract equivalently skilled workers into the jobs. This reveals the trade-offs between income and probability of death people are willing to make, and in that sense it reveals the monetary value they place on their own life. For example, the current VSL for the US is around US$10 million. This is not a value based on moral judgements, but on people's own decisions. Economists use VSL to monetise the reductions in lives lost predicted to occur as a result of climate change policy.

Another prominent set of non-financial impacts of climate change relates to the environment. For example, impacts on coral reefs, such as the Great Barrier Reef, are already occurring and are predicted to worsen. These have some financial costs, via impacts on tourism and fishing, but also important non-financial costs reflecting people's appreciation of and concern for reef ecosystems. These values would be monetised using a survey of the community that elicits the trade-offs people are willing to make between reef condition and other costs[4].

Accounting for time and uncertainty

A feature of climate policy is that it involves costs that commence now, but benefits that are largest in the future, potentially in the distant future. How should they be compared? An important insight from economics is there is an additional cost that needs to be considered: the cost of giving up the benefits that would have been generated if the resources used for GHG mitigation had instead been used for their best alternative use (the 'opportunity cost of capital'). Given a growing economy, the opportunity cost of capital compounds like interest on a home loan. This means the future benefits of a climate-change-mitigation policy need to be greater than just the costs of the policy itself – they also need to cover the 'interest' costs. Economists account for this by discounting future benefit and costs back to present values. The more distant the future time when a benefit or cost would occur, the smaller it is in present-value terms. The more rapidly the economy is assumed to grow, the greater the reduction in values when a future value is converted to a present value.

Discounting captures important realities about the world, but it has, perhaps, a disappointing consequence that the estimated benefits of a climate policy are reduced relative to the costs, making the policy less likely to be supported by an economic analysis.

Currently, interest rates are at unusually low levels, reflecting a low opportunity cost of capital. It has been suggested by some economists[5] that interest rates in the future may continue to be low relative to historical levels. If so, the present value of long-term benefits would be high, reinforcing the case for implementing strong policies to counter climate change.

One prominent study of the economics of climate policy[6] argued that the discount rate should be reduced below standard rates, in order to be fair to future generations. However, this argument for intergenerational equity was undercut by the fact that their analysis included the assumption people in the future would, on average, would be substantially better off than people in the present, even after allowing for the impacts of climate change. In that case, reducing the discount rate, supposedly to enhance equity, amounts to imposing costs on relatively poor people (in the present) to benefit relatively wealthy people (in the future).

Given the long timeframes involved, there is high uncertainty about both the with-project and without-project scenarios. One of the uncertain variables is the discount rate itself. We cannot know with confidence what the opportunity cost of capital will be in the very long term. Because of the way the maths of discounting and the maths of uncertainty work, an uncertain discount rate is equivalent to a declining certain discount rate[7]. This means uncertainty about the discount rate has the effect of increasing the expected benefits of a policy, in present-value terms.

On the other hand, there are many other sources of uncertainty when trying to quantify the benefits of a climate policy. They include uncertainty about technological changes, changes in the economy, social and cultural changes that influence how much people value different benefits, and, of course, the extent and timing of climate change itself. All of these mean any estimate of the benefits of a climate policy is really a

"Climate economists need to ensure that they communicate economic concepts and results well and in simple language."

4 John Rolfe and Jill Windle, 'Assessing community values for reducing agricultural emissions to improve water quality and protect coral health in the Great Barrier Reef', *Water Resources Research*, 47, 12, 2011.

5 Ross Garnaut, *Superpower*, La Trobe University Press, 2019.

6 Nicholas Stern, *The Stern Review on the Economics of Climate Change*, Cambridge University Press, 2006.

7 Martin L. Weitzman, 'Why the far-distant future should be discounted at its lowest possible rate', *Journal of Environmental Economics and Management*, 36, 1998, p. 201-208.

single point from probability distribution. Accounting well for such profound uncertainty remains a challenge for economists.

Another unresolved challenge is how to give appropriate consideration to intergenerational equity. Although lowering the discount rate is probably not an appropriate response, it remains an issue of high relevance. Currently, economists mostly leave it to politicians to make these difficult judgements, but it may be that a collaboration between philosophers and economists could provide an approach to analysis that assists decision makers.

Practical challenges

Although economics in general is sometimes criticised for lack of collaboration with other disciplines, such collaboration is common in environmental economics, including in climate-change economics. Achieving effective collaboration between disparate groups of experts remains a challenge. Difficulties can include the use of distinct sets of jargon, distinctive concepts and theories, the time required to build rapport and mutual understanding, and different norms for the way research is conducted and published. Nevertheless, it is crucial that these challenges are overcome if realistic and helpful economic analyses of climate change are to be produced.

More broadly, climate economists need to ensure they communicate economic concepts and results well. The complexities and subtleties of economics can be difficult to convey in simple language. Some aspects of the economics approach to climate change might even be unacceptable to some individuals in other disciplines or to some members of the general public, requiring particularly careful communication. The Value of a Statistical Life is one possible example. Some aspects of economics people may find offensive are actually just a result of making transparent things that are implied by decisions we all make, or politicians make on our behalf. The VSL is again an example.

"Like all research disciplines, the potential for economics to contribute to the debate about climate change policy has been hampered by the politicisation of the issue."

Like all research disciplines, the potential for economics to contribute to the debate about climate change policy has been hampered by the politicisation of the issue. Climate change has been caught up in the growing partisanship of politics in the US in particular, with an influence on many other countries, including Australia. As a result, adherence to particular views about climate change and policy has become a way of expressing tribal affiliation for some, making it all but impossible to have a discussion based on logic and evidence.

In conclusion, the task of devising policy responses addressing climate change effectively requires insights and analysis from a range of disciplines. Economists have responded to the challenges posed by climate change with energy and insight, and in doing so have had to grapple with a range of difficult conceptual and practical issues. The new thinking that has occurred will likely have influences across the economics discipline over time.

Possible changes

Given the challenges of deciding how to respond to climate change, and the difficulty of getting appropriate changes in place, it is interesting to consider what changes might occur, or might be beneficial if they did occur, in the academic discipline of economics.

The most high-profile debates among economists in relation to climate change have been about discounting: the process used by economists to express future benefits as present values so that decision makers can weigh them up against current costs of taking action. As noted above, various rationales have been proposed for using lower discount rates for more distant future benefits, one of which has found broad acceptance but others not. The question of how to consider inter-generational equity and general uncertainty in discounting remains an unresolved challenge, and one that could have profound implications for economics generally if it could be successfully addressed.

Uncertainty is always present in economic modelling, but in most cases it is not addressed in a comprehensive, systematic way. It may be worthwhile for economists to evaluate the modelling strategies used by climate modellers in relation to uncertainty. Notably, they sometimes make use of ensemble modelling strategies, using multiple models to address the same question, and presenting results from the collection of models rather than from an individual model[8]. This shows that different plausible models can generate substantially different results, suggesting that relying on any individual model is unsafe. Nevertheless, economic policy recommendations are almost always based on results from single models.

Another strategy used in climate science to address uncertainty is the definition of a standard suite of plausible future scenarios that reflect the uncertain range of possibilities. These scenarios are used to define the parameters of models for particular runs, and results for the suite of scenarios provide insights into the consequences of uncertainty. Economists tend to work with single projections or scenarios, potentially missing important insights about the range of possible outcomes.

More generally, the global effort to model and analyse climate change has highlighted the value of collaboration between disciplines. Although collaboration with natural scientists is common in some fields of economics (e.g. environmental economics, agricultural economics), in mainstream economics it is relatively unusual, and is under-recognised in appointments and promotions. The growth of behavioural economics has made collaboration with psychologists respectable for economists, but serious collaboration with a broader range of disciplines is needed to ensure economists are asking relevant questions and making realistic assumptions.

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8 Ensemble modelling strategies are also being used by epidemiologists to model the COVID-19 pandemic: Katriona Shea, Michael C. Runge, David J. Pannell, William J.M. Probert, Shou-Li Li, Michael Tildesley and Matthew Ferrari, 'Harnessing the power of multiple models for outbreak management', *Science* 368, 577-579, 2020.

Practitioner perspectives

Invest in health, divest from harm

Sajni Gudka

Twelve months ago, over a million school children worldwide deliberately, defiantly and collectively left their classrooms to rally against the climate and ecological crises as part of Global School Strike for Climate. On that day, I also left my desk and accompanied my children to the Perth rally to take part in the conversation that belongs to my children and to me, as a parent, a woman, an academic.

Almost 10,000 school kids in Perth and 300,000 more across Australia had one very clear message: that current progress on climate action is inadequate. Planet Earth is struggling to cope with global heating and biodiversity loss much faster than governments, industries and those with powers of influence are able, or willing, to respond.

They demanded urgent actions to decarbonise our economy and all human activity, not by 2050, not by 2030, but NOW! They demanded bold new approaches from their politicians, their educators and their parents, to act with urgency, for they fear opportunities to secure a climate-safe planet are being missed. They demanded that every single decision should take global and planetary health into account.

As the school kids sang in unison, 'climate action now', it dawned on me that these kids are the future of every higher academic institution, and that regardless of their choice of future study, be it engineering, business management, medicine, architecture, arts or social sciences, they will want their academic institutions to have a strong commitment to tackling the environmental and ecological crises.

To not speak and act, is to deny my children's future. So I speak, and I also take part in this conversation as a member of this University, where I completed my doctorate and where I have researched and taught. My contribution in the capacity as an academic and a public health professional, is to draw attention to the ways in which the situation we are facing is a public health emergency, and to help find ways in which we may address climate change from a public health perspective.

Climate change = public health emergency

In 2019, CSIRO published the most comprehensive set of climate change projections for Australia so far, showing just how vulnerable we are as a country. They projected that hot days will be more frequent and hotter (very high confidence); sea levels will rise (very high confidence); oceans will become more acidic (very high confidence), snow depths will decline (very high confidence), and extreme rainfall events will become more intense (high confidence).[1]

> "Growing infectious diseases, heat stress, mental illness, food insecurity, poor water quality and nutrition will mean that healthcare delivery, access and distribution will come under greater strain."

1 CSIRO, *2019 Climate Change information for Australia.*

This year we have seen how COVID-19, within in the space of 6 months, has placed significant strain on healthcare systems globally. The science of climate changes proves, without doubt, that the climate crisis will bring even more stressors. Healthcare delivery, access and distribution will be severely challenged by worsening climate change in the coming years and decades, as we get exposed to more infectious diseases, more heat stress, more mental illness, food insecurity, poor water quality and poorer nutrition.[2]

The planet as a patient

The InterAction Council, which consists of former Heads of Government and academics at the University of Southampton in England, published a manifesto, *Securing A Healthy Planet For All*, putting forward a bold perspective:[3]

"...if we were to consider our Planet as a Patient, as health professionals we would be seriously concerned about their health and would quickly diagnose that 'Patient Planet' was critically sick. A rapid assessment of the Planet's Health would find an escalating fever with difficulties breathing, a faltering circulation with metabolic acidosis and a toxic status, failing liver and kidney functions, a pale and blotchy skin indicating signs of shock and a rapidly declining mental state. From the perspective of the Planet's Doctor, we would urgently send 'Patient Planet' straight to Critical Care for emergency resuscitation and stabilisation."

The authors recognised that although there are significant differences in scale and function, the seriousness of planet Earth's failing eco-systems cannot be ignored.

"In simple terms, our changing climate is a public health emergency."

In simple terms, our changing climate is a public health emergency. It is also a biodiversity and ecological emergency, a housing emergency, a food emergency, an infrastructure emergency, a human rights emergency.

However, the framing of 'Patient Planet' requiring critical care, resonates with medical and public health practitioners, researchers and academics, and brings to the forefront the sentinel role they need to shoulder when dealing with climate change.

Invest in health, divest from harm

There are many scientific and evidence-based frameworks that provide health and medical disciplines with strategic and specific guidance on responding to climate change. For example, there are broad agenda frameworks such as the United Nations *Sustainable Development Goals*, *The Case for Investing in Public Health* by the World Health Organisation[4], and *A Global Charter for Public Health* by the World Federation of Public Health Associations.[5] Then, there are more specialised frameworks such as the Lancet Countdown on Health and Climate Change and the 41 health and climate change indicators.[6]

More locally, the West Australian (WA) Labor Government in 2019 published the *Sustainable Health Review*, and prioritised to reduce the environmental footprint of the WA health system.[7] They also initiated the aptly named Climate Health WA Inquiry, under the Public Health Act 2016, to review WA's current planning and response capacity to the health impacts of climate change. The findings from the inquiry are currently awaiting formal government response prior to their release, and will be used to create climate change mitigation and public health adaptation strategies for WA.

2 Nick Watts et al, 'The 2019 report of The Lancet Countdown on health and climate change: ensuring that the health of a child born today is not defined by a changing climate', *The Lancet*, 394 (10211), 2019, p. 1836-1878.

3 University of Southampton,*Securing a Health Planet for All. A Manifesto to Secure a Health Planet For All – A Call For Emergency Action*, University of Southampton, 2019.

4 WHO, *The Case for Investing in Public Health*, WHO Europe, 2014.

5 WFPHA, 'A Global Charter for the Public's Health – the public health system: role, functions, competencies and education requirements', *The European Journal of Public Health*, 8 March 2016.

6 Nick Watts et al, 'The 2019 report of The Lancet Countdown on health and climate change: ensuring that the health of a child born today is not defined by a changing climate', *The Lancet*, 394 (10211), 2019, p. 1836-1878.

7 Sustainable Health Review, *Sustainable Health Review: Final Report to the Western Australian Government*, Department of Health, Western Australia, 2019.

With a deep sustained knowledge of these, and other frameworks, I propose a cross-curriculum inquiry into the ways in which universities could take bold and courageous climate action, and how health and medical schools could use their position to influence academic institutions to invest in health and divest from harm. After all, no course curriculum or research focus is static, and those that respond responsibly serve as important role models to other sectors. Take for example the University of Manchester's bold 'Economics, Education and Unlearning' framework in response to the global financial crisis.[8]

Teach the science

The role of the healthcare sector is essential in communicating the health risks of climate change, and applying the necessary leverage to respond to climate change mitigation and public health adaptation strategies.

Public health and medical schools could replicate the approaches used in dealing with other major threats to health, such as smoking, drug and alcohol misuse, obesity and sugar intake, and take leadership in educating students on the impacts of climate change, exposures and vulnerabilities through the introduction of a 'Climate Health, Without Harm' unit.

Some Australian universities have already introduced units to this effect in their public health courses.[9] The Australian National University (ANU) through their Climate Change Institute has launched an ANU Below Zero Emissions target,[10] and the University of Sydney has created a joint partnership between state government departments and their public health researchers to understand climate change, human health and social impacts.[11]

However, to address climate change adequately from all different perspectives, it is imperative that all these units and research institutions do not sit in silos, but instead collaborate and incorporate their work across all academic disciplines, so that everyone in their university can collectively reframe how their efforts could be impactful in addressing climate change.

Invest in health

Universities should actively look for and create opportunities to mobilise new cross-sectoral partnerships and collaborations and to apply global metrics, data and health mitigation and adaptation strategies to locally specific climate hazards and population needs.

The *Sustainable Health Review of WA* called for the integration of Health Impact Assessments as a tool to identify climate change impacts on human health (similar to an environmental assessment, but human health focused) when projects and programs are implemented across a range of non-health sectors, such as infrastructure, built environment, mining, town planning, etc. Public health educators and researchers could respond to this, by integrating Health Impact Assessments into their work, and by providing expertise to other research groups within and outside the healthcare sector.

Universities should also consider employing and supporting researchers to focus on adaptation frameworks and methodologies for public health and health-related activities, such as:

- Assessing climate change impacts, vulnerability, and adaptation for health
- Conducting Health Impact Assessments
- Providing evidence-based climate information for health professionals and health services
- Advising on detecting, preparing and responding to health emergencies.

Divest from harm

Divesting from industries that cause public health harm sends a powerful message.

Health and medical professionals have in the recent past, powerfully and collectively changed the narrative about the harms of smoking, using evidence-based science, research, advocacy, and refusing funding or support – even in the face of powerful Big Tobacco lobby groups.

There are clear parallels between the harms of tobacco smoking and the harms of fossil fuels. Products of the fossil fuel industry harm health, by driving climate change through carbon emissions, and shortening lives through air pollution. There are also clear parallels between how big tobacco and fossil fuel lobbyists operate to manufacture consent while continuing their harmful activities.

8 PCES, *Economics, Education and Unlearning*, Economics Education at University of Manchester, Post-Crash Economics Society at the University of Manchester, 2014.

9 See, for example, Monash University, *Climate change and public health*, Monash University Handbook, 2020.

10 Climate Change Institute, Australian National University.

11 Climate Change, Human Health and Social Impacts research node, University of Sydney.

If we start to acknowledge, understand and openly talk about the systematic and intertwined complex nature of fossil fuels as a public health emergency, we *will* find new ways to invest in health (human and planetary health), and divest support, research, funding and our day-to-day reliance on fossil fuels – just as we did with Big Tobacco. This could be done by:

- Creating public health campaigns and advocacy tools, with a focus on positioning fossil fuels as the next new Big Tobacco
- Responding responsibly to the public health emergency and divest support, research and funding from fossil fuel industries. The divestment must become as legitimate a priority for all disciplines as refusing funding and support from Big Tobacco.

Communicate the science

As the knowledge of the health impacts of climate change increases, so does the urgency to increase efforts in protecting people from these adverse effects. Currently, the scale and pace of mitigation of harm caused by climate change is inadequate. Health and medical professionals are ideally placed to fill an essential role in communicating the health risks of climate change and driving the implementation of a robust response which will improve human health and wellbeing – across universities, in all health sectors and in all communities.

Universities should look at:

- Incorporating science communication skills development across all curriculums
- Creating a culture and workforce of competent staff who are responsible, and capable of responding to climate change mitigation and public health adaptation strategies in their teaching, research and advocacy
- Encouraging researchers to use their scientific voice, and engage in health and climate discussions.

The crossroads

The science of climate change describes a range of possible futures, which are largely dependent on the degree of action or inaction in the face of a warming world. The public health challenge is of course but one of the intersecting challenges that we face, including ecological and humanitarian, among others. Each of these needs addressing, and each starts with the question of how best we do this.

In the 2020 Global School Strike for Climate, future university students called for deeper co-operation on climate protection and a commitment from *everyone to do to everything that is necessary* to create a healthy, habitable planet.

Universities must make bold and courageous commitments to climate action. They need to urgently renew their course content to incorporate timely and current climate change knowledge, invest in planetary and public health, and divest from (if any) research or funding from fossil fuel industries. For the threats and challenges of climate are great, and time is short.

If the UWA Faculty of Health and Medicine commits to investing in health and divesting from harm, as they have when addressing numerous other threats to health in the recent past, it would serve as an important role model for other areas within the University and higher education institutions at large.

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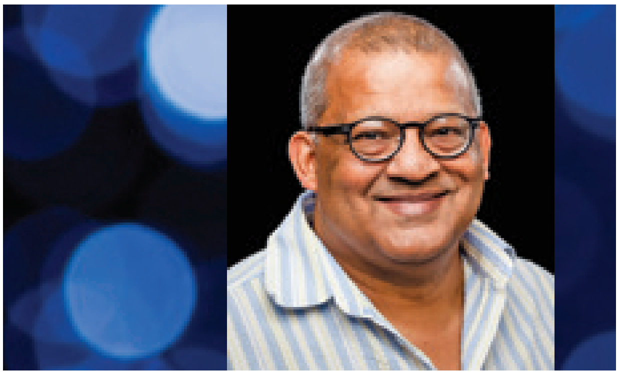
Coastal zone management: the role of Australian universities in preparing for change

Charitha Pattiaratchi and Julian Partridge



Nature and people at the land-sea interface

Coastal areas have attracted people and settlement throughout history. Initially this may have been simply because food was found at the sea's edge but, as coastal villages developed into cities, and harbours and estuaries grew into major ports, coastal areas often became the sites of major population centres and hubs of trade. As such, the complexity of human interactions in the coastal zone inevitably increased. Today, coasts are highly complex regions where land and inshore waters are used by a diverse range of stakeholders, often with competing interests, creating multifaceted physical, ecological, and socioeconomic interactions.[1] For management purposes, coastal regions can be envisaged in terms of their natural and built assets, both with associated economic value. Coastally located built assets (infrastructure) include industry and transport, as well as commercial and residential property. As natural assets, coastal and marine ecosystems provide habitats for many creatures, from microscopic, unseen mud-living infauna, to highly visible well-known animals like fish, birds or sea turtles. They are also valued habitats used by humans, both for work and recreation.

Physically, the coastline forms the energetic interface between the land and the ocean, absorbing and dissipating energy arriving in the form of waves, tides and currents, which are constantly changing the shape of the shoreline. The dynamic nature of the shoreline is expressed in terms of coastal erosion and accretion that take place naturally over long timescales, with mean sea level playing an important role in determining the speed of erosion and landward retreat of the water's edge. Such natural phenomena can be dramatically accelerated by human interference, be it the construction of coastal structures such as harbours or groynes, or activities such as sand extraction (either from the beach or from rivers) that alter the previously stable sediment balance.

Due to these many activities, the management of coastlines is challenging, and needs to reflect different stakeholder perspectives, values and interests. There are also many different policy issues to be considered, given the diverse concerns of government, non-governmental organisations, business, tourism, and local community groups, whose interests and priorities frequently clash within the coastal zone. Moreover, public affinity with the

1 Sally Brown, Robert J Nicholls, Susan Hanson, Geoff Brundrit, John A Dearing, Mark E Dickson, Shari L Gallop, Shu Gao, Ivan D Haigh, Jochen Hinkel, José A Jiménez, Richard J T Klein, Wolfgang Kron, Attila N Lázár, Claudio Freitas Neves, Alice Newton, Charitha B Pattiaratchi, Andres Payo, Kenneth Pye, Agustín Sánchez-Arcilla, Mark Siddall, Ali Shareef, Emma L Tompkins, Athanasios T Vafeidis, Barend van Maanen, Philip J Ward and Colin D Woodroffe, 'Shifting perspectives on coastal impacts and adaptation', *Nature Climate Change*, 4(9), 2014, p. 752–755.

coastal zone can place unusual and significant pressure on governing bodies to maintain and continuously develop the coastline for residency, recreation and industrial purposes, while simultaneously conserving natural attractions.

Rising sea level and its consequences in Australia

Despite the vastness of the Australian continent, 85 per cent of Australia's population lives within 50km of the ocean. Australians largely share a vision that identifies the benefits of coastal and marine sustainability, recognising such benefits as the basis of a healthy way of life and a buoyant economy. People value coastal zones for residential locations and celebrate marine biodiversity, but generally accommodate the reality that important industries must be located near the sea. The expectation is that this status quo will be successfully maintained, and that planners and decision makers have the tools in place to ensure successful long-term management of our coastal zone. At the same time, much of Australia's coastal population lives in regions that are potentially vulnerable to the impacts of rising sea levels through increased coastal flooding events, coastal erosion, salinisation of aquifers, wetlands and estuaries, and biodiversity loss.

World-wide, coastal zones tend to be densely populated and complex spaces that, in numerous global locations, are predicted to be particularly vulnerable to the impacts of climate change.

"World-wide, coastal zones tend to be densely populated and complex spaces that, in numerous global locations, are predicted to be particularly vulnerable to the impacts of climate change."

In Australia, many residential and industrial developments are concentrated along the banks of estuaries or are located on coastal plains inland from the beach. With the majority of these located at, or lower than, the current high tide mark, they will inevitably be vulnerable to flooding if sea levels rise. Coastal regions experience a well-documented rise and fall of sea levels that cycle over timescales from hours to years, and are governed by astronomical tides, meteorological conditions, seismic events, local bathymetry, and a host of other factors. The major drivers of sea level are the gravitational forces of the Sun and the Moon, which together result in tidal variability, with periods of 12 and 24 hours as the Earth circles the Sun, interacting with the 29.5-day lunar month. On top of these cycles are tidal modulations, with periods up to 18.6 years caused by oscillations in the Moon's orbit around the Earth.[2]

Ocean currents also influence sea level, and in Australia the longer-term seasonal and inter-annual variability is mainly due to changes in the volume transport (the mass flow of water) associated with major oceanic current systems. For example, off the west coast of Australia the Leeuwin Current strongly influences sea levels and varies seasonally, as well as year to year. Sea level is also influenced by El Niño-Southern Oscillation (ENSO) events.[3] ENSO events are observed as multi-year fluctuations in the temperature of the sea and atmosphere that originate in the Pacific Ocean and propagate around the north, north-west and western coastal boundaries of Australia, affecting both offshore and coastal marine environments. In El Niño years, the Western Australian coast experiences cooling, weakening the Leeuwin Current and reducing sea levels; as ENSO cycles in the opposite directions, La Niña events bring elevated sea temperature to Western Australia's coastal seas, increases the strength of the Leeuwin Current, and causes a rise in sea level.

Over decadal and longer time scales, the global mean sea level is rising due to climate change. This mean sea level rise (MSLR) is associated with two major processes: (1) an increase in the volume of water in the global ocean through thermal expansion; and (2) the addition of water to the oceans from reservoirs of melt-water originating from the ice caps, glaciers and ice sheets. MSLR is one of the main consequences of global warming and will continue to speed up into the future.[4] The global mean sea level has been increasing gradually since the start of the Industrial Revolution, but over the past few decades the rate of MSLR has been accelerating as the effects of atmospheric carbon dioxide manifest as climate change. The rates of MSLR around Australia, between 1.3mm and

2 Charitha B Pattiaratchi, 'Coastal tide gauge observations: dynamic processes present in the Fremantle record'. In Andreas Schiller and Gary B Brassington (eds), *Operational oceanography in the 21st century*, Springer, 2011, p. 185–202.

3 Ivan D Haigh, Matthew Eliot, Charitha B Pattiaratchi and T Wahl, 'Regional changes in mean sea level around Western Australia between 1897 and 2008', Proceedings of Coasts and Ports 2011, Engineers Australia, Perth, 28–30 September 2011.

4 JA Church, PU Clark, A Cazenave, JM Gregory, S Jevrejeva, A Levermann, MA Merrifield, GA Milne, RS Nerem, PD Nunn, AJ Payne, WT Pfeffer, D Stammer and AS Unnikrishnan, 'Sea Level Change'. In: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [TF Stocker, D Qin, G-K Plattner, M Tignor, SK Allen, J Boschung, A Nauels, Y Xia, V Bex and PM Midgley (eds.)]. Cambridge University Press, 2013; Arne Arns, Sönke Dangendorf, Jürgen Jensen, Stefan Talke, Jens Bender and Charitha B Pattiaratchi, 'Sea-level rise induced amplification of coastal protection design heights', *Scientific Reports*, 7, art no. 40171, 2017.

2.8mm per year, are similar to those seen globally, which range between 1.3mm and 2.3mm per year.[5] As seas rise, coastlines recede: there is a clear cause-and-effect relationship between increasing mean sea level and the magnitude of shoreline retreat. The general rule of thumb used by engineers and planners is called the Bruun Rule, which asserts a linear relationship between sea level rise and shoreline recession: for each centimetre of vertical sea level rise, a sandy beach may retreat by up to a metre or more, depending on the profile of the beach.

Because of MSLR, many coastal regions inland from sandy beaches will be under threat from sea level rise in the future. Generally, acute coastal erosion is associated with rapid beach destruction due to storm events involving large waves and abnormally higher water levels; for example, when a peak storm surge coincides with local tidal high water. If the inter-annual sea level is also higher, more extreme conditions result. Therefore, considering the dynamics and timescales of processes underlying extreme weather patterns is just as important as MSLR alone when assessing potential climate-change impacts on the shoreline beyond.

Aside from causing erosion and altering the shape of the coastline, MSLR also influences coastal ecosystems. For example, increased flooding of freshwater wetlands in the Northern Territory of Australia will make these wetlands saltier, affecting hundreds of species of birds, reptiles and amphibians that depend on these freshwater regions. In the southwest of Western Australia, the year-to-year changes in the mean sea level at Fremantle have been related to the strength of the Leeuwin Current[6] and have been statistically related to the abundance and/or catchability of a number of fisheries-targeted species along the WA coast. These include[7] the western rock lobster, Shark Bay scallops and king prawns, Australian salmon and herring, Albany pilchards, and whitebait. These relationships have been either positive (e.g. western rock lobster) or negative (e.g. Shark Bay scallops).

5 Neil J White, Ivan D Haigh, John A Church, Terry Koen, Christopher S Watson, Tim R Pritchard, Phil J Watson, Reed J Burgette, Kathleen L McInnes, Zai-Jin You, Xuebin Zhang and Paul Tregoning, 'Australian sea levels—Trends, regional variability and influencing factors', *Earth-Science Reviews*, 136, 2014, p. 155–174.

6 Charitha B Pattiaratchi and Steve J Buchan, 'Implications of long-term climate change for the Leeuwin current', *Journal of the Royal Society of Western Australia*, 74, 1991, p. 133–140.

7 RC Lenanton, Nick Caputi, Mervi Kangas and M Craine, 'The ongoing influence of the Leeuwin Current on economically important fish and invertebrates off temperate Western Australia – has it changed?', *Journal of the Royal Society of Western Australia*, 92, 2009, p. 111–127.

However, since 2001, the relationship between mean sea level and rock lobster recruitment has diminished, indicating that mechanisms underlying this relationship are not as simple as they first appeared.

Although much emphasis has been placed on large mean sea level changes occurring at inter-annual timescales, less extreme sea level variations can also have significant influence on coastal ecosystems. For example, extended and recurrent daytime low water levels decreased coral cover in emergent reefs in the Abrolhos Islands (WA) during spring 2018. Here, corals on shallow leeward reef platforms were exposed above water during the middle of day by a combination of diurnal tides, minima in the seasonal mean sea level, and inter-annual variability.[8] Similarly, extensive dieback of the mangrove forests in the Gulf of Carpentaria was associated with low sea levels related to an El Niño event in 2015–2016, combined with prolonged drought and higher air temperatures.[9]

Moving to proactive mitigation planning

As the above suggests, climate change impacts from MLSR and extreme weather events combine to present significant environmental, ecological, financial, social and legal risks to coastal populations. However, direct action and long-term planning for mitigation of these impacts are far from fully developed. We live in a society that is mainly reactive to natural disasters, rather than proactive. The best example of this is, perhaps, the development of tsunami warning systems.

In 2004, the Indian Ocean rim countries experienced one of the largest and most deadly tsunamis in history: an event that caused more than 230,000 deaths, and led to economic and personal hardship for many tens of thousands of people from Indonesia, Thailand, India, and Sri Lanka. In the Pacific Ocean, a tsunami warning system has existed since the early 1960s, having been established after many large trans-oceanic tsunami events, and the instrumentation required to monitor abrupt sea level changes was well understood. Although the need for a tsunami warning system for the Indian Ocean was recognised by scientists, and even proposed, it was only implemented after the 2004 tsunami. Research scientists need to learn from this, and find ways to communicate more effectively, highlighting that mitigation planning and actions for protecting coastal infrastructure are required well before significant coastal impacts occur, especially where all evidence indicates these can be expected in the near future.

To understand the immediacy of our problem it is necessary to be aware of the timescales of the different drivers of sea level and apply this understanding to specific locations, including those close to home. The global mean sea level is predicted to increase, relative to the year 2000 as follows: 9–18cm by 2030, 15–38cm by 2050, and 30–130cm by 2100.[10] Clearly there is a need to plan for this future. However, there are other factors to consider that strongly suggest we have a more urgent requirement for preparation, especially when particular locations are considered. For instance, ignoring climate change impacts, mean sea level along the Western Australian coast is predicted to rise by 20cm over the next five to eight years, due to the occurrence of a 'high stand' in the 18.6-year lunar orbit oscillation cycle (which is caused by variation of the moon's rotational axis about the earth). If this high stand coincides with a La Niña event, another 20cm would be added to the mean sea level. Thus, the combined effect of these two processes would result in a 40cm rise in sea level, with a relatively high probability that this may occur in the next decade. This sea level rise would be similar to the *upper* limit (38cm) predicted for MSLR for the year 2050 under current climate change scenarios. This illustrates the need for adaptation measures to be undertaken sooner rather than later if climate change impacts are to be minimised in the coastal zone, over both our short- and long-term futures. Just as the need for an Indian Ocean tsunami warning system had been identified prior to the 2004 tragedy, so too are proactive approaches to coastal zone management advisable closer to home.

Preparedness in research, education and training

The challenge for research institutions, including research-intensive universities, is to be ready to provide evidence-based solutions for policy and decision makers, and to highlight the urgency of actions that are proposed. It is also the responsibility of educational institutions to educate and appropriately train the next generation of people who will have to implement solutions to mitigate the worst impacts of climate change in the decades ahead.

8 Joanna Buckee, Charitha B Pattiaratchi and Jennifer Verduin, 'Partial mortality of intertidal corals due to seasonal daytime low water levels at the Houtman Abrolhos islands', *Coral Reefs*, 39(3), 2020, p. 537–543.

9 Catherine E Lovelock, Ilka C Feller, Ruth Reef, Sharyn Hickey and Marilyn C Ball, 'Mangrove dieback during fluctuating sea levels', *Scientific Reports*, 7, 2017, p. 1680.

10 IPCC: *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate*, 2019 [H-O Pörtner, DC Roberts, V Masson-Delmotte, P Zhai, M Tignor, E Poloczanska, K Mintenbeck, A Alegría, M Nicolai, A Okem, J Petzold, . Rama, NM Weyer (eds.)].

Climate change adaptation requires multi-dimensional issues be faced, and coastal regions will be disproportionately affected by the impacts of climate change. Solutions will be equally multi-dimensional, and university research, education and training, and communications all need to serve their purpose effectively. Research that leads to a clear understanding of future climate-induced challenges will always be needed to reduce risk and to facilitate decision making around mitigation options. But preserving the ecological, economic and societal benefits of these environments will rely on synergy across many disciplines. Thus, research is required across many fields, and educational training institutions need to prepare (i.e. educate and train) students with specific high-level skills in a range of subjects. However, they also need to equip students with the skills to work in cross-disciplinary teams and be receptive to ideas outside their own discipline. In addition, university researchers and their graduates must find ways to communicate better outside academia, to maximise the value of their knowledge and expertise.

Currently, there is significant apprehension among the general public and decision makers with regard to existing and potential future impacts of climate change on public infrastructure and buildings, and on private dwellings. What's more, liability of local government when making planning decisions regarding the location and nature of future development is of increasing concern. In coastal areas, coastal erosion and flooding that threaten infrastructure and/or private property are major causes of community unease. Proprietors of coastal infrastructure, including owners of private dwellings, often expect governments (local, state and/or federal) to protect their properties from being lost. Governments, in turn, have difficult decisions to make in terms of the extent to which they should directly intervene using public funds, and/or permit or prevent landowners from protecting their property. Given this situation, it is essential that universities develop better mechanisms to share knowledge with the public and decision makers and to step into positions of leadership for action.

Mitigating climate change effects in the coastal zone

There are essentially two strategies for mitigating coastal erosion and flooding: (1) managed (or planned) retreat, allowing the shoreline to advance landward, unimpeded by artificial structures. This includes strategic relocation of coastal structures and/or abandonment of land (including buildings and infrastructure); and (2) construction of coastal structures (e.g. seawalls, rock revetments) that require regular maintenance at high cost, and which may even fail and need to be rebuilt. In either case, planning for mitigation needs to start sooner rather than later, as delays will be more expensive, mitigation actions will be less ordered, and people could end up much worse off. Coastal communities threatened by rising sea levels will need to tackle a complex web of problems that cannot be considered in isolation.

Many communities globally are increasingly opting for retreat and, in some cases, whole communities have come together to be relocated. A good example of a successful relocation was in Oakwood Beach, Staten Island (New York, USA). The locality was repeatedly flooded over many decades, and Hurricane Sandy had a major effect, with the whole community impacted by inundation. The community approached the State of New York and convinced the Governor to set funds aside for their relocation. The Governor's Office acquired approximately 300 homes and the community was relocated. This model worked because it was not a response to a single event; it was a reaction to flooding events occurring over decades, where the frequency was clearly increasing. Essentially, the scientific understanding of the problem was sufficient for solutions to be defined and the community was well engaged to drive the change.

Mitigating climate change effects in the Swan-Canning Estuary

Climate change will have worldwide coastal zone impacts, including in Western Australia. An example of a scenario based locally, in the Swan River and estuary and their surrounds, illustrates the range of hydrographic problems currently encountered and the vulnerability of the surrounding areas, and identifies an engineering solution to this particular coastal zone challenge.

The Swan and Canning rivers are the dominant geographic features flowing through the heart of metropolitan Perth, a city of more than two million people and the capital of Western Australia. By 2030, the population in the catchment is projected to increase by about 33 per cent. The rivers are a major focal point for much of the State's economic development and are integral to Western Australia's identity, heritage and community wellbeing, but are at risk through climate change effects. One of the major influences of climate change on the river system is the reduction in rainfall and associated decrease in streamflow. The rainfall in the catchment has reduced by 30 per cent in the past 30 years, with significant changes in streamflow. Hydrodynamic conditions in the Swan River have changed as a result: the higher streamflow conditions during winter previously caused the flushing of seawater from the estuary, but the decreased streamflow of today is no longer able to flush this seawater into the ocean. This results in increased salinity of the Swan (one of the reasons why prawns are less common than decades ago) and vertical stratification, with a freshwater layer above a saltwater one in the majority of the estuary, leading to water quality issues because of the limited mixing. This highlights that the effects of climate change are already having a strong impact on the Swan/Canning river systems.

Another aspect of climate change in the Swan River is coastal flooding events that are exacerbated by MSLR, requiring protection of the river foreshore. The combined shorelines of the Swan and Canning rivers are more than 300km long and the riverbanks are highly urbanised and reclaimed, with the majority being low-lying and susceptible to flooding. This was highlighted by an event in January 2011 that could have been the 'perfect' storm in terms of coastal flooding along the Swan River. An extreme La Niña event that took place in 2011 increased the mean sea level by 25cm. Simultaneously, Tropical Cyclone Bianca originated in the north-west shelf of WA and propagated southward, parallel to the coastline. It was predicted to cross the coast just to the north of Perth, coinciding with the local tidal high water. Combined action of all of the sea level processes that contribute to changes in water level, including the storm surge, was predicted to be 2.5m (noting that the maximum recorded sea level at Fremantle to date is 2.12m). This would have resulted in significant flooding along the Swan River foreshore, including the Elizabeth Quay (Esplanade) railway station. About two hours prior to Bianca making landfall, the cyclone dissipated, the storm surge component did not eventuate, and the flooding event did not occur. This close call highlights the level of risk we face and the need for preparedness.

A recent study, undertaken by environmental engineering students at The University of Western Australia, examined the flood mitigation strategies for the Swan River in response to MSLR. The analysis identified key areas of heritage, commercial and economic infrastructure and prioritised these for protection. The protection options for the infrastructure were dependent on site-specific analysis of local flood mitigation strategies. The feasibility of these strategies was assessed based on stakeholder and cost/benefit analysis. Overall it was found that a 'do nothing' scenario presented significant costs compared to implementation of site-specific mitigations. A particular solution suggested in this study aimed to protect the entire estuarine system and was based on the construction of a storm surge barrier at Fremantle Railway Bridge. Bunbury, to the south of Perth, already has a storm surge barrier, constructed after the large-scale flooding resulting from Tropical Cyclone Alby in 1978, and many major cities globally are examining such options for future coastal flood events. In the case of the Thames estuary (London) and eastern Scheldt (The Netherlands) storm surge barriers have already been constructed, with New York and Venice barriers in the planning phase. The student study recommended that a lifting gates-type barrier at Fremantle Railway Bridge was most suitable because of its low maintenance costs, ease of construction and functional advantages. Their hydrodynamic modelling indicated that minimal impact would result from a concept design because changes to water elevation and current velocities were limited to the immediate vicinity of the structure.

The above exercise would seem to provide a clear answer to the needs of the Swan with respect to MSLR: a barrier in Fremantle. However, a single barrier is unlikely to provide a permanent long-term solution. Just as a planned retreat from the coast may need to be phased, so too a planned barrier solution may need future augmentation with additional barriers (as is under consideration in London). More importantly, the successful implementation of such an engineering solution would need a raft of other expertise, and extensive stakeholder engagement. A barrier may well be the best solution but, as sea levels rise, it would need to be closed more frequently: what would be the consequences of that to the river's ecology and hydrography? And what impact would frequent closure have on the wide range of river users? If it failed, who would be liable? When would a second barrier be needed, and where would it need to be placed? How would planners accommodate these unknowns in their decision making? To answer such questions, a broad, cross-disciplinary approach is needed.

Cross-disciplinary teams

When planning climate change mitigation actions, there is value in hypothetical scenarios considering the different options that may be available to coastal communities (e.g. a managed retreat versus the construction of coastal structures) to combat the effects of climate change, such as mean sea level rise and extremes in high water levels. To effectively and comprehensively examine options, we would need to assemble a team with a wide variety of expertise to perform many different tasks (see Table 1, below) before a viable solution could be determined. The extent of this list indicates today's complexity in the coastal zone, and the range of coastal zone stakeholders.

Expertise	Task
Applied economists	Undertake cost-benefit analysis of the total economic value (both use and non-use) of assets to be protected or abandoned by the community
Cultural/heritage experts	Define the cultural/heritage values of the community and assign monetary equivalent values
Indigenous leaders	Represent the values of Aboriginal or Torres Strait Islanders to understand the impacts of different options on sites of cultural importance
Social scientists	Liaise/prepare the community for possible abandonment of houses and infrastructure
Oceanographers	Predict time scales for coastal flood events, together with climate change scenarios
Psychologists/psychiatrists	Liaise/prepare the community and deal with adverse reactions to change
Local and state government and governance experts	To navigate the often complex jurisdictional and responsibility networks that oversee coastal governance decision making.
Coastal engineers	Design coastal protection structures, including long-term maintenance.
Geotechnical engineers	Define the foundation characteristics of proposed coastal protection structures
Civil/environmental engineers	Determine best options for water supply and sanitation
Coastal ecologists	Identify biodiversity and habitat issues; model short-term and long-term ecological perturbations and their direct and indirect consequences
Communications team	Keep the community informed by understanding how to communicate effectively with diverse stakeholders; engage the community in dialogue and decision making
Educators	Empower the community with enough understanding of different sea-level rise scenarios; explain how decisions can be made
Lawyers	Advise on the legal aspects of abandoning/retaining the community
Population health experts	Mental health, social networks, food security, infectious diseases, injury and health care access
Insurers	Compensate land owners where the current insurance framework requires

Table 1 – Competencies likely to be required in a team addressing coastal zone climate change mitigation options.

> "Climate change challenges cannot be solved by engineers and scientists alone. They need alliances with social scientists, cultural heritage specialists and others to join this collective endeavour."

Conclusion

Climate change is already having an impact on the planet. In the coastal zone, climate change will have many consequences, and significant impacts can be fully anticipated. Universities need to prepare for this reality and position themselves to help society make necessary adjustments. Research will be needed across a range of disciplines, and universities should review their research competences and determine how to be effective action leaders. They will also need internal structures, including multi-disciplinary institutes that avoid discipline silos, anticipating that many climate change challenges will be complex and multi-factored. Such institute structures allow for agility and are able to assemble appropriately skilled cross-disciplinary teams quickly to address questions and challenges as they are identified. Research will be needed to provide clear evidence that will inform decision makers. To be useful, however, this evidence will need to be clearly communicated in the form that the receiver of the information requires. Researchers therefore also need to know how to communicate effectively when providing evidence about the likely impacts of climate change, both broadly and as they relate to particular localities. At local levels, an understanding of how to engage in dialogue with local communities expected to be affected by coastal zone changes will be needed. Ideally, such communities will be directly involved in decision making, but dialogue with communities will only succeed if appropriate engagement approaches are employed and people in the communities are empowered with sufficient 'ocean literacy' to engage. Universities have a role in this element of public engagement too, providing both information in appropriate forms, and tools for non-specialists to use to understand the consequences of different decision options. Importantly, dialogue will only be effective if community values are understood, if the diversity of these values is embraced, and if the 'costs' of decisions are identified both in financial terms and in terms of other, often non-monetary, values.

As climate change impacts will continue to be revealed over coming decades, universities also have a role in preparing their graduates for future leadership roles. The diversity of disciplines and expertise required to identify measures to mitigate climate change highlights the challenge to educational/training institutes to produce graduates who have sufficient depth of knowledge and competence in their core subjects, but who also have sufficient understanding of other subjects to function effectively in cross-disciplinary teams. This suggests a challenge and future direction for course developers at universities. Changes to university training are therefore needed as part of this preparedness, noting that climate change challenges cannot be solved by engineers and scientists alone. The skills of psychologists, applied economists, social scientists, political specialists, public policy experts, lawyers, and professionals from many other disciplines are all needed, and students majoring in one discipline must learn to communicate with those from other areas of learning.

Together, such approaches will enable society to be proactive, not reactive, as climate change impacts in coastal areas become manifest. With so much of Australia's population concentrated in coastal areas, universities have a key role in combating this particular impact of climate change – its effect on coastal zones – and should prepare now for the inevitable challenge ahead.

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Charitha Pattiaratchi is Professor of Coastal Oceanography at The University of Western Australia. He uses field measurements, remote sensing, and computer modelling as the tools of his research to examine physical processes on coastal regions including impacts of climate change.

Practitioner perspectives

The changing tide of offshore engineering

Scott Draper and Phil Watson

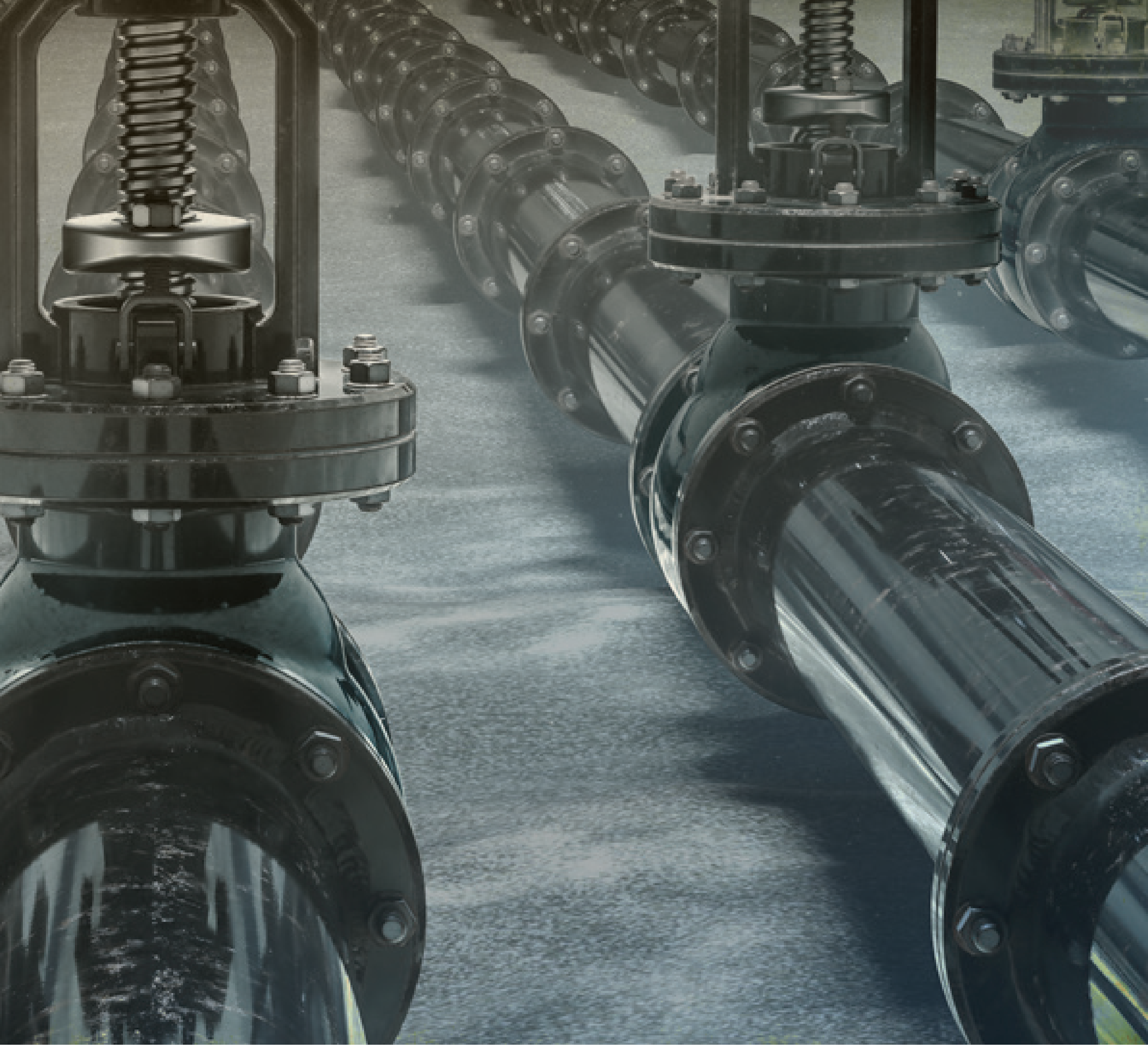
Over the last two decades, the offshore energy industry has seen significant growth, realised through billions of dollars of investment in new offshore natural gas developments in Australia alone. These developments have included subsea infrastructure, installed in water depths up to and exceeding 1000 metres, and connected via pipelines to offshore fixed or floating facilities. The gas is then piped to shore for liquefaction and export (an exception being Shell's Prelude FLNG, the largest floating facility of its kind, which exports from an offshore location).

Construction of these developments required engineers to overcome significant design challenges, with pipelines being a case in point. In Australian waters, the combination of light gas pipelines, complex soil conditions, and driving forces that include tropical cyclones and large internal waves, demands careful design to ensure the pipeline will remain stable during storm conditions. Accurate predictions of meteorological and ocean (metocean) conditions in remote locations have been critical, together with accurate assessment of loads on the pipeline due to near-seabed wave and current flows.

Throughout this period, Australia has cultivated world-leading expertise across offshore engineering – from offshore operators through to consultants and contractors. Research has also played a key role, through targeted collaboration with industry. Continuing the pipeline example, a number of Joint Industry Projects (JIPs) have advanced international design guidance through innovative and often radical thinking. The STABLEpipe JIP and SAFEBUCK JIP are two major programs in which the University of Western Australia has been involved. The central principle underlying the design method developed by STABLEpipe is that the seabed is less stable than the pipeline, meaning the pipe will generally become buried through scour and sediment transport, the result being it 'self-stabilises' over time[1]. Meanwhile, the SAFEBUCK JIP has promoted new approaches to address thermal expansion of pipelines, in which the pipe is permitted to buckle and displace across the seabed to relieve rather than resist the loading.

> "The development of the wider blue economy – particularly marine renewables and hydrogen – is driven by growing concerns over climate change."

1 T. Griffiths, S. Draper, D. White, L Cheng, H. An and A. Fogliani, 'Improved stability design of subsea pipelines on mobile seabeds: Learnings from the STABLEpipe JIP'. In *International Conference on Offshore Mechanics and Arctic Engineering*, Vol. 51241, p. V005T04A046, American Society of Mechanical Engineers, June 2018.



Looking ahead

Looking into the future, Australia is set to see significant growth in the wider blue economy, which is currently worth more than $68 billion per year and is forecast to grow to $100 billion by 2025. This growth will be fuelled by the maritime transport, offshore energy and tourism industries, but also by emerging offshore industries such as aquaculture, marine renewable energy, desalination and carbon sequestration. There are also opportunities to develop both blue and green hydrogen.

The development of these emerging industries – particularly marine renewables and hydrogen – are driven by growing concerns over climate change, and on the global stage, the offshore industry has already made significant inroads. Installed offshore wind-power capacity now exceeds 30GW worldwide, achieved through technological advances that have seen a reduction in cost to the level that fixed offshore wind is price competitive with other forms of energy generation. In Australia, the opportunity exists to benefit from these developments – the Star of the South Project proposes to place wind turbines off the south coast of Gippsland, Victoria, with the potential to supply up to 20 per cent of Victoria's electricity needs. Realising this outcome will require a collaborative effort amongst offshore engineers and energy economists. While fixed offshore wind, which is installed in relatively shallow water, is now well established, moving to deeper waters presents new challenges. In this case, realising similar price competitiveness will require the use of floating wind turbines, which is the focus of much recent research. One example is the Danish FloatStep project, a large-scale research program focused on making floating foundations cheaper and easier to produce. Denmark has long been a pioneer of offshore wind energy, and the FloatStep project is led by the Danish Technical University, drawing together both industry and researchers, including expertise from The University of Western Australia.

Growth of the blue economy and a commitment towards renewable energy provides significant opportunities to transfer knowledge and skills across Australia's offshore sector. In addition, rapid innovation will be needed to ensure cost-competitiveness on a global scale, while also satisfying safety and environmental regulations. New structures will need to be functional – whether for renewable energy generation or coastal protection, for example – but also resilient to withstand extreme ocean conditions. Our ability to meet this challenge is likely to depend in part on two important developments. The first is the integration of non-engineering disciplines to realise offshore opportunities. Having a complete multidisciplinary understanding of the ocean environment will be vital, for example, to ensure the success of open-ocean aquaculture. It also provides new opportunities to innovate, such as the development of nature-based solutions (e.g. aquatic vegetation) to provide coastal protection.

The second is the emergence of increasingly larger and richer offshore datasets, arising from experience with existing infrastructure, which provides a game-changing opportunity to interrogate how structures respond to environmental loading offshore. Interpreting this data by fusing advances in data science with engineering models is expected to provide significant potential for offshore industries to step beyond traditional design and make informed operating decisions with confidence. The importance of this to Australia was recently acknowledged through the award of the Australian Research Council Industrial Transformation Research Hub for Transforming energy Infrastructure through Digital Engineering.

In summary, offshore engineering will evolve to realise ocean-based solutions to the key challenges facing society, including climate change. The discipline will build off the rich experiences afforded by the growth of the offshore energy industry, including expertise across industry and research. However, it must also adapt to new problems by collaborating with other disciplines and capturing new insights afforded by data. Australia is particularly well placed to lead these developments.

Scott Draper is a civil engineer who has worked in offshore engineering since 2010. He is Associate Professor within the University of Western Australia's Oceans Graduate School and School of Engineering. His research focuses on predicting the response of offshore structures to waves, currents and movements of the seabed. He has been fortunate to work on numerous research projects with industry partners in Australia and globally.

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The Preparedness Report

Climate change and the challenges facing universities and professions

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